Estonian Business School

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THE COMMERCIALIZATION OF POLLINATION SERVICES – A CASE STUDY IN THE FINNISH ECONOMY

Bachelor's Thesis

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INTRODUCTION

Pollination services, according to the definition adopted by the Food and Agriculture Organization of the United Nations (FAO), is “pollination acts performed by all the various animals that dependably visit certain species of flowering plants.” (Buchmann and Nabhan, 1996). It is a process that is essential for successful agriculture (FAO, 2020a), with estimates of global food crops’ dependence on pollinators approximately 35 % (FAO, 2020b; Klein et al., 2006). It is a fact that managed beekeeping offering pollination as a service helps “crops produce optimally” (FAO, 2020b).

In Finland, agriculture is essential for employment (Haataja, 2017) and a significant part of the Finnish economy (Luke, 2019; Niemi and Väre, 2019). Many important crops grown in Finland are dependent on not just pollinators, but specifically, insect and bee pollination (Lehtonen, 2012). However, it has been noted that the state of pollinators in Finland is in danger (Yle, 2019). Previous research has focused on the valuation of commercialized honeybee pollination services provided by beekeepers, specifically the *Apis mellifera* species (Yläoutinen, 1994 in Lehtonen, 2012; Lehtonen, 2012). The data from this research is used by the Finnish Beekeepers Association (SML ry), the national organization of beekeepers, in their communications in the present day (SML ry, 2019). Since the publication of Lehtonen’s research, the number of farms (Luke, 2020b) and the value of agricultural production (Niemi and Väre, 2019) has been declining nationally.

Research on the beekeeping industry is available as preliminary results of the PÖLYHYÖTY project, by Heliölä and Holopainen (2020). More information is available from the Finnish Food Authority’s ongoing program for supporting the beekeeping industry (Ruokavirasto, 2019b). The program aims to expand beekeeping and pollination services in the country. The PÖLYHYÖTY project studies the valuation of pollination services as part of demographical research of active pollination service providers. Their recommendations for promoting beekeeping and pollination services are extensive, but the focus on business development of pollination services is lacking.

Academic research has focused on studying the breadth of ecosystem services. Beyond valuation however, research on ecosystem services as businesses is unavailable. The focus of literature is providing global institutions and governments with the knowledge to implement legislation to support ecosystem services and pollination services. None of this includes hands-on guides for how the private sector can be utilized in this, let alone beekeepers themselves. This is the gap in research I will set out to address. The knowledge available today needs to be analyzed to understand how actors in the industry, politics, and regular consumers can work together to realize the economic benefits of widespread commercialized pollination services.

In this thesis, I will evaluate the possibilities for the wide-scale adoption of commercial pollination services in Finland and suggest concrete steps to take to achieve this. I will undergo a literature review of the concept of ecosystem services to determine appropriate themes for where the issues and solutions lie in promoting the widespread adoption of pollination services. I choose to focus my research as a case study on pollination service providing beekeepers in Finland (hereon referred to as pollination service providers), due to the availability of data from various organizational resources. Rather than produce a unique data set, I will set about to complete a thematic analysis of the available data. To support the exploratory nature of the research, I will follow an inductive approach by the example set in Saunders, Lewis, and Thornhill (2016).

The completed report will present a thematic analysis of the case study and suggest actions of what is a suitable course of action to promote pollination service providers in Finland, accounting for the intricacies of the agricultural sector and the beekeeping industry. In the end, I will have answered my research question: "how can adopting widespread managed pollination services increase the economic output of Finnish agriculture?".

1. LITERATURE REVIEW

In this chapter, I will complete a review of the academic literature concerning pollination services. I will examine the resources of worldwide authorities, such as FAO, on the matter and produce themes for my analysis, which will be presented with the results of my analysis.

1.1. Pollination and Pollination Services: The State of the Field

FAO calls attention to the state of pollinators worldwide in an update on their website:

> "A growing number of pollinator species worldwide are being driven toward extinction by diverse pressures, many of them human-made, threatening millions of livelihoods and hundreds of billions of dollars' worth of food supplies, according to the first global assessment of pollinators. The volume of agricultural production dependent on animal pollination has increased by 300 percent during the past 50 years, but pollinator-dependent crops show lower growth and stability in yield than crops that do not depend on pollinators." (2016)

There are globally over 352,000 plants that need or benefit highly from pollination. An impressive number, considering that research referred to by the British Broadcasting Corporation (BBC), shows that there are approximately 390,900 different species of plants on Earth (not including algae, mosses, liverworts, or hornworts) (Morelle, 2016).

The information available in FAO's database shows "pollinators are essential for orchard, horticultural and forage production, as well as the production of seed for many root and fiber crops." (2020b). They further state that 35 % of the world's crop production is in some way affected by pollinators (FAO, 2020b), a figure supported by academic research (Klein et al., 2006).

The pollinators themselves include more than just honeybees. Non-bee animals such as birds, ants, wasps, spiders, flies, beetles, and butterflies account for approximately 38 % of the visits in food crop's flowers. Other bees account for 23% and honeybees for 39 % of all pollination (Rader et al., 2016), making both essential pollinators for food crops.

The positive effect of bee pollination on crop quality is a well-observed phenomenon (FAO, 2020b; Garratt et al., 2013). Klatt et al.'s study on the matter concludes:

> "- Smooth and abundant pollination reduces the deformation of the berries, which in turn improves the condition of the trade.
> - Pollination makes the berries bigger, which reduces the loss and makes the product more affordable.
> - A very pollinated berry is more solid, allowing it to stay longer in transport and on the shelf.
> - Rich pollination improves strawberry color and increases sugar content" (2014)

With pollination being a critical ecosystem service for food security (Giannini et al., 2015), there is already strong evidence for the high economic value of pollination. Estimates are done around the world to support this. In the United States of America (USA), the service is highly profitable, with a market value of 13 million euros (Morse and Calderone, 2000). A Cornell University study found that 26.8 billion Euros worth of farmer income could be attributed directly or indirectly (15.11 billion Euros and 11.69 billion euros, respectively) to pollination by honeybees and other pollinator insects (Ramanujan, 2012). In 2015 the pollination provided as an ecosystem service had been counted to be valued at about 3,000 euros per hectare, and the same ecosystem service provided by honeybees has been valued at about 2,692 euros per hectare in a study of 1,394 different crops dependent on pollination (Agence France-Presse, 2015).

In the European Union (EU), the potential value of pollination services is estimated to be 14.2 billion euros (Potts et al., 2015). In the United Kingdom alone, The British Bee Coalition estimates pollinators account for about 772 million euros of crop value on average, annually (2020).

Like developed economies, research shows pollination dependent crops to be important in developing economies too. Such are the markets of commodity food crops, many of which are exported to developed economies. These are hugely important for local economies in third world countries (Kasina et al., 2009). As an example of one such crop, coffee, dependent on pollination, is an important source of income in the economies with climates that support its growth: "Coffee... ranks among the five most valuable agricultural exports from developing nations… employs

25 million people worldwide... and is cultivated in many of the world's most biodiverse regions…" (Ricketts et al., 2004, p.12579).

