Deliverable 5.1- Bee-Management and Bee-Health Indicators

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Lead Partner for the compilation of this document

KARL-FRANZENS-UNIVERSITÄT GRAZ
UNIVERSITY OF GRAZ

Author of the report

Gratzer Kristina, MSc and Mag. Dr.rer.nat Brodschneider Robert

Project Coordinator contact:

Angela Zur
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
An der Alster 62,
20999 Hamburg, Germany
Angela.Zur@giz.de

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Executive Summary

In the first months of the SAMS project, within work package 5 (Api-Management), deliverable 5.1 (Bee-Management and Bee-Health Indicators), we contextualized the situation of honey bees and beekeeping in the two target countries Ethiopia and Indonesia in a scientific literature study, complemented by expert opinions from the two countries. The focus countries are very populous, with Ethiopia being the most populated landlocked country and Indonesia the fourth most populated state on earth, spread on more than 17,000 islands. This high population numbers underline the need for a highly developed apicultural sector which produces natural products for human nutrition and other purposes and could make a living for many people.

According to the data on honey import and export available from FAOSTAT, Ethiopia can be regarded a net exporter of honey (mostly to Europe), whereas Indonesia is a net importer (mostly from Asia). The different cultures of the two countries also result in a different extent and way of usage of honey bee products. In some regions of Ethiopia, the traditional alcoholic beverage *tej* is widely spread and the honey and wax processors and exporters are important buyers of honey. Hence, honey commerce is partially developed in Ethiopia. Official figures for Indonesia suggest a very low per capita consumption of honey, but honey obtained from honey hunting is likely not to be included in official statistics.

The situation of honey bee species and beekeeping in the two countries is very different from each other and from that of the European Union. Whereas in Ethiopia the Western honey bee *Apis mellifera* is autochthonous, this species was introduced by man to Indonesia in the 20th century. One of the biggest challenges in Ethiopia currently is the transition from traditional beekeeping in different traditional beehives such as clay, straw, bamboo, log etc. to the more profitable keeping of bees in modern hives, mostly Dadant, Langstroth or Zander. Ethiopia also holds a number of feral *A. mellifera* colonies that are used for honey hunting and as a reservoir for managed colonies. On the other hand, Indonesia is one of the global hotspots of autochthonous *Apis* bee species diversity. Traditionally, the Eastern honey bee *A. cerana* is managed, but similar to many other Asian countries, in recent years is replaced by the introduced Western honey bee *A. mellifera*. Little is published about the appropriateness of *A. mellifera* for Indonesian environment and the interactions of the introduced bee species with native bee species in

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Indonesia regarding competition for resources or spillover of honey bee pests. Whereas knowledge on beekeeping with *A. cerana* is traditionally available, hive management techniques for *A. mellifera* in Indonesia need to be developed. Additionally, other *Apis* species, for example *A. dorsata* are used for honey hunting in some regions of Indonesia. Therefore balancing beekeeping with the introduced *A. mellifera* and the native honey bee *A. cerana* is probably the biggest challenge for Indonesian honey production. Next to *Apis* bee species, both countries use bee products from meliponine (stingless) bee species, such as bees from the genus *Trigona*.

Honey bee health in Ethiopia and Indonesia is not investigated as thoroughly as for example in the European Union or in North America, though there are fewer knowledge gaps on bee health in Ethiopia, compared to Indonesia. Ethiopian *A. mellifera* subspecies seem to cope with the introduced parasitic varroa mite better than the subspecies present in Europe, and as a result, beekeepers do not apply regular colony treatments against the mite. There are also other pests and pathogens present in Ethiopia, including viruses, bacteria, protozoa, fungi or insects, such as the small hive beetle (*Aethina tumida*). Similarly, no treatment methods are applied against most of these pests, the most commonly applied control measures in Ethiopia focus on ants and wax moths. Regarding methods for pest control, the situation is likewise in Indonesia. Little information on commonly applied treatments against honey bee pests is available. In none of the two countries national honey bee health programs exist. For both countries, field research on honey bee health and the occurrence of pests and parasites, for example honey bee viruses, as well as training of beekeepers or extension workers in disease recognition and dissemination of control methods can be recommended.

In general, we could find many refereed scientific publications in English language on beekeeping, bee forage or honey bee health for Ethiopia. For Indonesia, there is by far fewer information available. Nevertheless, it is considered, that some problems are very similar in both countries (absconding of honey bees, lack of knowledge about beekeeping practices, bee forage problems, lack of storage facilities, lack of infrastructure, lack of market facilities, and the use of pesticides). In this report, we compiled whatever was available and accessible to us by applying usual scientific research methods. During the research, we also identified knowledge gaps, which deserve further research attention. We addressed these knowledge gaps for the two countries in the respective chapters of this report. These

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knowledge gaps could stimulate further research, for example on the occurrence and mitigation of several honey bee pests. We want specially thank all persons that helped compiling this information for this report by finding scientific information or translating literature that was published in non-English language.

The contextualization of the situation of bees and beekeeping in Ethiopia and Indonesia is not completed with this preliminary report, but the information collected here will be made publicly available for the deliverable 5.2 (Bee-Management and Bee-Health Database) of the SAMS project. We therefore will create a SAMSwiki, which will make all the collected scientific information (including references) available for further extension by other consortium members or other researchers in a wiki-like approach. This approach will also allow a potential translation of the content to local languages in the future and thereby facilitate dissemination of knowledge available.

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1. Introduction

1.1 The SAMS project

SAMS is a three year project supported by the European Union's Horizon 2020 research and innovation program with a budget of around 1.99 Mio EUR. The project with the focus on Smart Apiculture Management Services started in January 2018 and is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in collaboration with 7 partners from Germany, Latvia, Austria, Ethiopia and Indonesia.

Bees play a key role in the preservation of our ecosystem, the global fight against hunger as well as in ensuring our existence. They have high potentials to foster sustainable development in different sectors but they are often used inefficient. In the context of the SAMS consortium, this effects the partner countries in different ways:

Three continents - three scenarios

(1) In Europe, consumption and trading of honey products are increasing whereas the production is stagnating. Beside honey-production, pollination services are less developed. Nevertheless, within the EU 35% of human food consumption depend directly or indirectly on pollination activities.

(2) In Ethiopia, beekeepers have a limited access to modern beehive equipment and bee management systems. Due to these constraints, the apicultural sector is far behind his potential.

(3) The apiculture sector in Indonesia is developing slowly and beekeeping is not a priority in the governmental program. These aspects lead to a weak beekeeper rate, a low rate of professional processing, support and marketing and a lack of professional interconnection with bee products processing companies.

Therefor the overall objective of SAMS is to strengthen international cooperation of the EU with developing countries in ICT, concentrating on the field of sustainable agriculture as a vehicle for rural areas. The SAMS Project aims to develop and refine an open source remote sensing technology and user

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interaction interface to support small-hold beekeepers in managing and monitoring the health and productivity in their own bee colonies. Highlighted will be especially the production of bee products and the strengthening of resilience to environmental factors.

Specific objectives to achieve the aim:

- Addressing requirements of communities and stakeholder
- Adapted monitoring and support technology
- Bee related partnership and cooperation
- International and interregional knowledge and technology transfer
- Implementation SAMS Business cooperation

Based on the User Centered Design the core activities of SAMS include the development of marketable SAMS Business Services, the adaption of a hive monitoring system for local needs and usability as well as the adaption of a Decision Support System (DSS) based on an open source system. As a key factor of success SAMS uses a multi stakeholder approach on an international and national level to foster the involvement and active participation of beekeepers and all relevant stakeholders along the whole value chain of bees.

SAMS enhances international cooperation of ICT and sustainable agriculture between EU and developing countries in pursuit of the EU commitment to the UN Sustainable Development Goal (SDG N°2) "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". SAMS increases production of bee products, creates jobs (particularly youths/ women), triggers investments and establishes knowledge exchange through networks. SAMS results are of major interest for stakeholders along the whole value chain of honey production. In the long-term, it will have a positive effect on the local engineering capacity and innovation potential. By cooperation with other networks, SAMS technology will be promoted worldwide to beekeepers as well as data beneficiaries. Of course, this inter-sectoral and intercontinental cooperation aims to research causes and find solutions to fight the worldwide trend of decreasing bee population.

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1.2 Scope of the task/deliverable

Definition of local apiculture and biodiversity conditions in coherence with task 2.1. E.g. identification of specific bee species and subspecies including current regional conditions and need of nutrients as well as climatic pre-conditions. The database will be divided in two thematic categories: Bee-management & Bee-health. Definition of locally used beehives appropriate for bees and people. Definition of suitable hive specifications (material, volume of the hive, size of flight entrance, number of combs, comb-comb distance, etc.). The technical and software related conditions are integrated in the adaption of the HIVE (task 3.2) and DSS (tasks 4.1, 4.2 and 4.3). Both categories are based on comprehensive databases and human expertise.

Bee-Management is the overall management of bee-colonies beside health issues. Management comprises information on yields, time for harvest (individually for products honey, wax, pollen, propolis and Gelee Royal), maintenance information (cleaning, repair), movement of beehives (migratory beekeeping for pollination or honey yield), optimal local conditions (nature of the resource providing unit, to hot, to cold, to sunny, to humid, etc.) as well as information on quality optimisation and post-processing. This management will be a tool to help experienced or inexperienced beekeepers and later, SAMS operators, to keep track with their bees and to minimise time efforts and transport costs. This management system uses aggregated data on daily or weekly base to keep fully functional (Tier 1 within a later SAMS business). The necessary ICT can be simpler and therefore less expensive.

Bee-Health Management is the prophylactic response system, fully functional with real time data only. Bee-Health comprises issues on rapid losses due to rapid change of ambient conditions (fire, flooding, escape, damages on beehives, war, earthquakes, etc.) health (rapid decrease of yields or nutrient stores, loss of activities, different sound patterns in compliance with specific illnesses or colony activities, etc.) or intruder (robbing bees, bee-threatening insects, parasites, etc.). The bee-health management will be subdivided in an urgent response unit, giving automatic alert to the beekeeper or supervisor in charge (e.g. guard, SAMS-contractor) and a management unit, where subsequently data will be interpreted for development of specific long-term recovery schemes and future protection measures. As this system

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uses real-time data to keep fully functional (Tier 2 within a later SAMS business) the necessary ICT must be of higher quality and therefore more expensive, then for bee-management only.

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2. Key numbers of apiculture

Ethiopia: There is no official data on the total number of beekeepers in Ethiopia, but Gupta (2014) estimated it to be more than 1 million (Gupta, Reybroeck, van Veen, & Gupta, 2014).The number of bee hives in the country (2016) is 6,189,329 (FAO 2018), while the Ministry of Agriculture and Rural Development (2007) estimated the total number of honey bee colonies (hived and feral honey bee colonies) to be ~10 million (MoARD, 2007). The data has been put in context with the official numbers of the total population size and the total country area, resulting in 0.906 beekeepers/km^2, 6.189 colonies/beekeeper, 5.605 colonies/km^2 and 0.058 colonies/capita (Table 1).

Indonesia: There is no official data on the total number of beekeepers, nor the number of hives for Indonesia, but the Indonesian Central Bureau of Statistics (BPS) provided information on beekeeping with *A. mellifera* in West Java. Thus, the number of hives in West Java was 7,141 in 2016. The data has been put in context with the official numbers of the total population size (West Java) and the total country area (West Java) resulting in 0.202 colonies/km^2 and 0.000153 colonies/capita (BPS, 2018) (Table 1).

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Table 1: Available key numbers of apiculture (total population, total country area [km^2], no. of beekeepers, no. of hives, beekeepers/km^2, colonies/beekeeper, colonies/km^2, colonies/capita, and the total amount of honey/year are shown.

	Ethiopia	West Java (Indonesia)
Total Population (2017)	104,957,438 [2]	46,709,600 [4] (263,991,379) [4]
Total country area [km^2]	1,104,300 [2]	35,377 [4] (1,904,569) [5]
No. of beekeepers	>1 mio [1]	N/A (N/A)
No. of hives (*A. mellifera*)	6,189,329 [2]	7,141 [6] (N/A)
Beekeepers/km^2	0.906	N/A (N/A)
Colonies/beekeeper	6.189	N/A (N/A)
Colonies/km^2	5.605	0.202 (N/A)
Colonies/capita	0.058	0.000153 (N/A)
Total amount of honey/year [kg] (2016)	47,706,000 [2]	35,798.8 [6] (N/A)

References (Table 1):

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2.1. Honey bee species and subspecies

Table 2 represents native and introduced honey bee species and subspecies of Ethiopia and Indonesia. While in Ethiopia, six subspecies of *A. mellifera*, as well as different species of non-*Apis* species and the introduced *A. florea* are known, in Indonesia three subspecies of *A. cerana*, two of *A. dorsata*, 5 other *Apis* species and several non-*Apis* species are native.

