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BAHIR DAR UNIVERSITY

COLLEGE OF AGRICUTLURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

CHARACTERIZATION OF BEEKEEPING SYSTEMS, FLORA CALENDAR AND HONEY QUALITY DETERMINATION AROUND *ELLALA* FOREST IN GUANGUA WOREDA, AWI ZONE, AMHARA REGIONAL STATE, ETHIOPIA

M.Sc. Thesis

By

Tizazu Abebe Zegeye

December, 2022

Bahir Dar, Ethiopia

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF ANIMAL SCIENCES

CHARACTERIZATION OF BEEKEEPING SYSTEMS, FLORA CALENDAR AND HONEY QUALITY DETERMINATION AROUND *ELLALA* FOREST IN GUANGUA WOREDA, AWI ZONE, AMHARA REGIONAL STATE, ETHIOPIA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ANIMAL PRODUCTION

M.Sc. Thesis

By

Tizazu Abebe Zegeye

Principal advisor: Tessema Aynalem (PhD)

December, 2022

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M. Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. Tizazu Abebe entitled **"characterization of beekeeping systems, flora calendar and honey quality determination around *Ellala* forest in Guangua Woreda, Awi zone, Amhara regional state, Ethiopia''.** We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M. Sc.) in Animal Production.

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DECLARATION

This is to certify that the thesis entitled **"characterization of beekeeping systems, flora calendar and honey quality determination around *Ellala* forest in Guangua Woreda, Awi zone, Amhara regional state, Ethiopia''**, submitted in partial fulfillment of the requirements for the degree of **Master of Science in Animal Production** Department of Animal sciences, Bahir Dar University, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during the course of this investigation have been duly acknowledged.

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BIOGRAPHICAL SKETCH

The author was born in 1984 G.C, at Guangua Woreda Sigadi Kebele, Awi zone, Amhara region, Ethiopia. He completed his junior and secondary school education at Chagni and he got his diploma in Animal Production and Technology from Burie TVET College in 2006. After his successful completion of the college education, he joined Guangua woreda office of agriculture and worked as a development agent for 4 years. After attaining experience in livestock development, he joined Bahir Dar University and successfully completed and got his Bachelor of Science degree in Animal production. Then after, he joined Guangua Woreda Agricultural office expert and office head for 9 years. Currently, the author is employee of the zonal livestock expert. Now, he joined as M.Sc. student at College of Agriculture and Environmental Sciences, Bahir Dar University in 2020 specializing in Animal Production.

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The last but not the least I would like to thanks to all my families, my classmates and my best friends for their help, moral support and encouragement through my research work.

DEDICATION

This thesis is dedicated to my Father Abebe Zegeye, for his pure and unconditional love and respect for the family.

ABBREVIATIONS

AAU	Addis Ababa University
ANOVA	Analysis of variance
ARLDPA	Amhara Region Livestock Resource Development Promotion Agency
CAP	Center for Agricultural Policy Prosperity Initiative
COMESA	Common Market for Eastern and Southern Africa
CSA	Central Statistical Agency
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
ES	Ethiopian Honey Quality Standard
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GWAO	Guangua Woreda Agricultural Office
HBRC	Holeta Bee Research Center
HMF	Hydroxyl Methyl Furfuraldehyde
ILRI	International Livestock Research Institute
KTBH	Kenya top-bar Hive
MBH	Mud- block hives
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
PH	Power of Hydrogen
SNNPR	Southern Nations, Nationalities, and Peoples' Regional Government
SPSS	Statistical Package for Social Sciences
STAT	Statistics
TRS	Total Reducing Sugar
TTBH	Tanzania Top-Bar Hive

TVET	Technical, vocational and educational training
USA	United States of America
UV	Ultraviolent
YESH	Youth Entrepreneur in Silk and Honey

ABSTRACT

This study was conducted in Guangua woreda around Ellala forest, in Awi zone, Amhara National Regional State to characterize the beekeeping systems, to identify bee flora diversity, to know flowering period of bee floras and to determine honey quality in Guangua woreda around Ellala forest. Data were collected from 140 beekeepers having honeybee colonies and living in three different agro-ecologies. The study had two parts: part one was data collection among beekeepers with a semi-structured questioner by single- visit-multiple-subject formal survey method. Part two of study was the determination of honey quality and pollen analysis produced in the study area. All the collected data was analyzed by using SPSS v-26 Duncan's and one-way ANOVA method. From the total 140 sample beekeepers 90.7 % of them were male headed households and 9.3% were female headed households, 95.0 % of them are married, 2.9% of them were widowed and the rest 2.1% were divorced. Majority of the respondents (about 65.7%) were in the age range from 36 to 50 years and they owned a total 1956, 87 and 213 traditional, transitional and frame hived honeybee colonies respectively. The study result indicates that based on their level of technological advancement, three distinct types of beekeeping practices were used by the sample beekeepers in the area. These are traditional hive, transitional hive and moveable frame hive beekeeping practices. About 89.3% of the respondents tried to feed their colony at dearth periods, 55.7% of them get their colonies by catching the swarm colonies. The mean honey yield of traditional, transitional and framed type hives was 6.69, 11.90 and 20.57 kilogram per year. Ants (97.9%), black ants (89.3%), wax moth (54.3%), rats (45.7%), birds (37.1%), spider (35.0%), honey badger (32.9%), mice (17.1%), and bee lice were the major pests and predators to tackle the development of beekeeping around Ellala forest. Eighteen honey samples were collected from traditional, transitional hive and framed hive honey as two distinct groups from the represented 3 different agro-ecologies of the study area directly from the apiary farm gates with tightly closed half a kilogram of plastic containers analyzed for eight honey quality parameters (ash, moisture content, pH, HMF, free acidity, reducing sugar (fructose and glucose) and sucrose content) in the Holeta bee research center and in order to analyze pollen to identify pollen source in two seasons 6 samples were collected and analyzed in Analysis laboratory of School of Chemical and Food Engineering, Bahir Dar University, Ethiopia. The mean ash content, moisture content, pH vale, free acidity, HMF, reducing sugar (fructose + glucose) content and sucrose content are 0.19 %, 20.37%, *3.86, 21.89 meq/kg, 9.89 mg/kg, 72.94meq/kg and 2.67% respectively. All the eight determined parameters showed that 100 % of the sample means were situated in the acceptable range of the world honey quality standard set by Codex Almentarious, 2001. Based on the laboratory analysis of collected samples, 42 plant species also with six botanically unidentified species were identified. Among the identified plant species, 15 plant species were identified during the major honey harvesting season or season-one and 25 plant species were identified during minor honey flow season or season-two. The flowering time of the most identified honey source plants in major honey flow season were between August-January and in minor honey flow season were from December to May. Package designing for implementation of improved practices and extension services, gaining of efficient seasonal trainings, plantation of drought tolerant bee forages, integrating the responsible crop scientists, animal science experts and other administration organizations for efficient utilization of agrochemicals and farther study are recommended to enhance the sector.*

Key words: Bee forage, beekeeping characterization, *Ellala* forest, Honeybee, honey quality

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CHAPTER 1: INTRODUCTION

1.1. Background and Justification

Beekeeping is a long-standing agricultural tradition in Ethiopia. Many rural agricultural communities have used it as a sideline activity for the honey and beeswax production that helps finance development (MoARD, 2010). It also creates employment opportunities in the industry. In recent years, the role it plays in improving food security, poverty reduction, and food production through crop pollination has grown significantly. There is no well-documented information indicating when and where the practice of beekeeping began in Ethiopia. It began in the country between 3500 and 3000 BC, according to (Ayalew Kassaye, 1978).

According to Bekena Negash and Greiling J. (2017), honey production is one of the oldest agricultural activities in Ethiopia, which has been accelerated by favorable natural resource endowment, distinct agro-ecological conditions, and over 7,000 flowering species and only 1,000 flowering plants were bee floras as studied by Adimasu Adi *et al*. (2014), MoA and ILRI (2013), and has a comparative advantage in honey and wax production. Ethiopia's unique agro-climatic conditions and biodiversity aided the establishment of a rich honeybee flora as well as a significant number of honeybee colonies (Nuru Adgaba, 2007).

Similarly, according to Bekena Negash and Greiling J. (2017), Ethiopia has about 10,000,000 bee colonies and one 1,800,000 beekeepers. It has 6,986,100 beehives (CSA, 2021) million bees. Traditional hives make up 95.9 % of all hives, followed by frame hives at 2.6 % and transitional hives at 1.5 % (CSA, 2021).

According to Amsalu Bezabeh *et al*. (2004), morphometric characteristics of Ethiopian honeybee populations revealed five statistically distinguishable races of populations that exist and occupy different ecologies throughout the country: *A. m. jemenitica* grows in the northwest and eastern arid and semiarid lowlands, *A. m. scutellata* grows in the west, south, and southwest humid midlands, *A. m. bandansii* grows in the central moist highlands, *A. m. monticola* grows in the northern mountainous highlands, and *Woyi-gambela* grows in the south-western semi-arid to sub-arid lowlands.

Honey production in Ethiopia is still far from realizing it's potential for earning foreign currency in general and financial gain for honey producers in particular. Every year, the country has the capacity to produce up to 500,000 tons of honey and 50,000 tons of beeswax (Assefa, Getenet, 2017). However, recent honey and beeswax production levels are: 129,301 tons of honey and 5,790 tons of beeswax CSA, (2021) which is less than their potential. Exploitation of alternative high-value honeybee products is non-existent (MoA and ILRI, 2013), and the subsector's benefit is insufficient (Beyene Tadesse and David Phillips, 2010). Oromia, Amhara, and SNNPR (Southern Nations, Nationalities, and Peoples' Regional Government) are Ethiopia's top honey-producing regions, accounting for 54.3%, 19.5%, and 16.6 % of overall production, respectively (CSA, 2020).

Honey is a semi-liquid substance containing a complex blend of carbohydrates, primarily glucose and fructose (Ethiopian Quality Standard Authority (ES)), 1202 (2013). Other sugars may be present in trace amounts, depending on the floral source (Ethiopian Quality Standard Authority (ES), 1202 (2013)). Organic acids, lactones, amino acids, minerals, vitamins, enzymes, pollen, wax, and pigments are also present, all of which are key features used to define honey quality (Crane, 1990, Yaniv Z. and Rudich M. 1996; Silici, 2002). Honey with a high water content has a higher chance of fermenting. The mineral content of honey shows its biological origin; blossom honey contains fewer minerals than dew honey (Vorwohl *et al*., 1989).

The mutual advantages of bees and trees, according to D. B. HILL and T. C. WEBSTER, (1995), are dependent on the interaction of phenology, biogeography, economics, and bee dangers. The majority of these elements are location-specific and strongly reliant on seasonal weather patterns. While the basic biological processes that affect bees and trees are well established, much needed information is lacking. Although there is anecdotal and empirical evidence of a mutually beneficial relationship between trees and bees, little research has been done in Ethiopia to explain the nuances of this association. Other countries in the world have done more research, although specific scientific information is still scarce. This is due to a combination of factors, including a tree's extended pre-flowering phase, the intricacies of site and weather influences on flowering, nectar, and pollen production, and methodological challenges. Perhaps the significance of honeybees in tree pollination and trees in bee foraging and protection has also been overlooked.

According to Gichora M. (2003), it is critical to identify honeybee plants and analyze their abundance, usefulness to bees, blooming time, and flowering period for practical beekeeping and seasonal management planning. As a result, beekeepers in particular, as well as the country as a whole, are not reaping the promised benefits from the subsector (Gezahegne Tadesse, 2001; Nuru Adgaba, 2002). This is due to the fact that apiculture is one of the agricultural sub-sectors that has gotten little research and development attention.

The current study around *Ellala* forest (in Guangua woreda) was thought to have a diverse range of vegetation and farmed crops, as well as a high potential for beekeeping operations. However, little is known about the present types of beekeeping and honey quality. Furthermore, in the study area; varieties of flora and their calendar were not well understood or identified. This research was carried out focusing on characterization of beekeeping system, flora calendar and honey quality determination around *Ellala* forest in Guangua woreda, Awi zone, Amhara regional state, Ethiopia.

1.2. Statement of the Problem

Beekeeping makes a significant contribution to the community's economy, as well as the government's, and to the environment (Ajabush Dafar, 2018). This sub-sector has significant potential to contribute to job creation, local and worldwide market development, livelihood enhancement, and biodiversity protection, as well as assure economic benefits for women, youths, and Ethiopia's geographically disadvantaged households. Due to this, it is important to focus on this sector to maximize the production and productivity as per the surrounding potential and lastly, utilize all the benefits properly. In this study area, there are opportunities to advance the sector, but there were limitations from the government and community. Some of the problems that forced to carry out this research in the Guangua district around *Ellala* forest were:

- Even though there is nearly 6371 hectares of forest land (*Ellala* forest) in this woreda which is favorable for beekeeping practice to maximize productivity, still the farmers do not properly utilize the forest for beekeeping (Guangua Woreda Agricultural Office, 2015).

- The beekeeping system practiced around the *Ellala* forest in the woreda was not well characterized.
- Despite the presence of large forest land in the study area, the availability of bee flora and their flowering calendar were not well known.
- The quality of the honey that was obtained around the *Ellala* forest land was not well determined.

1.3. Objectives

1.3.1. General Objective

- To characterize the beekeeping systems, flora diversity and determine honey quality in Guangua woreda around *Ellala* Forest.

1.3.2. Specific Objective

- To characterize Beekeeping systems in Guangua district around *Ellala* forest.
- To determine floral resources and set floral calendar around *Ellala* forest.
- To determine the quality of honey Produced around *Ellala* forest.

1.4. Research Questions

The research was conducted to answer the following important questions:

• What were the characteristics of beekeeping practice in the study area?

• What are the bee floras and their flowering calendar in the study area?

• What was the position of honey quality around *Ellala* forest based on Ethiopian and International quality standard parameters?

CHAPTER 2: LITERATURE REVIEW

2.1. Honey Production and Marketing in Ethiopia

Ethiopia has beehives. Out of total hives 6,986,100, there exist 6,699,219 (95.9%) traditional, 102,957 (1.5%) transitional and 183,924 (2.6%) frame hives (CSA, 2021). Ethiopia stands ninth in the world and first in the Africa in honey production (Tesfaye Bekele *et al.,* 2017). The country has the potential of producing up to 500,000 tons of honey and 50,000 tons of beeswax per annum (EIAR, 2017). But currently production is limited to 129,301 tons of honey and 5,790 tons of wax CSA, (2021). Honey is produced in almost all parts of Ethiopia. However, the most important honey regions are Oromia which accounts for over 51% of the bee colonies and 38% of the honey production, followed by Amhara which accounts for about 21% of the colonies and 26% of the honey production. The Southern Nations, Nationalities Peoples Regional State, on the other hand, accounts for about 18% of the bee colonies and 18% of the honey production. while Tigray and Benshangul-Gumuz accounts for 5% and 4% of the total bee colonies, and 8% and 7% of the total honey production, respectively (AAU, 2015).

Around 67% of the world's annual honey output is sold in the country of origin, with the remaining 23 percent traded on the international market (ITC, 2003; MoARD, 2007). China has also surpassed the United States as the world's largest honey consumer, increasing its share of the worldwide market from 8% in 1993 to 16% in 2004. (CAP, 2008).

2.2. Honeybee Resources in Ethiopia

African honeybees are far more active than bees in temperate zones when it comes to collecting nectar (Ayalew Kassaye, 1990). Beekeeping is an appropriate and well-accepted farming activity that is well-suited to a wide range of tropical African habitats (Amssalu Bezabeh *et al*., 2012). In Africa, bees quickly make wax in response to the need to build new combs on a regular basis.

Diverse studies have come to different and contradictory conclusions concerning the origin of the honey bee species based on morphometric investigations. Ancient Egyptian hieroglyphs mention Abyssinia as a source of honey and beeswax. Beekeeping is thought to have begun around 5000 years ago in Northern Ethiopia, along with the early settlement of the people, based on historical evidence (Ayalew Kasaye, 1990). As a result, it has been a tradition for a long time, long before alternative farming systems existed.

Apis mellifera jemenitica is found in the eastern lowlands, *Apis mellifera monticola* in the southern mountains, *Apis mellifera litorea* in the extreme western lowlands, *Apis mellifera adansonii* in the southern mid-altitude areas, and *Apis mellifera abyssinica* in the central plateau and southwestern parts of the tropical forest (Ayalew Kasaye, 1990). Furthermore, according to Yetemwork Geberemeskel (2015), *A.m. jemenitica*, *A.m. bandasii*, and *A.m. sudanensis* are the three species found in Ethiopia, as described by (Radloff and Hepburn, 1997).

On the other hand, Amssalu Bezabeh *et al*. (2004) indicated that morphometric characters of the Ethiopian honeybee populations revealed five statistically discrete races of honeybee populations existing and occupying different ecologies of the country: *A. m. jemenitica*, in the northwest and eastern arid and semiarid lowlands; *A. m. scutellata* in the west, south, and southwest humid midlands; *A. m. bandansii*, in the central moist highlands; *A. m. monticola* from the northern mountainous highlands; and *Woyi-gambela*, in the south-western semi-arid to sub-humid parts of the country.

2.3. Honey Production Systems in Ethiopia

Ethiopia is blessed with abundant water supplies and a diverse honeybee flora, making beekeeping a fruitful platform for growth. Honey hunting and beekeeping have long been popular in the country for honey extraction. Honey hunting is still practiced in Ethiopia in regions where wild colonies of bees live in hollow trees and caves (Tessega Belie, 2009). In the study of Yetemwork Gebremeskel, (2015) carried out that, based on the input used and their management, two types of beekeeping practices were mainly used in the district Kilte Awlaelo, Eastern Tigray

Honey hunting and beekeeping have long been popular in the country for honey extraction. According to Tessega Belie (2009), honey hunting is still a prevalent pastime in Ethiopia in regions where wild colonies of bees live in hollow trees and caves. Furthermore, according to Ayalew Kassaye (2008), beekeeping is currently conducted in Ethiopia in three types of production systems: traditional, transitional, and frame beehive beekeeping.

2.3.1. Honey hunting

The earliest honey hunting evidence comes from rock paintings, equipment used and anthropological studies obtained first in Spain, which is dated back to 30,000-10,000 B.C. This practice (honey hunting), as a beekeeping system, is also widely practiced by some tribes of the south and southwest Ethiopia (like Messenger tribe in Gambela) (Tessega Belie, 2009).

2.3.2. Traditional beekeeping

Traditional beekeeping is Ethiopia's oldest and richest practice, having been practiced by Ethiopians for thousands of years. This is a common beekeeping practice that is strongly linked to swarm management: beehives are hung in trees to catch swarms, then transferred and placed in backyards with various types of hive sheds that protect them from the heat and rain. Traditional beehives (30-40 cm across and 1 m long) are crafted by creating a tube shaped structure using branches, straw, cow dung and clay. But, sometimes hives can be made from soft logs of a cactus tree (Gallmann and Thomas, 2012). Hence, several million bees 8 colonies are managed in these kinds of hives and traditional beekeeping methods in almost all parts of the country (Fichtl and Admasu Adi, 1994).

As reported by Beyene Tadesse and David P. (2007) under Ethiopian farmers' management condition, the average amount of crude honey produced from a traditional beehive is estimated to be 8 to 15 kg per harvest/beehive/year in which about 8-10% of its weight is beeswax. However, this harvest is achieved with minimal cost and labor, which is valuable to people living a marginal existence (Tessega Belie, 2009).

Based on the resources and knowledge available in the area, this beekeeping approach may vary from place to place and beekeeper to beekeeper. As a result, the country has two types of traditional beekeeping practices (forest beekeeping and backyard beekeeping). Forest beekeeping is widely practiced in some areas, particularly in the western and southern sections of the country, by hanging a number of traditional beehives from trees (Tessega Belie, 2009).

In most parts of the country, backyard beekeeping with relatively better management is the most common and dominant type of beekeeping (Nuru Adgaba, 2002; Gallmann and Thomas, 2012). However, traditional beehives in this system have their own disadvantages on colony management and honey harvesting activities including: difficulty in colony inspection for brood diseases, difficult to work with open hives in the night, not appropriate for artificial queen rearing, higher chance for a number of bees and a queen to be killed during operations, very difficult yield and behavior targeting selection (Nuru Adgaba, 2002; Gallmann and Thomas, 2012).

2.3.3. Transitional beekeeping

The report of HBRC (2004) shows that the transitional beekeeping system, which has been speculated to have started in Ethiopia since 1976, is a type of beekeeping which is intermediate between traditional and frame hive beekeeping. Transitional (intermediate) beekeeping practice has different advantages over the traditional system. These include: hives can be opened easily and quickly, the bees are guided to building parallel and unattached combs following individual top bars, top bars are easily removable and this enables beekeepers to work fast, top bars are also easier to construct, honeycombs can be removed from the hive for harvesting without disturbing combs containing broods, beehives can be suspended with wires or ropes and this gives protection against pests (HBRC, 2004).

However, transitional beekeeping system has its own disadvantages such as top bar hives are relatively more expensive than traditional beehives, and combs suspended from the top bars are more adopt to break off (HBRC, 2004). Thus, as reported by, HBRC (1997) the types of beehives used more frequently in this system are the Kenyan top-bar hives (KTBH), Tanzania top-bar hives (TTBH) and Mud- block hives (MBH). Among these, KTBH is widely known and commonly used in many parts of the country.

Generally, a top-bar hive is a single-story long box with slopping sidewalls inward toward the bottom and covered with top bars of a fixed width of 32 mm for east African honeybees (Segeren, 1995). Currently, intermediate or transitional beehives are either the Kenyan top bar hives or the locally made "chefeka" hives. According to Workneh Abebe *et al*. (2008), the honeybees have accepted the Chefeka hive made from locally available materials. According to the CSA (2015/16), the current distribution of transitional bee hives in Ethiopia is 70,753 or 1.2%.

