Stakeholder views on applied business models and their key descriptors in the EU

Deliverable D4.2

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B-GOOD

Giving Beekeeping Guidance by cOmputatiOnal-assisted Decision making

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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 business environment's complexity. It also sets out to evaluate the production efficiency, (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 (D4.2) is the second of five deliverables from WP4 'Socio-Economic Drivers'. It presents a second set of results from Task 4.1: SWOT-analysis and assessment of stakeholder views. D4.2 provides a descriptive analysis of stakeholder views on honeybee colony health, on currently applied and possible future successful business models for healthy and sustainable beekeeping, and identifies their key descriptors in EU beekeeping.

The insights presented on stakeholder views and opinions on what characterises a healthy bee colony will support and contribute to the data pool of the Health Status Index for honeybees (HSI) and health assessment methodology. The insights presented on stakeholder views on business models for healthy and sustainable beekeeping will be used to better understand the beekeeping business environment (in addition to the findings presented previously in D8.1 on SWOT of the EU beekeeping sector), helping to facilitate the identification of healthy and sustainable beekeeping business models towards the end of the B-GOOD project.

The contents of this report result from two consecutive studies that were conducted with stakeholders, i.e. 41 in-depth qualitative interviews, followed by a quantitative survey with a sample of 504 stakeholders. This Deliverable is divided into four sections: 1) Background, scope and objectives, 2) Materials and methods, 3) Results and 4) Conclusions. The two themes covered are honeybee colony health and business models for healthy and sustainable beekeeping.

Summary

B-GOOD is a multi-disciplinary project committed to providing solutions to the diverse problems in the EU beekeeping sector, particularly designing innovative technologies that help keeping healthy colonies and implementing healthy and sustainable business strategies. This report presents the current development of the B-GOOD Work Package 4, particularly Task 4.1: SWOT-analysis and assessment of stakeholder views.

Overall, the objectives for this deliverable can be split into two overarching goals. The first is to gather and assess stakeholder views on honeybee colony health, and the second is to gather and assess stakeholder views on currently applied and possible future successful business models for healthy and sustainable beekeeping. Particular attention is given to key descriptors of honeybee colony health and business models according to the views of stakeholders. To address this, we drew from stakeholder's interviews and surveys and performed both a qualitative and quantitative assessment of stakeholders' opinions on these topic areas. In this deliverable, the terms "actor" and "stakeholder" are used interchangeably.

1. Background, scope and objectives

1.1 Honeybee colony health

In the last few decades managed honeybees have faced widespread decline (Brodschneider et al., 2016; Genersch et al., 2010; Jacques et al., 2017; Lee et al., 2015) raising concerns for the sustainability of the beekeeping sector (Potts et al., 2010), and the sustainability of the agricultural sector, as bees provide pollination to the majority of crops grown in the European Union (EFSA, 2021). Honey bees play a key role in the maintenance of important ecosystems services such as pollination of both wild plants (Aguilar et al., 2006; Ashman et al., 2004) and cultivated crops (Bommarco et al., 2012, Bradbear, 2009, Klein et al., 2007).

Assessing honeybee health requires the consideration of multiple drivers and stressors which can be both internal (such as disease) or external (such as surrounding environmental quality). The medical conception of health has traditionally been the “absence of disease” with the main elements biological function and statistical normality, where diseases are internal states that depress a functional ability (Boorse, 1977). Honeybee health, however, whether simply based on the absence or presence of disease or based on the amount of ‘well-being’ of a colony, will always be influenced by the environment in which the colonies are located and by the beekeeper who may choose whether or not to intervene as part of his/her honeybee colony management.

This complexity at any point in time and space, invariably results in no single cause for the observed honeybee colony losses, and the subsequent conclusion is that ‘many contributing stressors may act in concert’ (Goulson et al., 2015). Recent research has shown the importance of considering the co-occurrence and interaction of different drivers and stressors when assessing honeybee colony health (Doublet et al., 2015; Goulson et al., 2015; F. Sánchez-Bayo et al., 2016). Methods for assessing honeybee colony health that take holistic and multidimensional approaches have been proposed such as the Health Status Index (HSI) (Gilioli et al., 2019). However, there remains a need for more collaboration between scientists and non-scientists for the further identification of the key drivers influencing honeybee colony health and the assessment of both the intensity and significance of their causal relationship.

As the ongoing phenomenon of honeybee colony collapse is a complex real-world problem that cuts across the categories of “biological,” “social,” and “environmental,” it is important to include beekeepers, farmers or agri-/horticultural actors, scientists, service providers, quality inspectors, non-governmental organisations (NGOs) and policy makers for sustained interactions over time in the context of their joint participation (Hall & Martins, 2020; Kleinman & Suryanarayanan, 2019; Suryanarayanan et al., 2018). By asking different types of stakeholders how they define a healthy honeybee colony and their opinions about honeybee colony health, key descriptors of honeybee colony health can further be defined and eventually complement the current Health Status Index (HSI).

Other studies have already stressed the importance of stakeholder views in various aspects of beekeeping (EFSA, 2021; Kouchner et al., 2019; Maderson & Wynne-Jones, 2016; PAN, 2012). EFSA (2021) highlights the need for risk assessments on multiple stressors in honeybees to take into account stakeholders’ perspectives. The Pesticide Action Network

(2012) has analysed policy makers' positions on neonicotinoids across Europe. Maderson & Wynne-Jones (2016) assessed beekeepers' views on pollinator conservation policy in the UK, and Kouchner (2019) involved stakeholders to assess the sustainability of honeybee farming systems in France.

These previous studies however are focused on national levels. The socio-economic research within B-GOOD's WP4 Task 4.1 and this resulting deliverable thus presents a broader geographical scope of stakeholder views on honeybee colony health, with the objective of encompassing a wide range of stakeholder types and several European countries/regions.

1.2 Business models for healthy and sustainable beekeeping

The importance of management decisions by beekeepers and their various business management styles in relation to honeybee colony health and colony loss in beekeeping have become fully recognised recently. Several studies confirmed that environmental conditions together with beekeeping management decisions and styles 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.

Best management practices for improved honeybee colony health have been identified (BPRACTICES, 2020; EIP-AGRI, 2019; Rivera-Gomis et al., 2019), but these sets of recommendations are generalised for all types of beekeepers. However, in reality, there is a huge variety of beekeeper types and management styles in Europe. Furthermore, only around one third of beekeepers in Europe are professional and the rest are hobby beekeepers with less than 50 colonies. The European beekeeping industry is highly heterogeneous in terms of characteristics, values, interests, motives, business models and beekeeping management styles, and a single professional business model and advice system may not benefit all – or not even the majority of beekeepers (Chauzat et al., 2013).

WP4 within B-GOOD has the goal to identify sustainable and viable business models tailored to different contexts for European beekeeping. Understanding the drivers behind management decisions by beekeepers is essential for deriving tailored advice and business models for different types of beekeepers (both professional and hobby) throughout Europe. These factors need to account for local and regional contexts such as ecological (e.g. quality of the natural environment) and institutional (e.g. political) environmental factors.

Possible business models for sustainable beekeeping will be presented in Deliverable 4.5 due in month 48 (May 2023). These business models will identify values and objectives (why), products and services (what) and markets (to whom) in line with the key attention points for strategy development identified in Deliverable 4.1 and the insights presented in the current Deliverable 4.2. The resulting business plans will include amongst others a marketing plan and cost-benefit analysis, while taking into account possible constraints and boundaries such as environmental and ecological landscape conditions, or the presence or absence of public interventions.

Sustainability will be a key aspect of developing business models and the 'business models for sustainability' theorem will be used to understand how beekeepers capture economic value

while maintaining natural, social and economic capital beyond its organisational boundaries, and how they communicate this value proposition to customers and stakeholders (Schaltegger et al., 2016). As a first step it is important to understand how stakeholders view this value, what are the most important services that honeybees provide, how honey production fits into the wider economy, and the different benefits that professional and hobby beekeepers provide, according to them.

We also ask stakeholders about the overall business environment surrounding the EU beekeeping sector, with specific focus on policy and climate change. Asking stakeholders' opinions on these topics will help to identify points for attention when developing business model recommendations.

1.3 Towards defining pathways to sustainable beekeeping management

This deliverable also focuses on defining pathways to sustainable beekeeping management. This is in response to the concern that problems in beekeeping and the production of apiary products have increased, some of which pose a threat to the development of the beekeeping sector worldwide (Ranz, 2020). Modern beekeeping practices associated with large scale honey production such as feeding honeybees sugar syrup, transporting honeybee colonies, and the use of chemicals within bee hives, have come into question (EFSA, 2016; EIP-AGRI, 2019; Fontana et al., 2018; Rivera-Gomis et al., 2019).

Environmentally sustainable practices for apiary management, veterinary medicines, disease management, hygiene, animal feeding, record keeping and training have been developed by the Agricultural European Innovation Partnership (EIP-AGRI, 2019), by the BPRACTICES consortium (BPRACTICES, 2020), and independently by a group of experts within the EU beekeeping sector (Rivera-Gomis et al., 2019), among others. However, sustainable beekeeping does not just involve an ecological improvement in apiary management, but involves an ecological balance between healthy honeybees and the environment while also safeguarding economic and social viability.

Moreover, the 2013 Common Agricultural Policy reform focused on technical assistance for beekeepers, measures to combat pests and diseases, and the implementation of applied research programmes in honeybee products (Commission, 2019; Popescu & Popescu, 2019). However, the limitations of the CAP especially concerning its fragmented approach have been widely acknowledged. Prevailing solutions have not reconciled the multiple aspects of sustainability (economic, social, and ecological), and have often traded them off against each other.

Hence, we address the focal theme of healthy and sustainable beekeeping management by using the Analytical Hierarchical Process (AHP) (described in section 2.3) to encompass all three pillars of sustainability (economic, social, and ecological), to understand how different types of stakeholders in different places perceive the challenges facing the EU beekeeping sector and how they define pathways to healthy and sustainable beekeeping management. The AHP process provides a way to assess stakeholder priorities across different sectors and stakeholder groups, which can 1) help to understand possible pathways to achieve healthy

and sustainable beekeeping, 2) help to tailor these pathways to difference sectoral priorities, and 3) help to determine focal themes and priorities for policy decision making.

1.4 Scope and objectives

The scope of this study is to analyse the views of stakeholders involved in the EU beekeeping sector on honeybee colony health on the one hand, and on healthy and sustainable beekeeping management and future viable business models on the other hand. Both focal themes have been addressed by implementing mixed qualitative and quantitative research methods. The resulting insights and findings stem from the content analysis of narratives obtained by means of 41 qualitative in-depth stakeholder interviews (section 2.1), complemented with quantitative data analysis of a stakeholder survey (section 2.2).

The main objective of the **qualitative in-depth interviews** with stakeholders was to pave the way for a deeper knowledge / understanding of honeybee colony health and sustainable beekeeping business models, to feed into the second study involving stakeholders in a quantitative survey. The findings of this study, gained from 41 in-depth stakeholder interviews, included the identification of key descriptors for honeybee colony health and sustainable beekeeping business models. This analysis illustrates the diversity of existing knowledge about and opinions on honeybee colony health and the diversity of existing knowledge about the business environment in which beekeepers operate among our interviewees.

The main objective of the **quantitative survey with stakeholders** was to implement a systematic multi-criteria approach for assessing stakeholder priorities regarding sustainability objectives for European beekeeping, as well as identifying challenges and viable measures for healthy and sustainable beekeeping management, business models and their key descriptors. Insights gathered from the survey on what might contribute to better management and policy decisions will help inform a possible range of future successful business models for healthy and sustainable beekeeping.

More specifically, the survey aimed to determine if there are differences in stakeholder preferences and priorities between scientists, service providers, beekeepers, quality inspectors, NGO representatives, policy makers, agri-/horticultural actors and commercial actors. Consulting with stakeholders is part of B-GOOD's core approach, which is to fully engage with stakeholder partnerships and networks for the co-creation of solutions, strengthened throughout the project's lifespan.

Moreover, the overall aim of B-GOOD is to pave the way towards healthy and sustainable beekeeping in the EU. The term *sustainability* within the B-GOOD project involves:

> *"both the development of management strategies to maintain bee health (correct identification and treatment of problems, and correct beekeeping practices) and understanding of the ecological balance between bees and the environment while safeguarding economic viability".*

Therefore, it is key to gathering stakeholder preferences and priorities on pathways to reach healthy and sustainable beekeeping management in terms of bee and environmental health

(ecological sustainability), feasibility in the current social and cultural context (social sustainability), and economic viability (economic sustainability). This study will support the identification of a possible range of future successful business models for healthy and sustainable beekeeping throughout the EU. The second objective of the quantitative survey with stakeholders was to perform a quantitative assessment of stakeholder views on aspects of honeybee colony health, derived from qualitative insights gathered during stakeholder interviews.

2. Materials and methods

2.1 Qualitative in-depth interviews (n=41)

2.1.1 Study protocol, topic guide and ethics approval

First, data have been collected through in-depth interviews with stakeholders with different backgrounds involved in the beekeeping sector. The interview topic guide was developed in collaboration with WP1 and WP8. It was tested with four members of the B-GOOD consortium. After testing, a number of minor changes were made to phrasing and amendment of certain questions.

The interview topic guide (Appendix 1) consisted of four sections. The following types and contents of data/information was collected:

1. SWOT of beekeeping in the EU: views and opinions on internal strengths (S) and weaknesses (W) of the beekeeping sector in the EU in general, in specific countries and regions; views and opinions on external opportunities (O) and threats (T) facing the beekeeping sector in the EU in general, in specific countries and regions;
2. Social networks of stakeholders for transfer of knowledge and information about honey bee health;
3. Bee health: views and opinions on what constitutes and characterises a healthy bee colony; the threats to bee colony health; future perspectives and challenges related to bee colony health;
4. Business models: views and opinions on current and future beekeeping business models; identification and profiling of beekeeping business models; forecast on future business models for healthy and sustainable beekeeping in the EU.

Results from sections 1 and 2 of the topic guide were already presented in Deliverable 4.1: SWOT/SOR-analysis of healthy and sustainable beekeeping in the EU in month 12. Here, we present results from sections 3 and 4 of the topic guide. Ethics approval was obtained on 17 January 2020 from the Ethical Committee of Ghent University's Faculty of Psychology and Educational Sciences (Faculteit Psychologische en Pedagogische Wetenschappen). A copy of the ethics approval letter is included as Appendix 4.

2.1.2 Participant recruitment and sampling

A total of 41 interviews have been completed during the period 24 January – 20 March 2020. Data collection from stakeholders has been done by means of personal (face-to-face or video call) interviews. Stakeholders were identified using a mix of snowball sampling and convenience sampling. Snowball sampling is a non-probability sampling method in which existing subjects provide referrals to recruit more samples (Johnson, 2014), and convenience sampling is a non-probability sampling method in which the sample is taken from a group of people easy to contact or to reach (Etikan et al., 2016). Using members of the EU Bee Partnership (EFSA, 2018) as a starting sample, we first invited these members for an interview and then subsequently gathered contacts from them to enable snowball sampling.

To increase our breadth of actor selection, we also contacted and interviewed 5 European members of the International Honey Commission, who were not snowballed from the EU Bee Partnership, since the International Honey Commission represents a global network on the forefront of honey and apiary product science. We also contacted a member of Bayer Agriscience and a member of the Food and Agricultural Organisation of the United Nations (FAO) separately. Overall, we selected 34 participants belonging to or snowballed from the EU Bee Partnership, and selected another 7 participants via complementary convenience sampling.

Stakeholders were interviewed by B-GOOD researchers in English or in their native language in case English was not feasible and as far as the linguistic skills of the interviewers enabled us to do so. This applied to a number of French-speaking and Portuguese-speaking stakeholders. Interviews were audio-recorded for transcription.

2.1.3 Sample composition, data handling and analysis

Of the 41 interviews gathered, the vast majority of respondents were male (n=31), which can be explained by the fact that the beekeeping sector is male-dominated. Our sample had an average age of 52.4 years with ages varying between 34 and 79 years old. The high average age can be explained by the level of representatives of organisations that mostly already had a substantial career related to the sector. All the respondents lived and worked in Europe and, with one exception, all were of European nationalities. The 10 nationalities represented in the sample are, by alphabetical order: Austria, Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Portugal, Slovenia and the United Kingdom.

We observed that the majority of respondents were from Western Europe with France, Germany and Belgium being the best represented. This is probably due to a high number of respondents having functions at an EU level and thus being centred around the EU institutions. Despite this, in our sample we have representatives from many European regions, which undoubtedly allows us to have access to the variety and regional specificities that characterises the beekeeping sector.

Regarding types of stakeholders, we obtained the following distribution: 9 in the Scientist category; 7 in service providers; 5 representing the category Beekeeper/Beekeeper Association; 5 in the Inspector category, mainly composed of beekeeping product quality inspectors and pesticide impact evaluators; 5 in the NGO category; 5 representing the Agri-/horticulture category and 5 in the Policy Maker category. To categorise each principal function, we used the job description provided in the interview in conjunction with the function within the organisation they represented.

All interviews have been transcribed using NVivo transcription. Full transcripts of the 41 in-depth (around 550 pages) are available upon request. Audio-records have been deleted following complete and checked verbatim transcription. Transcripts are stored in pseudonymised formats. Qualitative analysis was conducted using deductive coding in the software programme NVivo (Saldana, 2015).

We opted to use a deductive content analysis strategy first, since the interviews were semi-structured and categories were already present in the interview script. This strategy was then combined with an inductive strategy, insofar as it integrated this diversity of positions resulting from the empiricism. Hence, categories were created for the five questions related to honeybee colony health (Table 1) and the eight questions related to beekeeping business models (Table 2). For each of these categories, a set of sub-categories was identified based on each interview analysis. The sub-categories aim to identify/classify/code the main views and opinions expressed by stakeholders.

Table 1: Interview questions and categories related to honeybee colony health

Questions	**Category**
How do you define a healthy honeybee colony?	Bee Health Characteristics
Why do you think honeybee colonies die?	Threats and Causes of Death
How do you envision honeybee health in the future?	Future Prospects on Bee Health
Who do you think should be responsible for honeybee health?	Responsibility on Bee Health
How to improve honeybee health in the future?	How to improve Bee Health

Table 2: Interview questions and categories related to beekeeping business models

Questions	**Category**
Why do you think people keep honeybees in Europe?	Reasons to Have Honeybees
What are the most common honeybee practice types in Europe?	Identification & Profiling
What are the services that honeybees provide?	Services honeybee Provides
How do you think honeybees fit into the supply chain or the institutional environment?	Honeybee in the Supply Chain
How do you think the honey beekeeping sector in Europe has changed in the past 10 years?	Changes in the Honeybee Sector
And how has policy and regulation changes influenced the sector?	Policy and Regulation
To what extent do you think that climate change has had an impact on beekeeping, and what do you think it will in the future?	Climate Change
How do you think the economy is surrounding honey, honey beekeeping has changed and how will it change in the future?	Business Model Changes and Forecast

Each of these categories was studied independently, whereby the results section presents the sub-categories found and respective frequency of reference in relation to stakeholder type and in some cases, region of Europe.