The profession of beekeeping is at the forefront of making pollination services available to agriculture. The practice of commercial pollination service is a relatively new phenomenon. Velthuis and van Doorn's research suggests the commercialization came into existence only in 1987. However, the practice grew rapidly, with their research indicating there were up to 1 million colonies in production in 2004 (2006, p.441).

FAO cites research by Levin, Gordon and Davis, Southwick and Southwick, Morse and Calderone, Richards, and Costanza et al. showing the vast effect of pollination on crops, the diverse valuation methods available, and also the variation in these methods (2006). A deeper investigation has been conducted by Allsop, de Lange, and Veldtman with their work analyzing the different valuation methods used in practice today. Their work presents four contemporary ways of calculating pollination value. First, there is the "total production value," which is simply the annual production value of the crop in question. Second, "Proportion of total production value attributed to insect pollination" uses the annual production value, multiplied by its insect pollination factor. The third method is the "replacement value," which is the annual value attributed to insect pollination with the annual production value using pollinator replacement subtracted from it. Finally, "directly managed pollination value" accounts for the hive rental costs used in pollination service purchasing (Allsop, de Lange, and Veldtman, 2008, p.2).

To elaborate on what is meant by replacement, in this case, Allsop, de Lange, and Veldtman state that the only viable replacement to pollination by insects is mechanical pollination. This is pollination done by hand (manual laborers) or by machines, such as pollen dusters. Out of these choices, pollen dusters have been observed to be less effective than natural insect pollinators. Manual pollination, on the other hand, has been observed to produce matching or even greater yields of fruit than with insects. The issues, however, are restrictions on resources like labor and pollen. The replacement cost must consider the price of labor of the manual pollinators, who need to visit each flower and place pollen directly into the stigma of the flowering plant.

Due to the great differences in labor costs, cultivation of different plants, and other resource availability, Allsop, de Lange, and Veldtman conclude that calculating replacement costs is difficult, if not impossible (2008).

A further problem persists with all valuation methods. Fisher et al. note that developing economic valuation methods aid policymaking with cost-benefit analyses. Their review of a supply-and-demand framework for ecosystem service valuation highlights a major problem: that it is almost impossible to assign value to all benefits of ecosystem services in economic terms (2008). A broad reading of academic publications supports this conclusion (Pandeya et al., 2016; Tinch et al., 2019; Olander et al., 2017). Pollination services, however, have an advantage here. The biological research available on the topic and the tangible value of what is produced (honey, beeswax, and the produce that requires pollination to reproduce and grow) makes assigning economic value to pollination services easier.

Majewski cites the lack of utilizing pollination services to a general unawareness of them (2014, p.21). This was also discovered in a study conducted in Nigeria: Oladimeji, Ajao, and Abdulsalam show that a lack of knowledge of the availability of the service is a barrier to its adoption (2017). This general unawareness can also be attributed to the scientific nature of the information used in, for instance, government policy (Patterson and McLean, 2019). Furthermore, Allsop, de Lange, and Veldtman point out that even with the ecologically sound reasoning for pollination service use, it is financial evidence that often motivates decision-makers (2008).

1.2. Pollination Services as Ecosystem Services

Probably the most important research on ecosystem services has been conducted by the United Nations' (UN) Millennium Ecosystem Assessment initiative. It began in 2001 with "the objective... to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being" (Millenium Ecosystem Assessment, 2003; 2005). One of its key findings was that ecosystem services would continue an ongoing decline and slow progress of other UN development goals (Millenium Ecosystem Assessment, 2003; 2005).

Bourguignon notes in a briefing to the European Parliament that the Millenium Ecosystem Assessment popularized the concept of ecosystem services, and draws on this work in the EU's own ecosystem service valuation, along with The Economics of Ecosystems and Biodiversity (TEEB) initiative, founded in 2007 (TEEB, 2015).

The definition by the Millenium Ecosystem Assessment defines ecosystem services as "the benefits people obtain from ecosystems" (2003, p.53). TEEB further divides ecosystem services into four categories, namely provisioning services (services providing food, raw materials, freshwater, or medicinal resources), habitat or supporting services (for species or maintaining genetic diversity), a variety of cultural services, and regulating services (for local climate or air quality, moderating extreme events e.g., floods, carbon sequestration, and storage, wastewater treatment, erosion prevention, biological control, or pollination) (2020). The EU has conducted surveys on the state of its member state's ecosystem services. The results available today shows completed studies on the state of ecosystem services on a national level in only three member states (European Union, 2018).

Another EU initiative, called Mapping, and Assessment of Ecosystems and their Services (MAES), is also ongoing at the time of writing. The goal is to inform EU-wide policy on ecosystem matters by having access to accurate and up-to-date information on the state of ecosystem services in all member states (European Commission, 2020). While the results are yet to be published, preliminary results were showcased at a MAES conference in Helsinki, December 2019. They indicate that EU-wide, out of all ecosystem demand, including but not limited to pollination, 50 % is currently not being met. Specific to pollination, demand has increased by 17.5 % between the years 2000 and 2012. The preliminary results presentation concludes that to alleviate the situation and relieve the pressure on ecosystems, "better implementation of existing legislation and large-scale ecosystem restoration" is required (European Commission, 2019).

It is also necessary to address the issue in the term "ecosystem services." The concept has been under scrutiny with critics saying it is "too narrow to capture a broad range of worldviews, knowledge systems, and stakeholders" (Kadykalo et al., 2019, pp.269-

270). This has been addressed with the introduction of the term "Nature's Contribution to People… defined as 'all the positive contributions, losses or detriments, that people obtain from nature'" (Kadykalo, 2019, p.269). Kadykalo notes that the term arises from a need to include a broader diversity of different cultures' knowledge about ecosystem services into professional discourse (2019).

Diaz et al. conducted research on the term (2018), which the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) leans on their conceptual framework (2015). IPBES, in turn, informs the UN Environment Program and FAO, along with participating in, and welcomes participants from, other UN initiatives (IPBES, 2020). With FAO still retaining the use of "ecosystem services" in their policies and communications, it can be determined this term has been adopted in parallel on a smaller scale; as Kadykalo notes, the two terms complement each other, with plenty of overlap in meaning (2019).

It can be determined that for the purposes of economic analysis, a single discipline, the term "ecosystem services," still bears the most useful frame of reference.

1.3. Successful Practices with Pollination Services

FAO describes themselves as the international leader in the fight to defeat hunger across the world. Working in over 130 countries, their goal is to achieve global food security (2020c). Among their publicly available resources, the material concerning pollination service as part of this battle includes survey results of promoting pollination services in achieving their goal. The content is focused on the merits of using pollination services to argue for better success in agricultural practices (FAO, 2008). Drawing on FAO as a globally operating, UN-backed authority, I will draw on these cases to raise the themes to be used in analyzing the Finnish beekeeping industry and agricultural sector.