2.3.4. Frame hive beekeeping

The main purpose of frame hive beekeeping method is to obtain the maximum honey crop, season after season, without harming bees (Nicola, 2002). Accordingly, it uses different types of frame hives (Zander and Langstroth hives being common in the country, Dadant, modified Zander and foam hives are also found). However, these hives basically differ in the number and size of frames. Generally, frame hive consists of a precisely constructed rectangular boxes (hive bodies) superimposed one above the other in a tier. Similarly, the number of boxes (suppers used) varies with season, population size and activities of bees (Nicola, 2002).

The hives allow swarm control through Supering and colony management and they are easy to transport and allow the use of higher level technologies (Tessema Aynalem, 2010). However, equipment in this beekeeping system is relatively expensive, requires skilled manpower, and produces very little wax, only 1–2% of the honey yield, Gezahegne Tadesse (2001), and needs very specific precautions.

2.4. Major Contributions of Beekeeping in Ethiopia

In short, according to the below listed authors, beekeeping activity has an important contribution economically and ecologically (Ajabush Dafar, 2018). This sub sector has remarkable potential to contribute to employment generation, local and global market, livelihood improvement, and biodiversity conservation, and helps ensure the economic advantages of women, youths, and households in Ethiopia’s geographical position.

Development of the beekeeping practices could significantly enhance crop production, food security, maintenance of plant diversity and ecosystem stability (Apimondia International Symposium, 2018).

2.5. Honey Quality and Determinant factors in Ethiopia

The chemical properties of honey play an important role in determining the honey quality and affect international honey business (Abebe Mitikie, 2017). According to the Ethiopian Quality Standard Authority (ES), 1202 (2013) study, honey is a semi-liquid substance that contains a complex blend of carbohydrates, primarily glucose and fructose. Moisture content, apparent sucrose content, pH, acidity, diastase activity, reducing sugar concentration, HMF, and mineral content are all parameters to consider while analyzing honey from honeybees. Another author also stated that, chemical composition of honey mainly depends on the vegetation sources from which it derives. The properties of Ethiopian honey are reported by different researchers. External factors like climate, harvesting conditions and storage can also influence it as Crane (1980) indicated and Tessega Belie (2009) sited. Inappropriate materials used for honey handling, Careless storage conditions of honey leads to reduce its quality (Yetemwork Geberemeskel, 2015).

Honey ripeness, production methods, meteorological circumstances, processing and storage conditions, and nectar sources are all factors that influence honey quality (Sisay Gobessa *et al*., 2012). One of the most important parameters to be considered in the quality of honey is Moisture content since it affects storage life and processing characteristics (Chala Kinati., *et al*., 2001). Honey quality is also reported to be affected by high amounts of hydroxyl methyl furfural (HMF), loss of enzymatic activity, changes in flavor, color change/darkening, and microbiological development (Yetemwork Geberemeskel, 2015).

2.6. Honey Bee Floras and Their Flowering Calendar

Honey bees are fully dependent on flowering plants, so beekeeping is a floral-based industry. Of the 250,000 species present on the planet (Crane, 1990), about 40,000 plant species are key food sources for honey bees. About 500 plant species are high in nectar and pollen among Ethiopia's 6500–7000 flowering plants (Fichl and Admasu Adi, 1994; Edwards, 1976), with flowering plants including forest trees, shrubs, weeds, and cultivated crops (Fichl and Admasu Adi, 1994; Edwards, 1976; Edwards, 1976).

Abrol (1997) and Kumar (2015) reported that bee forage plants include fruit trees, vegetables, food crops, ornamental plants, herbs, shrubs, bushes, trees, forest and weeds. Honey production and other bee products depend on availability of floral resources and is a very important field for most beekeepers (Rucker *et al*., 2002). In honey production process, flowering plants provide nectar, pollen and other useful raw materials for bees and bees also serve them through pollination (Svensson, 1991). The plants that provided both pollen and nectar are named as bee pastures (Abrol, 1997). The availability of a large number of plant species provides surplus nectar and pollen to numerous types of honey bees making Ethiopia the best home for honey bees (Girema Deffar, 1998). The performance of bee colony as well as honey, bee wax and other hive products depend on the availability of bee forage (Alemtsehay Tekelay, 2011) and ecological suitability of the area (Nuru Adgaba, 2002). However, the amount of nectar and pollen obtained significantly varies from plant to plant, season and time of the day (Crane, 1990).

Identification of the honeybee plants and assessing their abundance, their value to bees, time of blooming and flowering period have a paramount importance for practical beekeeping as well as for planning appropriate seasonal management Gichora M. (2003). The distribution and type of honeybee plants as well as their flowering duration vary from one place to another due to variation in topography, climate and farming practices. Hence, every region in Ethiopia has its own honey flow and dearth periods of short or long duration. The major flowering period of honey plants in Ethiopia is from September to November and April to May, after the two known rainy seasons. After the main rainy season (June to August), the highlands of Ethiopia including central and northern Ethiopia are colored with golden-yellow flowers of Bidens spp, indigenous oil crops and red violent flower of Triflouim spp. Consequently, the major honey flow period is expected from end of October to early December for central and northern parts of Ethiopia. On the other hand, in south west and south eastern parts of the country, the major honey flow period occurs during May- June (Gichora M. 2003).

The major and minor honey flow period depends on the available nectar and pollen (Atwal, 2001). In Ethiopia, herbaceous and shrubby honey plant flower after the big rainy season (September to November) while honey trees flower during the small rainy seasons of April to May (Amsalu Bezabeh, 2002). During the flowering period, there is a considerable movement of honey bees between plants of the same species. Usually a honey bee can visit between 50 to 1000 flowers in one trip, which takes between 30 minutes to 4 hours. For instance, in Europe, a bee can make between 7 to 14 trips a day. A colony with 25, 000 forager bees, each making 10 trips a day, is able to pollinate 250 million flowers (FAO, 2010). Honey bees are critically important for the function of ecosystem and the maintenance of agricultural production through their pollinating activities. In Ethiopia, an experiment was conducted to determine the effect of pollination on the Niger (*Guizotia abyssinica*) and the result showed that honey bees increased the seed yield of Niger by about 43% (Admasu Adi and Nuru Adgaba, 2000) and Onion (*Allume cepa*) by two folds (Admasu Adi and Lamessa Debissa. 2008). This shows that honey bees play an indispensable role in boosting agricultural productivity and biodiversity conservation.

2.7. Apiculture and forestry (bees and trees)

According to the study of D. B. HILL and T. C. WEBSTER, (1995), the mutual benefits of bees and trees depend on the interaction of phenology, biogeography, economics, and hazards to bees. Most of these factors are specific to location, and depend heavily on seasonal weather patterns.

While the basic biological factors of bees and trees are understood, much necessary information is unavailable. Although a mutually beneficial interaction between trees and bees is anecdotally and empirically known, little or no research has been done in the United States to clarify the details of this relationship. More research has been done in other parts of the world, but overall, detailed scientific information is still limited. This absence is due partly to the long pre-flowering period of a tree, the complexities of site and weather influences on flowering, nectar and pollen production, and partly to methodological difficulties. Perhaps also the importance of bees in tree pollination and trees in bee forage and protection have not been fully appreciated (D. B. HILL and T. C. WEBSTER, 1995).

2.8. Challenges and Opportunities of Beekeeping in Ethiopia

2.8.1. Challenges for beekeeping in Ethiopia

2.8.1.1. Drought and deforestation of natural vegetation

In the study of Beyene Tadese and David P. (2007) indicated that, deforestation and overgrazing has nearly depleted the bee forage availability, ultimately resulting in low honey and beeswax production, cause colony migration. However, there is still the potential to increase honey production and to improve the livelihood of the beekeepers.

2.8.1.2. Limitation of rural credit service

The improved hives and working tools to the rural community are beyond the pockets of farmers and not easily available. There is limitation of the credit services for landless youths as well as households. Even if the rural credit service is around, they do not easily serve due to limitation of awareness creation (Keralem Ejigu *et al*., 2009).

2.8.1.3. Honeybee disease, pest and predators

According to the research of Hailegebriel Tesfay, (2014), pests and predators cause devastating damage on honeybee colonies within short period of time and even overnight. Ants, Honey Badger, Bee-eater birds, Wax moth, Varo mite, Spider and Beetles were the most harmful pests and predators in order of decreasing importance. Some studies indicate that the region in particular and the country at large appears to be free from various honeybee brood diseases and at the same time at low level of adult bee diseases incidences (Hailegebriel Tesfay, 2014). A major category of diseases which causes economic loss comprises amoeba, Nosema and Chalk brood (Kerealem Ejigu, 2009).

2.8.1.4. Indiscriminate application of agro-chemicals

Ethiopia has set chemical utilization and movement of bees and bee products proclamation since 2010, but not properly applied at the grass root level. The uses of Agrochemicals and pesticides have a huge influence on bee's health specially those areas of highly crop producers the real possibility of damaging the colony, as well as the contamination of hive products. Of the various kinds of chemicals, insecticides and herbicides are now major problems to the beekeepers (Kerealem Ejigu, 2010). Insecticides are the main destructive chemical than other pesticides.

Poisoning of honeybees by agrochemical has been increased from time to time. Some beekeepers lost their colonies totally due to agrochemicals. So, it needs special attention from the government to solve the problems by coordinating and integrating the responsible crop scientists, animal science experts and others bodies (Kerealem Ejigu, 2010).

2.8.1.5. High price of improved beekeeping technologies

The report of ALRDPA, (2013/14) shows that, improved beekeeping frame hives require different technological imputes like centrifuge honey extractor, hive tool, queen excluder and others are obtained from imported from abroad with foreign currency. The frame hives with its accessories can be produced in the region but their price is continuously increasing time to time and currently reaching to a price of birr 3500. For example, let us assume that someone needs to start beekeeping with 5 frame hives, then he/she needs a to invest the amount of money reaching up to 20,000 birr which is believed to be unaffordable for the resource poor farmer. So, the Amhara regional livestock development promotion agency advises those participants to use transitional beehive first then understanding the technology practice, they afford frame hive beekeeping system.

2.8.1.6. Poor post-harvest management of bee products

Honey quality is severely harmed as a result of some technical faults such as contaminants added during harvesting. Mixed in with the honey are the remains of dead bees, local hive building materials such as cow dung, bee brood, pollen, and even wax. Smoking at levels higher than the legal limit has been proven to alter the flavor of honey, making it unpalatable to consumers (ALRDPA, 2013/14).

2.8.1.7. Absence of business insurance

According to the report of ALRDPA, (2013/14), beekeeping is a sensitive business practice that can be easily risked by drought due to either a shortage of feed or water supply for the bees. The beekeeper may lose all the colonies within a month. Farmers are susceptible to disasters that can't tolerate the risk, even with a minimum loss of their livelihoods. They can't mitigate the problem easily by assuming the risk, and it leads to fear of technology acceptance at all.

2.8.2. Opportunities of Beekeeping

2.8.2.1. Agro-ecology of Beekeeping in the Country

The occurrence of many ecologies and agro climatic conditions encourages bees to migrate from one ecological area to another, allowing them to avoid hard seasons (EARO, 2000). There are five different varieties of honeybees in Ethiopia, each with its own ecological niche. In Ethiopia, millions of beehive colonies can be found in various agro-ecological zones (CSA, 2011/12). In general, honeybee colonies are denser in high biomass areas of the west and northwest of the country, compared to low biomass and moisture stress areas in the east (EIAR, 2017).

2.8.2.2. Diverse agro-Climatic Conditions

Because a variety of ecologies and agro climatic conditions exist, bees are encouraged to migrate from one ecological area to another, allowing them to avoid harsh seasons (EARO, 2000). In Ethiopia, there are five different types of honeybees, each with its specific ecological niche. CSA (2011) detected millions of beehive colonies in Ethiopia's diverse agro-ecological zones. Honeybee colonies are generally more numerous in high biomass areas of the west and northwest of the country, as opposed to low biomass and moisture stress areas in the east (EIAR, 2017).

2.8.2.3. Market Opportunities and Increasing Demand for Beekeeping Products

Ethiopia has a good export market possibility for bee products such as honey and bees wax, according to CSA's (2011/12) study. The demand for bee products is expanding at an alarming rate from time to time. The well-being of bees and the production of organic honey are both in great demand. Low pesticide use opens the door to organic beekeeping development.

CHAPTER 3: MATERIALS AND METHODS

3.1. Descriptions of the Study Area

Guangua woreda is part of the Awi Zone, in Amhara regional state and is bordered on the south and west by the Zigem woreda and Benishangul-Gumuz Region, on the north by Dangila, on the northwest by Fageta Lekoma and Banja Shekudad, and on the east by Ankasha Guagusa; part of its western border is defined by the Dura River, a tributary of the Abay River. Chagni is the woreda's administrative center. According to the Central Statistical Agency of Ethiopia (CSA, 2005), this woreda has a total population of 223,066, with 111,172 men and 111,894 women; 31,489 or 14.12 percent of the population living in cities.

According to Fikre Girma *et al*. (2015), lowland elevations range from 800–1500 meters above sea level, midland elevations range from 1500–2300 meters above sea level, and highland elevations range from 2300–3000 meters above sea level. The woreda's height varies depending on this, ranging from 1344 meters above sea level to 2637 meters above sea level, indicating that it has lowland, midland, and highland agro-ecology. The research area's (*Ellala* forest) elevation spans from 1483 to 2624 meters above sea level, making two Kebeles highland, two Kebeles midland, and one Kebele lowland in terms of agro-ecology (Guangua woreda Agricultural office, 2015).

This woreda has 3206 male beekeepers, 475 female beekeepers, and a total of 3679 beekeepers with three types of hives: traditional: 23,479, top bar: 647, and frame: 1537. Around *Ellala* forest there were, Males: 178, females: 37, and a total of 215 beekeepers with three types of hives: traditional: 2576, top bar hive: 92, and frame hive: 248 (Guangua woreda Agricultural office, 2015).

According to GWAO (Guangua Woreda Agricultural Office), (2015), the Guangua *Ellala* Forest (the research area) is located in Amhara Regional State, Awi Administrative Zone and Guangua Woreda. The study area is located between latitudes 10^0 44'0"N to $11^0$1'0"N and longitudes $36^0$26'30"E to $36^0$47'30"E (Fig.1). It is located 525 kilometers from Ethiopia’s capital, Addis Ababa and it has a total area of 63.71 kilometer square. The elevation ranges from 1483 to 2624 meters above sea level.

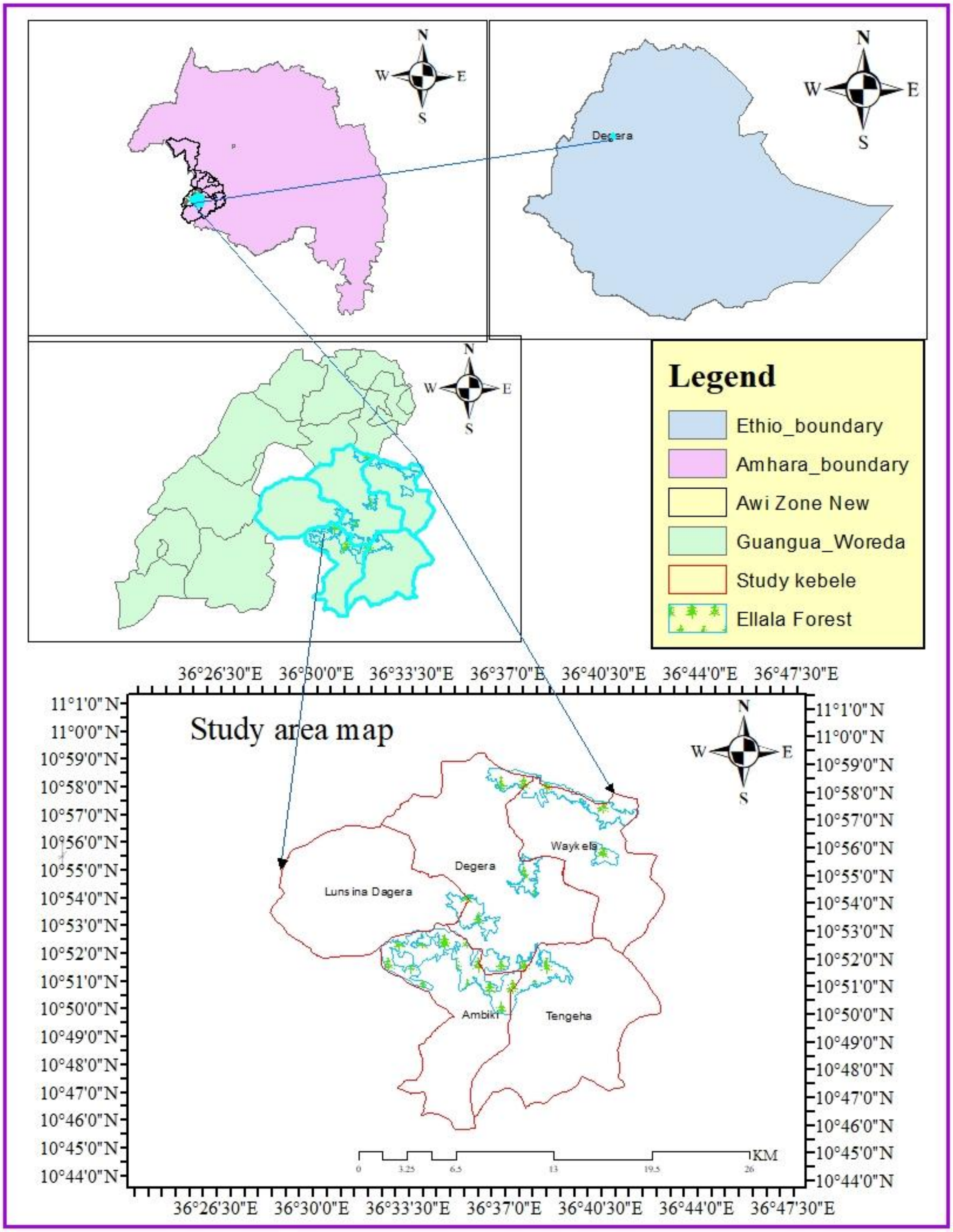


Figure 1: Map of the study area

(Source: Guangua woreda Agricultural Office, 2015)

3.2. Sampling Techniques and Sample size

Guangua woreda consists of 18 rural and 2 urban kebeles. In this case, five/whole/ kebeles which found around the *Ellala* forest were used, each having a different agro-ecology (lowland, mid-altitude, and highland). In this study beekeepers selected purposively and the number of respondents were determined using Yamane (1967) formula. Accordingly, a total of 140 beekeepers, 127 males and 13 females having the three types of hives were selected. The respondents own a total of 1956 traditional, 87 transitional and 213 frame hives.

$n=N/1+N\ (e^2)$

Where:

- n---sample size
- N---total population
- e---level of precision used (e=0.05)

Then $n = 215(1 + 215(0.05^2)) = 139.84 \sim 140$

The number of respondents identified was 140 beekeepers.

A total of 140 potential respondents were selected proportionally from each Kebeles by using purposive sampling technique for the survey. Generally, 5% sampling error was being used as a standard.

In this study, 18 honey samples 9 from each season from traditional, transitional, and frame bee hives around *Ellala* forest were used. The honey samples were collected using food-graded 500gm plastic containers from representative bee hives for quality test and at least 10 g of honey sample for pollen analysis was used. Then after, honey samples, after being cleared of different debris, dead bees, and other unwanted materials, it was prepared according to the "COMESA 002 (2004) Standard for Honey" protocol for quality analysis.

3.3. Data Source

Both primary and secondary data sources were used. Prior to data collection, checklist preparation, selected study site observation, questionnaire pre-testing with key informants and understanding the livelihood status and styles of the beekeepers was conducted. Accordingly, primary data was collected from sampled respondents from each of the selected kebeles through a semi-structured questionnaire. Furthermore, honey samples were collected from farm gate and then honey sample was extracted, as explained above. On the other hand, secondary data was collected from various sources like, previous research findings, reports of Ministry of Agriculture (MOA), Regional Livestock Resource Development Promotion Agency, district Livestock Resource Development Office and other governmental and non-governmental organizations).

3.4. Method of Data Collection

The study had two parts: part one was a survey work that was conducted among selected beekeepers with a semi-structured questioner. While part two was the determination of the qualities of honey produced and identification of flora by pollen analysis.

3.4.1. Survey

Prior to the actual survey, information was gathered from the secondary data and an informal survey conducted by the woreda and Kebele Agricultural office and key informants. Based on the information obtained from secondary data (Research thesis, journals, reports, published and unpublished documents, etc.) an informal survey was conducted and a semi-structured questionnaire was developed to meet the objectives of the study.

The whole kebeles found around *Ellala* forest with respect to honeybee colony potential, 5 peasant associations (2 from highland, 2 from midland and 1 from low highland) were used. The total of 140 respondents from the three agro-ecologies were purposively selected.

A purposive sampling technique was used to determine the number of sample households from beekeepers due to beekeepers having better colony number and hive type. A single household respondent was used as the sampling unit in this study. The data on beekeeping practice systems and types of flora with their flowering calendars was collected by using focus group discussion, key informants, and a pre-tested semi-structured questionnaire adopted from (FAO, 2011).

3.4.2. Honey Sampling and quality analysis

3.4.2.1. Honey sampling

A total of 18 honey samples (9 samples in each season) were collected during two seasons from three purposively selected potential beekeeping kebeles around *Ellala* forest. At farm gates, honey samples were collected from three types of hives around *Ellala* forest areas (6 traditional, 6 top bars, and 6 from frame hives) or 3 from traditional, 3 from top bar, and 3 from frame hives in one season from potential beekeepers selected purposively. During the peak honey harvesting seasons, 500 g a fresh honey sample in each season was taken from three types of hives and 10 g of honey for pollen analysis was taken (November to December, 2021 and April to May, 2022) (Figure 2).