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Table 2: ***Apis*** **species and non-*Apis* species used for bee products in Ethiopia and Indonesia are shown. + stands for species, occurring in the particular country, *+ describes introduced species**

		Ethiopia	**Indonesia**
Apis mellifera	*A. m. adansonii*	+ [1] [2]	
	A. m. bandasii	+ [2] [3] [4] [5]	
	A. m. monticola	+ [2] [3] [5] [6]	
	A. m. jemenitica	+ [2] [3] [4] [5] [6]	
	A. m. scutellata	+ [2] [3] [4] [5] [6]	
	A. m. woyi-gambella	+ [3] [5]	
	A. mellifera sp.		*+ [10]
Apis cerana	*A. c. himalayana*		+ [6] [11] [12]
	A. c. indica		+ [6] [11] [12]
	A. c. nuluensis		+ [6] [11] [12]
Apis dorsata	*A. d. binghami*		+ [6] [12] [13]
	A. d. dorsata		+ [14]
Other *Apis* species	*A. florea*	*+ [6] [7]	+ [6] [12] [13]
	A. andreniformis		+ [6] [13]
	A. koschevnikovi		+ [6] [12] [13]
	A. nigrocincta		+ [6] [13]
	A. nuluensis		+ [6] [12] [15]
Non-*Apis* species	*Trigona* spp.	+ [8] [9]	+ [6]

References (Table 2):

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2.2. Non-Apis managed bees or bees used for bee products

In Ethiopia, as well as in Indonesia, it is traditional practice to use stingless bees (Meliponidae) from genus *Trigona* spp. for honey and propolis production. Their colonies are arranged in nests that are situated in cavities of walls or at the underside of branches and in hollow trees (Awraris et al., 2012; Gupta et al. 2014). In comparison to most *Apis* species, natural colonies of stingless bees can be very easily transferred into hives (mud pot, stone wall, bamboo hive). They produce beeswax, honey, as well as high amounts of pollen and propolis. In Ethiopia, the honey yield of 200 ml/colony/year can be expected. In comparison, there is no data about the amount of harvested products of *Trigona* from Indonesia (Awraris et al., 2012; Gupta et al., 2014; Jensen, 2007). For a list of stingless bees, native to Indonesia, see Kahono et al. (2018).

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3. Honey bee products and honey bee sector

Based on the comparison of the import and export values (honey and beeswax), provided in following chapter, Ethiopia can be categorized as a net export-country, while Indonesia is considered as net import-country.

3.1. Honey

Ethiopia: The country belongs to the largest honey producers in Africa and is among the top ten worldwide (Adeday, Shiferaw, & Abebe, 2012). The annual honey production was estimated to 43,000 t/year with a potential honey production of about 550,000 t/year (MoARD, 2007; Negash, & Greiling, 2017; Taye, Desta, Girma, & Mekonen, 2016). The potential annual honey production was estimated based on a nationwide modernization of the beesector (modern hive, increased number of hives/beekeeper, ...) Approximately, 95% of bee hives (see: "hive types") in Ethiopia are traditional with low productivity (Negash, & Greiling, 2017). According to Gemechis (2016) and MoARD (2007) traditional beehives produce around 5-8 kg honey, while the average honey yield in modern hives ranges from 15-20 kg (Gidey, & Mekonen, 2010; Taye et al., 2015). According to FAO, the average amount of honey per hive over 24 years was 7.55 kg and therefore is in agreement with the prior mentioned observations (FAO, 2018). 70-80% of produced honey is used for the production of *tej* (traditional beverage) and the remaining percentage is sold as table honey (Gidey, & Mekonen, 2010; Legesse, 2014; SNV/Ethiopia, 2005). 10% of honey is consumed directly by the beekeeping households, while the rest is sold for gaining income (Gemechis, 2016). One major quality problem is the high moisture level of honey. Samples from all over the country revealed moisture content between 15.25% and 30.45%. The outcome varies with the type of used hives (traditional hives have 1.5-3.0% higher moisture content than modern hives) and the sample region (highly humid areas are more affected) (Gemechis, 2016). Honey from traditional hives is sometimes a mixture of pollen, wax and honey, because it is not common among some Ethiopian beekeepers to separate the crude honey from other components (Fichtl, & Adi, 1994; SNV/Ethiopia, 2005). To the favoured storage materials for honey belong plastic bags, tins/barrels, plastic containers, clay/log pots and animal skin (Awraris et al., 2012). The leading honey and beeswax

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producing regions in Ethiopia include Oromia (41%), SNNPR (22%), Amara (21%) and Tigray (5%) (SNV/Ethiopia, 2005).

According to FAO statistics (2018), the total volume of produced honey between the years of 1993 and 2004 increased constantly, but fluctuated afterwards: 24,000 t in 1993, 28,000 t in 1998, 40,900 t in 2004, and 42,000 t in 2008, 45,905 t in 2012, 0 t in 2013/2014 and 47,706 t in 2016 (FAO, 2018). As shown in figure 1, official data of FAO statistics (2018) also showed a honey production of 0 t in the years 2013 and 2014.

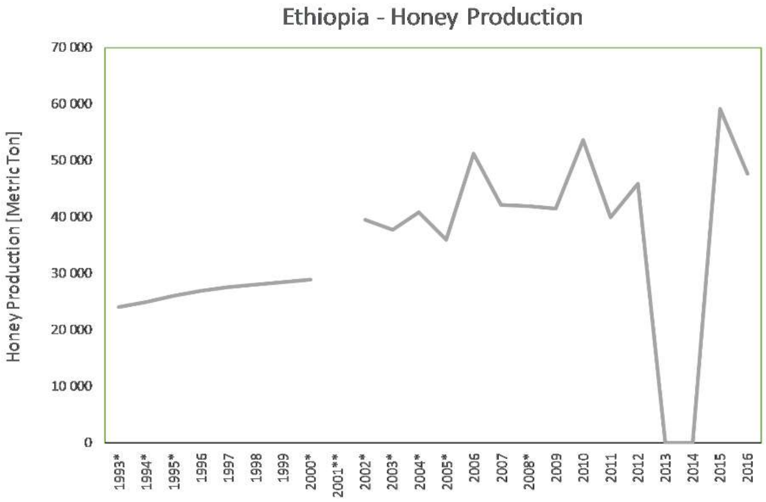

Figure 1: Honey production in Ethiopia (1993-2016); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO); **Data is not available.

The amount of produced honey per hive ranged between 6.86 kg in 1993 and 10.49 kg in 2006 with an average production of 7.55 kg/hive in the years 1993-2016 (Figure 2) (FAO, 2018).

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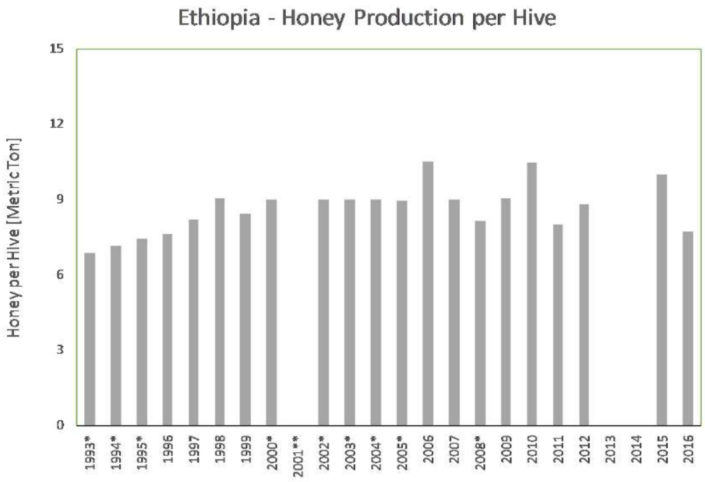

Figure 2: Honey yield per hive in Ethiopia (1993-2016); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO); **Data is not available.

Indonesia: Unfortunately, neither FAO, nor another statistical provider gives any data on the honey production of Indonesia. However, it is estimated, that Indonesia needs 3,750 t of honey per year, while there is a supply of only 500-2,000 t per year (Roman, 2006; Widiatmaka, Wiwin, Chandrasa, & Lailan, 2006). De Jong (2000) estimated the honey production in the region of Kalimantan (based on beekeeping with "honey boards"; see: hive types) between 53 kg and 267 kg per beekeeping operation (family) per year. It has to be mentioned, that beekeeping in Indonesia is still considered to be "second class farming" and therefore the beekeeping sector is still small. There are various forms of gaining honey, for example working with small colonies of stingless bees, or the practice of honey hunting on *A. dorsata*, where the forest honey is often consumed locally and therefore the data about the amount of harvested honey is not passed on for statistical assessments (de Jong, 2002). Further, the honey consumption per person per year is with 15 g very low (Widiatmaka, 2006). There is no current information on the quality of Indonesian honey, but a study in 1988 revealed high moisture content between 20.7 and 36.3% (22 samples from Sumatran village markets) and adulteration with sucrose (cane sugar, or sugar syrup) in most of the samplings. In addition, some of the investigated honey samples were boiled to evaporate the water for a higher viscosity of the product, which led to a high hydroxymethylfurfural (HMF) content (White, Platt, Allen-Wardell, & Allen-Wardell, 1988). According to a local scientist (Universitas Padjadjaran, Indonesia), Indonesian beekeepers sell their honey in two different forms, table honey

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(common honey packed in a glass jar) and nest honey, called “madu sarang” (honey sold including the whole comb). Selling nest honey is gaining more attractiveness, because of the widespread problem of honey adulteration.

3.1.1. Honey market value chain

A well-differentiated honey market value chain is equally important for producers, the distributors as well as for the consumer to provide uniform quality and further to increase the income.

Ethiopia: Gemechis (2016) wrote about the domestic honey market value chain of Ethiopia: Crude honey is sold to collectors (nearest town/village markets) by small scale beekeepers. They pass on a great amount of the product to whole sellers in bigger cities and to local *tej* breweries. The whole sellers act as distributors and sell the honey to retailers, *tej* houses, processors and consumers. Some beekeepers form marketing and producing cooperatives. They collect crude honey from members and sell the semi-processed product to processing companies or distributors. In Ethiopia, there is a lack of “good beekeeping practice”, thus, the cooperatives do not underlie quality controlling bodies, nor have business concepts and therefore suffer under quality loss and cannot compete with bigger companies (lack of proper collection, storage and transportation facilities). In addition, the domestic honey market has several problems: the smuggle and adulteration of honey bee products, complaints of consumers about increasing prices of honey products, while the beekeepers have the feeling that the business is not rewarding (Gemechis, 2016). For local beekeepers, it is not common to separate table honey from beeswax and other ingredients, but during the *tej*-brewing process, beeswax is separated as a byproduct that is passed on to beeswax collectors and exporters. Hence, they serve as important stakeholders in the beeswax business (SNV/Ethiopia, 2005).

Indonesia: According to a local scientist (Universitas Padjadjaran), fragments of a honey market chain exist, but work need to be done, to strengthen the value market chain. So far, beekeepers sell their products online in the form of bulk packaging by creating and marketing their own brand, or they offer it to collectors (i.e. distributors). In a next step, the collected products (honey, pollen, royal jelly, wax) will

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be further processed to adjust the quality of goods (flavour, water content, ...). Table honey is sold in bigger cities situated around the particular farms.

3.2. Beeswax

Ethiopia: Not only the honey, but also the beeswax business has great potential in Ethiopia. Ethiopia is the third biggest beeswax producer in the world and number one in Africa with approximately 3,000 harvested tonnes per year, while the experts estimate the production potential at 50,000 t/year (Gupta et al., 2014; Negash, & Greiling, 2017). The current production rate per hive is 0.95 kg/year, with the major yield of beeswax out of the crude harvest of honey and other bee products from traditional (wax portion: 8.0-10.0%) rather than modern hives (0.5-2.0%) (Gemechis, 2014; SNV/Ethiopia, 2005; Wilson, 2006). Despite the greater amount of beeswax yield in traditional hives, it is from lower quality, due to the more difficult purification process (increased amount of foreign material). Ethiopian beeswax' quality from all over the country was evaluated and in general, the quality is at a similar level as the rest of the world, but adulteration of the product constantly increases. The reasons are not only processing companies with unsuitable facilities for beeswax processing, but also the adulteration with cheaper fats (e.g. animal fat, plant oil and paraffins) (Gemechis, 2014). Another quality-lowering factor are *tej*-breweries. Most of the harvested honey goes directly into *tej*-brewing and during the process, beeswax is separated as a byproduct (*sefef*) and will be sold to beeswax exporters and collectors, but the quality of this byproduct is low. In 2005, there were 16 registered companies who export beeswax, but only 4 of them are active, due to a lack of supply, not to a lack of international need (Gemechis, 2014). So far, there is no published data on the use of beeswax in Ethiopia, but it is believed, that a significant amount of beeswax is used to produce candles for orthodox churches (Gemechis, 2014). For further information on the beeswax' import and export quotes see: "Import/Export of honey bee products".