2.2 Quantitative stakeholder survey (n=504)

2.2.1 Study protocol, questionnaire and ethics approval

The quantitative stakeholder survey (see Appendix 2) aimed to 1) identify stakeholder preferences with respect to pathways to sustainable beekeeping management, and this across different types of stakeholders using pairwise comparisons, 2) gather stakeholder views on honeybee colony health and 3) gather stakeholder views on hive monitoring technology. Findings related to the third focal theme fall beyond the scope of the present deliverable and will be reported elsewhere.

The survey contained a total of 82 questions divided in 7 sections:

Section 1: Demographics
Section 2: Sustainability objectives
Section 3: Improved ecological status
Section 4: Improved social status
Section 5: Improved economic status
Section 6: Honeybee health
Section 7: Hive monitoring technology

The survey was tested among 11 respondents, 2 in the UK, 1 in the Netherlands, 1 in Germany and 7 in Portugal. The average response time among test respondents was 16 minutes. Minor feedback was given by test respondents and the survey was adjusted accordingly. Some respondents experienced respondent fatigue with assigning relative importance to variables on a continuous scale, therefore the AHP questions format was changed to choosing between options A and B, and afterwards assigning relative importance scores. Suggestions were also provided on the wording of two AHP statements in section 3, the wording of one sentence in section 6, and the description of sustainability objectives in section 2 of the questionnaire. Pre-test data was entered into the AHP calculation template developed by Goepel (2013) for model verification and to check for consistency. Ethics approval was obtained on December 24, 2020 from the Ethical Committee of Ghent University's Faculty of Psychology and Educational Sciences (Faculteit Psychologische en Pedagogische Wetenschappen). A copy of the ethics approval letter is included as Appendix 5.

All information collected during this study was strictly anonymised. Only anonymised data was used for analysis and in all types of documentation, reports or publications concerning this study. Data is stored in anonymised format only and on secured institutional servers for at least 10 years. The online software Qualtrics was used to create and administer the survey, and the AHP-OS tool including the AHP calculation template developed by Goepel (2013) was used for the AHP analysis to determine the relative importance (which are also referred as weightings or priorities) of the options specified in the hierarchies (Janssen et al., 2000).

The master questionnaire was developed in English and then translated into eight additional languages: Dutch, Finnish, French, German, Italian, Polish, Portuguese, and Romanian. This was done with the online translator Deepl, and then checked by B-GOOD partners who were native speakers in identified countries. The multi-lingual survey allowed us to reach participants in the language they are most comfortable with, while still allowing results to be analysed together as a single data set.

2.2.2 Participant recruitment and sampling

The stakeholder sample covers a range of stakeholder types in eight categories; 1) scientists, 2) extension services and service providers, 3) beekeepers and beekeeper associations, 4) beekeeping product quality inspectors and pesticide impact evaluators, 5) NGO representatives, 6) policy makers, 7) agri-/horticultural actors and 8) actors with commercial/industry interests. The initial aim was to have at least 20 surveys completed by representatives from each of the eight categories, which as effectively been realised (see section 2.2.3).

The selection of stakeholders was focused on sampling respondents in key countries representing the beekeeping sector in the EU from North / South / East / West, in order to guarantee a pan European study and enable comparison between key target groups where responses may vary. Specific countries were selected based on the importance of the country in EU beekeeping, combined with the coverage of the B-GOOD consortium partners and availability of B-GOOD researchers to check accurate translations. Italy, UK, France, Germany, Romania and Poland classify among the key players within the EU, either in terms of number of beehives or number of beekeepers. This set of countries is complemented with countries that rank as medium-scale in terms of number of beehives and/or beekeepers, such as Portugal, UK, the Netherlands and Belgium. Finland has been selected as a beekeeping country with a distinct profile characterised by very high average honey yields, prices and production costs, despite its rather small scale. Each of the selected countries is also covered by partners in the B-GOOD consortium, which presents important assets in terms of language, local support and contacts with the local beekeeping community and its related stakeholders.

The final list of countries covered is as follows:

1. Belgium
2. Finland
3. France
4. Germany
5. Italy
6. Netherlands
7. Poland
8. Portugal
9. Romania
10. UK

B-GOOD partners in each were asked to provide a list of stakeholder contacts representing each stakeholder type in their countries. At least five names and email addresses were provided for each of the eight stakeholder categories in each of the 10 countries, creating at least 40 contacts in each country. An invitation email was sent to contacts in the stakeholders' native language, together with the informed consent literature, providing a link to the online survey, and requesting that they forward the survey link to five of their colleagues, using a mix of convenience sampling and snowball sampling (Johnson, 2014; Lavrakas, 2008).

2.2.3 Sample composition, data handling and analysis

Overall sample

A total of 504 stakeholders completed the survey during the fieldwork period from mid-January until end March 2021. Participants' age ranged from 20 to 83 years with a mean age of 53.1 years (S.D.=12.4). More than two thirds of the participants (70.4%) were males vs. 28.6% females and 1.0% reporting 'prefer not to say'. The large majority of the participants had tertiary education (i.e. post-secondary education, including high school and university degrees) (83.3%) vs. 14.5% and 2.2% who had secondary or primary education, respectively. Eighteen nationalities were represented. All participants resided in Europe with Portugal (n=78), Belgium

(n=71), Germany (n=68), Italy (n=57), Romania (n=56), Netherlands (n=41) and Poland (n=40) being most represented. Countries of residence were classified into Western (Austria, Belgium, France, Germany, Luxembourg, the Netherlands, Switzerland) (n=205; 40.7%), Southern (Italy, Portugal) (n=135; 26.8%), Northern (Denmark, Finland, Ireland, United Kingdom) (n=68; 13.5%) and Central (Poland, Romania) (n=96; 19.0%) in accordance with the United Nations Geoscheme for Europe classification.

Participants were asked to report their activities related with the EU beekeeping sector, first, by indicating whether their activities primarily fitted with one of eight stakeholder types, i.e., scientist, service provider, beekeeper, quality inspector, policy maker, agri-/horticultural actor, non-governmental organisation representative, commercial or industrial actor. Second, participants were also asked whether their activities also fitted with a second stakeholder type. The resulting information is classified as 'primary activity and 'secondary activity' (Table 3).

The last column of table 3 reports the total number of participants who were primary or secondary active as a particular stakeholder. Almost three quarters (71.4%) of the participants indicated to have also a secondary activity related with the EU beekeeping sector next to their main or primary activity. This concerned mainly activities as beekeeper (35.0%) or as service provider to the beekeeping sector (21.1%). Combinations of primary and secondary activities that were more than 10 times reported were: beekeeper and service provider (n=37), scientist and beekeeper (n=20), beekeeper and agri-/horticultural actor (n=16), scientist and service provider (n=15), beekeeper and commercial or industrial actor related to beekeeping (n=14), and beekeeper and non-governmental organisation representative (n=11).

Table 3: Number of stakeholders in the sample based on their primary and/or secondary activities related with the EU beekeeping sector

Stakeholder type	Primary activity	Secondary activity	Primary or secondary activity
Scientist	79	40	111
Service provider	49	76	116
Beekeeper	259	126	307
Quality inspector	14	16	27
Policy maker	25	21	38
Agri-/horticultural actor	44	37	71
NGO representative	23	20	42
Commercial or industry actor	11	24	32
Total	504	360	n.a.*

*n.a. = not applicable

Further details were collected about the primary activity of the study participants. Participants in the different stakeholder groups were characterised as follows:

- Three quarters (74.7%) of the scientists (n=79) were natural scientists, as opposed to social, technical or art and humanities scientists.

- 57.1% of the service providers (n=49) were providers of training or extension services and 18.4% were providers of veterinary services.
- 72.2% of the beekeepers (n=259) were hobbyists vs. 22.8% professionals.
- Quality inspectors (n=14) were mostly active in honey adulteration inspection (42.9%) or bee hive inspection (35.7%).
- An equal share of policy makers (n=25) was active at national (52.0%) and regional (48.0%) level.
- Agri-/horticultural actors (n=44) were mostly active in conventional agriculture (51.4%), horticulture (18.9%), organic agriculture (10.8%) or supplies to the agri-/horticultural sector (8.1%).
- Representatives of non-governmental organisations (n=23) were active in the environmental domain (41.7%), social domain (29.2%) or economic domain (16.7%).
- Actors with commercial or industrial activities (n=11) were mostly active as honey packers and distributors (47.1%) or as manufacturers of beekeeping equipment (23.5%).

200-stakeholder subsample

Given the relatively high share of beekeepers, scientists and service providers in the overall survey sample and with the aim to provide insight in stakeholder views based on equal representation of stakeholder types, a specific subsample of the overall survey sample has been selected. This subsample contains 200 cases with an equal share of each stakeholder type, i.e., 25 cases from each of the eight identified stakeholder types. This subsample has been selected through an iterative selection procedure while observing the following criteria:

- Stakeholder groups primarily contain cases whose primary activity corresponds with the group type. This was most straightforward for the group of policy makers where 25 participants reported ‘policy maker’ as their primary activity related to beekeeping. This criterion was met for all stakeholder groups where at least 25 participants reported this as their primary activity.
- Stakeholder groups contain as much as possible only cases who reported a primary activity, and no secondary activity, in relation to beekeeping, in order to ensure a single viewpoint and thus avoid eventually mixed viewpoints. Given that 360 participants out of the total of 504 reported also a secondary activity, this criterion could only be met for maximum 144 cases.
- Where less than 25 participants reported a primary activity (e.g. only 23 participants reported ‘ngo representative’ as their primary activity), additional cases were selected randomly from those who indicated the concerned activity as secondary while avoiding overlap with the already established groups (e.g. policy makers assigned to the ‘policy maker’ group did not classify anymore for assignment to the ‘ngo representative’ or any other stakeholder group).

- Where more than 25 participants reported a primary activity (e.g. 44 participants reported 'agri-/horticulture' as their primary activity), 25 cases were randomly selected while avoiding overlap with the already established groups.

The resulting 200-stakeholder subsample (n=200) consists of 129 males (65.8%) and 67 females (34.2%), plus four participants who reported 'prefer not to say'. The mean age within this subsample is 51.33 years (S.D.=12.10). Ninety percent of the subsample had tertiary education. Countries of residence that are represented are Austria (n=1), Belgium (n=18), Denmark (n=9), Finland (n=8), France (n=6), Germany (n=22), Italy (n=30), the Netherlands (n=17), Poland (n=15), Portugal (n=43), Romania (n=21) and the United Kingdom (n=10). In terms of European regions, the distribution is 32.0% Western, 36.5% Southern, 13.5% Northern and 18.0% Central. The 200-stakeholder subsample herewith contains slightly more females, is slightly younger, is slightly higher educated and better balanced between especially Western/Southern European regions as compared to the overall study sample.

2.3 Analytical Hierarchical Process analysis

Stakeholder perceptions related to healthy and sustainable beekeeping management can be channelled into two different factors; (1) the 'what', being preferences for objectives reflecting on what is more important to aim for and (2) the 'how', being preferences for viable measures for healthy and sustainable beekeeping management needed for reaching their objectives. The multi-criteria approach is a set of tools designed to deal with multiple dimensions of a problem and can address multiple objectives and options for reaching those objectives by assigning weights or priorities (Mostert et al., 2018; Saaty, 2004; Soma, 2003, 2010; Soma et al., 2018).

The method in this study follows the first part of the Analytical Hierarchical Process (AHP) which identifies relevant criteria, arranges them into value-trees, and then conducts pairwise comparisons to assign relative importance (Saaty, 2004). This study focuses on involving multiple stakeholders to assign preferences, i.e. weights, as an outcome of the survey, following the method of Soma et al. (2018).

Soma et al. (2018) identified four steps adapted from the systematic multi-criteria approach, using the initial part of AHP:

1) Identify relevant stakeholders;
2) Identify relevant options and arrange them into hierarchies;
3) Design a questionnaire survey with pairwise comparisons based on options in the hierarchies;
4) Estimate the relative importance for each option for each participating stakeholder, eventually followed by comparison across different stakeholder groups.

Following this approach:
1) Stakeholders were identified, i.e. the 41 stakeholders that were interviewed. These 41 stakeholders were identified from major organisations operating in the EU beekeeping sector. Stakeholders represented scientists, service providers, beekeepers, quality inspectors, NGO representatives, policy makers, agricultural and commercial interests, as described previously.

2) Semi-structured in-depth interviews, in which the interviewer asked both pre-determined questions and un-planned questions (Longhurst, 2009), were conducted with these 41 stakeholders in an initial problem structuring phase, generating a set of alternative management options for healthy and sustainable beekeeping (Soma, 2010; Soma et al., 2018). During the interviews, stakeholders have identified relevant options for healthy and sustainable beekeeping management, which emerged from all sections of the interviews (see Section 3.2.2) and were extracted from the transcripts during content analysis. The general and the specific options were arranged into so-called hierarchies by B-GOOD researchers. Note that levels in the hierarchy are not related to levels of importance but only to levels of specification.

3) A questionnaire survey aimed to identify stakeholder preferences across different types of stakeholders. The quantitative survey was completed by 504 stakeholders representing a different sample than those who participated in the in-depth interviews. The qualitative interview phase aimed at gathering in-depth information from a small number of stakeholders, whereas the quantitative pairwise comparison survey allows to reach a larger number of stakeholders using information gathered from the qualitative phase. The relative importance of the specified options was provided by stakeholders in the survey based on the structures of the hierarchies. The method applied is called pairwise comparison technique as stakeholders are asked to compare two options at the same time on a scale of importance (Table 4).

Table 4: Example of pairwise comparison of two options and the scale of importance, associated with the question: “In the following comparisons, please indicate which option is more important (relative to each other) and how much more important on a scale 1 to 9, for improved ecological status of the EU beekeeping sector? (1 = equally important, 9 = much more important)”

A or B?		**Equal**	**How much more?**							
Stricter regulation on pesticide use	**Stricter movement controls to limit spread of disease and pests**	1	2	3	4	5	6	7	8	9

4) Estimates of the relative importance of the specified options for different stakeholder types were then determined using the pairwise comparison technique of AHP (Saaty, 2004) and using the AHP-OS software tool (Goepel, 2013). Two options at a time were presented on a semi-quantitative scale in the survey, and stakeholders indicated their priorities over the relevant options. This comparative data, along with other data collected related to honeybee colony health was analysed and described in the results section.

3. Results

3.1 Stakeholder views on honeybee colony health

3.2.1 Insights from stakeholder interviews on honeybee colony health

Bee health characteristics

In the first question of the bee health section of the interviews, stakeholders were asked to define a healthy honeybee colony. The question was “How would you define a healthy honeybee colony?” This question generated several initial reactions, with most interviewees indicating that there was still no consensus on the characteristics that define a healthy honeybee colony. Interviewees were somewhat unsure about identifying these characteristics, a claim that can be drawn from the use of expressions such as “in my opinion”, “I think” and others, along with statements that declared they were not “experts”, neither the people “best qualified” to talk about this issue. For most interviewees, the characteristics that indicate a healthy honeybee colony were recognised as a topic of discussion and disagreement both in the scientific community as well as among and between the other stakeholders involved, despite the reference to written definitions by the scientific community.

In the category bee health characteristics, 12 sub-categories were identified from the in-depth interviews, shown together with their frequency of reference in Table 5. For example, the characteristic “No visible signs of disease” was spontaneously mentioned by 23 out of the 41 interviewees, which corresponds with a share of 56%.

Table 5: Frequency of bee health characteristics referenced by stakeholders

	Sub-category	**Frequency**	**Percentage**
1	No visible signs of disease	23	56%
2	Growth / active population	18	44%
3	Capacity to produce bee products	18	44%
4	Capacity of survival (during winter and hard conditions)	16	39%
5	The presence of a young queen	14	34%
6	Availability of food (quantity and quality)	7	17%
7	Don’t know / very difficult to answer	6	15%
8	Beekeepers’ attention	5	12%
9	Balanced health	3	7%
10	Minor use of drugs and medicines	3	7%
11	Ability to provide pollination services	2	5%
12	Having a long-life expectancy	2	5%

Regarding differences in stakeholder type, policy makers gave more importance to the characteristic “Growth / active population.” Agri-/horticulture stakeholders gave more importance to “No visible signs of disease” and “Capacity of survival (during winter and hard conditions)”. NGO representatives were the only stakeholder type that highlighted “Capacity to produce bee products” as the main characteristic. Quality inspectors and service providers highlighted the characteristic “No visible signs of disease” and “Growth / active population”. The scientist group was the only group to give special importance to “The presence of a young

queen." Beekeepers gave special importance to "No visible signs of disease", "Growth / active Population" and "Capacity to produce bee products".

Causes of bee death

The second question in the bee health section aimed to identify the main causes of death of honeybee colonies. The question was: "Why do you think honeybee colonies die?" When analysing the answers given, it does not seem that this question raised any doubts or hesitations for interviewees, and only 1 of the 41 stakeholders did not manage to provide an answer. During the analysis we noticed that there is a consensus on the complexity of the issue portrayed. Most interviewees recognised a number of factors can cause real damage to a honeybee colony, and consider the interplay of these multiple factors simultaneously that usually leads to the colony loss.

In the category bee death causes, 13 sub-categories were identified from the interviews, shown together with their frequency of reference in Table 6. During data analysis, we decided to create the sub-item "Varroa", making it independent from the sub-item "Diseases and pathogens" since it was clear in the interviews how important this was in the discourses of most stakeholders.

Table 6: Frequency of bee death causes referenced by stakeholders

	Sub-category	**Frequency**	**Percentage**
1	Quality of nutrition/lack of floral resources	23	56%
2	Beekeeper practices	23	56%
3	Pesticides	21	51%
4	Varroa	21	51%
5	Diseases and pathogens	20	49%
6	Lack of environmental resources	11	27%
7	Agricultural Practises (monoculture, equipment's)	8	20%
8	Climate Change	5	12%
9	Asian Hornets (or another predator)	4	10%
10	Queen problems	3	7%
11	GMOS	3	5%
12	Natural death	1	2%
13	No answer	1	2%

Regarding differences in stakeholder type, beekeepers, service providers and quality inspectors had very similar profiles, with the sub-categories most mentioned by the three groups being "Quality of nutrition/lack of floral resources" and "Pesticides." NGO representatives saw "Varroa" as the main causes of bee death. Scientists highlighted "Beekeeper practises," as well as "Pesticides." Agri-/horticulture stakeholders and policy makers also had similar profiles, highlighting especially "Beekeeper practices," and "Quality of nutrition."

Future perspectives for bee health

The third question of the bee health section collected information on the perspectives of each interviewee for the future of honeybee health. The question was "How do you envision

honeybee health in the future?" A substantial part (one third) of interviewees indicated they were optimistic about the future of honeybee health, with 10% believing in the expansion of the honeybee sector in the future. Almost one fifth (22%) of interviewees expressed doubts and apprehensions when thinking about the future of bee health, and 5% foresaw the extinction of the activity in Europe.

In the category future perspectives for bee health, 12 sub-categories were identified from interviews, shown together with the frequency of reference in Table 7.