Figure 2: Honey sample collection at farm gate

3.4.2.2. Method of honey quality Analysis

The physical and chemical composition of a honey sample (such as moisture content, pH, acidity, diastase activity, invertase activity, sucrose, electrical conductivity, HMF, and mineral continent) was proposed to determine using the International Honey Commission's Harmonized Method (Bogdanov S. *et al*., 2002 and Gremew Bultossa, 2005). But the physicochemical analysis was carried out based on only six parameters (Moisture content, pH value and free acidity, Reducing sugar (Fructose and Glucose) content, Sucrose, Ash content and Hydroxyl Methyl Furfural or HMF) due to unavailability laboratory chemicals at Holeta Bee Research Center and their cost expensiveness because of national and international market problems. The chemical properties were analyzed at Holeta Bee Research Center.

A. Moisture Content

Prepared samples were homogenized and put in a flask. The flasks were closed and placed in a water bath at a temperature of 50°C (± 0.2) until all the sugar crystals were dissolved. The solutions were cooled to room temperature and stirred again with checking that the flask were air tight. The cleanness and dryness of the prism of Refractometer were *ensured* first. After homogenization, the surface of the prism was evenly covered with the sample directly. After 2 minutes (Abbe refractometer), the refractive index was read. Each honey was measured twice and the average values were recorded. The corresponding moisture content was read from the table and the prism was carefully cleaned after use. The honey and water contents were calculated from the RI measured by applying the equation of Wed more (1955): Wed (%) = [-0.2681-10g (RI-l))/0.002243.

Or;

Five to Ten grams of honey sample was taken in to porcelain crucibles in treated and oven dried at 30 ^{0}C for 1 hour (Gremew, 2005). Percent moisture content was calculated according to the following formula:

$$\text{Moisture Content \%} = \frac{\text{I}-\text{F}}{\text{I}} \times 100$$

Where I = Initial weight of honey and F = Final weight of honey

B. pH and free acidity

Ten grams of the honey samples was dissolved in 75 ml of carbon dioxide free water (dissolved water) in a 250 ml beaker and stirred with the magnetic stirrer. Then the pH was measured with pH meter (Inolab, Germany), calibrated at 4.0 and 7.0. The solution further was titrated with 0.1 M Sodium hydroxide (NaOH) solution to pH 8.30 (a steady reading was obtained within 2 minutes of starting titration). For precision the reading to the nearest 0.2 ml using a 10 ml burette was recorded. Free acidity was expressed as mill equivalents or mill moles of acid/kg honey = ml of 0.1 M NaOH × 10 and the result was expressed to one place of decimals.

C. Ash

Ash content was determined after the sample is burned in an electric muffle furnace (Lenton Thermal Designs, England). First, the ash dish was heated in the electrical furnace at ashing temperature, subsequently cooled in a desiccator to room temperature, and weighed to 0.001g (M_2). Then, 5 to 10 grams of honey sample was weighed to the nearest 0.001g (M_0) and put in the prepared ash dish, and two drops of olive oil was added to prevent frothing. Then water was removed and the ashing commenced without loss (by foaming and overflowing) at a low heat, rising to 350–400^0 C by using an electrical device. A hot plate was used to char the sample before inserting it into the furnace. After the preliminary ashing with the hot plate, the dish was placed in the preheated muffle furnace (at 550^0 C) and heated for 1 hour. The ash dish was cooled in the desiccators and weighted. The ashing procedure was continued until a constant weight is reached (M_1).

Percent ash in g/100g honey was calculated using the following formula:

$$\text{Ash \%} = \frac{M1-M2}{M0} \times 100$$

Where M_0 = weight of honey taken, M_1 = weight of ash + dish and M_2 = weight of dish.

D. Reducing Sugar

This method is a modification of the Lane and Eynon (1923) procedure, involving the reduction of Soxhlet's modification of Fehling's solution by titration at boiling point against a solution of reducing sugars in honey using methylene blue as an internal indicator (Appendix 7.4). The difference in concentrations of invert sugar was multiplied by 0.95 to give the apparent sucrose content. This method is based on the original method of Lane and Eynon (1923) and is also used in the Codex Alimentarius standard (2001). The amount of water added bring the total volume of the reactants at the completion of the titration to 35 ml was calculated by subtracting the preliminary titration (X ml) from 25 ml. Pipette 5 ml Fehling's solution A was pipette into 250 ml Erlenmeyer flask and approximately 5 ml Fehling's solution B was added (Appendix 7.4). Add (25-X) ml distilled water, a little powdered pumice or other suitable antidumping agent and, from a burette, all but 1.5 ml of the diluted honey solution volume determined in the preliminary titration. The cold mixture was heated to boiling over wire gauze and maintained moderate ebullition for 2 minutes. 1 ml 0.2 % methylene blue solution was added whilst still boiling and the titration was completed within a total boiling time of 3 minutes by repeated small additions of diluted honey solution until the indicator was decolorized. Calculation and expression of result: C=25/W 2X 1OOOIY2 Where C = g invert sugar per 100 g honey W2 = weight (g) of honey sample Y2 = volumes (ml) of diluted honey solution.

E. Sucrose

The honey solution (50 ml) was placed in a graduated flask, together with 25 ml distilled water, heated to 65°C over-a boiling water bath. The flask was then removed from the heated bath and 10 ml of hydrochloric acid was added. The solution was allowed to cool naturally for 15 minutes, and then brought to 20°C and neutralized with sodium hydroxide, using litmus paper as indicator, cooled again, and the volume adjusted to 100 ml (diluted honey solution). Then the procedure of determining reducing sugar continued.

Apparent sucrose content = (invert sugar content after inversion - invert sugar content before inversion) xO.95. The result is expressed as g apparent sucrose per 100 g honey.

The percentage of sucrose was worked as follows:

Sucrose (%) = TRS after inversion – TRS before inversion × 0.95.

Where: 0.95 = Constant

E. Estimation of hydroxyl methyl furfural (HMF)

The reagents enlisted below, required to estimate the HMF content in honey samples, was prepared as follows:

Carrrez solution I – 15 g of potassium hexacyanoferrate $K_2Fe\ (CN)_6\ 3H_2O$ was dissolved in distilled water and volume was made to 100 ml.

Carrrez solution II – 30 g of zinc acetate, Zn $(CH_3.H_2O$ was dissolved in distilled water and volume was made to 100 ml.

Sodium bisulphate solution 0.20 g/100 g (0.2%) – 0.20 g of solid sodium bisulphate (NaHSO3) was dissolved in distilled water and diluted to 100 ml. A 5g sample of honey was taken and diluted in 25 ml of water before being poured into a volumetric flask. Then 0.5 ml of Carrrez solution I was mixed with 0.5 ml of Carrrez solution II to make up the volume. Then the solution was filtered through the filter paper, and the first 10 mL of filtrate was rejected. Five ml of sample was pipetted into two test tubes, and five ml of water was pipetted into one test tube and thoroughly mixed. To the reference solution (Table 1), 5 ml of 0.2% sodium bisulphate solution was added and mixed well.

Table 1: Dilution of sample and reference solution carried for estimation of HMF

Addition to test tubes	Sample solution (in ml)	Reference solution (in ml)
Initial solution	5.0	5.0
Water solution	5.0	-
Sodium bisulphate (0.3 %)	-	5.0

The absorbance of the sample determined against the reference solution with UV Spectrophotometer at wave length 284 and 336 nm using 1 cm quartz cells within one hour. Sample and reference solution was diluted with water and sodium bisulphate, if the absorbance exceeds 0.6 at 284 nm.

$$\text{Diluted D} = \frac{\text{Final volume of sample solution}}{10}$$

HMF expressed as mg/kg = $(A_{284} - A_{336}) \times 149.7 \times 5 \times D/W$.

A_{284} = Absorbance at 284 nm.

A_{336} = Absorbance at 336 nm.

149.7 = 126 × 1000 × 1000/16830 × 10 × 5.

126 = molecular weight of HMF.

16830 = molar absorptivity and HMF at 284 nm.

10 = conversion of g to mg

1000 = conversion of g to kg.

5 = Theoretical nominal sample weight.

D = Dilution factor (in case dilution is required).

W = Weight of honey sample in g.

3.4.3. Honey sample and pollen analysis

The honey samples used in the study were collected directly from the farm gates using tightly closed, chemical free plastic containers having the capacity of one a kilo gram. The samples were made free from foreign maters like dead bees, insects, debris, brood, and particles of the comb (Pavelkova A. *et al*., 2013).

To identify the pollen in the honey and check the identity, reference slides (prepared earlier from flower buds) were used. Honey pollen analysis was made using 10 gm. of honey dissolved in 30 ml of warm (distilled or clean tap water) not above 40◦C, centrifuged at about 2500-3000r/min for 10 min and supernatant liquid decanted or withdrawn/poured out. In case of dispersed sediment, the excess sugar was removed by centrifuging again with 10 ml water for 5 min. Then after, the entire sediment was mounted onto a microscope slide, glycerin jelly added for clear observation and covered with a slide cover to decrease the free movement of the pollen grains during counting. Dried and mounted/loaded slides were then adjusted on to a microscope and pollen grains were examined under a 400x magnification power. Number of total pollens, total number of pollen grains representing each of the pollen source plants, and their percentage occurrences were determined for major honey source plants in the area following the system adopted by (Louveaux J. *et al*., 1978) and the reference slides prepared (Figure 3).

Figure 3: Honey sample and pollen analysis at laboratory

3.5. Data Management and Statistical Technique

The collected data was summarized and analyzed using simple descriptive statistics (mean, standard deviation, frequency, percentage), determine correlation and compare mean using Statistical Package of Social Science (SPSS) version 26.

The physico-chemical honey quality parameters (Moisture content, PH value and Free acidity, Ash content, reducing sugar (fructose and glucose) content, Sucrose content, and Hydroxyl Methyl Furfural or HMF) from three types of hives around *Ellala* forest was analyzed.

Independent T-test and ANOVA was used to determine the differences in composition of honey around *Ellala* forest.

The following statistical Model was used to determine honey quality and season independently:

$$Y_{ij} = \mu + H_i + S_j + e_{ij}$$

Where, Y_{ij} = Honey quality parameters (response variable), μ = overall mean, H_i = the effect of i^{th} hive type, S_j= the effect of season and e_{ij} = random error.

CHAPTER 4: RESULTS AND DISCUSSIONS

Data for the survey work was collected from a total of 140 households selected from the three agro ecologies. The households in the three agro ecologies were found to have 1956, 87 and 213 honeybee colonies in traditional, transitional and frame hives, respectively. This indicated that the development of modern beekeeping system (transitional and frame hive beekeeping) in the study area being lower compared with traditional hive. This result is disagreeing with the study conducted in Kilte Awlaelo district, Eastern Tigray during 2015 which showed that among the sampled beekeepers 156 (95.5%) had honeybee colonies in frame hives with a mean of 6.39 and a maximum of 100 colonies (Yetemwork Geberemeskel, 2015).

4.1. Demographic Characteristics of the respondents

The demographic characteristics of beekeepers were summarized in terms of gender, marital status, age, education level, experience, land holding and others as follows and described in Tables below.

4.1.1. Gender of the respondent

From the respondents from the total of 90.7% were males, whereas 9.3% were females (Table 2). This result is similar with the result of Haftu Kebede *et al*. (2015) which stated that most of the interviewee household heads were male (89%) and the rest were female headed households (11 %). In the study area, beekeeper women constitute the less percentage. But, the women's share of beekeeping work (cleaning the apiary, protecting from birds and different pests) often exceeds that of men. Husbands decide how to work it and its advantage. This may be due to the reduced involvement of the government and non–governmental organizations in gender related trainings in the study area so as to support female house hold headed farmers through beekeeping activity. Consequently, in order to increase the women's motivation in the study area in honey production, it is important to focus on gender-based training.

4.1.2. Marital status of the respondent

About 95.0% were married, 2.9% were widowed. And 2.1% respondents were divorced (Table 2.). This indicates that beekeeping activities could be performed by every group of the community regardless of their marital status. Therefore, the participation of single person beekeepers was very small in the study area. This result is related with the study of Haftu Kebede and Gezu Tadesse (2014) which indicated that, of the total households interviewed, 96.8% are married.

In the study area the married ones were gave better attention for beekeeping whereas single respondents gave less attention for beekeeping. This should be corrected by giving equal support and continuous extension to maximize the production in this sector as well as to benefit single respondents.

Table 2: Gender and Marital status of the respondents

Variables		Altitude of the respondent's area						Total	
		Highland		Midland		Lowland			
		F	%	F	%	F	%	F	%
Gender	Male	31	86.1	75	92.6	21	91.3	127	90.7
	Female	5	13.9	6	7.4	2	8.7	13	9.3
Total		36	100	81	100	23	100	140	100
Marital status	Married	35	97.2	77	95.1	21	91.3	133	95.0
	Widowed	0	0.0	3	3.7	1	4.3	4	2.9
	Divorced	1	2.8	1	1.2	1	4.3	3	2.1
Total		36	100	81	100	23	100	140	100

F= Frequency

4.1.3. Family size

An average family size per household was 6.28± 1.847 members with a maximum of 11 and a minimum of 2 people (Table 3). This study agrees with the study of Abebe Metikie, (2017) average family size per household with a maximum of 8 and a minimum of 2 people. Family size is essential in beekeeping practices in order to share tasks and to maximize the production.

4.1.4. Land holding

The average land holding was about 1.40 hectares (with a range from 0.25 to 3.75 hectares) (Table 3). The data has described that the average land holding in the study area is below the national average (1.5 ha). This shows that beekeeping could be practiced with people who have very small plot of land in their mixed farming system.

Table 3: Age, number of family and land holding of the respondents around *Ellala* forest

	N	Minimum	Maximum	Mean	SD
Age of the respondents	140	25	72	40.49	7.65
Number of family	140	2	11	6.28	1.85
Land holding	140	0.25	3.75	1.40	0.74

N= number of observations; SD= standard deviation

4.1.5. Age of the respondents

Mean age of respondents in the study area was 40.49±7.65 years (ranging from 25 to 72 years). This could explain that beekeeping is an activity which can be carried out at different age groups and in most cases, people at younger and old ages are not actively engaged in beekeeping (Table 3). Of the sampled households 27.1% were under the age range of 20 to 35 years, 65.7% were in the age range from 36 to 50 years, 6.4% were in the ranges from 51 to 65 years and 0.7% were above 65 years old (Table 4). In this study, the survey result showed that farmers in the most productive age were actively engaged in beekeeping activities. The result of this study is agreed with Haftu Kebede and Gezu Tadesse (2014) which stated that the majority age of the beekeepers in the study area ranges between 40 to 49 years (37.6%).

This is due to productive age groups have motivation and have access for training than others in the study area. In order to engage all age groups in beekeeping intensive training and follow-up at grass root level is required from the responsible institutions and individuals.

4.1.6. Educational background of the respondents

In terms of educational back ground, 22.1% of the respondents were illiterates, 33.6% of beekeepers can read and write, 26.4% of beekeepers were grade 1-4, 11.4%, beekeepers were grade 5-8 and 6.4% of beekeepers were grade 9-12 (Table 4). Accordingly, illiterates and beekeepers who can read and write had high participation in beekeeping (55.7%) in the study area. On the other hand, beekeepers who got formal education have low participation in beekeeping, this means education and beekeeping in the study area are not well correlated because educated farmers didn't consider the sector as income source rather, they focused on other agricultural activities due to minimal know how. Due to the fact that the majority of beekeepers sampled were illiterate and read and write, we suggest that there is a need of intensive training and encouragement in transitional and movable frame hives beekeeping to move them to improved beekeeping systems. This result is in line with the study of Chala Kinati *et al.* (2013) which stated that, 34.4% of those interviewed beekeepers did not receive any formal or informal education. In the study area respondents started beekeeping practice without getting formal education by obtaining knowledge from early starter beekeepers.

Table 4: Age and educational status of the respondents

Variables		Age of the respondent						Total	
		Highland		Midland		Lowland			
		F	%	F	%	F	%	F	%
Age	20-35 years	10	27.8	17	21.0	11	47.8	38	27.1
	36-50 years	19	52.8	61	75.3	12	52.2	92	65.7
	51-65 years	6	16.7	3	3.7	0	0.0	9	6.4
	> 65years	1	2.8	0	0.0	0	0.0	1	0.7
Total		36	100	81	100	23	100	140	100
Educational status	Illiterate	8	22.2	19	23.5	4	17.4	31	22.1
	read and write	17	47.2	22	27.2	8	34.8	47	33.6
	grade 1-4	7	19.4	24	29.6	6	26.1	37	26.4
	grade 5-8	3	8.3	11	13.6	2	8.7	16	11.4
	grade 9-12	1	2.8	5	6.2	3	13.0	9	6.4
Total		36	100	81	100	23	100	140	100

F= frequency

4.1.7. Correlations between colony holding with sex and educational status of the respondents

Educational level of the respondents with colony holding has low degree of correlation but sex of the respondents and colony holding has no correlation that means ($P>0.05$). This indicates that educated farmers had not much more colony number than non-educated respondents and when the gender was considered, there was no equal participation males and females in beekeeping around *Ellala* forest as shown in Table 5.

Table 5: Correlations between colony holding with sex and educational status

		Sex	Educational status	Colony holding
Sex	Correlation	1		
Educational status	Correlation	0.02	1	
Colony holding	Correlation	-0.12	-0.06	1

N= number of cases; Sig= significance level at 0.05

4.1.8. Experience of beekeepers in different agro-ecologies

The experience of beekeeping activities, about 37.9% of the respondents have 10-15 years' experiences in beekeeping in the study area, which is higher in number than other year categories (Table 6). This shows that the existence of long years of beekeeping practice in the study area which is associated with indigenous knowledge, conducive weather conditions of the area and availability of honeybee flora.

Table 6: Experience of beekeepers in different agro-ecologies

Variable		Altitude of the respondent's area						Total	
		Highland		Midland		Lowland			
		F	%	F	%	F	%	F	%
Experience in beekeeping	< 10 years	9	16.7	18	22.2	8	34.8	35	25.0
	10-15 years	10	27.8	32	39.5	11	47.8	53	37.9
	16-20 years	8	22.2	15	18.5	2	8.7	25	17.9
	21-30 years	5	13.9	11	13.6	2	8.7	18	12.9
	31-40 years	1	2.8	3	3.7	0	0.0	4	2.9
	> 40 years	3	8.3	2	2.5	0	0.0	5	3.6
Total		36	100	81	100	23	100	140	100

F= frequency

4.2. Beekeeping practices and honey production

4.2.1. Beekeeping Practices

4.2.1.1. Source of honeybee colony to start beekeeping

The sources of honeybee colony for the beginner who wants to start beekeeping and increase the number of the honeybee colony were obtained in different ways. The result shows that; the majority of the respondents (55.7%) were obtained honeybee colonies by catching the swarm, while others 25.7%, 16.4% and 2.1% respondents were obtained their honeybee colony from their parents, from both parents and by catching swarm and both catching swarm and buying honeybee colony respectively.

Another sources of honeybee colonies were by purchasing them from different sites. About 72.9% of respondents purchased the honeybee colony with the price between 800.00 to 1000.00 ETB at their locality and the rest 27.1% of respondents purchase honeybee colony with the price between 1001.00 to 1250.00 ETB (Table 7).

Table 7: Source and price of colony

Variable		Altitude						Total	
		Highland		Midland		Lowland			
		F	%	F	%	F	%	F	%
Colony source	From parents	21	58.3	14	17.3	1	4.4	36	25.7
	Catching swarm	12	33.3	47	58.0	19	82.6	78	55.7
	From parents catching swarm	2	5.6	19	23.5	2	8.7	23	16.4
	Catching swarm & buying	1	2.8	1	1.2	1	4.4	3	2.1
Total		36	100	81	100	23	100	140	100
Colony price in ETB	800.00-1000.00	24	66.7	72	88.9	6	26.1	102	72.9
	1001.00-1250.00	12	33.3	9	11.1	17	73.9	38	27.1
Total		36	100	81	100	23	100	140	100

F= frequency; ETB= Ethiopian birr

4.2.1.2. Sources of honeybee hives

Beekeepers got honeybee hives from different sources for their purpose. According to the respondents, 92.9%, 4.3% and 2.9% the respondent obtained their traditional beehives by constructing him/herself, constructed locally and bought and bought from market respectively. About 20.7% respondents obtain transitional beehives by constructing themselves, 3.5% of them also obtained from constructed locally and bought, 17.2% of respondents obtained this hive type bought from market, 13.8% of the respondents obtained transitional hive from government on credit and 44.8% respondents have also obtained their transitional hive NGO’s with free. While, 3.7%, 27.8% and 68.5% of respondents got their frame hive by purchasing from market, supplied by government on credit and supplied by NGO’s respectively (Table 8). This result indicated that, most of the beekeepers constructed the traditional honeybee hives from locally available materials by themselves and most of their transitional and frame hives obtained from NGO’s with free around *Ellala* forest.

