Ref. Ares(2022)4051232 - 31/05/2022

Economic efficiency analysis of beekeeping in the EU and the role of health and environment

Deliverable D4.4

31 May 2022

Dana Freshley[1], Ludwig Lauwers[1], Fátima Alves[2], Claudina Martins[2] and Wim Verbeke[1]

1 Ghent University (UGENT); 2 University of Coimbra (UCOI)

B-GOOD

Giving Beekeeping Guidance by cOmputatiOnal-assisted Decision making

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817622.

Prepared under contract from the European Commission
Grant agreement No. 817622
EU Horizon 2020 Research and Innovation action

Project acronym:	**B-GOOD**
Project full title:	**Giving beekeeping guidance by computational-assisted decision making**
Start of the project:	June 2019
Duration:	54 months
Project coordinator:	Prof. Dirk de Graaf Ghent University www.b-good-project.eu
Deliverable title:	Economic efficiency analysis of beekeeping in the EU and the role of health and environment
Deliverable n°:	D4.4
Nature of the deliverable:	WP4
Dissemination level:	Public Report
WP responsible:	WP4
Lead beneficiary:	UGENT
Citation:	Freshley, D., Lauwers, L., Alves, F., Martins, C. & Verbeke, W. (2022). Economic efficiency analysis of beekeeping in the EU and the role of health and environment. Deliverable D4.4. EU Horizon 2020 B-GOOD, Grant agreement No. 817622.
Due date of deliverable:	Month n°36
Actual submission date:	Month n°36

Deliverable status:

Version	Status	Date	Author(s)
0.1	Draft	11 May 2022	Freshley, Lauwers, Alves, Martins, Verbeke
0.2	Review	30 May 2022	Williams, De Smet
Final	Final	31 May 2022	Freshley, Lauwers, Alves, Martins, Verbeke

Table of contents

Preface

WP4 aims to map the business environment and identify key socio-economic components of healthy and sustainable beekeeping in the EU. It investigates how stakeholders and beekeepers assess and might overcome the complexities of their beekeeping business environment. It also sets out to evaluate the production efficiency, the hive and health management decisions by beekeepers, and their personal, environmental and managerial determinants as the key to identify viable, healthy and sustainable business models of EU beekeeping.

This Deliverable (D4.4) is the fourth of five deliverables from WP4 'Socio-Economic Drivers'. It presents a set of results from 'Task 4.2: Beekeepers' attitudes, management decisions, production efficiency and determinants'. The previous deliverable, D4.3: EU beekeepers' views, opinions and attitudes towards healthy and sustainable beekeeping, reported on the first part of results from the B-GOOD WP4 pan-European beekeeper survey, whereas this deliverable (D4.4) presents the second part of results from the same survey, with a specific focus on economic data. Therefore, acknowledgements, methodology, and some results from that survey are the same as the previous Deliverable D4.3.

Like D4.3, the insights presented will support and contribute to the data pool of the Health Status Index for honeybees (HSI) and health assessment methodology in other WPs of B-GOOD. The insights will also feed into 'Task 4.3: Business models for sustainability', which aims to identify potential and viable future business models for sustainability for EU beekeeping.

This deliverable contains results from two separate beekeeper surveys, one survey (n=40) for which the fieldwork data collection was conducted from 4 December to 17 December 2020, and one survey (n=844) for which the fieldwork data collection was conducted from 8 October 2021 until 10 January 2022. The aim of the first survey was to give guidance and exploration for the second survey. This deliverable is divided into five sections: 1) Background and objectives, 2) Materials and methods, 3) Results – First wave exploratory beekeeper study (n=40), 4) Results – Second wave beekeeper study (n=844) and 5) Conclusions.

Summary

B-GOOD is a multi-disciplinary project committed to providing solutions to the diverse problems in the EU beekeeping sector, particularly also designing innovative technologies that help keeping healthy colonies and implementing healthy and sustainable business strategies. This report presents the latest developments of the B-GOOD Work Package 4, particularly Task 4.2: Beekeepers' attitudes, management decisions, production efficiency and determinants. Task 4.2 focuses specifically on EU beekeepers. The goal of this task is to map and interlink beekeepers' health-related management decisions to their personal characteristics such as their socio-demographics, attitudes and orientations towards beekeeping, economic performance and beekeeping management characteristics.

To achieve this, data collection from beekeepers was done in two waves. In the first wave, an intake survey was given to a sample of 40 beekeepers covering the 5 EU countries involved

in Field Study A, for which the survey data collection was conducted from 4 December to 17 December 2020. This first study gathered information on beekeeper socio-demographics, attitudes and orientations towards beekeeping, economic performance, honeybee colony health, and ecological-environmental characteristics.

In a second study, a larger pan-European sample of 844 beekeepers was surveyed for which the fieldwork data collection was conducted from 8 October 2021 until 10 January 2022.

The aim of the first wave survey was to give guidance and exploration for the second wave survey. The second wave study gathered similar information as the first study: beekeeper socio-demographics, attitudes and orientations towards beekeeping, economic performance, honeybee colony health, and ecological-environmental characteristics, as well an additional section on general beekeeping management which was not included in the first study.

Whereas the previous deliverable, D4.3 focused on presenting results on beekeeper socio-demographics, attitudes and orientations towards beekeeping, honeybee colony health and management practices, this deliverable, D4.4, focuses on economic performance and ecological-environmental characteristics. Therefore, the results in this deliverable are not separate from but build on the results of D4.3. The insights from D4.3 together with the additional information on economic performance and ecological-environmental characteristics will further help to identify the key socio-economic components of healthy and sustainable beekeeping.

Key findings indicate that environmental quality and perceived climate change impact may be associated with being an efficient and productive beekeeper. Beekeeper type (either hobby or professional), European region, and beekeeping experience emerged as important socio-economic factors contributing to healthy and sustainable beekeeping.

1. Background and objectives

Bees are critically important in the environment as they sustain biodiversity by providing essential pollination for a wide range of wild plants (Edwards et al., 2018; FAO, 2008). They contribute to human wealth and wellbeing directly through the production of honey and by providing pollination to the majority of crops grown in the European Union (EFSA, 2021). However, European beekeepers have reported increasing colony losses and weakening of bee numbers, varying from 5.8% to 32.0% annually (Gray et al., 2020). No single cause of declining bee numbers has been identified, however several possible contributing factors are intensive agriculture, pesticide use, environmental changes, viruses and poor hive management.

Hive management practices have been identified as a key factor in colony losses and honeybee health (EIP-AGRI, 2019; Rivera-Gomis et al., 2019; USDA, 2013). More particularly, the interaction of socio-economic factors such as beekeepers' demographic background, their management styles as well as their productivity and efficiency are all hypothesised to relate to colony loss.

The role of beekeeper background, knowledge, experience, and management practices have been shown to influence honeybee colony survival (Jacques et al., 2017). Studies such as Glăvan (2014) and Vural and Süleyman (2009) dealt with how the socio-economic profile of beekeepers influences honey production. Several other studies confirmed that environmental conditions together with beekeeping management determine *Varroa destructor* infestations in honeybee colonies (Giacobino et al., 2017; Pohorecka et al., 2014), but also indicated that the interplay between different sets of determinants is complex. Other studies assessed economic performance, though only in single EU countries or regions (Ceyhan, 2017; Gürer & Akyol, 2018; Makri et al., 2015). Although there is evidence of interactions between socio-economics and honeybee health, there is a need to better understand this interaction in order to give better management advice.

A better understanding of socio-economics of beekeeping was gained in D4.3, where the associations between beekeeping characteristics, beekeepers, motivations, beekeepers attitudes, beekeepers' management practices and colony health was described. While these insights provide a better picture of the role of socio-economics in beekeeping management in Europe, this deliverable addresses a key missing piece to the puzzle: economic performance of beekeeping. Assessing the economic performance of beekeeping is very important to understanding the management decisions made by beekeepers. Learning about the differences in economic performance can help to identify and profile beekeepers for tailored advice, recommendations and communication with maximum potential effectiveness and impact.

This deliverable therefore uses Data Envelopment Analysis (DEA) to measure efficiency within a group of beekeeping firms with multiple inputs and multiple outputs. DEA will also be used to analyse differences between beekeepers' input-output transformation to determine links between productivity, the quality of the surrounding ecological environment, and bee health. Beekeepers differ in input use, especially between hobby and professional beekeepers, but have similar outputs such as honey, other apiary products and/or the provision of pollination services. This difference in input use can be helpful to examine differences in beekeeping management styles.

The objectives for this deliverable can be split into two overarching goals.

1) The **first** is to provide a detailed production efficiency analysis of beekeeping in the EU, including an assessment of the association between economic performance and ecological-environmental characteristics as well as colony health status.
2) The **second** is to identify the key socio-economic components of healthy and sustainable beekeeping.

The first objective will be addressed using novel results presented in this deliverable, whereas the second objective will be addressed in combination with the results from D4.3, for example by using the Good Beekeeping Management Practices Index presented in D4.3 to compare with productivity and efficiency.

More specifically, this Deliverable 4.4 uses two pan-European quantitative surveys (n=40 and n=844) to explore the relationships between four components:

1) Socio-demographic variables and beekeeper/beekeeping characteristics
2) Economic performance in beekeeping
3) Honeybee colony health
4) Ecological-environmental characteristics

Results from the first component, socio-demographic variables and beekeeper/beekeeping characteristics and the third component, honeybee colony health, have already been reported from the second wave survey in D4.3, therefore some information may be repeated. Additionally, other information reported in D4.3 from the second wave survey such as beekeeper segments may also be repeated in order to assess these taking the additional component of production efficiency into account. Results from the first wave survey have not been reported in any deliverable until now.

1.2 Production economics and the purpose of Data Envelopment Analysis

As this deliverable's main focus is the economic and production efficiency of beekeeping, it is necessary to provide a background in the used methods of performance measurement. These methods can be applied to a variety of beekeeping operations. It is important to first define the terms **productivity**, **intensity** and **efficiency**, which are often used interchangeably but are not precisely the same things. We begin by defining **productivity** as the ratio of the output(s) that it produces relative to the input(s) that it uses, hence productivity = outputs/inputs.

When there is more than one input (which is often the case) then a method for aggregating these inputs into a single index of inputs must be used to obtain a ratio measure of **total** productivity, which is a measure involving all factors of production. Other measures of productivity such as labour productivity (kg of honey per man-day) or hive productivity (kg of honey per hive) in the case of beekeeping, are called **partial** measures of productivity. **Intensity,** on the other hand, is a measure of the resources needed for the production of a unit of a good or service = inputs/output, such as man-days per kg honey or man-days per hive.

A production frontier is used to define the relationship between the input and the output (see Fig. 1). The production frontier represents the maximum output attainable from each input level. Businesses operate either on that frontier, if they are technically efficient, or beneath the frontier if they are not technically efficient. Point *A* represents an inefficient case whereas points *B* and *C* represent efficient cases. Point *A* is inefficient because technically it could increase output to the level of point *B* without requiring more input.

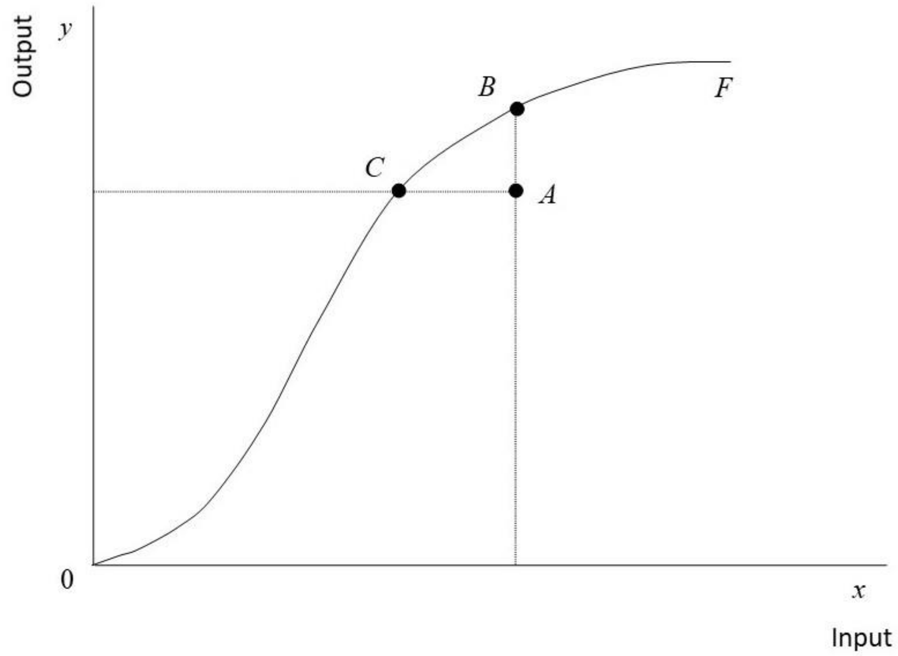

Figure 1. Graphical representation of production frontiers and technical efficiency

Extending this type of graphical analysis to a multiple input case is difficult, therefore it is common practice to plot the relationship between two of the variables while holding all others fixed. Fig. 2 represents a two-input production function and the relationship between the inputs x_1 and x_2 while holding the output fixed at the value q^0. The relationship between the two inputs when output is fixed at the values of q^1 and q^2, where $q^2 > q^1 > q^0$ are also plotted in Fig. 2. The curves in the figure are known as output isoquants, referring to the concept of 'equal quantities'. The slope (in a point) of the isoquant is known as the marginal rate of technical substitution (MRTS) which measures the rate at which x_1 must be substituted for x_2 in order to keep output at its fixed level.

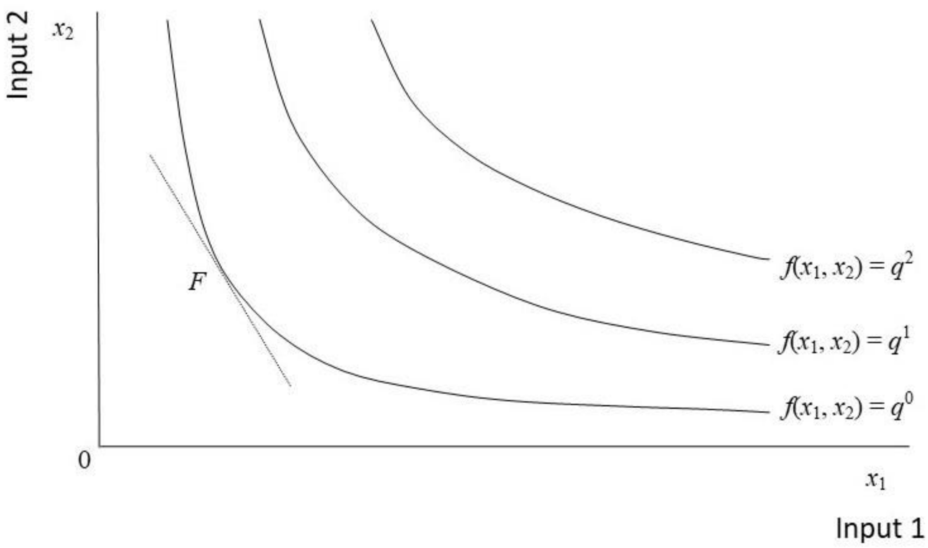

Figure 2. Graphical representation of output isoquants

The curve to the most northeast gives all combinations of x_1 and x_2 capable of producing the output level q^2, and is drawn to the northeast of the q^1 isoquant because q^2 requires more inputs. The slope of the isoquant at *F* represents the marginal rate of substitution at *F*. This visual representation is an effective way to understand the relationship between two inputs, however if we want to further understand the existence, if any, of excesses in inputs and shortfalls in outputs especially between individual firms, we must turn to input slacks. Fig. 3 illustrates efficiency measurements and input slacks, where the firms using input combinations *C* and *D* are the two efficient firms that define the frontier, and firms *A* and *B* are inefficient firms.

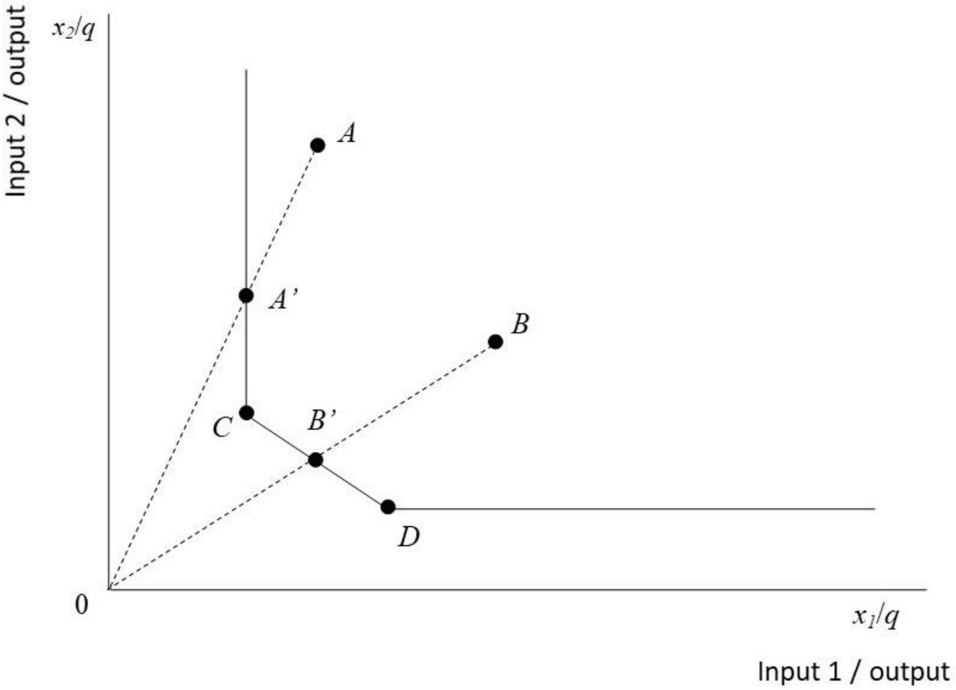

Figure 3. Graphical representation of efficiency measurement and input slacks

In Figure 3, firms *A* and *B* could reduce the amounts of inputs x_1 and x_2 and move to the frontier to become technically efficient, thus becoming *A*' and *B*'.

Efficiency is defined as the ratio between the weighted sum of outputs and that of inputs. Efficiency can be mathematically calculated using many different methods of which Data Envelopment Analysis (DEA) is a principle method. The most basic form in DEA to derive efficiency measures and the one used in the computer software DEAP (Coelli, 2008) is the following:

$$\min_{\theta,\lambda} \theta,$$
$$\text{st} \quad -q_i + Q\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0,$$

where θ is a scalar and λ is a *1*x1 vector of constants, subject to the constraints that all efficiency measures must be less than or equal to one. The value of θ obtained in the efficiency score for the *i*-th firm. It satisfies $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient firm.

As we aim to better understand the differences between beepeeking operations characterised by different beekeepers' management styles, DEA is used in this study to explore differences between beekeepers' operations and differences in their inputs and outputs. DEA is traditionally a tool for comparative analyses that assumes **homogeneity** across firms (Coelli et al., 2005), where all firms are assumed to be engaged in the same production process and are operating under similar conditions. However, beekeepers in our sample are not homogenous at all, and the European beekeeping sector is characterised by high diversity in production objectives and processes (Moore & Kosut, 2013; Velardi et al., 2021), as well as environmental conditions.

We therefore do not use DEA primarily for comparative analysis but rather as an exploratory tool to better understand **heterogeneity** between beekeepers. In this way, productivity and efficiency analysis offers an original angle to explore differences between beekeepers. This might seem like an improper use of DEA, however taking heterogeneity into account allows more targeted descriptions of farms or beekeepers (Ahikiriza et al., 2021; Ding et al., 2018; Espinoza et al., 2018; Rahman et al., 2019), which will serve the purpose of identifying and describing viable business models for healthy and sustainable beekeeping in the EU in the final phase of this B-GOOD research project.

2. Materials and methods

2.1 First wave beekeeper intake survey (n=40)

2.1.1 Study questionnaire

The so-called 'first wave beekeeper intake survey' is the survey used during the recruitment and enrolment of beekeepers for WP1's Tier 2 / Field Study A experimental study. The intake survey aimed to gather information on beekeeper socio-demographics, attitudes and orientations towards beekeeping, economic performance, honeybee colony health, and ecological-environmental characteristics. Hence, the structure of the survey was as follows:

Section 1. Demographics
Section 2: Economic performance in beekeeping
Section 3: Attitudes and orientations towards beekeeping
Section 4: Intention of beekeepers to use Internet of Things (IoT) technology
Section 5: Views on honeybee health
Section 6: Quality of the natural environment
Section 7: Expectations from taking part in the research

Sections 1, 2 and 6 (in bold) are reported in this deliverable, whereas the other sections fall outside of the scope of this deliverable and will be used in future activities and reporting in conjunction with WP1 and WP8.

The survey section on the economic performance in beekeeping asked beekeepers to provide data on their beekeeping operations for the year 2020. A copy of the questionnaire, including all economic questions asked are provided in Appendix 1. In all economic questions, beekeepers were asked to place a 0 in questions that did not pertain to them. For questions asked in monetary units, beekeepers were asked for values in either euros or Swiss francs, in the case of Swiss beekeepers, and were converted to euros before analysis.

2.1.2 Testing phase

An English version of the survey was distributed to 5 select B-GOOD partners for feedback. After this feedback was incorporated, the English version was translated to Dutch and both language versions were programmed into Qualtrics. The online English version was tested by 2 B-GOOD partners in the Netherlands and 7 B-GOOD partners in Gent, and the online Dutch version was tested by 1 B-GOOD partner in Gent and 5 B-GOOD partners in the Netherlands. Testers were invited to give feedback on what went well, what was difficult, and any suggestions they may have had for improvement. The testing phase ran from 19 October 2020 until 9 December 2020.

2.1.3 Translations

Following slight changes made to the English and Dutch versions after testing, the survey was translated into Finnish, French, German and Italian by B-GOOD partners. The survey was not distributed in English but rather in Dutch, Finnish, French, German and Italian. The English version was used as a starting point and as an effective way to gather feedback from all B-GOOD partners. All additional four language versions were then programmed into Qualtrics, a survey management software.

2.1.4 Sampling and survey distribution

Beekeepers for the first wave intake survey consisted of selected Tier 2 beekeepers by 5 regions/partners within B-GOOD; 1) Wageningen Research, Netherlands, 2) Universitaet Bern, Switzerland, 3) Martin-Luther-Universitaet Halle-Wittenberg, Germany, 4) BeeSources di Raffaele Dall'Olio, Italy and 5) Suomen Mehiläishoitajain Liitto, Finland.

For the selection of Tier 2 beekeepers, each of the 5 partners mentioned above has selected 8 experienced beekeepers from their region to participate. The beekeepers were selected based on 3 criteria: type of beekeeper, experience of the beekeeper and location of the apiary.

1) Type of beekeeper: minimum 1, maximum 2 professional beekeepers in each country. Tier 2 partners estimate whether or not to include a beekeeper as a professional beekeeper. This takes into account a bias, as a pre-selection has been made based on the insights of the Tier 2 partners.
2) Experience of the beekeepers - it was envisaged that half of the beekeepers will have 3 to 5 years of experience (new generation) and half of the beekeepers will have 20 or more years of experience (established generation). Years of experience was given only as a guideline and not as a strict rule.

3) Hive location - the sample was intended to reflect the diversity of landscapes in each country (flowers, elevation, etc.).

After these 8 beekeepers were selected by B-GOOD partners in each of the 5 countries, a personal survey link was created for each beekeeper using their email address, and the link was sent to them by email. Data collection began on 4 December and all 40 beekeepers completed the survey by 17 December 2020.

2.1.5 Data handling and ethics approval

Information collected during this study was pseudonymised and the key assigned to each beekeeper is only accessible to the investigators. Only pseudonymised data is used for analysis and in any type of documentation, reports or publications concerning this study. The controller of the data is Ghent University as the host institution of the principal investigator of the study. Ethics approval for this beekeeper survey was obtained on 24 November 2020 by the UZ Gent / UGent Medical Ethics Committee under application number **BC-08578** (see Appendix 3).

2.1.6 Sample composition

All 40 beekeepers selected by B-GOOD partners (8 beekeepers in each of the five countries) provided responses to the survey. Since non-parametric approaches like data envelopment analysis are very sensitive to the quality of data used, the economic data provided by the 40 beekeepers was carefully checked to identify outliers. The three main reasons for the presence of outliers are 1) typographical errors, 2) invalid observations and 3) unusual observations that are real outliers. The following procedures were used to identify outliers: looking for zeros in the data and checking whether these are meaningful, checking suspect data with alternative sources like beekeeping experts within the B-GOOD consortium, and checking basic ratios such as kg of honey per unit of labour and kg of honey per number of hives.

After these procedures it became clear to exclude five outliers: four beekeepers entered 0 for labour, and one beekeeper entered no economic data. Aside from these five cases with invalid data, three beekeepers needed their data to be corrected due typographical errors. Two beekeepers reported man-hours instead of man-days: one was corrected from 1500 man-hours to 188 man-days, and the other was corrected from 320 hours to 40 man-days. One beekeeper reported producing the unrealistic output of 100,000 kg of honey with 380 hives which was corrected to 10,000 kg, in which it is likely that an extra 0 was added by accident. This initial cleaning brought the valid dataset down from 40 to 35 cases.

2.2 Second wave beekeeper survey (n=844)

2.2.1 Study questionnaire

The second wave beekeeper survey (see Appendix 2) aimed to gather information for the previous Deliverable 4.3, as well as this Deliverable 4.4 (also within Task 4.2) and Deliverable

4.5 (within Task 4.3). Therefore, the objectives of the survey were broader than the objectives addressed in this deliverable alone.

The survey contained a total of 72 questions divided in eight sections:

Section 1: Socio-demographic variables and beekeeper/beekeeping characteristics
Section 2: Economic performance in beekeeping
Section 3: General beekeeping management
Section 4: Honeybee colony health
Section 5: Digital technology in beekeeping
Section 6: Beekeeper orientations towards honeybees
Section 7: Environmental quality
Section 8: Intention to use hive monitoring technology in beekeeping

Findings related to Section 1, Section 3, Section 4, and Section 6 were reported in the previous Deliverable 4.3, and some of the information from these four sections will be repeated in this deliverable in order to provide readers with a complete picture of key sample characteristics. Findings related to **Section 2** and **Section 7** are newly reported in this Deliverable 4.4. Section 5 and Section 8 fall out of the scope of this deliverable and will be used in future activities and reporting in conjunction with WP1 and WP8.

As the first wave survey asked beekeepers to report their (economic) data for the year 2020, the second wave survey asked beekeepers to report their (economic) data for the year 2021 (i.e. in both cases referring to the most recent and completed bee season). A copy of the questionnaire, including all economic questions asked are provided in Appendix 2. Similar to the first wave survey, in all economic questions beekeepers were asked to place a 0 in questions that did not pertain to them. Beekeepers were asked to specify their national currency and subsequently answer all economic questions in that currency. All currencies besides euros (Danish krone, Polish złoty, Romanian leu, Pound sterling, Bulgarian lev, and Swiss franc) were converted to euros before analysis.

Some questions in the economic section of the survey were amended based on evaluation and critique of the first wave survey, such as better formulation of questions regarding the selling price of honey and questions regarding labour. Details of these changes are documented in Appendix 5.

2.2.2 Testing phase

A test version of the survey was created in Qualtrics and the link was distributed to selected members of the B-GOOD consortium. All B-GOOD researchers who are personally also beekeepers were invited to participate as testers. The test survey provided an opportunity for B-GOOD consortium members to give detailed feedback on each survey section. In the test version, a comment box was provided at the end of each section where B-GOOD consortium members were invited to give feedback on what went well, what was difficult, and any suggestions they may have had for improvement. The testing phase ran from 27 July 2021 until 10 August 2021. A detailed description of the feedback that was received from survey testers is provided in Deliverable 4.3.

2.2.3 Translations and web-programming

Survey questions are most effective when they are precise and clearly contextualised, short and formulated in simple language, and when the terms used cannot be misinterpreted. Therefore, it was very important to have experts in beekeeping translate the survey to avoid misinterpretation of technical terms. The informed consent literature and master questionnaire were first developed in English, and then translated into 11 additional languages: Dutch, Danish, Finnish, French, German, Italian, Polish, Portuguese, Romanian, Spanish, and Bulgarian by B-GOOD partners who are native speakers in each country and are familiar with practical beekeeping and related terminology. The multilingual survey allowed respondents to be reached in the language they were most comfortable with, while still allowing results to be analysed together as a single data set after merging data from the individual language versions. Translations of the surveys and further pre-testing of the translated versions ran from 16 August to 30 August 2021. All language versions were web-programmed in the online survey software Qualtrics.

2.2.4 Sampling and survey distribution

The initial target for this study was to attain a minimum of 600 completed surveys, covering beekeepers located in Northern / Southern / Eastern and Western regions of Europe, reflecting different geographical, climatic and cultural influences within European beekeeping. The twelve language versions of the questionnaire were produced with the aim to distribute the survey among beekeepers in the following 14 countries:

1. Belgium (Dutch, French and German)
2. Denmark (Danish)
3. Finland (Finnish)
4. France (French)
5. Germany (German)
6. Italy (Italian)
7. The Netherlands (Dutch)
8. Poland (Polish)
9. Portugal (Portuguese)
10. Romania (Romanian)
11. Spain (Spanish)
12. United Kingdom (English)
13. Bulgaria (Bulgarian)
14. Switzerland (German, French, Italian)

A website was created with the link: **bgoodwp4.ugent.be**, which provided a selection button to each language version on the same webpage (see Figure 4). After a language button was clicked, the participant was directed to a page with the downloadable information sheet for participants and the informed consent form, and a button to start the survey (see Figure 5). This allowed the same link to be easily distributed to multiple countries regardless of language spoken.

Figure 4. Webpage under the link bgoodwp4.ugent.be used for survey distribution

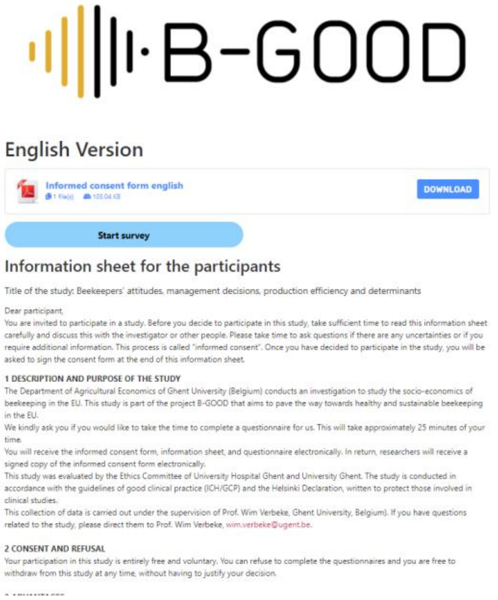

Figure 5. English version of the downloadable information sheet and "start survey" button

The web link was aimed to be distributed to beekeepers in each of the 14 countries in the following four phases:

1) First, the link was distributed to national beekeeping associations in each of the 14 countries with the help of B-GOOD partners in each country, requesting that they place the link in their monthly newsletters, send the link directly to their members by email, or post the link on their Facebook page.
2) Second, beekeeper contacts of involved partner institutions were utilised. This included newsletters from research institutions that targeted beekeepers.
3) Third, personal contacts of B-GOOD consortium partners were utilised.
4) Fourth, broader social/mass communication channels of B-GOOD were utilised.

Recruitment has been actively done in all countries with the exceptions of Spain and Denmark for the following reasons. Since there are no B-GOOD partners located in Spain, our network there was limited. The coordinator of the B-GOOD project, Prof. Dirk de Graaf, had a prominent contact in Spain who had contacts at the Asociación Veterinarios (ESPA) and the Asociación Española de Apicultores. Our Spanish contact attempted to motivate the associations several times without success. As a result, only a few Spanish beekeepers completed the survey. In Denmark, the Danish Beekeeper Association declined our request for survey distribution, since they had another major survey for beekeepers running simultaneously and did not want to burden their members.

Details on recruitment in the other 12 countries are provided in Deliverable 4.3.

2.2.5 Data handling and ethics approval

The collected personal data in this research project includes: socio-demographic and socio-economic characteristics such as age (years), gender, education, training, experience with the beekeeping sector, economic performance in beekeeping, as well as attitudes, beliefs, perceptions, opinions and views, which are all exclusively related to beekeeping and its context. All collected data are cross-sectional data collected at one point in time. Sensitive personal information relating e.g. to health, ethnicity, sexual lifestyle, political opinion, religious or philosophical conviction fell beyond the scope of B-GOOD and was not probed for.

The informed consent procedures and information sheets informed all data subjects of the purpose of the data collection, of what was to be done with the data and of the processing of the data. All data collection was fully anonymous; thus, data records are anonymous and are shared for study purposes and in dissemination activities only in aggregated form. Survey records do not include the name(s) or any personal identifier of the participants. Ethics approval for this WP4 beekeeper survey was obtained on 27 August, 2021 by the UZ Gent / UGent Medical Ethics Committee under application number **BC-10610** (see Appendix 4).

2.2.6 Sample composition

By the closure of the survey on 31 January 2022, a total of 1,460 beekeepers had started the survey, out of which 59% (860) had completed the entire survey and 41% (600) had given incomplete responses. Out of the 600 beekeepers who did not complete the survey:

- 55 (9%) started but stopped because of not consenting with one of the informed consent questions at the beginning of the survey;
- 197 (33%) fully consented to the study but stopped after seeing the first question of Section 1: Socio-economic variables: *A_1: What is your country of residence?* These beekeepers may have stopped because their country of residence was not on the list (since probably residing in a non-EU country) or because they changed their mind at that moment;
- 256 (43%) stopped after seeing question *B_9: What was the total quantity of honey that you produced in 2021 (kg)?* This is the first question where the survey requests that the beekeeper enters his or her own economic figures about their beekeeping practises, and it was where most beekeepers decided to quit;
- A remaining 92 (15%) stopped later in the survey, of which 31 stopped after completing Section 2: Economic performance; for the rest, no clear pattern emerges.