Table 7: Frequency of future perspectives for bee health referenced by stakeholders

	Sub-category	**Frequency**	**Percentage**
1	Optimistic	14	34%
2	Increased quality in beekeeping (more and better education)	10	24%
3	Doubt (future crises, climate change, new diseases)	9	22%
4	More / better investigation and methods	9	22%
5	More control on diseases and parasites	7	17%
6	Improvement on bee health	6	15%
7	New farming models	6	15%
8	New / different policies	5	12%
9	No answer	5	12%
10	More hives	4	10%
11	Better communication / exchange of knowledge	3	7%
12	Death of bees and the sector	2	5%

Regarding differences in stakeholder type, within the stakeholder group beekeepers, most of them mentioned "Doubt (future crises, climate change, new diseases)" and at the same time most of them mentioned "Optimistic" about the future of honeybee health. Scientists mentioned that in the future they foresee "More / better investigation and methods" with high frequency, and that they are also "Optimistic" about the future of honeybee health.

Responsibility on bee health

The fourth question of the bee health section asked "Who do you think should be responsible for honeybee health?" Some examples of answers include individual Member States, European Union and NGOs. Some interviewees stressed that responsibility should be shared by several bodies, from those acting at a more local level to those with mainly legislative and bureaucratic functions. Most of the interviewees (63%) nominated beekeepers as the main responsible for the bee health, for the sake of proximity and because the beekeeper has a duty towards the bees that he or she owns. The opinions referencing Member States and the EU were quite similar; 49% and 46% respectively.

In the category responsibility on bee health, 9 sub-categories were identified from interviews, shown together with the frequency of reference in Table 8.

Table 8: Frequency of responsibility on bee health referenced by stakeholders

	Sub-category	Frequency	Percentage
1	Beekeeper	26	63%
2	Individual Member States	20	49%
3	EU	19	46%
4	Regional / local Level	10	24%
5	Laboratories / knowledge institutes	9	22%
6	Beekeeping organisations	7	17%
7	No answer	5	12%
8	Community	4	10%
9	Veterinarian	3	7%

Regarding differences in stakeholder type, scientists almost unanimously suggested the EU should take responsibility for bee health, followed by the Member States. Beekeepers, service providers, quality inspectors, agri-/horticulture stakeholders and policy makers point to beekeepers as being mainly responsible. Interestingly, beekeepers, in addition to citing their own responsibility, highlighted the responsibility of the Member States. Agri-/horticulture stakeholders and policy makers recognised the sub-categories "Regional / local level" and "Laboratories / knowledge institutes" as agents of responsibility.

How to improve bee health

The last question of bee health section collected stakeholder opinions about the strategies to promote and improve honeybee health. The question was: "How do you think we could improve honeybee health in the future?" Most interviewees indicated that the training of beekeepers is a way to improve bee health.

In the category how to improve bee health, 9 sub-categories were identified from interviews, shown together with the frequency of reference in Table 9.

Table 9: Frequency of how to improve bee health referenced by stakeholders

	Sub-category	Frequency	Percentage
1	Training for beekeepers	18	44%
2	Collaboration with farmers at a local level	12	29%
3	Research	10	24%
4	Better communication from and to beekeepers	9	22%
5	Better legislation	9	22%
6	Sustainable and environment friendly practices	9	22%
7	More/ better national programmes	9	22%
8	No answer	5	12%
9	More and more active bee institutes / beekeeper associations	5	12%

Regarding differences in stakeholder type, the opinions of beekeepers were quite dispersed. The scientists, by the frequency of responses from each interviewee, had more consensus on how to improve bee health. For this group the main sub-category mentioned was "Collaboration with farmers at a local level" followed by "Training for beekeepers," "Research" and "Better legislation." For the stakeholder groups NGO representatives and service providers, the sub-category that had the highest prominence was "Training for beekeepers."

Finally, both policy makers and quality inspectors mentioned “Research” most often as strategies to improve bee health.

3.2.2 Results from stakeholder survey on honeybee colony health

Participants to the stakeholder survey (n=504, including the 200-stakeholder subsample) were asked to distribute and assign 100 points of importance across five factors that potentially impact honeybee colony health. The five factors were:

1. The beekeeper and his/her management of honeybees and hives (‘Beekeeper Mgmt.)
2. The quality and diversity of natural resources in the environment (‘Natural Res.)
3. The characteristics of the colony (size, queen, brood, colony genetics, …) (‘Colony Char.’)
4. The presence or absence of contaminants in the environment (‘Env. Contaminants’)
5. The presence or absence of parasites (such as varroa) and diseases in the hive (‘Parasites Diseases’)

The factors were presented to the participants in randomised order. Zero scores, equal scores across all five factors, as well as a score of 100 for one of the five factors were all allowed. The total of 100 points had to be assigned and the total could not surpass 100.

Descriptive statistics

Table 10 provides a first set of descriptive statistics with a focus on the share of participants who reported zero scores, scores of exactly ‘20’ and scores of ‘50’ or more for the different factors. Zero scores indicate that participants perceive a particular factor to be totally unimportant for honeybee colony health. Zero scores can be the result of assigning a score of ‘100’ to any of the other factors, though this occurred only in a few cases in the overall sample, namely once for each of ‘Beekeeper Mgmt.’, ‘Env. Contaminants’ and ‘Parasites and Diseases’.

Table 10: Percentage of zero, ‘20’ and ’≥50’ scores for five factors impacting honeybee colony health in the overall sample and the 200-stakeholder subsample

	Overall survey sample (n=504)			200-stakeholder subsample (n=200)		
Perceived importance	0	20	≥50	0	20	≥50
Beekeeper Mgmt.	4.6	26.8	3.8	2.0	24.0	6.5
Natural Res.	3.0	31.3	5.2	3.5	31.0	4.5
Colony Char.	9.7	27.6	0.8	9.0	26.0	0.5
Env. Contaminants	4.8	31.2	3.0	5.0	31.0	5.0
Parasites and Diseases	3.2	29.6	7.5	3.5	30.0	6.0

The data reported in Table 10 yield the following insights:

- A high degree of consistency is observed between the partial distributions of the overall sample and the 200-stakeholder subsample. Eventual differences can be

attributed to the relatively lower share of scientists, service providers and especially beekeepers in the 200-stakeholder subsample.

- One notable result was that a share of up to 10% of the stakeholders assigned zero importance to this colony characteristics while less than 1% attributed an importance score of 50 or more to this factor. This indicates that colony characteristics tend to be perceived to be of a lesser importance than the other factors according to participants.
- The higher share of '≥50' in the last column of Table 10 indicates that the perceived impact of the beekeeper and his/her management on honeybee colony health is higher within the 200-stakeholder subsample compared to the overall study sample.

A total of 47 participants (9.3%) in the overall sample and 22 participants (11.0%) in the 200-stakeholder subsample reported equal scores of '20' for each of the five factors contributing to honeybee colony health. As the reason for doing so, 87.2% of the overall sample and 81.8% of the 200-stakeholder subsample indicated because 'I am really convinced those five factors have equal weight'. The others indicated 'I have limited knowledge or no idea about all aspects' as the reason for having attributed equal weight to all five factors. There is no significant association between stakeholder type and assigning equal weight to each of the five factors contributing to honeybee colony health.

A second set of descriptive statistics is provided in Table 11 with an overview of the distribution of importance scores after categorising scores into 'low', 'medium' and 'high'. Low scores are defined as scores between 0 and 15; medium scores between 16 and 24; high scores as 25 or more. High importance scores are most frequent for 'the quality and diversity of natural resources in the environment', followed by 'presence of absence of parasites and diseases in the hive', and 'the beekeeper and his/her management of honeybees and hives' – the latter particularly in the 200-stakeholder subsample. By contrast, low importance scores have been attributed mostly to 'the characteristics of the colony'.

Table 11: Percentage of low (score 0-15), medium (score 16-24) and high (score 25-100) scores, median, interquartile range (IQR) and mean values for factors impacting honeybee colony health in the overall study sample and the 200-stakeholder subsample

	Overall survey sample (n=504)			200-stakeholder subsample (n=200)		
Perceived importance	Low	Medium	High	Low	Medium	High
Beekeeper Mgmt.	42.7	27.8	29.6	40.0	24.0	36.0
Natural Res.	25.0	32.7	42.3	26.5	31.5	42.0
Colony Char.	60.7	28.4	10.9	62.0	26.5	11.5
Env. Contaminants	39.7	31.9	28.4	37.5	31.5	31.5
Parasites and Diseases	27.2	30.4	42.5	33.5	30.5	36.0
	Overall survey sample (n=504)			200-stakeholder subsample (n=200)		
Perceived importance	Median	IQR	Mean	Median	IQR	Mean
Beekeeper Mgmt.	20	15.0	19.48	20	20.0	21.32
Natural Res.	20	14.8	23.36	20	15.0	22.67
Colony Char.	10	10.0	13.96	10	11.5	13.81
Env. Contaminants	20	15.0	19.48	20	20.0	20.35
Parasites and Diseases	20	15.0	23.72	20	10.0	21.87

For each of the five factors contributing to honeybee colony health, the given importance scores are not normally distributed. In order to further analyse these scores and their distributions, categorical analyses and non-parametric statistical tests have been performed. Median values are 20 for each of the factors, except for 'the characteristics of the colony' where the median is 10. The interquartile range (IQR) (i.e. the distance between the first and the third quartile, or also the range in which the middle 50% of the data are) is the largest for 'the beekeeper and his/her management of the honeybees and hives' and 'the presence or absence of contaminants in the environment', indicating a larger spread of the data for those factors. The IQR is the smallest for 'the characteristics of the colony'. Mean values are reported for information purpose only since the data are not normally distributed.

Differences between stakeholder groups

First, categorical chi-square association tests were performed within the overall sample to test for associations between stakeholder type (as a binary yes/no-variable combining primary and secondary activity related to the beekeeping sector) and 'low', 'medium' or 'high' scoring on factors contributing to honeybee colony health. This analysis revealed four significant associations:

- Scientists scored environmental contaminants relatively more as a low important factor (chi-square=7.46; p=0.024). Almost half of the scientists (49.5%) scored environmental contaminants low compared to 39.7% in the overall sample.
- A similar association was observed among service providers. Service providers scored environmental contaminants relatively more as a low important factor (chi-square=8.63; p=0.013); 50.9% of the service providers scored environmental contaminants low compared to 39.7% in the overall sample.

- By contrast, service providers scored beekeeper management relatively more as a high important factor (chi-square=8.69; p=0.013); 40.5% of the service providers scored beekeeper management high compared to 29.6% in the overall sample.
- Policy makers scored natural resources relatively more as a medium (rather than either low or high) important factor (chi-square=7.90; p=0.019); 52.6% of the policy maker scored natural resources a medium compared to 32.7% of the overall sample.

Second, categorical chi-square association tests were performed within the 200-stakeholder subsample to test for associations between stakeholder group membership (i.e. the eight types of stakeholders) and 'low', 'medium' or 'high' scoring on the five factors contributing to honeybee colony health. Within the 200-stakeholder subsample, none of the tested associations turned out to be significant. The association between stakeholder group membership and 'low', 'medium' or 'high' scoring on environmental contaminants was marginally significant (chi-square=22.66; p=0.066.) The results indicated a tendency that 'the presence or absence of contaminants in the environment' was scored by beekeepers as a factor of relatively high importance , in comparison to policy makers who indicated it as medium importance , whilst commercial and industry actors, service providers and quality inspectors indicated it as a factor of low importance impacting honeybee colony health.

Third, independent samples non-parametric Kruskal-Wallis tests have been performed to test for eventual differences in the distributions of the scores for each of the factors impacting honeybee colony health across stakeholder groups. These tests revealed significant differences in the distribution of 'the beekeeper and his/her management of the honeybees and hives' across categories of the 200-stakeholder subsample. The distributions for this factor and associated test statistics are presented in Figure 1. Pairwise comparison tests revealed that the distributions shown in Figure 1 are significantly ($p<0.05$) different between seven pairs of stakeholder groups: agri-/horticultural actors and quality inspectors; agri-/horticultural actors and service providers; agri-/horticultural actors and commercial or industrial actors; non-governmental organisation representatives and quality inspectors; non-governmental organisation representatives and service providers; non-governmental organisation representatives and commercial or industrial actors; and between scientists and commercial or industrial actors. Distributions for the other four factors are not significantly different across stakeholder groups.

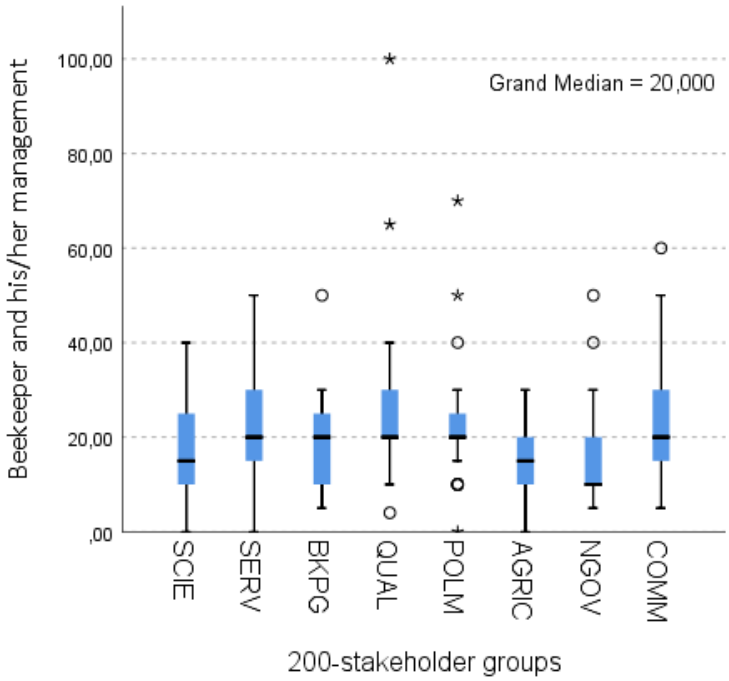


Figure 1. Comparison of distributions (box plots) of importance scores attributed to 'beekeeper and his/her management' across stakeholder groups (n=200); SCIE= scientists; SERV=service providers; BKPG= beekeepers; QUAL=quality inspectors; POLM=policy makers; AGRIC=agri-/horticultural actors; NGOV=non-governmental organisations representatives; COMM=commercial or industry actors. Kruskal-Wallis test statistic=15.83; p=0.027.

Differences between European regions and demographics

First, categorical chi-square association tests were performed within the 200-stakeholder subsample to test for associations between European regions and 'low', 'medium' or 'high' scoring on the five factors contributing to honeybee colony health. Three significant associations emerged from this analysis:

- Western European stakeholders attributed higher importance to 'the beekeeper and his/her management of honeybees and hives'. They accounted for 43.1% of the stakeholders who attributed a 'high' score to this factor impacting honeybee colony health, versus 36.0% in the total 200-stakeholder sample. By contrast, Central European stakeholders attributed 'medium' or 'low' scores to the role of beekeepers (chi-square=14.35; p=0.026).
- Western European and Northern European attributed lower importance to 'the presence or absence of contaminants in the environment'. They accounted for 51.6% and 48.1%, respectively, of the stakeholders who attributed a 'low' importance score to this factor, versus 37.5% in the total 200-stakeholder sample. By contrast, Southern European stakeholders attributed 'high' importance scores to this factor (chi-square=15.01; p=0.020).
- Western European stakeholders attributed a higher importance to 'the presence or absence of parasites and diseases in the hive'. They accounted for 51.6% of the stakeholders who attributed a 'high' score to this factor impacting honeybee colony

health, versus 36.0% in the total 200-stakeholder sample. By contrast, Northern European stakeholders attributed 'low' scores to the role of parasites or diseases; they accounted for 48.1% of those who gave a 'low' score to this factor, versus 33.5% in the total 200-stakeholder sample (chi-square=14.00; p=0.030).

Second, within the 200-stakeholder subsample, independent samples non-parametric Kruskal-Wallis tests have been performed to test for eventual differences in the distributions of the scores for each of the factors impacting honeybee colony health across stakeholder groups from different European regions (Northern, Western, Southern, Central). These tests revealed significant differences in the distributions of 'the presence or absence of contaminants in the environment' and 'the presence or absence of parasites and diseases in the hive' across UN Geoscheme regions. The distributions for these two factor and associated test statistics are presented in Figure 2 and Figure 3. Pairwise comparison tests for 'the presence or absence of contaminants in the environment' revealed that the distributions shown in Figure 2 are significantly ($p<0.05$) different between Northern and Central, between Northern and Southern, and between Western and Central. The same analysis for 'the presence or absence of parasites and diseases in the hive' revealed that the distributions are significantly different between Western and each of the other three European regions (Figure 3).

Finally, Mann-Whitney U-tests have been performed to test for eventual differences in the distributions of the factors impacting honeybee colony health across gender (male vs. female) and education level (primary or secondary vs. tertiary). None of these tests revealed significant differences.

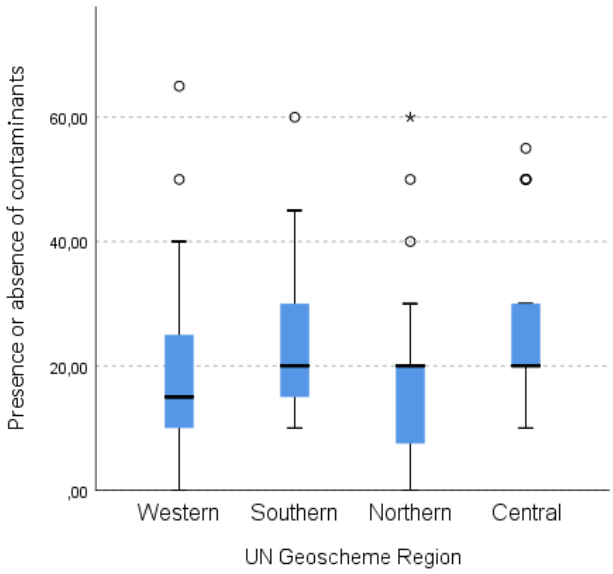


Figure 2. Comparison of distributions (box plots) of importance scores attributed to 'the presence or absence of contaminants in the environment' across European regions. Kruskal-Wallis test statistic=14.16; p=0.003.

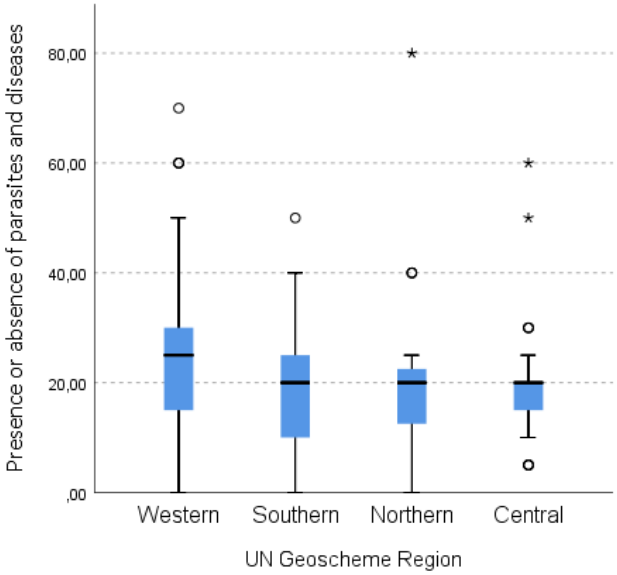


Figure 3. Comparison of distributions (box plots) of importance scores attributed to 'the presence or absence of parasites and diseases in the hive' across European regions. Kruskal-Wallis test statistic=8.45; p=0.038.