From the nine sites surveyed by FAO, six of them reported *Apis mellifera* honeybees to be important pollinators. Out of these, three sites had observed benefits from beekeeping. These are coffee farms in Ethiopia, mango plantations in Ghana, and blueberry farms in the USA (FAO, 2008).

The report on Ethiopia describes closely tied agrosystems and forests in the coffee producing Kaffa region. The community has been historically self-sufficient in its food production and embrace pollination benefiting practices widely. The report refers to a recent study showing coffee plants in the area benefit greatly from pollinators in terms of coffee bean yield. Furthermore, bees are considered the main pollinators for their behavior and frequent visits to the flowers. Large communal land spaces, filled with forest or bush, are utilized for beekeeping: local farmers are knowledgeable of the benefits of pollination on a general level, and many have even begun to practice beekeeping after hearing of good results from other farmers. Hives are at times placed in forest groves where coffee grows. Recently the introduction of new types of beehives has also promoted the practice. All of the reported practice comes down to embracing biodiversity: all production is organic, native vegetation is not cut down in favor of coffee but allowed to grow alongside it, alternative forage for bees is kept in cultivated areas, and in general practices protecting, encouraging, and protecting bees are noted. The only noted downside has been bee aggression against livestock. Formal education is not reported to be a factor in promoting pollination (FAO, 2008).

Elements of the practices reported from Ethiopia can be found in Ghana and the USA. In Ghana, mango plantations have noted the benefit of reduced weeding and promoting biodiversity, which sustains alternative forage for bees. Beekeeping has also been noted to be vital in the event of lost natural pollinators. In the USA, blueberry farmers note increased yields in their harvest when using rental hives. However, for the wild blueberry variants examined in the report, wild pollinators are noted to be the most important pollinators (FAO, 2008).

FAO points further to the USA as an example of pollination’s necessity in food crop production (2008). Rental hives are identified as a crucial part of almond pollination in California during the growing season; with insufficient natural pollinators, rental hives provided by professional beekeepers are a necessity for the almond farmers to stay in business from year to year (Stanford University, 2018). An example can be found in China of what might happen without these service providers. Farmers in Sichuan province must hire manual laborers to hand-pollinate the flowers of their food crops because pollinators are already completely extinct in the wild (Toivonen, 2020).

The USA is a prominent market for commercial beekeeping. The importance has been recognized on a high level. The federal government has supported beekeepers in the years when colony deaths over winter have occurred, or generally, lower income has been generated. The Committee on the Status of Pollinators in North America reports that this has strengthened the market after instances in 1995-96 and 2000-01 (2007, p.166). The opportunity to increase employment has been recognized, too, without work miners being retrained as beekeepers to earn an income (Lux, 2019).

2. RESEARCH METHODOLOGY

In this chapter, I will describe my chosen case: pollination service providers operating in Finland. I will further elaborate on my research methods, data collection, and analysis to explain my chosen research approach and how it will ensure my research goal is reached.

2.1. Case Study Research

I have selected my research strategy for this thesis to be a case study. The goal of this approach is to produce an in-depth report of "a case description and case-based themes." (Creswell, 2007, p.73). These themes and the descriptions are analyzed to create new knowledge and explanations of the case. Researchers commonly attribute this to be the best approach to produce in-depth knowledge and understanding of a topic of study (Saunders, Lewis, and Thornhill, 2016; Creswell, 2007; Bitsch, 2005; Heaton, 2008).

This research design is best handled with qualitative methods. Creswell defines research with qualitative methods as follows:

> "Qualitative research begins with assumptions, a worldview, the possible use of a theoretical lens, and the study of research problems inquiring into the meaning individuals or groups ascribe to a social or human problem. To study this problem, qualitative researchers use an emerging qualitative approach to inquiry, the collection of data in a natural setting sensitive to the people and places understudy, and data analysis that is inductive and establishes patterns or themes." (2007, p.37)

Further reasons for using qualitative methods for research in economics are stated by Bitsch to be:

> "(a) the description and interpretation of new or not well-researched issues; (b) theory generation, theory development, theory qualification, and theory correction; (c) evaluation, policy advice, and action research; and (d) research directed at future issues." (2005, p.76)

Creswell goes on further to note that the procedure suitable for a case study is supported by qualitative methods (2007, p.37). He explains these approaches work when the aim of the research is to explore an issue instead of relying on already established literature (2007, p.40). In this kind of qualitative study, Saunders, Lewis, and Thornhill note that an inductive approach works best, because of its usefulness in "generalizing from the specific [topic] to the general [topic]." (2016, p.145).

Following this method, adopting an objectivist stance for research is called for to achieve the goals of this thesis. Taking an objectivist stance means adopting an approach founded in analyzing observable and measurable facts. In this case study, we are taking scientific documentation and explaining their meaning by interpreting the relationships of the data (Saunders, Lewis, and Thornhill, 2016).

The nature of the research's purpose is to examine pollination services providers in Finland as a case study, what is ongoing in the field currently, and how it is expected to develop. These are characteristics of an exploratory approach to the research purpose, as defined by Saunders, Lewis, and Thornhill (2016, p.174). An approach suitable for this is conducting literature research (Saunders, Lewis, and Thornhill, 2016, p.175), like this thesis's literature review.

Choosing the thesis's research methods to be based on a qualitative case study is as such selected for its suitableness for an inductive approach to exploratory research. Furthermore, as the stated research goal is to outline ways of how to adopt pollination services in Finland, the purposes of qualitative methods for "description and interpretation… theory development…" and "research directed at future issues" (Bitsch, 2005, p.76) are satisfied with the definition of the research parameters.

The purpose of secondary data analysis is to use existing data for new research (OxbridgeEssays, 2020; Heaton, 2008). The benefits of the approach are the low threshold in terms of cost, time, the ability to easily access large amounts of data, and building on this existing data. Finally, and most importantly, secondary data research allows "re-assessing a data set with a different research question in mind" (OxbridgeEssays, 2020).

Secondary analysis of qualitative data has been of increasing interest in the academic community since the 1990s. Heaton defines three modes of secondary data analysis, namely formal data sharing, informal data sharing, and self-collected data. The former two refer to working with data acquired from another researcher directly, while the latter involves working with data acquired specifically for secondary data research to suit the needs defined for the ongoing research (Heaton, 2008).

2.3. Data Collection

I have chosen to conduct my research data collection in the form of a case study. Yin defines a case study as "an in-depth inquiry into a topic or phenomenon within its real-life setting" (2014, in Saunders, Lewis, and Thornhill, 2016, p.184). Creswell describes case studies being examinations of a phenomenon occurring in a "bounded system... [involving] multiple sources of information" (2007, p.73). He further describes the data collection process to be an approach based on inquiry, with the aim of creating a description of the case being studied (2007).

As outlined appropriate for case studies, my research will incorporate multiple sources for data (Creswell, 2007). The primary ones will be documents and observations. To create a broad case study, the data has been collected from records of multiple organizations. In the remainder of this chapter, I will explain the selection of these data sources for the benefit of the case study, outline some of the specific choices in terms of comparability, and explain the selected valuation method for the calculations of commercial valuation of pollination services in Finland.