Out of the 860 beekeepers who completed the survey, 16 have been deleted from the dataset as invalid for several reasons, yielding a dataset for analysis counting 844 valid cases. The reasons for deleting 16 invalid cases from the dataset were:

- large numbers of missing values on a series of question items where responses were not forced (n=11);
- zero number of beehives reported, i.e. does not fit the criteria for inclusion since not considered as a beekeeper (n=2);
- non-EU/UK/Switzerland country of residence, i.e. does not fit the criteria for inclusion since not considered as an EU/British/Swiss beekeeper (n=1);
- age below 18 years, i.e. does not meet the criteria for inclusion in line with the adult age limit for participation and the ethics approval obtained for the study (n=1);
- obvious response bias, specifically acquiescence and non-differentiation bias in this concerned case (e.g. ticking series of ‘1’s or ‘5’s as response values) (n=1).

3. Results – First wave exploratory beekeeper study (n=40)

3.1 Sample and beekeeping characteristics

Table 1 summarises the socio-demographics of the valid sample of 35 beekeepers.

Table 1. Socio-demographic profile of the sample (n = 35)

Sample characteristics		Frequency (%)
Age	<46 years	34,3
	46-59 years	45,7
	60 or more years	20,0
Country	The Netherlands	22,9
	Italy	22,9
	Germany	17,1
	Finland	14,2
	Switzerland	22,9
Gender	Male	80,0
	Female	20,0
Education	Elementary education (6 yr of schooling)	0,0
	Secondary education (12 yr of schooling)	37,1
	Tertiary education (bachelor or masters)	62,9
Years of experience	Less than 10 years	54,3
	10 years or more	45,7
Number of hives	0-19	42,9
	20-99	45,7
	100-600	11,4
Beekeeper type	Professional	20,0
	Hobby	80,0

Of the 35 beekeepers in the sample, 45.7% of them were between the ages of 46 and 59 years. The majority (80%) were male and 20% were female. The majority (62.9%) had a bachelor or masters degree. Slightly more than half of the sample had less than 10 years of experience. Beekeepers were asked whether they identified themselves as hobby or professional beekeepers, in which 28 identified as hobby beekeepers and 7 identified as professional beekeepers (see Figure 6).

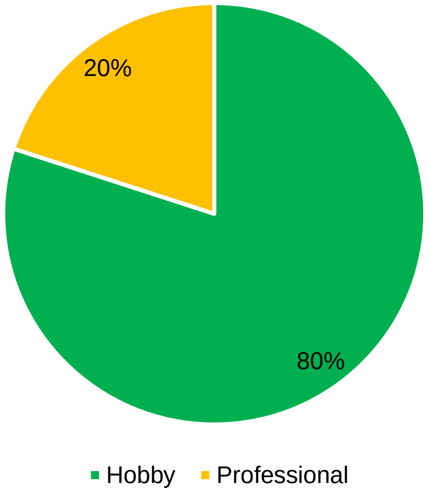

Figure 6. Percentage of respondents by beekeeper type (n=35)

The average number of hives in the entire sample was 63 hives. Out of the sample, 42.9% had less than 20 hives, while only 11.4% had 100 or more hives. The number of hives between hobby and professional beekeepers are shown in Figure 7.

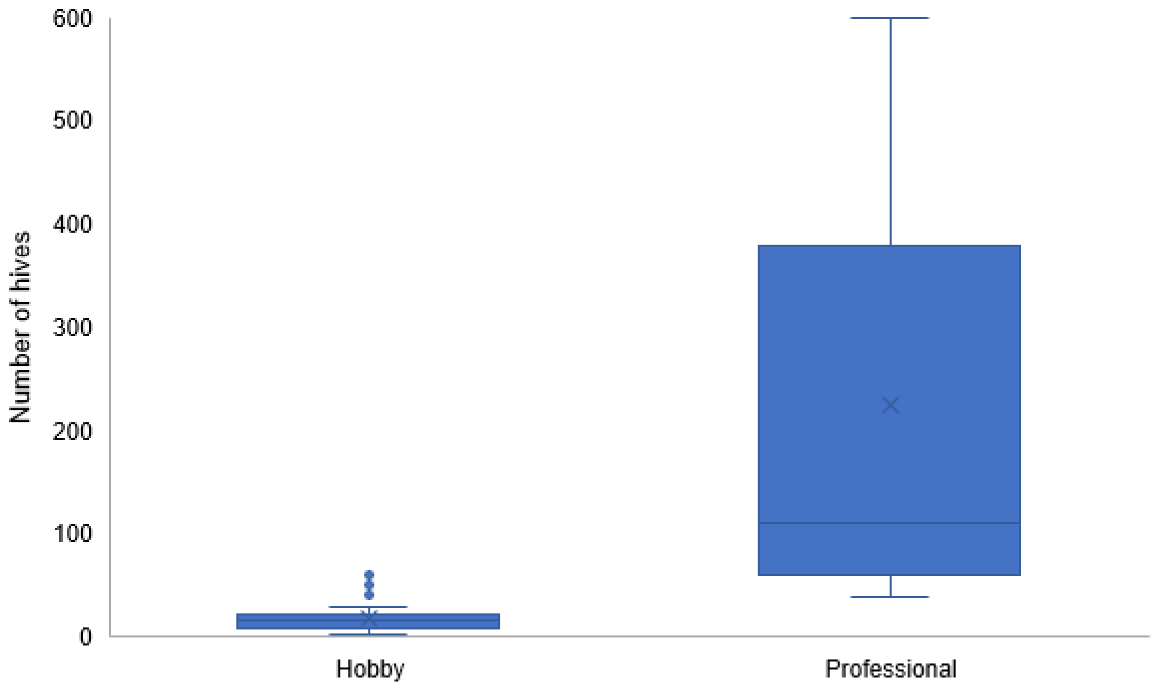

Figure 7. Number of hives between hobby and professional beekeepers (n=35)

The average number of hives for hobby beekeepers was 18 hives and the average number of hives for professional beekeepers was 225 hives.

3.2 Beekeeping inputs

Inputs are any resources that beekeepers use to produce honey, provide pollination services, or produce any other apiary products such as wax, propolis, royal jelly, etc. Examples of inputs in beekeeping include labour, hives, chemical treatments, or packaging materials like jars and lids. Beekeepers spend time and money on these inputs in order to keep bees. These costs can often be split into 1) money spent at the beginning of a beekeeping practice, which provide future benefits to beekeepers, called capital costs, and 2) money spent to keep the beekeeping practice in operation on a daily basis, called operational costs. A summary and descriptive statistics for beekeeping inputs of the sample are provided in Table 2.

Table 2. Descriptive statistics for beekeeping inputs (n=35)

Capital costs	Min	Max	Mean	SD
Hives (€)	50	2310	627,0	559,8
Colonies (€)	37	2772	554,6	718,9
Equipment (€)	40	4158	635,8	873,9
Operational costs				
Labour (man-days)	8	500	62,9	91,1
Feed (€)	9	8000	916,1	1644,1
Disease prevention and treatment (€)	14	2500	248,0	494,0
Honey harvesting and packaging (€)	10	6000	1126,4	1536,3
Fuel and electricity (€)	1	5000	857,4	1346,2
Other expenditures (€)	68	8000	1538,6	2232,7

In Table 2, all costs were requested in euros except for labour which was requested in man-days. “Colonies” are separated from “hives” in capital costs, since sometimes hives (=housing) and colonies (=bees) are purchased separately at the beginning of a new beekeeping practice, or sometimes hives are inherited whereas new colonies are purchased.

Not all beekeepers reported on all inputs. Almost all (97%) of beekeepers reported having equipment costs, 94% reported having hive costs, and 69% reported having colony costs at the beginning of their beekeeping practice. All beekeepers reported on labour, 91% reported on feed, disease prevention and treatment, and honey harvesting and packaging, 89% reported on fuel and electricity, and 40% reported on other expenditures. To illustrate capital costs, Figure 8 shows the relative percentage of hive costs, colony costs and equipment costs within total capital costs for hobby and professional beekeepers.

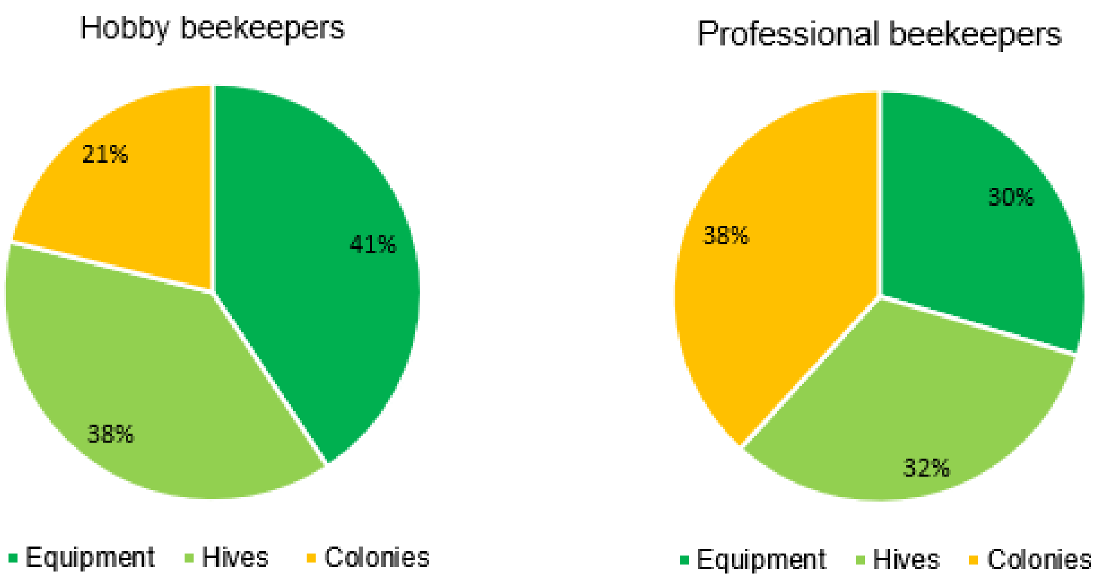

Figure 8. Percentage of each type of capital cost represented for hobby and professional beekeepers (n=35)

Professionals spent similar amounts on equipment, hives and colonies, however hobbyists spent more than 35% of their capital costs on equipment and hives and only 21% on colonies. Figure 9 shows the relative percentage of feed costs, disease prevention and treatment costs, honey harvesting and packaging costs, fuel and electricity costs, and other expenditures within total operational costs for hobby and professional beekeepers.

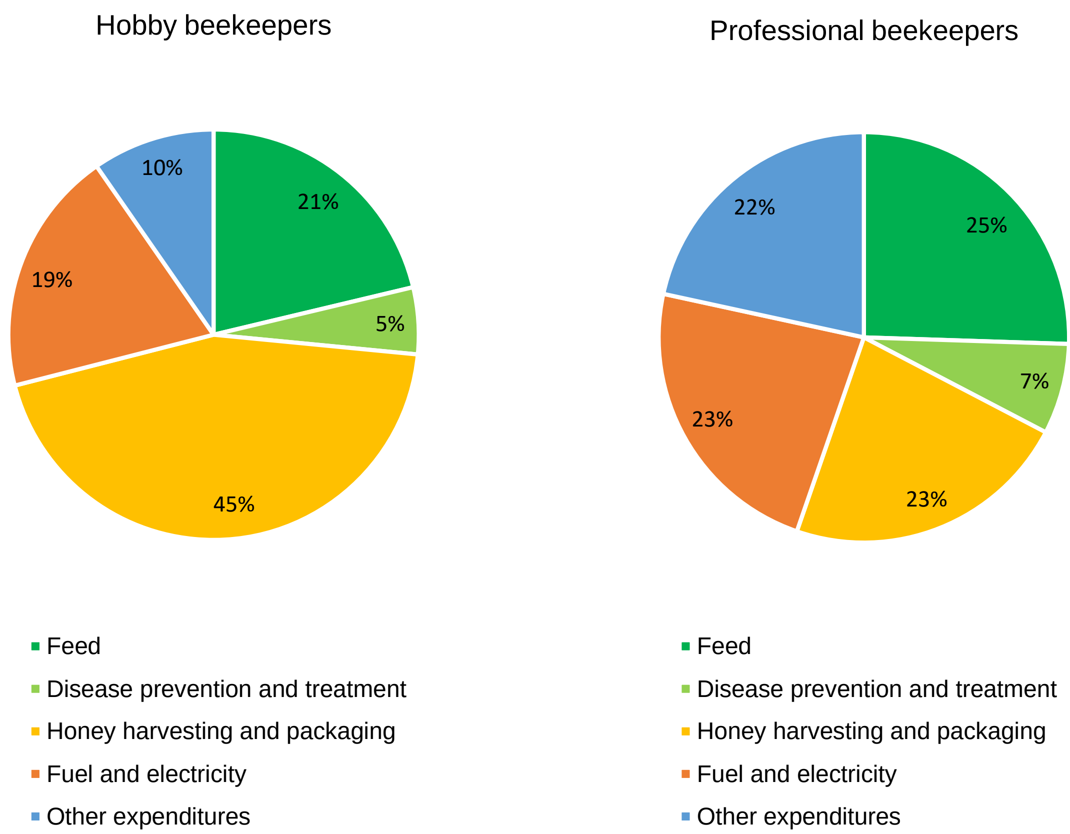

Figure 9. Percentage of each type of operational cost represented for hobby and professional beekeepers (n=35)

Professionals spent similar amounts on feed, honey harvesting and packaging, fuel and electricity, and other expenditures, whereas hobbyists spent almost half of their total operational costs on honey harvesting and packaging, which includes costs for jars and lids.

Regarding labour intensity, beekeepers (and their eventual employees) spent from 8 to 500 man-days and an average of 62.9 days on their beekeeping practice (per year, i.e. 2020 in this case). Hobbyists spent an average of 2.2 days per hive on their beekeeping practice and professionals spent an average of 1.0 day per hive on their beekeeping practice. More on labour productivity will be discussed in Section 3.4 Exploratory Data Envelopment Analysis.

3.3 Beekeeping outputs

Outputs are the products or services that beekeepers produce. Table 3 describes the beekeeping outputs of the sample in both units and euros. Propolis (€) is in grey since no beekeeper indicated selling propolis.

Table 3. Descriptive statistics for beekeeping outputs (n=35)

Output (units)	Min	Max	Mean	SD
Honey (kg)	8	35000	1854,0	5942,1
Wax (kg)	1	500	49,6	99,1
Propolis (kg)	1	6	3,5	2,5
Colonies (#)	2	100	19,7	32,9
Queens (#)	2	400	160,4	147,8
Pollination (# colonies rented)	2	400	95,8	162,7
Output (€)				
Honey	250	175000	11846,9	30645,0
Wax	28	1666	529,5	567,7
Propolis				
Colonies	231	8000	1933,6	2626,7
Queens	65	18507	6574,4	6813,9
Pollination	20	40000	7962,9	13748,1

All beekeepers in the sample produced honey, followed by 80% who produced wax, 26% who provided pollination services, 20% who produced colonies, 14% who produced queens and 6% who produced propolis (see Figure 10).

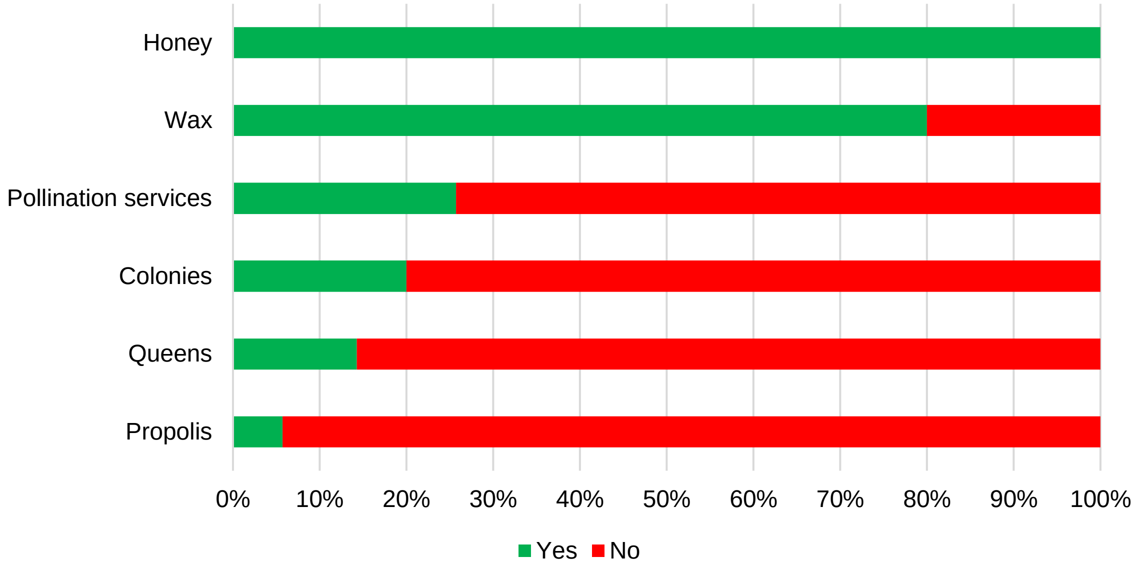

Figure 10. Production of apiary products, bees and services (n=35)

As most of the sample were hobby beekeepers who may not sell all of their beekeeping products, 91% sold their honey but only around 30% sold their wax, 20% sold pollination services, 20% sold colonies, 14% sold queens and none sold propolis. Hobbyists made an average of €4,151 per year in revenues on their beekeeping operation and professionals made an average of €54,756 per year on their beekeeping operation.

3.4 Exploratory Data Envelopment Analysis

Exploratory bi-dimensional graphs and outlier detection

As the aim is to use DEA to explore the diversity of beekeepers and to examine associations between management styles and socio-economic factors, a series of bi-dimensional graphs were made to explain the complexity of beekeepers' operations and better understand differences between beekeepers' input use. Graphs were also examined for the presence of outliers to examine whether the outliers make sense in relation to other beekeepers in the dataset. Note that outliers identified in the graphs are not excluded from the analysis. Outliers therefore are identified for the purpose of examination, but they are not necessarily considered anomalies.

As honey is the main output produced by the sampled beekeepers, we begin by plotting the relationship between honey and other basic inputs such as the number of hives (Figure 11) and labour in man-days (Figure 12).

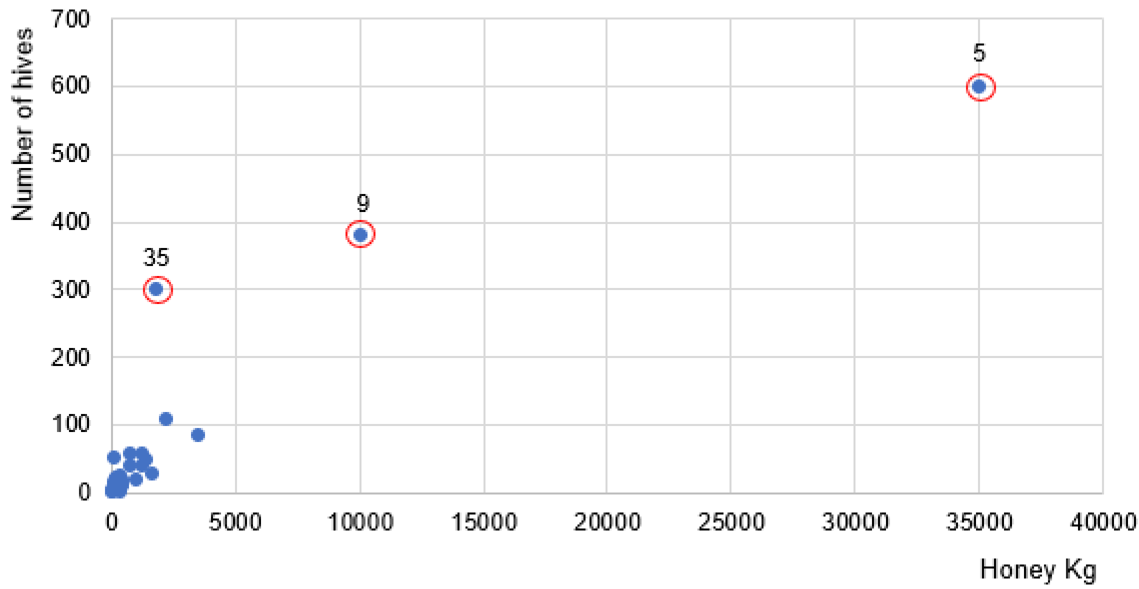

Figure 11. Honey production (kg) vs. number of hives (n=35)

In Figure 11, the general trend suggests that as the number of hives increases, honey in kg increases. Beekeepers 5, 9 and 35 were identified as outliers due to exceptionally large beekeeping operations compared to the rest of the sample, but were not excluded from analysis. Beekeeper 5 is from The Netherlands and beekeeper 9 is from Italy. Both beekeepers are professional beekeepers with more than 20 years of experience and total revenues of over €60,000 per year. Beekeeper 35, from Switzerland, makes most of his revenue from breeding / selling queens (€18,507 out of €25,166) which is the main reason for his high number of hives compared to honey in kg.

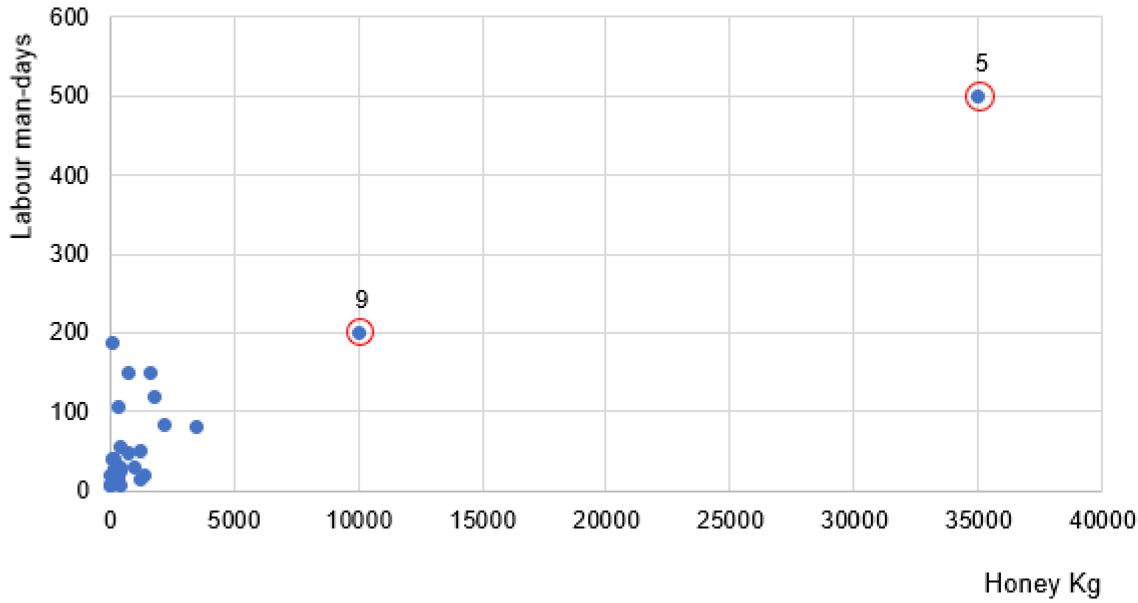

Figure 12. Honey production (kg) vs. labour (man-days) (n=35)

In Figure 12, the same beekeepers 5 and 9 were identified as outliers due to exceptionally large beekeeping operations compared to the rest of the sample, but were not excluded from analysis. Both of these beekeepers produce more than just honey; beekeeper 9 also produces wax and provides pollination services, and beekeeper 5 also produces wax, colonies, queens and provides pollination services.

Next, honey is plotted together with total revenue (most of which is resulting from sales of honey), to view the relationship between two different types of outputs (see Figure 13).

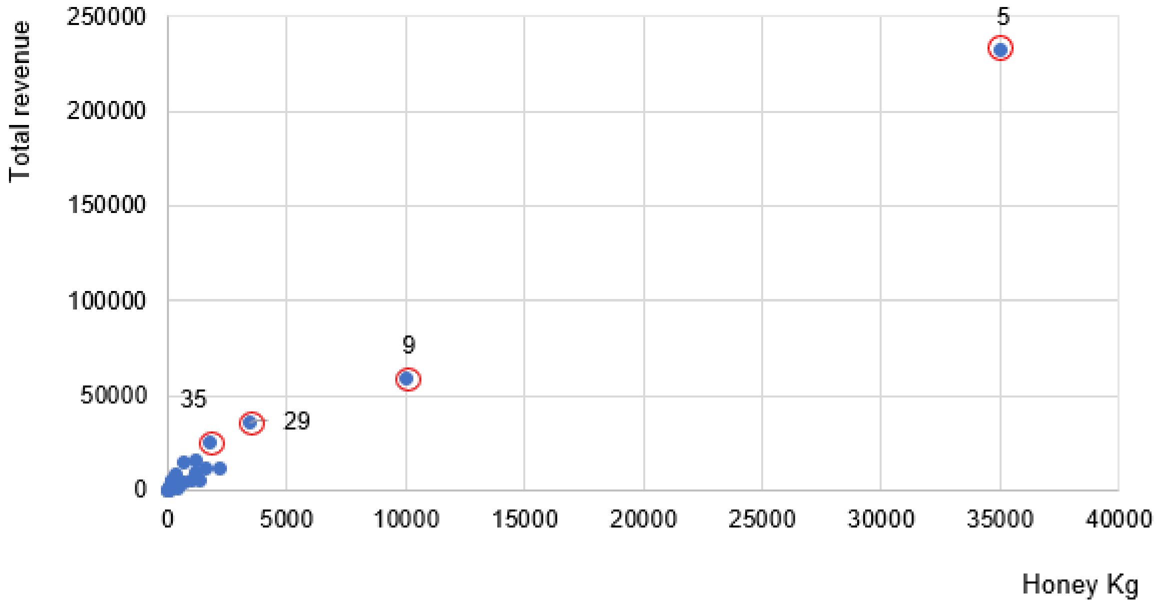

Figure 13. Honey production (kg) vs. total revenue (euro) n=35)

Figure 13 shows the same outliers as the previous two graphs, however beekeeper 29 enters the picture as a beekeeper with high revenues. Beekeeper 29 is a very experienced beekeeper from Finland who also produces wax and queens. The next sections will describe two basic productivity measures, hive productivity and labour productivity, and further outliers will be identified in the next sections.

Hive productivity

Hive productivity is seen as a key component in the economic analysis of beekeeping and a main measure that will be used throughout this report. Hive productivity was calculated by dividing the total kg of honey produced by the number of hives, i.e. yielding honey per hive (kg). Hive productivity between hobby and professional beekeepers are shown in Figure 14.

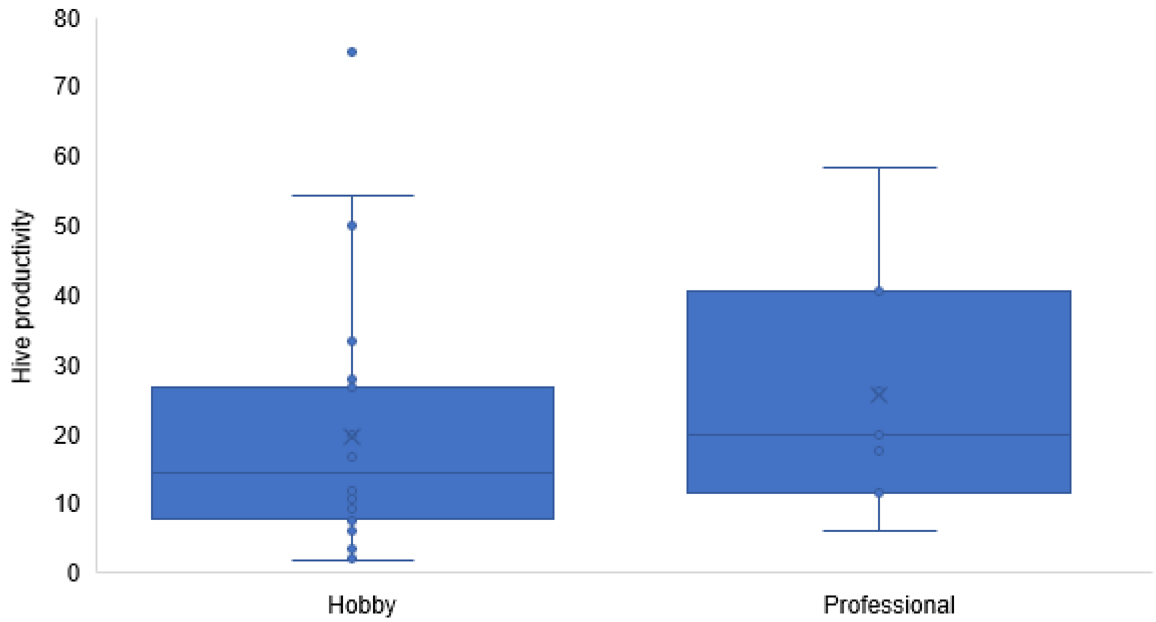

Figure 14. Hive productivity (kg of honey per hive) between hobby and professional beekeepers (n=35)

The average hive productivity for the entire sample was 21 kg. As seen in Figure 14, hobby beekeepers had an average hive productivity of 20 kg and professional beekeepers had an average hive productivity of 26 kg, indicating that professionals had an overall more efficient use of their hives for honey production.

Average hive productivity was compared between the five countries represented, where beekeepers in Italy exhibited higher average hive productivity than the other countries (27 kg per hive), followed by Finland with an average of 26 kg per hive (see Figure 15). It should be noted that these differences also reflect the differential presence of professional beekeepers in the respective country samples.

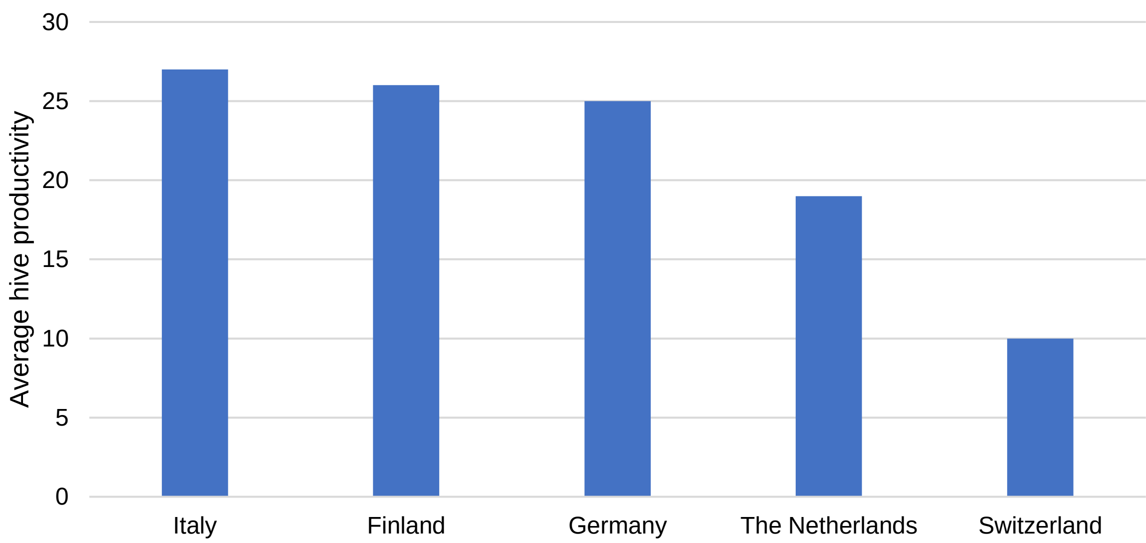

Figure 15. Average hive productivity between all countries represented (n=35)

Hive productivity was also compared between other socio-demographic characteristics such as age, education, years of beekeeping experience, and number of hives. Beekeepers who were less than 46 years old tended to be more productive than beekeepers who were 46-59 years or more than 60 years old. Beekeepers with secondary education exhibited higher hive productivity than those with tertiary education. Beekeepers with 10 years or more of beekeeping experience exhibited higher hive productivity than those with less than 10 years of beekeeping experience. Average hive productivity increased with number of hives, as beekeepers with 100-600 hives had a higher hive productivity (28 kg per hive) than beekeepers with 20-99 hives (21 kg per hive) and beekeepers with 0-19 hives (19 kg per hive).

Hive productivity was also calculated in euro, by total revenues per hive, as an indicator of productivity in terms of revenue or money made. Hive productivity in **kilograms** therefore measures productivity in honey whereas hive productivity in **euro** measures productivity in revenues from all beekeeping outputs (honey, wax, pollination, etc.). Hive productivity in euro was not compared between hobby and professional beekeepers or other demographic variables since data on the selling price of beekeeping products and services varied widely (especially among hobby beekeepers who sell locally) and may not be reliable or comparable. The variable is instead used to explore the relationship between productivity indicators (see Figure 16).

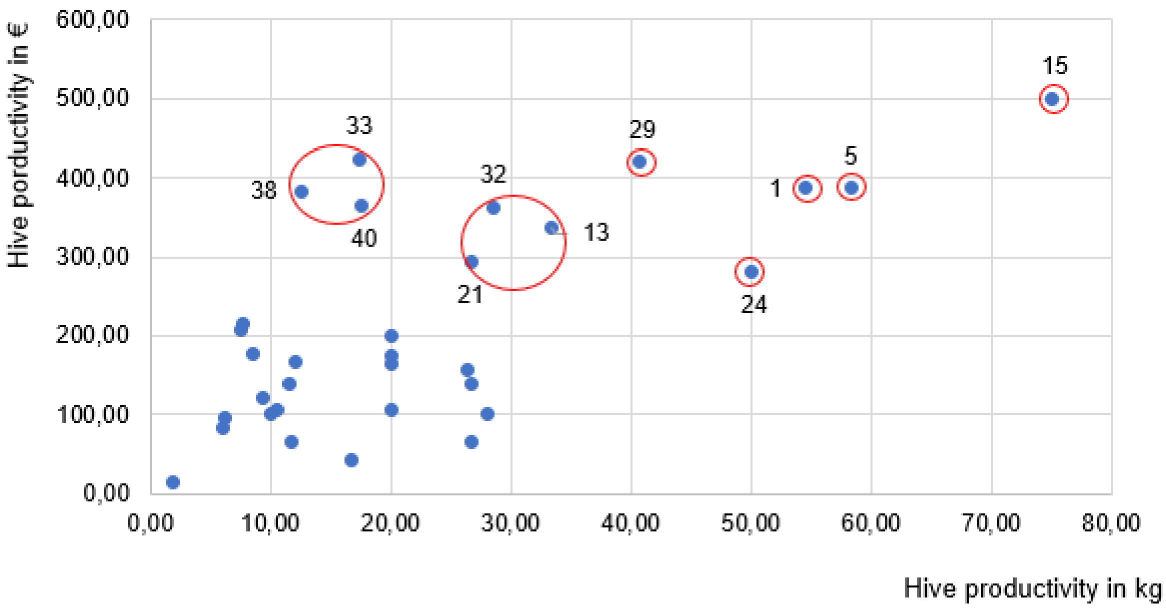

Figure 16. Hive productivity in kg vs. hive productivity in euro (n=35)

The outliers identified in Figure 16 will be explained from right to left. All 11 beekeepers identified as outliers are still included in the analysis. Beekeepers 15, 5 and 1 were identified as outliers for their high hive productivity in both kg and euro. Beekeeper 15 is from Italy who only produces honey but reported that he gets 75 kg of honey from each of his 4 hives. Beekeepers 1 and 5 both have more than 20 years of beekeeping experience, are both from The Netherlands, and both sell queens and provide pollination services.