Indonesia: Prior to 1996 and 1997 official data on the import and export quotes were provided to FAO, respectively. Ever since, the trading quotes of beeswax were based on estimations (see: "Import/Export of honey bee products") (FAO, 2018). In general, there is no information on the beeswax business in Indonesia: what is the production, is there a general use for beeswax, is it even harvested, is there a

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market chain, etc. According to a local scientist (Universitas Padjadjaran, Indonesia) beeswax is widely used for the production of cosmetics. He further claims, that to purchase beeswax, a direct order has to be made to the particular beekeeper.

3.3. Propolis

Ethiopia: It is known, that propolis can be harvested from every hive type and 95% of Ethiopian beekeepers use traditional hives (Gidey, & Mekonen, 2010; Nuru, Hepburn, & Radloff, 2002; Taye, Desta, Girma, & Mekonen, 2016). While the yield of propolis is higher in traditional hives, the quality is lower due to a contamination of pure propolis with beeswax, hive debris or body parts of bees (Nuru et al., 2002). So far, there is no information on propolis in tropical Africa (e.g. best harvesting time, how much propolis can be expected per colony, impact of propolis production on other bee products, factors that affect the propolis production, official numbers, ...). Nuru et al. (2002) conducted a study, where propolis production was induced in traditional and in modern hive-systems. They exposed the hives to the external environmental conditions, by creating gaps within the hive. Bees show the behaviour of filling those openings and, as prior expected, the propolis yield was higher in manipulated hive-systems. They found not only a correlation between the data of local weather stations and the propolis production, but also a significantly higher amount of harvested propolis in traditional, compared to modern bee hives. The authors claim, that small, cost effective methods can help to increase the outcome significantly (Nuru et al., 2002).

Indonesia: Stingless bees of the genus *Trigona* are known to collect higher amounts of propolis, compared to *Apis* species, therefore, Indonesian beekeepers use mainly colonies of *Trigona* spp. for the propolis production ("meliponiculture"; see: "Non-*Apis* managed bees or bees used for bee products") (Agussalim, Umami, & Erwan, 2015). Unfortunately, there is no information on propolis business in Indonesia (e.g. best harvesting time, how much propolis can be expected per colony, impact of propolis production on other bee products, factors that affect the propolis production, official numbers, ...). In Indonesia, propolis is categorized as an herbal product and it is used for medical purposes (Hasan, Mangunwidjaja, Sunarti, Suparno, & Setiyono, 2013. The existing interest and the potential is reflected

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by studies, conducted to improve extraction methods of the product (Hasan et al., 2013; Wiwekiwati, & Walianto, 2017).

3.4. Import and export of honey bee products

3.4.1. Export of Honey

Ethiopia: The total volume of exported honey between the years of 2000 and 2013 increased constantly: 1 t in 2000, 19 t in 2004, 196 t in 2008 and 904 t in 2013 (FAO, 2018). With increasing honey export quantity, the export volume of Ethiopia reached more than 3.25 million USD (Figure 3) (FAO, 2018).

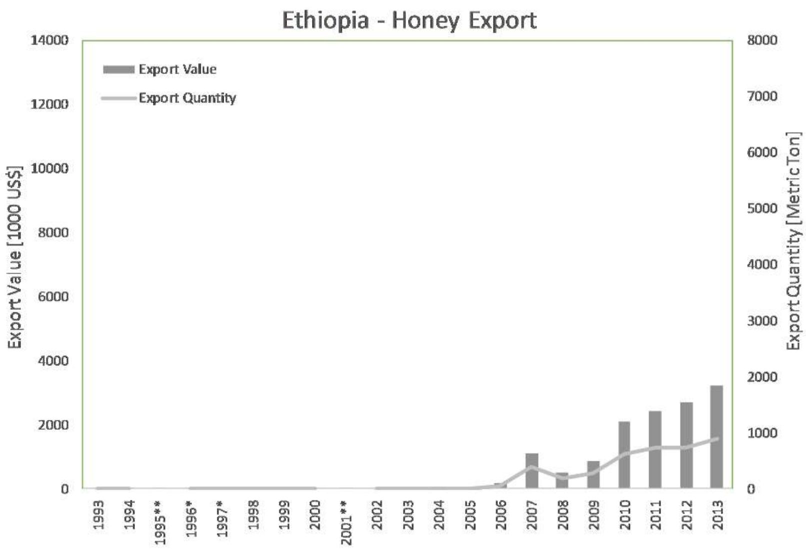

Figure 3: Export data of honey-Ethiopia (1993-2013); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO); **Data is not available (FAO, 2018).

Indonesia: On average, the total amount of exported honey between the years of 2000 and 2012 increased, but decreased again in 2013: 32 t in 2000, 1,270 t in 2004, 2,000 t in 2008, 765 t in 2012 and 207 t in 2013. There is a tremendous peak in 2009 with 7,355 t of exported honey. According to FAO, the data was officially provided, nevertheless there is a lack of information, how such a high increase can be

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explained (FAO, 2018). In 2013 the export volume of Indonesian honey reached 2.35 million USD (Figure 4) (FAO, 2018).

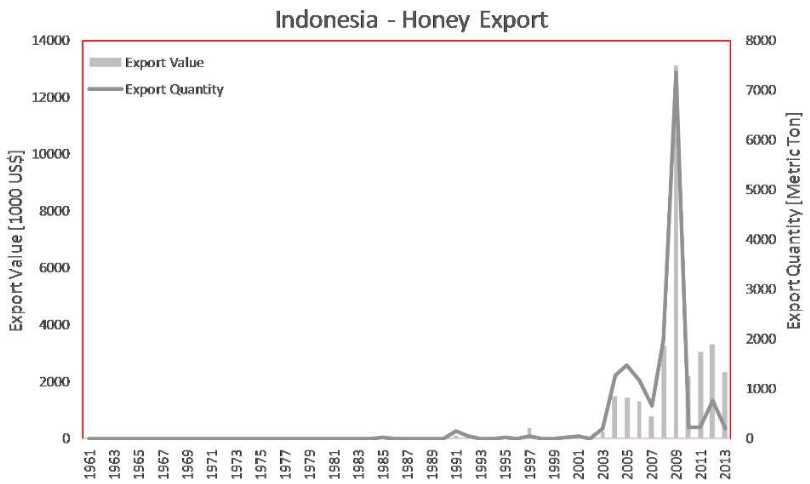

Figure 4: Export data of honey-Indonesia (1961-2013) (FAO, 2018).

3.4.2. Export of Beeswax

Ethiopia: From 1993 until 1998 the total volume of exported beeswax increased constantly (247 t in 1993 and 956 t in 1998), while the year after, until 2001, the export quota declined (267 t in 1999 and 53 t in 2001). Ever since, the total amount of exported beeswax is fluctuating: 233 t in 2002, 402 t in 2003, 321 t in 2006, 372 t in 2007, 365 t in 2012 and 341 t in 2013 (FAO, 2018). In 2013 the export volume of Ethiopian beeswax reached more than 2.69 million USD. Thus, according to FAO, the export value has almost doubled within 7 years (1.42 million USD in 2006), although the export quantity has not increased significantly (Figure 5) (FAO, 2018).

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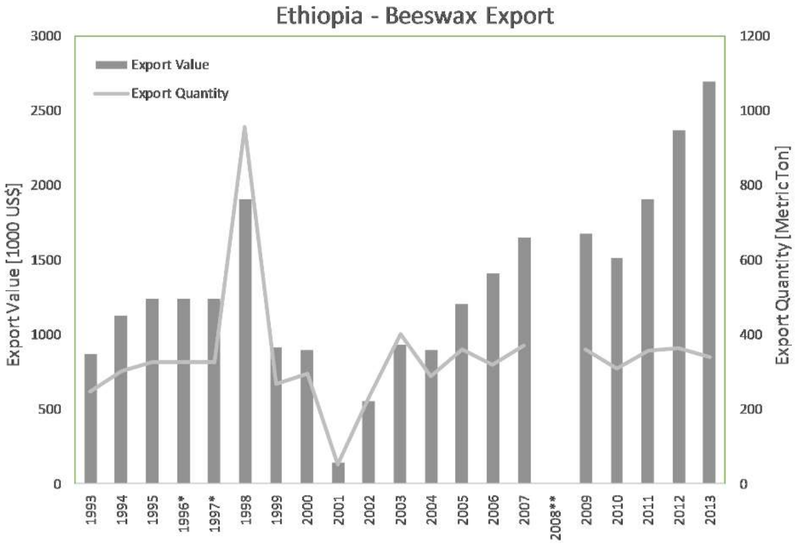

Figure 5: Export data of beeswax-Ethiopia (1993-2013); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO); **Data is not available (FAO, 2018).

Indonesia: While the beeswax export quota of 1997 until 2013 are only based on estimations of the FAO, official data is available from 1961 to 1996. There are three major peaks in the years 1965 with 156 t, 1979 with 647 t and 1990 with a total amount of 1009 t. In the remaining years, the total volume of exported beeswax fluctuated (FAO, 2018). The export volume of Indonesian beeswax reached 401,000 USD in 1979, while the FAO estimated no export of beeswax at all between the years 1997 and 2013 (0 USD) (Figure 6) (FAO, 2018).

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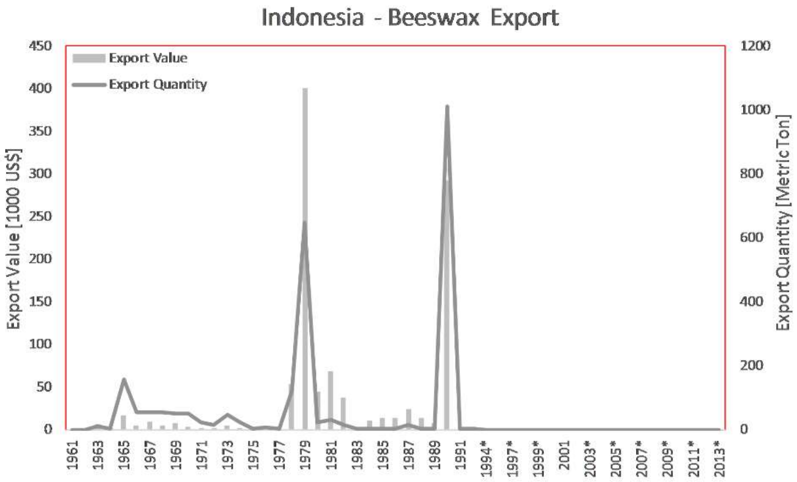

Figure 6: Export data of beeswax-Indonesia (1961-2013); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO, 2018).

3.4.3. Import of Honey

Ethiopia: There are several peaks regarding the import volume of honey: 10 t in 2006, 28 t in 2008, 49 t in 2013 (FAO, 2018). While the value of imported honey was about 23,000 USD in 2012, the import volume of honey reached more than 198,000 USD in 2013. Thus, according to FAO, the export value increased almost 8.5 times within a year, while the export quantity grew 12 times (Figure 7) (FAO, 2018).