The collected data on beekeepers in Finland represents the most recent available data on the industry. This has been published by the Finnish Food Authority in connection with its three-year plan for the beekeeping industry in Finland (Ruokavirasto, 2019b).

The collected data includes the number of registered beekeepers in Finland, the number of these beekeepers with 150 hives or more, and the number of hives the keepers with 150 hives or more have between them.

The data collected to calculate the market values of the crops produced in Finland that depend on or benefit from honeybee pollination represent the most recent available data from the agricultural industry. The crop harvest volumes have been published by Natural Resource Institute Finland, The Finnish Cereal Committee, and The Finnish Food Authority; the values used in the calculations are averages of the harvests of 2017 and 2018. The crop market values have been published by Natural Resource Institute Finland, The Finnish Cereal Committee, Kasvitieto Oy, and The Finnish Food Authority; the values used in the calculations are averages of market values of the crop in the years 2017-18.

The data on the crop's reliance on pollinators and honeybees specifically are from the research by Lehtonen (2012), presented as the average ratios of the crop's pollination dependent on insect pollinators, and a separate ratio for the crop's pollination dependent on honeybees.

This data has been selected due to its availability and reliability. Natural Resource Institute Finland and The Finnish Food Authority are governmental actors with interest to publish unbiased data for the benefit of developing the Finnish agricultural and food industries. Earlier research also depends on the information provided by Kasvitieto Oy, which offers a validation this thesis can depend on too. The Finnish Cereal Committee consists of multiple public sector actors and private corporations, with the intent to improve industrial efficiency (Vilja-alan yhteistyöryhmä, 2020).

Furthermore, the data on the specific crops in calculating the commercial valuation of the pollination services in Finland has been selected to provide a consistent update to previous research. This previous research is Lehtonen's thesis, which originally selected the crops it did due to the availability of pollinator ratio research (2012).

2.4. Discrepancies with Earlier Research

Lehtonen (2012) reported the value of pollination services for 20 different cultivated crops. Even though these were statistics reported on by Statistics Finland, the national center for statistics, the continued reporting for some of the crops have since been discontinued.

According to the Senior Statistician on crop production statistics at the Natural Resources Institute Finland, the statistics for red clover are no longer being collected and reported at the time of research (Partala, 2020).

In Lehtonen (2012), harvests and values for turnip mustard and rapeseed are reported in separate statistics. In data available from 2017-18, the two crop's values are combined into one (Luke, 2020a). To create comparable data, I have calculated the averages for the combined crops for Lehtonen's data too. The available data also aggregates the blackcurrant data with a green currant variant. As this is not a separate species (SuomalainenTaimi.fi, 2013), this thesis will consider it comparable data with Lehtonen's reported black currant data from 2008-10.

2.5. Valuation Method for Commercial Pollination Services

As noted in the literature review, valuation methods for ecosystem services and pollination services are numerous, all with inherent strengths and drawbacks. In the interest of creating data consistent with previous research in Finland, I will adopt the formula used by Sandhu (2016), as the same formula has been used by the research Lehtonen (2012) conducted for SML ry. This is the valuation method for the attributed value of insect pollinators.

According to Sandhu, the value pollination can bring to crops could be calculated according to the following equation:

"$TEVpsc = Vmc\ X\ Dic\ X\ Phbc$,

Where *TEVpsc* = Total Economic Value attributed to pollination services by bees in each crop

Vmc = Market Value of the crop

Dic = Insect dependency ratio of the crop

Phbc = Proportion of insect pollinators that are honeybees in each crop.” (Sandhu, 2016)

To utilize this formula with data specific to the Finnish environment, research by Teittinen (1979, cited in Lehtonen, 2012), Yläoutinen (1994, cited in Lehtonen, 2012), Korpela (1988, cited in Lehtonen, 2012) and Nousiainen et al. (1978, cited in Lehtonen, 2012) has been included in the ratios of insect and honeybee pollination dependency. To form a complete picture, the averages of these and sources from other locations have been calculated in Lehtonen (2012).

The pros for using this formula is that it is extremely simple. It also allows us to use current market values of the end products that the Finnish agriculture produces in addition to plotting the current number of beehives. Also, using this formula allows us to use reliable data on how pollinators, especially honeybees, affect the process of reproduction and, therefore, harvested amounts of crops.

2.6. Data Analysis

To analyze the collected data in a way to achieve the goals set for this thesis, a thematic analysis was chosen to analyze the case study. I will analyze activities around promoting pollination services to create the description for and outline the themes of this case, to produce my final report.

Thematic analysis is by Braun and Clarke’s definition of a “foundational method for qualitative analysis” (2006, in Saunders, Lewis, and Thornhill, 2016, p. 579). Saunders, Lewis, and Thornhill define the purpose of the analysis to be to find patterns or themes within data sets; the data sets themselves can be any form of documentation (2016). The advantage of the approach comes from its flexibility to process data without theoretical limitations and extracting insightful summaries of the processed data (Nowell et al., 2017).

An inductive approach for analyzing the data has been chosen to make the research data-driven. This way, “data collection is used to explore a phenomenon, identify themes and patterns…” (Saunders, Lewis, and Thornhill, 2016, p. 145).

In this thesis, the themes for analysis were defined as part of the literature review of pollination services. These themes, which will be elaborated on in chapter 3, can be categorized into issues affecting pollination services and solutions for promoting pollination services. Issues affecting pollination services are food security, the decline of ecosystem services, and lack of biodiversity. Solutions for promoting pollination services are education, market-based drivers, and decision-maker action.

3. RESULTS

In this chapter, I will present the updated calculations for the values of pollination for chosen food crops in Finland, present my results for the thematic analysis from my literature research, and the analysis of the case study on the Finnish agricultural sector.

3.1. Case Description: Pollination Service Providers in Finland

I have chosen to analyze pollination service providers in Finland. I made this choice due to the accessible information, my personal interest and familiarity with the topic, and the availability of multiple sources of information. To elaborate on the clients the pollination service providers work with, it is useful to briefly discuss the main features of the agricultural sector in the Finnish economy.

Over 2.3 hectares of arable land (Vilja-alan yhteistyöryhmä, 2019), Finland had 46,717 farming and gardening companies in 2019 (down by 900 since 2018) (Luke, 2020b). Out of these farms, 5,000 farms were dedicated to organic farming in 2018 (Proluomu, 2019). Presumably, this figure has decreased too. The farmers themselves are, on average, 53 years old, of whom 86 % own a family farm, as opposed to corporate or commonwealth ownership, which is the next most popular form of ownership (Luke, 2020b).

The most recently compiled data on revenue by Luke is available from 2017. That year, the value of the production of the Finnish agricultural sector was 4.4 billion euros, a number on a steady decline since 2013, when the figure was 5.1 billion euros (Niemi and Väre, 2019). Over the same time, the Finnish gross domestic product (GDP) per capita grew by 1,927 euros (Tilastokeskus, 2020). In 2017, the size of the Finnish labor force, all 17-74-year-old citizens, was 2,473,000 (Tilastokeskus, 2017). Approximately 8 % of them were employed in agriculture, either directly or indirectly (Haataja, 2017).