3.2 Stakeholder views on beekeeping business models

3.2.1 Insights from stakeholder interviews on beekeeping business models

Reasons for keeping honeybees

In the first question of the business model section of the stakeholder interviews, we asked stakeholders to explain the reasons that lead to keep honeybees. The question was: “Why do you think people keep honeybees in Europe?” All interviewees identified at least one or more explanations that lead to different reasons that people keep honeybees.

In the category reasons to keep honeybees, 10 sub-categories were identified from interviews, shown together with the frequency of reference in Table 12.

Table 12: Frequency of reasons to keep honeybees referenced by stakeholders

	Sub-category	**Frequency**	**Percentage**
1	Second profession / second income	13	46%
2	Commercial purpose	12	43%
3	Passion for beekeeping	11	39%
4	Honey for self- consumption	10	36%
5	As a hobby	10	36%
6	Promote environmental sustainability	9	32%
7	Pollination service	7	25%
8	Contact with nature	5	18%
9	Cultural interest	2	7%
10	Don’t know	1	4%

Regarding differences in stakeholder type, across all stakeholder types, we found the sub-categories “As a hobby” and “Passion for Beekeeping” as the most frequent answer to the question, except for beekeepers. Beekeepers referred to “Second profession / second income” most frequently, justifying its activity through the economic component. Beekeepers also responded “Promote environmental sustainability,” as a reason to keep honeybees.

Identification and profiling

The second question of the business model section was “What are the most common honeybee practice types in Europe? Amateur, professional, pollination services, honey production?” Although the question probes for more detail, all interviewees divided the types of honeybee practices into professional or amateur/hobbyists. To extract the largest set of available information, we included other sub-categories referenced to better understand and compare how the activity is organised in the eyes of stakeholders.

In the category identification and profiling, 6 sub-categories were identified from interviews, shown together with the frequency of reference in Table 13.

Table 13: Frequency of most common beekeeper types referenced by stakeholders

	Sub-category	Frequency	Percentage
1	Hobbyists	27	93%
2	Professional	18	62%
3	Sector dominated by hobbyists	13	45%
4	A sector with a small share of professionals	3	10%
5	Younger beekeepers	2	7%
6	Sector dominated by professionals	1	3%

Three fifths (62%) of interviewees referred to the existence of the professional practice but only 3% declared "Sector dominated by professionals" contrasting with the 10% that declared "Sector with a small share of professionals." Regarding differences in stakeholder type, all stakeholder types referred more often to "Hobbyists," illustrating also the sub-category "Sector dominated by hobbyists" which demonstrates hobby predominance in European beekeeping. All stakeholder types referred to "Professional" as the secondary beekeeping group.

Services that honeybees provide

In the third question of the business model section, we asked to the stakeholders to list the services that honeybee provide. The question was: "What are the services that honeybees provide?" The sub-categories ranged from the most traditional or common service such as honey production to some less known services as medical purposes, cosmetic purposes, educational services, or aesthetic services.

In the category services that honeybees provide, 6 sub-categories were identified from interviews, shown together with the frequency of reference in Table 14.

Table 14: Frequency of services that honeybees provide referenced by stakeholders

	Sub-category	Frequency	Percentage
1	Honey production	23	79%
2	Pollination services	22	76%
3	Product production (propolis, wax, royal jelly)	16	55%
4	Medical / cosmetic purposes	5	17%
5	Balanced ecosystem	5	17%
6	Other (educational services / aesthetic services)	4	14%

Data across the different stakeholder types showed unanimity and that the main services provided by honeybees are honey production and pollination.

Honeybees and the supply chain

The fourth question of the business model section aimed to gather stakeholder views on how honeybees should integrate within the agro-food supply chain. The question was "How do you think honeybees fit into the supply chain or the institutional environment? Are bees part of the livestock sector? Are they part of agricultural sector? How do you think they fit into the agricultural system?" Many interviewees showed some confusion and lack of understanding about the question asked, and therefore Table 15 should be interpreted as an approximate indication.

In the category honeybees and the supply chain, 8 sub-categories were identified from interviews, shown together with the frequency of reference in Table 15.

Table 15: Frequency of sector where honeybees fit referenced by stakeholders

	Sub-category	Frequency	Percentage
1	Livestock sector	14	48%
2	Agriculture sector	9	31%
3	Needs better regulation	7	24%
4	Don't know	5	17%
5	Environmental sector	3	10%
6	Honey sector	2	7%
7	Don't have a place	1	3%
8	Pollination sector	1	3%

The most frequent opinion expressed among interviewees (referred in 48% of the interviews) was that honeybees should be considered livestock. Most interviewees argue this should be the primary classification because honeybees are domesticated as other production animals. Although this question leads to a somewhat confusing topic of discussion that often seemed to go beyond the knowledge of the stakeholders involved, beekeepers, agri-/horticulture stakeholders and scientists believed most strongly that bees should be categorised in the supply chain as livestock. Policy makers as well as beekeepers also mentioned many times that it "Needs better regulation."

Changes to the sector over the past 10 years

The fifth question of the business model section intended to gather stakeholder views on the EU beekeeping sector changed over the past 10 years. The question was: "How do you think the honey beekeeping sector in Europe has changed in the past 10 years"? The highest sub-category referenced by interviewees was increasing scientific research with 38% of the interviewers referring to it, as the main thing that has changed in the sector for the last 10 years. 21% of the interviewees who responded to this question also iterated that the sector is growing in the number of hives, as well as the number of beekeepers. It was also iterated that beekeepers are now younger (average) than they were 10 years ago.

In the category changes to the sector, 10 sub-categories were identified from interviews, shown together with the frequency of reference in Table 16.

Table 16: Frequency of changes to the sector referenced by stakeholders

	Sub-category	Frequency	Percentage
1	Increasing scientific research	11	38%
2	Increased number of hives	6	21%
3	Increased number of beekeepers	6	21%
4	Politicised sector (present in the political agenda)	6	21%
5	Deficiency in bee health	4	14%
6	Younger beekeepers	3	10%
7	Don't know	1	3%
8	Increasing bee products quality	1	3%
9	More fraud in honey production	1	3%
10	Increased production costs	1	3%

Regarding differences in stakeholder type, we found the sub-category “Increased in Scientific Research” as the main answer to the present question, except for NGO representatives who mentioned most “Increased in Number of Beekeepers”. The response “Politicised sector (present in the political agenda)” seems to be transversal to most of the stakeholder types under analysis, being especially referred to by quality Inspectors and agri-/horticultural actors. It is also relevant to mention that NGO representatives, service providers, and agri-/horticultural actors state, “Increased number of hives” and “Increased number of beekeepers” as changes that have occurred in the sector. Most of the stakeholder types also referred “Deficiency in bee health” as a change in the sector.

Policy and Regulation

In the sixth question of the business model section, stakeholders were asked “How have policy and regulatory changes influenced the sector?” Many answers were given, creating a total of 9 sub-categories. In some responses, stakeholders also contributed their views on the policy changes that should be made, and initiatives that should be taken to improve some aspects of the sector.

In the category policy and regulation, 9 sub-categories were identified from interviews, shown together with the frequency of reference in Table 17.

Table 17: Frequency of policy influence on the sector referenced by stakeholders

	Sub-category	**Frequency**	**Percentage**
1	Regulation on bee medicines and agricultural chemicals	13	35%
2	Eco-innovation / agro-ecology	11	30%
3	Policies for production regulation	10	27%
4	International honey trade policies	9	24%
5	Policies based on scientific evidence	8	22%
6	Policies for price stabilisation	7	19%
7	Training for beekeepers on marketing and management	7	19%
8	More funding programmes	6	16%
9	Don’t know	4	11%

We see a dispersion of responses across all sub-categories, with none achieving more than 40% reference frequency across interviews. The most referred to sub-category was “regulation on bee medicines and agricultural chemicals” (35%), suggesting what seems to be a consensus among stakeholders on the need for control of both pesticides in agriculture and medicines in beekeeping. “Eco-innovation / agro-ecology,” which refers to the more sustainable and environmentally friendly practices in agriculture, such as changing the model of agriculture towards agroecology, was mentioned in 30% of the interviews.

Regarding differences in stakeholder type, beekeepers stand out on this issue because they mention the sub-category “Policies for price stabilisation” more often, which may be an illustration of economic challenges that beekeepers are currently facing. Scientists and quality inspectors have shown particular concern with the sub-category “Policies for production regulation.”

Climate change

The seventh question of the business model section aimed to find out stakeholders' opinions on climate change both now and in the future. The question was: "To what extent do you think that climate change has had an impact on beekeeping, and what do you think it will be in the future?" While some stakeholders agreed that climate change is harming the environment and the survival of bees, others stakeholders argued that this is not such a major problem and that it could even bring benefits to beekeeping, e.g. in Northern countries.

Therefore, it becomes necessary not only to look at the data from the perspective of stakeholder type but also to add a modality of regional differentiation. Thus, the stakeholders have been divided into southern European countries (Portugal, Italy and Greece) and northern countries (Austria, Belgium, Denmark, France, Germany, Netherlands, Slovenia and UK) in an attempt to understand whether the perception of climate change is influenced by the country in which the stakeholder lives.

In the category climate, 13 sub-categories were identified from interviews, shown together with the frequency of reference in Table 18.

Table 18: Frequency of impact of climate change referenced by stakeholders

	Sub-category	**Frequency**	**Percentage**
1	Harsher climate (drier summers, colder winters)	17	57%
2	Fewer food resources	14	47%
3	New and stronger diseases (Varroa)	8	27%
4	Alteration in the natural cycle	6	20%
5	Better weather for honey production in Northern countries	5	17%
6	Good adaptability of honeybees to the weather	5	17%
7	Don't know	4	13%
8	Less production of honey	4	13%
9	Southern countries are more affected	4	13%
10	Not the biggest challenge	3	10%
11	Climate change affects regions differently	2	7%
12	Honeybees will get weaker	1	3%
13	Migration of honeybees	1	3%

The sub-category mentioned by most of the stakeholders was "Harsher climate (drier summers, colder winters)" (57%), although there was no consensus on whether climate change is a negative or a positive aspect for the beekeeping sector because it affects countries or regions in different ways.

Regarding stakeholder types, all stakeholder types have expressed special concern by referring to the sub-category "Harsher climate (drier summers, colder winters)". Scientists and Service providers emphasised "fewer food resources" as one of the main concerns of climate change. The reference to the sub-category "Better weather for honey production in Northern countries" by NGO representatives was more remarkable than when compared to other stakeholder types.

Regarding the location of stakeholders, stakeholders in Southern countries have high reference frequencies for the following sub-categories: “Harsher climate (drier summers, colder winters)” (43%), “Fewer food resources” (57%), and “Good adaptability of honeybees to the weather” (29%) compared to the Northern countries, 41%, 31%, and 9%. The sub-category “Southern countries are more affected” was mentioned more in Southern countries (14%) than in Northern countries (9%). Stakeholders in Northern countries referred to the sub-categories “Better weather for honey production in Northern countries,” “Not the biggest challenge,” and “Climate change affects regions differently,” whereas stakeholders in Southern countries have not mentioned these sub-categories at all.

Business environment changes and forecast

The last question of the business model section aimed to understand the changes in beekeeping business models in Europe, as well as the expectations that stakeholders have for the future business environment of the sector. The question was: “How do you think the economy surrounding honey and beekeeping has changed and how will it change in the future?” From the answers of the stakeholders, it was possible to gather 10 sub-categories. These sub-categories either pointed to current concerns about the honey sector in Europe or were otherwise measures that stakeholders would like to see implemented in the future.

In the category business environment changes and forecast, 10 sub-categories were identified from interviews, shown together with the frequency of reference in Table 19.

Table 19: Frequency of business environment forecast referenced by stakeholders

	Sub-category	**Frequency**	**Percentage**
1	Concerns about the European honey market	16	46%
2	Need for better legislation / policy	12	34%
3	Concerns about the quality of honey	12	34%
4	Need for training for beekeepers on business strategy	7	20%
5	Need for more funds for veterinary medicine	6	17%
6	Optimistic	6	17%
7	Need for stricter legislation on chemicals and pesticides	6	17%
8	Pessimistic	4	11%
9	Opportunities for digitalisation/hive-monitoring technology	3	9%
10	Need for more data exchange	3	9%

According to the interviews, one of the major concerns of stakeholders was the import of honey from Asian countries (especially China), which have lower food quality standards and more affordable prices to the consumer, compared to the prices on the European market. 46% of stakeholders declared they had “Concerns about the European honey market,” most of them were concerned that the economic aspect of the European honey market is starting to deteriorate due to the sale of honey on large scale at cheaper prices.

About one third (34%) of the stakeholders indicated that it is essential to have “Need for better legislation / policy” in the future, especially controlling the quality of honey. About one third (34%) of the stakeholders also mentioned “Concerns about the quality of honey,” claiming that the amount of ‘non-pure’ honey currently marketed is increasing in the European market.

Overall, when looking to the future of the European honey sector, 17% were optimistic while 11% were pessimistic.

Regarding stakeholder type, scientists, NGO representatives, and quality inspectors paid special attention to the sub-category “Concerns about the European honey market” during the interviews. Scientists have also made significant reference to the need for “Need for stricter legislation on chemicals and pesticides.”

3.2.2 Business models for healthy and sustainable beekeeping in the EU: AHP-analysis

Sustainability objectives

The Analytical Hierarchical Process (AHP) method has been implemented to assess stakeholders’ views on healthy and sustainable beekeeping and to identify the key components of future beekeeping business models that fit within / contribute to this concept. Sustainability objectives are split into three underlying core categories of ecological, economic and social objectives. The three sustainability objectives are based on the European Union’s three pillars of sustainability which includes ecological, economic and social objectives (Commission, 2020; Qiu & Jones, 2013). This is also in accordance with the terms for sustainable development by the World Summit on Sustainable Development (Nations, 2002), with the definition of sustainability within B-GOOD, and with the approach followed by Soma et al. (2018). Figure 4 depicts core sustainability objectives identified, in line with the study by Soma et. al (2018). These broad interpretations of sustainability and its core components provide opportunities for context-specific interpretations of what is relevant.

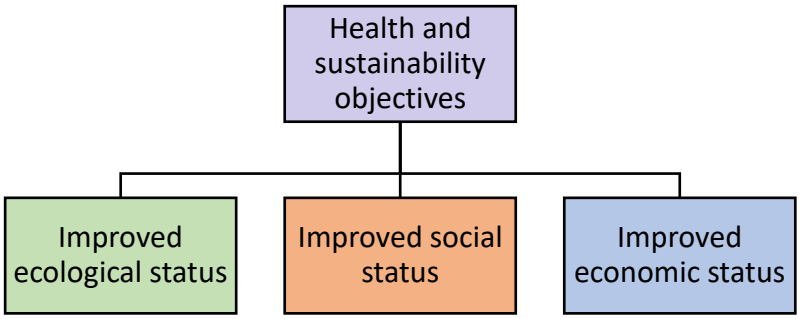


Figure 4. Components of sustainability objectives contributing to health and sustainability objectives as the overarching themes for the AHP analysis

Viable measures for healthy and sustainable beekeeping management

The viable measures for healthy and sustainable beekeeping management address how to possibly achieve the identified health and sustainability objectives (i.e. improved ecological, social and economic status) are presented in Figure 5. These viable measures were included as options for pairwise comparisons in the survey, and were identified from the responses obtained during the qualitative in-depth interviews and through literature review. Each possible

measure was chosen since it emerged frequently, and thus due to its importance during discussion with stakeholders during interviews, and its importance in the literature. Hypotheses for how each of the measures may contribute to healthy and sustainable beekeeping, as well as both interview and literature sources to justify their selection are provided in Appendix 3.

Improved ecological status		**Improved social status**	**Improved economic status**		
Reduced impacts of pesticides	Improved biodiversity	Improved social interactions and knowledge transfer	Limit negative impacts of global trade	Improved consumer awareness of quality / value bee products	Improved hive management
Stricter regulation on pesticide use	Increased agricultural crop diversification, permanent grassland and pollinator friendly field hedges	Improved communication / cooperation between farmers and beekeepers	Minimum price regulations for EU bee products	Improved quality control of bee products (testing for adulteration and contaminants)	Increased use of hive monitoring technology
Increased use of alternatives to pesticides	Stricter hive movement controls to limit spread of disease and pests	Increased promotion of small-scale beekeeping		Improved labelling of bee products (origin and quality)	Improved education / training on hive management for beekeepers
	Stricter regulation on bee breed exchange	Increased effort to provide standard veterinary practices		Increased promotion of beekeeping as a valuable service, both environmentally and economically	
	Increased use of biological disease treatments by beekeepers	Improved education / training on marketing for beekeepers		Stricter regulations on beekeeper and beehive registrations	
		Improved transfer of scientific knowledge to beekeeping practice			
		Improved cooperation between beekeeping associations across Europe			

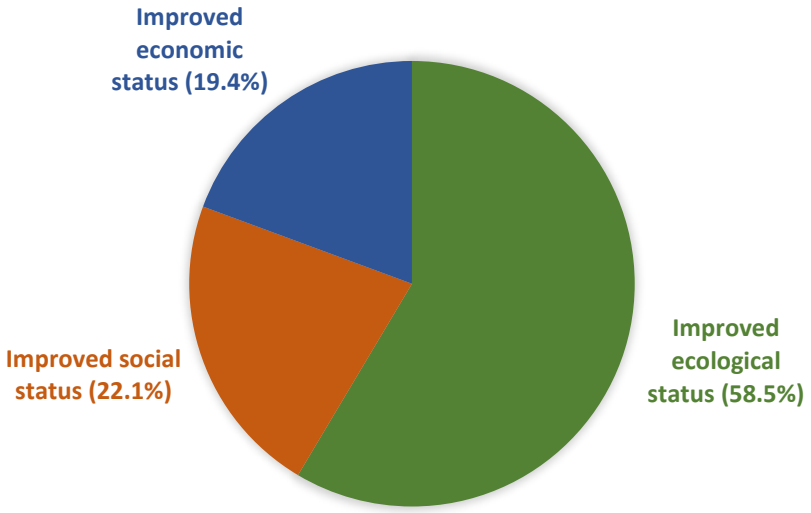
Figure 5. Viable measures for healthy and sustainable beekeeping management

In Figure 5, measures are split into 6 sub-objectives by B-GOOD researchers: reduced impacts of pesticides, improved biodiversity, improved social interactions and knowledge transfer, limit negative impacts of global trade, improved consumer awareness of quality / value bee products, and improved hive management. The 6 sub-objectives are the 'what' being preferences for objectives to become realised, and reflecting on what is more important to aim for. The statements underneath reflect the 'how' being preferences for concrete measures in terms of healthy and sustainable beekeeping management practices for reaching the overarching objectives.