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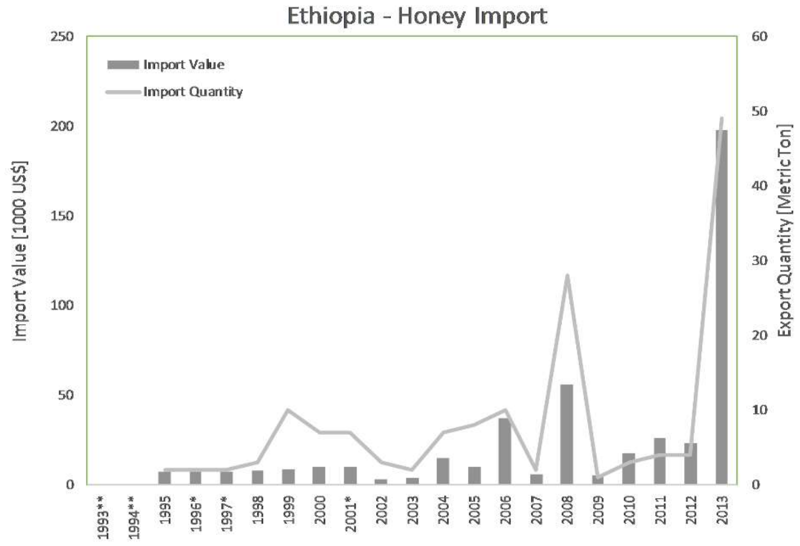

Figure 7: Import data of honey-Ethiopia (1993-2013); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO, 2018)

Indonesia: The data of the years 1961 to 2013 show fluctuations in the import quota of honey: 8 t in 1965, 124 t in 1970, 37 t in 1975, 97 t in 1980, 56 t in 1985, 217 t in 1990, 577 t in 1995, 747 t in 2000, 776 t in 2005, 15,595 t in 2010 and 2,177 t in 2013 (FAO, 2018). However, among the mentioned years, there is an observable trend of an increasing amount of imported honey. The import volume of honey reached over 8.33 million USD in 2013 (Figure 8) (FAO, 2018).

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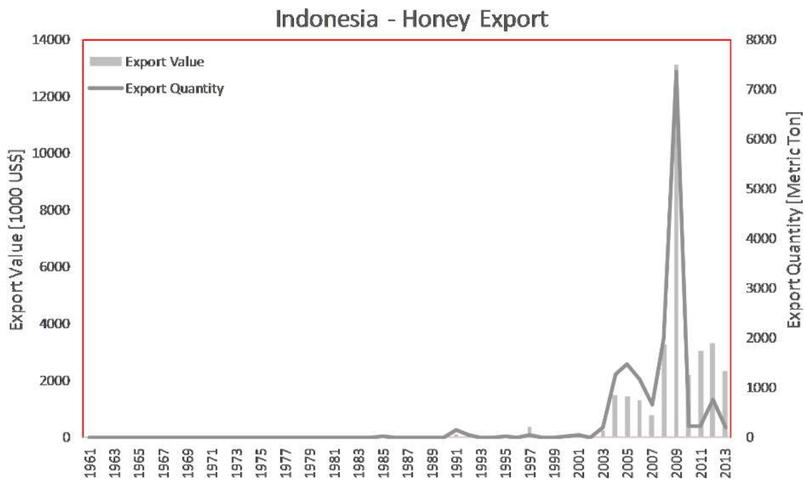

Figure 8: Import data of honey-Indonesia (1961-2013); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO, 2018).

3.4.4. Import of Beeswax

Ethiopia: Regarding the import quota of beeswax in Ethiopia compared to those of honey, almost half of the years were not available at all. Focusing on the remaining data set, the import quantity fluctuates: 1 t in 2002, 2 t in 2004, 652 t in 2006, 0 t in 2008, 2 t in 2010 and 1,847 t in 2013 (FAO, 2018). Similar observations were made for the import value data of beeswax: 2,000 USD in 2002, 4,000 USD in 2004, 416,000 USD in 2006, 0 USD in 2008, 6,000 USD in 2010 and 3.43 million USD in 2013 (Figure 9) (FAO, 2018).

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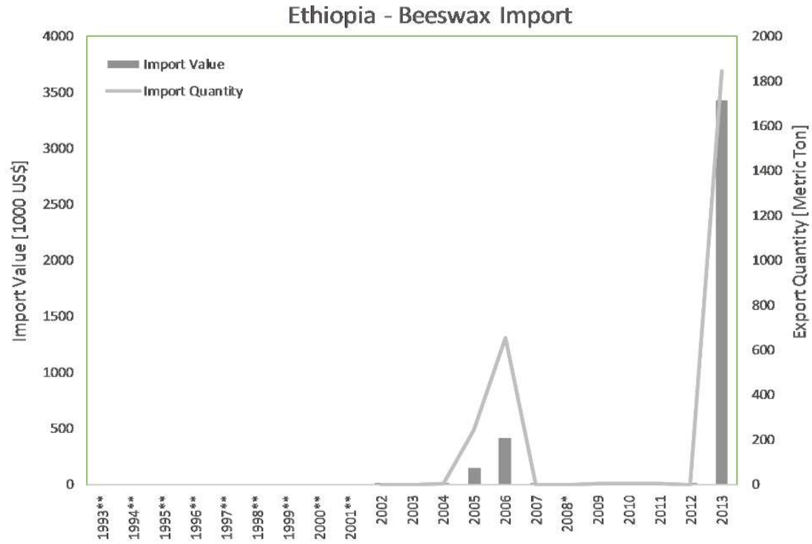

Figure 9: Import data of beeswax-Ethiopia (1993-2013); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO, 2018).

Indonesia: While the beeswax import quota of 1996 until 2013 is only based on estimations of the FAO, official data was provided from 1961 to 1995. Indonesians' import of beeswax fluctuated between 1961 and 1995, but in general, there is an observable trend of increasing demand on beeswax: 0 t in 1965, 7 t in 1970, 62 t in 1975, 27 t in 1980, 28 t in 1985, 107 t in 1990 and 82 t in 1995, with peaks in 1978 (102 t) and 1990 (107 t) (FAO, 2018). Regarding the import value of beeswax, there is a high variance within years: in the year 1975 Indonesia payed 29,000 USD for a total amount of 62 t of beeswax, while the import value reached 490,000 USD for 82 t in 1995 (Figure 10) (FAO, 2018).

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Figure 10: Import data of beeswax-Indonesia (1961-2013); *Data is based on estimations of the Food and Agriculture Organization of the United Nations (FAO, 2018).

3.5. Prizes

Ethiopia: In 2015, the average honey and colony prices were 131 Ethiopian Birr (ETB)/kg (6.34 USD) and 667 ETB/colony (32.28 USD), respectively (Yetimwork, Berhan, & Desalegn, 2015). According to a local scientist (Holeta Bee Research Center, Ethiopia), the prices increased (2018) to 260 ETB/kg (9.45 USD) for honey and to 1,200 to 1,500 ETB (43.64 USD to 54.55 USD) for new colonies. The price for 1 kg of purified beeswax was 250-300 ETB (25-30 USD) in 2014 (Gemechis, 2014).

Indonesia: There is no official data regarding prices of honey bee products, but according to a local scientist (Universitas Padjadjaran, Indonesia), the price for 1 kg table honey is at around 200,000 Rupiahs (14.20 USD) (2018). Indonesian beekeepers often catch feral honey bee colonies to house them in hives. This may be the reason, while there is a lack of data on colony prices.

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4. Bee Forage

4.1. Climate

Ethiopia: Depending on different classifications, there are three to five climate zones. The widely approved climate zones are: "Kolla" (hot zone; 1500-1800 m altitude) with an average temperature of 26 °C and an average rainfall of 300-700 mm, the flowering period is known to be short and therefore the honey bees are very productive as well as aggressive; "Woina-Dega" (cold-warm zone; 1,800-2,400 m altitude) with an average temperature of 22 °C and an average rainfall of 700-1,000 mm) and "Dega" (cold zone; 2,400-3,500 m altitude), where flowering occurs throughout the year, with an average temperature of 16 °C and an average rainfall of 1,000-1,200 mm (Bekele-Tesemma, & Tengnäs, 2007; Gupta et al., 2014; Gangwar, Gebremariam, Ebrahim, & Tajebe, 2010). The remaining climate zones are: "Bereha" (<1,500 m altitude) with an average temperature of >26 °C and an average rainfall of <300 mm and "Worech" (>3,500 m altitude) with an average temperature of 12 °C and an average rainfall of 1,200-1,500 mm). While the highlands of Ethiopia are widely populated, the colder lowland region is only sparsely populated by nomadic and semi-nomadic herdsmen (Le Houérou, & Corra, 1980). Winds, originating from over the Atlantic Ocean mark seasonal rainy periods resulting in most of its rainfall occurring in the highlands (mid-June to mid-September), as well as short periods of light rains. The second main rainy season occurs in April and May (Admasu, Kibebew, Ensermu, & Amssalu, 2014).

Indonesia: The prevailing tropical climate is characterized by its high temperatures throughout the year, the small day- to day changes (high standing sun), droughts, excessive rain and high humidity (Crane, 1990; Seidel, Fu, Randel, & Reichler, 2007). The average temperature is 26 °C and the average rainfall is at about 300 mm (CCKP, 2018). In addition, there are El Niño events in Indonesia, which lead to a later onset of the rainy season and drought events followed by unsecured food safety (Hamada et al., 2002; Hughen, Schrag, & Jacobsen, 1999; Naylor, Falcon, Rochberg, & Wada, 2001). By analysing the Indonesian rainfall data of the years 1961-1990, and by comparing the results with those before 1960, Hamada et al. (2002) concluded that there are four major climatic subregions in Indonesia. The main part of Indonesia is situated in the southern hemisphere and is characterized by an annual cycle with its

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rainfall maximum during September to February. The regions situated near the equator or in the northern hemisphere show a semi-annual cycle with its annual rainfall maximum in September-November in western parts of the Kalimantan central mountains and a different annual cycle with a maximum during March-August (relatively small rainfall). The other areas of Indonesia are known to not have clearly defined rainy and dry seasons (Hughen et al., 1999).

4.2. Number of melliferous plants and important literature

Ethiopia: The most important melliferous plants are well documented. Fichtl & Adi (1994) described over 500 species of melliferous plants in Ethiopia (400 herbs/shrubs and 100 trees). Another important book by Admasu et al. (2014) describes nearly 400 important species. Abera (2017) also describes important plants focussing on the south-eastern region of Ethiopia. Nevertheless, a floral calendar covering all regions in Ethiopia does not exist!

Indonesia: So far, there is no literature available on important melliferous plants in Indonesia, but there is a study by Jasmi (2017) which describes important melliferous plants for *A. cerana* in polyculture plantation.

4.3. Major honey flows (plants, seasons)

The classification of a plant species as "important" honey bee plant often depends on different opinions of surveyed beekeepers, due to different criteria selecting and recognizing them (nectar flow, pollen amount, flowering period, quality, frequency of honey bee visits, ...).

Ethiopia: There are several important melliferous plant species within following botanical families: Acanthaceae (*Asystasia gangetica, Hypoestes forskaolii, Justicia bizuneshiae*), Agavaceae (*Agave sisalana*), Aloaceae (*Aloe* spp.), Anacaridaceae (*Ozoroa insignis*), Araliaceae (*Schefflera abyssinica*), Arecaceae (*Borassus aethiopum, Phoenix reclinata*), Asteraceae (*Bidens macroptera, B. pachyloma, Carduus camaecephalus, Carthamus tinctorius, Crassocephalum macropappum, Guizotia abyssinica, G.*

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scabra, Helichrysum citrispinum, Mikaniopsis clematoides, Vernonia amygdalina), Boraginaceae (*Cordia africana*), Cactaceae (*Opuntia ficus-indica*), Campanulaceae (*Lobelia rhynchopetalum*), Combretaceae (*Combretum molle, Terminalia brownii*), Ericaceae (*Erica arborea, E. trimera*), Euphorbiaceae (*Croton macrostachyus, Euphorbium candelabrum*), Fabaceae (*Acacia* spp.*, Acacia albia, A. brevispica, A. pentagona, A. senegal, A. seyal, A. sieberiana, A. tortilis, Albizia* spp.*, Dichtrostachys cinera, Piliostigma thonningii, Trifolium* spp.), Hypericaceae (*Hypericum revolutum*), Lamiaceae (*Becium grandiflorum, Satureja punctata*), Leguminosae (*Cassia arereh*), Malvaceae (*Grewia mollis, G. villosa*), Moraceae (*Ficus sur*), Myrtaceae (*Eucalyptus globulus*), Oleaceae (*Olea Africana*), Poaceae (*Andropogon abyssinicus*), Rhamnaceae (*Berchemia discolor, Ziziphus pubescens*), Rosaceae (*Hagenia abyssinica*), Rubiaceae (*Coffea arabica*), Sapotaceae (*Aningeria adolfi-friederici, Mimusops laurifolia*) and Ulmaceae (*Celtis africana, C. toka*) (Admasu et al., 2014; El Mahi, & Magid, 2014; Gupta et al., 2014; Haftom, Zelealem, Girmay, & Awet, 2013). It has to be mentioned, that there may be more plant families relevant for honey bees.