An explanation for the contracting production in the agricultural sector might be found in the changing economic landscape. Rikkonen explains that since 1994, market prices have fluctuated unpredictably, and large producers have gained ground over smaller ones in the challenging circumstances brought on (2016). Challenges can also be found in the decline of ecosystems (Pouta, Hyvönen and Miettinen, 2016) and the climate, with many authorities and observers, citing the challenging climate as a weight on the agricultural sector (Ministry of Agriculture and Forestry of Finland, 2019; Ruokatieto, 2020; Tukes, 2018). These factors have implications on what crops are grown and ultimately on how much demand there is for pollination services, keeping in mind the impact on how said pollinators can sustain themselves.

According to Helsinki University, Professor of Biology Heikki Hokkanen, there is observed evidence of a lack of pollinators in certain areas of Finland. This has been seen in a drop in crop yields despite the adoption of modernized agricultural practices. Intensive farming in South-Western Finland has, for example, decimated the habitats of natural pollinators (Vairimaa, 2015). The national authority on agriculture in Finland, MTK, corroborates this observation, calling for more research and tracking of the developments in natural pollinator populations (Yle, 2019). It is estimated that as many as 20% of wild Finnish honeybees might be endangered (Ymparisto.fi, 2016).

Pollination services provided by beekeepers with domesticated *Apis mellifera* could be a solution for this. At present, however, numbers to cover this are lacking. An unpublished report estimates that the number of beehives in Finland would be sufficient for only 50% of cultivated crops in low-intensity farming regions like

Kainuu, and only 3% in high-intensity farming regions like Varsinais-Suomi (Tikkanen, 2016). Overall, it is estimated that existing beehives in Finland currently would satisfy 25 % of pollinator demand nationally (Toivonen, 2020). Some farmers in this situation have turned to import pollinators from abroad. Bumblebees are not locally raised in Finland and have been brought in from countries like the Netherlands. However, bumblebees do not fare well for greenhouse plantation pollination, and the lack of natural light in the Finnish winter disorientates them (Kähönen, 2016; Heiskanen, 2019). Furthermore, importing pollinators may pose a risk for the wild and managed bee populations. A small local market might be particularly vulnerable to diseases spread by imported equipment and pollinators, such as queen bees or foreign bumblebees (Vairimaa, 2015). Elaborating on the risks further, Vesterlund described in her thesis:

> "Over 200,000 imported bee and bumblebee individuals (bumblebee numbers are not separately reported by the Finnish Food Safety Authority, Evira) to Finland yearly shows a wide interest in using commercial pollinators, and their use will most probably increase in the future. Thus, the opportunities for non-native pathogens and other disturbances linked to commercial pollination are likely to become more common in Finland, which further increases the need for efficient monitoring and controlling systems" (Vesterlund, 2015).

The authority responsible for the development of pollination services nationally is the Finnish Food Authority. Working together with SML ry, their ongoing program for the betterment of professional beekeeping in the country is the most hands-on action in the field. Their four-year plan for years 2019-2022 identifies education of beekeepers along with farmers and the public as a key objective. This is tied to the welfare of the agricultural sector, as the mission statement declares the bee economy to be a crucial part of agriculture in Finland, especially the pollination services provided by beekeepers. The program identifies challenges in developing professional beekeeping in the country, and key factors in addressing development are education, research, and collaboration among professionals. For concrete action outlined in improving pollination services, the program's two points are providing logistical support for moving beehives to the correct places and development of an online portal for supply and demand of the service to meet in one place (Ruokavirasto, 2019b).

According to the Finnish Food Authority, only 53 beekeepers had over 150 beehives in Finland in 2018. The same year there were a total of 3,200 registered beekeepers in

Finland with a growing trend in both categories since 2017. The beekeepers, with over 150 hives, have a total of 15,600 hives between them (Ruokavirasto, 2019b). The average age of all beekeepers in 2020 was reported to be 52 years, which has been decreasing and is forecast to do so still (Korpela, 2020; Ruokavirasto, 2019b). The high average age is striking considering the physical requirements for beekeeping labor. The cost of the service is highly physical, meaning the average pollinator is challenged in this. Depending on the materials opted for beekeeping, one wooden compartment may weigh as much as 8 to 10 kilograms - compared to a styrofoam one which weighs 1.45 kilograms. When being filled with honey and bees, one compartment weights from 17 to 26 kilograms (Korpi, 2017).

The survey on beekeepers' intentions around pollination services by Heliölä and Holopainen is still incomplete at the time of writing but offers the most recent quantifiable status of the state of pollination service providers in Finland. The data suggests the practice is extremely informal: 92% of Finnish beekeepers offering pollination services have a verbal contract or no contract at all with the farmer or producer they are offering it to. 98% of these beekeepers say their business is not their main occupation (2020).

To summarize the results collected by Heliölä and Holopainen's survey for the PÖLYHYÖTY project, the reasons that beekeepers reported for not providing pollination services were the small scale or early days of their beekeeping activities, too much work for insufficient compensation, lack of information and networks, economic unsustainability, unaware of general demand, concern for the health of their colonies due to pesticides, not enough hives to be used, sales work too time consuming, and farmers not appreciating pollination services. Overall, pollination services in Finland are poorly utilized in agriculture, and in cases where it is, the beekeeper rarely receives financial compensation (Heliölä and Holopainen, 2020). Providing pollination services can also increase the workload on a beekeeper in return for insufficient compensation. As farmers that cultivate rapeseed themselves operate in low-profit margins, they might be equally disincentivized to pay for pollination services (Vairimaa, 2015). Furthermore, the Finnish Food Authority bans beekeepers who would like to produce organic honey from offering pollination services due to issues about confirming if bees visit only organically produced crops (Manninen, 2015).

Recently, an edited volume of biodiversity research in Finland was published with a foreword calling for individuals, organizations, and decision-makers to work for a better future in the spirit of the publication (Mattila, 2020). The calls to action resound throughout the volume, making it the most recently available information to promote biodiversity in the Finnish economy and agricultural sector.

Pollinators are addressed directly in several chapters of the volume, offering an interesting insight into the intricacies of the Finnish environment and agricultural sector for managed pollinators. Research shows that domesticated honeybees are not the most efficient pollinators for food crops grown in Finland. Wild pollinators are equally important as their domesticated counterparts in this sense. Having more domesticated bees could raise their importance in food crop pollination. Actions suggested to the readers regarding promoting pollinator-friendly practices in agriculture are centered around individuals consciously modifying their consumer behavior and purchasing products from local farmers who embrace biodiversity in their agricultural practices (Toivonen, 2020). With the lack of action and the resulting collapse in pollination services and biodiversity, researchers raise the danger of rising food prices, a detriment to people's diet, and further negative outcomes as a result (Toivonen, 2020; Hiedanpää, Kniivilä, and Pouta, 2020).