Table 8: Source of hive around *Ellala* forest

Variables		Altitude						Total	
		Highland		Midland		Lowland			
		F	%	F	%	F	%	F	%
Traditional	Constructed him/her self	30	83.3	79	97.5	21	91.3	130	92.9
	Constructed locally and bought	2	5.6	2	2.5	2	8.7	6	4.3
	Bought from market	4	11.1	0	0.0	0	0.0	4	2.9
Total		36	100	81	100	23	100	140	100
Transitional	Constructed him/her self	0	0.0	6	31.6	0	0.0	6	20.7
	Constructed locally and bought	1	16.7	0	0.0	0	0.0	1	3.5
	Bought from market	2	33.3	3	15.9	0	0.0	5	17.2
	By government with credit	3	50.0	0	0.0	1	25.0	4	13.8
	By Ngo's with free	0	0.0	10	52.6	3	75.0	13	44.8
Total		6	100	19	100	4	100	29	100
Frame hive	Bought from market	1	7.1	1	3.5	0	0.0	2	3.7
	By government with credit	2	14.3	11	37.9	2	18.2	15	27.8
	By Ngo's with free	11	78.6	17	58.6	9	81.8	37	68.5
Total		14	100	29	100	11	100	54	100

F= frequency

2.2.1.3. Beekeeping Equipment

According to this study, from the total respondents who have had honeybee colony in traditional hives 11.4% used protective cloth, 27.1% used smoker, 19.3% used bee brush, 100% used knife and 8.6% respondents used water sprayer during honey harvesting time. And those respondents having bee colonies in transitional hives 24.1% used protective cloth, 27.6% used smoker, 69.0% used bee brush, 100% used knife, 13.8% used water sprayer and 31.0% respondents also used chisel during honey harvesting time while, those respondents who have had bee colonies in frame hives 77.8% used protective cloth, 48.2% used smoker, 64.8% respondents used bee brush, 18.5% used water sprayer and 25.9% of the respondents used chisel during honey harvesting time (Table 9). The study agrees with the study of Tessega Belie (2009) the adoption of improved beekeeping practices relies on the supply of these basic materials (equipments). Access and proper use of the beekeeping equipments is still, the problem of beekeepers in the study area.

Even though there was some provision and usage of equipments for beekeepers, still there is limitation of using all the equipments for all types of hives during honey harvesting time due to awareness limitation and equipment access problem, and some respondents responded as totally they have no any beekeeping equipment even the protective cloth. Due to this, farmers follow traditional way of beekeeping practice. As the result the production was not as expected production potential. Governmental and non-governmental Organizations should encourage the beekeepers to use appropriate beekeeping technologies (inputs) and accessories to increase the production of the sub-sector.

Table 9: Equipment utilization percentage for honey harvesting at different agro-ecologies

		Altitude							
		Highland N=36		Midland N=81		Lowland N=23		Total N=140	
		F	%	F	%	F	%	F	%
Traditional	Protective cloth	5	13.9	9	11.1	2	8.7	16	11.4
	Smoker	3	8.3	27	33.3	8	34.8	38	27.1
	Bee brush	10	27.8	14	17.3	3	13.0	27	19.3
	Knife	36	100	81	100	23	100	140	100
	Water sprayer	1	2.8	10	12.3	1	4.4	12	8.6
Transitional	Protective cloth	2	33.3	4	21.1	1	25.0	7	24.1
	Smoker	1	16.7	6	31.6	1	25.0	8	27.6
	Bee brush	6	100	11	57.9	3	75.0	20	69.0
	Knife	6	100	19	100	4	100	29	100
	Water sprayer	1	16.7	1	5.3	2	50.0	4	13.8
	Chisel	2	33.3	5	26.3	2	50.0	9	31.0
Frame	Protective cloth	12	85.7	19	65.5	11	100	42	77.8
	Smoker	5	35.7	15	51.7	6	54.5	26	48.2
	Bee brush	10	71.4	17	58.6	8	72.7	35	64.8
	Water sprayer	2	14.3	7	24.1	1	9.1	10	18.5
	Chisel	6	42.9	7	24.1	1	9.1	14	25.9

N= number of cases; F= frequency

4.2.2. Honey production system

4.2.2.1. Traditional honey production system

According to the survey result, the honeybee colonies in traditional hives owned by sampled beekeepers were out 2256 hives 27.2%, 49.2% and 23.6% in the high land, mid land and low land kebeles respectively (Table 10). Because of the presence of diversity of trees species around this forest, in high land, in mid land and in the low land of the study area beekeepers have great number of colonies. The minimum and maximum number of bee colonies owned by the respondents in the study area was 2 and 50 respectively. This result agrees with Haftu Kebede and Gezu Tadesse (2014) which reported that 90.7% of beekeepers own traditional hive.

In general, from the total of 2256 honeybee colonies assessed about 86.7% were kept in traditional beekeeping system which is the predominant hive type in the area. This result agrees with Nahusenay Tamer, (2018) which states as beekeeping is a traditionally well-established household activity in almost all parts of Ethiopia including the study area.

The mean productivity of the traditional hive in the study area have been found 6.06 ± 0.92 in the high land, 6.48 ±1.16 in the mid land and 8.39 ±0.94 in the low land kg/hive/year (Table 11). Small differences between agro ecologies could be due to supplementation of feeding and watering practices of honeybees during the dearth periods and differences in colony management practices. This is comparable with the result of Atsbaha Haile Mariam *et al*. (2015) in Tigray region which reported that the mean amounts of honey produced from traditional hive per annum in Kolla-temben, Medebezana and Raya-azebo was 11.9%, 17.9% and 7.6%, respectively. Bee keepers (82.1%) answered that traditional hive has short service year (5-15 years) than transitional and frame hive (Table 12). Traditional beekeeping system was dominantly practiced in the study area due to low initial cost of production

Figure 4: Traditional hive with honey bee in the study area

4.2.2.2. Transitional honey production system

Out of the total of 87 transitional hives in the study area, 26.4%, 46.0% and 27.6% in the high land, in the mid land and in the low land respectively shown in Table 10 and the respondents owned minimum of 1 and maximum of 10 honeybee colonies. In addition to that, in terms of hive productivity, beekeepers explained that they have found a mean of 8.67± .816 honey kg/hive/year in the high land, 12.21±1.99 honey kg/hive/year in the mid land and 15.25 ± 0.96 honey kg/hive/year in the low land, with volume of honey ranging from 8kg/hive to 16 kg/hive/year (Table 11). Similarly, this could be due to the variations in seasonal management, differences in vegetation prevailing conditions, herbicide and insecticide application problems and some other factors. The respondents started to use transitional hive as showed in Figure 5 and that is why about 58.6% respondents responded as transitional hive had 26-40 service year which is better than traditional hive (Table 12).

According to the respondents in the study area, transitional beekeeping system has different advantages and disadvantages as well. Individual honey or brood combs can be inspected without destruction when compared to traditional hives. In addition to that, when we compare it with frame hives, as a potential disadvantage, respondents have agreed that in this hive, as honey combs are cut and harvested as a whole, honeybee colonies are forced to construct new honey combs again and again which is time and resource consuming and has negative impact on productivity of the colonies they said.

Figure 5: Transitional hive with honey bee in the study area

4.2.2.3. Frame hive honey production system

In the study area, frame hives were introduced by different non-government organizations (NGOs) like YESH project and the government, and its introduction was greater than the transitional hives. Consequently, the current survey shown that respondents from study area owned a total of 213 frame hived honeybee colonies, 24.4% in the high land, 48.8% in the mid land and 26.8% in the low land as shown in Table 10 with owning minimum of 1 and maximum of 10 honeybee colonies in the study area.

The mean honey productivity of the frame hive in the study area is 15.57 ±1.91 in the high land, 20.97± 3.20 in the mid land and 25.91 ±3.11 kg/hive year in the low land (Table.11). This difference could be because of management difference and difference in flora type. This result was less than the result of Atsbaha Haile Mariam *et al*. (2015) in Tigray region which reported that the mean amount of honey produced from frame hive was 28.29 kg per annum, this is may be the difference of management. Even if the honey yield from these hives is better than that of traditional hives, easy to inspect colonies, enables them to harvest better quality honey and has better service year as indicated in Table 12 from the total respondents. Though the initial cost to purchase the hive and colony is high, about 79.6% of respondents replied as frame hive has 26-40-year service (Table 12). High cost of production, minimal awareness and equipment unavailability makes frame hive beekeeping system weak in the study area.

Figure 6: Frame hive with honey bees in the study area

Table 10: Colony holding in different altitude around *Ellala* forest

Variables	Altitude						Total N= 2256	
	High land		Mid land		Low land			
	N	%	N	%	N	%	N	%
Traditional	532	27.2	963	49.2	461	23.6	1956	86.7
Transitional	23	26.4	40	46.0	24	27.6	87	3.9
Frame	52	24.4	104	48.8	57	26.8	213	9.4

N= number of cases

Table 11: Amount of honey from one hive per year

Variables	Altitude	N	Mean	SD
Traditional hive	High land	36	6.06	0.92
	Mid land	81	6.48	1.16
	Low land	23	8.39	0.94
Transitional hive	High land	6	8.67	0.82
	Mid land	19	12.21	1.99
	Low land	4	15.25	0.96
Frame hive	High land	14	15.57	1.91
	Mid land	29	20.97	3.20
	Low land	11	25.91	3.11

N= number of cases; SD= standard deviation; SE= standard error

Table 12: Service year and price of hives

Variables		Altitude							
		Highland		Midland		Lowland		Total	
		F	%	F	%	F	%	F	%
Traditional hive service year	5-15	23	63.9	69	85.2	23	100	115	82.1
	16-25	11	30.6	11	13.6	0	0.0	22	15.7
	26-40	2	5.6	1	1.2	0	0.0	3	2.1
Total		36	100	81	100	23	100	140	100
Transitional hive service year	16-25	2	33.3	8	42.1	2	50.0	12	41.4
	26-40	4	66.7	11	57.9	2	50.0	17	58.6
Total		6	100	19	100	4	100	29	100
Frame hive service year	16-25	2	14.3	7	24.1	2	18.2	11	20.4
	26-40	12	85.7	22	75.9	9	81.8	43	79.6
Total		14	100	29	100	11	100	54	100
Price of traditional hive-ETB	70-140	32	88.9	76	93.8	0	0.0	108	77.1
	141-210	4	11.1	5	6.2	23	100	32	22.9
Total		36	100	81	100	23	100	140	100
Price of transitional hive-ETB	1300-1800	5	83.3	9	47.4	3	75.0	17	58.6
	1801-2400	1	16.7	10	52.6	1	25.0	12	41.4
Total		6	100	19	100	4	100	29	100
Price of frame hive-ETB	2500-2900	9	64.3	17	58.6	3	27.3	29	53.7
	2901-3250	5	35.7	12	41.4	8	72.7	25	46.3
Total		14	100	29	100	11	100	54	100

F= frequency; ETB= Ethiopian birr

4.3. Honeybee Colony Management Practices

4.3.1. Placement of honey bee hives around *Ellala* forest

Table 13: Hive placement around *Ellal*a forest

Placements	Traditional		Transitional		Frame	
	N	%	N	%	N	%
Backyard	1286	65.8	87	100	209	98.1
Under eaves	630	32.2	-	-	4	1.9
Hanging on trees near home	40	2.1	-	-	-	-
Total	1956	100	87	100	213	100

N= number of hives

Proper placement of honeybee colonies plays the great role for external and internal inspection, colony welfare, appropriate honeybee colony management, seasonal measure to take for increasing honey production and the productivity in the sub-sector (FAO. 2020). This may be to prevent honeybee colonies from rain, extreme sunshine and predators.

4.3.2. Honey bee colony inspection

Regarding to the honey bee colony inspection, the result obtained from the respondents has showed the frequency of internal and external honeybee colonies inspection. From the total respondents about 45.0%, 22.9% and 32.1% inspect their colony external only, internal only and both external and internal. Most of beekeepers (79.6% and 57.7%) inspect their colony sometimes externally and internally respectively (Table 14). Moreover, only 13.0% and 9.0% of the respondents frequently inspecting their colonies externally and internally respectively but the rest 7.4% and 33.3% respondents rarely inspect their hives externally and internally respectively. Though, colony and apiary inspection is very vital to maintain honeybee colonies from different natural risks and enemies such as pests, predators, diseases and chemical poisoning.

Experiences show that only external colony inspection can be done in lesser times frequently but external and internal inspection can be done sometimes which was better. Efficient and continues training and follow up for beekeepers should be considered necessary.

Table 14: Hive Inspection frequency

Type of inspection	F	%	Inspection frequency	Type of inspection External %	Type of inspection Internal %
External only	63	45.0	Frequently	13.0	9.0
Internal only	32	22.9	Sometimes	79.6	57.7
External and Internal	45	32.1	Rarely	7.4	33.3
Total	140	100	Total	100.0	100

F= frequency

4.3.3. Feed types and seasonal Feeding

According to the survey result from the total of 140 beekeepers 125 (89.3%) of them provide feed for their colonies in different seasons of the year such as: August to October: 1.6% respondents fed their colony May to July 32.8% and both August to October and May to July 65.6% respondents also fed the bee colony. The types of supplementary feeds which were commonly provided to honeybees by the beekeepers in the study area include: Shiro (Pea powder) 0.8% respondents fed, Sugar syrup 1.6% respondents, honey and water 44.0% respondents, shiro and sugar 20.0% respondents, sugar and honey 24.0% and beso (barely powder) and honey 9.6% respondents fed their colony with the amount ranging from 1.2 up to 4 kilogram/colony/season but they did not properly identify the bee's starvation and provide feed on time. The rest of the beekeepers 15 (10.7%) beekeepers did not give attention to provide feed for their honeybee colonies (Table 15).

This result is in agreement with the result of Zewudu Wondifraw, (2018) in North-East Dry Land Areas of Amhara National Regional State, Ethiopia, who reported that, the most commonly used supplementary feeds include; grain flour 42.3% respondents used for feeding, sugar syrup 20.9%, shiro 13.3%, honey and water 12.7% and besso 10.8% used to feed their bee colonies. This difference may due to lack of knowledge, resource availability and lack of extension services. Those who tried to fed their colony do not properly identify the peak dearth period, it needs frequent follow up and extension service of livestock expertise in the study area.

Table 15: Colony feeding, period of feeding, type of feed and method of feeding

Variables		Altitude							
		Highland		Midland		Lowland		Total	
		F	%	F	%	F	%	F	%
Feeding	Yes	29	80.6	73	90.1	23	100	125	89.3
	No	7	19.4	8	9.9	0	0.0	15	10.7
Total		36	100	81	100	23	100	140	100
Period of feeding	Aug-Oct	2	6.9	0	0.0	0	0.0	2	1.6
	May-Jul	6	20.7	33	45.2	2	8.7	41	32.8
	Aug-Oct and May-Jul	21	72.4	40	54.8	21	91.3	82	65.6
Total		29	100	73	100	23	100	125	100
Type of feed	Shiro	1	3.5	0	0.0	0	0.0	1	0.8
	Sugar syrup	1	3.5	0	0.0	1	4.4	2	1.6
	Honey and water	7	24.1	26	35.6	22	95.6	55	44.0
	Shiro and sugar	1	3.5	24	32.9	0	0.0	25	20.0
	Sugar and honey	16	55.2	14	19.2	0	0.0	30	24.0
	Beso and honey	3	10.4	9	12.3	0	0.0	12	9.6
Total		29	100	73	100	23	100	125	100
Method of feeding	Internal	0	0.0	6	8.2	16	69.9	22	17.6
	External	27	93.1	62	84.9	5	21.7	94	75.2
	Both	2	6.9	5	6.9	2	8.7	9	7.2
Total		29	100	73	100	23	100	125	100

F= frequency

4.3.4. Honey harvesting frequency and period

According to the survey result; even if there was not higher amount of honey yield, all beekeepers harvest honey twice a year. This was due to the availability of forest in the study area and there was better source of bee forage and water source. The honey harvesting seasons were first season November to January and second harvesting season was February to April (Table 19). This study agrees with the study of Abebe Mitikie (2017), frequency of honey harvesting in Tehulederie district of the south Wollo zone was two times per year. Frequency of honey harvesting per year was better but it needs maximizing amount of honey per hive per year because of better bee forage availability. In order to harvest honey more than two times per year, upgrading overall managemental practices is mandatory in the study area.

4.3.5. Amount of honey yield in different hives

The amount of honey yield in the three different hive types (traditional, transitional and movable frame hives) as well as in each agro-ecology was not the same in the study rea. The overall means of honey yield were 6.69 kg ±1.32, 11.90 kg ±2.58 and 20.57 kg ± 4.55 in traditional, transitional and frame hives respectively in the woreda (Table 16). The amount of honey yield over the year has no significance difference ($P > 0.05$) (Appendices Table 5) but varied in number in different agro-ecologies around *Ellala* forest. This may be due to hive type, availability of honeybee flora, management practices and prevalence of pests and predators.

Table 16: Amount of honey from one hive per year in kg

Altitude		Traditional	Transitional	Frame
Highland	N	36	6	14
	Minimum	5	8	12
	Maximum	8	10	18
	Mean	6.06	8.67	15.57
	SD	0.92	0.82	1.91
Midland	N	81	19	29
	Minimum	5	9	15
	Maximum	9	15	26
	Mean	6.48	12.21	20.97
	SD	1.16	1.99	3.20
Lowland	N	23	4	11
	Minimum	7	14	20
	Maximum	10	16	30
	Mean	8.39	15.25	25.91
	Std. Deviation	0.94	0.96	3.11
Total	N	140	29	54
	Minimum	5	8	12
	Maximum	10	16	30
	Mean	6.69	11.90	20.57
	SD	1.32	2.58	4.55

N= number of cases SD= standard deviation

4.3.6. Swarm prevention and catch swarming

According to the respondents, in the study area swarming mostly occurs from October to December. From the total 140 respondents, about 65.0% of beekeepers reported that they were practiced swarm prevention but the rest 35.0 % respondents did not practice swarm prevention. 35.0% respondents used to prevent swarming, 4.3% used removing developing queen cell, 5.0% used splitting colony and 20.7% respondents used killing queen to prevent swarming of bee colonies (Table 17).

From the total 140 respondents 50.7% reported that, swarming is advantageous to them to increase number of colonies, to replace the non-reproductive bee colonies and to sale and get income (Table 17). And also, all respondents were tried to catch swarming and from all catching mechanisms 73.6% respondents practiced spraying water on swarmed colony (Table 17).

Table 17: Presence of swarm prevention, prevention methods, swarm advantage and catching mechanisms

Variables		Altitude							
		Highland		Midland		Lowland		Total	
		N	%	N	%	N	%	N	%
Prevention	Yes	15	41.7	70	86.4	6	26.1	91	65.0
	No	21	58.3	11	13.6	17	73.9	49	35.0
Total		36	100	81	100	23	100	140	100
Methods prevention	Not prevent	21	58.3	11	13.9	17	73.9	49	35.0
	Increase hive size	5	13.9	39	48.1	5	21.7	49	35.0
	Remove queen cell	2	5.6	4	4.9	0	0.0	6	4.3
	Split colony	2	5.6	5	6.2	0	0.0	7	5.0
	Killing queen	6	16.7	22	27.2	1	4.4	29	20.7
Total		36	100	81	100	23	100	140	100
Swarm advantageous	Yes	12	33.3	38	46.9	21	91.3	71	50.7
	No	24	66.7	43	53.1	2	8.7	69	49.3
Total		36	100	81	100	23	100	140	100
Reasons for advantage	Not advantageous	24	66.7	43	53.1	2	8.7	69	49.3
	To increase colony	2	5.6	27	33.3	11	47.8	40	28.6
	To sale	10	27.8	4	4.9	3	13.0	17	12.1
	To replace	0	0.0	7	8.6	7	30.4	14	10.0
Total		36	100	81	100	23	100	140	100
Catching mechanisms	Dust dispersing	0	0.0	13	16.1	1	4.4	14	10.0
	Spraying water	32	88.9	55	67.9	16	69.6	103	73.6
	Hanging hive on trees	0	0.0	8	9.9	6	26.1	14	10.0
	Catching queen	4	11.1	5	6.2	0	0.0	9	6.4
Total		36	100	81	100	23	100	140	100

N= number of cases

4.3.7. Trend of honey bee colony and yield

According to the respondents saying, honey yield as well as the honeybee colony population varied depending on hive type, honeybee flora, management practices, prevalence of pests and predators and others in the study area. From this study it is summarized that, 36.4% of respondents answered colony number and yield from traditional hive became decrease, 41.1% the respondents said from transitional hive colony number and yield became stable and 51.9% of respondents answered colony number and yield from movable frame hive became increasing way (Table 18). This was due to advancement of new technology acceptance of beekeepers and the response of frame hive yield.

Table 18: Trend in colony number and yield

Variables		Altitude							
		Highland		Midland		Lowland		Total	
		N	%	N	%	N	%	N	%
Traditional	Increase	7	19.4	20	24.7	12	52.2	39	27.9
	Stable	11	30.6	29	35.8	10	43.5	50	35.7
	Decrease	18	50.0	32	39.5	1	4.3	51	36.4
Total		36	100	81	100	23	100	140	100
Transitional	Increase	3	50.0	2	10.5	2	50.0	7	24.1
	Stable	1	16.7	10	52.6	1	25.0	12	41.4
	Decrease	2	33.3	7	36.8	1	25.0	10	34.5
Total		6	100	19	100	4	100	29	100
Frame	Increase	4	28.6	16	55.2	8	72.7	28	51.9
	Stable	5	35.7	4	13.8	1	9.1	10	18.5
	Decrease	5	35.7	9	31.0	2	18.2	16	29.6
Total		14	100	29	100	11	100	54	100

N= number of cases

4.3.8. Occurrence of seasonal activities

According to the result of this study, respondents 72.1% said the main season for brood rearing was November to January, 81.5% of respondents answered the main season for hive supering was also November to January, 80.0% of respondents confirmed the main season for swarming bee colonies was November to January and 100% respondents harvest their honey during this season. This indicates majority of the bee colony activities were done from November to January months (Table 19). From the total 140 respondents, only 125 respondents fed their honey bee colony when the dearth period came and bees starved but the rest 15 respondents did not feed their colony (Table 15).