Compared to beekeepers 15, 5 and 1, beekeeper 24 has a lower selling price per kg of honey at €5. Beekeeper 29 produces and sells wax and queens besides honey, making up €6,120 of his total revenue of €26,120 increasing his hive productivity in euro. The two groups of beekeepers, 13, 32 and 21, and 40, 33 and 38 contain beekeepers whose main output is honey and who have a somewhat high selling price per kg of honey. The range of selling price per kg of beekeepers 13, 32 and 21 is between €10.00 and €12.50. The range of selling price per kg of beekeepers 40, 33 and 38 is between €20.00 to €26.00 and all three are from Switzerland.

Overall, based on observations of Figure 16, a high hive productivity in kg but not in euro reflects obtaining a lower selling price per kg of honey, and a high hive productivity in euro but not in kg reflects obtaining a high selling price per kg, or having other outputs besides honey, such as wax, being the main source of revenue.

Labour productivity

Labour productivity is the amount of goods and services that a group of workers produce in a given amount of time. Labour productivity for the sample of beekeepers was calculated by the total kg of honey produced per man-day. Labour productivity between hobby and professional beekeepers are shown in Figure 17.

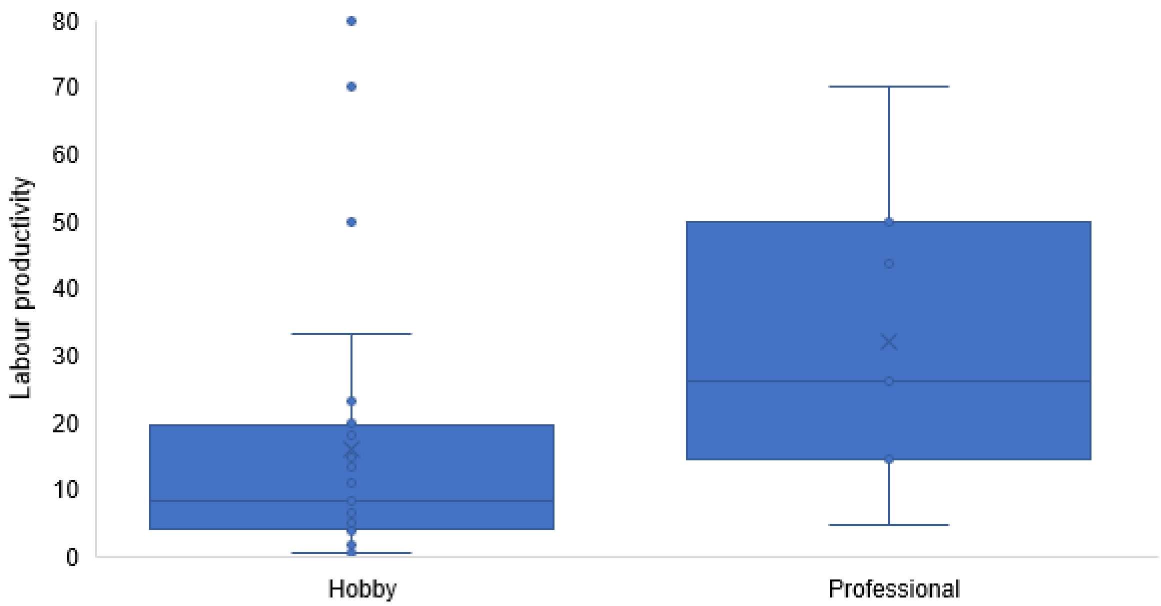

Figure 17. Labour productivity (kg of honey per man-day) between hobby and professional beekeepers (n=35)

The average labour productivity for the entire sample was 19 kg of honey per man-day. As seen in Figure 17, hobby beekeepers had an average labour productivity of 16 and professional beekeepers had an average labour productivity of 32, indicating that professionals had an overall more efficient use of their labour for honey production.

Labour productivity was also compared between other socio-demographic characteristics such as age, education, country, years of beekeeping experience, and number of hives. Beekeepers who were less than 46 years old tended to have higher labour productivity than beekeepers who were 46-59 years or more than 60 years old. Beekeepers in Finland had the highest average labour productivity among all five countries, followed by Germany, Italy, The Netherlands and finally Switzerland who had the lowest labour productivity. Beekeepers with a secondary education exhibited higher labour productivity than those with a tertiary education. Beekeepers with 10 years or more of beekeeping experience exhibited higher labour productivity than those with less than 10 years of beekeeping experience. Average labour productivity increased with the number of hives, as beekeepers with 100-600 hives had a higher labour productivity (40 kg per day) than beekeepers with 20-99 hives (23 kg per day) and beekeepers with 0-19 hives (10 kg per day).

Efficiency scores

Efficiency measures for the sample were calculated via linear programming using the software DEAP (Coelli, 2008), using an input oriented Data Envelopment Analysis (DEA) model with one output, **honey**, and two inputs, **labour** in man-days and number of **hives used for honey production**. These variables had the highest response rate among the sample, meaning all 35 beekeepers reported values for honey, labour and number of hives, allowing us to include the entire sample in our DEA model.

In this exploratory research phase, the DEA model is run assuming constant returns to scale (CRS), which means that any change in inputs is assumed to produce a proportional change in outputs. This approach assumes there is no relationship between the size of the beekeeping operation and its efficiency, i.e. that small-scale hobbyist beekeepers can be equally efficient as large-scale professionals, for example. The resulting efficiency scores, which range from 0 (non-efficient) to 1 (fully efficient), serve as an indication of how (technically) efficient the beekeepers are in their combined use of 1) labour and 2) hives to produce honey. Note that efficiency scores are not meant to be an indication of performance in this case but rather as a way to explore differences in beekeepers' use of labour and hives.

It should also be noted that the flexibility of the frontier that is constructed using DEA is one of the often quoted advantages of the method relative to parametric frontier methods. However, this aspect can also create problems especially when dealing with small datasets, as is the case in this exploratory research phase. The various input and output variables may not be realistic for some beekeeping operations (too large or too small), therefore the applicability of the efficiency measures obtained must be approached with caution. Additionally, the inclusion of beekeepers from different countries may reduce efficiency scores.

Figure 18 shows the frequency distribution of technical efficiency scores among the sample (n=35). Efficiency scores ranged from .03 to 1, with .38 being the average among the sample.

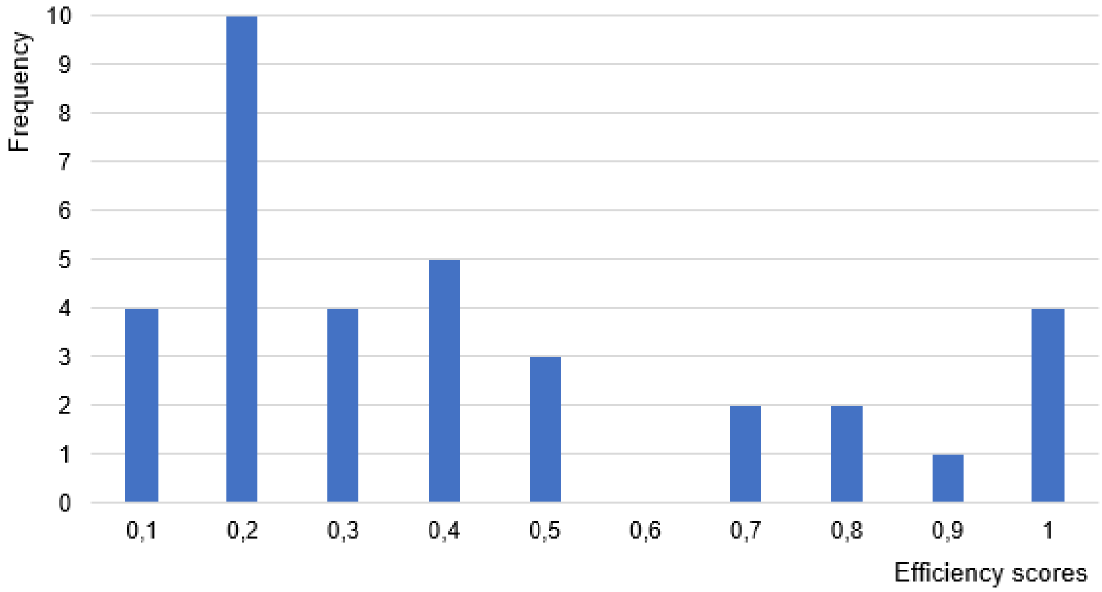

Figure 18. Frequency distribution of efficiency scores (n=35)

Efficiency scores between hobby and professional beekeepers are presented in Figure 19. The average efficiency score for hobby beekeepers was .35 whereas for professionals it was .49. While efficiency scores among the sample are quite low, beekeepers who received a score of 1 contained both hobby and professional beekeepers, indicating that both hobby and professional beekeepers have the ability to be fully efficient.

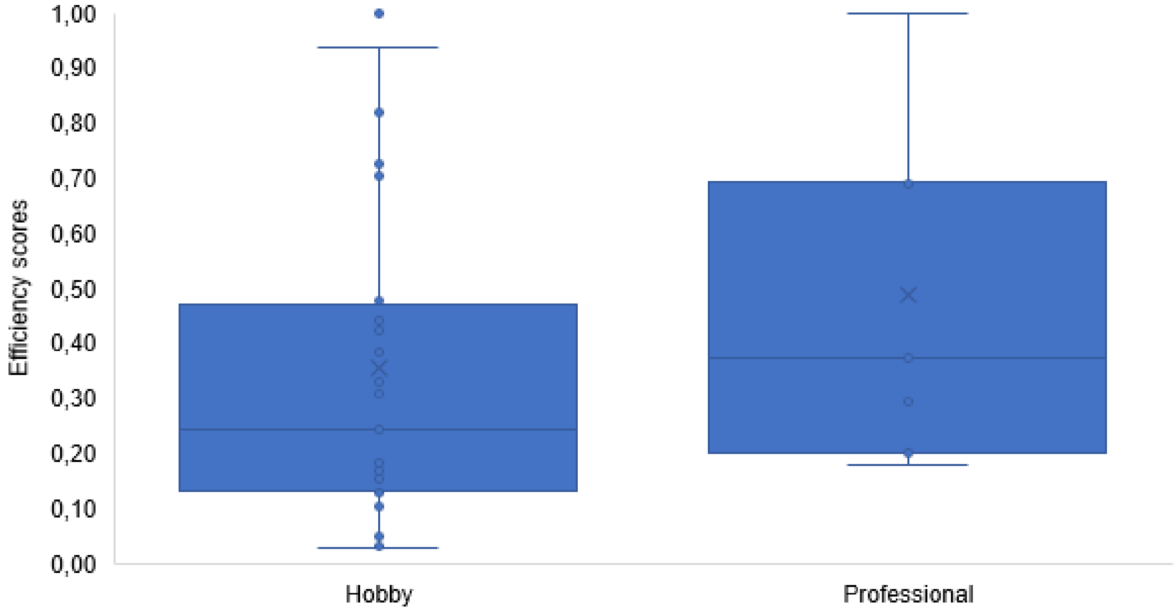

Figure 19. Efficiency scores between hobby and professional beekeepers (n=35)

Average efficiency was compared between the five countries represented, where beekeepers in Finland exhibited higher average efficiency than the other countries (.58), followed by Germany and Italy both with an average efficiency .41 (see Figure 20).

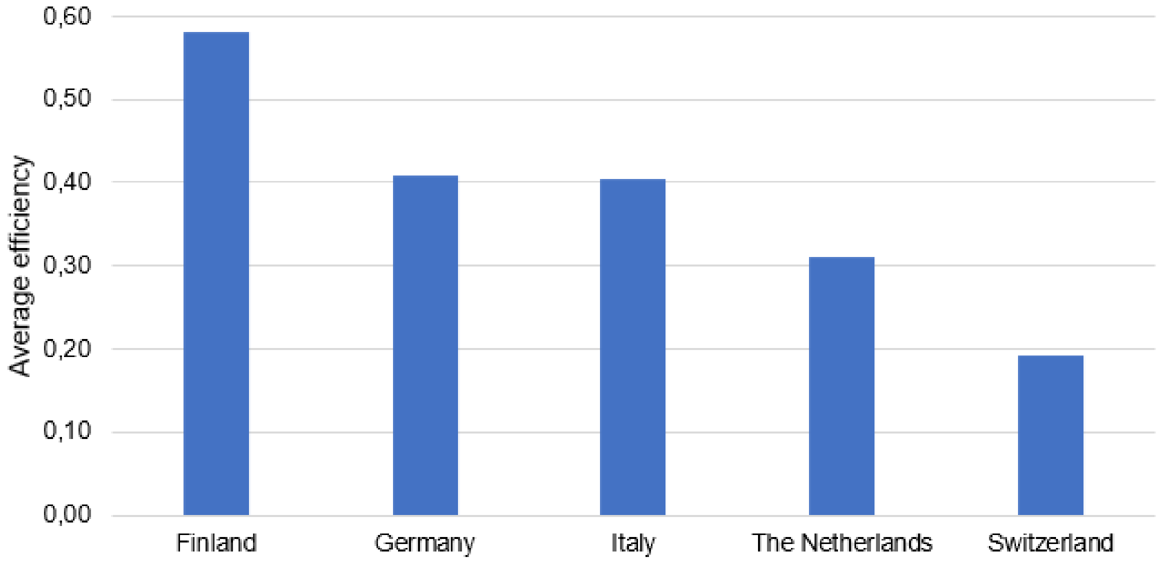

Figure 20. Average efficiency between all countries represented (n=35)

Efficiency was also compared between other socio-demographic characteristics such as age, education, years of beekeeping experience, and number of hives. Beekeepers who were less than 46 years old tended to be more efficient than beekeepers who were 46-59 years or more than 60 years old. Beekeepers with a secondary education exhibited higher average efficiency than those with a tertiary education. Beekeepers with 10 years or more of beekeeping experience exhibited higher average efficiency than those with less than 10 years of beekeeping experience. Average efficiency increased with the number of hives, as beekeepers with 100-600 hives had a higher average efficiency (.57) than beekeepers with 20-99 hives (.42) and beekeepers with 0-19 hives (.29).

Isoquant analysis

To further demonstrate efficiency, the relationship between the two inputs, labour and hives is plotted in a visual and observable production function. Figure 21 shows the relationship between the number of hives and labour while holding the output (kg of honey) fixed. Figure 21 represents a two-input production function and the curve represents an output isoquant.

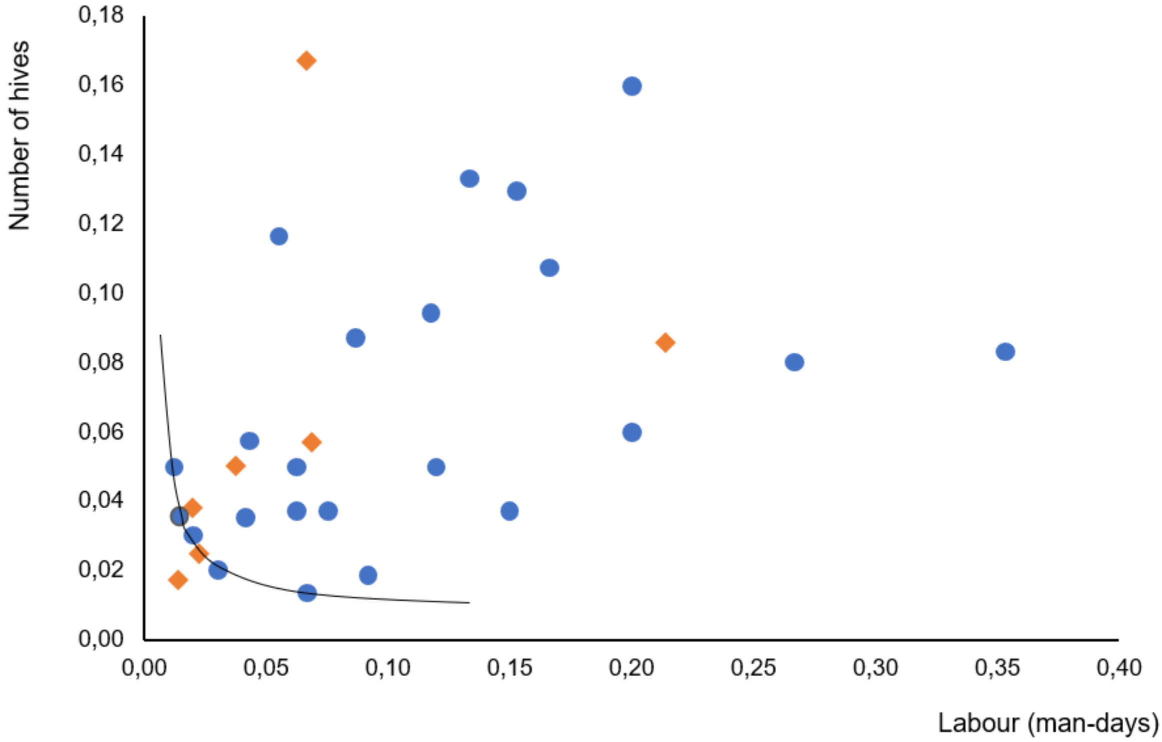

Figure 21. Production function with two inputs: number of hives and labour (n=31); hobby beekeepers are represented in blue dots; professional beekeepers are represented in orange squares

In Figure 21, 4 beekeepers were left out of the graph due to extremely low efficiency scores, for better readability of the graph, but still included in the analysis. These beekeepers were hobby beekeepers whose only purpose was to produce honey for themselves; they did not sell honey or any other products or services and also had a low hive productivity. Beekeepers situated along the isoquant curve represent the most efficient beekeepers.

The hobby beekeepers situated along the isoquant curve had higher efficiency scores than the average professional. These 5 hobby beekeepers were compared with the 5 least efficient hobby beekeepers, and we found that the most efficient hobby beekeepers had more beekeeping experience, had a higher hive productivity, a higher amount of hives and higher operational costs.

Two main types of efficient beekeepers are shown in Figure 21: 1) those that have a small amount of hives with a high labour use and 2) those with a large amount of hives with low labour use. To understand the differences between these two groups, two subpopulations of beekeepers, those situated along the horizontal (x) axis and those situated along the vertical (y) axis, were compared to each other. Beekeepers situated along the x axis display a higher use of labour, and thus a less effective use of labour, and those situated along the y axis display a higher use of hives, and thus a more effective use of labour.

To demonstrate the differences between these beekeepers, nicknames of Northern European cities were given to beekeepers along the x axis, and nicknames of Southern European cities were given to beekeepers along the y axis (see Figures 22 and 23).

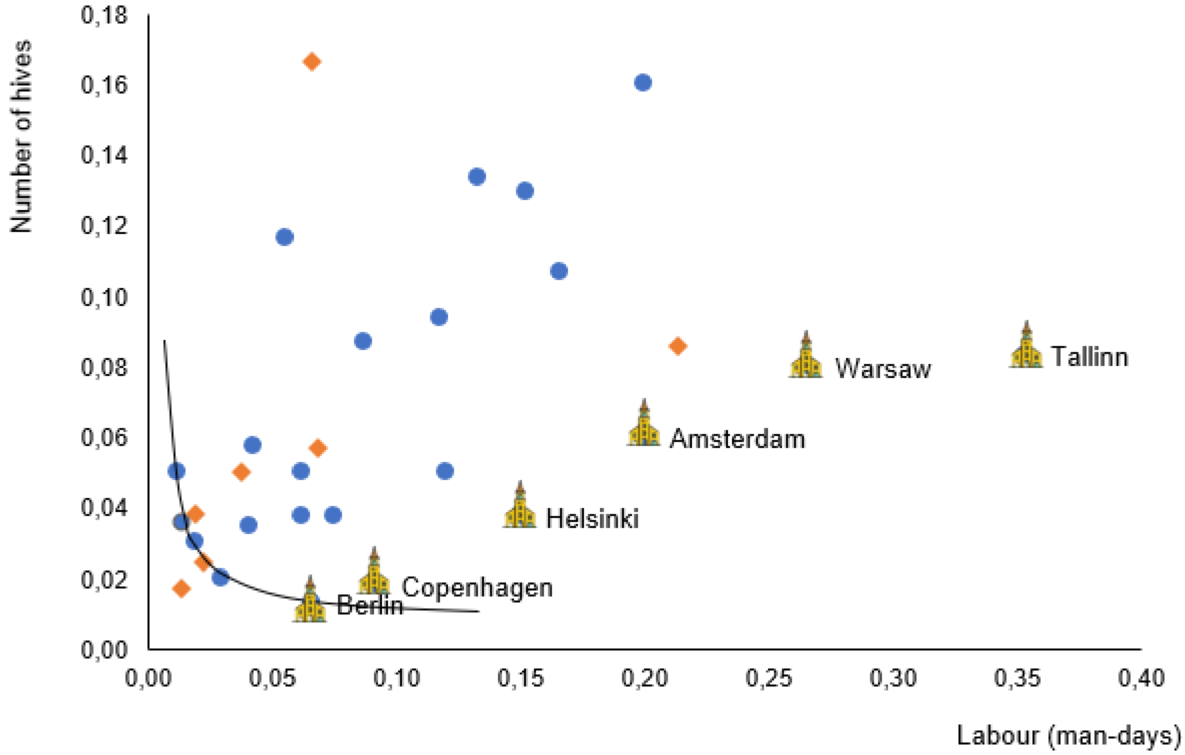

Figure 22. Production function with nicknames of Northern European cities (n=31)

Starting with beekeepers along the x axis, Berlin is situated on the isoquant curve and is a fully efficient beekeeper with an efficiency score of 1. Copenhagen, however, could reduce the number of hives slightly to become technically efficient. Copenhagen is an experienced hobby beekeeper from the Netherlands with 30 hives. He was one of only 5 beekeepers in the sample to sell queens to other beekeepers, and also rents several colonies for pollination services, which might explain this surplus of hives, in which more hives may be needed for pollination services.

Helsinki, Amsterdam, Warsaw and Tallinn all use a surplus of labour in their beekeeping operations. Helsinki is an experienced beekeeper from Italy and with 15 hives from which he/she produces 400 kg of honey per year using 55 days of work. Helsinki also produces wax, which may explain the higher amount of labour required for wax harvesting. Amsterdam and Warsaw also both produce wax, which may explain the higher amount of labour required for wax harvesting. Tallinn has 25 hives from which he/she produces 300 kg of honey per year using 106 days of work. He/she has a labour productivity of 3 kg per day which is very low compared to the average labour productivity for hobbyists which is 16 kg per day. Therefore we might assume that as a hobby beekeeper, Tallinn may not have the goal to be fully efficient in her use of labour or enjoys beekeeping and therefore spends more time on his practice.

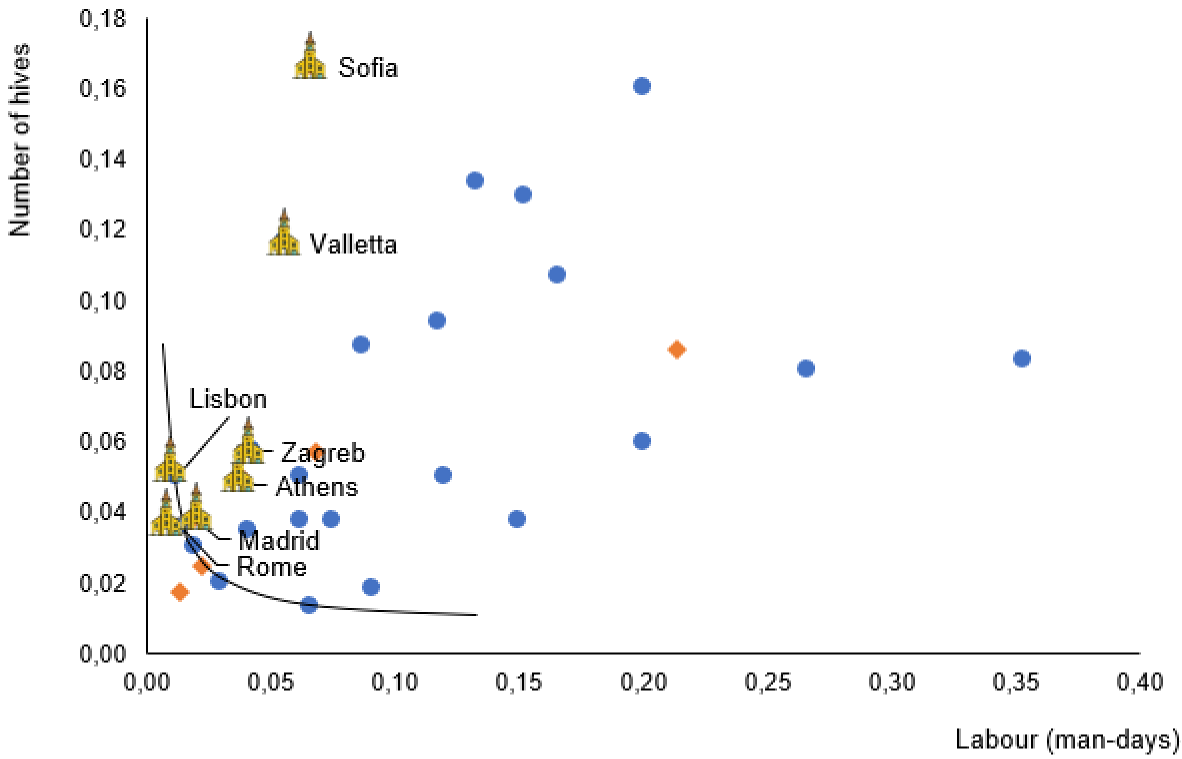

Figure 23. Production function with nicknames of Southern European cities (n=31)

Concerning beekeepers along the y axis, Rome and Lisbon are both situated on the isoquant curve and have very high efficiency scores (.94 and 1). Madrid, however, could reduce labour use only slightly to become technically efficient. Madrid is an experienced professional beekeeper from Italy with 380 hives who produces honey but also rents colonies for pollination services, which might explain this surplus of labour use, in which more labour is needed to transport the colonies to pollination sites.

Zagreb, Athens, Valletta and Sofia all have a more efficient use of labour but a surplus of hives. Zagreb is a hobby beekeeper from Switzerland with 20 hives from which he produces 348 kg of honey per year using 15 days of work. Zagreb also produces wax, colonies and queens which could explain his/her surplus of hives as he houses colonies and queens to be sold. Athens is a professional beekeeper from Finland with 110 hives, from which he/she produces 2200 kg of honey using 84 days of work. Athens also produces colonies which may explain his/her surplus of hives as he/she houses colonies to be sold.

Valletta is a hobby beekeeper from Switzerland with 21 hives from which he produces 180 kg honey with 10 days of work. Valletta also produces wax and colonies which could explain his/her surplus of hives as he houses colonies to be sold. Sofia is a professional beekeeper with 300 hives from which he/she produces 1800 kg of honey with 120 days of work. Sofia also produces wax, pollination, colonies and queens which may explain his/her surplus of hives to house more colonies to be sold and to be used for pollination services. In summary, Zagreb, Athens, Valletta all sell colonies which may explain their surplus of hives.

Overall, when comparing Northern European cities to Southern European cities, Southern European cities (those with a more effective use of labour) were older, lower educated, had a higher amount of hives, had higher annual operational costs and had higher efficiency scores overall. This suggests that beekeepers having a higher amount of hives with higher operational costs but lower labour use were more efficient overall.

3.5 Ecological-environmental characteristics

The term **environment** is used to describe factors that could influence the efficiency of a beekeeper, where such factors are not traditional inputs and are assumed not under the control of the manager. In the case of beekeeping, accounting for the quality of the ecological environment surrounding of hives is important since beekeeping is more dependent on complex environmental factors than any other livestock or food production sector (Chauzat et al., 2013; Olate-Olave et al., 2021; Wakgari & Yigezu, 2021).

To measure the ecological environmental quality surrounding hives, beekeepers were asked to score six environmental quality indicators on 5-point Likert scales (1 = strongly disagree to 5 = strongly agree):

1) There are sufficient floral resources surrounding my hives
2) The environment surrounding my hives is biodiverse
3) The environment surrounding my hives contains chemical contaminants
4) I collaborate with farmers to encourage pollinator-friendly landscapes
5) Current policy measures in my region adequately address issues of floral resources, biodiversity, and landscape diversity
6) Climate change has had a negative impact on my beekeeping practices

The environment surrounding my hives is biodiverse, receiving the highest mean agreement score (3.8) followed by *there are sufficient floral resources surrounding my hives* (3.6) (see Figure 24).

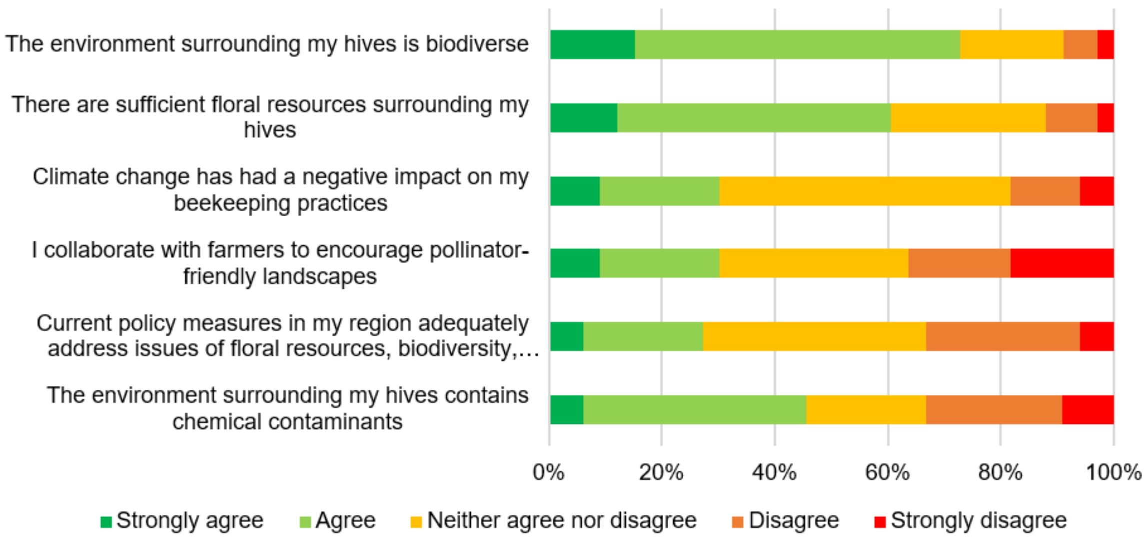

Figure 24. Mean agreement scores for environmental quality items (n=35)

Environmental scores for each beekeeper were calculated using the sum of the 6 agreement scores after reversing the scores for negative environmental indicators (indicators 3 and 6). Total scores could range from 6-30. The average environmental score among the sample was

18. Hobbyists had a slightly higher average environmental score (19) compared to 17 for professionals. Beekeepers in Finland had the highest average environmental score (21.4) whereas beekeepers in Italy had the lowest (16.6) (see Figure 25).

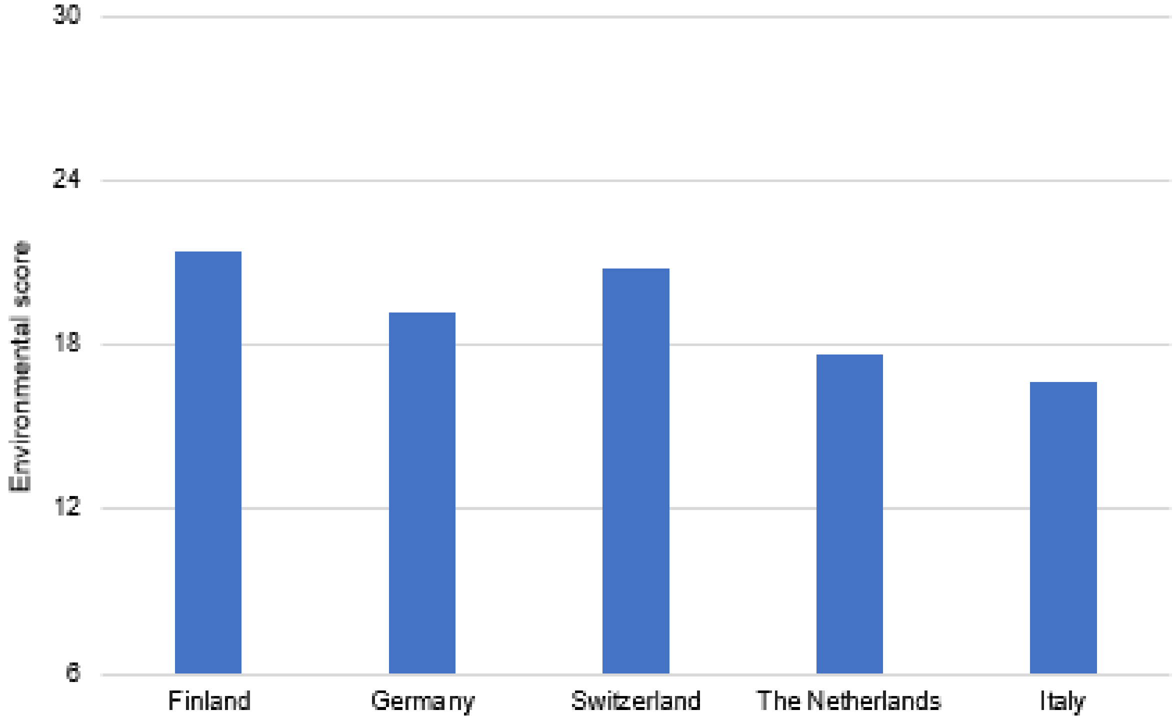

Figure 25: Environmental scores by country (n=35)

Three categories were created for environmental scores: beekeepers with a score of 9 to 17 were categorised as having **low** environmental scores (10 beekeepers), a score of 18 to 20 were categorised as **medium** (16 beekeepers), and a score of 21 to 28 were categorised as **high** (9 beekeepers). These were examined in the context of the DEA to explore possible associations between the quality of the natural environment and productivity and efficiency (see Table 4).