The valuation of ecosystem services has been researched in Finland. Mainly focusing on studying ecosystem services of swamps, researchers have used a choice experiment approach, where a hypothetical market is defined for a survey, and respondents are asked about their potential preferences if their consumer choices could influence ecosystem services directly. A survey-based on such methods was conducted in 2016. Consumers were asked of their knowledge of ecosystem services and how much they would be willing to pay for services guaranteeing biodiversity for agriculture. Results showed the understanding of biodiversity varied greatly, and 34 % of respondents were willing to pay up to 500 EUR per year for ecosystem services guaranteeing agricultural biodiversity.

In the same survey, farmers were asked how much compensation they would require for producing these hypothetical services. A majority had high compensation demands, but 27 % of responding farmers had compensation demands lower than what surveyed consumers were willing to pay, showing potential for some farmers to produce ecosystem services, including pollination services in the form of beekeeping (Hiedanpää, Kniivilä, and Pouta, 2020).

3.2. Commercial Valuation of Bee-pollinated Crops in 2017-2018

The data obtained on the harvest and produce market prices show increased yields across the board, save for a few exceptions. The crops that have had lower production in the average annual harvests of 2017-18, compared to the 2008-10 average figures, are Turnip mustard and rapeseed, blackcurrant, and cucumber. As table 1 shows, all of these are highly dependent on insect pollination, yet all the ratios of honeybee pollination are less than 0.5.

In turn, the production of fava beans, apples, strawberries, lingonberries, and bilberries have increased by millions of kilograms each. Except for strawberries and fava beans, all of these crops are highly dependent on insect pollination. The highest ratio of honeybee pollination out of these is for apples at 0.6; lingonberries and bilberries both require the least honeybee pollination, both having a ratio of 0.1. The net value of honeybee pollination for apples has increased the most, with cucumber and raspberry close behind, all having their potential honeybee pollination value increased by over 2 million euros in the 2017-18 figures. Raspberry is also highly dependent on the insect (ratio 0.6) and honeybee (ratio 0.6) pollination.

The full calculations based on the formula discussed earlier can be found in Appendix I.

3.3. Themes Identified in the Literature Review

From the literature review, three key issues arose which affect pollination services. First, food security, involving the success and supply of food crops, has been noted to concern a large part of them. Pollinators in decline in the wild reflect on this issue becoming more prominent. Second, the overall decline of ecosystem services, the system which encompasses pollination services, is especially well noted in Europe, with EU institutions showing a clear rise in demand for pollination services in the wake of declining pollinators. Third, the lack of biodiversity is a barrier to improving pollinator health and wider adoption of managed pollination services, as academic literature is concerned.

In analyzing the state of beekeeping, three solutions are broadly presented as simultaneously solutions to improve the state of pollination services, and that can be directly helped by increasing the supply of pollination services. The first one, education in the general sense of raising pollinator awareness, has been suggested to be offered and directed at farmers, nature conservationists, and the public. This would ideally be in the form of highlighting the positive benefits and outright necessity of pollinators. This would help in promoting responsible decision making, consumer behavior, and agricultural practices that would benefit honeybees. Furthermore, education on what beekeeping is, and why and how it is practiced is identified as crucial in getting more people to take up the practice and thus increase the supply of pollination services in the market.

Second, decision-maker action has been encouraged on a general level from actors such as the EU and FAO. Policy and law are to be used as a tool to promote responsible decision making on a governmental level. With the issues being recognized in high places on the international stage, the largest push can be identified on the extra-national level with the stakeholders. However, especially as seen in the EU's lack of response on a member state level, there is a clear area for improvement in bringing political action to lower local levels.

Third, market-based drivers have been explored in the form of economic valuation of commercialized pollination services. As the major economic beneficiary of pollination services are the agrosystems producing the world's food supply, research has looked at how economic incentives can be employed to promote pollination services and practices to help preserve biodiversity. There is a noted rise in demand for pollination services, which is an encouraging sign for the continued development of commercializing pollination services offered by beekeepers. The most prominent example of this is almond farmers in the USA, whose crops depend on commercial pollination services, and manual pollinators in China, in areas where pollinators are extinct in the wild.

3.4. Case Study

Analyzing the state of the Finnish agricultural sector and the beekeeping industry, agriculture is a major part of the Finnish economy. What is concerning to see is that during a period of GDP expansion, the share of agriculture in it has been declining. As a major employer and consisting of many families owned farms, a continued contraction might produce devastating results on a national level. In a way, many of these farmers and practically all beekeepers are in the same boat competing against large corporations in the sector.

What is recognized as a reason for the sector's contraction is climate change, which affects pollinators heavily too. However, the current research on wild pollinators is in its infancy, with only estimates to run on and a volunteer-based project as the basis for a future nation-wide understanding of the situation. What these estimates do show is the urgency developing in regions with the most intensive farming practices; this bears unmistakable parallels with the dire lack of pollinators on USA's almond farms and the outright extinction of them in China's Sichuan province. On the grounds of the research of this thesis, it is irresponsible to suggest this is the direction the Finnish agricultural sector at large is taking now. Rather, the extreme examples should serve as a warning for the outcome of completely ignoring the situation.

What can be observed are harmful practices, with negative externalities that will be noticed in the short term. With nation-wide honeybee hives amounting to only 25 % of demand for pollination, farmers have turned to import pollinators from abroad, increasing the risk of the already small population of domestic pollinators. With the lack of supply also comes the surveyed lack of market knowledge among practicing beekeepers. Citing the lack of knowledge for their unwillingness to offer pollination services comes down to lack of education on not necessarily just beekeeping, but the economy and the markets for agricultural goods in general. The Finnish Food Authority's beekeeping program only identifies the need to develop knowledge of beekeeping and pollination services, and not economics. It is not surprising as such that the farmers' demand for pollination services has been answered by professionals whose primary operations are in larger markets outside of Finland. From the research conducted for this thesis, it is probable that the Finnish Food Authority's plan of action for aiding in hive logistics and developing digital tools to be used by disincentivized service providers appears to not be enough to generate economic incentives to promote the practice of pollination services. This is compounded with legal frameworks in place limiting honey producers in calling their produce organic as the Finnish Food Authority does not find pollination service bees' honey to satisfy their criteria. Just one example of how decision-maker inaction and incorrect action can constrict the practice greatly.

Positive development can be recognized, however. Survey data and academic research show the existence of direct consumer demand for pollination services as part of broad ecosystem services. Moreover, a small number of farmers are reported to be willing to take up the mantle for providing such services, pollination included. The emphasis on education is placed on the consumer. However, as Hiedanpää, Kniivilä, and Puota presented in the survey results, the consumer is potentially wildly unaware of the basics of biodiversity (2020). The assumption in the Finnish Food Authority's program further seems to be that the consumer is generally unaware, making calls to action for consumers to improve their purchasing behavior to be on shaky standing. It is probable that consumer education is needed in rather high amounts before positive externalities can be seen from investing in these actions. Education, as such, requires heavy support from market-based drivers and decision-maker action to improve the state of the industry.