Identified stakeholder preferences for healthy and sustainable beekeeping management

In this section, the outcomes of the survey assessing stakeholder perceptions on healthy and sustainable beekeeping management are presented. The following analysis is conducted on the 200-stakeholder subsample defined in methods section 2.2.3. This implies that each of the eight identified stakeholder groups is represented in the dataset for analysis by at least 25 cases. The core outcomes of relative preferences from the data analysis are presented below, for; 1) overall sustainability objectives, 2) measures contributing to the ecological objectives, 3) measures contributing to the social objectives and 4) measures contributing to the economic objectives. Figure 6 provides relative preferences for overall sustainability objectives for healthy and sustainable beekeeping management among stakeholders.

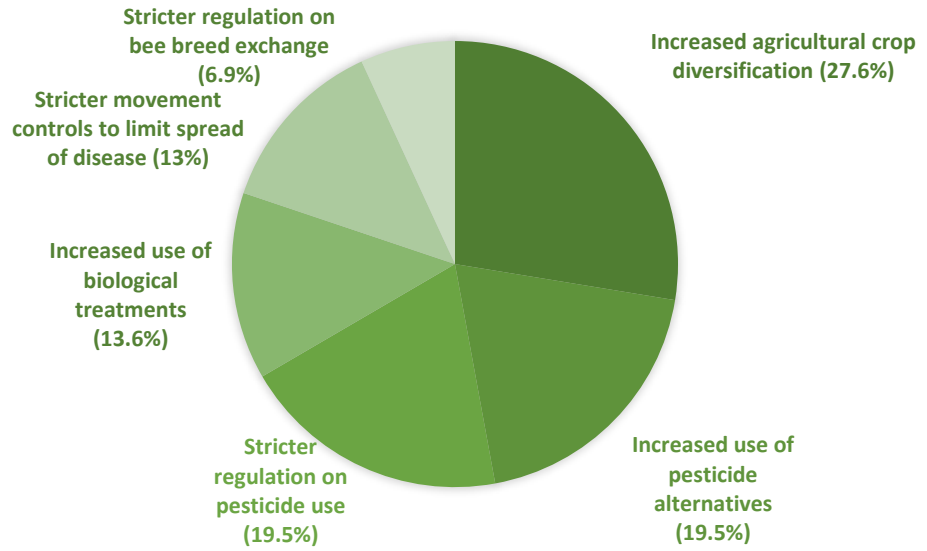
Figure 6. Relative preferences for overall health and sustainability objectives for the EU beekeeping sector.



As seen in Figure 6, stakeholders gave first priority to ecological objectives (58.5%), second priority to social objectives (22.1%) and third priority to economic objectives (19.4%) in their relative importance of these objectives for the EU beekeeping sector.

The relative preferences for measures to achieve health and sustainability objectives are presented in Figures 7 through 9. Starting with ecological objectives, Figure 7 shows relative preferences to achieve an improved ecological status of the EU beekeeping sector.

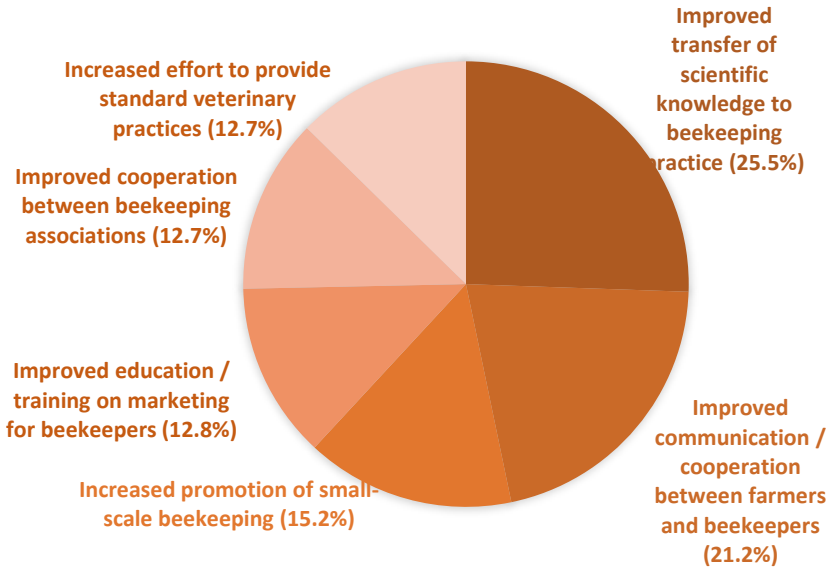
Figure 7. Relative preferences for how to achieve an improved ecological status of the EU beekeeping sector.



Within ecological objectives, stakeholders gave priority to increased agricultural crop diversification (27.6%), followed by increased use of pesticide alternatives and stricter regulation of pesticide use, which each received 19.5% of overall importance, followed by increased use of biological treatments (13.6%) and stricter movement controls to limit the spread of disease (13%). Stakeholders gave least preference to stricter regulation on bee breed exchange (6.9%).

Relative preferences to achieve an improved social status of the EU beekeeping sector are presented in Figure 8.

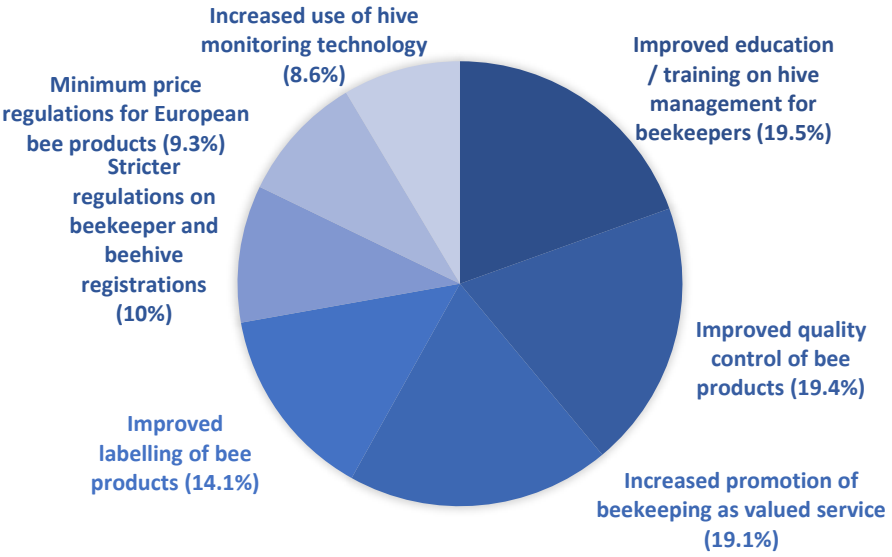
Figure 8. Relative preferences for how to achieve an improved social status of the EU beekeeping sector.



Within social objectives, stakeholders gave priority to improved transfer of scientific knowledge to beekeeping practice (25.5%), followed by improved communication / cooperation between farmers and beekeepers (21.2%), followed by increased promotion of small-scale beekeeping (15.2%), followed by improved education / training on marketing for beekeepers (12.8%). Improved cooperation between beekeeping associations and increased effort to provide standard veterinary practices both received the least amount of preference, both at around 12-13%.

Relative preferences to achieve an improved economic status of the EU beekeeping sector are presented in Figure 9.

Figure 9. Relative preferences for how to achieve an improved economic status of the EU beekeeping sector.



Within economic objectives, stakeholders gave similar priority to improved education / training on hive management for beekeepers (19.5%), improved quality control of bee products (19.4%), and increased promotion of beekeeping as valued service (19.1%), followed by improved labelling of bee products (14.1%), followed by stricter regulations on beekeeper and beehive registrations (10%), followed by minimum price regulations for European bee products (9.3%). Finally, the least amount of preference was for increased use of hive monitoring technology (8.6%).

Stakeholder preferences for measures to achieve improved ecological, social and economic objectives were consolidated to reflect preferences with respect to the overall health and sustainability objectives, based on the structure of the AHP hierarchies presented in section 3.2.2. Table 21 shows consolidated preferences for ways to achieve overall sustainability of the EU beekeeping sector, showing all three categories (ecological, social and economic) simultaneously.

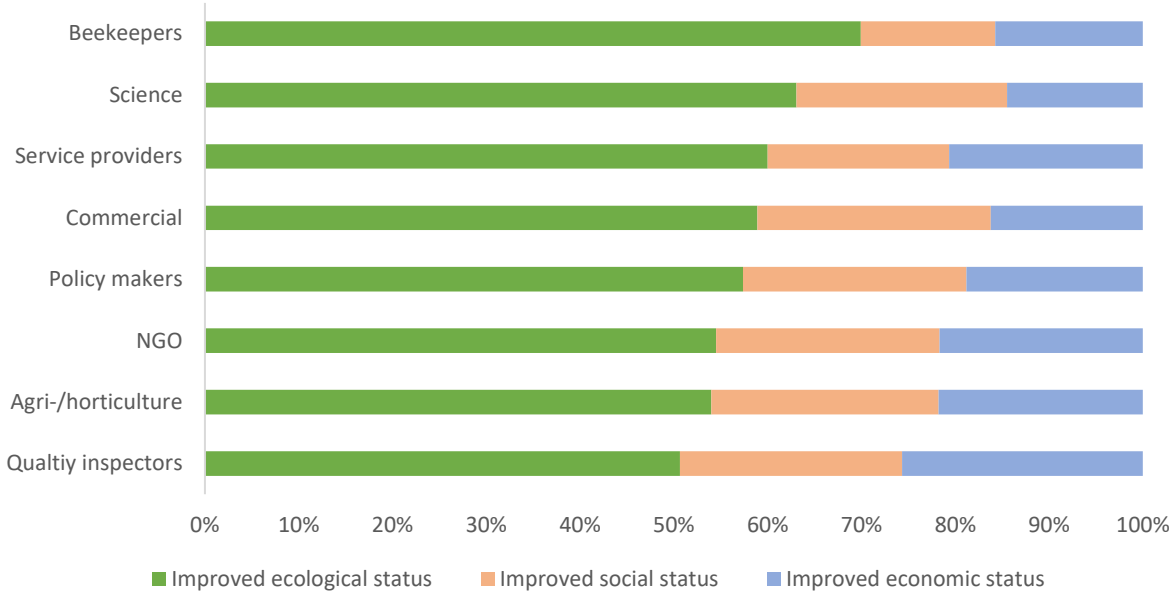
Table 21. Consolidated stakeholder preferences for viable measures to achieve overall sustainability objectives (green = improved ecological status, orange = improved social status, blue = improved economic status), ranked from highest to lowest priority.

Rank	Viable measures	Mean (%)
1	Increased agricultural crop diversification	16.14
2	Stricter regulation on pesticide use	11.87
3	Increased use of pesticide alternatives	11.61
4	Increased use of biological treatments	7.56
5	Stricter movement controls to limit spread of disease	7.41
6	Improved transfer of scientific knowledge to beekeeping practice	5.44
7	Improved communication / cooperation between farmers and beekeepers	4.44
8	Stricter regulation on bee breed exchange	3.95
9	Improved education/training on hive management for beekeepers	3.75
10	Increased promotion of beekeeping as valued service	3.74
11	Improved quality control of bee products	3.73
12	Increased promotion of small-scale beekeeping	3.54
13	Increased effort to provide standard veterinary practices	3.03
14	Improved education / training on marketing for beekeepers	2.97
15	Improved labelling of bee products	2.76
16	Improved cooperation between beekeeping associations	2.67
17	Stricter regulations on beekeeper and beehive registrations	1.94
18	Minimum price regulations for European bee products	1.76
19	Increased use of hive monitoring technology	1.69
	Total	100.00

Differences between stakeholder groups

The relative importance of overarching health and sustainability objectives across the different stakeholder groups are provided in Figure 10.

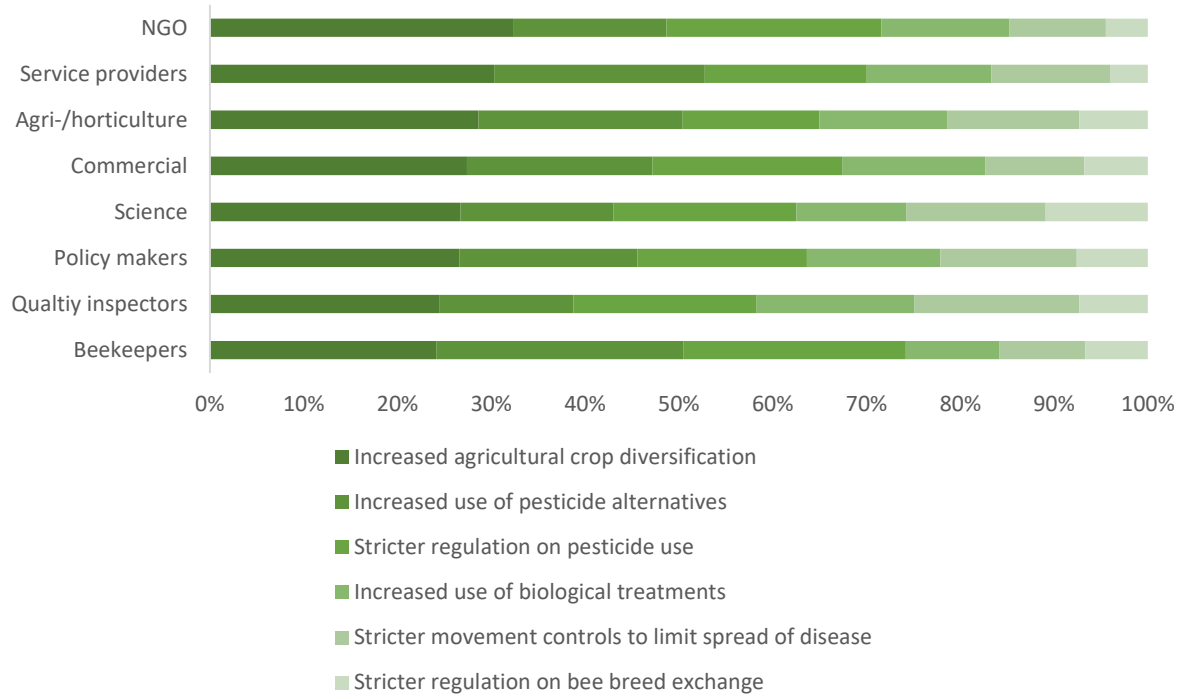
Figure 10. Stakeholder preferences identified for overarching health and sustainability objectives according to stakeholder group



Comparing the core objectives at the most general level; ecological objectives (green), social objectives (orange) and economic objectives (blue), all stakeholder groups gave priority to ecological objectives, with beekeepers rating this the highest. Relative preferences for the three sustainability objectives were compared between stakeholder groups using one-way ANOVA tests, and the observed differences were not statistically significant between stakeholder groups.

The relative preferences for viable measures to achieve ecological, social and economic objectives were also compared between stakeholder groups as presented in Figures 11 through 13. Starting with ecological objectives, Figure 11 shows the relative preferences for viable measures to achieve an improved ecological status per stakeholder group.

Figure 11. Relative preferences for viable measures to achieve an improved ecological status per stakeholder group

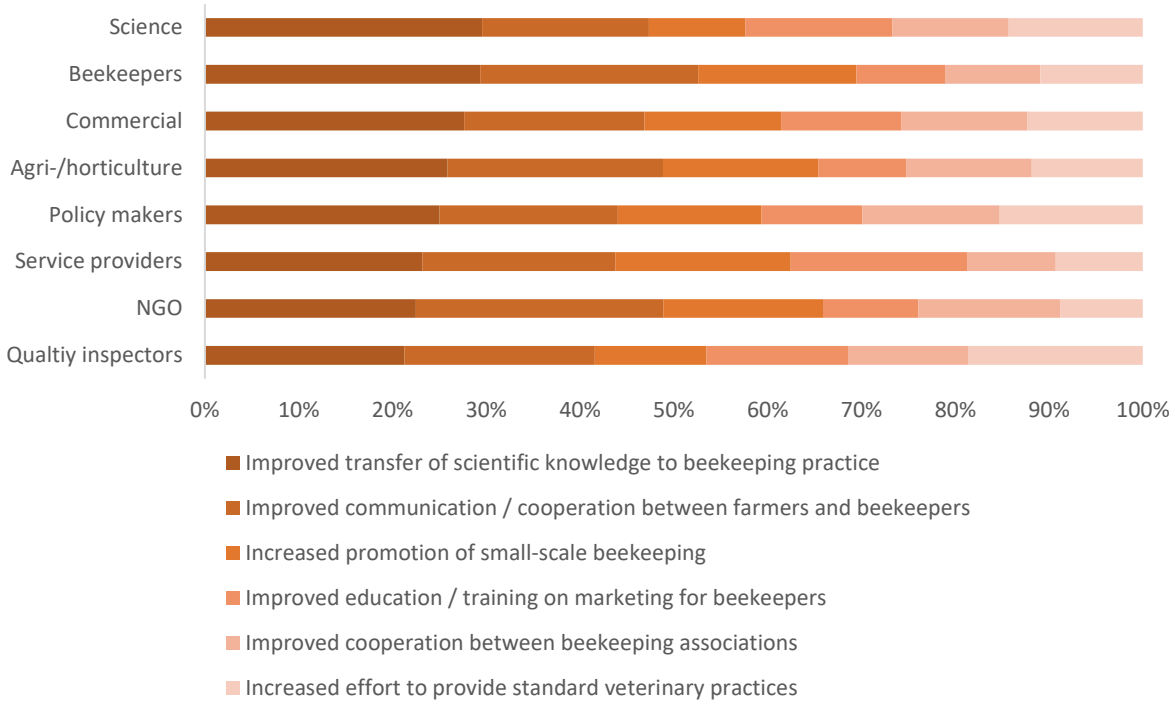


From Figure 11, we can observe that increased agricultural crop diversification was by average the highest preferred measure to achieve ecological objectives. The following three highest preferred measures relate to pesticide use and alternative to pesticides. One-way ANOVA F-tests were conducted to test differences between stakeholder groups for all six ecological measures, and we found statistical differences between the stakeholder groups for increased use of pesticide alternatives and stricter regulation on bee breed exchange. Regarding increased use of pesticide alternatives, Tukey post-hoc tests indicated that beekeepers had a significantly stronger preference for increased used of pesticide alternative than quality inspectors did. In a similar vein, scientists had a significantly stronger preference for stricter regulation on bee breed exchange than service providers and NGO representatives did.

Although no statistical differences were found between stakeholder groups for the other ecological measures, other notable differences can be observed from the graph, such as that NGO representatives showed the strongest preference for increased crop diversification, followed by service providers. Beekeepers, scientists, NGO representatives, and commercial stakeholders preferred stricter regulation on pesticide use more than other stakeholder groups, especially agri-/horticultural stakeholders who value stricter regulation on pesticide use the least.

For social objectives, Figure 12 shows the relative preferences for viable measures to improve the social status per stakeholder group.