Table 4. Average productivity and efficiency between low, medium and high environmental score categories (n=35)

Environmental score category	Average hive productivity	Average labour productivity	Average efficiency score
Low	21,16	15,01	0,34
Medium	17,54	16,51	0,32
High	26,47	29,16	0,54

Table 4 indicates that beekeepers in the **high** environmental score category had a higher average hive productivity, average labour productivity and average efficiency scores. Additionally, the hobby beekeepers situated along the isoquant curve had higher average environmental scores than the least efficient hobby beekeepers. This suggests a possible association between environmental scores and productivity and efficiency.

3.6 Conclusions and limitations

Conclusions

Overall, our exploratory DEA allowed for the visualisation of beekeepers' relationships to one another and a better understanding of heterogeneity between beekeepers. When exploring the efficiencies of beekeepers a major observation is that efficiency scores among the sample were quite low, which suggests a high variation in honey productivity. The average efficiency score (.38) is lower than average scores reported elsewhere in literature on production efficiency of beekeepers (Ceyhan, 2017; Gürer & Akyol, 2018; Kaya & Gürcan, 2020; Makri et al., 2015). A possible reason suggested for low efficiency scores may be because some beekeepers were not principally employed with beekeeping (Makri et al., 2015), as also reported in our sample. Another explanation can be found in the fact that beekeepers are not primarily oriented towards honey production, but eventually also to the production of other apiary products or even simply to the sheer pleasure of keeping honeybees without economic motivation.

In general, beekeepers in the sample exhibited large variability between production patterns, similar to the high heterogeneity of hive management styles documented in previous studies of beekeeping in Europe (Chauzat et al., 2013; Song et al., 2020). A second major observation is that despite professionals having substantially more hives than hobbyists, they had only slightly higher hive productivity, labour productivity and efficiency scores than hobbyists.

We found that hive productivity may be associated with:

- Being a professional beekeeper
- Younger age
- Having a non-university education
- More years of experience
- Higher amount of hives

Additionally, we found that hive productivity in euro may have to do with having a high selling price per kg, or having other outputs besides honey, such as wax, be the main source of revenue.

We found that labour productivity may be associated with:

- Being a professional beekeeper
- Younger age
- Having a secondary education
- More years of experience
- Higher amount of hives

We found that overall technical efficiency may be associated with:

- Being a professional beekeeper
- Younger age
- Having a secondary education
- More years of experience
- Higher amount of hives

Finally, beekeepers with high perceived environmental quality had a higher average hive productivity, average labour productivity and average efficiency scores, suggesting that the environmental quality surrounding hives may positively contribute to hive productivity, labour productivity and efficiency scores.

The DEA model applied in this exploratory research phase assumed constant returns to scale (CRS). Yet, the results suggest meaningful differences between hobbyist and professional beekeepers that may eventually stem from differences in scale, i.e. the existence of a relationship between the size of the beekeeping operation and efficiency. Therefore, exploring DEA modelling approaches with variable returns to scale (VRS) is warranted in further quantitative conclusive analysis.

Limitations

Some limitations must be mentioned, firstly the fact that analysis was made on a small and purposefully selected sample which limited the capability of making statistical inferences. However, the small sample size was an advantage for a thorough exploratory and comparative analysis between beekeepers. Second, our sample contained very active, highly involved and rather highly educated beekeepers (63% with a university education and 37% with a secondary education) which may introduce bias in our analysis on the role of education levels on productivity and efficiency.

Third, based on the analysis of the bi-dimensional graphs and the isoquant, beekeepers with lower productivity or efficiency levels, both measured in terms of honey, may have other outputs besides honey - or other ambitions and motivations apart from honey production - which may reduce their productivity or efficiency as defined in the present study. However, the goal was not to compare beekeepers' performance as such but rather to explore the diversity of beekeepers.

Finally, data collected in monetary units (€) was less reliable than data collected in quantities (e.g. kg or man-days), and the most reliable exploration was made on input and output units excluding price data. This may partly be explained by the fact that beekeepers have different goals and ambitions, which do not always include beekeeping for economic reasons (Moore & Kosut, 2013). In reality, beekeepers are influenced by economic, personal, or environmental factors in relation to how they value their bees (Velardi et al., 2021). Economic incentives may not be enough to encourage certain beekeepers to consider some of the production alternatives available (Howley et al., 2015)

4. Results – Second wave beekeeper study (n=844)

4.1 Sample and beekeeping characteristics

Sample and beekeeping characteristics of the 844 beekeeper survey were already reported in Deliverable 4.3. Some sample and beekeeping characteristics such as country, region of Europe, age, gender, education level, beekeeper type, number of hives, and experience will be repeated here, as these remain relevant for the economic efficiency analysis reported in this deliverable. Other sample characteristics such as urban location, beekeeper association membership, attendance of beekeeping courses, migration with bees for honey flow, and inheritance of beekeeping practices are described in detail in Deliverable 4.3.

Beekeepers in the study sample resided in 18 countries, with most beekeepers residing in either Belgium or The Netherlands. Table 5 gives an overview of both the frequency and percentage of each country represented, and Figure 26 displays the relative percentages in a pie chart.

Table 5. Frequency and percentage of survey respondents by country

Country	Frequency	Percent
Belgium	170	20.1
The Netherlands	169	20.0
Germany	93	11.0
Portugal	78	9.2
Poland	74	8.8
Italy	73	8.6
Romania	67	7.9
Finland	53	6.3
United Kingdom	23	2.7
France	18	2.1
Bulgaria	13	1.5
Switzerland	4	0.5
Czechia	2	0.2
Slovenia	2	0.2
Spain	2	0.2
Austria	1	0.1
Lithuania	1	0.1
Sweden	1	0.1
Total	844	100.0

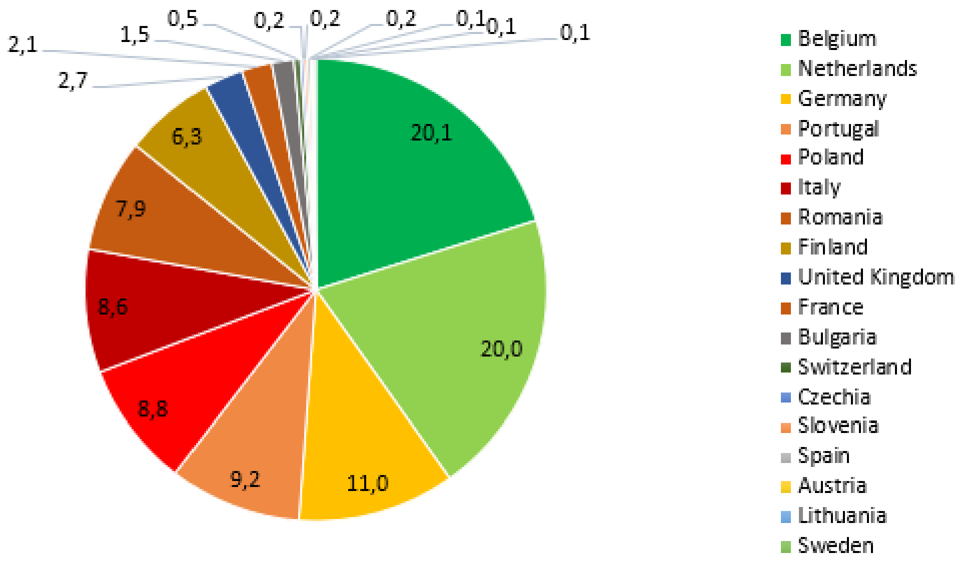

Figure 26. Percentage of each country represented by the sample (%, n=844)

Beekeepers were split into four regions of Europe (North, South, East and West) using the United Nations Geoscheme for Europe, in which the majority of beekeepers resided in Western Europe. Table 6 gives an overview of both the frequency and percentage of each region represented, and Figure 27 displays the relative percentages in a pie chart.

Table 6. Frequency and percentage of survey respondents by UN geoscheme region

UN geoscheme region	Frequency	Percent
Western	455	53.9
Eastern	156	18.5
Southern	155	18.4
Northern	78	9.2
Total	844	100.0

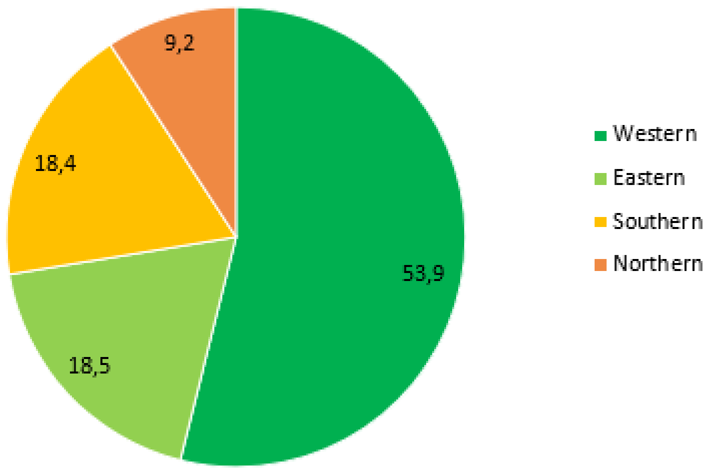

Figure 27. Percentage of each European region represented by the sample, according to the UN geoscheme for Europe (%, n=844)

Beekeepers' ages ranged from 18 to 91 years old, with the mean age among the sample being 53 years old. Age groups were created based on tertiles, where beekeepers were divided into three age groups; less than 46 years, 46-59 years, 60 years or more, each containing a third of the sample. Table 7 gives an overview of both the frequency and percentage of each age group represented, which shows that two thirds of beekeepers are over the age of 46 years.

Table 7. Frequency and percentage of survey respondents by age

Age	Frequency	Percent
Less than 46 years	279	33.1
46-59 years	293	34.7
More than 60 years	272	32.2
Total	844	100.0

Around four fifths of beekeepers were male and around one fifth were female, with six beekeepers indicating other or preferred not to say. Table 8 gives an overview of both the frequency and percentage of each gender represented in the sample, revealing that beekeepers in our sample are predominantly male.

Table 8. Frequency and percentage of survey respondents by gender

Gender	Frequency	Percent
Male	681	80.7
Female	157	18.6
Other / Prefer not to say	6	0.7
Total	844	100.0

Beekeepers reported being highly educated, where 39.5% had a Master degree and 28.9%

had a Bachelor degree. Table 9 gives an overview of both the frequency and percentage of the education levels represented, and Figure 28 displays the relative percentages in a pie chart, which shows that almost three quarters of the beekeepers in the sample had a university education.

Table 9. Frequency and percentage of survey respondents by education level

Education level	Frequency	Percent
Secondary education or lower	267	31.6
University college or university education, Bachelor level	244	28.9
University college or university education, Master level or higher	333	39.5
Total	844	100.0

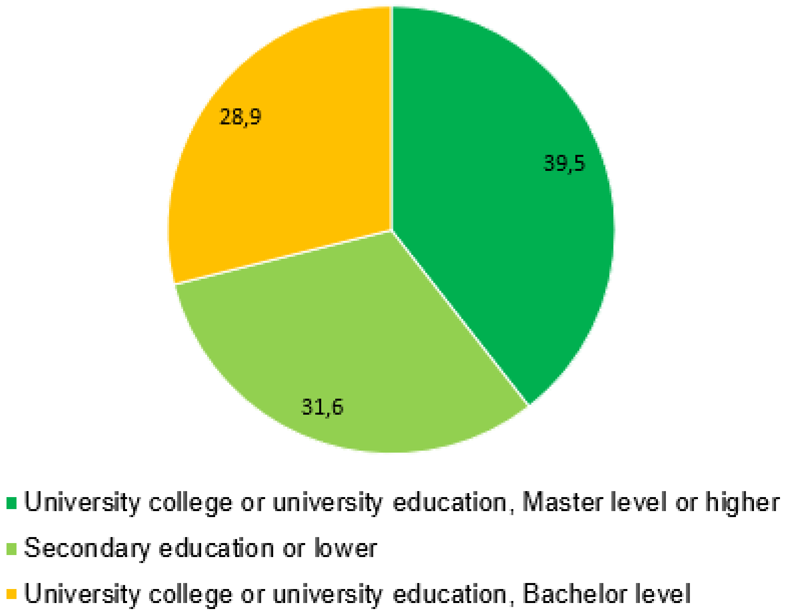

Figure 28. Percentage of each education level represented by the sample (%, n=844)

In the survey, beekeepers were asked to classify themselves on a 5-point categorical scale as a hobby or professional beekeeper based on on size and economic value, by which 46.9% of beekeepers classified themselves as purely hobbyist, 21.9% as rather hobbyist, 12.2% as neither hobbyist nor professional, 10.2% as rather professional and 8.8% as fully professional (see Table 10).

Table 10. Frequency and percentage of beekeeper types (n=844)

Beekeeper type	Frequency	Percent
Purely hobbyist	396	46.9
Rather hobbyist	185	21.9
Neither hobbyist nor professional	103	12.2
Rather professional	86	10.2
Fully Professional	74	8.8
Total	844	100.0

A new dummy variable was created to classify beekeepers as either hobby or professional beekeepers, where professional beekeepers were those who indicated either “rather professional” or “fully professional” on the original 5-point scale. Based on this classification, 684 beekeepers (81%) were classified as hobby beekeepers whereas 160 beekeepers (19%) were classified as professional beekeepers. This classification will be used unless specified otherwise.

We asked beekeepers to report their total number of hives, their number of hives used for honey production and their number of hives used for pollination services. The number of hives total reported by beekeepers in the entire sample ranged from 1 to 6,100, with a mean of 72 hives and a median of 15 hives. Professionals exhibited a higher average number of hives total than hobbyists, shown in Table 11. The total number of hives between hobby and professional beekeepers shows a significant difference (t = - 6.1; p<0.001).

Table 11. Total number of hives, number of hives used for honey production and number of hives used for pollination services between hobby and professional beekeepers (n=844)

Number of hives total	**Hobby (n=684)**	**Professional (n=160)**
Mean	21	291
Standard deviation	29	556
Minimum	1	5
Maximum	301	6100
Number of hives used for honey production	**Hobby (n=654)**	**Professional (n=159)**
Mean	17	217
Standard deviation	66	428
Minimum	1	3
Maximum	1616	4588
Number of hives used for pollination services	**Hobby (n=210)**	**Professional (n=74)**
Mean	18	143
Standard deviation	24	144
Minimum	1	4
Maximum	180	830

When comparing the average total number of hives between the different regions of Europe based on the UN geoscheme, beekeepers from the Southern region had the highest average number of hives (136), followed by beekeepers in the Eastern (118), Northern (116) and Western (27) regions. One-way ANOVA tests were conducted to test differences between regions for the number of hives, and we found the numbers of hives per beekeeper for the Western region to be statistically lower than other regions (F=9.9: p<0.001).

Considering beekeeping experience, the average number of years that beekeepers have been active with beekeeping among the sample was 15 years, with a median of 10 years, a minimum of 1 year and a maximum of 80 years. The number of years active as a beekeeper was correlated with beekeepers' age (Pearson r=0.475; p<0.001) as well as with the size of the apiary expressed in total numbers of hives in 2021 (Pearson r=0.183; p<0.001), though the latter correlation is only moderate.

Groups based on beekeeping experience were created based on tertiles, where beekeepers were divided into three groups; less than 5 years of experience, 6-15 years of experience and 16 years or more of experience, each containing a third of the sample. Table 12 gives an overview of both the frequency and percentage of each experience group represented, which shows that around one third of the total sample has less than 5 years of beekeeping experience.

Table 12. Frequency and percentage of survey respondents by beekeeping experience

Beekeeping experience	Frequency	Percent
6-15 years	311	36.8
16 years or more	273	32.3
Less than 5 years	260	30.8
Total	844	100.0

4.2 Beekeeping inputs

The previous section reported on sample and beekeeping characteristics of the entire sample of 844 beekeepers. The sample of 844 beekeepers was also used in Deliverable 4.3 in the analysis of beekeepers motivations, beekeepers orientations towards honeybees and beekeeping, beekeeping management practices, colony health and European beekeeper segments. However, since the economic survey section contains many free-form questions, the economic survey section required thorough checking for typographical errors and reliable numbers reporting. Around 12% (98) of the cases were excluded due to typographical errors and implausible or unrealistic numbers. A full description of the data cleaning process is provided in the Data Cleaning Repository in Appendix 6. The resulting dataset contained 746 beekeepers out of which 125 were professionals and 621 were hobbyists. This smaller dataset of 746 beekeepers is only used in the economic analysis; sections 4.6 Ecological-Environmental Characteristics and 4.7 Colony Health Status use the dataset of 844 beekeepers.

Concerning inputs for the sample of 746 beekeepers, capital costs, operational costs and labour for both hobby and professional beekeepers are summarised in the following tables and figures. As beekeepers were not required to provide values for every variable, the 'Missing' column refers to beekeepers who did not provide a value for the variable, and the n represents the valid number of beekeepers who did provide a value.

Table 13. Summary of capital costs (in euro) between hobby and professional beekeepers (n=746)

Capital costs	Missing	n	Min	Max	Mean	SD
Hives and colony costs (€)						
Hobby	98	523	1	30000	1401	2519
Professional	30	95	48	255833	13902	33830
Beekeeping equipment costs (€)						
Hobby	98	523	1	20000	948	1751
Professional	24	101	20	45000	4698	7699

Around four fifths (84%) of hobby beekeepers and around three fourths (76%) of professionals reported a value for hives and colony costs at the beginning of their beekeeping practice. Around four fifths (84%) of hobby beekeepers and around four fifths of professional beekeepers (80%) reported a value for beekeeping equipment costs at the beginning of their beekeeping practice.

Figure 29 shows the relative percentage of hive and colony costs and equipment costs within total capital costs for hobby and professional beekeepers.

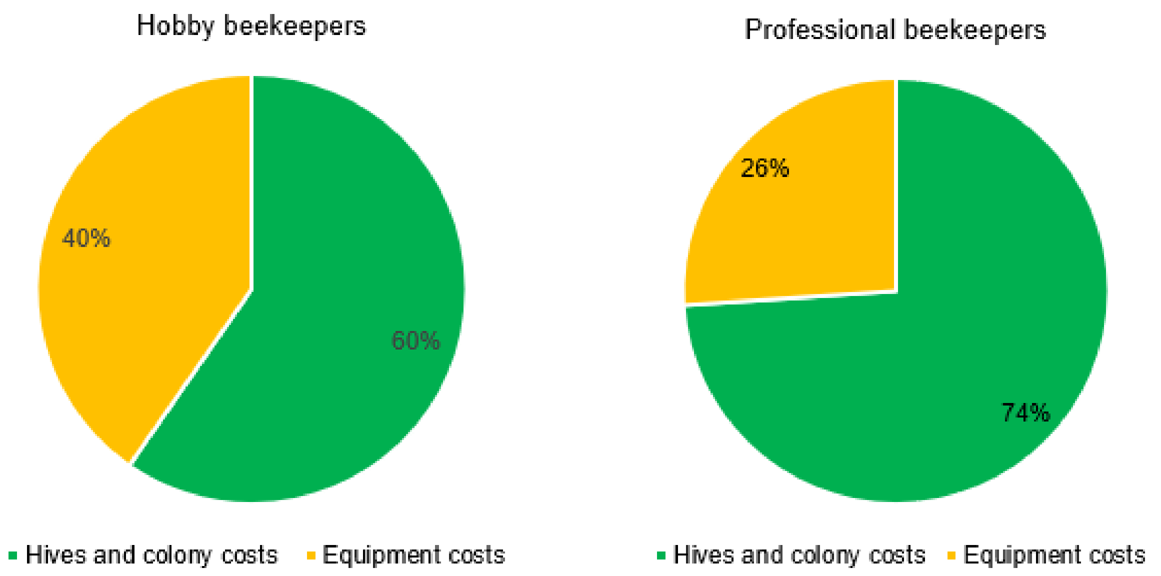

Figure 29: Percentage of each type of capital cost represented for hobby and professional beekeepers (n=746)

Regarding the capital costs displayed in Figure 29, professional beekeepers spent around three fourths (74%) on hives and colonies and one fourth (26%) on equipment whereas hobby beekeepers spent three fifths (60%) on hives and colonies and two fifths (40%) on equipment at the beginning of their beekeeping practice.

A summary of operational costs between hobby and professional beekeepers is provided in Table 14.

Table 14. Summary of operational costs (in euro) between hobby and professional beekeepers (n=746)

Operational costs	Missing	n	Min	Max	Mean	SD
Feed costs (€)						
Hobby	50	571	1	5000	270	475
Professional	5	120	15	76746	3501	7821
Disease prevention and treatment costs (€)						
Hobby	70	551	1	1800	102	148
Professional	5	120	10	25182	1290	2675
Honey harvesting and materials costs (€)						
Hobby	128	493	1	16803	320	846
Professional	22	103	20	50000	3286	6742
Fuel costs (€)						
Hobby	239	382	1	2998	230	383
Professional	11	114	50	61169	2915	6378
Electricity costs (€)						
Hobby	309	312	1	800	56	107
Professional	25	100	2	37522	1076	3947
Water costs (€)						
Hobby	319	302	1	970	27	65
Professional	38	87	4	11092	344	1257
Other costs (€)						
Hobby	463	158	10	6500	490	918
Professional	77	48	22	164283	6363	23626

Almost all (92%) of hobbyists and 96% of professionals reported a value for feed costs, 89% of hobbyists and 96% of professionals reported a value for disease prevention and treatment costs, 79% of hobbyists and 82% of professionals reported a value for honey harvesting and packaging costs, 62% of hobbyists and 91% of professionals reported a value for fuel costs, 50% of hobbyists and 80% of professionals reported a value for electricity costs, 49% of hobbyists and 70% of professionals reported a value for water costs, and 25% of hobbyists and 38% of professionals reported a value for other costs.

Figure 30 shows the relative percentage of feed costs, disease prevention and treatment costs, honey harvesting and packaging costs, fuel costs, electricity costs, water costs and other costs within total operational costs for hobby and professional beekeepers.

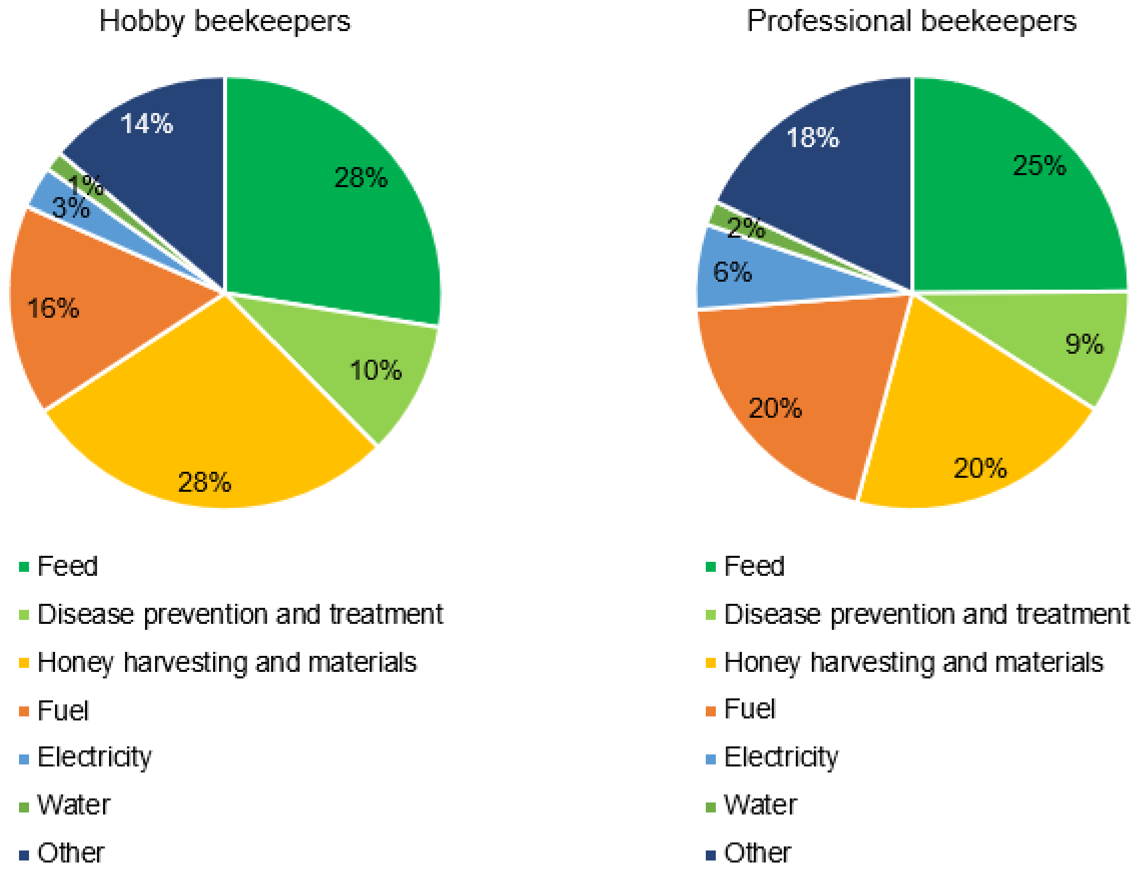

Figure 30. Summary of operational costs (in euro) between hobby and professional beekeepers (n=746)

Regarding yearly operational expenditures, hobby beekeepers spent the most on honey harvesting and materials (28% of their total operational costs) whereas professionals spent the most on feed (25% of their total operational costs). Hobby beekeepers spent equal amounts on feed and honey harvesting and materials, whereas for professionals, feed was a larger portion of total operational costs. Both professionals and hobbyists spent the least on water and electricity.

Other costs made up a considerable part of both professional and hobby beekeepers' operational costs. We asked beekeepers to describe these other costs, to which 196 (26%) provided legible responses in the description box. These responses were translated to English and categorised. These categories of other costs are presented in Table 15, which shows the number and percentage of beekeepers who provided a response in each category and the total cost per category. The table is sorted by total cost per category, in which 'Other materials (clothing, storage) had the highest costs and 'Taxes' had the lowest costs. Note that some beekeepers described more than one type of cost in the description box.

Table 15. Categorisation of "other costs" described by beekeepers in the survey (n=746)

Category	Number of beekeepers	Percentage of beekeepers	Total cost per category (€)
Other materials (clothing, storage)	37	19%	33999
Transport services/fuel	15	8%	21803
Marketing	17	9%	21022
Hive tools	29	15%	19416
Insurance	4	2%	12840
Hive boxes	11	6%	12665
Administrative costs	4	2%	11930
Packaging material (labels, jars)	33	17%	6140
Queens	12	6%	5990
Diseases control	4	2%	5313
Certifications	5	3%	5200
Memberships associations/activities	10	5%	2293
Websites	7	4%	2210
Courses/lessons	5	3%	1961
Wax	10	5%	1600
Hive technology	2	1%	1500
Workforce	3	2%	1214
Maintenance	6	3%	725
Bee feed	1	1%	557
Taxes	3	2%	405

Regarding labour, beekeepers were asked for their total annual labour (in man-days) on beekeeping, with their own labour included. We specified that this should include time spent both on managing bees and other aspects related to beekeeping (e.g. cleaning, sales, bookkeeping, etc.) and to assume a total of 8 working hours for one man-day. We also asked beekeepers how accurate (precise) they believed their number for man-days was, to which 30% indicated it was a very rough estimate, 35% indicated a rather rough estimate, 29% indicated a rather good estimate, and 6% indicated a highly accurate estimate. We also asked beekeepers for the average hourly rate they paid for hired beekeeping labour, if applicable.

Hobby beekeepers spent an average labour intensity of 4.2 days per hive (during bee season 2021) on their beekeeping practice and professionals spent an average labour intensity of 2.7 days per hive on their beekeeping practice. Table 16 summarises labour both in man-days and hourly rate for paid labour as far as the latter was relevant and this information has been provided.

Table 16. Summary of labour between hobby and professional beekeepers (n=746)

Labour	#Zeros	n	Min	Max	Mean	SD
Labour in man-days						
Hobby	14	607	1	2640	60	165
Professional	2	123	4	34000	715	3250
Hourly rate paid for labour (€)						
Hobby	595	26	3	55	14	12
Professional	91	34	1	30	7	6

Almost all 98% of hobbyists and 98% of professionals reported their labour in man-days, however only 4% of hobbyists and 27% of professionals reported on their hourly rate paid for labour. Based on this limited data, and looking at only figures from professional beekeepers, we could estimate that the hourly rate that beekeepers paid their workers ranged from €4 to €24 per hour in Northern countries, €4 to €9 per hour in Eastern countries, €4 to €9 per hour in Southern countries, and €10 to €24 per hour in Western countries. More on labour will be discussed in Section 4.4 Data Envelopment Analysis.

4.3 Beekeeping outputs

Regarding the apiary products, bees and services that beekeepers in our sample produced and sold, almost all (93%) of beekeepers produced honey, followed by 28% who produced wax, 21% who produced propolis, 21% who produced colonies, 13% who produced queens, 12% who produced pollen, 8% who provided pollination services and 3% who produced royal jelly (see Figure 31).

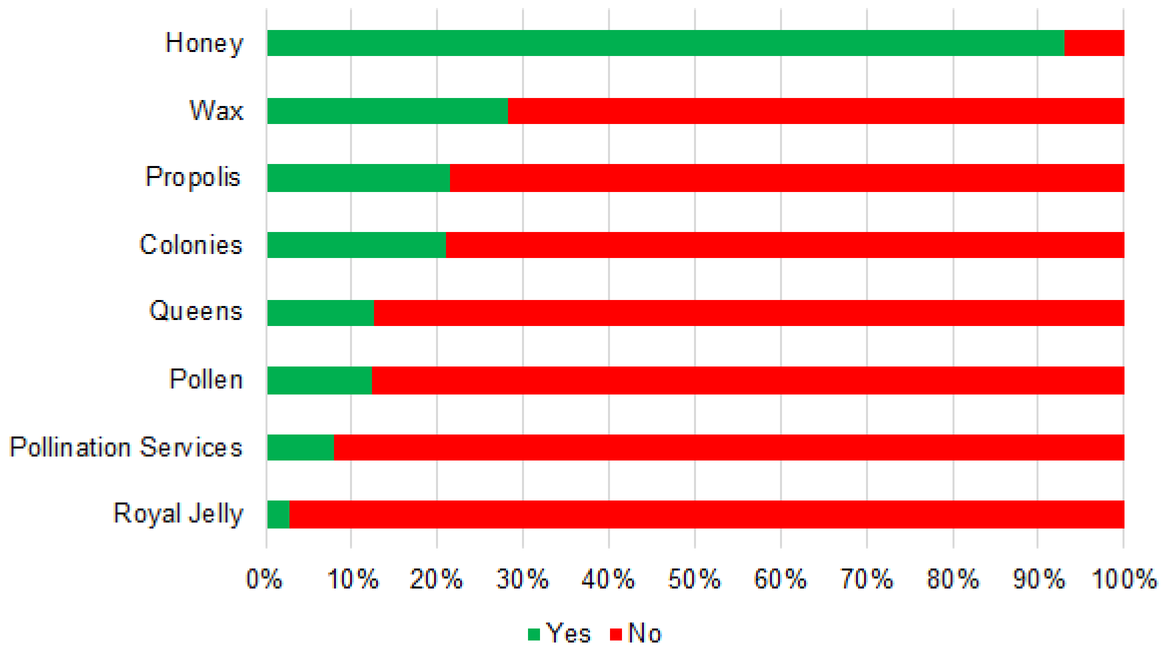

Figure 31. Production and sales of apiary products, bees and services (n=746)

The kilograms of honey that beekeepers produced, as well as their revenues from honey, pollination services and revenues from other beekeeping activities between hobby and professional beekeepers are summarised in the following tables and figures. Similarly to the tables summarising inputs, as beekeepers were not required to provide values for every variable, the 'Missing' column refers to beekeepers who did not provide a value for the variable, and the n represents beekeepers who did provide a value. A summary of outputs and revenues between hobby and professional beekeepers are provided in Table 17.

Table 17. Summary of outputs and revenues between hobby and professional beekeepers (n=746)

Outputs and revenues	Missing	n	Min	Max	Mean	SD
Total kg honey						
Hobby	52	569	1	4400	238	381
Professional	1	124	15	125000	4460	11852
Total revenue honey (€)						
Hobby	178	443	1	80000	1903	4456
Professional	13	112	8	1331055	32511,56	127208
Hives pollination services						
Hobby	430	191	1	180	17	23
Professional	70	55	4	830	149	147
Total revenue pollination (€)						
Hobby	581	40	10	30000	1271	46889
Professional	106	19	100	40000	7031	11382
Total revenue other beekeeping activities (€)						
Hobby	444	177	1	16000	1247	2112
Professional	37	88	28	182271	10794	23552

Around 91% of hobbyists and 99% of professional beekeepers reported a value for total kilograms of honey produced, and 71% of hobby beekeepers and 90% of professional beekeepers reported a value for revenue from honey. Only 31% of hobbyists and 44% of professionals reported a value for hives rented for pollination service, and only 6% of hobbyists and 15% of professionals reported a figure for revenues from pollination services. Concerning revenue from other beekeeping activities, only 29% of hobby beekeepers and 70% of professional beekeepers reported a value for this.

Figure 32 shows the relative percentage of revenue from honey, pollination services and other beekeeping activities (such as wax, propolis, colonies, queens, pollination services, etc.) between hobby and professional beekeepers.