The literature is not consistent when it comes to major honey harvesting seasons. While Gemechis (2016) claims, that there are two seasons of honey harvesting: October-November and April-June (before and after rainy season), Gidey et al. (2012) distinguish between honey harvesting periods in the lowlands and midlands (November-December) and in the highlands (April-June). In general it can be said, that the best time for honey harvesting depends on the particular regions, due to the various climate zones in Ethiopia ("mini" harvesting seasons): e.g. in south western Ethiopia there is a major harvesting season from April-June, and a minor one from November-January (Awraris et al. 2012).

Indonesia: In general, almost no literature exists on important melliferous plants in Indonesia. Furthermore, there is no information about important floral species for *Apis mellifera*. However, due to the similar morphology and nutritional ecology of *A. mellifera* and *A. cerana*, it can be assumed, that floral species, important for *A. cerana*, also act as potential melliferous plant species for *A. mellifera*: Acanthaceae (*Asystasia coromandeliana*), Anacardiaceae (*Mangifera indica, Mangifera* spp.), Arecaceae (*Areca catechu, Arenga pinnata, Caryota mitis, Cocos nucifera*), Asteraceae (*Bidens pilosa, Clibadium surinamensis, Eupatorium inulifolium, E. odoratum, Galinsoga parviflora, Tithonia diversifolia, Mikania micrantha, Spilanthes iabadicensis, S. paniculata*), Bombacaceae (*Durio zibethinus*), Brassicaceae

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(*Brassica rapa, Brassica* sp.*, Rorippa indica*), Caricaceae (*Carica papaya*), Cucurbitaceae (*Momordica charantia, Cucumis sativus, Sechium edule*), Cyperaceae (*Cyperus kyllingia*), Euphorbiaceae (*Aleurites moluccana, Homalanthus pupulneus*), Fabaceae (*Acacia auriculiformis, A. mangium, A. crassicarpa, Leucaena glauca, Mimosa invisa, M. pigra, M. pudica, Pithecellobium lobatum, Parkia speciosa*), Graminae (*Oryza sativa, Zea mays*), Lauraceae (*Cinnamomum burmanii, Persea americana*), Loranthaceae (*Loranthus europaeus*), Lythraceae (*Cuphea* spp.), Meliaceae (*Melia azedarach, Toona sureni*), Myrtaceae (*Psidium guajava*) and Verbenaceae (*Tectona grandis*) (Jasmi, 2017; Pribadi, 2016).

There is no published data on major harvesting seasons in Indonesia, but according to an informal survey, conducted by the Universitas Padjadjaran (2018), the most important harvesting season in West Java takes place from January to May, while it is also common to harvest minor amounts of honey during the whole year, if there is personal need.

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5. Beekeeping

5.1. Discussion about the advantages and disadvantages of beekeeping with A. mellifera and A. cerana in Indonesia

There is a lack of data about beekeeping with *A. mellifera* in Indonesia, although it has been reported, that beekeeping with the native Asian honey bee *A. cerana* decreased. There is no uniform opinion regarding the introduction date of *A. mellifera* in Indonesia. According to the Indonesian Apiary Association, Indonesian boy scouts either introduced *A. mellifera* in 1972 or 1967, while Hadisoesilo et al. (2002) consider at least one unsuccessful (1877 by Mr. Rijkens from Praque) and one successful introduction in 1972. Afterwards, the European honey bee spread all over Java, and until today the majority of *A. mellifera* apiaries are found on Java (Kahono, Chantawannakul, & Engel, 2018). The golden years of *A. mellifera* beekeeping were in the early 2000s, followed by a decrease of colonies due to the spread of *V. destructor*, weather changes and food source deficits (API Indonesia, 2018). A survey revealed that in Indonesia the remaining percentage of managed *A. cerana* lays between 45-60% (compared to introduced *A. mellifera*) (Theisen-Jones, & Bienefeld, 2016). Beekeepers in Asia believe in the advantages of *A. mellifera* and therefore there is an increasing trend to give up beekeeping with *A. cerana*. This practice leads to a reduction of honey bee species and in further consequence it is possible that native species are almost completely replaced by the introduced *A. mellifera* (e.g. in Bhutan beekeeping with *A. cerana* decreased by 95%) (Theisen-Jones, & Bienefeld, 2016).

Nevertheless, there are several advantages of the Western honey bee compared to *A. cerana*. The startup costs for hives that are suitable for beekeeping with *A. mellifera* are low, but the costs for building traditional hives (for *A. cerana* and *A. mellifera*) oneself, or by buying them are still lower. The colony size of *A. mellifera* ranges from 30,000-50,000 (in contrast, the colony size of *A. cerana* ranges from 2,000-20,000), they have higher productivity and therefore the harvesting of honey bee products is more profitable. *A. cerana* has a high tendency to abscond (triggered by tropical climate, pressure of pathogens/pests/predators, and insufficient forage-opportunities) (Koetz, 2013). *A. cerana* is also known to be more sensitive to Thai Sac Brood Virus (Theisen-Jones, & Bienefeld, 2016). Due to the higher aggressiveness of *A. mellifera*, they are often successful in robbing honey from other honey bee species

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and subspecies, which leads to damage of these colonies (Oldroyd, & Nanork, 2009; Theisen-Jones, & Bienefeld, 2016). Studies revealed, that *A. mellifera* and *A. cerana* drones are attracted by similar pheromones secreted by the particular queen. Though, the mating between species is not possible due to incompatible organs, *A. cerana* colony size is significantly lower and therefore they are less able to complement high drone losses (Moritz, Härtel, & Neumann, 2005; Ruttner, & Maul, 1983)

The question is, regarding to the short-term gain from its products in comparison to the long-term costs of replacing *A. cerana* colonies, if *A. mellifera* is the better alternative for future beekeeping all over the world? Oldroyd and Nanork (2009) do not believe in a severe impact of *A. mellifera* on *A. cerana* colonies, because feral *A. mellifera* colonies in Asia are so far unknown. This fact may have different reasons: the climate of the tropics brings only minor variation in day length and thus, European honey bees cannot further adapt on these conditions (e.g. brood production). In comparison, feral *A. mellifera* may be only a question of time, if there are efforts to introduce African *A. mellifera* that is adapted to tropical climate (Ruttner, & Maul, 1983). If infestation of *Varroa* spp., or *Tropilaelaps* spp. stays untreated, the survival chance of *A. mellifera* colonies is further impacted (Ellis, & Munn, 2005; Theisen-Jones, & Bienefeld, 2016). *A. cerana* is not as productive as *A. mellifera*, but they do have gentle temperament, and are known to be less susceptible against parasitic mites. The higher resistance is based on increased hygiene standard (bees clean themselves and others at higher frequency, infected brood is removed before sealing the brood cells) and therefore the treatment with acaricides against *Varroa* infestation is not necessary (Boecking, & Spivak, 1999). *A. cerana* has further advantages like they do not need any supplementation if forage is available year round (e.g. coconut plantation), they need less foraging areas, and if well-acclimated, they react less sensitive to changes in climate conditions and are able to forage under more extreme conditions (Oldroyd, & Nanork, 2009; Theisen-Jones, & Bienefeld, 2016). Furthermore, we do not know if beekeeping with *A. mellifera* is profitable in every region of Indonesia due to the particular flora and climate. It has to be mentioned, that before the selection of desired traits, *A. mellifera* produced, similar to *A. cerana*, only 2-5 kg honey per colony (Theisen-Jones, & Bienefeld, 2016). Hence, it is very likely that selective breeding of *A. cerana* will also result in higher honey yield per colony. This may be a possible compromise that favours beekeeping with, and therefore the preservation, of *A. cerana* (Theisen-Jones, & Bienefeld, 2016). Several projects exist, aiming to

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encourage the people of Indonesia to harvest honey not from *A. cerana*, but from *A. dorsata* nests, rather than changing to beekeeping with *A. mellifera*. Provided, honey hunting is practiced in a sustainable and hygienic way: only harvest the honeycombs instead of destroying the whole nest, wearing protective clothes, or filtrating the honey through simple closed mashed nets (Oldroyd, & Nanork, 2009).

In summary, knowledge about beekeeping with the indigenous honey bee species *A. cerana* already exists, while beekeeping with introduced *A. mellifera* has to be developed from scratch. Native bee species are known to be more resistant against pests and pathogens, while beekeeping with the European *A. mellifera* implicates regular hive-inspection and care and therefore is more time-consuming (Chantawannakul, Petersen, & Wongsiri, 2004; Theisen-Jones, & Bienefeld, 2016). Nevertheless, the higher amount of invested time is relativized with the higher productivity of *A. mellifera* that leads to a significantly higher income of beekeepers. In conclusion, it has to be mentioned, that "poor people should not be expected to bear the burden of conservation, which is the responsibility of us all" (Oldroyd, & Nanork, 2009).

5.2. Other types of gaining bee products, including honey hunting and meliponiculture

Besides the worldwide known beekeeping, there are also other ways of gaining bee products in Ethiopia and Indonesia.

Ethiopia: The country provides a rich flora and suitable ecological conditions for not only hived, but also for feral *A. mellifera* colonies. Thus, "honey hunting" from feral *A. mellifera* colonies is a common practice in Ethiopia. Honey hunters trace and rob wild honey bee colonies to make profit out of their products (Fichtl, & Adi, 1994; Gemechis, 2016).

Indonesia: Almost every species of honey bees and stingless bees is used for "honey hunting", but in Indonesia the practice is mainly focussed on *A. dorsata* colonies (Kahono et al., 2018). *A. dorsata* are known to build single comb nests and so far, it was not possible to properly manage them. The honey yield of one *A. dorsata* colony is expected between 5-15 kg, while a whole "honey tree" (*Sompuat*),

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housing numerous colonies, provides 50-300 kg of honey (Lahjie, & Seibert, 1990). In some regions of Indonesia, there are efforts to manage *A. dorsata* colonies by, for example, attracting them with a hollowed pole (*tikung*) at which the migrating bee colonies build their nests. People harvest the bee products (mainly wax and honey) by cutting the whole nest off the *tikung* (Crane, Luyen, Mulder, & Ta, 1993). To increase the attractiveness for feral honey bee colonies, some natural forests are managed and honey trees are preserved (De Jong, 2002). Honey from *A. dorsata* is an important product in parts of western Kalimantan (Lubis, Handayani, & Muazir, 2009). Another way to gain bee products is the meliponiculture with stingless bees from the genus *Trigona*. Due to their low honey production, they are mainly used to gain propolis and wax. *Trigona* are easy to manage, do not require special beekeeping skills, and they can be housed in hollow logs, mud pots, bamboo pits, coconut shells, wooden boxes and pottery vessels (Gupta et al., 2014; Lubis et al., 2009).

5.3. Hive types

A hive type is an enclosured structure in which honey bees are housed by apiarists. Every hive type has its own characteristics. On the one hand, traditional hives do not need special skills to build them, have low starting costs and are often made of simple, locally available materials. On the other hand, they have also disadvantages: the bee management is difficult (inspecting, harvesting, disease prophylaxis, adding supplementary food, …), hives are more susceptible against external environmental stress (climate conditions, pests and predators, …), the yield of honey bee products is often lower compared to modern types, and some hive types are even destructive to the surrounding forests (e.g. bark hives, log hives, …) (Gupta et al., 2014).

Ethiopia: About 95% of Ethiopian beekeepers use traditional hive-systems made of cheap, locally available materials (clay, straw, bamboo, bark, logs, …). The remaining percentage of beekeepers use transitional (promoted since 1978) and modern hives (Gidey, & Mekonen, 2010; Taye, Desta, Girma, & Mekonen, 2015). A survey by Tesfaye & Tesfaye (2007) revealed reasons, why most beekeepers do not possess modern hives-systems: the starting costs are high, lack of managing skills, unavailability of modern bee hives in the particular area, or a combination of the mentioned issues. The number of

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movable frame hive-systems was estimated to be 100,843 (2009) (Gemechis, 2016). Modern beekeeping is mostly practiced in the southwestern and central highlands and commonly used hive types are the Zander hive, Langstroth hive, and Dadant hive, respectively (Gupta et al., 2014). Popular transitional beehives are either the Kenyan top bar hive, or the locally made "Chefeka" hive (Gemechis, 2016).