Table 19: Major seasonal activities occurrences

Variables		Altitude							
		Highland		Midland		Lowland		Total	
Activities	Season	N	%	N	%	N	%	N	%
Brood rearing	Aug-Oct	10	27.8	9	11.1	0	0.0	19	13.6
	Nov-Jan	18	50.0	62	76.5	21	91.0	101	72.1
	Feb-Apr	8	22.2	10	12.5	2	8.7	20	14.3
Total		36	100	81	100	23	100	140	100
Hive supering	Nov-Jan	11	78.6	23	79.3	10	90.9	44	81.5
	Feb-Apr	3	21.4	6	20.7	1	9.1	10	18.5
Total		14	100	29	100	11	100	54	100
1st honey harvesting	Nov-Jan	36	100	81	100	23	100	140	100
2nd honey harvesting	Feb-Apr	36	100	81	100	23	100	140	100
Super reduction	Aug-Oct	4	28.6	4	13.8	1	9.1	9	16.7
	May-Jul	10	71.4	25	86.2	10	90.9	45	83.3
Total		14	100	29	100	11	100	54	100
Absconding	Aug-Oct	11	30.6	20	24.7	13	56.5	44	31.4
	May-Jul	25	69.4	61	75.3	10	43.5	96	68.6
Total		36	100	81	100	23	100	140	100
Swarming	Aug-Oct	2	5.6	5	6.2	1	4.3	8	5.7
	Nov-Jan	31	86.1	67	82.7	14	60.9	112	80.0
	Feb-Apr	3	8.3	9	11.1	8	34.8	20	14.3
Total		36	100	81	100	23	100	140	100
Migration	Aug-Oct	12	33.3	18	22.2	8	34.8	38	27.1
	May-Jul	24	66.7	63	77.8	15	65.2	102	72.9
Total		36	100	81	100	23	100	140	100
Dearth period	Aug-Oct	6	16.7	18	22.2	1	4.4	25	17.9
	May-Jul	30	83.3	63	77.8	22	95.6	115	82.1
Total		36	100	81	100	23	100	140	100

N= number of cases

4.4. Honey storage materials and duration of storage

The respondents kept their honey for different period of time; 6.4% of the interview say I don't store, I will sale immediately after harvest or it will be consumed during harvesting, majority of the respondents 60.0% store honey for 1-6 months' others 15.0%, 10.7% and 7.9% kept their honey for 7-12 months, 1-2 years and greater than 2 years respectively (Table 20). The reason that 41.4% respondents store for medical value, 1.4% for food, 7.9% for both medical value and for food, 42.1% for both price increment and medical value and lastly 0.7% of respondents store honey for price increment and medical value.

Traditionally beekeepers used different storage containers for different storage duration. 45.0% of respondents used plastic jar and 30.7% of the respondent plastic and clay jar (Table 20). According to Gichora M. (2003) sited by Kerealem Ejigu (2005) plastic container is the ideal storage material for the quality of honey. But the clay pot may pass and absorb the moisture and bad smell from the atmosphere due to the hygroscopic nature of the honey. According to the Ethiopian honey quality standard (ES1202:2013) storage containers made of improper material shall be coated completely with beeswax or food grade plastic lines to avoid any direct contact between honey and the container.

Table 20: Duration, reasons for storage and containers honey around Ellala forest

Variables		Altitude							
		Highland		Midland		Lowland		Total	
		N	%	N	%	N	%	N	%
Duration	Note store	5	13.9	4	4.9	0	0.0	9	6.4
	1-6	13	36.1	51	63.0	20	87.0	84	60.0
	7-12 months	8	22.2	13	16.1	0	0.0	21	15.0
	1-2 years	2	5.6	10	12.4	3	13.0	15	10.7
	> 2 years	8	22.2	3	3.7	0	0.0	11	7.9
Total		36	100	81	100	23	100	140	100
Reasons	Not store	5	13.9	4	4.9	0	0.0	9	6.4
	medical value	17	47.2	20	24.7	21	91.3	58	41.4
	Food	1	2.8	1	1.2	0	0.0	2	1.4
	medical and food	1	2.8	8	9.9	2	8.7	11	7.9
	Price and medical	11	30.6	48	59.3	0	0.0	59	42.1
	Price, medical and food	1	2.8	0	0.0	0	0.0	1	0.7
Total		36	100	81	100	23	100	140	100
Containers	Plastic jar	7	19.4	40	49.4	16	69.6	63	45.0
	Clay jar	2	5.6	13	16.1	0	0.0	15	10.7
	Plastic and clay jar	14	38.9	22	27.2	7	30.4	43	30.7
	Plastic and metallic	13	36.1	6	7.4	0	0.0	19	13.6
Total		36	100	81	100	23	100	140	100

N= number of cases

4.5. Pollen Analysis of Honey Samples around *Ellala* forest

By using pollen count analysis technique from the samples collected in two seasons, a total of 42 honeybee floras were identified in the study areas. As shown in Appendix table 4, the major honeybee flora in the study area across two seasons are dominated by *Bidden spp*, *Madicago polymarpha, Guizotia scabra, Brassica spp, Cordia africana, Eucalpytus spp, Justitie schimperiana, Syzygium guiness, Croton macrostachys*.

In season one, 17 bee forage plants with four locally unknown forage plants were identified. Among these plant species *Bidden spp (16.5%), Madicago polymarpha (11.5%), Guizotia scabra (10.0%), Brassica spp (9.5%) and Cordia africana* (9.5%) pollen count were the dominant species identified in the honey samples during major honey flow season. In addition, *Guizotia abyssinica, Sesbania sesban, Euphorbia abyssinica, Acacia nilotica, Dadmoanea viscosa, Acanthus senni, Clematis hirusta, Rannculus multitidus, Zea mays, Lepdium satium, Brassica spp and Rubus steudneri* were among the honey source plant species which were identified with lower pollen grain frequencies during the major honey flow season of the study area (Appendix table 4).

Honey samples collected during the second season (minor honey flow season) have contributed for the majority (25) of identified honey source plants with two botanically and five locally unidentified species. Among these, *Syzygium guiness, Eucalpytus spp, Justitie schimperiana, Croton macrostachys* were the dominant honey source plant species which contributed 12.4%, 11.2%, 10.7% and 10.1% of the pollen frequencies, respectively. However, honey source plants like *Vemonia spp, Acacia albidia, Rosa abyssinica, Coffee arabica, Carrissa edulis, Rubus spp, Albizia gummifera, Combertum molle, Olea africana, Juniperous procera, Capparis tomentosa, Apodyles dimidiate, Rhammus prinocides* and others indicated in Appendix table 4, were found to be low pollen count source plants identified during the dearth period or season-two. Therefore, these plant species were abundantly available and visited by worker honeybees frequently during a time of flowering period in the study areas (Appendix table 4).

Pollen analysis result revealed that out of the total collected honey samples from the study area, the highest pollen frequency (16.5%) was recorded in season-one while 12.4 %, 11.2 %, and 10.7% of the pollen frequencies were obtained from samples collected during season-two and the flowering period of floras during honey flow season was from August to February and minor honey flow season (season-two) was from December to May.

4.6. Floras and flowering calendars of the major honeybee floral sources

According to the research result, all of the respondent beekeepers were dependent on *Ellala* forest for their beekeeping practices and the buffer zone of the forest grew different crops that help for them as bee forage for nectar and pollen source in different seasons. The tree and shrub species grown in the *Ellala* forest as the main source of pollen and nectar during the honey flow season were Wanza (*Cordia africana*), Enjory (*Rubus spp*), Sesbania (*Sesbania sesban*), Kitkita (*Dadmonaea viscosa*), Adeyabeba (*Biden spp*), Wajima (*Madicago polymarpha*), Koshashilia (*Acanthus senni*), Mech (*Guizotia scabra*), Dengorita (*Vemonia bifarae*) and Chibeha *(Acacia nilotica)*. Additional sources of pollen and nectar during honey flow season were different crops that are grown in buffer zone of the *Ellala* forest like: Finger millet, Maize (*Zea mays*), Teff (*Eragrostic abicinicus*), barley (*Hordeum vulgare*), Wheat (*Triticum aestivum*), Oil seeds: Nug (*Guitozia abyssinica*), Gomenezer (*Brassiea Spp*), Buna (*Coffee arabica*) and others (Appendix Table 7).

The majority of flowering plants (trees and shrubs) gave their flower during minor honey flow season, which were very important for honey bees during the season of forage scarce time and vital to harvest honey for the second time. Some of these includes: Bisana (*Croton macrostachys*), Girar (*Acacia albida*), Girawa (*Vemonia spp*) Dokima (*Syzygium guiness*), Agam (*Carissa edulis*), Sesa (*Albizia gummifera)*, Kega (*Rosa abyssinica*), Woira (*Olea africana*), Gumero (*Capparis tomentosa*), Dong (*Apodyles dimidiate*), Azohareg (*Calemti*s *hirusta*), Tid (*Juniperous procera*), Bahirzaf (*Eucalpytus spp*), Semiza (*Justitie schimperiana*) and Bagur (*Combertum molle*) (Appendix Table 7).

Around *Ellala* forest, there was limited improvement of bee forages development except availability naturally grown different tree species which were used as source of bee forage. The study of Gichora M. (2003) supports this study that identification of the honeybee plants and assessing their abundance, their value to bees, time of blooming and flowering period have a paramount importance for practical beekeeping as well as for planning appropriate seasonal management. Availability of more seasonal bee forages results in high honey production provided that other environmental factors are suitable for bees (Ofelia A. *et al*., 2010).

However, there was an extension structure to producers at grass root level, but poorly linked with beekeepers and forage development and conservation, that resulted in slugged development of the sector. The major tree and shrub bee plants species of the study areas based on respondents' response which are available in the study area with flowering periods are listed as indicated below (Appendix Table 7).

4.7. Major trees Used for hive hanging and smoking

4.7.1. Trees used for hive hanging

According to the survey result, beekeepers used different big or giant tree species for hive hanging purpose and caught the swarmed or migratory colonies to begin beekeeping or to increase colony number. From those major trees in the study area Wareka (*Ficus vasta*) was dominantly used (24.3%) because of its many branches and others indicated in Table 21.

Table 21: Major Trees used for hive hanging in the study area

Major trees		Altitude							
		Highland		Midland		Lowland		Total	
Local name	Scientific name	N	%	N	%	N	%	N	%
Wareka	*Ficus vasta*	16	44.4	14	17.3	4	17.4	34	24.3
Sesa	*Albizia gummifera/schimperiana*	6	16.7	17	21.0	6	26.1	29	20.7
Bisana	*Croton macrostachy*	12	33.3	15	18.5	1	4.3	28	20.0
Dokima	*Syzgiv mgimeese*	0	0.0	6	7.4	8	34.9	14	10.0
Girar	*Acacia albida*	0	0.0	10	12.3	2	8.7	12	8.6
Wanza	*Cordia Africana*	0	0.0	9	11.1	1	4.3	10	7.1
Shola	*Ficus sur*	0	0.0	5	6.2	1	4.3	6	4.3
Chibeha	*Acacia nilotica*	0	0.0	4	4.9	0	0.0	4	2.9
Bahir zaf	*Eucalyptus spp*	2	5.6	1	1.2	0	0.0	3	2.1
Total		36	100	81	100	23	100	140	100

N= number of cases

4.7.2. Trees used for hive smoking

In order to attract and catch swarmed or migratory colonies to the hanging hive, cleaning hive properly and fumigate the hive with best aromatic smoke is very crucial task in beekeeping sector. According to the respondents around *Ellala* forest, 27.1%, beekeepers used Bagur /*Combertum molle*/ and others used for hive smoking shown in table 22. In addition to major trees listed above, Corn cobs, cow dung and other locally available smoke source are used to fumigate their hive to provide best attractant aroma for bee colonies.

Table 22: Trees used for hive smoking

Major trees		Altitude							
		Highland		Midland		Lowland		Total	
Local name	Scientific name	N	%	N	%	N	%	N	%
Bagur	*Combertum mole*	14	38.9	12	14.8	12	52.2	38	27.1
Agam	*Carissa edulis*	2	5.6	12	14.8	2	8.7	16	11.4
Gumero	*Capparis tomentosa*	10	27.8	11	13.6	1	4.3	22	15.7
Woira	*Olea africana*	6	16.7	13	16.0	2	8.7	21	15.0
Dokima	*Syzgiv mguineese*	1	2.8	18	22.2	5	21.7	24	17.1
Kega	*Rosa abisinica*	3	8.3	15	18.5	1	4.3	19	13.6
Total		36	100	81	100	23	100	140	100

N= number of cases

4.8. Opportunities and constraints of beekeeping in the study area

4.8.1. Potentials of beekeeping Around *Ellala* Forest

4.8.1.1. Availability of honeybee flora

The availability of multipurpose trees, shrubs, herb and other crop types in the study area has been identified as major sources of pollen, nectar and propolis for honeybees. As a result, the interdependency between honeybees and honeybee flora resources also allows the reproduction, productivity and diversification of plants on the earth through pollination services of honeybees (D. B. HILL and T. C. WEBSTER, 1995). Very recently, establishment of apiaries became near to a forest and villages areas is the common practice in the study area. This is because of the fact that, beekeepers have indigenous knowledge about the values of honeybee floral resources to increase honey production and survive the honeybee colonies.

About 41 plant species and crop type honeybee flora used as sources of pollen, nectar and propolis in the study area were identified by the respondent 41 These plant species (flora sources) were trees, shrubs, weeds and cultivated crops like oil crops, cereals, and coffee. From the mentioned honeybee flora: 16 species were trees, 15 species were shrubs, 3 species were herbs, 7 were different crops and coffee. And the result of this study is indicated in Appendix Table 7.

4.8.1.2. The sources of water for honeybees around *Ellala* forest

Beekeepers reported that, water sources were from streams, rivers, streams and rivers, streams and ponds and from fetched water (Table 23). This result shows that; water resource is not a bottle neck problem for the sub-sector in the study area. During apiary site selection as availability of honeybee flora, prevalence of pests and predators and availability of water for honeybees is recommended (Haftu Kebede and Gezu Tadesse, 2014). Around *Ellala* forest including lowlands of the study areas availability of water much enough not only for the sub-sector but also for irrigation, animal drink and daily human activities.

Table 23: Source of water for honey bees

Variables		Altitude							
		Highland N=36		Midland N=81		Lowland N=23		Total N=140	
		N	%	N	%	N	%	N	%
Sources of water	Stream	2	5.6	19	23.5	7	30.4	28	20.0
	Rivers	10	27.8	20	24.7	13	56.5	43	30.7
	Stream and river	23	63.9	29	35.8	3	13.0	55	39.3
	Stream and pond	0	0.0	5	6.2	0	0.0	5	3.6
	Fetched water	1	2.8	8	9.9	0	0.0	9	6.4
Total		36	100	81	100	23	100	140	100

N= number of cases

4.8.2. Constraints of beekeeping around *Ellala* forest

4.8.2.1. Indiscriminate use of agro-chemicals in the area

The farmers around *Ellala* forest predominantly produce wheat, maize, barely, *Teff*, small millet, coffee, and horticultural crops. The main agricultural chemicals that are used by the beekeepers as well as by the non-beekeeper farmers in the study area were 2-4D, Roundup, Malathion, DDT and other Fungicides types which freely distributed in the free market. All respondents responded that around their apiary site there was inappropriate agro-chemical application from the beekeepers and non-beekeeper farmers. Application of agrochemicals is high in midlands because of large croplands found around this area and high number of respondents present in this agro ecology (Fig 7). Agro-chemicals are agricultural inputs that used to control weeds, pests and fungus so as to increase crop production and productivity (Desalegn Begna, 2015).

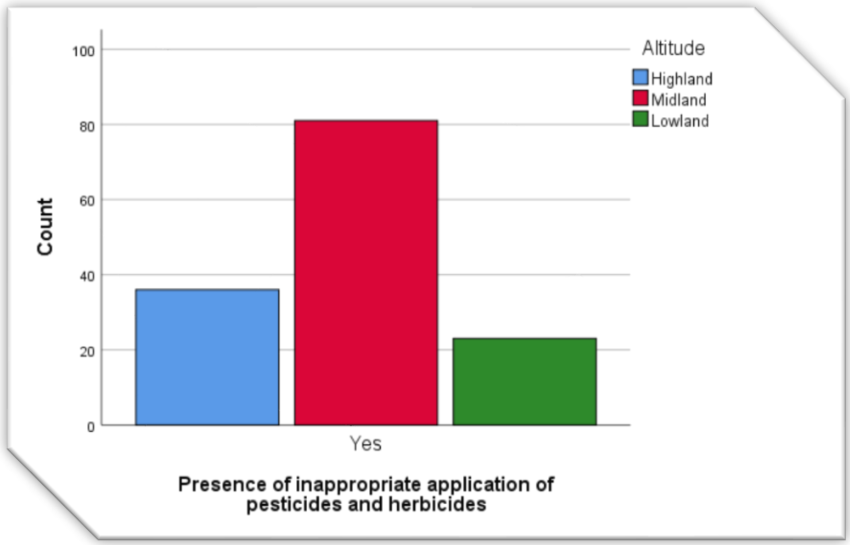


Figure 7: Inappropriate application of agro-chemicals around *Ellala* forest

4.8.2.2. Presence of poisonous plants to honeybees around *Ellala* forest

From the total of 140 beekeepers, all of them identified the presence of honeybee poisonous plants around their community which affects beekeeping. The result showed that, the knowledge of beekeepers as regards the devastation caused by poisonous plants on honeybees was relatively better but they do not have knowledge to protective measures of poisonous plants.

With indigenous knowledge of the beekeepers some of the major poisonous plants to honeybees were identified such as: Kulkual (*Euphorbia spp.)*, Quantir (*Petrolobium stellatum)*, Amekila (*Hygrophilie auriculata*), Bisana (*Croton macrostachy) and* Semiza (*Justitie schimperiana)* found around *Ellala* forest which the honey produced from their nectar are toxic to honeybees because respondents said that when honey bees used nectar from these flowering plants, they observed inactive at the entrance of hive and some of them looked died and irritate to humans while eating. From those identified poisonous plants, Quantir (*Petrolobium stellatum)* was found in the three agro-ecologies of the study area which was answered 39.3% of the total respondents (Table 24).

Table 24: Presence of poisonous plants to honeybees around *Ellala* forest

Poisonous plants		Altitude							
		Highland N=36		Midland N=81		Lowland N=23		Total N=140	
Local name	Scientific name	N	%	N	%	N	%	N	%
Kulkual	*Euphorbia spp.*	0	0.0	8	9.9	4	17.4	12	8.6
Quantir	*Petrolobium stellatum*	14	38.9	33	40.7	8	34.8	55	39.3
Amekila	*Hygrophilie auriculata*	0	0.0	8	9.9	1	4.3	9	6.4
Bisana	*Croton macrostachy*	9	25.0	17	21.0	8	34.8	34	24.3
Semiza	*Justitie schimperiana*	13	36.1	15	18.5	2	8.7	30	21.4
Total		36	100	81	100	23	100.0	140	100

4.8.2.3. Prevalence of pests and predators

In the study area, the bottle neck pests and predators of honeybees were ants and black ants which totally or partially destructed the honeybee colonies (Table 25). This in line with the study of Chala Kinati *et al*. (2012) where pests and predators were mentioned as the major constraints of beekeeping activities. Thus, Pest and predator prevention and control methods should be done locally and scientifically to safe the beekeeping practice in the study area.

Table 25: Major honey bee pests and predators

Pests and predators	Altitude								Rank
	Highland N=36		Midland N=81		Lowland N=23		Total N=140		
Name	N	%	N	%	N	%	N	%	
Ants	36	100	78	96.3	23	100	137	97.9	1
Black ants	36	100	66	81.5	23	100	125	89.3	2
Wax moth	20	55.6	40	49.4	16	69.6	76	54.3	3
Rats	12	33.3	32	39.5	20	87.0	64	45.7	4
Birds	28	77.8	15	18.5	9	39.1	52	37.1	5
Spiders	16	44.4	29	35.8	4	17.4	49	35.0	6
Honey badger	24	66.7	10	12.3	12	52.2	46	32.9	7
Termites	9	25.0	18	22.2	11	47.8	38	27.1	8
Mice	8	22.2	13	16.0	3	13.0	24	17.1	9
Bee lice	8	22.2	6	7.4	8	34.8	22	15.7	10

N= number of cases

4.9. Honey Quality

The chemical properties of honey play an important role in determining the honey quality and affect international honey business (Abebe Mitikie, 2017). Like other honey quality studied by different researchers in the country, this study focused honey that collects directly from different hives in three agro-ecologies and two seasons of honey collection periods.

4.9.1. Ash content

The ash content of the samples from the current study or around *Ellala* forest ranged from 0.06 to 0.83% with a mean of 0.20%. The result is similar with Addis Getu and Malede Birhan (2014) mean value of 0.17% obtained from Libokemkem woreda of Amhara region ranged from 0.014-0.31% with a mean value of 0.17%. The accepted ash content is less than 0.6% (Quality and Standards Authority of Ethiopia (2013). The mean of ash content of honey samples from *Ellala* forest honey is acceptable within the Ethiopian national standard quality level (Table 29).

The maximum ash content was obtained from samples which were collected from lowland than highland and midland. This result is against with the result of Yetimwork Gebremeskel, (2015) which indicated that honey produced from the highland agro-ecology had moderately higher ash content than honey produced from lowland areas. But there is slight difference between two seasons: season-one and season-two. Season-two (minor honey flow season) honey sample had moderately higher ash content than season-one (honey flow season). But there is no significant difference in ash content ($P>0.05$) across different agro ecologies (Appendices Table 1). Ash content of the sampled honey was within the national international standards.

4.9.2. Moisture Continent

The moisture content of honey in the study area across different agro ecologies, in different seasons and in three hive types ranges from 17.30 to 23.00 with the mean of 20.37 (Table 26, 27 and 28) and from 18 samples the result of 10 samples were below 21 and 8 samples were greater than or equal to 21. All of the honey samples in the study had moisture content within the acceptable range of both the world FAO/WHO as well as the national standard levels. The mean results indicated that honey produced from the highland and midland agro-ecologies has slightly higher moisture content than honey produced from low land areas. Because during sample collection period there was unseasonal rain that could be contribute for moisture content increment when harvesting.