The case of the Finnish agricultural sector exhibits the concerns of food security, lack of biodiversity, an overall decline in features very synonymous with overall results from academic research elaborated on in the literature review. The general solutions promoted in response to these issues are presented with heavyweight on education, a perplexing but unsurprising lack of decision-maker action (similar to what is seen across the EU member states), and with currently unrealized potential in market-based drivers.

4. DISCUSSION

Three key results of the thesis's research are inexorably intertwined:

In the economically declining Finnish agricultural sector, pollination dependent crop harvests have a higher market value than in the past and have risen when total GDP has risen.

Education, market-based drivers, and decision-maker action are not only helpful in promoting pollination services but a necessity in realizing their economic value.
The Finnish agricultural sector needs more pollination services and has identifiable features to improve upon market-based incentives for developing them.

In this chapter, I will discuss the findings as per each identified theme at the beginning of the research and explain the judgments I have made on the data and analysis.

Food security: The factors for the increased harvest value in pollination dependent crops are numerous and probably are not explainable by pollination alone (especially in the estimated pollinator decline). The key takeaway for this is that the potential to maximize the value of valuable crops has the potential of happening through widespread pollination practices. If the current supply of pollination services is at 25 % of the demand, imagine what could be done with four times the number of beehives in Finland with adequate management. Concerns for food security could be widely addressed with increased domestic crop production.

Ecosystem service decline: Pollination services may be only one piece of the ecosystem puzzle. However, with the economic action taken to improve upon, it would serve as a call to raise awareness for other vital ecosystem services. As Finnish research on pollination is conducted as part of broader ecosystem research, the spillover effect from valuing one ecosystem service could benefit them all. Not forgetting, of course, that researchers have already expanded into the territory of attempting to value other ecosystem services. It is a feature of the Finnish case that is a lesson other researcher could benefit from.

Lack of biodiversity: Not merely adopting pollination services for their main benefit would result in positive externalities. The observed benefits of pollination services for the entire ecosystem, adding more biodiversity promoting practices into the mix, would potentially raise the quality and value of Finnish agricultural products further. As established in the ecosystem service valuation literature, it is impossible to measure all of this in economic value, making it difficult to explain the practice to business owners concerned with bottom-line profit. Yet, as seen in Ethiopia, word of mouth on the benefits of pollination spread from farmer to farmer and resulted in further adoption of beekeeping. Not everything as such is necessary to formalize and explain, rather like the saying "let nature take its course."

Education: What has been recognized in studies by FAO is the critical role farmers play in adopting pollination services. In their examples from Ethiopia and Ghana, it was the farmers who take up beekeeping, unlike in the USA. Finnish farmers, in the minority, reported willingness to act in this capacity too. Collaboration among actors in Finnish agriculture could utilize these benefits fast. Mobilizing farmers in becoming beekeepers themselves is one approach which so far seems to have been unexplored in Finland.

Finland has long-standing traditions of formal education, which are reflected in the Finnish Food Authority's beekeeping program. The national strength could be turned to an advantage in this area, too, with mindfulness of the fact that this is not the only form of education to rely on.

FAO's survey of Ethiopian coffee farmers shows that local knowledge of ecosystems plays a critical role in continued cultivation. It is here where the lack of depth in the term ecosystem service can be pointed, and arguments for discussing and utilizing the concept Nature's Contributions to People to encompass more traditional knowledge beyond academic and economic research.

Market-based drivers: Lehtonen concluded that the commercialization of honeybee pollination could be considered as a reasonable option for farmers due to the encouraging values obtained in the value calculations. Even though the calculations did not contain all crops produced in Finland, the results were very promising. One key reason for increasing honeybee pollination is that it could ensure a large and good quality harvest for them. However, offering honeybee pollination as an ecosystem service would require a systematic and efficient approach (Lehtonen, 2012).

In Finland, the unique situation of research verified consumer demand for pollination services is a commodity that should not be wasted. If a business model for pollination service providers can be linked with the consumer directly, financial stability for the business would be on solid footing.

Decision-maker action: The USA’s government compensation for colony winter deaths serves as an example of how to incentivize producers. Not only is it ensuring the continuity of business, but it is no doubt beneficial for replenishing pollinator numbers in the event of numerous colonies dying offseason. In Finland, the compensation offered to beekeepers in spreading mold repellent shows that adopting proactive financial incentives is a realistic possibility in the legal and business environment beekeepers are part of. Enhancing these practices, along with eliminating legal barriers, are what Finnish decision-makers can do.

4.1. Suggestions for Further Research

The limitations of secondary data research are mainly the lack of original, perhaps more suitable data being produced to serve the specific purposes of the research (OxbridgeEssays, 2020). The topics explored in this thesis might have benefitted from conducting more purposeful surveys on beekeeping and agriculture professionals in Finland to produce more accurate data.

Future research on the topic should focus on evaluating future business models for pollination services drawing on the analysis in this thesis. Knowledge of the opportunity can serve as a key driver in establishing businesses, especially when barriers to entry to the market are low.

Work must continue with farmers to enable their independent development of pollination services and beekeeping. There is a vast knowledge bank of best practices available, which are applicable to the Finnish agricultural sector in many ways. As farmers are people with their own established businesses, it might even prove easier to develop the farming business models rather than develop beekeepers' informal businesses based primarily on bee products.

Collaboration between beekeeping and farming communities is another area that requires renewed focus. Qualitative research on beekeeping and farming business cultures can help identify further commonalities and help in finding a mutual understanding of compensation for pollination service providers.

As mentioned in the previous section, formal education is not the only way to educate stakeholders. Further market research on who are the most likely end consumers of agricultural products that would pay for a share of pollination services would also be necessary to kickstart further market-based drivers for pollination services.

With knowledge I have gathered here, it would have been beneficial at the beginning of the research to ensure the consistency of the statistics available and handpicked only the information from past research that had exactly the corresponding data available in the present day. An example of this is Lehtonen's research data (2012). This can be further noticed in inconsistent monitoring of beekeepers in Finland but not the importers of bumblebees. Beekeeping is well monitored, but it seems anyone can order bumblebees from the Netherlands. It is discrepancies like these that make creating a complete picture of the situation, all the way from the status of pollinators in Finland, extremely hard.

CONCLUSION

In this thesis, I have completed a literature review of pollination services in attempting to reach my goal of evaluating the possibilities for the wide-scale adoption of pollination services in Finland and suggesting concrete steps to take to achieve this. My literature review uncovered several key themes involving the practice of pollination services. These were in two groups: issues affecting pollination services and potential solutions to solve these issues. The first category's themes were concerns about food security, lack of biodiversity, and ecosystem service decline. The second category's solutions were education, market-based drivers, and decision-maker action.