Indonesia: There is almost no published data available on hive types in Indonesia, but according to a local scientist (Universitas Padjadjaran, Indonesia), most beekeepers construct their own hives. Traditional hives consist, similarly to Ethiopia, of various, simple and locally available materials. For example, stingless bees (*Trigona*; see: Other types of gaining bee products) may be housed in hollowed logs, mud pots, bamboo pits, coconut shells, wooden boxes, or pottery vessels (Gupta et al., 2014). Modern models of housing Meliponini are wooden, vertical, terraced hives (Kahono et al., 2018). Further examples for commonly used traditional hives for *A. cerana* are wall hives (Theisen-Jones, & Bienefeld, 2016), or the "glodok" that consists of a horizontal bamboo hive. Honey is harvested by cutting the glodok into two halves (Crane, 1990). However, homemade hives that look similar to modern hive-systems are also defined as traditional. The habitus of the hives differ regionally by dimension, used materials, entrance hole size, and the number of frames inside. For example, while movable frame-hives with different sizes are used by beekeepers in the highlands of Bogor and Sukabumi, hives with double entrances are used in Halmahera, Ambon and Mollucas. Despite there is no officially standardized size for bee hives or research on what hive types best fit the two different *Apis* species in Indonesia, the national State Forest Own Company (PERHUTANI) provides their own hive type for *Apis cerana* colonies and a large number of beekeepers try to copy the PERHUTANI bee hive-size for their own constructions (Perhutani, 1992).

5.4. Hive management

Hive management, performed by beekeepers, is defined as active manipulation of a honey bee colony, to augment honey bee production and to ensure the survival of the colony. Common hive (see: hive types) management practices include: disease prophylaxis and treatment of infested colonies, swarm prevention/control, supplementary feeding, removing queen cells for swarm prevention, etc. (Carrol,

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2006). Due to fragmentary published data, it has to be mentioned, that none of the provided information is representative for the whole country, but for regions only.

Ethiopia: A survey on beekeeping techniques in the Jijiga Zone revealed, that 13%, 14% and 23% of respondents inspect their hives internally every week, every fifteenth day, or once in a month, respectively. A greater amount (15% weekly, 23% every fifteenth day and 28% once in a month) inspect their hives externally (Fikru, 2015). There is no further description on the detailed process of "internal" and "external inspection" (manipulating the hive, or just observation of the colonies).

Indonesia: There is no official information available on hive inspection, but a local scientist (Universitas Padjadjaran, Indonesia) claims, that the number of hive inspections vary between once in a week and once in a month, depending on the forage availability, the urge of harvest, and on the beekeeping level of the beekeeper (main income, or additional income). Further, beekeepers who start the inspection, clean the area surrounding the hive, followed by opening the hive and assessing the status of the colony (honey bee health status, queen presence, ...). If necessary, experienced, and high skilled beekeepers even expand their hives.

5.4.1. Feeding

Especially, during periods of forage unavailability, supplementary feeding is essential to avoid absconding and to ensure the survival of the colony. The suitable supplement must be chosen depending on the type of food shortage (pollen, nectar or water) (Crane, 1990).

Ethiopia: A study in 2006 revealed, that the best time to offer additional food (*A. mellifera bandasii*) is the occurrence of 4-5 sealed brood combs and freshly secreted, white beeswax on top of the frames at the base of the hive (Kibebew, & Dereje, 2006). An assessment on beekeeping practices in the Jigjiga Region (2015) revealed that interviewed beekeepers are aware of the importance of water availability for their honey bees. They provide water in form of waterholes, ponds, or rivers/streams near the apiaries (Fikru, 2015). To provide carbohydrates, Ethiopian beekeepers feed sugar-, or honey solution, or

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flour of roasted grain (barley and maize). Due to various climate conditions, there are regional differences on the time of additional feeding. Beekeepers of the Tigray region offer supplementary food mostly in the months February to May. According to Fichtl and Adi (1990), there are some regions, where it is common to offer "freshly slaughtered meat scraps" as a supplementary protein source. However, this method seems to be questionable regarding the possible human pathogens that may be enriched in the bee products. More common pollen substitutes are chickpeas and peas (Fichtl, & Adi, 1994; Solomon, 2009). In a study by Zaghlou et al. (2017) three different supplementary diets were compared (soy bean, chickpeas and yellow corn) resulting in an increase of honey yield, laid eggs/day and area of brood, while a supplementary diet on chickpeas led to the lowest increase.

Indonesia: Feeding of honey bee colonies is not common in every part of the country. Flowering occurs throughout the year, and therefore it is often believed, that honey bees have enough forage (plants in flower may produce pollen but not nectar and vice versa) (Crane, 1990). There is no published data available on supplementary feeding in Indonesia, but a local scientist (Universitas Padjadjaran, Indonesia) claims, that additional nourishment is practised among beekeepers during the dry season. The most common supplementary carbohydrate source is sugar solution due to its easy availability and affordability. Beekeepers place the supplement inside the hive (small branch is placed inside the solution to provide protection). Widowati et al. (2013) compared local pollen substitutes with different composition. They found, that a mixture of soy flour, skimmed milk, yeast, honey and sugar syrup was preferred by *A. cerana* colonies and its consumption led to the highest productivity. The study showed, that locally available ingredients can be used to produce a high quality protein source for honey bees.

5.4.2. Swarm prevention

Swarming may occur as either reproductive swarming, where the colony divides itself or as absconding, where the honey bee colony leaves its nest site if an environmental stress becomes high. While reproductive swarming is triggered by the size of the colony (Crane, 1999), absconding is related to various factors like drought, overgrazing, deforestation, honey bee diseases and pests, shortage of

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water, poor hive management, a lack of protection against bad weather, or a shortage of melliferous plants (pollen, nectar), etc. (Haftom et al., 2013; Tesfaye, & Tesfaye, 2007).

Ethiopia: To prevent reproductive swarming, the beekeepers cut parts of the brood combs, remove queen cells, enlargen the volume of the hives, or provide instantly available new nesting sites in form of empty hives (Fikru, 2015; Solomon, 2009).

Indonesia: There is no information available on management practices to prevent swarming, but in the regions of Pager Ageung, Tasikmalaya, Bawean Island and Gresik, beekeepers do not avoid swarming, instead, they let their colonies abscond during the drought season and recapture feral colonies during the flowering season (Kahono et al., 2018). According to a local scientist (Universitas Padjadjaran, Indonesia), beekeepers eliminate drone and queen cells, place "bee traps" nearby their hives, or produce offshoot colonies to prevent swarming events.

5.4.3. Bee health management:

Ethiopia: According to a local scientist (Holeta Bee Research Center, Ethiopia), beekeepers, recognizing health issues within their bee colonies, have to report to the district livestock offices (chapter: "Dealing with honey bee health issues"). If a beekeeper is not able to recognize the disease, the district livestock offices will help with the identification and offer advice on treatment methods.

Indonesia: According to a local scientist (Universitas Padjadjaran, Indonesia), the beekeepers of disease affected apiaries do not pass on the information to a governmental office, nor to a beekeeping association, but informally exchange their observations with other beekeepers who already gathered experience with the particular honey bee health issue (see: "Dealing with honey bee health issues").

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5.5. Biggest problems in beekeeping

Ethiopia: Unsteady yield leads to unsteady income. Due to several factors like poor management of honey bee colonies and traditional production systems, the productivity and quality of bee products in Ethiopia is considered low (Beyene, Abi, Chalchissa, WoldaTsadik, 2016). The main problems are limited availability of bee forage (poisonous plants, seasonal availability, deforestation), water shortage (drought), the swarming behaviour and absconding of honey bees, colony mortality, reduction of honey bee colonies, pests and predators (ants, honey badger, wax moths, *varroa* mites...), absence or poor quality of beekeeping equipment/materials, indiscriminate use of pesticides and herbicides, the lack of storage and marketing facilities and, in general, a lack of know how (Gidey, Bethelhem, Dawit, & Alem, 2012; Gidey, & Mekonen, 2010; Legesse, 2014; Sisay, Gebremedhin, & Awoke, 2015; Yetimwork, et al. 2015). A study by Tesfaey & Tesfaye (2007) revealed that 98% of respondents, living in the mid rift valley region, never participated on any training in terms of beekeeping. Furthermore, beekeeping seems to be uninteresting for some of the surveyed people due to above-mentioned constraints and due to a combination of those factors. Internal hive inspection seems to be totally unknown among many beekeepers, although they were visiting their hives for external inspection every day. Most beekeepers do not know about the impact of supplementary food after honey harvesting season, nor about the importance of controlling swarming events (see: "Hive Management"-swarming prevention) of honey bees (Solomon, 2009). Conductors involved in the project ASPIRE, that assessed problems in business development, found out, that smallholder beekeepers especially suffer under a lack of credit/finance, a loose linkage of producer-processor market, low quality in honey bee products, supply chain problems for inputs, international market linkages and the capacity border of sector associations (Negash, & Greiling, 2017). Pots, skins and fertilizer bags are often used for honey packaging, but they are not suitable for it, which results in a decrease of honey quality. The transport from rural to urban regions often takes place with the use of labour animals, due to a lack of infrastructure (SNV/Ethiopia, 2005). Approximately 95% of bee hives in Ethiopia are traditional bee hives, that are difficult to manage and of low productivity (Negash, & Greiling, 2017). Traditional hives cannot be managed probably (no moveable frames) and this results in the damage of honey bee colonies during harvesting which causes severe population reduction. Traditional beekeeping with traditional hives (e.g. log hives) often contains the

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involvement of climbing high trees. Due to Ethiopian culture, climbing trees and therefore practicing forest beekeeping is not allowed for females (Awraris et al., 2012).

Indonesia: The poor quality of honey bee products is the major problem in Indonesia (>25% moisture, poor hygiene, diluting of honey with sugar syrup) (Amir, & Pengembangan, 2002; Crane, 1990). In addition to a lack of know how on proper bee keeping, the honey bee product yield is low (Amir, & Pengembangan, 2002). Most of the Indonesian beekeepers use *A. cerana* for beekeeping, but this honey bee species is known to be less productive than *A. mellifera* and to show increased absconding behaviour (Oldroyd, & Nanork, 2009). Unfortunately, there is not as much information on beekeeping in Indonesia compared to Ethiopia, but it is considered, that some problems are very similar in both countries (absconding of honey bees, lack of knowledge about beekeeping practices, bee forage problems, lack of storage facilities, lack of infrastructure, lack of market facilities, and the use of pesticides) (Amir, & Pengembangan, 2002; Akratanakul, 1987; Crane, 1990; Peluso, 1992).

5.6. Status of migratory beekeeping

Ethiopia: There is almost no information available on migratory beekeeping in Ethiopia, but it is considered as a rare practice (Kibebew, in press.). It is known, that in a region called Gijjam, simple migratory beekeeping is practiced. It is done for additional income, instead of increasing pollination. Farmers close the traditional baskets with fresh cow dung and carry the hives on the shoulders to the selected fields (Fichtl, & Adi, 1994).

Indonesia: There is a lack of nationwide data on migratory beekeeping in Indonesia, but in Java, migratory beekeeping is practiced with *A. mellifera* colonies, locally familiar as "mobile" beekeeping. Local habitants, stakeholders, landowners and official government representatives are owners of gardens, including their potential forage plants for honey bees. They often do not know about the benefits, and the role of the honey bee as a pollinator and therefore, the rejection of honey bees by the

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population is great. In addition to missing regulations on bee hive placement and extensive monocultures, mobile beekeeping evolved and today is still a common practice in Java (Kahono et al. 2018). One example of a migration schedule of *A. mellifera* in Java was given by a local scientist (Universitas Padjadjaran, Indonesia) who cooperated with the national State Forest Own Company (PERHUTANI): in May, to July *A. mellifera* hives are placed in Central Java to forage on mostly kapok and randu, in August they are moved to Mt. Arca and Sukabumi to forage on calliandra, from September to October, beekeepers place their hives in Subang (rambutan forage), from November to April *A. mellifera* colonies are found in Cimangkok and Sukabumi to collect pollen of maize-plants.

5.7. Beekeeping associations

Ethiopia: About 10 years ago, SOS-Sahal was an important beekeeping project, providing beekeeping training (Gupta et al., 2014). The Ethiopian Apiculture Board (EAB) was established in 2009 and it aims to improve the honey production and productivity by ensuring quality production and safety issues. The Ministry of Agriculture is the patron of EAB. There are also the Ethiopian Society of Apiculture Science (ESAS; former Ethiopian Beekeepers Association) and the Ethiopian Honey and Beeswax Producers and Exporters Association (EHBPEA) (Negash, & Greiling, 2017). Projects like ASPIRE (Apiculture Scaling up Program for Income and Rural Employment) and government initiatives like ATA (Agricultural Transformation Agency) aiming also the supporting of beekeeping interests. In addition, a lot of organizations (GOs and NGOs) and initiatives offer training on beekeeping every year. Despite all the efforts, the apisector still develops very slowly (ASPIRE, 2018; ATA, 2018).