Similarly, the results of Addis Getu and Malede Birhan, (2014), conducted at Libokemkem woreda of Amhara Region showed that none of the honey samples exceeding the limit set by the Codex and Council of the European Union (EU). Honey samples collected in honey flow season had relatively higher moisture content than dearth period honey because of there was increased environmental moisture during season-one honey. Transitional and Traditional hive honey had higher mean moisture content than Frame hive honey samples. This could be due to difference of honey harvesting method. Even though there was slight difference in mean moisture content across different agro ecologies, seasons of collection and hive types, there was no significant difference in moisture content between groups with in both in agro-ecologies, season and hive type (P>0.05).

4.9.3. The pH values

The pH values of honey across different agro ecologies, seasons and hive types ranged from 3.19-4.83 with mean value of 3.86 ± 0.40 (Table 26, 27 and 28) and 2 samples were above the maximum limit (4.5). The pH value result is lower than the result of Alemayehu Kebede, (2011) which was conducted in Selte woreda ranged from 4. l3 to 5.02. Similarly reported pH of 3.49 to 5.58 from Burie woreda, Ethiopia (Tesega Belie, 2009). Published reports indicated that acceptable pH of honey to be between 3.2 and 4.5 (Quality and Standards Authority of Ethiopia, 2013). This result is also with in the quality regulation level proposed by Codex (1993) and EU (1974). This study also agrees with the study of Bogdanov S. *et al*. (1997), the pH of honey should be between 3.2 and 4.5. The honey sample collected from different agro ecologies, season and hive type have no significant difference in pH values (P>0.05). This indicates that the honey from *Ellala* forest is fairly acidic which could be in part responsible for the excellent stability of honey against fermentation and natural flavor (Gebregziabher Gebremedhin *et al*., 2013). The variations in pH across different agro ecologies, and seasons might mainly be resulted due to difference in acids found in different floral types (Hussain N. *et al*., 1989).

4.9.4. Free acidity

The mean free acidity values of the honey samples collected and analyzed from different agro ecologies, season and hive types are indicated in Table 29. The overall mean free acidity of honey samples analyzed was 21.89% (Table 29) and only one sample exceeded 40 meq/kg. This result is similar with Abebe Mitikie, (2017) which was carried out in Tehulderie district and Alemayehu Kebede, (2011) which was conducted in Selte wereda ranged from 19.5 to 25.5meq acid/kg with mean of 22.3 meq. acid/kg. All the honey samples were within the acceptable limits (≤40meq/kg) set by QSAE and CAC. None of the samples exceeded the limit set, which may be taken as indicative of freshness of all the honey samples of the *Ellala* forest.

The average acidity content of honey samples collected from different agro-ecologies, different seasons and hive types (21.89%) is not significantly different (P>0.05) (Appendices Table 1, 2 and 3). But there was slight difference in mean free acidity content, for samples collected from Lowlands (25.08%) which is slightly higher than mean free acidity content of Midland (22.25%) and Highland samples (18.33%). Free acidity may be explained by taking the presence of organic acids into account, which are proportional to the corresponding lactones, or internal esters, and some inorganic ions such as phosphates or sulphates (Finola M.S. *et al*., 2007). Variation in free acidity among different honeys can be attributed to floral origin or to variations in the harvesting season (Alemayehu Kebede, 2011). Acidity of the honey is one of its merits for its antimicrobial property and when the acidity becomes high, the honey becomes sour (Alemayehu Kebede, 2011).

4.9.5. HMF (Hydroxy Methyl Furfur aldehyde)

The HMF values of honey samples collected from different agro-ecologies, season and hive type in this study ranged from 2.10-20.55mg/kg with mean value of 9.89±5.13 mg/kg (Table 26, 27 and 28). The acceptable HMF value of honey is a maximum of 40 to 80 mg/kg World, FAO/WHO and National (QSAE, 2013). The mean HMF value of *Ellala* forest honey is below the maximum value of FAO/WHO and National standard. This result is similar with the study of Gebreegziabher Gebremedhin *et al*., (2013) which was conducted in Northern Tigray that ranged from 2.9-26 mg kg with a mean value of 11.18 mg kg for the processed honey. When compared with different agro ecologies, it is higher in midland agro-ecology than highland and lowland and also from the two seasons of honey harvesting periods, honey flow season samples had higher HMF value than dearth period sample because it could be the difference of flora type. When the hive types are considered, frame hive honey sample had higher HMF value than transitional and traditional samples. However, there is no significant difference between groups (number of honey samples) of the honey samples either agro ecologies, season difference or the hive types (P>0.05).

HMF is minimal or absent in fresh/newly produced honey and hydroxyl methyl furfural (HMF) is a byproduct of fructose decay, formed during storage or during heating (Bogdanov S. *et al*., 1997). Thus, its presence is considered as the main indicator of overheated honey, aged or adulterated with invert sugar (hydrolyzed sucrose (FAO. 1996).

4.9.6. Reducing Sugar (Fructose and Glucose)

The reducing sugar (Fructose and Glucose) composition of honey samples collected around *Ellala* forest in Guangua woreda from different agro-ecologies, seasons and hive types vary from 61.45 to 90.51 meq/kg with the mean of 72.94% meq/kg positioned with in recommended range of 65% which is the minimum standard of FAO/WHO and 65% which is the minimum standard of National but out of World standard 60% to 70% (QSAE, 2013). It has no significant difference in reducing sugar (P> 0.05%) between groups of different agro-ecologies, season and the hive types. Similarly results in reducing sugar by Gebreegziabher Gebremedhin *et al*., (2013) in Tigray region honey which accounted about 70.95% on an average.

The reducing sugars content obtained in this study (72.94%) is higher than the finding of Tessega Belie (2009) and Tewodros Alemu (2010) who reported 65.73% and 67.33% for honey samples collected from Burie and Sekota, respectively. Thus, the analysis result of the mean reducing sugars content (72.94%) shows that the study area honey meets the quality requirements for reducing sugars established by local and international legislation.

4.9.7. Sucrose

The contents of apparent sucrose (non-reducing sugar) of *Ellala* forest honey samples vary from 0.86- 4.81% with the mean of 2.67% (Table 26, 27 and 28). The mean value of sucrose content obtained from *Ellala* forest is within the standard range of World, FAO/WHO and national 3-10 %, 5-10% and 5% maximum respectively (QSAE, 2013). But there is simple difference between agro-ecologies and between hive types. Honey sample collected from highlands had higher mean sucrose amount than midland and lowland and also Samples of honey collected from frame hives had higher mean sucrose than samples from transitional and traditional hives. But there is no difference observed from those samples collected in different seasons (honey flow season and dearth period). There is no significant difference (P>0.05) between groups of the sample both in agro-ecologically, in season and hive types. The result showed that all of the samples are in the acceptable range. This result is lower than the result carried out by Tewodros Alemu, (2010) reported that sucrose content of honey collected from Sekota, Ethiopia ranged from 1.04 - 5.19% with the mean value of 3.11%. The mean sucrose content of the study area's honey (2.67 %) is within the national standard maximum 5% (QSAE, 2013).

Higher sucrose contents could be the result of an early harvest of honey, i.e., the sucrose has not been converted to fructose and glucose (Azeredo L.C. *et al*., 2003). The amount of sucrose in honey differs according to the degree maturity and nectar compound of the honey. As the degree of ripeness increase, the amount of sucrose found in honey decreases, these indicate the level of sucrose decrease with the maturity of honey. The Sucrose content of honey lower than 0.20% can be attributed to the enzymatic activity of invertase which causes a decrease in the amount of this non-reducing disaccharide during the storage (Anklam E. 1998). Both physical and chemical actions are involved in transformation of nectar into honey, with the activity of enzymes being most prominent. Since these enzymes remain in the honey, their action may continue at a declining rate. The determination of sucrose and fructose: glucose ratio is valuable for assessing adulteration by sucrose and to predict honey crystallization tendency (Ruoff K. 2006).

Table 26: Physicochemical properties of honey produced from different agro-ecologies in the study area

Variables		N	Range	Mean ± SD
Ash (%)	Highland	6	0.10-.24	0.15 ± 0.05
	Midland	6	0.06-.37	0.17 ± 0.11
	Lowland	6	0.09-..83	0.26 ± 0.28
	Total	18	0.06-.83	0.20 ± 0.17
Moisture (%)	Highland	6	18.50-22.50	20.43 ± 1.53
	Midland	6	19.80-22.50	20.93 ± 0.94
	Lowland	6	17.30-23.00	19.73 ± 2.23
	Total	18	17.30-23.00	20.37 ± 1.63
pH value	Highland	6	3.51-4.83	3.93 ± 0.50
	Midland	6	3.60-4.58	3.88± 0.37
	Lowland	6	3.19-4.23	3.77 ± 0.37
	Total	18	3.19-4.83	3.86± 0.40
Acidity (meq/kg)	Highland	6	14.50-28.50	18.33 ± 5.39
	Midland	6	11.50-30.00	22.25 ± 6.24
	Lowland	6	11.00-50.00	25.08 ± 13.43
	Total	18	11.00-50.00	21.89 ± 9.01
HMF (mg/kg)	Highland	6	2.10-17.35	9.92 ± 5.78
	Midland	6	3.95-20.55	11.86 ± 6.03
	Lowland	6	4.60-12.50	7.88 ± 3.14
	Total	18	2.10-20.55	9.89 ± 5.13
Fructose (Reducing sugar) (meq/kg)	Highland	6	31.54-4786	39.73 ± 5.57
	Midland	6	32.17-39.72	36.63 ± 2.58
	Lowland	6	32.07-42.16	38.45 ± 3.57
	Total	18	31.54-47.86	38.27 ± 4.07
Glucose (Reducing sugar) (meq/kg)	Highland	6	30.13-38.49	36.06 ± 3.05
	Midland	6	29.91-39.38	32.96 ± 3.69
	Lowland	6	30.28-42.65	34.98 ± 4.98
	Total	18	29.91-42.65	34.67 ± 3.97
Sucrose (%)	Highland	6	2.19-4.81	3.37 ± 1.01
	Midland	6	0.86-3.35	2.15 ± 1.10
	Lowland	6	1.50-3.37	2.49 ± 0.78
	Total	18	0.86-4.81	2.67 ± 1.06

N= number of samples; HMF= hydroxyl methyl furfural; SD= standard deviation

Table 27: Physicochemical properties of honey produced during different season in the study area.

Variables	Season	N	Range	Mean ± SD
Ash (%)	Season-one	9	0.10-.18	0.14±.03
	Season-two	9	0.06-0.83	0.24±0.24
	Total	18	0.06-0.83	0.20±0.17
Moisture (%)	Season-one	9	17.30-23.00	20.80±1.82
	Season-two	9	17.40-21.50	19.93±1.39
	Total	18	17.30-23.00	20.37±1.63
pH value	Season-one	9	3.19-4.83	3.90±.52
	Season-two	9	3.60-4.23	3.82±.23
	Total	18	3.19-4.83	3.86±.40
Acidity (meq/kg)	Season-one	9	11.00-28.50	20.44±6.18
	Season-two	9	14.50-50.00	23.33±11.38
	Total	18	11.00-50.00	21.89±9.01
HMF (mg/kg)	Season-one	9	4.05-20.55	11.97±5.29
	Season-two	9	2.10-12.80	7.81±4.25
	Total	18	2.10-20.55	9.89±5.13
Fructose	Season-one	9	31.55-41.79	36.05±3.72
(Reducing sugar)	Season-two	9	37.42-47.87	40.49±3.19
(meq/kg)	Total	18	31.54-47.86	38.27±4.07
Glucose	Season-one	9	30.12-37.33	33.24±2.53
(Reducing sugar)	Season-two	9	29.91-42.65	36.10±4.74
(meq/kg)	Total	18	29.91-42.66	34.67±3.97
Sucrose (%)	Season-one	9	1.53-3.36	2.69±0.55
	Season-two	9	0.86-4.81	2.65±1.44
	Total	18	0.86-4.81	2.67±1.06

N= number of samples; HMF= hydroxyl methyl furfural; SD= standard deviation.

Table 28: Physicochemical properties of honey produced from different hives in the study area

Variables	Hive type	N	Range	Mean ± SD
Ash (%)	Traditional	6	0.10-0.37	0.18±0.11
	Transitional	6	0.07-0.24	0.13±0.06
	Frame	6	0.06-0.83	0.26±0.28
	Total	18	0.06-0.83	0.20±0.17
Moisture (%)	Traditional	6	19.30-23.00	21.27±1.61
	Transitional	6	17.30-21.50	20.27±1.58
	Frame	6	17.40-21.30	19.57±1.50
	Total	18	17.30-23.00	20.37±1.63
pH value	Traditional	6	3.54-4.23	3.78±.24
	Transitional	6	3.19-4.58	3.82±.49
	Frame	6	3.60-4.83	3.98±.45
	Total	18	3.19-4.83	3.86±.40
Acidity (meq/kg)	Traditional	6	14.50-27.00	20.67±4.23
	Transitional	6	11.00-30.00	18.83±8.41
	Frame	6	15.00-50.00	26.17±12.34
	Total	18	11.00-50.00	21.89±9.01
HMF (mg/kg)	Traditional	6	4.05-20.55	8.75±6.18
	Transitional	6	2.10-17.35	8.64±5.89
	Frame	6	7.55-15.05	12.27±2.49
	Total	18	2.10-20.55	9.89±5.13
Fructose (Reducing sugar) (meq/kg)	Traditional	6	32.08-41.79	38.20±3.68
	Transitional	6	35.81-39.89	37.56±1.55
	Frame	6	31.55-47.87	39.06±6.24
	Total	18	31.54-47.86	38.27±4.07
Glucose (Reducing sugar) (meq/kg)	Traditional	6	33.37-39.40	36.65±2.59
	Transitional	6	29.91-42.66	35.10±4.97
	Frame	6	30.13-37.98	32.25±3.20
	Total	18	29.91-42.65	34.67±3.97
Sucrose (%)	Traditional	6	1.53-3.37	2.68±0.80
	Transitional	6	0.93-4.81	2.48±1.34
	Frame	6	0.86-4.38	2.85±1.14
	Total	18	0.86-4.81	2.67±1.06

N= number of samples; HMF= hydroxyl methyl furfural; SD= standard deviation

Table 29: Results of honey in the study areas, National and International standard

Parameters tested	Standards			Study area Result (Mean)
	World	FAO/WHO	National	
Total ash, % by mass	0.25 – 1	0.6 -1	0.60 max.	0.20
Moisture content, % by mass	18 – 23	21 – 23	21max.	20.37
Ph	3.2 – 4.5	-	-	3.86
Acidity, milli equiv. acid/kg	5 – 54	40/kg	40/kg	21.89
Hydroxy methyl furfural mg/100g	40 -80	80 max.	40 max.	9.89
Fructose content, % by mass	-	-	-	38.27
Glucose content, % by mass	-	-	-	34.67
Reducing sugar (Fructose + Glucose)	60-70	65 min.	65 min.	72.94
Sucrose content, % by mass	3 -10	5 -10	5 max.	2.67

Source: Quality and Standards Authority of Ethiopia (2013) and the study results.

4.9.8. Correlation between the chemical properties of honey

Different honey quality parameters had different correlation results between each other in different agro-ecologies, different season and different hive type around *Ellala* forest or in the study area The ash content has highly significant (P<0.01) positively and moderately correlated with free acidity. Other parameters have either weak positive or weak negative correlation each other (Appendices Table 6).

CHAPTER 5: CONCLUSSION AND RECOMMENDATIONS

5.1. Conclusion

Guangua district as well as kebeles those are found around *Ellala* forest has a long tradition of beekeeping practice as a sideline activity with other agricultural activities of income sources. Based on their level of technological advancement, three distinct types of beekeeping practices are used by the sample beekeepers (140) in the area. These are traditional (local) hive based (140), transitional hive based (29) and moveable frame hive based (54) beekeeping practices. However, the adoption of extension to three types of beekeeping systems with advanced technologies was not as such upgraded as its potential in the area and beekeepers were not properly utilize the forest for beekeeping practices.

Based on the result of this study, most of the beekeepers use the traditional knowledge for beekeeping practices except those who got help from non-governmental organizations, due to this they were dominantly dependent traditional beekeeping system. Most beekeepers have not got help about colony over all management practices, construction of transitional bee hives, frame hive beekeeping system and its material utilization and about seasonal colony management practice.

The amount of honey produced from one bee hive per year varies across agro ecologies, seasons and hive types. The mean honey yield of traditional, transitional and framed type hives was 6.69, 11.90 and 20.57 kilogram per year respectively. The difference was mainly due to the input applied differences, management of the beekeepers, season difference and the environmental situation of the study area.

Even if there is non-governmental organization which work on beekeeping practices around *Ellala* forest and tried to improve bee keeping practices in the study area, swarming of bees is still a source of foundation stock for most of the beekeepers. Most beekeepers around *Ellala* forest are using their own traditional knowledge for beekeeping practices by using beehives constructed from locally available materials.

Despite all the challenges currently facing the beekeeping subsector, around *Ellala* forest has still enormous opportunities and a huge potential for improved beekeeping practice to boost the production and improve the quality of hive products. This can be expressed by results obtained from some transitional and frame hive beekeeping in the study area which produced comparatively better quality and quantity of honey from limited number of colonies and all the laboratory results of the parameters of the honey sample are within the national and international standards because of there are better availability of diverse honeybee floras in most part of the study area across different agro-ecologies, different seasons and have better availability of different water resources in and around *Ellala* forest. Experience of the beekeepers leads to ease them to use the frame hive type technologies through training and good market demand of the product honey and bees wax. The result of pollen analysis showed that the study area had better opportunity of flora with good flowering periods throughout the year. Therefore, government and non-government organizations should collaborate together to change the life of rural people and to gain cumulative benefit from beekeeping.

5.2. Recommendations

Based on the result of this study issues that require consideration by government and concerned development organizations are recommended below:

- Establishing the package, selecting local participants based on their preferences, educating (train them) and providing them with the whole package of beekeeping technologies with ongoing follow-up.
- Considerations include planting drought-tolerant bee forages close to the apiary, preserving the area's natural forest and using crops as bee fodder. Using the available water resources to hydrate bee forages during a drought to supplement the bee population.
- Pest and predator prevention and control methods should be done locally and scientifically to safe the beekeeping practice in the study area.
- The indiscriminate use of agricultural chemicals escalated occasionally in the poisoning of honeybees. In order to make the previously existing proclamation effective, the government must pay special attention to solving these difficulties by coordinating and integrating the related entities, such as crop production specialists, animal science experts and other government institutions.
- Further study should be needed on detection of chemical residue in honey and other advanced quality tests.

- Further study should be needed in different years and seasons to know quality of honey and to identify flora calendar around *Ellala* forest on those beekeepers and areas this study not addressed.

6. REFERENCES

Addis Ababa University. 2015. Addis Ababa University: Strategic Plan to Develop a Globally Competitive Honey Industry in Ethiopia. Addis Ababa, Ethiopia.

Abebe Mitikie. 2017. Characterization of beekeeping systems and evaluation of honey quality in Tehulederie District of the South Wollo Zone, Amhara region, Ethiopia, http://ir.bdu.edu.et/handle/123456789/12413.

Abrol D.P. 1997. Bees and Bee-Keeping in India, Edn1, Kalyani Publishers, New Delhi, 110-130.

Addisu Getu and Malede Birhan. 2014. Chemical Analysis of Honey and Major Honey Production Challenges in and Around Gondar, Ethiopia. Department of Animal Production and Extension, Faculty of Veterinary Medicine, University of Gondar, Ethiopia. Academic Journal of Nutrition 3 (1): 06-14, 2014.

Adgaba Nuru, Al-Ghamdi A., Shenkute G., Ismaiel S and Al-Kahtani S. *et al*. 2014. Socio economic Analysis of Beekeeping and Determinants of Box-hive Technology Adoption in the Kingdom of Saudi Arabia. The Journal of Animal and Plant Sciences 24(6): 1876 –1884.

Admassu Adi, Kibebew Wakjira., Amssalu Bezabih and Ensermu, Kelbbessa. 2014. Honeybee Forages of Ethiopia. United Printers, Addis Ababa.

Admasu Adi and Nuru Adgaba. 2002. Effect of Honeybee Pollination on Seed Yield and Oil Content of Niger (*Guizotia abyssinica*). Proceedings of the first National Conference of Ethiopian Beekeepers Association, Addis Ababa, Ethiopia.

Admasu Adi and Lamessa Debissa. 2008. Bee plant inventory and the Beekeeping potentiality of Menagesha Suba state forest. Journal of Biological Society of Ethiopia, 8(2), 85-97, 2009.

Ajabush Dafar. 2018. Review of Economic and Ecological Importance of Bee and Bee Products in Ethiopia. Journal of Animal Husbandry and Dairy Science, 2(2): 18-26.

Alemayehu Kebede. 2011. Honeybee production practice and honey quality in Selte woreda, Ethiopia. MSc Thesis Submitted to College of Agriculture and 73 Environmental Sciences, School of Animal and Range Sciences, Haramay Universityhttps:llwww.researchgate.net/publication.

Alemtsehay Tekelay. 2011. Seasonal Availability of Common Bee Flora in Relation to Land Use and Colony Performance in Gergera Watershed Atsbi Wenberta Woreda Eastern zone of Tigray, Ethiopia. MSc thesis, Hawassa University, Ethiopia.

ALRDPA (Amhara Region Livestock Resource Development Promotion Agency). 2013/14. Annual report.

ALRDPA (Amhara Region Livestock Resource Development Promotion Agency). 2014/15. Annual report.

Amsalu Bezabeh. 2004. Beekeeping in South and South Western Ethiopia. Journal of Bees for Development, 73: 8.

Amsalu Bezabeh, Alemayehu Gebregziabher, Taye Neguse and Desalegn Begna. 2012. Toxicity effect of commonly used Agro chemicals to Ethiopian honeybees. Holeta Bee research Centre. Beekeeping for food security and combating climate change. Proceeding of the third Api-expo Africa held at the millennium hall, October 2012, Addis Ababa Ethiopia.