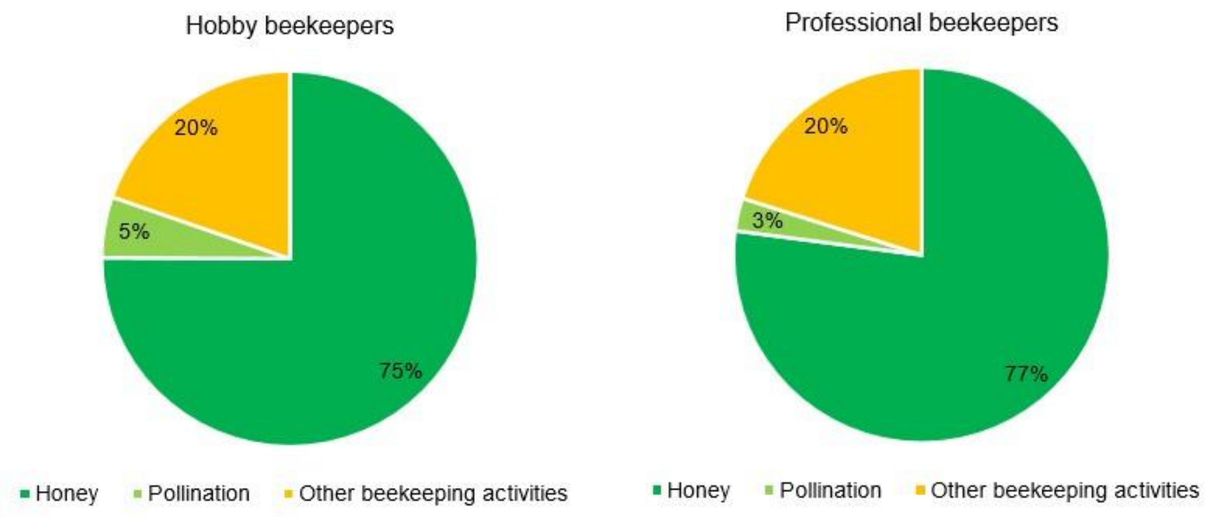

Figure 32. Summary of revenue sources between hobby and professional beekeepers (n=746)

Figure 32 shows that the share of types of revenues between hobby and professional beekeepers is very similar. Professionals make 77% of their total revenue from selling honey whereas hobbyists make 75% of their total revenue from selling honey. Regarding pollination, hobbyists make a slightly higher percentage of their total revenue (5%) from pollination while professional beekeepers only make 3% of their revenue from pollination. Hobbyists made an average of €2473 per year in revenues on their beekeeping practices and professionals made an average of €40730 per year on their beekeeping practices.

4.4 Data Envelopment Analysis

Exploratory bi-dimensional graphs and outlier detection

Similar to the first wave exploratory study, a series of bi-dimensional graphs were made to explain the complexity of beekeepers' operations and better understand differences between beekeepers input use. Graphs were also examined for the presence of outliers, since non-parametric approaches like Data Envelopment Analysis are very sensitive to the quality of data used. Therefore, before running the final DEA model, a rigorous analysis of both **outliers** and **anomalies** was performed.

Note: In the following analysis, **outliers** are identified in the graphs for the purpose of examination but are not excluded from the analysis, whereas **anomalies** are identified as cases that are irregular and therefore excluded from analysis.

First, 68 anomalies were excluded due to missing data: all beekeepers who entered 0s for honey in kg, number of hives for honey production or labour in man-days were excluded. 53 cases reported 0 for honey in kg, 2 cases reported 0 for number of hives used for honey production, and 13 cases reported a 0 for labour in man days. This brought the dataset down from 746 cases to 678 cases.

Next, similarly to the first wave study, we begin by plotting the relationship between honey and other basic inputs such as the number of hives used for honey production (Figure 33) and man-days (Figure 34).

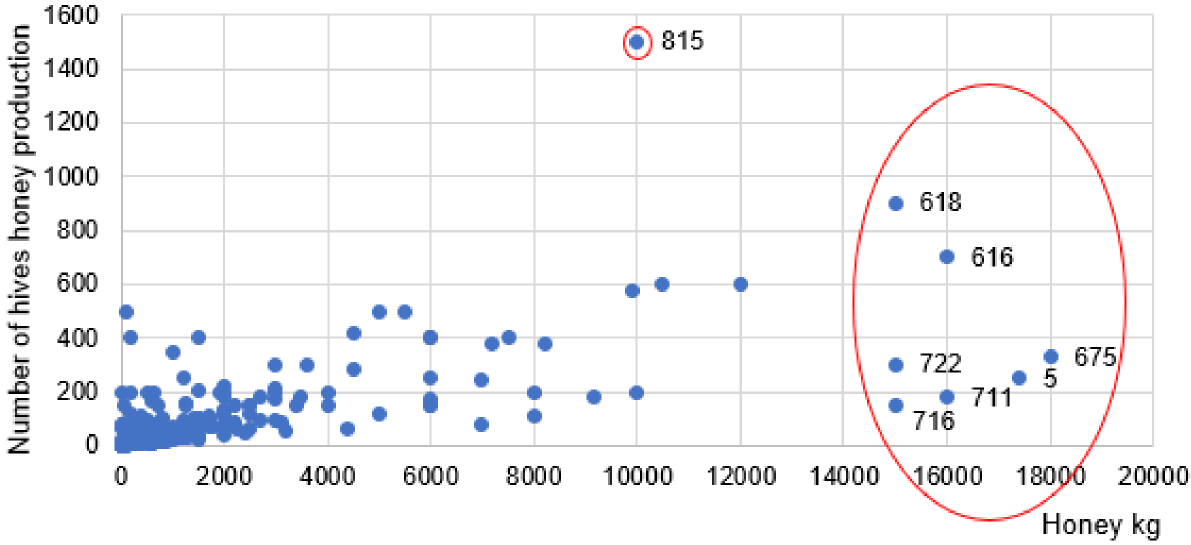

Figure 33. Honey production (kg) vs. number of hives (n=678)

In Figure 33, two beekeepers were left out of the graph (beekeepers 10 and 806) for better readability of the graph, but still included in the analysis. These two beekeepers both have more than 1400 hives, which we speculate to be large beekeeping businesses with multiple employees and hives in multiple locations. Beekeepers 618, 616, 722, 716, 711, 5 and 675 were identified as outliers due to their very high amounts of honey in kg and low number of hives. Beekeeper 815 was identified as an outlier due to his high amount of hives.

Beekeepers 675, 5, 711, 716 and 722 all have a high hive (yet, realistic) productivity of 50 kg per hive or more and very large beekeeping operations of at least 200 hives. They have at least 10 years of beekeeping experience and are all from Romania or the UK. Beekeepers 618 and 616 are both from Italy and have large beekeeping operations with 1000 hives each. They have 15 and 44 years of beekeeping experience and a high labour productivity of 26,67 and 30 which may explain their high hive productivity.

Beekeeper 815 is a beekeeper from Bulgaria with a large number of hives with a low hive productivity and a lower labour productivity than other outliers in the graph. He is the second largest beekeeper in the dataset, which explains his position as an outlier in the graph.

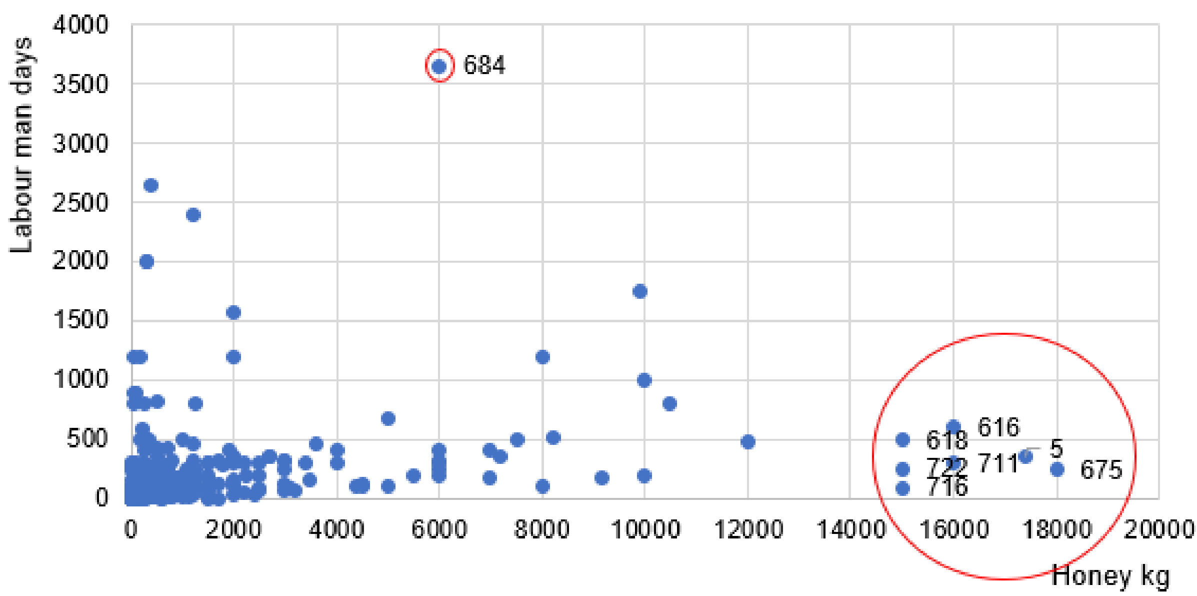

Figure 34. Honey vs. Labour (n=678)

In Figure 34, beekeepers 10 and 806 were left out of the graph for better readability of the graph, but still included in the analysis. Beekeepers 675, 5, 616, 711, 618, 722 and 716 were also identified as outliers in the previous graph. All of these beekeepers have large beekeeping operations and at least 10 years of experience.

Beekeeper 684 on the other hand reported a high amount of labour compared to honey in kg. This beekeeper also reported producing wax, propolis, royal jelly, pollen, colonies, queens, combs, apilarnil, and venom, which may explain his need for more labour to harvest wax, royal jelly, combs, etc.

Next, honey is plotted together with total revenue, to view the relationship between two different types of outputs (see Figure 35).

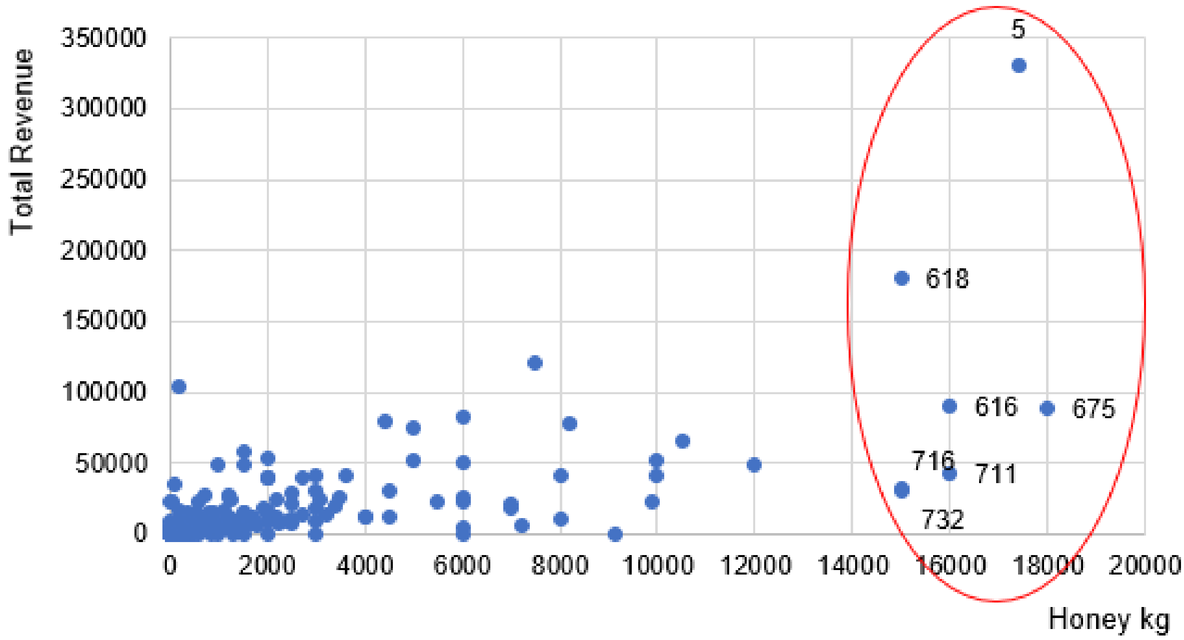

Figure 35. Honey production (kg) vs. total revenue (euro) (n=678)

In Figure 35, beekeepers 10 and 806 were left out of the graph for better readability of the graph, but still included in the analysis. Beekeepers 675, 616, 711, 716, 732 and 5 were also identified as outliers. These beekeepers all have large operations and at least 10 years of beekeeping experience. Beekeepers 5 and 618 are positioned higher than the other outliers in the graph since they have more output types than the other outliers, which may contribute to more revenue.

Next, hive productivity in honey was compared with hive productivity in euro, similarly to the first wave exploratory study, to explore the relationship between productivity indicators.

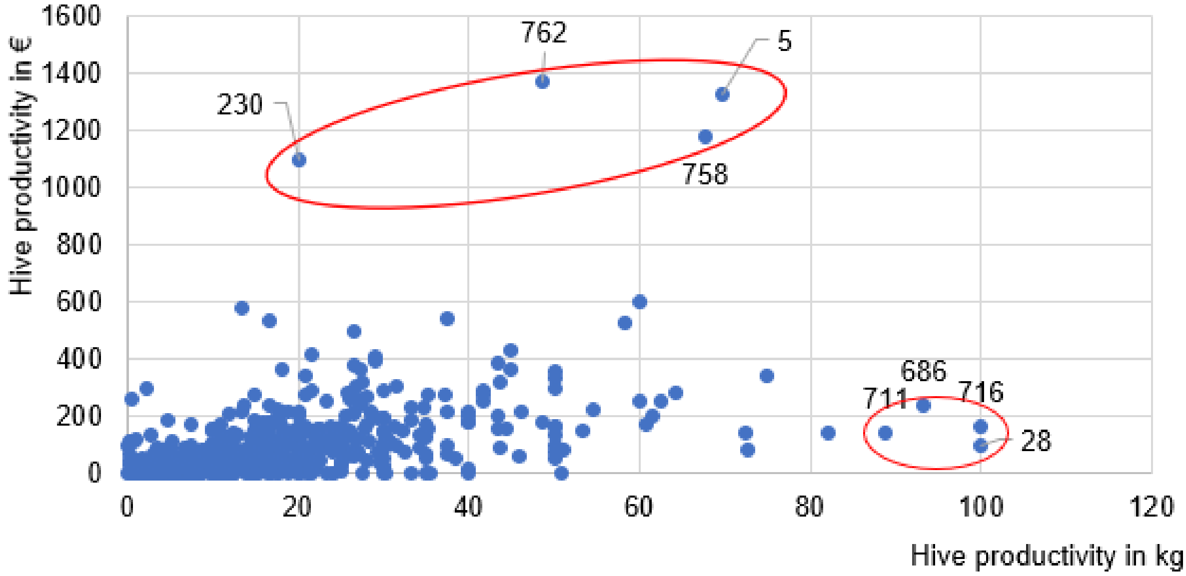

Figure 36. Hive productivity in kg vs. hive productivity in euro (n=678)

Starting with the cluster on the right-hand side, beekeepers 716, 711, and 686 have a low selling price per kg of honey of €2,15, €2,5 and €2,8 respectively. These three beekeepers produce mainly honey and are all from Romania. Beekeeper 28 is from the UK and has a very high productivity in kg (100 kg per hive) but does not sell his honey. He gains most of his revenue from queens which may be why his hive productivity in euro is so low when compared with his hive productivity in kg.

Looking at the cluster on the left-hand side, beekeeper 5 makes more than half of his total revenue (€182271 out of €330968) from selling other outputs besides honey such as wax, propolis, pollen and colonies. Similarly, beekeeper 230 makes 98% of his revenue from selling wax and only 2.4% (€400 of the total of €16400) from selling honey. Similarly, about half of the total revenue of beekeeper 762 comes from honey and the other half from wax.

Beekeeper 758 produces wax, propolis, pollen and colonies. His high hive productivity in both honey and euro could be associated with his location in Finland. Overall, high hive productivity in euro may be associated with having other outputs besides honey being the main source of revenue.

Next, 16 anomalies were excluded from analysis for the following reasons:

- Four beekeepers identified in Figure 36 (5, 762, 230 and 758) were excluded due to their main output being a beekeeping product other than honey;

- Beekeepers 716 and 791 were excluded due to an exceptionally high labour productivity of 167 kg and 94 kg of honey produced per man-day, which was believed to be non-plausible;
- Ten beekeepers with a labour intensity of less than 0.2 man-days per hive were excluded, since spending less than 0.2 days per hive was believed to be non-plausible.

These exclusions brought the dataset down from 678 cases to 662 cases that will be used in further economic analysis. The final dataset of 662 contains 117 professionals and 545 hobbyists.

Hive productivity

Hive productivity was calculated by the total kg of honey produced divided by the number of hives used for honey production. Average hive productivity among the same (n=662) was 17.1. Hive productivity between hobby and professional beekeepers are shown in Figure 37, in which hobby beekeepers had an average hive productivity of 16.6 and professional beekeepers had an average hive productivity of 19.6. Professional beekeepers did not have a statistically higher hive productivity than hobbyists.

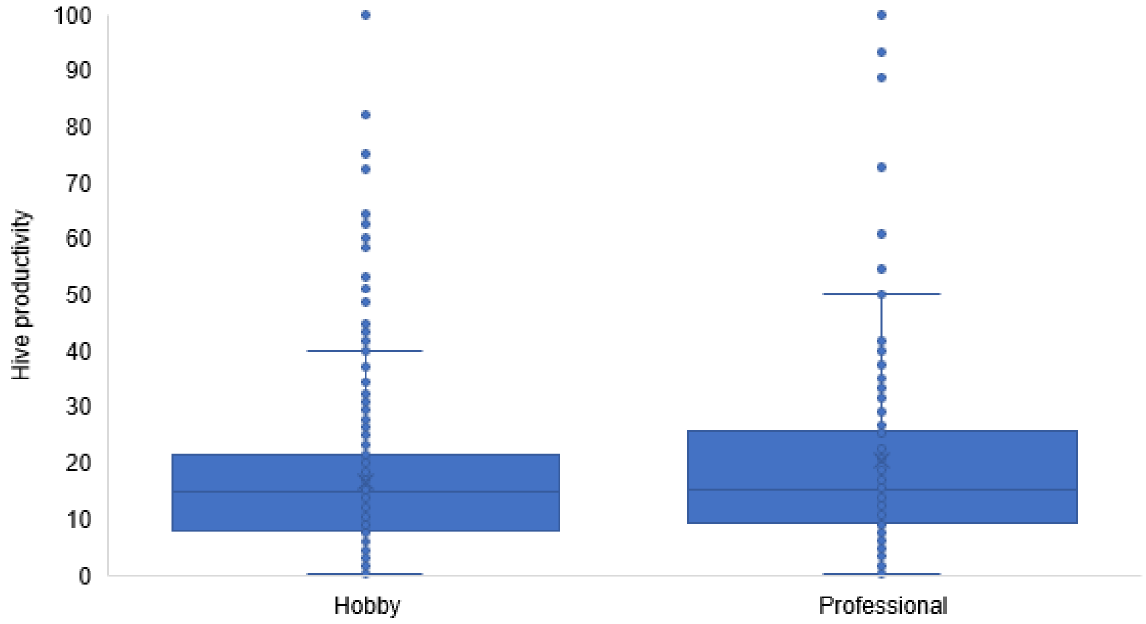

Figure 37. Hive productivity (kg of honey per hive) between hobby and professional beekeepers (n=662).

No statistically significant differences were found in average hive productivity between beekeepers who were less than 46 years old, 46-59 years and more than 60 years old. No statistically significant differences were found in average hive productivity between males and females. No statistically significant differences were found in average hive productivity between beekeepers with a secondary education, bachelors or masters degree. Hive productivity was not statistically correlated with the number of hives used for honey production or the number of total hives.

Beekeepers in Northern Europe had the highest mean hive productivity (29 kg per hive) compared with beekeepers in the Eastern region (18 kg per hive), Western region (16 kg per hive) and Southern region (11 kg per hive) (see Figure 38). Beekeepers in the Southern region exhibited statistically significant lower hive productivity than the other regions, and beekeepers in the Northern region exhibited statistically higher hive productivity than the other regions (F=24.9; p<0.001). Additional analysis on the external validity of the B-GOOD beekeeper survey data based on average hive productivity per country has been provided in Deliverable 4.3.

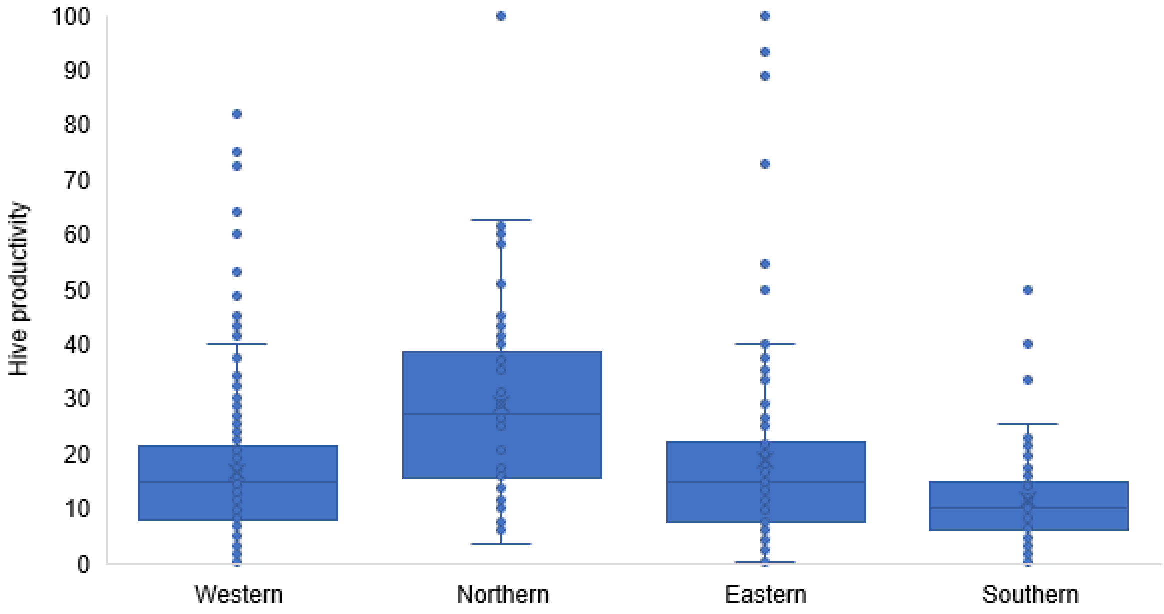

Figure 38. Hive productivity (kg honey per hive) across European regions (n=662)

Beekeepers with 16 or more years of beekeeping experience had statistically higher average hiver productivity than beekeepers with less than 5 years and beekeepers with 6-15 years of experience (F=8.04; p<0.001). Average hive productivity was also compared between the 5 beekeeper clusters (i.e. Urban-Explorer, Average-Cool, Professional, Passionate-Hobbyist, and Passionate-Skilled) identified in Deliverable 4.3, and no statistically differences in hive productivity were found between the clusters.

Labour productivity

Labour productivity for the sample of beekeepers was calculated by the total kg of honey produced per man-day. The average labour productivity among the entire sample was 9 kg of honey per man-day. Labour productivity between hobby and professional beekeepers are shown in Figure 39.

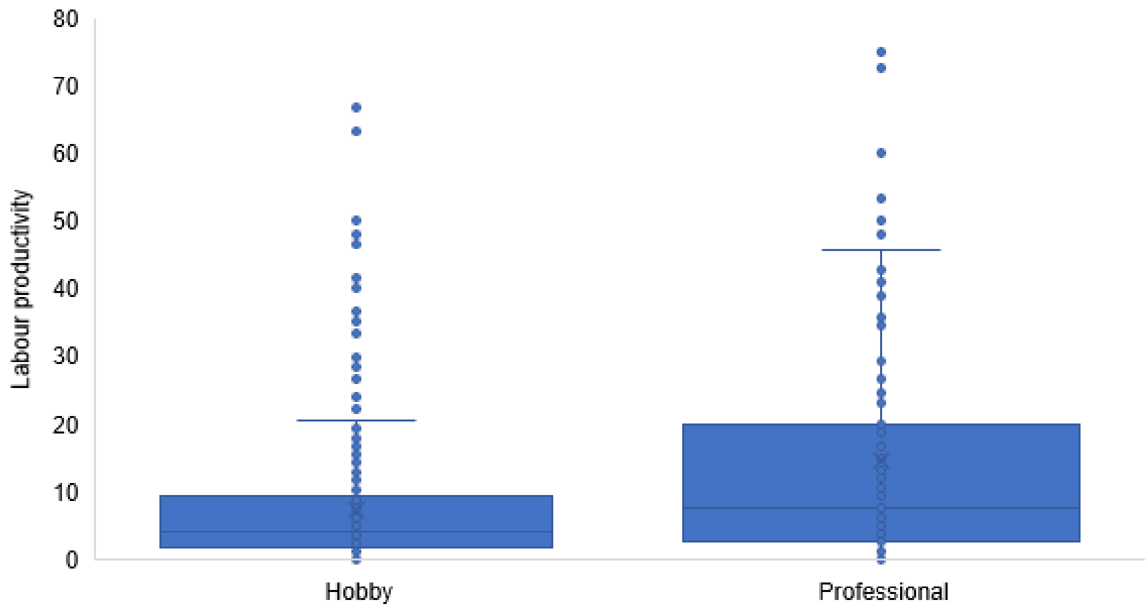

Figure 39. Labour productivity (kg of honey per man-day) between hobby and professional beekeepers (n=662)

Hobby beekeepers had an average labour productivity of 7 and professional beekeepers had an average labour productivity of 15, indicating that professionals had an overall more efficient use of their labour for honey production. Professional beekeepers had a statistically higher labour productivity than hobbyists (t=4.69; p<0.001).

Beekeepers who were younger than 46 years had a significantly higher labour productivity than beekeepers who were 60 years or older (F=4.15; p=0.016). No statistically significant differences were found in average labour productivity between males and females. Beekeepers with a masters degree had a significantly higher labour productivity than beekeepers with a secondary education (F=3.99, p=0.019). Labour productivity was positively correlated with the number of hives (r=.099; p=0.011).

Beekeepers in Northern Europe had the highest mean labour productivity (16 kg per day) compared with beekeepers in the Eastern region (13 kg per day), Southern region (8 kg per day) and Western region (6 kg per day). Beekeepers in the Northern and Eastern regions had significantly higher labour productivity than beekeepers in the Southern and Western regions (F=25.02; p<0.001).

Beekeepers with 6-15 years or 16 or more years of beekeeping experience had significantly higher labour productivity than beekeepers with 5 years or less of beekeeping experience (F=11.3; p<0.001). Average labour productivity was also compared between the 5 beekeeper clusters identified in Deliverable 4.3, and Cluster 3 'Professionals' had significantly higher labour productivity than the other four clusters (F=12.22; p<0.001).

Efficiency scores

Similar to the exploratory first wave study, efficiency measures were calculated via linear programming using the software DEAP (Coelli, 2008). First, a DEA was performed on the entire sample of 662, using the same model as the first wave study: an input oriented model with one output, **honey**, and two inputs, **labour** in man-days and number of **hives used for honey production**.

We chose to use a variable returns to scale (VRS) DEA model, as a VRS is typically used to estimate efficiencies when an increase or decrease in input does **not** result in a proportional increase or decrease in output, as was suggested by the outcomes of the exploratory research phase.

Our variable for labour, labour in man-days, present in our model, assumes that this variable is composed of labour required for honey production but also the labour required for the production of other outputs. As a consequence, an increase/decrease in labour in man-days does not mean a proportional increase/decrease in our output (honey), as many beekeepers produce other outputs besides honey for which they need more labour in man-days. Thus, according to our model, labour in man-days input is not directly related to our output honey, therefore VRS is the most appropriate approach.

Figure 40 shows a frequency distribution of technical efficiency scores among the sample. Efficiency scores ranged from 0.0030 to 1.000 with 0.3307 being the average among the sample.

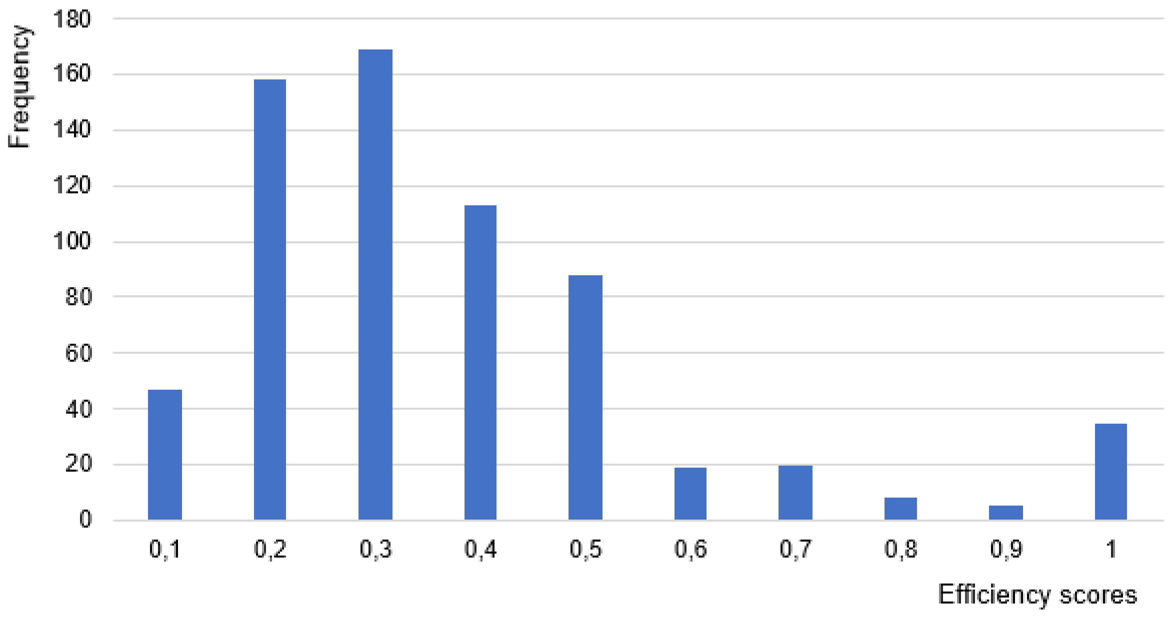

Figure 40. Frequency distribution of efficiency scores (n=662)

Efficiency scores between hobby and professional beekeepers are presented in Figure 41. The average efficiency score for hobby beekeepers was .34 whereas for professionals it was .29. Hobby beekeepers had a significantly higher average efficiency than professionals (t=-2.303; p=0.022).

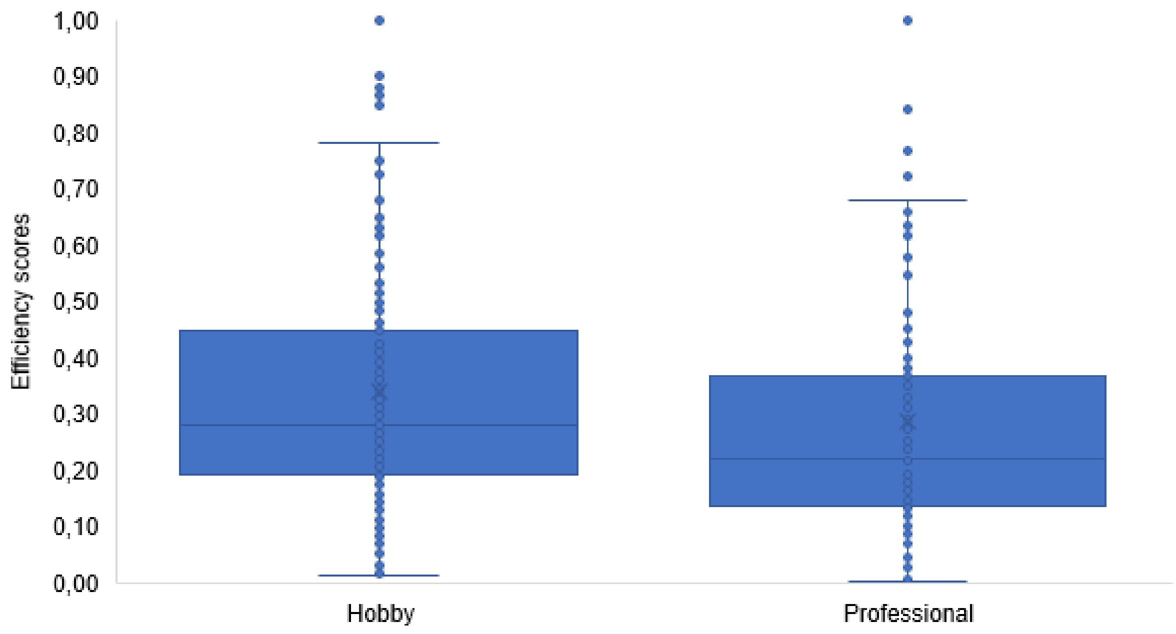

Figure 41. Efficiency scores between hobby and professional beekeepers (n=662)

The labour variable, as well as the outputs that each group produces may explain the higher efficiency scores among hobby beekeepers.

Looking at professional beekeepers in our sample, 16% of them produce exclusively honey, 20% of them produce one other output besides honey, and 64% of them produce at least two other outputs besides honey. On the other hand, looking at hobby beekeepers, 54% of them produce exclusively honey, 24% of them produce one other output besides honey, and 22% of them produce at least two other outputs besides honey. Professional beekeepers thus are more likely to have other outputs than hobbyists.

While producing more outputs besides honey does not necessarily mean more hives, since hives for honey production can also generate other outputs such as wax and propolis, producing more outputs does however require more labour. Thus, an increase in labour in man-days in hobby beekeepers is more likely to turn into a higher efficiency score (with honey as the output), since this group contains more beekeepers who produce honey exclusivity or produce only one other output.

It is less likely that the same increase in labour hours would translate into a higher honey output for professional beekeepers, since the majority of professional beekeepers produce more than two different outputs besides honey, demonstrating that their labour is dispersed between different outputs.