I chose to evaluate the data collected in the case study of the Finnish agricultural sector with a qualitative study of data. I found out that Finnish research and industry actions were aligned well with the overall challenges on pollination services identified in my themes. The solutions were aligned to a degree, with a heavy emphasis placed on forms of education, and seemingly lacking on decision-maker action and market-based drivers. What my analysis uncovered was evidence of market-based driver preconditions existing in Finland, most notably with researched consumer demand for ecosystem services.

I also conducted an update to calculations completed in previous research on the economic value of honeybee pollinator-dependent crops in Finland to discover that their value has increased since the last measurements. Most notably, this has happened in a time when the Finnish agricultural sector has experienced a contraction in GDP value.

With my key findings, I discussed suitable steps to take in realizing the economic value of pollination services about my identified themes. From there, I suggested ideas for further research to uncover more ways to support these suggested actions.

The information presented in this thesis is useful for key stakeholders, namely beekeepers, farmers, decision-makers, and consumers, in understanding the importance of pollination services for the environment and our economy. Academic researchers can lean on my findings in taking research of ecosystem service valuations to a practical level and apply more thorough economic analysis to begin paving a way for a new field of research in commercializing pollination services. Applied knowledge of the field can further benefit ecology via case examples of how utilizing the forces of the private sector in preserving ecosystems by tying their success to profit and prosperity. What was earlier on an abstract level, like evaluating the value of biodiversity, can be said to be on a more tangible level. All of this represents the seriousness of this once in a lifetime opportunity to learn from past mistakes to secure a sustainable future for the benefit of future generations. We might be late to begin but not too late to make a difference.

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Appendix 1: Updated Pollination Valuation Calculations for Food Crops Grown in Finland

Table 1. Calculated averages of crop dependencies on insect pollination and honeybee pollination. Based on Lehtonen, 2012.

Crop	Crop dependency on insect pollination (Lehtonen, 2012)	Crop dependency on honeybee pollination (Lehtonen, 2012)
Turnip mustard and rapeseed*	0.5	0.2
Fava bean	0.3	0.4
Apple	0.9	0.6
Blueberry	1.0	1.0
Blackcurrant	0.7	0.3
Redcurrant	0.7	0.2
Strawberry	0.2	0.3
Raspberry	0.6	0.6
Cucumber	0.9	0.4
Zucchini	0.9	0.6
Lingonberry	1.0	0.1
Bilberry	1.0	0.1

**combined average based on Lehtonen's (2012) figures*

Table 2. Average prices of each crop in euros per kilogram
Composed by the author based on Luke 2020, VYR 2020, Ruokavirasto 2019, Mavi 2017, Kasvitieto 2020

Crop	2017 average price (€/kg)	2018 average price (€/kg)	Average (€/kg)
Turnip mustard and rapeseed	0.383	0.355	0.369
Fava bean*	-	-	0.226
Apple	1.64	1.478	1.559
Blueberry	10.241	11.297	10.769
Blackcurrant	3.342	3.248	3.295
Redcurrant	2.632	2.522	2.577
Strawberry	5.724	6.059	5.8915
Raspberry	10.043	10.159	10.101
Cucumber	0.962	0.961	0.9615
Zucchini	0.904	0.842	0.873
Lingonberry	0.88	1.56	1.22
Bilberry	1.82	1.87	1.845

**with no available long-term data of the fava bean, the average has been calculated from prices reported in week 11 (beginning March 9th), 2020.*

Table 3. Harvest sizes in 2017 and 2018 for selected crops
Composed by the author based on Luke 2020, VYR 2019, Mavi 2017, Ruokavirasto 2019

Crop	2017 Harvest (tonne)	2018 Harvest (tonne)	Average harvest (tonne)
Turnip mustard and rapeseed	91,200	70,900	81,050
Fava bean	24,100	33,700	28,900
Apple	6,758	7,196	6,977
Blueberry	135	128	131.5
Blackcurrant	402	990	696
Redcurrant	401	366	383.5
Strawberry	13,785	15,333	14,559
Raspberry	1071	949	1,010
Cucumber	7,233	9,140	8,186.5
Zucchini	1,455	1,406	1,430.5
Lingonberry	5,243	2,076	3,659.5
Bilberry	3,617	5,855	4,736

Table 4. Total potential honeybee pollination in euros
Composed by the author based on Lehtonen 2012, Luke 2020, VYR 2019 & 2020, Mavi 2017, Ruokavirasto 2019

Crop	Potential value of honeybee pollination (€/kg)	Average crop market value (€)	Total potential value of honeybee pollination (€)
Turnip mustard and rapeseed	0.03	29,907,450.00	2,691,670.50
Fava bean	0.03	6,531,400.00	783,768.00
Apple	0.87	10,877,143.00	6,036,814.37
Blueberry	10.77	1,416,123.50	1,416,123.50
Blackcurrant	0.66	2,293,320.00	458,664.00
Redcurrant	0.36	988,279.50	138359.13
Strawberry	0.3	85,774,348.50	4,288,717.43
Raspberry	3.64	10,202,010.00	3,672,723.60
Cucumber	0.33	7,871,319.75	2,728,724.18
Zucchini	0.49	1,248,826.50	699,342.84
Lingonberry	0.12	4,464,590.00	446,459.00
Bilberry	0.18	8,737,920.00	844,665.60

Table 5. Aggregated market values of honeybee pollination and total crop
Composed by the author based on Lehtonen 2012, Luke 2020, VYR 2019 & 2020, Mavi 2017, Ruokavirasto 2019

Aggregated market value of selected crops (€)	Aggregated value of honeybee pollination (€)	Aggregated crop value not dependent on honeybee pollination (€)
170,312,730.80	24,206,032.14	146,106,698.60

Table 6. Development of values between Lehtonen's (2012) research on 2008-2010 averages vs. 2017-2018 averages.
Composed by the author based on Lehtonen 2012, Luke 2020, VYR 2019 & 2020, Mavi 2017, Ruokavirasto 2019

Crop	Harvest growth (annual average) (tn)	Market price development (€/kg)	Harvest market annual value development (€)	Development of annual potential honeybee pollination value (€)
Turnip mustard and rapeseed	-54,650.00	+0.045	-14,092,550.00	-6,378,329.50
Fava bean	+12,600.00	+0.041	+3,531,400.00	+383,768.00
Apple	+2,706.00	+0.259	+5,277,143.00	+2,996,814.37
Blueberry	+57.50	+2.169	+616,123.50	+816,123.50
Blackcurrant	-517.00	+1.595	+293,320.00	+58,664.00
Redcurrant	+140.50	+0.877	+588,279.50	+78,359.13
Strawberry	+3,554.00	+2.2915	+46,674,348.50	+1,988,717.43
Raspberry	+466.70	+2.701	+6,202,010.00	+2,172,723.60
Cucumber	-933.50	+0.1615	+171,319.75	+2,698,724.18
Zucchini*	-	-	+448,826.50	+299,342.84
Lingonberry	+2,959.50	+0.12	+3,664,590.00	+366,459.00
Bilberry	+3,936.00	+0.245	+7,537,920.00	+724,665.60

**harvest size and market price from 2008-2010 unavailable. Calculations based on total market value of the harvest*