Amsalu Bezabeh. 2002. Multivariate morphometric analysis and behavior of Honeybees (Apis mellifera L.) in the Southern Regions of Ethiopia. PhD dissertation. Rhodes University, Department of Zoology and Entomology, South Africa.

Amssalu Bezabeh, Nuru Adgaba, Radloff SE. and Hepburn, H.R. 2004. Multivariate morphometeric analysis of honeybees in the Ethiopian region. Apidologie, 35, 71–81.

Anklam E. 1998. A review of the analytical methods to determine the geographical and botanical origin of honey. Food Chemistry, v. 63, n. 4, p. 549-562.

Apimondia International Symposium. 2018. The Role of Bees in Food Production. Apimondia International Symposium, Addis Ababa, Ethiopia.

Assefa Getenet. 2017. Livestock and Fisheries Research Strategies: Poultry, Fisheries, Apiculture and Sericulture (2016-2030).

Atsbaha Hailemariam, Taye Tolemariam and Kebede Debele. 2015. Assessment of production system, constraints and opportunities in three selected Woredas of Tigray Region, Ethiopia.

Atwal A.S. 2001. Essentials of Beekeeping and Pollination, Edn1, Kalyani Publishers, New Delhi, 201-218.

Ayalew Kassaye. 1978. Beekeeping extension in Ethiopia. Holeta Bee Research Center, Holeta, Ethiopia. Unpublished report.

Ayalew Kassaye. 1990. The Honeybee (Apis mellifera) of Ethiopia: A Morphometric Study. M.Sc. Thesis. Agricultural University of Norway, Norway.

Ayalew Kassaye. 2001. Promotion of Beekeeping in the Rural Sector of Ethiopia. In proceedings of the 3rd Ethiopian beekeepers' association (EBA).

Ayalew Kassaye. 2008. Honey and beeswax value chain of boom program establishment of apiculture data base in Ethiopia.

Azeredo L.C. Azeredo M.A.A., Souza and S.R., Dutra V.M.L. 2003. Protein contents and physicochemical properties in honey samples of *Apis mellifera* of different floral origins. Food Chemistry 80, 249–254.

Bekena Negash and Greiling J. 2017. Quality focused apiculture sector value chain development in Ethiopia. J. Agric. Sci. Technol. A, 7, pp.107-116.

Beyene Tadesse and David Phillips. 2007. Ensuring small scale producers in Ethiopia to achieve sustainable and fair access to honey markets. Paper prepared for International Development Enterprises (IDE) and Ethiopian Society for Appropriate Technology (ESAT). Addis Ababa, Ethiopia, pp 1-64.

Bogdanov S. Martin, and P. Lullmann. 1997. Harmonized methods of the European honey commission. Apidologie.: 1-59.

Bogdanov S., Martin, P. and Lullmann, C. 2002. Harmonized methods of the international honey commission. Swiss Bee Research Centre, FAM, Liebefeld, 5, pp.1-62.

CAP (Center for Agricultural Policy Prosperity Initiative). 2008. Small-scale Review of Honey: Short analysis of demand and supply in the honey sector. Center for Agricultural Policy Prosperity Initiative. Ministry of Agriculture and Rural Development (MARD) of the Government of Viet Nam. Retrieved August 30, 2011 from http://prosperityinitiative.org/images/stories/Small-scale Review of Honey.pdf.

Chala Kinati, Taye Tolemariam, Kebede Debele and Tadele Tolosa. 2012. Opportunities and challenges of honey production in Gomma district of Jimma zone, South-west Ethiopia, 4(4), pp. 85–91. Doi: 10.5897/JAERD11.047.

Chala Kinati, Taye Tolemariam, Kebede Debele. 2013. Production and marketing system in Goma District, South Western Ethiopia, G. J. Bus. Mana.Stu. 3(3):99-107.

Chala Kinati, Taye Tolemariam, Kebede Debele and Tadele Tolosa. 2001. Quality evaluation of honey produced in Goma Woreda of South Western Ethiopia. Livestock Research for Rural Development 23 (9).

COMESA 002. 2004. Standard for Honey. Revised codex Almentarious standard for honey. Codex standard 12-1981, rev.1 (1987), rev.2 (2001)1.

Crane E. 1990. Bees and Beekeeping: Science, Practice and World Resources. Comstock Publishing Associates (Cornell University Press), Ithaca, New York.

CSA (Central Statistical Agency). 2007. Census 2007 Tables: Amhara Region Archived 2010-11-14 at the Way back Machine, Tables 2.1, 2.4, 2.5, 3.1, 3.2 and 3.4.

CSA (Central Statistical Agency). 2011/12. Agricultural Sample Survey 2010/11. Report on Livestock and Livestock Characteristics, Addis Ababa, FDRE, Ethiopia.

CSA (Central Statistical Agency). 2015. Livestock and Livestock Characteristics, Agricultural Sample Survey, Volume II.

CSA (Central Statistical Agency). 2016/17. Agricultural Sample Survey 2016/17. Report on livestock and livestock characteristics. Addis Ababa, FDRE, Ethiopia.

CSA (Central Statistical Agency). 2018/19. Agricultural Sample Survey 2018/19. Report on livestock and livestock characteristics. Addis Ababa, FDRE, Ethiopia.

CSA (Central Statistical Agency). 2020. Federal Democratic Republic of Ethiopia Central Statistical Agency: Agricultural Sample Survey, Livestock and Livestock Characteristics (Private Peasant Holders).

D. B. HILL and T. C. WEBSTER. 1995. Department of Forestry, University of Kentucky, Lexington, KY 40546-0073; t Cooperative Extension Program, Community Research Service, Kentucky State University, Frankfort, KY 40601, USA. Agroforestry Systems 29: 313-320.

Desalegn Begna. 2015. Honeybee Diseases and Pests Research Progress in Ethiopia-A review. African Journal of Insect, 3(1): 093-096.

EARO (Ethiopian Agricultural Research Organization). 2000. Apiculture Research Strategy. Animal Science Research Directorate, Ethiopia, p. 30-42.

Edwards S. 1976. Some wild flowering plants of Ethiopia. Addis Ababa University press, Addis ababa, Ethiopia.

EIAR (Ethiopian Institute of Agricultural Research). 2017. Livestock and Fisheries Research Strategies. Poultry, Fisheries, Apiculture and Sericulture. Addis Ababa, Ethiopia, pp. 153-224.

Ethiopian Quality Standard Authority (ES). 2013. Ethiopian honey quality and standard (ES 1202:2005), Addis Ababa, Ethiopia.

European Honey Directive (EU). 1974. On the harmonization of the laws of the member states relating to boney. 74/409/EEC, Official Journal of the European communities, NOL 221114.

FAO (Food and Agriculture Organization of the United Nations). 1996. Value-added Product of Beekeeping. FAO Agricultural Services Bulletin No 124, FAO, Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). 2010. FAOSTAT database on Agriculture and Nutrition. Food and Agricultural Organization of the United Nations, Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). 2007. Statistical yearbook, FAOSAT.http://www.fao.org/es/ess/top/commodity.html? item 1182&langen &year 2005.

FAO (Food and Agriculture Organization of the United Nations). 2017. Food and Agriculture Organization: Livestock Primary.

FAO (Food and Agriculture Organization of the United Nations). 2020. Good beekeeping practices: Practical manual on how to identify and control the main diseases of the honeybee (Apis mellifera). TECA – Technologies and practices for small agricultural producers, 1. Rome. https://doi.org/10.4060/ca9182en.

FAO-STAT. 2021. Global Production Data on Honey and Beeswax. FAO. http://www.fao.org/faostat/en/#data/QL. (Accessed 9 March 2021).

Fichtl, R. and Admasu Addi. 1994. Honeybee Flora of Ethiopia. MargrafVerlag, Germany.

Fikre Girma, Tarun kumar Raghunvanshi, Tenalem Ayenew and Trufat Hailemariam. 2015. Landslide hazard zonation in Ada Berga district, Central Ethiopia- AGIS Based Statistical Approach.

Finola M.S., Lasagno, M.C. & Marioli, J.M. 2007. Microbiological and chemical characterization of honeys from central Argentina. Food Chemistry, 100, 1649–1653.

Gallmann P. and Thomas H. 2012. Beekeeping and honey production in south western Ethiopia. Ethiopia: Honey bee investigation 2012.

Gebreegziabher Gebremedhin, Gebrehiwot Tadesse and Etsay Kebede. 2013. Physiochemical Characteristics of Honey Obtained from Traditional and Modern Hive Production Systems in Tigray Region, Northern Ethiopia. Momona Ethiopian Journal of Science (MEJS), V5 (l):115-128, 2013, ©CNCS, MekeIIe University, and ISSN: 2220-184X.

Geremew Bultosa. 2005. Food chemistry laboratory manual. Department of food science and post-harvest technology, Alemaya University, Ethiopia.

Gezahegne Tadesse. 2001. Beekeeping (In Amharic), Mega Printer Enterprise, Addis Ababa, Ethiopia.

Gichora M. 2003. Towards Realization of Kenya's Full Beekeeping Potential. A case Study of Baringo District. Ecology and Development Series No.6, 2003. Cuvillier Verlag Gottingen, Germany. pp. 155-158.

Girema Deffar. 1998. Non-Wood Forest Products in Ethiopia. EC-FAO Partnership Programme (1990- 2000). Addis Ababa. Pp. 1-5.

GWAO (Guangua Woreda Agricultural Office). 2015. Natural resource annual report of Guangua Woreda Agricultural Office.

Haftu Kebede and Gezu Tadesse. 2014. Survey on honey production system, challenges and Opportunities in selected areas of Hadya Zone, Ethiopia.

Hailegebriel Tesfay, 2014. Honey Bee Diseases, Pest and Their Economic Importance in Ethiopia. International Journal of Innovation and Scientific Research Vol. 10 No. 2 pp. 527-535.

HBRC (Holeta Bee Research Center). 2004. Beekeeping training manual.

HBRC (Holeta Bee Research Center). 1997. Holeta Bee Research Center. Beekeeping Training Manual (unpublished), HBRC, Holeta, Ethiopia.

Hussein N. &. Omar M.O.M. 1989. The 7th Arab Pesticide Conference, Tanta Univ.,78-85.

Kebede Nigusssie, Subramanian P., Gebrekidan Mebrhatu. 2011. Physicochemical Analysis of Tigray Honey: An Attempt to Determine Major Quality Marker of Honey. Chemical Society of Ethiopia, Addis Ababa, Ethiopia.

Kerealem Ejigu. 2005. Honeybee production systems, opportunities and challenges in Anebse sar midir wereda (Amhara region) and Amaro special woreda (Southern nations, nationalities and peoples' region), Ethiopia. Department of animal science, school of graduate studies Alemaya University.

Kerealem Ejigu, Tilahun Gebey and Preston T. R. 2009. Constraints and Prospects for Apiculture Research and Development in Amhara Region, Ethiopia (unpublished).

Kumar D., Bharti U. 2015. Tropic Niche Specialization of Buteamonosperma from Chandigarh. Journal of Entomology and Zoology Studies, 3(4), 83-85.

Louveaux J, Maurizio A, Vorwohl G. 1978. Methods of Melissopalynology. Bee World 59: 139- 157.

MoA, I.L.R.I. (Ministry of Agriculture and International Livestock Research Institute). 2013. Apiculture value chain vision and strategy for Ethiopia. Addis Ababa: Ministry of Agriculture and International Livestock Research Institute.

MoARD (Ministry of Agriculture and Rural Development). 2003. Honey and Beeswax marketing and development. In: Development MoARD, editor. Plan 2003. Addis Ababa, Ethiopia.

MoARD (Ministry of Agriculture and Rural Development). 2010. The 3rd National Monitoring Plan for Residues in Honey from Ethiopia. The Animal and Plant Health Regulatory Directorate under the Ministry of Agriculture and Rural Development (MoARD), Addis Ababa, Ethiopia Pp. 70.

Morse R. and Calderone N. 2000. The value of honeybees as pollinators of US crops in 2000. Bee Culture, Pp.1- 15.

Nahusenay Teamer Gebrehiwot. 2018. Honey Production and Marketing: The Pathway for Poverty Honey Production and Marketing: The Pathway for Poverty Alleviation the Case of Tigray Regional State, Northern Ethiopia, (June 2015).

Nicola B. 2002. Taking the sting out of beekeeping. Arid Lands Information Network- East Africa (CD-ROM). Nairobi, Kenya.

Nuru Adgaba. 1999. Quality state and grading of Ethiopian honey. pp. 74-82. Proceedings of the first National Conference of Ethiopian Beekeepers Association (EBA), June 7-8, 1999, Addis Ababa, Ethiopia.

Nuru Adgaba. 2002. Geographical races of the Honeybees (*Apis mellifera*) of the Northern Regions of Ethiopia. PhD. Dissertation. Rhodes University, South Africa.

Nuru Adgaba. 2007. Atlas of Pollen Grains of Major Honeybee Flora of Ethiopia. Addis Ababa, Ethiopia. pp. 152.

Nuru Adgaba, Admasu Addi, Dereje Waltdje. 2001. Pollen Spectrum of Honeys and Honeybee Floral Calander of West Shoa. Addis Ababa, Ethiopia.

Ofelia Anjos., Natalia R., Eurico L., Teresa A., Fatima P. and Margarida A. 2010. Floral Monitoring and Biophysics Parameters as a Tool to Beekeepers Installation Decision. 13th AGILE International Conference on Geographic Information Science 2010 pp 1-3. Guimaraes, Portugal.

Pavelkova A., Kacaniova M., Cubon J., Svecova1 Z., Knazovicka1 V.and Felsociova S. 2013. Physicochemical and Microbiological Quality of Honey from Liptov Region. Journal of Microbiology, Biotechnology and Food Sciences. Slovak University of Agriculture, Nitra, Slovakia.

Ruoff Kaspar. 2006. Authentication of the Botanical Origin of Honey. Ph. D. Thesis at The Institute of Food Science and Nutrition, ETH Zurich, In Collaboration with The Swiss Federal Research Station for Animal Production and Dairy Production, Liebefeld – Bern Switzerland. Pp75.

Segeren, P.1995. Beekeeping in the Tropics, 5 thed.Agrodokseries No32, CTA/AGROMISA, Wageningen, The Netherlands.

Silici S. 2002. Further chemical and palynological properties of some unifloral TurkishHoney. The first Germ a beeproducts and Apitherapy congress passau, Germany, pp.23-27.

Sisay Gobessa, Eyassu Seifu and Amsalu Bezabih. 2012. Honey Produced in the Homesha District of Western Ethiopia. Haramaya University. Journal of Apicultural Science.

Tesfaye Bekele, Genet Dadi and Temaro Gelgelu. 2017. Assessment of Honeybee Enemies (Pests and Predators) in Bale Zone, Southeastern Ethiopia. Journal of Agricultural Extension and Rural Development, 9(4): 53-61.

Tessega Belie. 2009. Honeybee Production and Marketing Systems, Constraints and Opportunities in Burie District of Amhara Region, Ethiopia. A Thesis Submitted to the Department of Animal Science and Technology, School of Graduate Studies, Bahir Dar University. Pp 28-67 (unpublished).

Tessema Aynalem. 2010. Assessment of Beekeeping Practices with Emphasis on Improved Beekeeping Technologies in Gubalafto woreda, Amhara Region M.Sc. Thesis Bahir Dar University. pp.103.

Tewodros Alemu. 2010. Assessment of Honeybee Production Practices and Honey Quality in Sekota Woreda of Waghimra Zone, Ethiopia. MSc Thesis Presented to the School of Graduate Studies of Haramaya University. Pp.122.

Vorwhohl G., Salem M.S. & Nour M.E. 1989. Chemical and physical properties of Egyptian honey. Proc.4thInternational Conf. Apiculture in Tropical climates, Cairo, pp.240-244.

Workneh Abebe, Nuru Adgaba and Sebsibie Zuber. 2008. Participatory Beekeeping Technology promotion: A Case study of Chefeka hive Author.

Yaniv Z & Rudich M. 1996. Medicinal herbs as a potential source of high quality honey. In: A. Mizrahi and Y. Len sky (eds.), Bee products, New York, NY: Plenum press, pp.77-81.

Yetimwork Gebremeskel. 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. PhD Dissertation, Dissertation. Addis Ababa University.

Zewudu Wondifraw, 2018. Challenges and opportunities of honey production in north-east dry land areas of Amhara National Regional State, Ethiopia.

APPENDICES

Appendix Tables 1: ANOVA table of honey quality from different agro-ecologies

		Sum of Squares	Df	Mean Square	F	Sig.
Percentage of Ash	Between Groups	.040	2	.020	.623	.550
	Within Groups	.482	15	.032		
	Total	.522	17			
Moisture content	Between Groups	4.360	2	2.180	.796	.469
	Within Groups	41.080	15	2.739		
	Total	45.440	17			
pH value	Between Groups	.084	2	.042	.245	.786
	Within Groups	2.570	15	.171		
	Total	2.654	17			
Acidity value	Between Groups	137.861	2	68.931	.833	.454
	Within Groups	1241.917	15	82.794		
	Total	1379.778	17			
HMF amount	Between Groups	47.410	2	23.705	.891	.431
	Within Groups	399.244	15	26.616		
	Total	446.654	17			
Amount of Fructose	Between Groups	29.034	2	14.517	.863	.442
	Within Groups	252.352	15	16.823		
	Total	281.386	17			
Amount of Gluctose	Between Groups	29.585	2	14.793	.930	.416
	Within Groups	238.552	15	15.903		

	Total	268.137	17			
Amount of Sucrose	Between Groups	4.769	2	2.384	2.510	.115
	Within Groups	14.252	15	.950		
	Total	19.020	17			

Appendix Table 2: ANOVA table for honey quality from different hives

		Sum of Squares	Df	Mean Square	F	Sig.
Percentage of Ash	Between Groups	.051	2	.026	.815	.461
	Within Groups	.471	15	.031		
	Total	.522	17			
Moisture content	Between Groups	8.760	2	4.380	1.791	.201
	Within Groups	36.680	15	2.445		
	Total	45.440	17			
pH value	Between Groups	.136	2	.068	.404	.674
	Within Groups	2.518	15	.168		
	Total	2.654	17			
Acidity value	Between Groups	174.778	2	87.389	1.088	.362
	Within Groups	1205.000	15	80.333		
	Total	1379.778	17			
HMF amount	Between Groups	51.039	2	25.519	.968	.402
	Within Groups	395.615	15	26.374		
	Total	446.654	17			
Amount of Fructose	Between Groups	6.730	2	3.365	.184	.834
	Within Groups	274.656	15	18.310		

	Total	281.386	17			
Amount of Glucose	Between Groups	59.776	2	29.888	2.152	.151
	Within Groups	208.361	15	13.891		
	Total	268.137	17			
Amount of Sucrose	Between Groups	.414	2	.207	.167	.848
	Within Groups	18.606	15	1.240		
	Total	19.020	17			

Appendix Table 3: ANOVA table of honey quality from different season

		Sum of Squares	Df	Mean Square	F	Sig.
Percentage of Ash	Between Groups	.043	1	.043	1.437	.248
	Within Groups	.479	16	.030		
	Total	.522	17			
Moisture content	Between Groups	3.380	1	3.380	1.286	.274
	Within Groups	42.060	16	2.629		
	Total	45.440	17			
pH value	Between Groups	.032	1	.032	.193	.666
	Within Groups	2.622	16	.164		
	Total	2.654	17			
Acidity value	Between Groups	37.556	1	37.556	.448	.513
	Within Groups	1342.222	16	83.889		
	Total	1379.778	17			
HMF amount	Between Groups	77.917	1	77.917	3.381	.085
	Within Groups	368.737	16	23.046		
	Total	446.654	17			
Amount of Fructose	Between Groups	88.711	1	88.711	7.367	.015
	Within Groups	192.675	16	12.042		
	Total	281.386	17			

Amount of Glucose	Between Groups	36.765	1	36.765	2.542	.130
	Within Groups	231.372	16	14.461		
	Total	268.137	17			
Amount of Sucrose	Between Groups	.008	1	.008	.007	.935
	Within Groups	19.012	16	1.188		
	Total	19.020	17			

Appendix Tables 4: Some identified honey bee floras by pollen analysis around *Ellala* forest

Season one or honey flow season flora

No.	Local name	Scientific name	Total pollen count	%
1	Mech	*Guizotia scabra*	40	10.0
2	Nug	*Guizotia abyssinica*	32	8.0
3	Adey	*Bidden spp*	66	16.5
4	Wajima	*Madicago polymarpha*	46	11.5
5	Sesbania	*Sesbania sesban*	21	5.3
6	Wanza	*Cordia africana*	38	9.5
7	Quliqual	*Euphorbia abyssinica*	9	2.3
8	Chibeha	*Acacia nilotica*	12	3.0
9	Kitikita	*Dadmoanea viscosa*	6	1.5
10	Kushashilie	*Acanthus senni*	8	2.0
11	Azohareg	*Clematis hirusta*	16	4.0
12	-	*Rannculus multitidus*	13	3.3
13	Bekolo	*Zea mays*	36	9.0
14	-	*Lepdium satium*	8	2.0
15	-	*Crassocephalum vitelinum*	6	1.5
16	Gomen zer	*Brassica spp*	38	9.5
17	-	*Rubus steudneri*	4	1.0
18	Total		399	100.0