Overall, 35 beekeepers achieved an efficiency score of 1, meaning they are fully efficient. Out of these 35 beekeepers:

- 86% (30) are hobby beekeepers and 14% (5) are professional beekeepers.
- 34% are from the Netherlands, 34% from Belgium, 11% from Romania, 9% from Finland, 6% from the UK, and 3% from Portugal and 3% from Italy.

- Out of the 5 fully efficient professional beekeepers, 4 are from Romania and 1 is from the UK.
- 40% of beekeepers are more than 60 years old, 31% are less than 46 years old and 29% are between 47 and 59 years old.
- 34% have a master degree, 40% have a bachelor's degree and 26% have secondary education.
- 71% produce honey exclusively, 17% produce one other output besides honey. 9% produce 3 other outputs besides honey and 3% produce 4 other outputs besides honey.
- 54% beekeepers have between 0 to 5 years of beekeeping active experience, 26% have between 6 to 15 years of beekeeping experience and 20% have more than 16 years of active beekeeping.
- 80% of beekeepers have only between 1 and 10 hives, 14% have more than 20 hives, and 6% of beekeepers have between 11 and 20 hives.
- A variable to measure floral resources, *Floral Resources Land,* was computed and described in the next section 4.6 Ecological-Environmental characteristics, in which these 35 beekeepers scored higher by average on this variable (7.83) than the average for the entire dataset (7.66).
- The majority (54%) indicated that climate change had a ‘neither negative nor positive’ impact on their beekeeping activities, whereas 40% indicated ‘negative,’ 3% indicated ‘very negative’ and 3% indicated ‘positive.’
- The majority (54%) reported an average honeybee colony winter loss rate of between 0-10% and only 6% reported an average honeybee colony winter loss rate of more than 30%.

No statistically significant differences were found in average efficiency between beekeepers who were less than 46 years old, 46-59 years and more than 60 years old. Female beekeepers had significantly higher efficiency scores than male beekeepers ($t=-2.14$; $p=0.033$). Beekeepers with a secondary education had significantly lower efficiency scores than beekeepers with a bachelors or masters degree ($F=4.53$; $p=0.011$). Efficiency was not statistically correlated with the number of hives used for honey production or the number of total hives.

Beekeepers in the Northern region of Europe had the highest mean efficiency (0.473) compared with beekeepers in the Western region (0.355), Eastern region (0.276) and Southern region (0.229). Beekeepers in the Northern region had significantly higher efficiency scores than all other regions, and beekeepers in the Western region had significantly lower efficiency scores than the Northern regions but still higher than the Eastern and Southern regions, who had significantly lower efficiency scores ($F=21.352$; $p<0.001$).

Beekeepers with less than 5 years of beekeeping experience had significantly higher efficiency scores than beekeepers with 6-15 or 16 or more years of beekeeping experience ($F=7.95$, $p<0.001$). Average efficiency was also compared between the 5 beekeeper clusters identified in Deliverable 4.3, where Cluster 1 ‘Urban-Explorer’ had significantly higher efficiency scores than Cluster 2 ‘Average-Cool,’ Cluster 3 ‘Professional,’ and Cluster 5 ‘Passionate-Skilled.’

Efficiency was positively correlated with hive productivity ($r=0.553$; $p<0.001$). Efficiency was negatively correlated with the GBMP index presented in Deliverable 4.3 ($r=-0.088$; $p=0.024$), although the correlation is extremely weak and therefore not very meaningful.

Efficiency scores – Professionals

Since DEA is a comparative method in which the resulting efficiency scores are influenced by all beekeepers in the dataset, a separate DEA was performed for beekeepers who indicated being ‘fully professional’ (n=56) in order to examine efficiency scores within a select sample of beekeepers who practise beekeeping for purely economic reasons. This classification of professionals is a more strict classification than previously used, namely only those with 'fully professional'. For the dataset of fully professional beekeepers, a DEA using the same model (VRS, honey, labour and hives) was run.

Figure 42 shows a frequency distribution of technical efficiency scores among the sample of fully professional beekeepers. Efficiency scores ranged from 0.087 to 1.000 with 0.487 being the average among the professional sample, which is a slightly higher average than the entire sample.

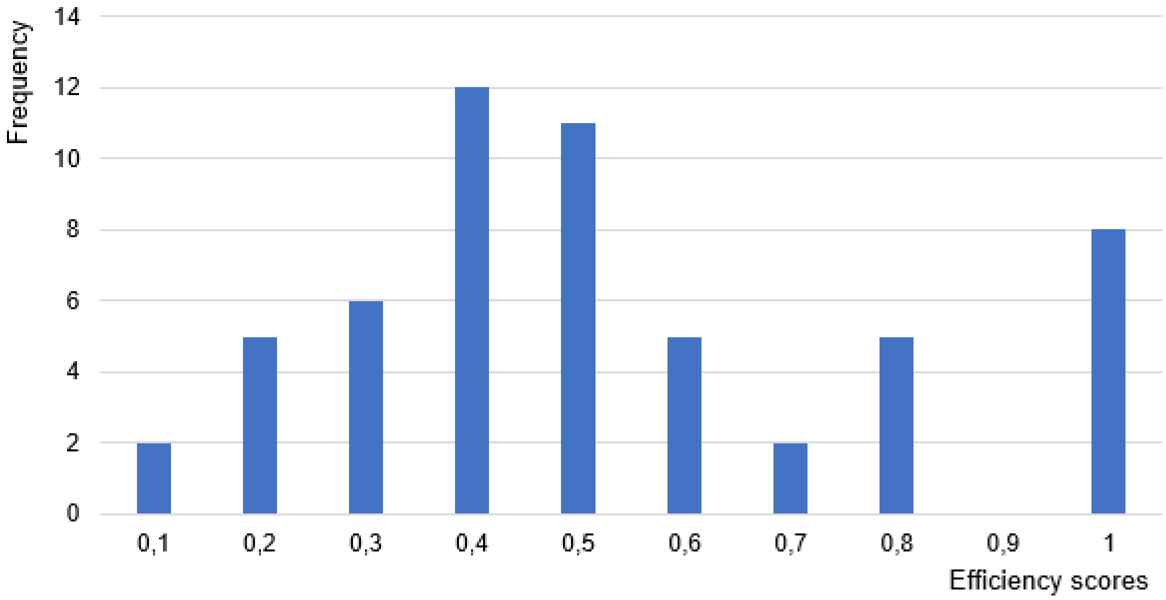

Figure 42. Frequency distribution of efficiency scores for fully professional beekeepers (n=56)

Six professional beekeepers achieved full efficiency with an efficiency score of 1. These six beekeepers are described as the following:

- 2 beekeepers are from the UK, 2 from Romania, 1 from Portugal and 1 from Poland.
- 4 beekeepers are less than 46 years old, 1 is between 47 and 59 years old and 1 is more than 60 years old.
- 2 have a master degree, 3 have a bachelor's degree and 1 has a secondary education.
- 2 produce honey exclusively, 1 produces one other output besides honey and 3 produce 3 other outputs besides honey.
- 3 beekeepers have between 6 to 15 years of beekeeping experience and 3 have more than 16 years of beekeeping experience.
- 5 beekeepers have more than 21 hives and 1 has between 11 and 20 hives

- These six beekeepers scored higher by average on the variable *Floral Resources Land* (7.83) than the average for the entire dataset (7.66).
- 2 beekeepers indicated that climate change had a 'positive' impact on their beekeeping activities, 2 indicated 'neither negative nor positive,' 1 indicated 'negative' and 1 indicated 'very positive.'
- 4 beekeepers reported an average honeybee colony winter loss rate of between 0-10%, and 2 beekeepers reported an average honeybee colony winter loss rate of above 10%.

A second DEA was run for professionals using **total revenues** as the output instead of honey, since figures concerning revenue are more reliable among professional beekeepers in our sample. In the model using total revenues as the output, the **total number of hives** is used instead of hives used for honey production. Five of the 56 beekeepers reported no revenue, so the following DEA is run with 51 beekeepers.

Figure 43 shows a frequency distribution of technical efficiency scores among the sample of fully professional beekeepers, using total revenues instead of honey in kg. Efficiency scores ranged from 0.141 to 1.000 with 0.568 being the average among the sample, which is higher than the efficiency scores exhibited by professionals using honey in kg. This suggests that fully professional beekeepers may be more efficient in their ability to make money from their beekeeping practice than efficiency in their ability to produce honey.

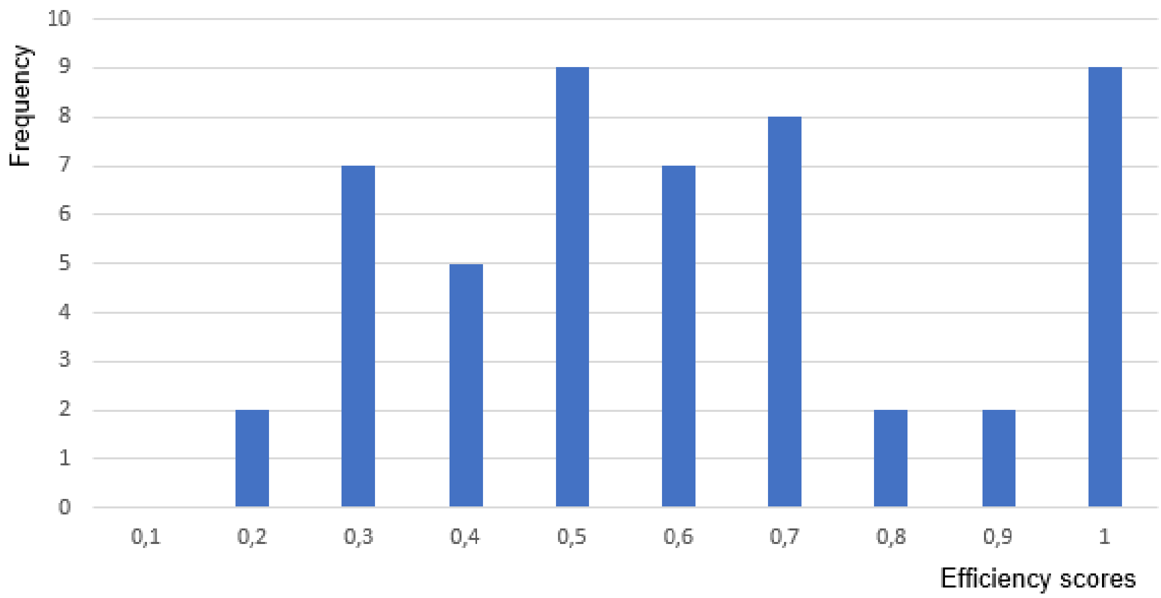

Figure 43. Frequency distribution of efficiency scores for fully professional beekeepers using **total revenues** (n=51)

Seven professional beekeepers achieved full efficiency with an efficiency score of 1, from which three of these achieved full efficiency in both DEA models (honey kg and total revenues). These seven beekeepers are described as the following:

- 2 are from Italy, 1 is from Bulgaria, 1 from Finland, 1 from Poland, 1 from Romania and 1 from the UK.

- 5 beekeepers are less than 46 years old, 1 is between 46 and 59 years old and 1 is more than 60 years old.
- 3 have a master degree, 2 have a bachelor's degree and 2 have a secondary education.
- 1 produces honey exclusively, 1 produces two other outputs besides honey, 2 produce 3 other outputs besides honey and 2 produce 4 other outputs besides honey.
- 4 beekeepers have between 6 to 15 years of beekeeping experience and 50% have more than 16 years of beekeeping experience.
- 6 beekeepers have more than 21 hives and 1 beekeeper has between 11 and 20 hives.
- These seven beekeepers scored higher by average on the variable *Floral Resources Land* (8.43) than the average for the entire dataset (7.66).
- 3 beekeepers indicated that climate change had a 'neither negative nor positive' impact on their beekeeping activities, 2 beekeepers indicated 'negative,' 1 beekeeper indicated 'positive' and 1 beekeeper indicated 'very negative.'
- 3 beekeepers reported an average honeybee colony winter loss rate of between 0-10%, and 4 beekeepers reported an average honeybee colony winter loss rate of between 10-30%.

4.5 Ecological Environmental Characteristics

To measure the ecological environmental quality surrounding hives, beekeepers were asked three sets of questions. The first set of questions aimed to understand the type of location where the majority of beekeepers' hives were situated. Beekeepers were asked if the landscape surrounding their hives was mainly 1) agricultural crop production, 2) agricultural livestock production / pasture, 3) forest or 4) human constructions / urban area on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree).

The highest mean agreement score was for mainly agricultural crop production (2.92), followed by mainly forest (2.80), followed by mainly livestock production/pasture (2.63) and lastly mainly human constructs/urban area (1.99) (see Figure 44).

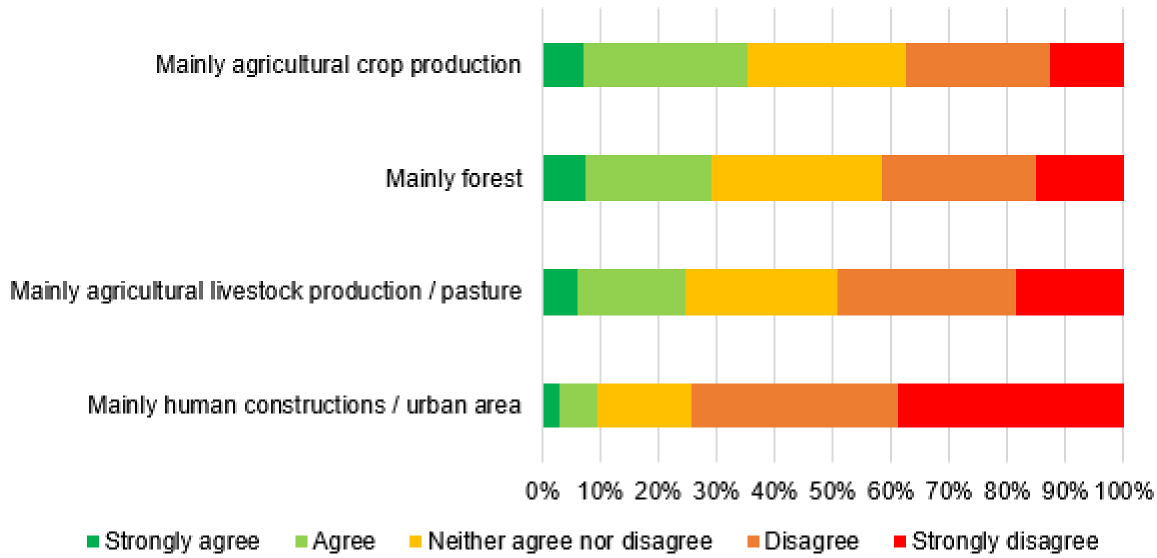

Figure 44. Mean agreement scores for type of hive location (n=844)

The second of questions set aimed to gather insight on the quality of the natural environment. Beekeepers were asked to what extent they agree to the following items on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree):

1) There are sufficient floral resources surrounding my hives from early to late in the bee season
2) The environment surrounding my hives is biodiverse in terms of floral resources
3) The environment surrounding my hives contains chemical contaminants
4) I collaborate with farmers in my region to encourage pollinator-friendly landscapes
5) Current policy measures in my region adequately address issues of floral resources, biodiversity, and landscape diversity

Item 2 *The environment surrounding my hives is biodiverse in terms of floral resources* received the highest mean agreement score (3.98) and Item 3 *The environment surrounding my hives contains chemical contaminants* received the lowest mean agreement score (2.31) (see Figure 45). This suggests that many beekeepers in our sample have chosen biodiverse locations to place their hives.

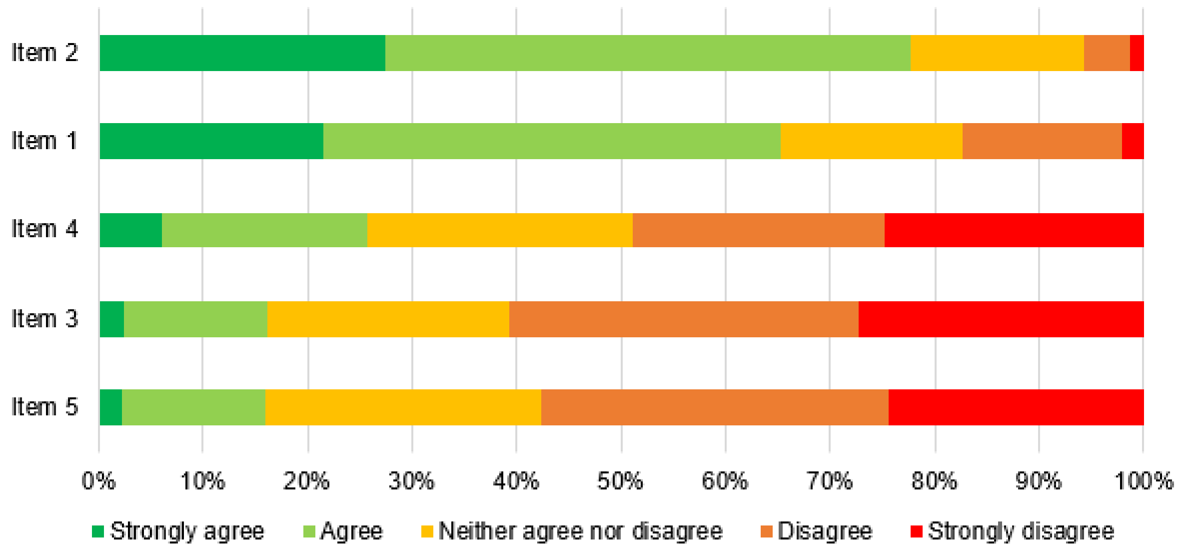

Figure 45. Mean agreement scores for environmental quality items (n=844)

The 4 items concerning type of environment and the 5 items concerning environmental quality were then taken together as 9 items and checked for positive correlations between them. The two items 1) agricultural crop production and 2) agricultural livestock production / pasture had the second largest correlation coefficient (r=0.299) and were aggregated to create a new variable, *Agricultural Land* which represents agricultural land both in crops and livestock (alpha=0.461). We found that Agricultural Land was not correlated with efficiency, hive productivity or labour productivity. This suggests that being in an environment surrounded by agricultural land may not be associated with efficiency or productivity.

The two items 1) There are sufficient floral resources surrounding my hives from early to late in the bee season and 2) The environment surrounding my hives is biodiverse in terms of floral resources had the largest correlation coefficient (r=0.541) and were aggregated to create a new variable *Floral Resources Land* which represents land that is biodiverse and has sufficient floral resources (alpha=0.694). We found that Floral Resources Land was positively but weakly correlated with efficiency (r=0.085; p=0.029), but not with hive productivity or labour productivity. This suggests that being in an environment that is biodiverse in terms of floral resources may increase the efficient use of labour and hives together, but not necessarily increase honey production alone.

Looking at chemical contaminants as a separate item, it was not correlated with efficiency, hive productivity or labour productivity, suggesting that chemical contaminants may not be as important for beekeeping performance as floral resource diversity.

Finally, the third set of questions aimed to address and gather information on the impact of climate change. We asked beekeepers if climate change has a positive or negative impact on their beekeeping activities on a 5 point scale (1 = very negative to 5 = very positive) called *Perceived Climate Change Impact* (see Figure 46). Regions of Europe were compared, in which climate change in Southern regions had a significantly more perceived negative impact than in other regions, and climate change in the Western and Northern regions had a significantly more perceived positive impact (F=49.8; p<0.001).

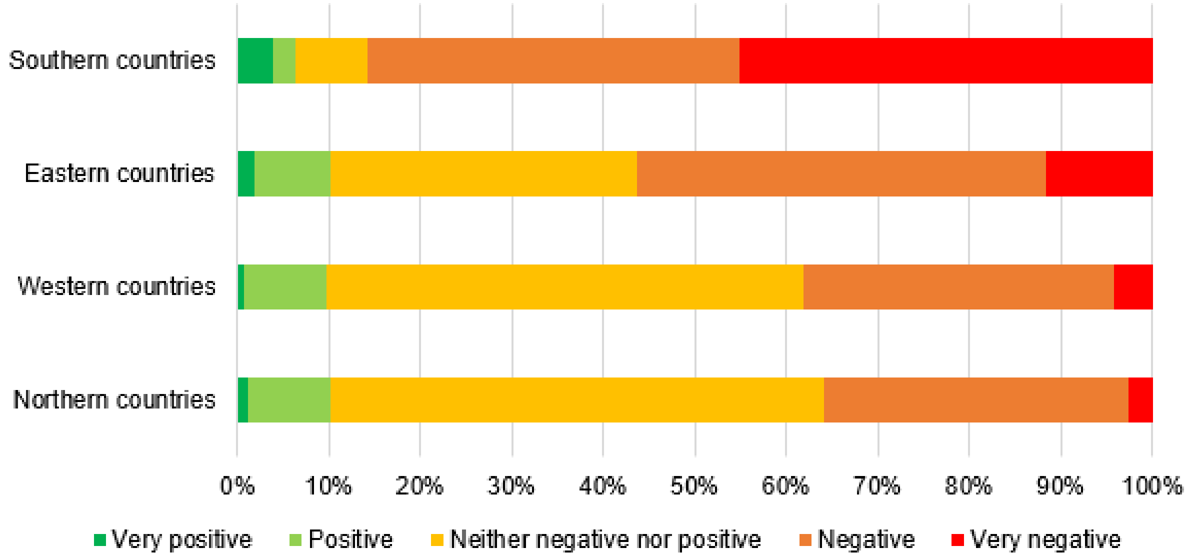

Figure 46. Perceived Climate Change Impact between European regions (n=844)

We also asked beekeepers to indicate the extent they believe climate change has a positive or negative impact on the following items on a 5 point scale (1 = very negative to 5 = very positive). To rank the items in terms of perceived negative impact, the sum of total percentages for ‘negative’ and ‘very negative’ were computed for each item. In Figure 47, the largest perceived negative impact of climate change has been on ‘local weather conditions’ followed by ‘honey yield’ and ‘food resource availability.’

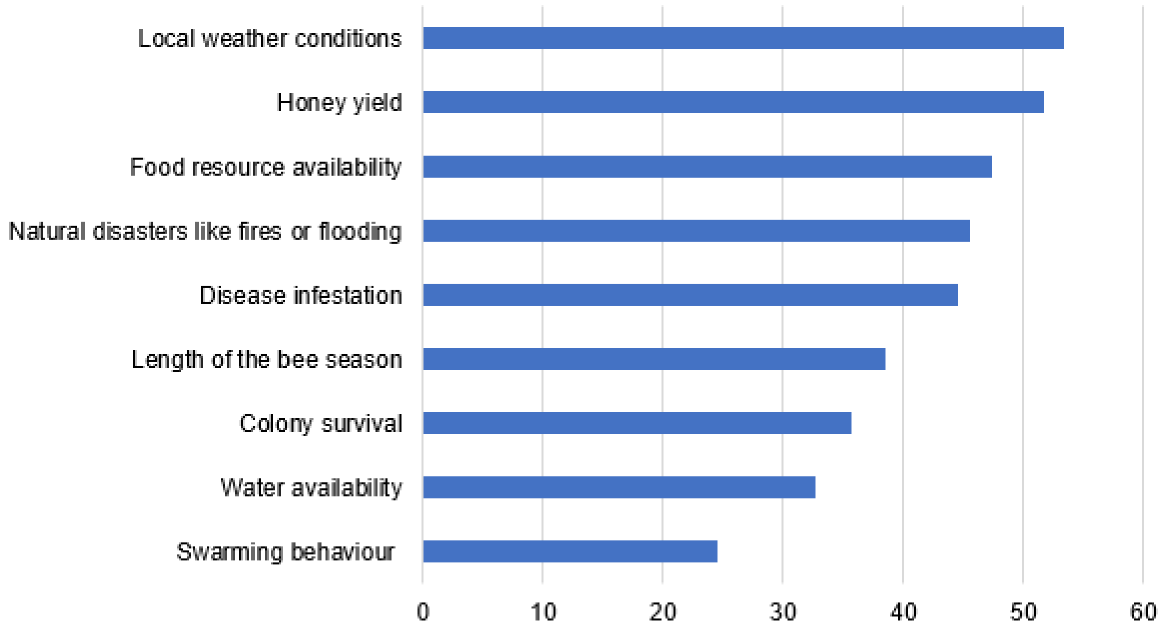

Figure 47. Perceived negative impacts of climate change, ranked from most negative to least negative (n=844)

We found that the variable Perceived Climate Change Impact was positively correlated with efficiency ($r=0.119$; $p=0.002$) and hive productivity ($r=0.136$; $p<0.001$) but not labour productivity. This suggests that positive impacts of climate change may be positively associated with efficiency and hive productivity. It also suggests that positive impacts from climate change may be more associated with hive productivity than the type of environment surrounding hives (agricultural land or biodiverse land), or the amount of chemical contaminants in the surrounding environment.

4.6 Colony health status

Colony health status was already reported in Deliverable 4.3, in which we gathered two main measures for colony health status 1) Honeybee colony winter loss rate and 2) Colony health status monitoring index. Both measures were already described in Deliverable 4.3 and will briefly be described again below.

Honeybee colony winter loss rate

In order to gain an estimate of the health status of beekeepers' colonies, we asked beekeepers for their average honeybee colony winter loss rate over the past five years. Regarding the reported average colony winter loss rate over the past five years, almost half of the beekeepers in our sample (48.2%) reported an average colony winter loss rate of 0-10%, followed by 30.7% of beekeepers having an average colony winter loss rate of 10-20% (see Figure 48). Additional analysis of the external validity of the B-GOOD beekeeper survey data based on honeybee colony winter loss rates is provided in Deliverable 4.3.

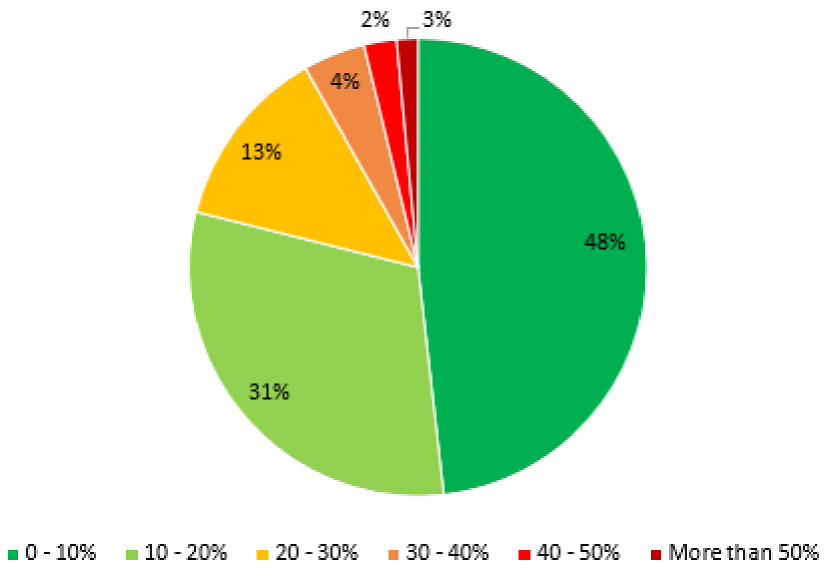

Figure 48. Honeybee colony winter loss rate among the total sample (n=844); in response to the question 'What is your average beehive winter loss percentage over the past five years?'

To allow reliable statistical association testing with other variables, colony winter loss rate was re-coded into four categories through merging the three largest groups into one category as more than 30% '>30%'. There were no significant differences between these groups in average efficiency scores. Beekeepers with 0-10% colony winter loss had significantly higher hive productivity than beekeepers with more than 30% colony winter loss (4.998; p=0.002). Beekeepers with more than 30% colony loss rate had lower average labour productivity than beekeepers with 20-30%, 10-20%, and 0-10% colony winter loss (F=4.891; p=0.002).

Colony health status monitoring index

Beekeepers were asked how often they check for a series of health indicators of their colonies during the beekeeping season on a categorical frequency scale (1=never, 5=at every inspection), shown in Figure 49, where more than three fifths of beekeepers reported checking for the presence of all stages of brood, sufficient amount of nutrition, suitable space for colony development and sufficient amount of adult bees at every inspection, suggesting that most beekeepers in our sample take their beekeeping practice seriously.

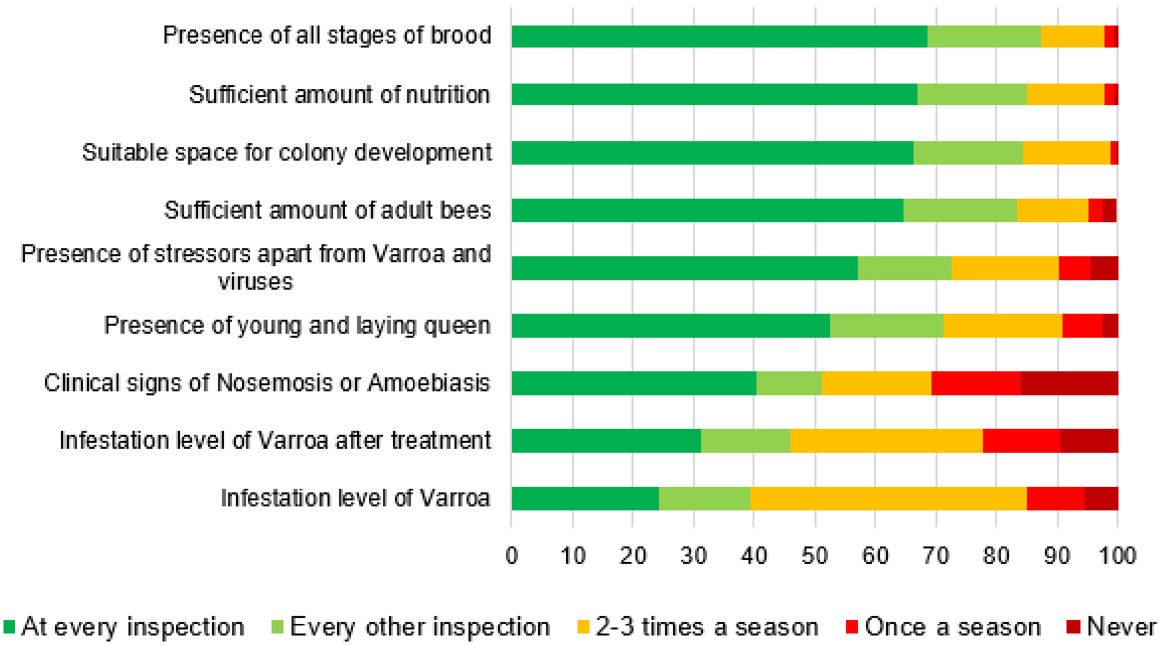

Figure 49. Frequency of colony health status checks during the bee season (n=844)

To create a health status monitoring index, we computed a score for each beekeeper by taking the first six colony health status checks into consideration. For the last three health checks: "Clinical signs of Nosemosis or Amoebiasis," "Infestation level of Varroa after treatment" and "Infestation level of Varroa," we cannot assume that checking these at a higher frequency is necessarily better, e.g. beekeepers may apply only 2-3 varroa treatments during the bee season, and therefore may check varroa infestation levels only 2-3 times a season. For the rest of the six indicators, where it can be assumed that checking these at every hive inspection is best practice, each beekeeper was given a score of '1' if they indicated 'at every inspection' and '0' otherwise, and these scores were summed to create a health status monitoring index, which ranges from 0 to 6.

This scoring method using only 'at every inspection' was used since almost all beekeepers in our sample generally implement good practices, indicating that they show responsibility towards their bees. Therefore, to distinguish between groups, we must analyse the extremes thus identifying those who are extremely good or consistent in the practices they implement. The resulting variable is called the colony health status monitoring index.

The colony health status monitoring index was negatively but weakly correlated with efficiency (r=-0.099; p=0.005), but not correlated with hive productivity or labour productivity.

5. Conclusions and limitations

Conclusions

This deliverable has used the results of two beekeeper surveys to provide a detailed production efficiency analysis of beekeeping in the EU, including an assessment of the impact of ecological-environmental characteristics and colony health status. In the following paragraphs, the major differences and similarities between the two studies are discussed.

In both studies, the percentage of hobby to professional beekeepers was around 20% professional beekeepers and 80% hobby beekeepers. Regarding beekeeping inputs, in both studies, hobby beekeepers spent a higher percentage of their capital costs on beekeeping equipment at the beginning of their beekeeping practice than professionals. This may be because many hobby beekeepers inherit or borrow hives at the beginning of their practice so therefore their costs for hives make up a lower percentage of their capital costs than professional beekeepers.

In both studies, hobby beekeepers spent a higher share of their operational costs on honey harvesting and packaging than professionals. This may be because professionals are able to buy packaging materials in bulk at a lower price. In both studies, professionals had lower labour intensity (man-days per hive) on their beekeeping practice than hobbyists, which may be because beekeeping is a passion for many hobby beekeepers in which they enjoy spending time on their practice. Another possible explanation may be that hobbyist beekeepers less rigorously keep track of the time spent on their beekeeping operation and thus eventually underreported labour. The average total revenue for hobby (€2,000 to €4,200) and professional beekeepers (€40,000 to €55,000) was quite similar in both studies.

Professionals exhibited a higher average hive productivity than hobbyists in both studies. The difference in hive productivity between hobby and professional beekeepers was larger in the exploratory study, perhaps due to the small sample size and purposive sampling method. In both studies, higher average hive productivity was exhibited by beekeepers in Northern Europe, and beekeepers with more experience. In the exploratory study, higher average hive productivity was exhibited among beekeepers who were younger, who had a secondary education, and who had more hives, but this was not confirmed by the larger-scale second study. High hive productivity in euro may be associated with selling other outputs, or having a high selling price per kg of honey.

Professionals exhibited a higher average labour productivity than hobbyists in both studies. The difference in labour productivity between hobby and professional beekeepers was larger in the exploratory study, also perhaps due to the small sample size and purposive sampling method. In both studies, higher average labour productivity was exhibited by beekeepers in Northern Europe, beekeepers who were younger, beekeepers with more experience and beekeepers with a higher amount of hives.

When comparing efficiency scores between hobbyists and professionals in both studies, hobby beekeepers exhibited similar average scores in both studies (0.35 and 0.34), however professionals' efficiency scores were lower in the second study compared to the first due to a different DEA model used. A constant returns to scale (CRS) was used in the first study, in which the purpose of DEA was to explore differences between beekeepers. In the first study, we found efficiency to be associated with the number of hives. A variable returns to scale (VRS) was used in the second study, in which the purpose of DEA was to provide an accurate measure of efficiency. In the second study, efficiency was not statistically correlated with the number of hives used for honey production or the number of total hives, since the VRS model accounts for eventual disproportional effects of scale increase or decrease.