Figure 12. Relative preferences for viable measures to improve social status per stakeholder group

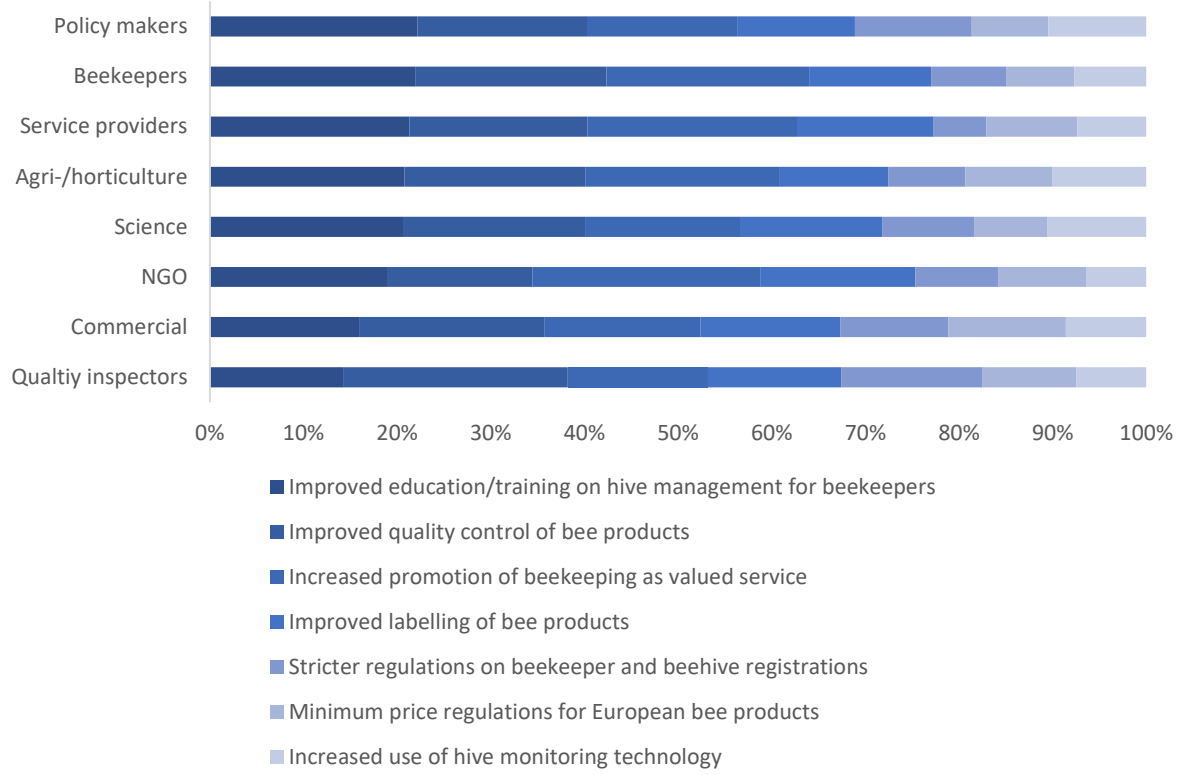


Within social objectives, improved transfer of scientific knowledge to beekeeping practice was by average the highest preferred way to achieve social objectives. One-way ANOVA F-tests and Tukey post-hoc tests were conducted to test differences between stakeholder groups for all six social measures. Significant differences were found for two measures. First, quality inspectors had a significantly stronger preference for increased efforts to provide standard veterinary practices as compared to NGO representatives and service providers (which also includes veterinarians). Second, service providers had a significantly stronger preference for improved education/training on marketing for beekeepers compared to agri-/horticultural actors, beekeepers themselves and NGO representatives.

In addition, some notable differences can be observed from the graph, such as that scientists, beekeepers, commercial stakeholders and agri-/horticultural stakeholders showed the strongest preference for improved transfer of scientific knowledge to beekeeping practice. Improved communication between farmers and beekeepers was preferred most by beekeepers and NGO representatives. Most stakeholder groups showed similar preference for improved cooperation between beekeeping associations, except for service providers and beekeepers who gave this less preference than the other stakeholder groups.

For economic objectives, Figure 13 shows the relative preferences for viable measures to improve the economic status per stakeholder group.

Figure 13. Relative preferences for viable measures to improve the economic status per stakeholder group



Within economic objectives, improved education / training on hive management for beekeepers and improved quality control of bee products were by average the two highest preferred ways to achieve economic objectives, both receiving an average preference of around 20%. One-way ANOVA tests were conducted to test differences between stakeholder groups for all seven economic measures, and we found statistical differences between the stakeholder groups for only one measure: stricter regulations on beekeeper and beehive registrations. For this measure, Tukey post-hoc tests showed that the preferences of quality inspectors were stronger than those of service providers.

Although no statistical differences were found between stakeholder groups for the other economic measures, some notable differences can be observed from the graph, such as that improved education / training on hive management for beekeepers was preferred most by policy makers, beekeepers, service providers, and agri-/horticulture stakeholders. Not surprisingly, quality inspectors showed the strongest preference for improved quality control of bee products.

Improved labelling of bee products was preferred most by NGO representatives, whereas agri-horticultural stakeholders, policy makers and beekeepers showed the least preference for improved labelling of bee products. Minimum price regulation for European bee products was preferred most by commercial stakeholders, quality inspectors and service providers, whereas it was not as preferred by scientists, policy makers or beekeepers. Finally, increased use of

hive monitoring technology was preferred most by scientists and agri-horticulture stakeholders, and least by NGO representatives.

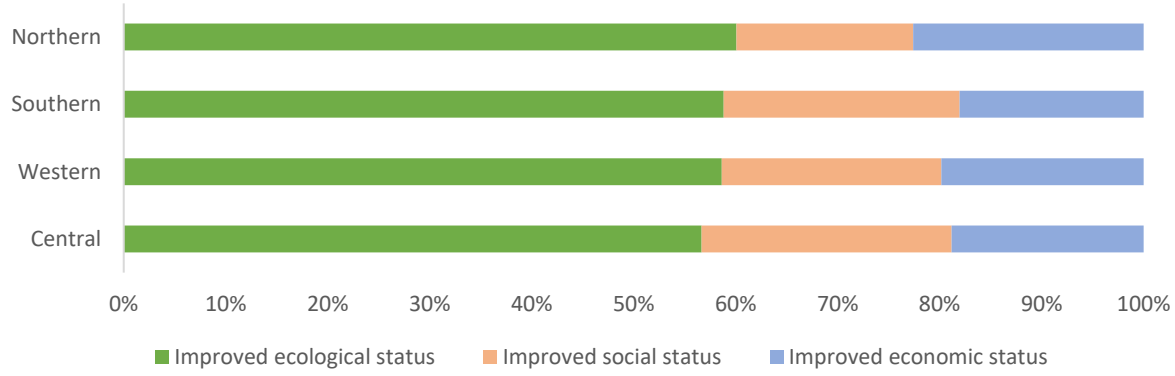
When comparing consolidated preferences (as reported in Table 21) across stakeholder groups, significant differences were found for three of the 19 measures following ANOVA F-test and Tukey post-hoc tests:

- Beekeepers have a stronger consolidated preference for increased use of alternatives to pesticides than quality inspectors, NGO representatives, scientists and policy makers.
- Scientists have a stronger consolidated preference for stricter controls on bee breed exchange than service providers, NGO representatives, agri-/horticultural actors and quality inspectors.
- Quality inspectors have a stronger consolidated preference for stricter regulations on beekeeper and beehive registrations than service providers and beekeepers themselves.

Differences between European regions and demographics

Preferences for overall health and sustainability objectives and viable measures to improve the ecological, social and economic status were compared between stakeholders depending on their European region (Western, Southern, Northers and Central). No statistically significant differences were found between the four regions when comparing preferences for the overall sustainability objectives. The relative importance of core health and sustainability objectives across stakeholder regions has been visualised in Figure 14.

Figure 14. Relative stakeholder preferences identified for health and sustainability objectives according to region.



Although there are only slight differences between regions, Figure 14 shows that stakeholders in Northern regions preferred economic objectives over social objectives, and stakeholders in Southern regions preferred social objectives over economic objectives.

Consolidated preferences for the 19 viable measures were compared between stakeholders depending on their region of provenance. Regarding differences between stakeholder regions for the six viable measures to reach ecological objectives, Tukey's tests revealed that the

consolidated preferences between stakeholder regions differed only on increased agricultural crop diversification, where Northern regions showed a higher preference for this measure than Southern and Central regions.

Regarding differences between stakeholder regions for the six viable measures to reach social objectives, there were no statistically significant difference between regions on any of the measures. Regarding differences between stakeholder regions for the seven viable measures to reach economic objectives, Tukey's tests revealed that the preferences between stakeholder regions differed only on improved labelling of bee products, where stakeholders in the Western region had less preference for this than stakeholders in Northern regions.

Independent samples t-tests were performed to test for differences in preferences for overall sustainability objectives and the consolidated preferences for the 19 viable measures to achieve healthy and sustainable beekeeping across gender (male vs. female) and education level (primary or secondary vs. tertiary). We found a significant difference between males and females for increased use of pesticide alternatives and stricter movement controls to limit spread of disease, where females had the stronger preference. We found a significant difference between stakeholders with primary or secondary vs. tertiary education for increased use of biological treatments and improved education/training on hive management for beekeepers, where those with tertiary education had a stronger preference. For improved education/training on marketing for beekeepers and stricter regulations on beekeeper and beehive registrations, those with primary or secondary had a stronger preference.

4. Conclusions

Honeybee colony health

1) Defining honeybee colony health

- The complexity of the multiple drivers and stressors affecting honeybee colony health is reiterated by stakeholders, as there were many different factors identified for what defines, determines or contributes to a healthy honeybee colony in both stakeholder samples (n=41 and n=504). The concept is clearly multifaceted according to stakeholders.

Interview sample:

- Within the interview sample we found that the more traditional definition being the "absence of disease" was the most mentioned definition of honeybee colony health. However, this traditional definition was mentioned more by stakeholders who had a closer proximity to the practical side of beekeeping, such as beekeepers, quality inspectors, service providers, and agri-/horticulture stakeholders.

Survey sample:

- Overall, four of the five factors included in the survey received an almost equally high weight in contributing to honeybee colony health. As observed in the interviews, stakeholders in the survey sample also gave high importance to the presence of absence of parasites and diseases in the hive, but equally so to the quality and diversity of natural resources in the environment, the presence or absence of contaminants in the natural environment and the beekeeper and his/her management of honeybees and hives. The only factor that stood out as being perceived as somewhat less important was colony characteristics.
- Beekeepers in the survey sample attributed environmental contaminants as an important factor for honeybee colony health, more so than by other stakeholder groups.
- Colony characteristics, such as colony size, queen, brood, and colony genetics was perceived to be of a lesser importance than the other factors by stakeholders in the survey sample. Scientists attributed the highest weight to this factor in shaping honeybee colony health.

2) Responsibility for honeybee health

Interview sample:

- The reasons why honeybee colonies die remains a complex interplay of multiple factors, however quality of nutrition/lack of floral resources and beekeeper practices emerged as the most frequently mentioned reasons for why colonies die among stakeholders in the interview sample.
- Regarding who should be responsible for honeybee health, beekeepers were regarded the most responsible among the interview sample, followed by individual Member States and the EU overall. Furthermore, there was no

mention of environmental organisations or agricultural organisations as those responsible for honeybee health.

3) How to improve honeybee health

Interview sample:

- As most stakeholders within the interview sample regard beekeepers as most responsible for honeybee colony health, it is not surprising that training for beekeepers was most suggested as a way to improve honeybee colony health.
- Collaboration with farmers was another frequently mentioned way to improve honeybee colony health in the interviews, indicating the importance and potential of partnerships between agricultural and beekeeping organisations.
- More research on honeybees was also mentioned as a way to improve honeybee colony health, but this was highlighted especially by policy makers though not so strongly by scientists.
- Stakeholders were overall more optimistic than doubtful about honeybee colony health in the future. Beekeepers varied the most in their opinion about honeybee colony health in the future, whereas scientists were optimistic about better research and research methods.

Business models for sustainable beekeeping

The interview section on beekeeping business models aimed to identify the complexity and key factors of the ecological, social, technological, economic and political environment in which beekeepers operate, to determine which factors have an influence on management decisions and business models of beekeepers. It also aimed to gather information on which aspects of healthy and sustainable beekeeping stakeholders value, to derive what might contribute to better management decisions, and what both beekeepers and policy should focus on in the future to improve the blueprint for what a healthy and sustainable beekeeping business model might look like.

1) Characterising the sector

Interview sample:

- Stakeholders within the interview sample recognised that hobby beekeeping is the most common type of beekeeping in Europe, however also emphasised that beekeeping for commercial purposes or second income may be an important reason to keep honeybees in Europe.
- Honey and pollination services emerged as the two main services that honeybees provide, and most stakeholders identify honeybees as being part of the livestock sector in specific instead of the agricultural sector more generally.

2) Better regulation

Interview sample:

- The need for better regulation was a common theme discussed by stakeholders in the interviews, affirmed by their confusion for which sector, livestock or agriculture in general, honeybees belong to.

- Stakeholders within the interview sample recognise that there is better regulation on bee medicines and agricultural chemicals and more scientific research on honeybees compared to the past, but were concerned about the European honey market and the quality of honey. As solutions for this, many stakeholders suggested more regulation on honey production and honey trade policies for price stabilisation, together with more training for beekeepers.

Survey sample:

- The top three ways to achieve overall sustainability objectives from the AHP analysis were 1) increased agricultural crop diversification, 2) stricter regulation on pesticide use and 3) increased use of pesticide alternatives, which all relate to improved ecological status.
- Improved transfer of scientific knowledge to beekeeping practice emerged as the highest preferred way to achieve social objectives.
- Improved education/training on hive management for beekeepers emerged as the highest preferred way to achieve economic objectives.

3) Climate change

Interview sample:

- Stakeholders within the interview sample believe that climate change will have more of a negative impact on European beekeeping than a positive one, naming concerns such as a harsher climate, fewer food resources, new and stronger diseases, and an alteration in the natural ecological cycle. Stakeholders in Northern countries were not as concerned about climate change than those in Southern countries. Some stakeholders mentioned possible advantages of climate change for beekeeping in Northern countries.

4) Pathways forward

Survey sample:

- The AHP analysis aimed to further define the pathways for healthy and sustainable beekeeping management in the EU, to pave the way towards the future identification of viable healthy and sustainable business models.
- Stakeholders clearly see an improvement in ecological status as the utmost important pathway towards a healthy and sustainable European beekeeping sector, much more than an improvement in social or economic statuses.
- Increased agricultural diversification emerged as the most preferred way to achieve healthy and sustainable of beekeeping in the EU.
- Pesticide regulation and the use of pesticide alternatives also emerged as highly preferred ways to achieve healthy and sustainable beekeeping in the EU.
- Other notable pathways that emerged from the AHP analysis within social objectives were improved transfer of scientific knowledge to beekeeping practice, and within economic objectives were improved education / training on hive management for beekeepers, and improved quality control of bee products, which parallels results from the stakeholder interviews.

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Appendices

Appendix 1. Topic guide for stakeholder interviews

TOPIC GUIDE

IN DEPTH INTERVIEWS WITH STAKEHOLDERS

Introduction
Introducing the researchers and explaining the purpose of the interview
Informed consent procedure
- Introduction: Explain the purpose of the interview: investigate the views and opinions of stakeholders about 1) beekeeping in the EU, 2) connections and relationships with other stakeholders, 3) what characterises a healthy bee colony and 4) current and future honey beekeeping models in the EU. Confidentiality is guaranteed: no names of persons, organisations or companies in the report. The conversation is audio-recorded and will be transcribed to facilitate reporting. Reporting: the executive summary of a report based the interviews will be distributed among the participants.

Interviewer notes: Prior to conducting this interview the participant should be sent an email with the study information and consent form and read the following.

Introduction script:

This interview will take approximately 2 hours to complete. In order to insure that all information will remain confidential, I will not record your name. I will only use a code for this interview when noting your answers.

Your name or any details that might identify you will not be published and transcripts of this call will be securely stored electronically. All personal information you provide will be kept confidential, anonymous and treated according to the EU regulations on personal data ownership.

Just to remind you, your participation is voluntary and you may refuse to participate at any time and do not need to give me a reason. You will not be paid for participating in this study and there will be no cost or risk for you to participate. If you would like a copy of the summary report for this study please let me know at the end of the interview and I will add your name to a list that I will maintain separately. If you have questions later about this study, please contact me at <insert interviewer phone number>.

Please can you confirm you have received and read the study information sheet and consent form. Consent form sent and received.

☐ Yes

I would like to record this interview. Do you agree to continue and participate in this study and that this interview is recorded?

☐ Yes ☐ No (if no terminate interview)

Do you have any questions about the project, or this conversation before we begin?

Participant consent needs to be obtained before conducting the interview. Two informed consent forms must be completed. The original is kept by the investigator for a period of 25 years, the copy is given to the participant.

Interviewee: ……. (name and institution)

Date: …….

Participant code: …….

Interviewer note: Respondent names should not be recorded here. Please use the spreadsheet provided to record respondent names against the codes provided e.g. T4.1_1a_x (predetermined numeric code)

Stakeholder biographical information
Interviewer note: Please insert as much biographical information as possible prior to the interview and confirm with interviewee, as necessary.
Suggested script: do you mind if I ask you a few questions about yourself?
1. Gender 2. Year of birth 3. Nationality 4. Marital status ☐ Single ☐ Married ☐ Divorced ☐ Widowed ☐ … 5. Do you have children?

6. Place of residence?

7. What is your profession?

8. What is your specialisation within the EU beekeeping sector?

9. How long have you been in this position?

10. What is your organisations interest in the beekeeping sector? What aspects are particularly important to your organisation?

Topic 1: SWOT facing the EU honey beekeeping sector

Getting to know stakeholder's views on the EU honey beekeeping sector

Suggested script: A first aim of our study is to get a view on the characteristics of the beekeeping sector in the European Union and those of the environment in which this sector operates. This task is also known as SWOT-analysis, which means that we will try to identify strengths, weaknesses, opportunities and threats.

1 What is an important internal characteristic of the EU honey beekeeping sector?

Interviewer note: May need to clarify internal characteristics.

Suggestion: By internal factors I mean are factors that the sector itself can change, improve. They constitute strengths, weaknesses, or neutral factors.

Can you tell me what you think are the main internal characteristics that are of interest / concern for your organisation?

Prompt if interviewee gets stuck: examples: organisation of the sector, quality and experience of beekeepers, quality of extension services, unified vs. dispersed, beekeeping facilities, image and reputation of beekeeping, marketing skills, research and development, profitability…

Is this a <u>strength</u>, <u>weakness</u> or neutrality?
Why do you believe so ?
Can this be generalised across the EU, or is it specific for certain regions, countries, types of beekeepers, …?

- What is another important characteristic of the EU honey beekeeping sector?

Repeat previous …

- What is another important characteristic of the EU honey beekeeping sector?

Repeat previous …
Continue until no additional internal characteristics are mentioned.

2 What is an external factor that influences the EU honey beekeeping sector?

Interviewer note: May need to clarify external characteristics.

Suggestion: By external factors I mean facts, trends or evolutions in the business environment that the beekeeping sector experiences, undergoes, notices, …, and that may require a response, reaction, … They constitute opportunities, threats or neutral factors.

Can you tell me what you think are the main external characteristics that are of interest / concern for your organisation?