Season two or dearth period flora

1	Bahir zaf	*Eucalpytus spp*	40	11.2
2	Semiza	*Justitie schimperiana*	38	10.7
3	Dokima	*Syzygium guiness*	44	12.4
4	Girawa	*Vemonia spp*	28	7.9
5	Bissana	*Croton macrostachys*	36	10.1
6	Girar	*Acacia albidia*	16	4.5
7	Kega	*Rosa abyssinica*	13	3.6
8	Buna	*Coffee arabica*	26	7.3
9	Agam	*Carrissa edulis*	12	3.4
10	Enjory	*Rubus spp*	8	2.4
11	Sesa	*Albizia gummifera*	4	1.1
12	Woira	*Olea africana*	10	2.8
13	Tid	*Juniperous procera*	6	1.7
14	Gumero	*Capparis tomentosa*	14	3.9
15	Dong	*Apodyles dimidiate*	4	1.1
16	Gesho	*Rhammus prinocides*	8	2.4
17	Bagur	*Combertum molle*	8	2.3
18	-	*Pentas schimperides*	6	1.7
19	-	*Unidentified*	2	0.6
20	-	*Unidentified*	12	3.4
21	-	*Cirtus aurantium*	6	1.7
22	-	*Saturieja paradova*	4	1.1
23	-	*Gounia longispicata*	5	1.4
24	-	*Hypericum quartianiam*	2	0.6
22	-	*Geranium arbicum*	4	1.1
	Total		356	100.0

Appendix Tables 5: Amount of honey obtained from one hive/year in kg

Hive type		Levine's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Traditional	Equal variances assumed	5.399	.022	-1.940	115	.055	-.426	.220	-.861	.009
	Equal variances not assumed			-2.118	83.520	.037	-.426	.201	-.826	-.026
Transitional	Equal variances assumed	4.178	.053	-4.205	23	.000	-3.544	.843	-5.287	-1.800
	Equal variances not assumed			-6.273	20.901	.000	-3.544	.565	-4.719	-2.369
Frame	Equal variances assumed	5.783	.021	-5.804	41	.000	-5.394	.929	-7.271	-3.517
	Equal variances not assumed			-6.884	38.928	.000	-5.394	.784	-6.979	-3.809

Appendix Table 6 : Correlation results between different chemical properties of sample honey

Variables		Ash %	Moisture content %	pH value	Acidity (meq/kg)	HMF (mg/kg)	Fructose (meq/kg)	Glucose (meq/kg)	Sucrose %
Ash %	Pearson Correlation	1							
	Sig. (2-tailed)								
	N	18							
Moisture	Pearson Correlation	-.442	1						
	Sig. (2-tailed)	.067							
	N	18	18						
pH value	Pearson Correlation	.117	.055	1					
	Sig. (2-tailed)	.643	.828						
	N	18	18	18					
Acidity (meq/kg)	Pearson Correlation	.662**	-.140	-.135	1				
	Sig. (2-tailed)	.003	.578	.594					
	N	18	18	18	18				
HMF (mg/kg)	Pearson Correlation	.052	-.071	-.066	.144	1			
	Sig. (2-tailed)	.836	.779	.794	.568				
	N	18	18	18	18	18			
Fructose (meq/kg)	Pearson Correlation	.215	-.415	-.282	.012	-.218	1		
	Sig. (2-tailed)	.391	.087	.256	.963	.384			
	N	18	18	18	18	18	18		
Glucose	Pearson Correlation	-.104	.220	-.192	-.393	-.367	.257	1	

(meq	Sig. (2-tailed)	.683	.381	.446	.107	.134	.304		
/kg)	N	18	18	18	18	18	18	18	
Sucr	Pearson Correlation	.226	-.205	.271	-.320	.093	.351	.265	1
ose	Sig. (2-ta.iled)	.367	.415	.276	.196	.714	.154	.287	
%	N	18	18	18	18	18	18	18	18

**. Correlation is significant at the (p<0.01) (2-tailed).
N= number of cases; Sig= significant level

Appendix Tables 7: Major trees and shrubs used for source of bee forage.

Season-1 or honey flow season identified floras

Local name	Scientific name	Plant type	Source	Flowering period
Adeyabeba	*Biden spp*	H	N&P	September to November
Wajima	*Madicago polymarpha*	H	P	September to November
Koshashilia	*Acanthus senni*	S	N	November to January
Mech	*Guizotia scabra*	H	N&P	September to November
Dengorita	*Vemonia bifarae*	S	N&P	October to December
Wanza	*Cordia africana*	T	N&P	October to December
Sesbania	*Sesbania sesban*	S	N&P	November to January
Kitkita	*Dadmonaea viscosa*	T	N&P	September to October
Kulkual	*Euphorbia abyssinica*	S	N&P	October to January
Azohareg	*Calemtis hirusta*	S	N&P	October to December
Chibeha	*Acacia nilotica*	T	N&P	November to January
Additionally, there are other sources which farmers planted for other purposes like:				
Nug	*Guitozia abyssinica*	Oil seed	N&P	October to November
Maize	*Zea mays*	Crop	P	August to October
Gomenezer	*Brassica spp.*	Oil seed	N&P	August to October

Small millet/dagusa/		Crop	N&P	October to December
Teff	*Eragrostic abicinicus*	Crop	N&P	October to November
Barely	*Hordeum vulgare*	Crop	N&P	November to January
Wheat	*Triticum aestivum*	Crop	N&P	November to January

Season-2 or dearth period identified floras

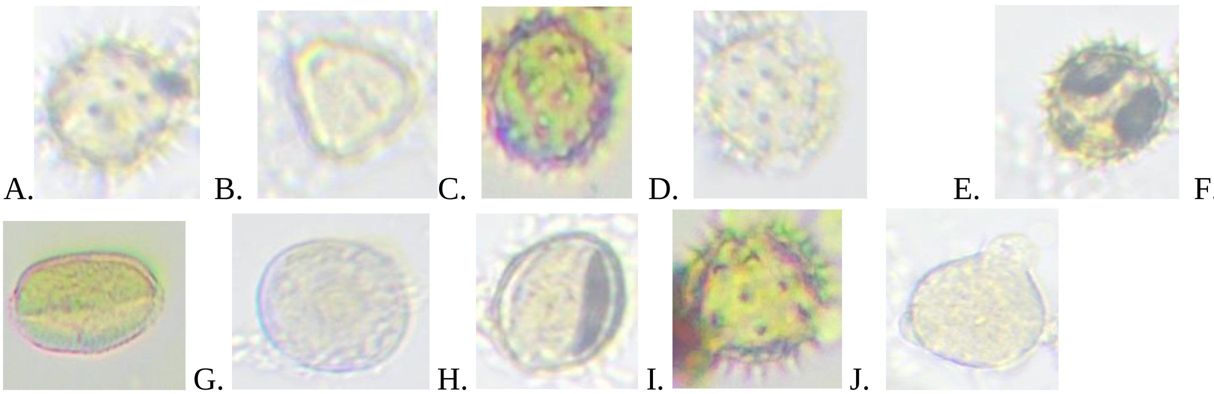
Local name	Scientific name	Plant type	Source	Flowering period
Bisana	*Croton macrostachys*	T	N&P	February to May
Girar	*Acacia albida*	T	N&P	February to March
Girawa	*Vemonia spp*	T	N&P	February to March
Enjory	*Rubus spp*	S	N&P	December to January
Dokima	*Syzygium guiness*	T	N&P	April to May
Agam	*Carissa edulis*	S	N&P	April to May
Sesa	*Albizia gummifera*	T	N&P	January to March
Kega	*Rosa abyssinica*	T	N&P	February to May
Woira	*Olea Africana*	T	N&P	March to April
Gumero	*Capparis tomentosa*	S	N&P	March to April
Dong	*Apodyles dimidiate*	T	N&P	January to February
Tid	*Juniperous procera*	T	P	February to April
Bahirzaf	*Eucalpytus spp*	T	N&P	January to February
Semiza	*Justitie schimperiana*	S	N	January to March
Endod	*Phytolacca dodecandra*	S	N&P	January to April
Kentafa	*Entada abyssinica*	S	N&P	January to March
Amekila	*Hygrophilie auriculata*	S	N&P	
Avalo	*Combertum globiferus*	T	N&P	March
Birbera	*Mellite ferruginee*	T	N&P	March to April
Quantir	*Petrolobium stelltum*	S	N&P	March to April
Bagur	*Combertum molle*	T	N&P	January to March
Additionally, there are other sources which farmers planted for other purposes like:				
Buna	*Coffee arabica*	S	N&P	March to April

Gesho	*Rhammus prinocides*	S	N&P	March to May

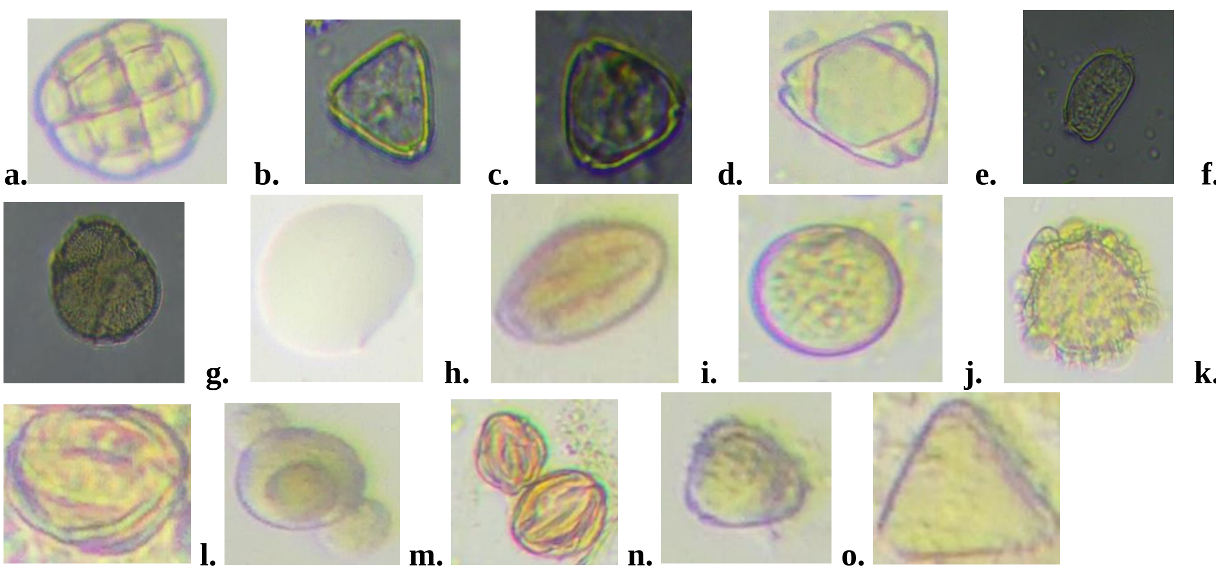
T= tree; S= shrubs; H= herbs; P= pollen; N= nectar

Figures 1: Morphology of some pollen grains

Some identified pollen grain photos in season-one



Some identified pollen grain photos in season-two



Season-one: *(A)Bidden spp (B) Cordia africana (C) Guizotia scabra (D) Guizotia abyssinica (E) Euphorbia abyssinica (F) Clematis hirusta (G) Ranunculus multifidus (H) Lepidium sativum (I) Crassocephalum vitellinum (J) Rubus steudneri*

Season-two: *(a)Acacia albida (b) Syzygium guiness (c) Rosa abyssinica (d) Eucalpytus spp (e) Justitie schimperiana (f) Coffee arabica (g) Geranium arabicum (h) Hypericum quartianiam (i) Gounia longispicata (j) unidentified (k) Satureja paradoxa (l) Cirtus aurantium (m) Unidentified (n) Pentas schimperiana (o) Rubus steudneri*.

Questionnaire 1: Questionnaire for the survey

1. House hold characteristics

1.1. Name of respondent ------------------------

1.2. Responsibility ------------------------

1.3. Sex: 1, Male   2. Female

1.4. Marital status: 1. Married   2. Single   3. Widowed   4. Divorced

1.5. Age-----

1.6. A Number of years lived in the area ----------------

1.7. Educational status: 1. Illiterate 2. Read and write --------- 3. Grade (1-4) ----------- 4. Grade (5-8) --------------- 5. Grade (9-12) ----------- 6. (Higher level) -------------

1.8. Responsibilities in the community 1. Political leader 2. Spiritual leader 3. Elder 4. Other (specify))

1.9. Family member and their educational level

No.	Age *	Number	Sex		Education**
			1	2	
	<8				
	8-15				
	15-28				
	>28				

* 1. Below 8   2. 8-15   3.15-28   4. Above 28

** 1. Read and write   2. Grade 1-4;   3. Grade 5-8;   4. Grade 9-12.   5. Higher level

1.10. Division of work including off-farm activities according to age group

Sex	Age			
	8-15	16-28	29-45	46-60
Male				

Female				
Total				

1.11. Landholding (ha) of the Respondents

No.	Type of land	Unit	Quantity	Remark
1.	Farm and	Hectare		
2.	Forest land	Hectare		
3.	Grazing land	Hectare		
4.	Others	Hectare		
5.	Total landholdings	Hectare		

1.12. Do you keep honey bees? 1. Yes 2. No

1.13. If yes, how long did you start bee keeping? -------------Year (s)

2. Beekeeping activities and honey production

2.1. How you start beekeeping?

No.	Source	Total	Traditional	Transitional	Frame hive
1	From parents				
2	Catching swarm				
3	Buying				
4	Others (specify)				

2.2. If your answer for question 2.1 is buying, is there a selling practice of bee colony in your locality? 1. Yes 2. No

2.3. If yes what is the price of one colony in ETB?

1. Traditional hived--------------------------

2. Transitional hived--------------------------

3. Frame hived--------------------------

2.4. How many honey bee colonies you owned?

No.	Years	Traditional		Transitional		Frame		Remark
		No.	Honey (kg)	No.	Honey (kg)	No.	Honey (kg)	
1	2017							
2	2018							
3	2019							
4	2020							
5	2021							

2.5. What are the sources and costs of the bee hives you are using?

No.	Item	Unit	Traditional	Transitional	Frame
1	Constructed by himself/herself	No.			
2	Constructed locally & bought	No.			
3	Bought from market	No.			
4	Supplied by government	No.			
	1. On credit bases	No.			
	2. Free of charge	No.			
5	Supplied by NGOs	No.			
	1. On credit bases	No.			
	2. Free of charge	No.			
6	Price of one hive	(ETB)			
7	Service years	Year			

2.6. What are the major materials used for hive construction in the study area?

1. From bark of tree 2. From clay 3. From mud 4. From straw made
5. Others

2.7. What are the major advantages of different bee hives?

No.	Criteria	Traditional		Transitional		Frame hive	
		Yes	No	Yes	No	Yes	No
1	Material availability						
2	Suitability of harvest						
3	Better Quality of honey						
4	Temperature maintenance						
5	Less swarming frequency						
6	Convenience to construct						
7	Durability						
8	Cost effective						
9	Others (specify)						

2.8. Which equipment do you use for harvesting honey? (Mark one or more)

Hive type	Protection cloth	Smoker	Bee brush	Knife	Water sprayer	Chisel	Other (specify)
For traditional							
For Transitional							
For frame hive							

2.9. Mention months of the dearth period and active season?

1. Dearth period, -------------- to -----------------------

2. Active season, -------------- to-----------------------

2.10. How much honey do you harvest from one hive per year?

No.	Hive type	Average (in kg)	Max.	Min.
	Traditional			

	Transitional			
	Frame hive			

2.11. How many times do you harvest honey per year? 1. 1 2. 2 3. 3 4. 4

3. Farmers practices and colony management

3.1. Where did you keep your colonies?

No.	Site or placement of hive	Traditional	Transitional	Frame hive
1	Back yard			
2	Under the eaves of the house			
3	Inside the house			
4	Hanging on trees near homestead			
5	Hanging on trees in forests			
6	Water shed forests land			
7	Others (specify)			

3.2. For how long your colonies remain or stay in the hive (without absconding)?!!

1. Traditional: Minimum__________ year (s) Maximum____________ years
2. Transitional: Minimum_________ year (s) Maximum____________ years
3. Frame: Minimum________ year (s) Maximum____________ years

3.3. The major types of tree species preferred for hive hanging during swarm catching

No.	Scientific name	Local name	Reason for preference
1			
2			
3			
4			

3.4. The major types of tree species preferred for hive smoking before hanging during swarm catching---

No.	Scientific name	Local name	Reason for preference
1			
2			
3			
4			

3.5. What are the major honey Bee plant species /flora/ found in the study area?

No	Plant type (tree/shrub)	Scientific name	Local name	Flowering months ____to____	Source (pollen, nectar, both)	Remark
1						
2						
3						
4						
5						
6						
7						
8						
9						

3.6. How could you increase your colony number? 1) By swarm catching 2) By simple multiplication techniques 3) By grafting 4) Others………………

3.7. If the answer is 2 or 3, how many daughter colonies you got from one colony per a single multiplication? 1. Max………… 2. Minimum……….

3.8. What type of techniques is used to capture swarmed colony?

1. Dispersing dust onto swarmed colony-----------------
2. By spraying water onto swarmed colony----------------
3. By hanging hives on branches of a tree-----------------4. Others (specify) ………………

3.9. Do you practice swarm prevention? 1) Yes 2) No

3.10. If the answer is yes, what methods you used? 1) Increasing the hive size: 2) Removing developed queen cells 3) splitting the colony 4) other (specify) -------

3.11. Is swarming advantageous to you? 1. Yes 2. No

3.12. If yes, describe the reason(s): 1. Increase the number of colony 2. To sale and income 3. To replace non-productive bee colonies 4. Others (specify)

3.13. Do you inspect your colonies? 1. Yes 2. No

3.14. If yes, which type of inspection you perform? 1. External hive inspection 2. Internal inspection 3. Both

3.15. Frequency of external hive inspection (circle one or more) 1. Frequently 2. Sometimes 3. Rarely

3.16. Frequency of internal hive inspection (circle one or more) 1. Frequently 2. Sometimes 3. Rarely

3. 17. When the following major activities occur in your locality?

No	Activities	Season(s)				
		Aug – Oct	Nov-Jan	Feb-App	May-Jul	Others
1	Brood rearing period					
2	Hive Supering /spacing/					
3	Honey harvesting					
4	Super reduction					
5	Absconding					
6	Swarming					

7	Colony migration					
8	Dearth period					
9	Colony feeding					

3.18. For how long do you store your honey? (Circle one or more).

1. I don't store, I will sale / it will be consumed during harvesting
2. One to six months
3. Seven to twelve months
4. One year to two years
5. More than two years

3.19. For what reason do you store honey? 1. Due to price 2. To increase medicinal value 3. Others (explain) ----------------

3.20. What types of containers- are used for honey collection and storage?

1. Plastic barrel/jar 2. Clay jar

3. Metallic container 4. Others specify.............

3.21. If your honey is granulated or crystallized, did you change it to viscous honey? 1. Yes 2. No

3.22. If yes, what methods do you use? 1. Direct heating using fire 2. Putting in boiled water 3. Using sun light 4. Others………….

3.23. How do you rate the quality of your Honey? 1. By color 2. Smelling 3. By its odor 4. By testing 5. By its thickness 6. Others (specify)………

3.24. What type of other bee products do you produce? (Can tick more than one answer). 1. Bees wax 2. Propolis 3. Royal jelly 4. Bee venom 5. Pollen 6. Bee brood

3.25. Do you feed honey bee colonies? 1. Yes 2. No

3.26. If yes when do you feed your honey bee colonies (months)…………

3.27. What kind of feed you offer to your bees?

No	Type of feed	Amount offered/season/colony	Cost per kg(ETB)

1	Besso		
2	Shiro		
3	Sugar		
4	Honey		
5	Others (specify)		

3.28. How do you feed them? 1. Internal feeding 2. External feeding

4. Potential and constraints of apiculture in the area

4.1. What is the trend of your colony number and honey yield?

No	Types of beehives	Number and yield trend increase/Stable/decrease	Reason
1	Traditional		
2	Transitional		
3	Frame hive		

4.2. If there is an increase in trend in the number of bee colonies and honey Yield over the years, what are the reasons? 1) Good market price 2. Added more bee colonies 3. Use of new technologies 4. Others (specify) ____________

4.3. If there is a decrease in trend in the number of bee colonies and honey yields over the year, what are the causes and measures in order of importance?

No	Causes	Rank	Season of occurrence	Measures taken
1	Lack of bee forage			
2	Lack of water			
3	Drought (lack of rainfall)			
4	Migration			
5	Absconding			
6	Pests and predators			
7	Diseases			

8	Pesticides and herbicides application			
9	Death of colony			
10	Luck of credit			
11	Increased cost of production			
12	Others (specify)			

4.4. What are the major honey Bee plant species /flora/ found in the study area?

No	Plant type (tree/shrub)	Scientific name	Local name	Flowering months ____to____	Source (pollen, nectar, both)	Remark
1						
2						
3						
4						
5						
6						
7						
8						
9						

4.5. Which types of plant species are more visited by honey bees? (Choose No from 4.4) 1. ------ 2. ------- 3. --------- 4. ----------- 5. -------

4.6. The honey from which plant species are more preferred among consumers? 1. ------ 2. ------- 3. --------- 4. ----------- 5. -------

4.7. Is there any plant species which are toxic for bees in the study area? 1. Yes 2. No

4.8. If yes mention some of them:

Local Name local

Scientific Name

4.9. Does water available for your honey bees at all the time? 1. Yes 2. No

4.10. If yes, where do your honey bees get water? (Circle one or more) 1. Stream 2. Rivers 3. Lakes 4. Ponds 5. Water harvesting 6. Others

4.11. If your response is No, how do you provide water to your bee colonies? ---------------------- --

4.12. If there is any bee diseases in the study area what are they? --------------------------------------

4.13. Is there inappropriate application of pesticides and insecticides? 1. Yes 2. No

4.14. In which category of hives your colonies do more likely affected by the disease? 1. Traditional 2. Transitional 3. Frame hive

4.15. What are the major pests & predators found in the area that threat your colonies? List in order of importance.

No	Pests/predators	Rank	Local control methods
1			
2			
3			
4			
5			
6			
7			
8			