Regarding the role of the ecological-environment, results from the exploratory study indicated that beekeepers with high perceived environmental quality had a higher average hive productivity, average labour productivity and average efficiency scores. In the large-scale second study, we found that having adequate floral resources surrounding hives was positively correlated with efficiency, but not with hive productivity or labour productivity. We also found that perceived climate change impact was positively correlated with efficiency and hive productivity but not with labour productivity.

Finally, regarding the role of colony health, we found no association between colony loss and efficiency scores. However, we did find an association between colony loss and hive productivity, in which beekeepers with lower average colony winter loss had higher hive productivity. We also found an association between average colony loss and labour productivity, in which beekeepers with higher average colony loss rate had lower average labour productivity.

Limitations

Limitations to both studies are described as follows. First, beekeepers in both study samples were rather highly educated in which more than 60% had a university or secondary education, which could bias our results regarding the role of education levels in productivity and efficiency. Second, it must be noted that in both datasets, there were a few beekeepers with much larger beekeeping operations than the rest of the dataset. There were no more than three of these beekeepers in each study, however their large numbers may influence the calculation of averages throughout the report.

Next, when assessing beekeepers in terms of their **honey** production, either by hive productivity or efficiency scores, the presence of other outputs in the beekeeping operations influences these results, making it difficult to gather accurate results. This can be solved by assessing beekeepers in terms of their total revenue, which takes all outputs into account, however an assessment using **total revenues** can only be accurately done with fully professional beekeepers, since data on revenue from hobby beekeepers was less reliable, possibly due to lower accuracy in economic record keeping among hobbyist beekeepers.

Third, the use of Data Envelopment Analysis on heterogeneous samples of beekeepers has proven to be a valuable approach to explore and study diversity among European beekeepers, but its outcomes need to be interpreted carefully and within that specific context. DEA is generally used as a performance indicator to identify the best performers and compare other beekeepers against the best performers. However, this method usually assumes that all businesses are operating under similar conditions. Since our sample contained mainly hobby beekeepers with very different types of operations, goals and management styles, and located in very different areas, the use of DEA to compare them is limiting. Hive productivity however may be a more reliable indication of performance.

Finally, the data we have on honeybee colony health status is limiting, especially since we lacked an indication of colony health status in the first wave study. We therefore use data gathered on honeybee colony health in the second study, however this was a subjective assessment of colony health. The health monitoring index for example, was a subjective assessment of how often beekeepers check on the health status of their bees, which may be an indication of more time spent on their bees. Since efficiency contains a measure of beekeepers' efficient use of labour, it was difficult to combine and analyse these variables together.

6. Key socio-economic variables of healthy and sustainable beekeeping

Making European beekeeping healthy and sustainable is the core topic of the B-GOOD project. Healthy and sustainable can be interpreted in two parts: “healthy” meaning healthy honeybees, and “sustainable” meaning all three pillars of sustainability identified in Deliverable 4.2: ecologically sustainable, socially sustainable and economically sustainable. In the large pan-European survey with 844 beekeepers, we have gathered information on certain **indicators** of healthy and sustainable beekeeping such as:

- Good Beekeeping Management Practices’ Index
- Honeybee colony winter loss rate
- Colony health status monitoring index
- The quality of the ecological environment surrounding hives
- Productivity (labour and hive productivity)
- Efficiency

We have also gathered information on several socio-economic variables such as:

- Country
- Region
- Age
- Gender
- Education
- Beekeeper type
- Number of hives
- Experience

In the following paragraphs, key socio-economic variables that have emerged as key variables for the indicators of healthy and sustainable beekeeping will be discussed. Note that information will be drawn from both Deliverable 4.3 and this Deliverable 4.4.

The Good Beekeeping Management Practices’ Index (GBMP-index) is a measure of good beekeeping management practices which is fully described in Deliverable 4.3. The highest GBMP-index scores were obtained for beekeepers characterised as rather or fully professional, Northern European, female, who are 16 or more years active as a beekeeper. Beekeepers with higher GBMP-index scores generally reported lower annual colony winter losses.

The colony health status monitoring index is a measure of how often beekeepers check for a series of health indicators, which is fully described in Deliverable 4.3. Region of Europe emerged as a key factor in colony winter loss rate and the colony health status monitoring index. Beekeepers in Northern Europe suffered the least colony winter losses and had the highest mean colony health status monitoring index among the four European regions. The highest colony health status monitoring index scores were obtained by beekeepers with 6-15 years of experience and 16 years or more of beekeeping experience.

Regarding hive productivity, region also emerged as a key factor as beekeepers in Northern Europe exhibited higher average hive productivity. The highest average hive productivity was obtained by beekeepers who were professionals, and beekeepers with more experience. Regarding labour productivity, also beekeepers in Northern Europe exhibited higher average labour productivity. The highest average labour productivity was obtained by beekeepers who were professionals, who were younger, beekeepers in Northern Europe exhibited higher average efficiency.

Overall, looking at all healthy and sustainable indicators, beekeeper type (either hobby or professional), European region, and beekeeping experience emerged as three important socio-economic factors contributing to healthy and sustainable beekeeping.

References

Ahikiriza, E., Van Meensel, J., Gellynck, X., & Lauwers, L. (2021). Heterogeneity in frontier analysis: does it matter for benchmarking farms? *Journal of Productivity Analysis*. doi:10.1007/s11123-021-00608-x

Ceyhan, V. (2017). Production efficiency of Turkish beekeepers and its determinants. *Custos e Agronegocio, 13*, 149-171.

Chauzat, M.-P., Cauquil, L., Roy, L., Franco, S., Hendrikx, P., & Ribière-Chabert, M. (2013). Demographics of the European Apicultural Industry. *Plos One, 8*(11), e79018. doi:10.1371/journal.pone.0079018

Coelli, T. (2008). DEAP: A Data Envelopment Analysis (Computer) Program (Version DEAP Version 2.1).

Ding, T., Chen, Y., Wu, H., & Wei, Y. (2018). Centralized fixed cost and resource allocation considering technology heterogeneity: a DEA approach. *Annals of Operations Research, 268*(1), 497-511. doi:10.1007/s10479-017-2414-6

EIP-AGRI. (2019). *EIP-AGRI Focus Group: Bee health and Sustainable Beekeeping*. Retrieved from Brussels: https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_fg34_bee_health_starting_paper_2019_en.pdf

Espinoza, M., Fort, R., Morris, M., Sebastian, A., & Villazon, L. (2018). *Understanding heterogeneity in Peruvian agriculture: A meta-frontier approach for analyzing technical efficiency*. Paper presented at the 2018 Conference, Vancouver, British Columbia.

Giacobino, A., Pacini, A., Molineri, A., Cagnolo, N. B., Merke, J., Orellano, E., . . . Signorini, M. (2017). Environment or beekeeping management: What explains better the prevalence of honey bee colonies with high levels of Varroa destructor? *Research in Veterinary Science, 112*, 1-6. doi:10.1016/j.rvsc.2017.01.001

Glăvan, E. (2014). Socio-economic aspects of beekeeping in Romania. *Journal of Community Positive Practices, XIV*, 95-112.

Gürer, B., & Akyol, E. (2018). An empirical analysis of technical efficiency determinants in beekeeping farms: evidence and policy implications from Niğde Province, Turkey. *Journal of Agriculture and Environment for International Development, 112*, 343-359. doi:10.12895/jaeid.20182.790

Howley, P., Buckley, C., Donoghue, C. O., & Ryan, M. (2015). Explaining the economic@ irrationality of farmers' land use behaviour: The role of productivist attitudes and non-pecuniary benefits. *Ecological Economics, 109*, 186-193.

Jacques, A., Laurent, M., Consortium, E., Ribière-Chabert, M., Saussac, M., Bougeard, S., . . . Chauzat, M.-P. (2017). A pan-European epidemiological study reveals honey bee colony survival depends on beekeeper education and disease control. *Plos One, 12*(3), e0172591. doi:10.1371/journal.pone.0172591

Kaya, U., & Gürcan, S. (2020). An evaluation of the efficiency of beekeeping enterprises in Hatay province with data envelopment analysis. *Ankara Üniversitesi Veteriner Fakültesi Dergisi*. doi:10.33988/auvfd.754619

Makri, P., Papanagiotou, P., & Papanagiotou, E. (2015). Efficiency and economic analysis of Greek beekeeping farms. *Bulgarian Journal of Agricultural Science, 21*, 479-484.

Moore, L. J., & Kosut, M. (2013). *Buzz Urban Beekeeping and the Power of the Bee*: New York University Press.

Olate-Olave, V. R., Verde, M., Vallejos, L., Perez Raymonda, L., Cortese, M. C., & Doorn, M. (2021). Bee Health and Productivity in Apis mellifera, a Consequence of Multiple Factors. *Veterinary Sciences, 8*(5), 76. Retrieved from https://www.mdpi.com/2306-7381/8/5/76

Pohorecka, K., Bober, A., Skubida, M., & Zdańska, D. (2014). A Comparative Study of Environmental Conditions, Bee Management and the Epidemiological Situation in Apiaries Varying in the Level of Colony Losses. *Journal of Apicultural Science, 58*, 107-132. doi:10.2478/JAS-2014-0027

Rahman, M. T., Nielsen, R., Khan, M. A., & Asmild, M. (2019). Efficiency and production environmental heterogeneity in aquaculture: A meta-frontier DEA approach. *Aquaculture, 509*, 140-148. doi:https://doi.org/10.1016/j.aquaculture.2019.05.002

Rivera-Gomis, J., Bubnic, J., Ribarits, A., Moosbeckhofer, R., Alber, O., Kozmus, P., . . . Formato, G. (2019). Good farming practices in apiculture. *Revue scientifique et technique (International Office of Epizootics), 38*(3), 879-890. doi:10.20506/rst.38.3.3032

Song, X., She, S., Xin, M., Chen, L., Li, Y., Heyden, Y. V., . . . Chen, L. (2020). Detection of adulteration in Chinese monofloral honey using 1H nuclear magnetic resonance and chemometrics. *Journal of Food Composition and Analysis, 86*, 103390. doi:https://doi.org/10.1016/j.jfca.2019.103390

USDA. (2013). *Report on the national stakeholders conference on honey bee health*. Paper presented at the National Stakeholders Conference on Honey Bee Health, Alexandria, Virginia.

Velardi, S., Leahy, J., Collum, K., McGuire, J., & Ladenheim, M. (2021). “You treat them right, They'll treat you right”: Understanding beekeepers' scale management decisions within the context of bee values. *Journal of Rural Studies, 81*, 27-36. doi:https://doi.org/10.1016/j.jrurstud.2020.12.002

Vural, H., & Süleyman, K. (2009). Socio-Economic Analysis of Beekeeping and the Effects of Beehive Types on Honey Production. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 5*(22). doi:10.15835/nbha3723298

Wakgari, M., & Yigezu, G. (2021). Honeybee keeping constraints and future prospects. *Cogent Food & Agriculture, 7*(1), 1872192. doi:10.1080/23311932.2021.1872192

Appendices

Appendix 1. First wave beekeeper survey questionnaire

WP4 – Task 4.2 – Questionnaire for Beekeepers (n=40)

	Introduction
Intro_1	Dear participant, Thank you for agreeing to participate in this survey. Your participation in the study is very important to us and your input valued in helping us to learn about and develop healthy and sustainable beekeeping practices. This questionnaire should take you approximately 15 minutes to complete. If you are unsure of a specific answer, please give a rough estimate instead of leaving a question blank. In order to ensure that all information will remain confidential, your name will not be recorded or used. All personal information you provide will be kept confidential and treated according to the EU regulations on personal data ownership. Your participation is voluntary and you may refuse to participate at any time. Stay safe! -The B-GOOD research team
Intro_2	B-GOOD This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817622.

Informed consent

1) I have read and understood the document "Information sheet for participants" pages 1 to 2 and I have received a copy of this document. I have been informed of the nature of the research, its purpose, its duration and what is expected of me.

2) I understand that participation in the study is voluntary and that I can withdraw from the study at any time without giving a reason for this decision and without this having any influence on my further treatment.

3) I agree to participate in the study.

4) I agree that my e-mail address will be used to send the questionnaires.

Section 1: Demographics

How many years have you been practicing beekeeping?	
Do you consider yourself a professional beekeeper?	Yes/No
What do you think is a professional beekeeper? Please describe using a few words.	
What is your profession (if other than beekeeping)?	
What is your place of residence? (City and country)	
What is your age? (In years)	
How many honeybee colonies did you have in the summer of 2020?	Number of colonies

What is your gender?

Male	Female	Other/prefer not to say
1	2	3

What is your highest education level?

Primary education	Secondary education	Tertiary education or post-secondary education (including universities and high schools)
1	2	3

To what extent were the following reasons motivations for you to start beekeeping? Indicate to what extent you agree or disagree with every reason.	Strongly disagree	Rather not	Neither nor	Rather yes	Definitely yes
Financial reasons	1	2	3	4	5
Family or a family history in beekeeping	1	2	3	4	5
Personal interest	1	2	3	4	5

Section 2: Beekeeping profiles

Below, we ask for your economic figures to the best of your knowledge. If you are unsure of an answer, **please provide an estimate**. If a question does not apply to you, enter 0.

The purpose of asking for economic figures is to come up with sustainable and profitable business models for beekeeping. The information you provide will be treated confidentially and not shared with anyone besides the B-GOOD research team.

1	What year did you start beekeeping, and with how many honeybee colonies?	Year started: Number of colonies:
2	When you began beekeeping, what was your total cost for hives (including frames, bottom boards, queen excluders, feeders)?	€
3	When you began beekeeping what was your total cost for honeybee colonies?	€

4	When you began beekeeping, what was your total cost for beekeeping equipment (such as smoker, hive tools, protective gear, …)?	€
5	What was the total quantity of honey that you produced in 2020 (kg)?	Kg Selling price per kg: € In case your honey is sold at different selling prices depending on the type of honey or customer, please report total revenue from honey sales: €
6	What was the total quantity of wax that you produced in 2020 (kg)?	Kg: Selling price per kg: €
7	What was the total quantity of propolis that you produced in 2020 (kg)?	Kg: Selling price per kg: €
8	How many colonies did you rent to farmers for pollination services in 2020?	Number of colonies: Renting price per colony: €
9	How many colonies and/or queens did you sell in 2020?	Number of colonies: Price per colony: € Number of queens: Price per queen: €
10	What was your total annual labour (in man-days) on beekeeping in 2020? Assume a total of 8 working hours for one man-day.	Number of man-days:

11	What were your total costs for feed for 2020?	€
12	What were your total costs for disease prevention and treatment for 2020?	€
13	What was your total cost for honey harvesting (e.g., rent of honey extractor; cost of external services for honey extraction; depreciation cost* of your honey extractor) and sales, including for honey packaging (e.g., jars and lids) in 2020? *depreciation cost = purchase price divided by the expected number of years that the extractor will be used	Total costs honey harvesting and sales €
14	What were your total costs for fuel and electricity (for your beekeeping activities) for 2020?	€
15	Did you have other expenditures for production or marketing in 2020? If so, what were they and how much did they cost?	Other expenditure for production: € Other expenditure for marketing: €

Section 3: Attitudes and orientations towards beekeeping

	To what extent do you agree or disagree with the following statements?	Strongly disagree	Rather not	Neither nor	Rather yes	Definitely yes
1	Colonies have to be kept in an environment that is as natural as possible	1	2	3	4	5
2	It is important for colonies to be able to express natural behaviour	1	2	3	4	5

3	Seeing a neglected colony doesn’t affect me as much as it would affect most people	1	2	3	4	5
4	The idea of a “natural environment” applies to honeybees as well as wild insects	1	2	3	4	5
5	Production efficiency should be first priority of the beekeeper	1	2	3	4	5
6	A beekeeper should think of his/her colonies mainly in terms of the profit they will bring in.	1	2	3	4	5
7	A beekeeper should think of his/her colonies mainly in terms of their market value or cost	1	2	3	4	5
8	I tend to think of colonies as being very similar to machines	1	2	3	4	5
9	A colony that is healthy experiences good well-being by definition	1	2	3	4	5
10	If a colony is reproducing efficiently its well-being standards must be good	1	2	3	4	5
11	If a colony is growing well, it must be experiencing good well-being	1	2	3	4	5
12	A colony that is healthy cannot be suffering	1	2	3	4	5

Section 4: Technology implementation

In the section below, “digital hive monitoring” means using electronic devices in beekeeping that are connected to other devices or networks that can operate interactively. Examples of digital hive monitoring in beekeeping include hive monitoring, colony surveillance, swarm detection, bee counting and using a digital logbook.

	To what extent do you agree or disagree with the following statements?	Strongly disagree	Rather not	Neither nor	Rather yes	Definitely yes
INT1	I intend to use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
INT2	I plan to use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
INT3	I will try to use digital hive monitoring in in my beehives within the next two years	1	2	3	4	5
INT4	I am determined to use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
ATT1	I feel that using digital hive monitoring would be a good idea for my beehives within the next two years	1	2	3	4	5
ATT2	I feel that using digital hive monitoring would be beneficial for my beehives within the next two years	1	2	3	4	5
ATT3	I would enjoy using digital hive monitoring in my beehives within the next two years	1	2	3	4	5
ATT4	I feel that using digital hive monitoring would be important for me and my beehives within the next two years	1	2	3	4	5
SN1	Most people whose opinions I value think I should use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
SN2	My decision to use digital hive monitoring in my beehives within the next two years is because the media encourages the use of digital hive monitoring	1	2	3	4	5

SN3	Most people who are important to me think that I should use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
SN4	Many beekeepers who are like me think I should use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
PBC1	It is within my control to use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
PBC2	I have the financial resources to implement digital hive monitoring in my beehives in the next two years	1	2	3	4	5
PBC3	I have the technical know-how to implement digital hive monitoring in my beehives in the next two years	1	2	3	4	5
PBC4	I can easily obtain digital hive monitoring equipment for my beehives in the next two years	1	2	3	4	5

To what extent do you agree or disagree with the following statements? In your beekeeping practice …	Strongly disagree	Rather not	Neither nor	Rather yes	Definitely yes
I would choose to use digital hive monitoring to save time	1	2	3	4	5
I would choose to use digital hive monitoring to save costs	1	2	3	4	5
I would choose to use digital hive monitoring for easier management	1	2	3	4	5

I would choose to use digital hive monitoring to decrease colony loss	1	2	3	4	5
I would choose to use digital hive monitoring to enhance colony health	1	2	3	4	5

To what extent do you agree or disagree with the following statement?	Strongly disagree	Rather not	Neither nor	Rather yes	Definitely yes
I currently use smart devices in other areas of my life besides beekeeping (i.e., for kitchen appliances, door locks, television, lighting, heating, speakers, etc.)	1	2	3	4	5

Section 5: Views on honeybee health

How important are these colony attributes to honeybee health according to you?	Definitely not important	Not important	Somewhat important	Impportant	Very important
Queen presence and performance i.e. potential fecundity of a queen, longevity of a queen, natural queen replacement.	1	2	3	4	5
Behaviour and physiology i.e. the organisation of work within colonies, thermoregulation, and colony foraging activity.	1	2	3	4	5
Demography of the colony i.e. colony size, brood demography, dead bees, brood pattern consistency.	1	2	3	4	5
The amount and quality of in-hive bee products (honey, beebread, wax) and the presence of chemical contaminants in the hive.	1	2	3	4	5

Disease, infection and infestation i.e. *Varroa* infestation level in the hive and presence of *Paenibacillus. Larvae* (American foulbrood) in the hive.	1	2	3	4	5

Section 6: Quality of the natural environment

To what extent do you agree or disagree with the following statements? **(Please refer to your hives that are enrolled in Tier 2)**	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The landscape surrounding my hives is mainly agricultural crop production	1	2	3	4	5
The landscape surrounding my hives is mainly agricultural livestock production/ pasture	1	2	3	4	5
The landscape surrounding my hives is mainly forest	1	2	3	4	5
The landscape surrounding my hives is mainly human constructions/urban area	1	2	3	4	5
There are sufficient floral resources surrounding my hives from early to late in the bee season	1	2	3	4	5
The environment surrounding my hives is biodiverse in terms oral resources	1	2	3	4	5
The environment surrounding my hives contains chemical contaminants	1	2	3	4	5

To what extent do you agree or disagree with the following statements?	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I collaborate with farmers in my region to encourage pollinator-friendly landscapes	1	2	3	4	5
Current policy measures in my region adequately address issues of floral resources, biodiversity, and landscape diversity	1	2	3	4	5
Climate change has had a positive impact on my beekeeping practices	1	2	3	4	5
Climate change has had a negative impact on my beekeeping practices	1	2	3	4	5

Section 7: Expectations from taking part in the research

To what extent do you agree or disagree with the following statements?	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Participating in this research project will benefit my beekeeping management practices	1	2	3	4	5
Participating in this research project will benefit the health and sustainability of my colonies	1	2	3	4	5
Participating in this research project will increase my knowledge about beekeeping	1	2	3	4	5
Participating in this research project will improve my access to scientific information	1	2	3	4	5

Participating in this research project will strengthen my connections with people in the beekeeping community	1	2	3	4	5
Using the BEEP app and/or base will benefit my beekeeping management practices	1	2	3	4	5
Using the BEEP app and/or base will benefit the health and sustainability of my colonies	1	2	3	4	5
Using the BEEP app and/or base will increase my knowledge about beekeeping	1	2	3	4	5
Using the BEEP app and/or base will improve my access to scientific information	1	2	3	4	5
Using the BEEP app and/or base will strengthen my connections with people in the beekeeping community	1	2	3	4	5

Appendix 2. Second wave beekeeper questionnaire

WP4 – Task 4.2 – Questionnaire for Beekeepers

	Introduction
Intro_1	Dear participant, Thank you for being willing to participate in this study. Your participation in the study is very important to us and your input is valued in helping to gather your insights on beekeeping in the EU. This survey should take you approximately 25 minutes to complete. In order to ensure that all information will remain anonymous, your name will not be recorded or used. No personal data or data that can identify you as participant will be shared with any third party. The data provided will be analysed in an anonymous way and the results of the survey will be communicated and disseminated in aggregated anonymous format only. Your participation is entirely voluntary and you may refuse to participate or withdraw at any time. Thank you and stay safe! The B-GOOD research team
Intro_2	GHENT UNIVERSITY B-GOOD This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817622.

Confirmation of informed consent and agreement to participate

Intro_3) I have read and understood the "Information sheet for the participants", page 1 to page 2, and I have received a copy of this document. I have been informed of the nature of the study, its purpose, its duration and what is expected of me.

Yes/No, please consider reading the information sheet for participants at this link before proceeding: bgoodwp4.ugent.be

Intro_4) I understand that participation in the study is voluntary and that I can withdraw from the study at any time without giving a reason for this decision and without this having any implication for myself.
Yes/No

Intro_5) I agree to participate in the study.

Yes/No

Block A: Socio-economic variables

A_1	What is your country of residence?	(Choose one from list of all European countries) Austria Belgium Bulgaria Croatia Cyprus Czechia Denmark Estonia Finland France Germany Greece Hungary Ireland Italy Lativa Lithuania Luxembourg Malta Netherlands Poland Portugal Romania Slovakia Slovenia Spain Sweden

		Switzerland United Kingdom None of the above
A_2	What is your age? (years)	

A_3) What is your highest completed education level?

Primary education (until the age of 12) or lower	1
Lower secondary education (until the age of 15)	2
Higher secondary education (until the age of 18)	3
University college or university education, Bachelor level	4
University college or university education, Master level or higher	5

A_4) What is your gender?

Male	Female	Other/prefer not to say
1	2	3

A_5	What is your maximum total number of beehives in 2021?	
A_6	What is your maximum total number of beehives for honey production in 2021?	
A_7	What is your maximum total number of beehives used for pollination services in 2021?	

A_8) Please indicate to what extent you would classify your beekeeping activities based on their **size and economic value** as being rather hobbyist versus rather professional using the following scale.

I consider my beekeeping activities considering their size and economic value as:

Purely hobbyist	Rather hobbyist	Neither hobbyist nor professional	Rather professional	Fully Professional
1	2	3	4	5

A_9) Please indicate to what extent you would classify your beekeeping activities based on your **personal expertise and beekeeping skills** as being rather hobbyist versus rather professional using the following scale.
I consider my beekeeping activities considering my personal expertise and beekeeping skills as:

Purely hobbyist	Rather hobbyist	Neither hobbyist nor professional	Rather professional	Fully Professional
1	2	3	4	5

A_10) Please indicate to what extent you would classify your beekeeping activities based on **the location of your hives during the main bee season** as being rather rural versus rather urban using the following scale.
I consider my beekeeping activities as:

Purely urban	Rather urban	Neither urban nor rural	Rather rural	Fully rural
1	2	3	4	5

A_11) Please indicate whether you are member of, or registered with, the following types of apicultural or beekeepers' associations.

An informal club of friends or colleagues who are beekeepers	Yes/No
A local or regional beekeepers association	Yes/No
More than one local or regional beekeepers associations	Yes/No
A cooperative or honey producer group	Yes/No
The national beekeepers association of my own country	Yes/No
The national beekeepers association of other countries	Yes/No
An international beekeepers association	Yes/No

A_12	Do you assume responsibility as chairman, secretary or board member of any beekeepers association?	Yes/No

A_13	Did you migrate, move or travel with honeybee colonies in 2021 for honey flow?	Yes/No

A_14) Please indicate to what extent you have attended training courses in beekeeping (since you started with beekeeping).

I have attended one or more starter courses	Yes/No
I have attended one or more advanced courses	Yes/No
I have had a beekeeper apprenticeship or have worked with another beekeeper	Yes/No

A_15	To what extent do you attend follow-up lectures, demonstrations, workshops or seminars on beekeeping? Note: We are aware that there were less opportunities during the last 18 months because of COVID. Therefore, please think of the pre-COVID period (e.g. 2019 or 'normal times') as reference.	Never Less than once a year Once a year Several times a year

A_16	How many years have you been active with beekeeping?	

A_17) **Please indicate to what extent the following reasons applied to you as your personal motivation when you started keeping honeybees?** I started keeping honeybees…	Not at all	Rather not	Neither nor	Rather yes	Definitely yes

As my main source of income	1	2	3	4	5
As a secondary source of income	1	2	3	4	5
Out of passion for honeybee keeping	1	2	3	4	5
Out of passion for nature and the ecological environment	1	2	3	4	5
As a hobby	1	2	3	4	5
To produce honey for own consumption	1	2	3	4	5
To produce honey for sales	1	2	3	4	5
To provide pollination services	1	2	3	4	5
I inherited this from parents or grandparents	1	2	3	4	5

A_18) **Please indicate to what extent the following reasons apply to you as your personal motivation for keeping honeybees today?** **I am keeping honeybees today…**	Not at all	Rather not	Neither nor	Rather yes	Definitely yes
As my main source of income	1	2	3	4	5

As a secondary source of income	1	2	3	4	5
Out of passion for honeybee keeping	1	2	3	4	5
Out of passion for nature and the ecological environment	1	2	3	4	5
As a hobby	1	2	3	4	5
To produce honey for own consumption	1	2	3	4	5
To produce honey for sales	1	2	3	4	5
To provide pollination services	1	2	3	4	5

Block B: Economic Performance

B_1) Below, we ask for your economic figures to the best of your knowledge. If you are unsure of an answer, **please provide a reasonable estimate**. If a question does not apply to you, please leave the answer **blank**.

The purpose of asking for economic figures is to identify economically sustainable and profitable business models for beekeeping. The information that you provide is anonymous, it will be treated confidentially and shared only in aggregated format with anyone besides the B-GOOD research team.

Please answer all economic figures in your national currency, and all economic figures should include VAT if applicable.

In the questions regarding figures for the entire year 2021, please add future predictions based on expectations for the rest of 2021 in the figure.

B_2	What is your national currency? (the currency you will also use to enter economic figures)	Euro (EUR) Danish krone (DKK)

		Polish złoty (PLN) Romanian leu (RON) Pound sterling (GBP)_ Bulgarian lev (BGN) Swiss franc (CHF)

B_3) **Please indicate to what extent you believe your honeybees by means of pollination contributed to improve or increase…**	Not at all	Rather not	Neither nor	Somewhat	A lot
Agricultural crop production	1	2	3	4	5
Horticultural crop production	1	2	3	4	5
Fruit production	1	2	3	4	5
Overall biodiversity in your environment	1	2	3	4	5

B_4	Do you provide pollination services that are paid for?	Yes/No
B_5	If **yes**, What is your total revenues from paid pollination services that you provided in 2021?	
B_6	If **yes**, Do you esteem this amount paid for pollination services as a sufficient and fair reimbursement?	Yes/No
B_7	If **no**, Would you like to get paid for the pollination services that you / your honeybees provide?	Yes/No

B_8	If **no**, What is the reason why you don't get paid for the pollination services that you / your honeybees provide?	

B_9	What was the total quantity of honey that you produced in 2021 (kg)?	
B_10	Do you perform other economic activities (besides beekeeping)?	Yes, I am employed with a fixed wage Yes, I have my own business besides beekeeping No, beekeeping is my only economic activity
B_11	How much of your beekeeping activities contribute to your income?	Less than 50% More than 50% but less than 100% Beekeeping is my only source of income
B_12	What is your total revenue from honey harvested in 2021?	
B_13	What is your total revenue from other beekeeping activities in 2021, besides the provision of pollination services and honey production? This may include for example the production and sales of queens, colonies, or other apiary products such as wax, royal jelly, pollen or propolis.	
B_14	What were your total costs for feed in 2021?	
B_15	What were your total costs for disease prevention and treatment (including against varroa) in 2021?	

B_16	What were your total costs for honey harvesting materials (e.g. rent of honey extractor or depreciation cost* of your own honey extractor) and packaging materials (e.g. jars and lids) in 2021? *depreciation cost = purchase price divided by the expected number of years that the extractor will be used (do not include labour costs for honey harvesting in this figure)	
B_17	What were your total costs for fuel (for your beekeeping activities) in 2021?	
B_18	What were your total costs for electricity (for your beekeeping activities) in 2021?	
B_19	What were your total costs for water (for your beekeeping activities) in 2021?	
B_20	Did you have other beekeeping expenditures for production or marketing in bee season 2021? If so, what were they and how much did they cost?	Description of other expenditures Total cost for other expenditures
B_21	When you began beekeeping, what was your total cost for hives and colonies (including frames, bottom boards, queen excluders, feeders)?	
B_22	When you began beekeeping, what was your total cost for other beekeeping equipment (such as honey extractor, smoker, hive tools, protective gear, …)?	
B_23	What was your total annual labour (in man-days) on beekeeping, your own labour included, in 2021? This should include time spent both on managing bees and other aspects related to beekeeping (e.g. cleaning, sales, bookkeeping, etc.) Assume a total of 8 working hours for one man-day.	

	For example: 4 working days of 8 hours for 2 people = 8 man-days	
B_24	Given your answer for number of man-days above, how accurate (precise) would you say this number is?	It is a very rough estimate It is a rather rough estimate It is a rather good estimate It is a highly accurate estimate
B_25	What was the average hourly rate that you paid for hired beekeeping labour, if applicable?	
B_26	Do you produce and sell other apiculture products (wax, propolis, royal jelly, etc.)?	Wax Propolis Royal Jelly Pollen Colonies Queens Other _____
B_27	What is the average price (per kg) you got in 2021 for honey sold locally in consumer units?	
B_28	What is the average price (per kg) you got in 2021 for honey sold in bulk (e.g. in buckets or barrels to honey packers)?	

B_29) Compared to previous years, how do you evaluate your bee season 2021 from a **honey production** point of view?

Very bad	Bad	Neither bad nor good	Good	Very good
1	2	3	4	5

B_30) Compared to previous years, how do you evaluate your bee season 2021 from an overall **economics** point of view (this means considering production, honey yield, costs, revenues, profits)?

Very bad	Bad	Neither bad nor good	Good	Very good
1	2	3	4	5

Block C: General beekeeping management

C_1) Please indicate to what extent you perform the following activities in your beekeeping practice.

C_2) I replace my queens:

Never, I leave it to the bees to decide when	Only when they no longer perform well	Every two or three years	Every year

C_3	On an annual basis, what percentage of your combs do you replace on average?	

C_4) What share of the wax you use in your hives (e.g. new combs) comes from your own closed wax cycle:

Zero, I do not recycle and reuse my own wax	Less than 50%	More than 50%, but not all	All the wax I use comes from my own closed wax cycle

C_5) If you have to purchase wax, does this concern:	Yes	No	Not applicable
Local (not imported) wax			
Organic wax			
Wax with a specific certification other than local or organic			

C_6) To what extent do you buy honeybee colonies from others?

Never	Less than 20% of my colonies	20-50% of my colonies	More than 50% of my colonies

C_7) To what extent do you buy queens from others?

Never	Less than 20% of my queens	20-50% of my queens	More than 50% of my queens

C_8) Please indicate to what extent you implement the following practices in your beekeeping.

		No / Never	From sometimes to mostly	Completely / Always
1	I observe quarantine measures for all new introductions I make to my apiaries			
2	My hives are identified with a unique code for documentation			
3	I do efforts to prevent acts of looting or robbery among the colonies			
4	I monitor and adapt hive capacity to discourage swarming			
5	I monitor the welfare of my colonies, especially the younger and weaker colonies			
6	I do not use purchased honey to feed my bees			
7	I use the bee smoker only when needed			
8	I do not transfer combs from one colony to another without certainty about the colony's health status			
9	I periodically mow the grass or vegetation in front of my hives			
10	I regularly clean my beekeeping equipment			
11	I regularly disinfect my beekeeping equipment			
12	I consult experts in case of anomalies with my bees or hives			
13	My beekeeping activities are officially registered in line with national guidelines, systems or registers			
14	I keep track of productive records of my colonies			
15	I keep track of economic records of my beekeeping activities			

16	I keep track of time records (for time spent on my beekeeping activities)			
17	I raise my own queens for queen replacement			
18	I mark my queens			
19	I participate in a breeding programme			
20	I repair my hives and frames whenever needed			
21	I make use of a weighting scale under (at least some of) my hives			
22	I plant nectar and pollen producing plants in the neighbourhood of my hives			
23	I inspect the suitability of the environment and surroundings for my hives			
24	I monitor the health status (e.g. absence of diseases) of my colonies			
25	I monitor the welfare status (e.g. food stocks) of my colonies			
26	I only apply drugs or substances that are officially registered in my country for use in honeybees			

Block D: Honeybee health

D_1) To what extent do you believe the following items are important in terms of impacting honeybee colony health?
You are asked to distribute 100 points across the following five items, where 0 means this item is not important at all according to you. A score of 100 given to one of the items would mean this is the only items that matters according to you; scores of 20 for each of the items would mean the items are all equally important. The total of 100 points must be used and not exceeded.