Indonesia: PUSBAHNAS (National Apiary Center) (PUSBAHNAS, 2018), API Indonesia (Indonesian Apicultural Association, 2018) this organization is sub of Asian Apicultural Association (AAA). AAA aims to "promote the exchange of scientific and general information relating to honeybee sciences and apiculture in Asia, and to encourage international co-operation in the study of problems of common interest" (AAA, 2018).

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6. Bee pathology

There are numerous pests, pathogens and predators which affect the health of honey bee colonies and further may cause economic loss. Therefore, it is important for beekeepers to know about existing threats and how to treat a possible infestation. In the following chapter, an assessment on honey bee health status, major pests and predators and local treatment methods was conducted. Summarized, there is a wide variety of pests a pathogens that affect honey bee health in Ethiopia and Indonesia. They range from viruses, protozoa, bacteria, fungi and insecta to mites and mammals. In general, the research indicated that beekeepers in both countries underestimate the risk of honey bee diseases and that treatment methods, that are commonly used in the western world are unknown in Ethiopia and Indonesia. It is necessary to work on education and dissemination to enlarge the understanding of honey bee biology and further increase the income.

6.1. Honey bee health

Table 3 represents a list of the most important pests and pathogens, affecting the health of honey bees in Ethiopia and Indonesia.

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Table 3: Pests and pathogens present in Ethiopian and Indonesian honey bee colonies. N/A (not available) stands for a lack of data, +/- stands for a present/absent pest/pathogen.

			Ethiopia	Indonesia
Viruses		DWV, IAPV, SBV, VDV-1	**N/A**	**N/A**
Protozoa	**Amoeba**	*M. mellificae*	+ [1]	**N/A**
Bacteria	**Foulbrood**	AFB	**N/A**	**N/A**
		EFB	**N/A**	**N/A**
Fungi	**Nosema**	*N. Apis*	+ [1] [2] [3] [4]	**N/A**
		N. ceranae	**N/A**	+ [2] [12]
	Chalkbrood	*A. Apis*	+ [1] [4]	**N/A**
Insecta	**Lepidoptera**	G. mellonella	+ [4] [5]	**N/A**
		A. grisella	+ [4] [5]	**N/A**
	Diptera	*B. coeca*	+ [4] [6]	**N/A**
	Coleoptera	*A. tumida*	+ [1] [4]	**N/A**
		Cetoniinae	+ [1] [4]	**N/A**
	Hymenoptera	Ants	+ [4] [7] [8]	+ [13]
Mites	**Parasitic mites**	*Varroa destructor*	+ [4] [9]	+ [14] [15] [16] [17] [18]
		V. jacobsoni	**N/A**	+ [14] [15] [16] [17] [18]
		Tropilaelaps spp.	**N/A**	+ [14] [15] [16] [17] [18]
	Tracheal mites	*A. woodi*	+ [4]	- [2]
Birds		Meropidae	+ [4] [8] [10]	**N/A**
Mammals		*Mellivora capensis*	+ [10] [11]	- [19]

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6.1.1. Viruses

Pirk and colleagues reviewed, that in the year 2015, at least 23 "honey bee viruses" were known globally (Pirk, Strauss, Yusuf, Démares, & Human, 2015). Important viruses reported in Asia and/or Africa are: Black Queen Cell Virus (BQCV), Sacbrood Virus (SBV), Israeli Acute Paralysis Virus (IAPV), Deformed Wing Virus (DWV), *Varroa destructor* Virus 1 (VDV-1) and Acute/Chronic Bee Paralysis Virus (ABPV and CBPV) (Morse, & Nowogrodzki, 1990; Pirk et al., 2015). Despite there may be similar symptoms such as wing deformation in DWV and VDV-1, the pathogenesis of mentioned viruses differ from each other. The symptoms range from loss of hair to even paralysis of bees (Mumoki, Fombong, Muli, Muigai, & Masiga, 2014; Pirk et al., 2015).

Ethiopia: So far, 9 different viruses affecting honey bee health were detected in Africa (Pirk et al., 2015). However, there is a lack of information regarding the honey bee virus status in Ethiopia.

Indonesia: According to Ellis and Munn, 6 different honey bee viruses were observed in Asia (Ellis, & Munn, 2005). Unfortunately, there is a lack of data on the virus status in Indonesia.

6.1.2. Foulbrood

The European (EFB) and American (AFB) foulbrood disease are caused by *Paenibacillus larvae* and *Melissoccocus plutonius* two widespread bacteria, respectively. While both pests are highly contagious diseases, AFB is known to be more acute and wider distributed (Mumoki et al., 2014).

Ethiopia: The status of foulbrood is unknown, but AFB and EFB are present in the neighbouring country Eritrea, while it is absent, or suspected to be absent in Kenya, Sudan, South-Sudan and Uganda (Ellis, & Munn, 2005).

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Indonesia: There is also a lack of knowledge regarding the foulbrood status in Indonesia!

6.1.3. *Nosema*

Nosema spp. (Dissociodihaplophasida; Nosematidae) is known to be a parasitic microsporidian and the causative agent of nosemosis (Morse, & Nowogrodzki, 1990). The infectious non-germinated spore of the pathogen is transmitted through the oral-faecal route of adult bees, or through mating. The most popular treatment in many countries is "fumagillin". While *N. apis* has a relatively wide distribution with a prevalence for colder climate, *N. ceranae* is mostly prevalent in the tropics and sub-tropics (Mumoki et al., 2014). Nothing is known about the presence of *N. ceranae* in Ethiopia.

Ethiopia: *Nosema* existence in Ethiopia has been reported for the first time in 1989 by the Holeta Bee Research Centre (HBRC), Holeta. In a study by Desalegn and Amssalu (2015) over 200 honey bee colonies from all over Ethiopia were analysed and 37% were tested positive for *N. Apis*. They further investigated the severity of an infestation and concluded, that this disease is considered to be a negligible risk for Ethiopian honey bee colonies (Desalegn, 2015; Ellis, & Munn, 2005; Mumoki et al., 2014).

Indonesia: *N. ceranae* is present but there is a lack of data regarding the dangerousness and treating methods of the pathogen, indicating that *Nosema* to our current knowledge represents a negligible risk in Indonesia (Botías et al., 2012; Ellis, & Munn, 2005; Wilson, & Nunamaker, 1983).

6.1.4. Chalkbrood

Ascosphaera apis (Onygenales; Ascosphaeraceae) is known to be a heterothallic fungi and the causative agent of the chalkbrood disease. Germinated spores in the intestinal tract of the brood lead to a mummification of the host. If untreated, the pathogen causes death of infected brood due to enzymatic toxicological and mechanical damage (Morse, & Nowogrodzki, 1990; Mumoki et al., 2014).

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Ethiopia: *A. apis* is present and its geographical distribution and infestation rate is unequal within Ethiopia. Desalegn (2006) surveyed apiaries around Holetta and found that chalkbrood occurred in 17.4% of inspected honey bee colonies. Unfortunately, no further information is available on chalkbrood disease in Ethiopia (e.g. treatment options, distribution pattern, severity, ...) (Haylegebriel, 2014; Pirk et al., 2015).

Indonesia: No information is available on chalkbrood disease in Indonesia.

6.1.5. *G. mellonella*

Galleria mellonella as well as *Achroia grisella* (Lepidoptera; Pyralidae) are also known as wax moths. Wax moth larvae consume remaining combs and stores. They are also known to not only infest living honey bee colonies, but also the wax comb storages of the beekeeper (i.e. field and store pest). They damage the honey bee colony by tunnelling through the hive with its honey combs, brood and even through the wood. By reducing the mass of the combs, an infestation with wax moths can lead to bald brood and galleriasis. The moths can also function as vector for pathogens. In general, it can be considered, that an infestation with wax moths get severe, if the honey bee colony was already weakened in the first place (Morse, & Nowogrodzki, 1990; Pirk et al., 2015; Pribadi, 2016).

Ethiopia: Wax moths are present all over Ethiopia (>20% infestation level) with the highest prevalence in the months December to March. A study revealed that among the infested colonies, 56-75% absconded or were affected by the parasite (Desalegn, 2015; Pirk et al., 2015). A study conducted by Tolera & Dejene (2014) reported, that wax moths are one of the most threatening pests in the Jimma Zone. Participant beekeepers reported, that 18% of their honey bee colonies were weak and affected by a numerous amount of wax moths. Cleaning the apiary, removing of old combs or hives and strengthening of the colony are considered methods to treat an infestation, or to avoid one with wax moths (*G. mellonella, Achroia grisella*) (Yetimwork, Berhan, & Desalegn, 2015).

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Indonesia: According to Crane (1990) an infestation of *A. cerana* with *G. mellonella* can get severe, especially during the summer dearth. This kind of infestation is one of the main reasons of absconding (Crane, 1990). It is recommended to reduce the size of the hive entrance to avoid intrusion of adult wax moths (Pribadi, 2016). However, there is a lack of data on the dangerousness and presence of *Galleria mellonella* and *Achroia grisella* in Indonesia (Kwadha, Ong'amo, Ndegwa, Raina, & Fombong, 2017).

6.1.6. *B. coeca*

Braula coeca (Diptera; Braulidae), also known as bee louse, feeds on nectar and rich in protein jelly directly from the honey bee, as well as on material secreted by the host. Their larvae tunnel through the hive, damaging it and nourish on the honey and pollen (Morse, & Nowogrodzki, 1990). There is evidence, that an infestation of *B. coeca* leads to a reduction of worker bees and further reduces honey production rate (Adeday, Shiferaw, & Abebe, 2012). A study showed, that a treatment with tobacco smoke reduces the amount of *Braula orientalis* and increases honey yield (compared to untreated hives) (Al Ghzawi, Zaitoun, & Shannag, 2009). This method may also be effective for hives, infested with *B. coeca*. At low presence, impact on honey bee populations is negligible, but *Braula* is known to play an important role as a vector of viruses and other diseases (Pirk et al., 2015).

Ethiopia: Adeday et al. (2012) reported an infestation level of 3-6% in Ethiopia, but *B. coeca* is considered to be a negligible risk (Pirk et al., 2015). A study by Haylegebriel (2014) revealed, that the hive type (transitional<modern<traditional) and the management type (apiary<backyard beekeeping) are significantly associated with the prevalence in infestation rate of *B. coeca*.

Indonesia: So far, there is no information on the presence and dangerousness of *B. coeca* in Indonesia.

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6.1.7. Coleoptera

Aethina tumida (Coleoptera; Nitidulidae) and species from the family Cetoniinae (e.g. *Oplostomus fuligineus*, *Oplostomus haroldi*; Coleoptera; Scarabaeidae) are known as the small, and the adult large hive beetle, respectively (Neumann, Pettis, & Schäfer, 2015; Pirk et al., 2015). The large hive beetle consumes honey, pollen and honey bee brood. It invades the hive, instead of breeding in it (Crane, 1990; Ellis, Hepburn, Delaplane, Neumann, Elzen, 2003). The small hive beetle uses the honey bee hive as a protection from various environmental influences and as a food ressource. The larvae tunnel through the hive and comb store and cause damage to it (i.e. honey combs, brood and pollen) (Neumann, Pettis, & Schäfer, 2015). Based on an endemic distribution range in sub-Saharan Africa, the SHB was brought over sea and introduced to other continents (i.e. America, Australia, Europe) (Ellis, & Munn, 2005). Assuming the beetles are not present in numerous amount and the honey bee colony is not already weakened, it can be considered, that an infestation with Cetoniinae does not significantly impact the colony (Pirk et al., 2015). Otherwise, the presence increases the rate of absconding in weakened honey bee colonies. In addition, they do play an important role as a vector of viruses and bacteria (Haylegebriel, 2014).

Ethiopia: Small (SHB) hive beetles, native to the sub-Saharan Africa (Neumann, Pettis, & Schäfer, 2015), and the large (LHB) hive beetle are present, but so far it is considered as a negligible pest. However, a study by Alemayehu et al. (in press) revealed, that the small hive beetle may have a negative effect on honey bee colonies, especially in poor managed apiaries and/or hives. They described, that the presence of SHB led to severe reduction in honey bee products (honey, pollen, and also brood). The amount of SHB was higher in months following the dearth periods. Unfortunately, there is no further information on the impact and infestation rate of Cetoniinae on Ethiopian honey bee colonies (Ellis, & Munn, 2005; Pirk et al., 2015).