Prompt if interviewee gets stuck: examples: e.g. economic forces, political forces, social forces, structural forces, natural environment, technological and scientific environment, trends and evolutions among suppliers and customers to/from the beekeeping sector…

Is this a <u>opportunity</u>, <u>threat</u> or neutrality?
Why do you believe so ?
Can this be generalised across the EU, or is it specific for certain regions, countries, types of beekeepers, …?

- What is another external factor that influences the EU honey beekeeping sector?

Repeat previous …

- What is another external factor that influences the EU honey beekeeping sector?

Repeat previous …

Continue until no additional internal characteristics are mentioned.

Topic 2: Transfer of knowledge and information about honey bee health

Gaining insight into the knowledge networks that exist between stakeholders, especially concerning honey bee health. Gaining insights into connections within and outside of the EU Bee Partnership.

Suggested script: I would now like to talk to you about your connections within and outside of the EU Bee Partnership.

1 In the past year, did you turn to other members of the EU Bee Partnership (see the list) for **technical advice** about specific problems relating to honey bee health (such as varroa, pesticides, inadequate nutrition, pathogens, etc.)?

Interviewer note: technical advice/knowledge here is defined as technical support to solve problems.

1a If so, can you provide names for all those you have contacted, and the organisation they work for? Probe to list all contacts they can think of. (Should be no more than 12)

1b For all of the people you just mentioned, can you indicate the three people you have had the most contact with?

Interviewer note: Record the order and the names of the three most contacted people and ask following questions for each of these named people. If they can only name one or two, record this.

Name 1: …….
Name 2: …….
Name 3: …….

Repeat three times for names 1 2 and 3

1c How often have you been in contact with *(name)* in the last year? 1= very occasionally (once in last year); 2 = occasionally (every 6 months); 3 = frequent (every month); 4 = very frequent (weekly)

1d How did you contact them? 1 = meetings in person; 2 = conference in person; 3 = by email; 4 = by telephone; 5 = other (please note)

1e What technical knowledge did you discuss / exchange?

1f Concerning technical knowledge about honey bee health, did you give information, receive information, or both?

2 In the past year, did you turn to anyone outside the EU Bee Partnership for **technical advice** about specific problems relating to honey bee health (such as varroa, pesticides, inadequate nutrition, pathogens, etc.)?

Interviewer note: technical advice/knowledge here is defined as technical support to solve problems.

2a If so, can you provide names for **all** those you have contacted, and the organisation they work for? Probe to list all contacts they can think of

Interviewer note: Record the order and all names given.

2b For all of the people you just mentioned, can you indicate the four people you have had the most contact with?

We intend to contact these people for an interview. Could you provide their contact details?

Interviewer note: Record the order, names, and contact details of the three most contacted people and ask following questions for each of these named people. If they can only name one or two, record this.

Name 1: ……. Email: …….
Name 2: ……. Email: …….
Name 3: ……. Email: …….
Name 4: ……. Email: …….

Repeat three times for names 1, 2, 3 and 4

2c How often have you been in contact with *(name)* in the last year? 1= very occasionally (once in last year); 2 = occasionally (every 6 months); 3 = frequent (every month); 4 = very frequent (weekly)

2d How did you contact them? 1 = meetings in person; 2 = conference in person; 3 = by email; 4 = by telephone; 5 = other (please note)

2e What technical knowledge did you discuss / exchange?

2f Concerning technical knowledge about honey bee health, did you give information, receive information, or both?

2g For each of these 4 names how influential would you rate them?
1 = not influential; 2 = somewhat influential; 3 = very influential

2h How much do you trust the technical advice you give or receive? 1 = do not trust at all; 2 = somewhat trust; 3 = fully trust

Topic 3: Healthy bee colony
Gaining insight into opinions on what characterises a healthy honey bee colony, a dead honey bee colony, and honey bee health in the future.
Suggested script: I would now like to talk to you honey bee health.
1 How would you define a healthy honey bee colony? **2** In your opinion, what are the most relevant characteristics of a healthy honey bee colony? Why? **3** Why do you think honey bee colonies die? In your opinion, what are the most relevant factors that can make a bee colony sick? Why? **4** How do you envision honey bee health in the future? Why? **5** Who do you think should be responsible for honey bee health? Is it mostly the responsibility of individual member stakes or the European Union? Why? **6** In your opinion, what are feasible steps to improve honey bee health in the future?

Topic 4: Current and future beekeeping practices
Gaining views on current beekeeping practices and potential for beekeeping practice innovation and sustainability. Mapping of the complexity of the business environment and identification of the key attention points for strategy development.
Suggested script: I would now like to talk to you about honey bee keeping practices in Europe.
1 Why do you think people keep honey bees? **2** In your opinion, what are the most common honey beekeeping practice types in Europe? *Interviewer note: honey beekeeping practices can be range from fully professional to hobbyist, from small to large scale, from rural to urban environments, and from businesses with predominantly economic to integrated social and ecological objectives.* *Examples of honey beekeeping practices:* *Sheer enjoyment of keeping bees (amateur beekeepers)* *Honey production or pollination services (farmer/beekeeper)* *Earning a living (professional beekeepers)* *Education and extension purposes* **3** What are the services honey bees provide? Why are these services of interest to your organisation? **4** In Europe, how do honey bees fit into the supply chain/institutional environment? E.g. are bees part of the livestock sector, agricultural sector, or other sector? How is the institutional environmental structured? Where are bees placed in the value chain? **5** Do you think that the honey beekeeping sector in Europe has changed in the past 10 years? How? **6** How have policies and regulation changes influenced the honey beekeeping sector? In what ways?

7 What kind of policies should be developed in order to protect honey bee health in Europe? Do you thing this responds also to regional challenges in the beekeeping sector? Why?

8 Do you think climate change has had an impact on honey beekeeping? How so?

9 What impact will climate change have in the future?

10 How has the economy surrounding honey beekeeping changed?

11 How do you think the economy surrounding beekeeping will change in the future?

Appendix 2. Stakeholder questionnaire: master English version

WP4 – Task 4.1 – Questionnaire for Stakeholders

Introduction
Dear participant, Thank you for agreeing 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 15 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 the participant will be shared. The data provided will be analysed in an anonymous way and the results of the survey will be shared 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

Informed consent

1) 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

2) I agree to participate in the study
   Yes/No

3) 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
   Yes/No

Section 1: Demographics

What is your age (years)?	
What is your place of residence (country) ?	
What is your nationality?	Same as country of residence Other, please specify _____

In which stakeholder group do you / your professional activities in relation to beekeeping **primarily** fit?	Science	In which scientific field of research do you best fit? 1. Natural sciences 2. Social sciences 3. Technical/Technological sciences 4. Arts and Humanities 5. Other, please specify _____
	Service provision to beekeepers	Which category best describes your services? 1. Veterinary services 2. Beekeeping equipment maintenance provision 3. Training and extension services 4. Other, please specify _____
	Beekeeping	Which beekeeper type do you best represent? 1. Hobbyist beekeepers 2. Professional beekeepers 3. Other, please specify _____
	Quality inspection	Which type of inspection best describes your activities? 1. Honey adulteration inspection 2. Honey chemical residue inspection 2. Bee hive inspection

		3. Other, please specify _____
	Policy making	At which level are you most active? 1. Regional 2. National 3. International 4. Other, please specify _____
	Agriculture, horticulture, and their suppliers	Which sector do you best represent? 1. Conventional agriculture 2. Organic agriculture 3. Horticulture 4. Seed producers 5. Plant breeding 6. Fertilizer producers 7. Supplying other to agriculture or horticulture, please specify _____
	Non-governmental organisation (NGO)	Which sector interests does your NGO most represent? 1. Environmental 2. Social 3. Economic 4. Other, please specify _____
	Commercial or industrial activities related to beekeeping	Which industry do you best represent? 1. Honey packers and distributors

		2. Manufacture and sales of beekeeping equipment 3. Other, please specify _____
In case you / your professional activities in relation to beekeeping may fit in more than one stakeholder category, please also indicate your secondary stakeholder type	1) Science 2) Service provision to beekeepers 3) Beekeeping 4) Quality inspection 5) Policy making 6) Agriculture, horticulture and their suppliers 7) Non-governmental organisation (NGO) 8) Commercial or industrial activities related to beekeeping 9) Other, please specify _____ 10) **Not applicable**	

What is your gender?

Male	Female	Non-binary / third gender	Prefer not to say
1	2	3	4

What is your education level?

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

Section 2: Sustainability objectives (Soma et al., 2018)

In what follows, we present you several pairs of options that might contribute to more healthy and sustainable beekeeping in the EU.

In the following comparisons, please indicate which option is more important (relative to each other) and how much more important on a scale 1 to 9, for more healthy and sustainable beekeeping in the European Union (EU). If you think both options are equally important, you must still select one option, and then indicate “Equal” above the number 1.

(1 = equally important, 9 = much more important)

Improved ecological status: Allows EU beekeeping to become more environmentally sustainable by improving factors such as biodiversity, floral recourse availability, and climate change.

Improved social status: Allows EU beekeeping to become more socially sustainable by improving factors such as social equity, liveability, community development, and quality of life.

Improved economic status: Allows EU beekeeping to become more economically sustainable by improving factors such as economic growth, profit, production and related improvements in technology.

1	**A or B?**		**Equal**	**How much more?**						
	Improved ecological status	**Improved social status**	1	2	3	4	5	6	7	8	9
2	**A or B?**		**Equal**	**How much more?**						
	Improved ecological status	**Improved economic status**	1	2	3	4	5	6	7	8	9
3	**A or B?**		**Equal**	**How much more?**						
	Improved economic status	**Improved social status**	1	2	3	4	5	6	7	8	9

Section 3: Improved ecological status

In what follows, we present you several pairs of options for **improved ecological status** of the EU beekeeping sector.

In the following comparisons, please indicate which option is more important (relative to each other) and how much more important on a scale 1 to 9, for **improved ecological status** of the EU beekeeping sector?

(1 = equally important, 9 = much more important)

1	**A or B?**		**Equal**	**How much more?**						
	Stricter regulation on pesticide use	**Increased use of alternatives to pesticides**	1	2	3	4	5	6	7	8	9
2	**A or B?**		**Equal**	**How much more?**						
	Stricter regulation on pesticide use	**Increased agricultural crop diversification, permanent grassland and pollinator friendly field hedges**	1	2	3	4	5	6	7	8	9
3	**A or B?**		**Equal**	**How much more?**						

	Stricter regulation on pesticide use	**Stricter movement controls to limit spread of disease and pests**	1	2	3	4	5	6	7	8	9
4	**A or B?**		**Equal**						**How much more?**		
	Stricter regulation on pesticide use	**Stricter regulation on bee breed exchange**	1	2	3	4	5	6	7	8	9
5	**A or B?**		**Equal**						**How much more?**		
	Stricter regulation on pesticide use	**Increased use of biological treatments by beekeepers**	1	2	3	4	5	6	7	8	9
6	**A or B?**		**Equal**						**How much more?**		
	Increased use of alternatives to pesticides	**Increased agricultural crop diversification, permanent grassland and pollinator friendly field hedges**	1	2	3	4	5	6	7	8	9
7	**A or B?**		**Equal**						**How much more?**		
	Increased use of alternatives to pesticides	**Stricter movement controls to limit spread of disease and pests**	1	2	3	4	5	6	7	8	9
8	**A or B?**		**Equal**						**How much more?**		
	Increased use of alternatives to pesticides	**Stricter regulation on bee breed exchange**	1	2	3	4	5	6	7	8	9
9	**A or B?**		**Equal**						**How much more?**		
	Increased use of alternatives to pesticides	**Increased use of biological treatments by beekeepers**	1	2	3	4	5	6	7	8	9
10	**A or B?**		**Equal**						**How much more?**		
	Increased agricultural crop diversification,	**Stricter movement controls to limit**	1	2	3	4	5	6	7	8	9

	permanent grassland and pollinator friendly field hedges	**spread of disease and pests**									
11	**A or B?**		**Equal**	**How much more?**							
	Increased agricultural crop diversification, permanent grassland and pollinator friendly field hedges	**Stricter regulation on bee breed exchange**	1	2	3	4	5	6	7	8	9
12	**A or B?**		**Equal**	**How much more?**							
	Increased agricultural crop diversification, permanent grassland and pollinator friendly field hedges	**Increased use of biological treatments by beekeepers**	1	2	3	4	5	6	7	8	9
13	**A or B?**		**Equal**	**How much more?**							
	Stricter movement controls to limit spread of disease and pests	**Stricter regulation on bee breed exchange**	1	2	3	4	5	6	7	8	9
14	**A or B?**		**Equal**	**How much more?**							
	Stricter movement controls to limit spread of disease and pests	**Increased use of biological treatments by beekeepers**	1	2	3	4	5	6	7	8	9
15	**A or B?**		**Equal**	**How much more?**							
	Stricter regulation on bee breed exchange	**Increased use of biological treatments by beekeepers**	1	2	3	4	5	6	7	8	9

Section 4: Improved social status

In what follows, we present you several pairs of options for **improved social status** of the EU beekeeping sector.

In the following comparisons, please indicate which option is more important (relative to each other) and how much more important on a scale 1 to 9, for **improved social status** of the EU beekeeping sector?

(1 = equally important, 9 = much more important)

1	**A or B?**		**Equal**	**How much more?**						
	Improved communication / cooperation between farmers and beekeepers	**Increased promotion of small-scale beekeeping**	1	2	3	4	5	6	7	8	9
2	**A or B?**		**Equal**	**How much more?**						
	Improved communication / cooperation between farmers and beekeepers	**Increased effort to provide standard veterinary practices**	1	2	3	4	5	6	7	8	9
3	**A or B?**		**Equal**	**How much more?**						
	Improved communication / cooperation between farmers and beekeepers	**Improved education / training on marketing for beekeepers**	1	2	3	4	5	6	7	8	9
4	**A or B?**		**Equal**	**How much more?**						
	Improved communication / cooperation between farmers and beekeepers	**Improved transfer of scientific knowledge to beekeeping practice**	1	2	3	4	5	6	7	8	9
5	**A or B?**		**Equal**	**How much more?**						
	Improved communication / cooperation between farmers and beekeepers	**Improved cooperation between beekeeping associations across Europe**	1	2	3	4	5	6	7	8	9
6	**A or B?**		**Equal**	**How much more?**						
	Increased promotion of small-scale beekeeping	**Increased effort to provide standard veterinary practices**	1	2	3	4	5	6	7	8	9

7	**A or B?**		**Equal**	**How much more?**							
	Increased promotion of small-scale beekeeping	**Improved education / training on marketing for beekeepers**	1	2	3	4	5	6	7	8	9
8	**A or B?**		**Equal**	**How much more?**							
	Increased promotion of small-scale beekeeping	**Improved transfer of scientific knowledge to beekeeping practice**	1	2	3	4	5	6	7	8	9
9	**A or B?**		**Equal**	**How much more?**							
	Increased promotion of small-scale beekeeping	**Improved cooperation between beekeeping associations across Europe**	1	2	3	4	5	6	7	8	9
10	**A or B?**		**Equal**	**How much more?**							
	Increased effort to provide standard veterinary practices	**Improved education / training on marketing for beekeepers**	1	2	3	4	5	6	7	8	9
11	**A or B?**		**Equal**	**How much more?**							
	Increased effort to provide standard veterinary practices	**Improved transfer of scientific knowledge to beekeeping practice**	1	2	3	4	5	6	7	8	9
12	**A or B?**		**Equal**	**How much more?**							
	Increased effort to provide standard veterinary practices	**Improved cooperation between beekeeping associations across Europe**	1	2	3	4	5	6	7	8	9
13	**A or B?**		**Equal**	**How much more?**							
	Improved education / training on	**Improved transfer of scientific**	1	2	3	4	5	6	7	8	9

	marketing for beekeepers	**knowledge to beekeeping practice**									
14	**A or B?**		**Equal**	**How much more?**							
	Improved education / training on marketing for beekeepers	**Improved cooperation between beekeeping associations across Europe**	1	2	3	4	5	6	7	8	9
15	**A or B?**		**Equal**	**How much more?**							
	Improved transfer of scientific knowledge to beekeeping practice	**Improved cooperation between beekeeping associations across Europe**	1	2	3	4	5	6	7	8	9

Section 5: Improved economic status

In what follows, we present you several pairs of options for **improved economic status** of the EU beekeeping sector.

In the following comparisons, please indicate which option is more important (relative to each other) and how much more important on a scale 1 to 9, for **improved economic status** of the EU beekeeping sector?