The beekeeper and his/her management of the honeybees and hives	
The quality and diversity of natural resources in the environment	
The characteristics of the colony (size, queen, brood, colony genetics …)	
The presence or absence of contaminants in the environment	

The presence or absence of parasites (such as varroa) and diseases in the hives	
Total	**100**

D_2) You attributed equal importance to each of the 5 items that may impact honeybee colony health in the previous question. What was your main reason for doing so?

☐ I am really convinced those 5 items have an equal weight

☐ I have limited knowledge / no idea about all aspects and therefore gave all 5 items equal weight

☐ I may have misunderstood the question

D_3) Please indicate how often you check for the following when assessing the health status of your colonies during the beekeeping season?

	Never	Once a season	Two or three times a season	Every other inspection	At every inspection
The presence of all stages of brood	1	2	3	4	5
Sufficient amount of adult bees	1	2	3	4	5
The presence of a young and laying queen	1	2	3	4	5
Sufficient nutrition: water, forage, and food stores available (inside and/or outside the hive)	1	2	3	4	5
The presence of (apparent) stressors (apart from varroa and viruses, thus e.g. wasps, other animals, anything that can produce shocks or disturbance to the hives) that would lead to reduced colony survival and/or growth potential	1	2	3	4	5

Suitable space (not too much or too little) for current & near-term expected colony size that is sanitary, defensible, and spacious enough for egg laying	1	2	3	4	5
Infestation levels of Varroa	1	2	3	4	5
Infestation levels of Varroa after treatments to evaluate if more treatments might be necessary	1	2	3	4	5
Clinical signs of Nosemosis or Amoebiasis	1	2	3	4	5

D_4	What is your average beehive winter loss percentage over the past five years?	0 – 10% 10 – 20% 20 – 30% 30 – 40% 40 – 50% More than 50%

Block E: Digital technology

E_1) Please indicate which practices you apply in the following checklist. In the following checklist, to “monitor” is not simply to measure but rather to check, observe and interpret over a period of time.

Do you digitally monitor the **weight** of at least some your hives?	Yes/No
Do you digitally monitor the **temperature** inside at least some your hives?	Yes/No
Do you digitally monitor the **humidity** inside at least some your hives?	Yes/No
	Yes/No

Do you digitally monitor the **sound** of at least some your hives?	
Do you use a **digital bee counter** for at least some of your hives?	Yes/No

E_2	What percentage of your hives are digitally monitored?	

Block F: Beekeeper orientation

F_1) **To what extent do you agree or disagree with the following statements?**	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Honeybee colonies should be ideally kept in a suitable environment that is as natural as possible	1	2	3	4	5
It is important for honeybee colonies to be able to express natural behaviour	1	2	3	4	5
Seeing a neglected honeybee colony affects me more than it would affect my colleague beekeepers	1	2	3	4	5
Production efficiency of the honeybee colonies should be the first priority of the beekeeper	1	2	3	4	5
A beekeeper should think of his/her honeybee colonies mainly in terms of the profit they will bring	1	2	3	4	5
A beekeeper should think of his/her honeybee colonies mainly in terms of their market value or cost they represent	1	2	3	4	5
A honeybee colony that is healthy experiences good welfare by definition	1	2	3	4	5

If a honeybee colony is reproducing efficiently, its welfare standard must be good	1	2	3	4	5
If a colony is growing well, it must be experiencing good welfare	1	2	3	4	5

Block G: Environmental quality

G_1) In case your hives are at multiple locations, the following questions apply to the location of the **major part of your hives**.

G_2) **To what extent do you agree or disagree with the following statements?**	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The landscape surrounding my hives is mainly agricultural crop production	1	2	3	4	5
The landscape surrounding my hives is mainly agricultural livestock production / pasture	1	2	3	4	5
The landscape surrounding my hives is mainly forest	1	2	3	4	5
The landscape surrounding my hives is mainly human constructions/urban area	1	2	3	4	5
There are sufficient floral resources surrounding my hives from early to late in the bee season	1	2	3	4	5
The environment surrounding my hives is biodiverse in terms of floral resources	1	2	3	4	5
The environment surrounding my hives contains chemical contaminants	1	2	3	4	5

G_3) **To what extent do you agree or disagree with the following statements?**	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I collaborate with farmers in my region to encourage pollinator-friendly landscapes	1	2	3	4	5
Current policy measures in my region adequately address issues of floral resources, biodiversity, and landscape diversity	1	2	3	4	5
Climate change has forced me to change my beekeeping practices (changes in treatment, changes in monitoring frequency and activities, etc.) .	1	2	3	4	5

	Very negative	Negative	Neither negative nor positive	Positive	Very positive
G_4) According to my personal experience, climate change has a ... impact on my beekeeping activities (changes in honey yield, changes in season length, etc.)	1	2	3	4	5

G_5) **Please indicate the extent you believe climate change has a positive or negative impact on your beekeeping activities, based on your personal experience.**	Very negative	Negative	Neither negative nor positive	Positive	Very positive
Food resource availability	1	2	3	4	5

Water availability	1	2	3	4	5
Honey yield	1	2	3	4	5
Colony survival	1	2	3	4	5
Disease infestation	1	2	3	4	5
Length of the bee season	1	2	3	4	5
Swarming behaviour	1	2	3	4	5
Natural disasters like fires or flooding	1	2	3	4	5
Local weather conditions	1	2	3	4	5

Block H: Intention to use hive monitoring technology

H_1) In the section below, "digital hive monitoring" means checking, observing and interpreting data collected by means of electronic devices for beekeeping that are connected to other devices or networks over time. Examples of digital hive monitoring in beekeeping include hive monitoring, colony surveillance, swarm detection, bee counting and using a digital logbook.
In the questions below, the questions pertain to at least some, and not necessarily all of your hives.

	H_2) **To what extent do you agree or disagree with the following statements?**	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
INT1	I intend to use digital hive monitoring in my beehives within the next two years	1	2	3	4	5

INT2	I plan to use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
INT3	I will try to use digital hive monitoring in in my beehives within the next two years	1	2	3	4	5
INT4	I am determined to use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
ATT1	I feel that using digital hive monitoring would be a good idea for my beehives within the next two years	1	2	3	4	5
ATT2	I would enjoy using digital hive monitoring in my beehives within the next two years	1	2	3	4	5
ATT3	I feel that using digital hive monitoring would be important for me and my beehives within the next two years	1	2	3	4	5
SN1	Most people whose opinions I value think I should use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
SN2	Most people who are important to me think that I should use digital hive monitoring in my beehives within the next two years	1	2	3	4	5

SN3	Many beekeepers who are like me think I should use digital hive monitoring in my beehives within the next two years	1	2	3	4	5
PBC1	I have the financial resources to implement digital hive monitoring in my beehives in the next two years	1	2	3	4	5
PBC2	I have the technical know-how to implement digital hive monitoring in my beehives in the next two years	1	2	3	4	5
PBC3	I can easily obtain digital hive monitoring equipment for my beehives in the next two years	1	2	3	4	5

H_3) **To what extent do you agree or disagree with the following statements? In your beekeeping practice…**	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would choose to use digital hive monitoring to save time	1	2	3	4	5
I would choose to use digital hive monitoring to save costs	1	2	3	4	5
I would choose to use digital hive monitoring for easier management	1	2	3	4	5
I would choose to use digital hive monitoring to decrease colony loss	1	2	3	4	5
	1	2	3	4	5

I would choose to use digital hive monitoring to enhance colony health					

H_4) **To what extent do you agree or disagree with the following statement?**	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I currently use smart devices in other areas of my life besides beekeeping (i.e. for kitchen appliances, door locks, television, lighting, heating, speakers, etc.)	1	2	3	4	5

Appendix 3. Copy of ethics approval - first wave survey (BC-08578)

Afz.: Commissie voor Medische Ethiek

Prof. dr. Wim Verbeke
Vakgroep landbouweconomie - LA01
ALHIER

contact	telefoon	e-mail	
Commissie voor medische Ethiek	+32 (0)9 332 41 81	Ethisch.comite@uzgent.be	
Ons kenmerk	Uw kenmerk	datum	pagina
BC-08578	NVT	24/11/2020	1/3

Betreft :

Advies voor monocentrische studie met als titel:

"Beekeepers' attitudes, management decisions, production efficiency and determinants."

B.U.N.: NVT
EudraCT:
Fase (Phase): NVT

*Financiële overeenkomst dd. 11/9/2020 consortium agreement B-GOOD
*Vragenlijsten dd. 11/9/2020
*Protocol dd. 11/9/2020
*Antwoord onderzoeker ontv. dd. 23/10/2020
*Patiënteninformatie- en toestemmingsformulier versie 4.2
*Begeleidende brief dd. 23/10/2020
*Adviesaanvraagformulier ontv. dd. 23/10/2020

Advies werd gevraagd door: Prof. dr. Wim Verbeke

ALGEMENE DIRECTIE
Commissie voor Medische Ethiek

VOORZITTER:
Prof dr. P. Deron

SECRETARIS
Prof dr. R. Peleman

STAFMEDEWERKER
Muriel Fouquet
T +32(09) 332 33 36
Sara De Smet
T +32(09) 332 68 55
Sabine Van de Moortele
T +32(09) 332 68 54

SECRETARIAAT
Sebastian Callewaert
T +32(09) 332 41 81
Marieke De Meyer
T +32(09) 332 05 06
Charlotte De Wolf
T +32(09) 332 22 68
Sandra De Paepe
T +32(09) 332 26 88
Ann Haenebalcke
T +32(09) 332 22 66

INGANG 75
ROUTE 7522

BOVENVERMELDE DOCUMENTEN WERDEN DOOR HET ETHISCH COMITÉ BEOORDEELD. ER WERD EEN POSITIEF ADVIES GEGEVEN OVER DIT PROTOCOL OP 24/11/2020 INDIEN DE STUDIE NIET WORDT OPGESTART VOOR 24/11/2021, VERVALT HET ADVIES EN MOET HET PROJECT TERUG INGEDIEND WORDEN.

Vooraleer het onderzoek te starten dient contact te worden genomen met HIRUZ CTU (09/332 05 00).

THE ABOVE MENTIONED DOCUMENTS HAVE BEEN REVIEWED BY THE ETHICS COMMITTEE.A POSITIVE ADVICE WAS GIVEN FOR THIS PROTOCOL ON 24/11/2020 IN CASE THIS STUDY IS NOT STARTED BY 24/11/2021, THIS ADVICE WILL BE NO LONGER VALID AND THE PROJECT MUST BE RESUBMITTED.

Before initiating the study, please contact HIRUZ CTU (09/332 05 00).

DIT ADVIES WORDT OPGENOMEN IN HET VERSLAG VAN DE VERGADERING VAN HET ETHISCH COMITE VAN 15/12/2020.
THIS ADVICE WILL APPEAR IN THE PROCEEDINGS OF THE MEETING OF THE ETHICS COMMITTEE OF 15/12/2020.

* *Het Ethisch Comité werkt volgens 'ICH Good Clinical Practice' - regels*
* *Het Ethisch Comité beklemtoont dat een gunstig advies niet betekent dat het Comité de verantwoordelijkheid voor het onderzoek op zich neemt. Bovendien dient U er over te waken dat Uw mening als betrokken onderzoeker wordt weergegeven in publicaties, rapporten voor de overheid enz., die het resultaat zijn van dit onderzoek.*
* *In het kader van 'Good Clinical Practice' moet de mogelijkheid bestaan dat het farmaceutisch bedrijf en de autoriteiten inzage krijgen van de originele data. In dit verband dienen de onderzoekers erover te waken dat dit gebeurt zonder schending van de privacy van de proefpersonen.*
* *Het Ethisch Comité benadrukt dat het de promotor is die garant dient te staan voor de*

UZ GENT
UNIVERSITEIT GENT

Pagina
2/3

conformiteit van de anderstalige informatie- en toestemmingsformulieren met de nederlandstalige documenten.

- *Geen enkele onderzoeker betrokken bij deze studie is lid van het Ethisch Comité.*
- *Alle leden van het Ethisch Comité hebben dit project beoordeeld. (De ledenlijst is bijgevoegd)*
- *The Ethics Committee is organized and operates according to the 'ICH Good Clinical Practice' rules.*
- *The Ethics Committee stresses that approval of a study does not mean that the Committee accepts responsibility for it. Moreover, please keep in mind that your opinion as investigator is presented in the publications, reports to the government, etc., that are a result of this research.*
- *In the framework of 'Good Clinical Practice', the pharmaceutical company and the authorities have the right to inspect the original data. The investigators have to assure that the privacy of the subjects is respected.*
- *The Ethics Committee stresses that it is the responsibility of the promotor to guarantee the conformity of the non-dutch informed consent forms with the dutch documents.*
- *None of the investigators involved in this study is a member of the Ethics Committee.*
- *All members of the Ethics Committee have reviewed this project. (The list of the members is enclosed)*

Namens het Ethisch Comité / On behalf of the Ethics Committee

Prof. dr. P. Deron
Voorzitter / Chairman

CC: UZ Gent – HIRUZ CTU
FAGG - Research & Development; Victor Hortaplein 40, postbus 40 1060 Brussel

UZ GENT
UNIVERSITEIT GENT
Universitair Ziekenhuis Gent
C. Heymanslaan 10 | B 9000 Gent
www.uzgent.be

Appendix 4. Copy of ethics approval - second wave survey (BC-10610)

Afz.: Commissie voor Medische Ethiek

Prof. Dr. Wim Verbeke
Vakgroep landbouweconomie - LA01
ALHIER

contact	telefoon	e-mail	
Commissie voor medische Ethiek	+32 (0)9 332 41 81	Ethisch.comite@uzgent.be	
Ons kenmerk	**Uw kenmerk**	**datum**	**pagina**
BC-10610	NVT	26/08/2021	1/3

Betreft : Advies voor monocentrische studie met als titel:

"Beekeepers' attitudes, management decisions, production efficiency and determinants: Follow-up pan-EU B-GOOD survey"

B.U.N.: B6702021000814
EudraCT: N.V.T
Fase (Phase): NVT

- Financiële overeenkomst versie 3 dd. 13/5/2010
- GCP certificaat versie 2.1 dd 5/2/2020 Yung Hung
- Vragenlijsten versie 1 dd. 15/7/2021
- Patiënteninformatie- en toestemmingsformulier versie 1 dd. 15/7/2021 voor de deelnemers
- Adviesaanvraagformulier versie 1 dd. 15/7/2021 doc. C (volledig ontvangen op 02/08/2021)
- Begeleidende brief dd. 15/7/2021 (ontvangen op 02/08/2021)
- Protocol versie 1 dd. 15/7/2021

Advies werd gevraagd door: Wim Verbeke

BOVENVERMELDE DOCUMENTEN WERDEN DOOR HET ETHISCH COMITÉ BEOORDEELD. ER WERD EEN POSITIEF ADVIES GEGEVEN OVER DIT PROTOCOL OP 25/08/2021 . INDIEN DE STUDIE NIET WORDT OPGESTART VOOR 25/08/2022, VERVALT HET ADVIES EN MOET HET PROJECT TERUG INGEDIEND WORDEN.
Vooraleer het onderzoek te starten dient contact te worden genomen met HIRUZ CTU (09/332 05 00).

THE ABOVE MENTIONED DOCUMENTS HAVE BEEN REVIEWED BY THE ETHICS COMMITTEE.A POSITIVE ADVICE WAS GIVEN FOR THIS PROTOCOL ON 25/08/2021. IN CASE THIS STUDY IS NOT STARTED BY 25/08/2022, THIS ADVICE WILL BE NO LONGER VALID AND THE PROJECT MUST BE RESUBMITTED.
Before initiating the study, please contact HIRUZ CTU (09/332 05 00).

* *Het Ethisch Comité werkt volgens 'ICH Good Clinical Practice' - regels*
* *Het Ethisch Comité beklemtoont dat een gunstig advies niet betekent dat het Comité de verantwoordelijkheid voor het onderzoek op zich neemt. Bovendien dient U er over te waken dat Uw mening als betrokken onderzoeker wordt weergegeven in publicaties, rapporten voor de overheid enz., die het resultaat zijn van dit onderzoek.*
* *In het kader van 'Good Clinical Practice' moet de mogelijkheid bestaan dat het farmaceutisch bedrijf en de autoriteiten inzage krijgen van de originele data. In dit verband dienen de onderzoekers erover te waken dat dit gebeurt zonder schending van de privacy van de proefpersonen.*
* *Het Ethisch Comité benadrukt dat het de promotor is die garant dient te staan voor de conformiteit van de anderstalige informatie- en toestemmingsformulieren met de nederlandstalige documenten.*
* *Geen enkele onderzoeker betrokken bij deze studie is lid van het Ethisch Comité.*
* *Alle effectieve leden van het Ethisch Comité, of hun plaatsvervangers,hebben dit project beoordeeld. (De ledenlijst is bijgevoegd)*

ALGEMENE DIRECTIE
Commissie voor Medische Ethiek

VOORZITTER:
Prof.dr. P. Deron

SECRETARIS
Prof.dr. R. Peleman

INGANG 75
ROUTE 7522

UZ GENT

UNIVERSITEIT GENT

Universitair Ziekenhuis Gent
C. Heymanslaan 10 | B 9000 Gent
www.uzgent.be

Pagina
2/3

* *The Ethics Committee is organized and operates according to the 'ICH Good Clinical Practice' rules.*
* *The Ethics Committee stresses that approval of a study does not mean that the Committee accepts responsibility for it. Moreover, please keep in mind that your opinion as investigator is presented in the publications, reports to the government, etc., that are a result of this research.*
* *In the framework of 'Good Clinical Practice', the pharmaceutical company and the authorities have the right to inspect the original data. The investigators have to assure that the privacy of the subjects is respected.*
* *The Ethics Committee stresses that it is the responsibility of the promotor to guarantee the conformity of the non-dutch informed consent forms with the dutch documents.*
* *None of the investigators involved in this study is a member of the Ethics Committee.*
* *All effective members of the Ethics Committee, or their representatieves, have reviewed this project. (The list of the members is enclosed)*

Namens het Ethisch Comité / On behalf of the Ethics Committee

Prof. dr. P. Deron
Voorzitter / Chairman

CC: UZ Gent – HIRUZ CTU
FAGG - Research & Development; Victor Hortaplein 40, postbus 40 1060 Brussel

UZ GENT
UNIVERSITEIT GENT
Universitair Ziekenhuis Gent
C. Heymanslaan 10 | B 9000 Gent
www.uzgent.be

Appendix 5: Differences between economic sections in first wave survey and second wave survey

Regarding the selling price of honey:

First wave survey:

1. Selling price per kg: €
2. In case your honey is sold at different selling prices depending on the type of honey or customer, please report total revenue from honey sales:

Second wave survey:

1. What is the average price (per kg) you got in 20021 for honey sold locally in consumer units?
2. What is the average price (per kg) you got in 2021 for honey sold in bulk (e.g. in buckets or barrels to honey packers)?

Regarding fuel and electricity costs:

First wave survey:

1. What were your total costs for fuel and electricity (for your beekeeping activities) for 2020?

Second wave survey:

1. What were your total costs for fuel (for your beekeeping activities) in 2021?
2. What were your total costs for electricity (for your beekeeping activities) in 2021?

Regarding labour:

First wave survey:

1. What was your total annual labour (in man-days) on beekeeping in 2020? Assume a total of 8 working hours for one man-day.

Second wave survey:

1. What was your total annual labour (in man-days) on beekeeping, your own labour included, in 2021? This should include time spent both on managing bees and other aspects related to beekeeping (e.g. cleaning, sales, bookkeeping, etc.)Assume a total of 8 working hours for one man-day. For example 4 working days of 8 hours for 2 people = 8 man-days

Questions added to second wave survey:

1. How much of your beekeeping activities contribute to your income?
2. What were your total costs for water (for your beekeeping activities) in 2021?
3. Given your answer for a number of man-days above, how accurate (precise) would you say this number is?
4. What was the average hourly rate that you paid for hired beekeeping labour, if applicable?
5. Do you produce and sell other apiculture products, Royal Jelly and Pollen were added in this selection.

Appendix 6: Data Cleaning Repository

Changes made to Master dataset Beekeeper 844 survey - Master_January_11

Changed the spelling of Age_tirtiles in to tertiles.

Dummy variable created Association_Member, recoded from question A_11_2.

Dummy variable created Association_Chair, recoded from question A_12 from 1=yes, 2=no to 1=yes, 0=no.

To create new variable Association_Member, 4 variables re-coded from 1=yes, 2=no to 1=yes, 0=no:

- A_11_2 Local or regional BA
- A_11_5 National BA of my country
- A_11_6 National BA of other countries
- A_11_7 International BA

New variable Association_Member created taking the sum of the above 4 variables, then re-coding for 1, 2, 3, and 4 =1 and 0=0.

Changed label for variable Honey_per_hive from “Average honey production per hive, B_9 divided by A_6, both numeric” to “Honey production per hive” for SPSS graph making purposes.

New variable created **Health_status_index**, which is the sum of variables D_3_1 to D_3_9 all 9 health checks. Values can range from 9 to 45.

Changes made to Beekeeper 844 dataset - Master_January_18

New variable created **Starter_BK** as 1= those who are 3 or less years active as beekeeper (n=144); 0=4 or more years active (n=700)

New variable created **Clusters_Orient** which is the cluster membership number (1,2 or 3) based on orientations

Changes made to Beekeeper 844 dataset – March 22

New variable created **ValidCases** as 1=valid, 0=invalid

Data cleaning in questions B_5, B_9, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20_2, B_21, B_22, B_23, B_25, B_27, B_28

- All symbols deleted, periods and commas appropriately marked;
- All “Ca” or “approximately” replaced by actual value;
- In question B_25 “What was the average hourly rate that you paid for hired beekeeping labour, if applicable?” all answers that indicated “none” or “not applicable” or “don’t know” were transformed into 0 and marked as valid;

- All blank cells replaced with 0, except for B_5 since these questions did not appear to all respondents;

Cases marked as invalid in variable **ValidCases** if at least one cell in questions B_5, B_9, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20_2, B_21, B_22, B_23, B_25, B_27, B_28 contained:

- Cases where a range was indicated, i.e., 100-150;
- Cases with text;
- Cases indicating a “per” or “/”.

Changes made to Beekeeper 844 dataset – 6 April 2022

Invalid cases checked and corrected, variable **ValidCases** updated.

0s added in blank spaces for questions B_26_1 through B_26_6, in order to create sum for number of output types.

New variable created **Number_output_types** to indicate the amount of output types (wax, propolis, royal jelly, pollen, colonies, queens) sold by beekeepers.

New variable created **Number_hives_tertiles,** in which 0-7 hives=1, 8-20 hives=2 and 21-1430 hives=3.

Variables B_5, B_9, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_21, B_22, B_23, B_24, and B_25 all changed type from String to Numeric in order to do proper SPSS calculations, therefore all free form text in these questions has disappeared. However, all the questions with remaining text were deemed as invalid cases.

Changes made to Beekeeper 844 dataset – 8 April 2022

Currency conversion from Zloty (Polish Currency) to Euros – On 8th of April 4,64 PLN corresponds to 1€, according to Google Currency Converter

(https://www.google.com/search?client=firefox-b-d&q=goole+currency+conertion).

Complete conversions on questions B_5, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20_2, B_21, B_22, B_25, B_27, B_28.

In all currency conversions, zeros were remained untouched.

In the cell corresponding t to **Beekeeper_ID:23 question B_27**, there was the following range **“35-40”** which was altered to **37,5** and then converted to €.

Changes made to Beekeeper 844 dataset – 11 April 2022

Question B_2 what is your national currency, all Polish złoty changed from a 3= Polish złoty to a 1=euros, taking only **ValidCases** into consideration

Currency conversion from Romanian Leu to Euros – On 11 April, 4,94 RON corresponds to 1€, according to Google Currency Converter

(https://www.google.com/search?client=firefox-b-d&q=goole+currency+conertion).

Complete conversions on questions: B_5, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20_2, B_21, B_22, B_25, B_27, B_28

In all currency conversions, zeros were remained untouched.

Question B_2 what is your national currency, all Romanian Leu changed from a 4= Romanian Leu to a 1=euros, taking only ValidCases into consideration.

Changes made to Beekeeper 844 dataset – 12 April 2022

Currency conversion from **Pound Sterling to Euros**- On 12th April, 0,83 GBP corresponds to 1€, according to Converter.

(https://www.google.com/search?client=firefox-b-d&q=goole+currency+conertion).

Complete conversions on questions: B_5, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20_2, B_21, B_22, B_25, B_27, B_28.

In question B_2 responses given with Pound Sterling currency, were converted from “5” = Pound Sterling to “1” = Euros, taking only **ValidCases** into consideration.

Currency conversion from Bulgarian **Lev to Euros – On 12th April**, 1,95€ Bulgarian Lev corresponds to 1€, according to Google Currency Converter.

Complete conversions on questions: B_5, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20_2, B_21, B_22, B_25, B_27, B_28

In question B_2 responses given in Bulgarian Lev currency, were converted from “6” = Bulgarian Lev to “1” = Euros, taking only **ValidCases** into consideration

Changes made to Beekeeper 844 dataset – 13 April 2022

Currency conversion from **Swiss Franc to Euros- On 13th April**, 1,01 Swiss Franc corresponds to 1€, according to Google Currency Converter.

Complete conversions on questions: B_5, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20_2, B_21, B_22, B_25, B_27, B_28.

In question B_2 responses given in Swiss Franc currency, were converted from “7” = Swiss Franc to “1” = Euros, taking only **ValidCases** into consideration.

Question H_2: To what extent do you agree or disagree with the following statements? On a 5 point Likert scale, a 6 was entered in the responses of 23 Portuguese beekeepers, these 6s were changed to 2=disagree after checking actual responses in Qualtrics.

Changes made to Beekeeper 844 dataset – 19 April 2022

Questions B_27 and B_28 changed from string to numeric.

New variable created B_5_PER_HIVE which is total revenues from pollination B_5 divided by A_7 hives for pollination services.

New variable created B_9_PER_HIVE which is total quantity of honey produced B_9 divided by A_6 hives for honey production.

Question B_12 changed from string to numeric.

Changes made to Beekeeper 844 dataset – 20 April 2022

New variable created B_12_PER_HIVE which is total revenues from honey divided by A_5 number hives total.

New variable created B_14_PER_HIVE which is total cost for feed B_14 divided by A_5 number hives total.

New variable created B_15_PER_HIVE which is total cost for disease prevention B_15 divided by A_5 number hives total.

New variable created B_16_PER_HIVE which is total cost for honey harvesting B_16 divided by A_5 number hives total.

New variable created B_17_PER_HIVE which is total cost for fuel B_17 divided by A_5 number hives total.

New variable created B_20_2_PER_HIVE which is total cost for other B_20_2 divided by A_5 number hives total.

New variable created B_23_PER_HIVE which is labour in man-days B_23 divided by A_5 number hives total.

Changes made to Beekeeper 844 dataset – 25 April 2022

Notes on implausible cases:

- We have decided to leave professional beekeeper 10 in the dataset since his numbers make sense, although he has more than 6000 hives and is the only beekeeper we have to that large scale
- 37 beekeepers reported a value for revenue from other beekeeping activities besides honey and pollination, while reporting no other beekeeping activities besides honey and/or pollination, which is strange. However, these were left as-is (except for the values for beekeeper 2 and 610 were replaced by 0s, see below) since these numbers can be valuable for our analysis, and perhaps they reported a number but then later in the survey did not want to specify what their other beekeeping activities were.
- Professional beekeeper 115 makes 267 euros per hive rented for pollination services which is much higher than anyone else, however we decided to leave him in because hives can be rented multiple times a year.

- Hobby beekeeper 77 makes 167 euros per hive rented for pollination services which is much higher than any hobby beekeeper, however we decided to leave him in because hives can be rented multiple times a year.
- Hobby beekeeper 360 only has one hive and reported a cost of 50 euros for electricity, which comes to 50 euros per hive which is a higher electricity cost per hive than any professional or hobby, however we decided to leave him in because we have no reason to assume that as a starting beekeeper he could have high costs for electricity.

Data changes – implausible cases:

- Hobby beekeeper 433 reported an unusually high number for revenue from honey (which comes to 50 euros per kg), which does not match the selling price her reported (10 euros per kg), therefore, question B_12 for this beekeeper was changed from 15000 to 3000. Which is 10 x quantity of honey produced 300 kg.
- Hobby beekeeper 769 reported an unusually high number for disease prevention and treatment costs (306 euros per hive), so for this beekeeper question B_15 the value 7650 was replaced by the Finnish national average within the dataset for this value, 117. Note: National average calculated without beekeeper 769 included.
- Hobby beekeeper 253 reported an unusually high number for disease prevention and treatment (520 euros per hive), so for this beekeeper question B_15 the value 2080 was replaced with the Dutch national average within the dataset for this value, 50. Note: National average calculated without beekeeper 253 included.
- Hobby beekeeper 377 reported an unusually high number for fuel costs (2146 per hive), so for this beekeeper question B_17 the value 15020 was replaced by the German national average within the dataset for this value, 147. Note: National average calculated without beekeeper 377 included.
- Professional beekeepers 658 and 607 excluded due to unusually high hive productivity (250 and 138 kg per hive), changed from valid to invalid in variable **ValidCases.**
- Hobby beekeeper 58 reported an usually high number for feed costs (765 euros per hive), so for this beekeeper question B_14 the value 1530 was replaced by the Dutch national average within the dataset for this value, 206. Note: National average calculated without beekeeper 58 included.
- Hobby beekeeper 623 reported an unusually high number for honey harvesting and packaging costs (714 euros per hive), so for this beekeeper question B_16 the value 5000 was replaced by the Italian national average within the dataset for this value, 1830. Note: National average calculated without beekeeper 623 included.
- Hobby beekeeper 422 reported paying 12000 in beekeeper association fees, so for the beekeeper question B_20_2 was replaced with 0.
- Hobby beekeeper 60 reported an unusually high value for man-days, which comes to 124 man-days per hive which is higher than any professional or hobby, so for this beekeeper question B_23 the value 624 was replaced by the Belgian national average within the dataset for this value, 35. Note: National average calculated without beekeeper 60 included.
- Professional beekeeper 2 reported an unusually high value for total revenue from other beekeeping activities of 110000, which doesn't make sense since he reported no other beekeeping activities besides producing honey, so for this beekeeper question B_13 was replaced with a 0. Note: 35 other beekeepers (besides 2 and 610) reported a value for revenue from other beekeeping activities besides honey and pollination, while

reporting no other beekeeping activities besides honey and/or pollution, but these were left in.

- Hobby beekeeper 610 reported an unusually high value for total revenue from other beekeeping activities of 30000, which doesn't make sense since he reported no other beekeeping activities besides producing honey, so for this beekeeper question B_13 was replaced with a 0. Note: 35 other beekeepers (besides 2 and 610) reported a value for revenue from other beekeeping activities besides honey and pollination, while reporting no other beekeeping activities besides honey and/or pollution, but these were left in.

New variable created B_13_PER_HIVE which is total revenues from other beekeeping activities B_13 divided by A_5 number hives total

Changes made to Beekeeper 844 dataset – 26 April 2022

Checking for empty spaces that should be changed to "0".

Variables confirmed: A_6, B_9, B_12, B_13, B_14, B_15, B_16, B_17, B_18, B_19, B_20, B_21, B_22, B_23, B_25, B_27, B_28.

Implausible cases found through DEA:

- Beekeeper 549 says he produces 1 kg of honey from 502 hives, no pollination services reported, no other beekeeping activities reported- was eliminated form DEA and marked as invalid.
- Beekeeper 372 reported 160 man-days with 1kg of honey and 0 hives used for honey production, no other beekeeping activities reported - was eliminated from DEA and marked as invalid.

Changes made to Beekeeper 844 dataset – 3 May 2022

New variable created Fav_Nat_Env which is: G_2_5 floral resources year round + G_2_6 floral resource diversity; alpha=0.694.

New variable created **Cases_DEA** which includes the 678 cases used for the DEA model honey, hives, labour. This number comes from the starting valid cases of 746, minus 53 beekeepers who reported 0 for honey in kg, 13 beekeepers who reported 0 for labour in man-days, and 2 beekeepers who reported 0 for hives for honey production. Variable is 1=DEA case and 0=non-DEA case.

New variable created **Efficiency_scores** which are the efficiency scores from DEA with one output honey and two inputs number of hives and colonies, run with DEAP week of 25 April.

New variable created **Total_capital_costs** which is B_21 + B_22.

New variable created **Total_revenue** which is B_12 + B_13.

New variable created **Total_operational_costs** which is B_14 + B_15 + B_16 + B_17 + B_18 + B_19+ B_20_2.

Changes made to Beekeeper 844 dataset – 09 May 2022

New variable created **EfficiencyZERO** which is a dummy variable for beekeepers with efficiency scores as 0. 1= efficiency as 0, 0= rest of sample.

New variable created **Revenue_per_hive** which is revenue per hive total revenue divided by A_5 number hives total.

Changes made to Beekeeper 844 dataset – 18 May 2022

4 new variables created:

1. TE_All_VRS - Efficiency scores from DEA honey, hives, labour, Variable returns to scale
2. TE_All_CRS - Efficiency scores from DEA honey, hives, labour, Constant returns to scale
3. TE_Professional_VRS - Efficiency scores from DEA honey, hives, labour, Variable returns to scale
4. TE_Professional2_VRS - Efficiency scores from DEA total revenues, hives, labour, Variable returns to scale

New variable created **Labour_productivity** which is Honey kg divided by man-days.

Changes made to Beekeeper 844 dataset – 25 May 2022

New variable created Agri_Land, which is G_2_1 + G_2_2; alpha=0.461

New variable created Floral_Res_Land, which is G_2_5 + G_2_6, alpha=0.694