Indonesia: So far, there is no information on hive beetles in Indonesia (e.g. presence, infestation severity, ...) (Neumann, Pettis, & Schäfer, 2015), but assuming a successful host swap, Oldroyd and

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colleagues believe, that *A. tumida* may become a threat to *A. cerana* due to infested shipments from Australia to Asia (Oldroyd, & Nanork).

6.1.8. Ants

Many types of ants are known to affect honey bee colonies, by entering the hive and removing food and brood (Pirk et al., 2015). In general, the bees are able to defend their hive entrance against ant attacks, but if the colony is weakened, or the particular ant species is known to act aggressive, ants can severely impact the colony (Morse, & Nowogrodzki, 1990). To avoid an infestation with ants, Crane (1990) suggests to clean vegetation near the bee hives, use ant-proofed hive stands (long legs, that stand in shallow containers filled with oil, or diesel) and the use of pesticides (Crane, 1990).

Ethiopia: Ants are present and have a severe impact on weakened colonies (especially in honey bee hives with poor hive management) (Awraris et al., 2012; Gidey, & Mekonen, 2010; Teklu, 2016). A study conducted by Tolera & Dejene (2014) revealed, that ants are one of the most threatening pests in the Jimma Zone (Tolera, & Dejene, 2014). In southeast Ethiopia ants belong to the most severe pests in beekeeping (Gidey et al., 2012). The assessment of an infestation with ants (western and southern Shoa zone) revealed that 44.2% of honey bee colonies were yearly attacked by ants. 24% of invaded honey bee colonies abscond, while 4.2% are too weak to survive the ant attack. An overall economic loss of 3,839,810 Ethiopian Birr (ETB)/year is estimated due to infestations with ants (Desalegn, 2015).

Indonesia: There is a lack of data regarding the severity of ant-attacks on honey bee colonies in Indonesia, but Crane (1990) mentioned, that ants and their impact on honey bee colonies are one of the most widespread problems for beekeepers in tropical regions. According to her, migrating ant colonies can contain up to 700,000 individuals that raid and kill along its path. Army ants, that are also present in Indonesia, for example forage in groups and are able to invade and destroy a bee hive within a few hours (Morse, & Nowogrodzki, 1990; Terrence, & MCGlynn, 1999).

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6.1.9. *Varroa*

Varroa spp.* (Acari; Varroidae) - *V. destructor, V. jacobsoni, V. underwoodi, V. rindereri

Varroa belongs to the parasitic mites and is known to be one of the most dangerous pests in honey bees worldwide. *Varroa* weakens the colony by feeding on their haemolymph and by acting as a vector for viruses and other pathogens. They enter brood prior capping and reproduce in the sealed brood cells (Crane, 1990; Morse, & Nowogrodzki, 1990; Mengistu, Kebede, & Begna, 2016). The natural host of *V. destructor* was the Asian honey bee *A. cerana*, but due to a host-switch, when the Western honey bee was introduced to Asia, *V. destructor* spread worldwide (Botías et al., 2012).

Ethiopia: There are no reports of high colony losses that are directly linked to the parasitic, introduced *V. destructor* mite, thus in Ethiopia it is not common to treat infested honey bee colonies chemically. Surveys revealed that most Ethiopian beekeepers do not know about the possible impact of *V. destructor* on their colonies (Ebisa et al., 2016). Researcher also do not rule out that honey bee populations in Africa may be more resistant against *V. destructor* due to several factors like climate conditions (i.e. almost no overwintering) (Muli et al., 2014; Pirk et al., 2015).

Indonesia: Several species of *Varroa* exist in Indonesia (*V. destructor, V. jacobsoni, V. underwoodi, V. rindereri*), known to infest different honey bee species and subspecies. Regarding the beekeeping with *A. cerana*, studies revealed, that *V. destructor* seems to be not economically important, not only due to the increased hygiene behavior of *A. cerana*. Though, increased grooming behavior of *A. cerana* in cleaning and removing *Varroa* mites is not only triggered by exogenous stimuli through visual and olfactory detection, but also on genetics. Unfortunately, there is no data on the impact of *V. destructor* on Indonesian *A. mellifera* (i.e. infestation rate, severity, ...) (Diao et al., 2018; Gupta et al., 2014; Oldroyd, & Nanork, 2009; Rosenkranz, Aumeier, & Ziegelmann, 2010).

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6.1.10. *Tropilaelaps spp.*

Tropilaelaps spp. (Mesostigmata; Laelapidae) - *T. clareae* belongs to the tracheal mites and naturally infests *A. dorsata* colonies. *T. clareae* is not able to life longer than a few days on adult honey bees, but they are able to infest up to 90% of the brood (Crane, 1990). The infestation of *T. clareae* on *A. mellifera* colonies leads to severe damage, that are similar to those of *Varroa destructor* (Oldroyd, & Nanork, 2009). Besides *T. clarae*, other Tropilaelaps species, namely *T. mercedesae* and *T. koenigerum'* are native to Asia (Denis, Anderson, & Morgan, 2007).

Ethiopia: There is no information about a possible presence of *Tropilaelaps spp.* in Ethiopia.

Indonesia: *Tropilaelaps spp.* is present in Indonesia, but there is no data about dangerousness, nor treatment, indicating that *Tropilaelaps* represents a negligible risk in Indonesia (Oldroyd, & Nanork, 2009; Ellis, & Munn, 2005).

6.1.11. *A. woodi*

Acaris woodi (Acari; Tarsonemidae) belongs to the tracheal mites and is known to infest young adult honey bees and nourish on their haemolymph. It has been shown, that the presence of *A. woodi* negatively affects the life span of bees. Crane (1990) claimed that the infestation rate of *A. woodi* is correlated with the quality of the beekeeping and the richness of melliferous plants in the environment (Crane, 1990).

Ethiopia: There is information on the presence of *A. woodi*, but none on the dangerousness of the parasite on African (i.e. Ethiopian) honey bee colonies (Pirk et al., 2015).

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Indonesia: According to Ellis and Munn (2005) *A. woodi* is expected to be absent in Indonesia, due to limited investigations made with negative results (Ellis, & Munn, 2005).

6.1.12. Others

There are several other pests, pathogens and predators affecting the health of honey bees:

Malpighamoeba mellificae (Amoebozoa; Malpighamoebidae) is known to be the causative agent of amoeba disease. *M. mellificae* is a single celled parasite affecting the malpighian tubules of honey bees. As a result, the life cycle of bees is shortened (Haylegebriel, 2014).

Ethiopia: Within Ethiopia, the existence of *M. mellificae* has first been reported in 1998 by Amssalu and Desalegn, but the risk of an infestation is considered negligible (Desalegn, 2015; Haylegebriel, 2014).

Indonesia: There is a lack of data regarding the status of *M. mellificae* in Indonesia!

Birds of the family Meropidae (Coraciiformes). A single bee eater is able to consume up to 600 honey bees per day (Pirk et al., 2015).

Ethiopia: Bee eaters are present within Ethiopia, but their occurrence does not have a severe impact on local apiaries. They attack honey bee colonies especially during rainy seasons and beekeepers may decrease bird pressure by setting up scarecrows in their apiary (Awraris et al., 2012; Pirk et al., 2015; Teklu, 2016).

Indonesia: So far, there is no information on the impact of birds on honey bee health in Indonesia.

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Mellivora capensis (Carnivora; Mustelidae). The honey badger breaks up the hive to rob the combs and feed on it (Crane, 1990).

Ethiopia: The honey badger damages honey bee colonies in the months November to April due to increased brood and honey in the hives (Awraris et al., 2012; Gidey et al., 2012).

Indonesia: *M. capensis* is not present in Indonesia (Jana, Vanderhaar, & Hwang, 2003).

6.2. Dealing with honey bee health issues

Ethiopia: According to a local scientist (Holeta Bee Research Center, Ethiopia), beekeepers, who recognize honey bee health problems within their bee colonies, have to report to the district livestock offices. Most of the beekeepers have a lack of knowledge when it comes to identify pests like *Varroa*, or microscopic pathogens like fungi or bacteria. Thus, they report the observed symptoms and/or pass on samples of the hive to the district livestock offices. The office respond to the report and if they cannot help properly, they collect the information or even samples from the particular apiary to send it to the Holeta Bee Research Center for further identification and to provide required solutions. Based on the outcome, they give feedback and offer suggestions for handling the health issue. If there is no outcome, the honey bee health team will travel to the localities to further study the case. Unfortunately, there is a lack of published information on that topic.

Indonesia: According to a local scientist (Universitas Padjadjaran, Indonesia), the beekeepers of disease affected apiaries do not pass on the information to a governmental office, nor to a beekeeping association, but informally exchange their observations with other beekeepers who already gathered experience with the particular honey bee health issue. There is no regularly conducted assessment on honey bee health of Indonesian government, because beekeeping is still considered to be a "second class farm activity". Unfortunately, there is a lack of published information on that topic.

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6.3. Treatments (if any) commonly applied to different pests

Ritter and Akratanakul (2006) published a guide that summarizes the most common honey bee pests and diseases as well as its most favourable treatment methods. The publication is available as open access via the website of FAO (Ritter, & Akratanakul, 2006).

Ethiopia: To treat an infestation with ants, Ethiopian beekeepers use several traditional methods such as placing the hive on small cans and fill them with ash and dirty engine oil, bring out ash around the hive, frequent smoking or using local eucalyptus leaves for fumigation (Gidey, & Mekonen, 2010; Teklu, 2016). Several studies revealed that ants are one of the most threatening pests in Ethiopia (Teklu, 2016; Tolera, & Dejene, 2014). Modern methods include the use of benzene, malathion and smooth iron sheets (Teklu, 2016). So far, no information on regular treatment against varroa mites was published, it therefore can be considered, that in most regions of Ethiopia, no treatment at all is applied. One reason may be a lack of knowledge on the severe impact of *Varroa* spp. on honey bees. Studies suggested, that propolis acts as a natural acaricide and therefore may be a possible treatment method against *Varroa* (Ebisa et al., 2016; Shimelis, Yared, & Desalegn, 2016). In a study conducted by Teklu (2016), beekeepers from southern Ethiopia practiced following traditional methods to destroy mites in the hives: burning, killing, and removing the whole hive. To treat an infestation with Small Hive Beetle (SHB), Alemayehu et al. (in press) recommend to combine seasonal colony management (removing unoccupied frames, regular hive cleaning, additional feeding in the dearth period, …) with the trapping of SHBs' larvae by dead brood trap to increase the treatment success. Other treatment methods include the use of DDT, or roach killer (Teklu, 2016). Cleaning the apiary, removing of old combs or hives and strengthening of the colony are considered methods to treat an infestation, or to avoid one with wax moths (*G. mellonella*, *Achroia grisella*) (Yetimwork, Berhan, & Desalegn, 2015).

Indonesia: So far, there is no information on treatment methods against pests affecting honey bees in Indonesia.

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6.4. Threats for introduction of new pests

Throughout history, with all the exploration trips and globalization, diseases affecting honey bee health have been spread worldwide. That led to host-shifts of pests/pathogens between introduced and native honey bee species and subspecies. *Varroa destructor* and *Nosema ceranae* are known to have swapped over from *A. cerana* to *A. mellifera*, when the Western honey bee was introduced to Asia. On the opposite, Thai Sac Brood Virus, Israeli Acute Paralysis Virus and several tracheal mites were originally observed in *A. mellifera* before spreading to *A. cerana* (Botías et al., 2012; Theisen-Jones, & Bienefeld, 2016).

Ethiopia: The exchange of diseases or parasites is always possible through neighbouring countries (i.e. Eritrea, Uganda, Somalia, Kenya, Sudan, South-Sudan, or Djibouti). For example foulbrood is so far no officially observed disease in Ethiopia, but was detected in Eritrea and therefore may spread through the international border to Ethiopia and other neighbouring countries (Ellis, & Munn, 2005). Another notable factor is the international trade and transport of honey bee colonies.

Indonesia: The country consists mainly of islands but also shares borders with Malaysia and Australia. Despite Australia is known to have strict border regulations, the rate of disease exchange is high at over-land boundaries (Thompson et al., 2003). There is almost no information on honey bee disease distribution in Indonesia, but it is considered, that the transport of goods over sea is also a major risk for the distribution of pests and pathogens. One example for a possible future threat for Indonesians' *Apis*ector is the small hive beetle (SHB). While there is no data on the presence/absence in Indonesia, SHB occurs in the neighbouring Australia (Theisen-Jones, & Bienefeld, 2016). As mentioned above, international trade and transport of honey bee colonies is also considered to be a risk regarding the introduction of new pest

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