(1 = equally important, 9 = much more important)

1	**A or B?**		**Equal**	**How much more?**							
	Minimum price regulations for European bee products	**Improved quality control of bee products (testing for adulteration & contaminants)**	1	2	3	4	5	6	7	8	9
2	**A or B?**		**Equal**	**How much more?**							
	Minimum price regulations for European bee products	**Improved labelling of bee products (origin and quality)**	1	2	3	4	5	6	7	8	9
3	**A or B?**		**Equal**	**How much more?**							
	Minimum price regulations for	**Increased promotion of**	1	2	3	4	5	6	7	8	9

	European bee products	**beekeeping as valued service, both environmentally and economically**									
4	**A or B?**		**Equal**	**How much more?**							
	Minimum price regulations for European bee products	**Stricter regulations on beekeeper and beehive registrations**	1	2	3	4	5	6	7	8	9
5	**A or B?**		**Equal**	**How much more?**							
	Minimum price regulations for European bee products	**Increased use of hive monitoring technology**	1	2	3	4	5	6	7	8	9
6	**A or B?**		**Equal**	**How much more?**							
	Minimum price regulations for European bee products	**Improved education / training on hive management for beekeepers**	1	2	3	4	5	6	7	8	9
7	**A or B?**		**Equal**	**How much more?**							
	Improved quality control of bee products (testing for adulteration & contaminants)	**Improved labelling of bee products (origin and quality)**	1	2	3	4	5	6	7	8	9
8	**A or B?**		**Equal**	**How much more?**							
	Improved quality control of bee products (testing for adulteration & contaminants)	**Increased promotion of beekeeping as valued service, both environmentally and economically**	1	2	3	4	5	6	7	8	9
9	**A or B?**		**Equal**	**How much more?**							
	Improved quality control of bee products (testing for adulteration & contaminants)	**Stricter regulations on beekeeper and beehive registrations**	1	2	3	4	5	6	7	8	9

10	**A or B?**		**Equal**	**How much more?**							
	Improved quality control of bee products (testing for adulteration & contaminants)	**Increased use of hive monitoring technology**	1	2	3	4	5	6	7	8	9
11	**A or B?**		**Equal**	**How much more?**							
	Improved quality control of bee products (testing for adulteration & contaminants)	**Improved education / training on hive management for beekeepers**	1	2	3	4	5	6	7	8	9
12	**A or B?**		**Equal**	**How much more?**							
	Improved labelling of bee products (origin and quality)	**Increased promotion of beekeeping as valued service, both environmentally and economically**	1	2	3	4	5	6	7	8	9
13	**A or B?**		**Equal**	**How much more?**							
	Improved labelling of bee products (origin and quality)	**Stricter regulations on beekeeper and beehive registrations**	1	2	3	4	5	6	7	8	9
14	**A or B?**		**Equal**	**How much more?**							
	Improved labelling of bee products (origin and quality)	**Increased use of hive monitoring technology**	1	2	3	4	5	6	7	8	9
15	**A or B?**		**Equal**	**How much more?**							
	Improved labelling of bee products (origin and quality)	**Improved education / training on hive management for beekeepers**	1	2	3	4	5	6	7	8	9
16	**A or B?**		**Equal**	**How much more?**							
	Increased promotion of beekeeping as valued service, both environmentally and economically	**Stricter regulations on beekeeper and beehive registrations**	1	2	3	4	5	6	7	8	9

17	**A or B?**		**Equal**	**How much more?**							
	Increased promotion of beekeeping as valued service, both environmentally and economically	**Increased use of hive monitoring technology**	1	2	3	4	5	6	7	8	9
18	**A or B?**		**Equal**	**How much more?**							
	Increased promotion of beekeeping as valued service, both environmentally and economically	**Improved education / training on hive management for beekeepers**	1	2	3	4	5	6	7	8	9
19	**A or B?**		**Equal**	**How much more?**							
	Stricter regulations on beekeeper and beehive registrations	**Increased use of hive monitoring technology**	1	2	3	4	5	6	7	8	9
20	**A or B?**		**Equal**	**How much more?**							
	Stricter regulations on beekeeper and beehive registrations	**Improved education / training on hive management for beekeepers**	1	2	3	4	5	6	7	8	9
21	**A or B?**		**Equal**	**How much more?**							
	Increased use of hive monitoring technology	**Improved education / training on hive management for beekeepers**	1	2	3	4	5	6	7	8	9

Section 6: Honeybee health

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 items 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**

→ If respondent assigns equal importance to each of the 5 items, display question:
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

Section 7: Hive monitoring technology

1 Please indicate to what extent you agree with the following **benefits** of the adoption of hive monitoring technology by beekeepers in the EU. Adopting hive monitoring technology would help …

	Totally disagree	Disagree	Neither agree nor disagree	Agree	Totally agree
beekeepers to save time					
beekeepers to save costs					
beekeepers to manage their colonies more easily					

beekeepers to decrease colony loss					
beekeepers to become more connected with one another					
beekeeping to become more sustainable					
beekeepers to better monitor the health of their colonies					
scientists to interact better with the beekeeping community					
scientists to better set research priorities					
policy makers to make more effective policy decisions					

2 Please indicate that what extent you agree with the following **concerns** related to the adoption of hive monitoring technology by beekeepers in the EU. Adopting hive monitoring technology would …

	Totally disagree	**Disagree**	**Neither agree nor …**	**Agree**	**Totally agree**
not be affordable for all beekeepers in Europe					
put the privacy of beekeepers' data at risk					

not be feasible due to the regulatory landscape i.e. inconsistent policies between different countries or regions or lack of subsidies					
not be feasible due to technological anxiety by beekeepers i.e. beekeepers using traditional methods					
not be feasible due to lack of training for beekeepers					

Appendix 3: Justification for selection of viable measures for sustainable beekeeping management

Statement	Hypothesis	Interview source	Literature source
Stricter regulation on pesticide use	Current pesticide use is causing insect declines. Pesticide can be restrained by stricter regulations.	01: We should be a lot more effective at the member state level, especially the member states that where civil society is not very developed. You know, like Romania, for example, you know, huge problems with pesticides, but completely underdeveloped civil society to do anything about it. 03: We have seen improvements over the last 10 years, much more it's a scrutiny being applied and it's continuing. There's much more knowledge being gathered at scientific level, which is always a good news if it leads to some substances being banned. 03_2: You just relying on a succession of flowering plants in the wider landscape? You know that that is going to be a challenge. And of course, there are also, you know, the chemicals that they encounter within their environment and pesticides are, you know, part of that. 05_01: Pesticides for example are the most relevant or one of the most relevant to the cause of bee diseases and bee mortality.	Honey bees and other pollinating insects are seriously threatened by very serious environmental factors of anthropic origin. These are mainly chemical pollution, especially due to massive and widespread use of pesticides (Fontana et al., 2018; Porrini et al., 2003; Tosi et al., 2018). Agro-chemical use considered significant cause of insect declines (Jones, 2004; Francisco Sánchez-Bayo & Wyckhuys, 2019). Regulation of pesticides have been debated at a global level, e.g. in relation to disparities (regulation in developed / developing countries) and need for harmonisation (Handford et al., 2015). The incorporation of a more holistic approach in pesticide risk assessment would be useful to take into account the impacts of multiple stressors when formulating appropriate regulations (EFSA, 2016).
Increased use of pesticide alternatives	Conventional pesticides can be toxic for bees, and alternatives to pesticides can offer more environmentally friendly pest-management.	10: There's something else happening with the toxicity of a particular insecticide. But that's handled through the pesticide legislation. But more relevant is, in my opinion, the lack of habitat which could be driven by herbicides. And 40 percent of all pesticide use are herbicides. Under the Green Deal, then, then I would expect there is a huge push for alternatives to pesticides. A huge push for sustainable agriculture. Alternatives to pesticides are crucial.	Non-chemical alternatives for plant pest and disease prevention and control such as crop rotation and use of biological control have been proposed to ensure the sustainability of beekeeping (EIP-AGRI, 2019). Alternative pest control methods in agricultural such as natural chemical compounds, biological control, weeding, and genetically improved plant varieties offer alternatives to neonicotinoids, however as farmers struggle economically,

			alternative methods may be less reliable (Jactel et al., 2019).
Increased agricultural crop diversification, permanent grassland and pollinator friendly field hedges	Increased measures to promote biodiversity within agricultural landscape benefits pollinator species.	11_1: In some places the landscapes simplified to increase the production of crops. No edges, no forests anymore no bushes, no side plants on the margins of the fields. Those things have a big impact as well as the large use of pesticides. And then this goes with the Common Agricultural Policy to increase small parcels instead of big monocultures... to increase the amount of plant diversity and things like that. 03_2: Seventy percent of the landscape of the UK is farmed. So, you know, farmers also have an interest in managing the countryside in a way that supports biodiversity and supports wildlife and that includes bees. 03_3_1: But we can produce intensely, but also marginally, organise the botanical landscape to bring the resource to all the pollen consumers who are the origin of other food chains, especially in small birds and other insects. 04: Colonies containing more varroa mites and placed in highly fragmented landscape with substantial amounts monocultural crops specially maze, have lower survival probability. 05_02: I think the intensive agricultural use of wide areas of our landscape, this affects beekeeping and in a very strong way. 03: The cropping landscape gets more and more monotonous for many crops. That leads to a situation that over large areas there is not much forage for the bees or over large part of the year. 11: I think a considerable part of the landscape should really be managed more for the natural resources. The	Future protection strategies should prioritise promotion of policies aimed at minimising habitat loss and making agricultural landscapes 'bee-friendly' (Fontana et al., 2018). The sum availability of flower resources within the landscape can, therefore, have a substantial effect on colony size and productivity (EFSA, 2016). A main threat to honeybees in the agricultural landscape is the monoculture model without agri-environmental measures, like flower strips or other similar measures (EIP-AGRI, 2019). Public-private partnerships such as management of public green spaces directly can benefiting pollinators. In particular in places where competent authorities adopt more ecologically-sound management practices, roadsides can hold are markable biodiversity. (Underwood et al., 2017).

		greening of the landscape. Well the small landscape elements and the margins and so on.	
Stricter movement controls to limit spread of disease and pests	Diseases and pests can very easily spread throughout bee populations, since bees often intermix with different hives, which poses a threat to honey bee health and beekeepers' livelihoods.	03_2: If something breaks down within your hives in terms of bee health, then you put at risk all of the hives around you because your bees will interact with other hives, bees or the hives will come in if you've got a weak colony that will come in and rob out your hives. Colonies interact and they will spread disease and pests so you're part of a national herd and with that comes responsibility. 05_1: [A key issue related to globalisation] is the spread of the disease is spread of the diseases all over the world , as we saw about varroa, about Nesemaceranae , about Aethinatumida.	The new EU Animal Health Law adopted in April 2019, provides the legal framework for essential elements such as general definitions and principles for disease control measures and movements, however honeybees are not explicitly covered in this (Commision, 2016). The desire to facilitate cross-border honeybee trade should be diminished, and more funds should become available for the control of disease, technical assistance, applied research, and honey analysis (Jones, 2004).
Stricter regulation on bee breed exchange	There is a need for conservation of local breeds that are better suited to their local environments and therefore more resilient to pests and diseases.	03_2: Honeybees are they are domesticated. And, you know, they have been bred over thousands of years by people into strains that I guess are a fairly robust as well as delivering good levels of honey crop. But they're pretty kind of robust and resistant. And that's been done across all sorts of geographic and climatic zones. And because people are managing them. People do breed them to you know, they do go through generations of queens and they will breed them to kind of locally adapt. They will select out the ones that do better in their local climatic situation 07_2_4: With bees there's exchanges between them, bees from hobbyists breed with bees from professionals and there is almost no control over that and [this is] a weakness for me. 22: Because there are, for example also programs to breed specific bee races which are more resistant against Varroa.	The increasing transport of bees outside their relative areas of origin, as well as the increasing use of commercial cross-breed honey bees by beekeepers, poses a great threat to the biodiversity of A. mellifera and makes the adoption of restrictive guidelines urgently needed, given that if stabilisation is postponed the situation could soon be no longer recoverable (De la Rúa et al., 2009; Fontana et al., 2018; Meixner et al., 2010). Techniques for queen breeding has contributed to compromising the conservation of the native subspecies of A. mellifera (Lodesani & Costa, 2003). Large-scale replication of the genetic heritage of a limited number of individuals today plays a negative role in conserving a large gene pool within the various indigenous sub-species (Fontana et al., 2018).

Increased use of biological disease treatments by beekeepers	Increased use of biological treatments as opposed to artificial chemicals might improve bee health as well as product quality and safety.	05_2: And then when it comes to the diseases and disease treatment, we need a lot of research too. To better understand what is going on and to develop better technologies of reducing diseases. Breeding is a very effective tool. Nevertheless, breeding is not well-developed in all the countries. They are looking for alternative methods. I see a growing interest in the more nature conform treatment of disease issues. So strengthen bee health by appropriate management techniques. 05: Beekeepers, because this is one of the weaknesses, is that they don't know the effects of the chemical treatment on their own livestock. In my opinion, all chemical treatments that we do in the colonies, they cover the problem and they reduce the new system because it's chemical. Then if we improve this and we are absolutely sure if everybody everybody's doing organic treatments on bees from the other side you have the environment. It seems that the chemical treatment, it's more easy for them. Organic treatment can be efficient, but it needs a little bit more effort. So easiness and less manpower comes with the chemicals, the synthetic chemicals. 07_3: Yes they want to use some biological or organic treatment to control the mites… But when you read really the scientific paper , it doesn't work but they tell them to use it.	Natural medicines such as formic acid, oxalic acid, thymol and menthol have recently been beneficial as alternative treatments against the honey bee parasitic mite varroa (Gunes et al., 2017). The varroa mite should be continuously (monthly) managed within honey bee colonies using mechanical methods or treatment with essential oils (mainly thymol) and others also. In severe cases, and especially during the fall and not during honey seasons, the use of chemical materials can be done with preference to oxalic or formic acid (Devi et al., 2019).
Improved communication / cooperation between farmers and beekeepers	Farmed landscape provide key resources for beekeeping, but limited exchange between farmers and beekeepers hinders effective use of these. In many cases, farmers and beekeepers have similar interests and could be more efficient if they joined forces.	07: In some regions of France they are trying to work together because the beekeepers were unhappy, because the farmer was using pesticides, et cetera. And the farmer was not happy because he could not use pesticides. They came together and they have agreed on for instance, do not use pesticides before	Communication and cooperation between beekeepers, farmers and their advisors are the most effective way to protect the bee health. When growers and beekeepers are aware of each other's locations, concerns and management practices they can avoid causing exposure to pesticides to honeybee

		five o'clock in the morning. Do not do use it during the night. And on the other side, the farmers agreed to put some trees around their lands. Trees with flowers so that they can't have pollen for the bees. And that is, it come back to always the same story. You must dialogue with the people. 07_3: For the pesticides I'm working with the farmers . I say some pesticides in some place… And every year we don´t a lot of pesticides and not exactly what all the people in the media say then , we have not a lot of pesticides , but we are working with the farmers to help them to have the same use or the same quantity of money , at least that same time to reduce the effects on the environment . [collaboration with farmers and beekeepers] it's more common, but it's not enough common.	colonies and foraging bees (EIP-AGRI, 2019). Farmers who are informed about the importance of pollination and pollinators to fruit quality are more likely to take up measures to benefit pollinator populations and reduce pesticide impacts (Underwood et al., 2017). Many beekeepers sell colonies, rear queen bees and provide pollination services to farmers (Rivera-Gomis et al., 2019), and veterinary products used by farmers for livestock have also been implicated in poisoning of bees (EFSA, 2016). Although many farmers keep track of the pesticides used for their farming activities, it is very difficult to retrieve the information for all the different crops that are grown (EFSA, 2016).
Increased promotion of small-scale beekeeping	Large scale beekeeping creates greater pressure in resource availability and disease infection rates, both between managed colonies and wild populations of bees and other pollinators.	03_3_2: I think the average beekeeper in Germany has like seven to eight colonies. So it's really, really small scale. Well, to me, I think this is good because of course the level of professionalism is, well, not that high, but if you if you compare, you know, if I'm like an average beekeeper, I have like six or seven colonies. The time I spend on these six or seven colonies, when I compare it to like 70 is ten times higher. I can spend ten times more time on my colonies, take care of them when compared to having like 70 colonies. 04: I'm not sure that by being a professional beekeeper, you automatically are always better than a so-called amateur or so-called hobby beekeeper. Or if big scale is always better than small scale...You know, you can be you can be a small scale professional beekeeper, as	In several cases large scale can be detrimental to bee health and promotion of smaller more sustainable apiaries could help hinder bee mortality and stress (Cilia, 2019). Beekeeping operations are more sustainable if they have adaptive capacity, which depends on the flexibility of their management practices, on the ability of the beekeeper to learn, and on the diversity of the system (Kouchner et al., 2019).

		you can be a large scale hobby beekeeper. 09: For maybe smaller scale beekeepers, the fact that there is so much, uh, knowledge now about the importance of keeping bees and people are really happy when they meet a beekeeper, it's a social economical aspect. The fact that it's very easy to sell honey locally at a good price when you're a small scale beekeeper.	
Increased effort to provide standard veterinary practices	Coordinated and standardised veterinary practices can help bee health by providing appropriate treatments and diagnosis for all beekeepers.	07_1: The waiting period is going to be left to the interpretation of the veterinarian. But since most beekeepers don't even use medication or go directly to the pharmacist to get their medication, there is no supervision. Once again, regulations will have an impact or beekeepers will not report anything. They're going to do everything on their own to avoid being controlled. Or they will market drugs for which there is no framework, no health safety. 03_1_1: We think subsidised treatment for varroa would have a huge effect on bee health. And there's two reasons that have an effect. One is because you would be treating all the colonies. But the second is you would know for all the colonies where because as soon as she put a subsidy up against it, everybody would register to get the subsidy.	Honeybee veterinarians are already being formed and coordinated at different levels in some countries (Formato et al., 2010; Smith et al., 2008). EU level standardisation seems to be lacking in veterinarian practices regarding honeybees (Iatridou et al., 2019). Bees are still viewed as an exotic species for veterinarian practice, a standardisation of veterinarian specialised education and bee health support systems like those that exist for other animal related industries would bring higher standards for bee health and beekeeping (Formato et al., 2010; Smith et al., 2008).
Improved education / training on marketing for beekeepers	Providing ease of access to quality education and training for beekeepers on marketing can help to promote European beekeeping as a valued service.	03_03_02: We are clearly lacking in this kind of thing. Basically, its marketing. They need to know the basics of marketing to sell your honey appropriately. 05_2: And I think there is a good chance for the local producers was Europe, to extend their production and still find good marketing situation. If they can easily compete with imported honeys.	There was no compulsory training for beekeepers prior to starting beekeeping activity in any of the EU countries. However, in Portugal and Romania some training was compulsory during beekeeping activity (Chauzat et al., 2013). Extension services are great guarantors of the labour, organisational, and marketing skills necessary to block beekeeper management mistakes and

		35: I think beekeepers are less good at marketing their product and could do a lot more to encourage people to buy their product over the supermarket honey.	sector threats (Novelli et al., 2021).
Improved transfer of scientific knowledge to beekeeping practice	Improving the flow of information and improving beekeepers' access to scientific knowledge can help beekeepers to understand how management practices can help improve colony loss better, and in turn help scientists complement their research with beekeepers´ empirical and traditional knowledge.	03_3: So in order to improve honeybee health, then there needs to be more collaboration between associations. The technology needs to reach beekeepers. There needs to be more research on like parasites and pathogens. And then this also needs to be more accessible by beekeepers 42: In between universities and beekeepers' association to have an interface (…) there is a real need for education and more practical sessions on beekeeping, and also to learn beekeepers about the biology of bees and the behaviour of bees 03_03_2: So if there are new results from research, from scientific sources, they need to be available for all the beekeepers in time. So, yeah, I guess this is this is this is quite essential.	Practicing a certain aspect under supervision of an experienced and well-educated tutor, and being able to fall back on a trustworthy person when questions arise, is the best way to change methods and beliefs in beekeeping (Ernst et al., 2020). Through their regular observation of the activity of bees, traditional beekeepers have elaborated an extensive knowledge of local climate variability and change as part of their traditional ecological knowledge, which is acquired and transferred through generations. They could play a prominent role in monitoring the incidence of global change on local biodiversity, in places where this incidence is insufficiently assessed by the scientific community (Lehébel-Péron et al., 2016).
Improved cooperation between beekeeping associations across Europe	As the beekeeping community in Europe is currently fragmented, improving cooperation between beekeeping associations across Europe can help to identify and share common goals and challenges.	03_1_1 And I mentioned knowledge exchange. I think knowledge exchange is a new concept to be farmers and to be people throughout Europe. And I think knowledge exchange would be a hugely beneficial route for all beekeepers and bee farmers to go down. 05_2 Would like to see the support for bringing people together. Meetings, exchange between beekeepers, Beekeepers Association and extensionists and scientists, so the whole network. And there are also some technical things which should be supported.	We understand, thus, the relevance of collective organisations (beekeeping associations) mainly relating to the viability of initiatives that individually have a more difficult path to success (Lengler et al., 2011). The official figures on beekeepers and honeybee colony populations were underestimated at the European level. This underreporting made difficult to ensure correct health surveillance (Chauzat et al., 2013).
Minimum price regulation for EU bee products	Fixing commodity prices for European beekeepers could help reduce competition from imported honey and could therefore strengthen beekeepers' livelihoods.	01: [The EU beekeeping sector] doesn't really have a long tradition of, you know, doing lobbying and stuff like that, it's basically and completely underfunded.	Beekeepers in the EU face an extremely volatile honey market due to a surge of cheap imported honey from outside of the EU such as China and Mexico (Copa-

		38: I think it's a big pressure from imported cheap honey. Which is difficult to compete with. And that has meant that the Danish honey market has collapsed more or less 11_2: There are possibly some [economic] problems with honeys of lower quality or not real honey from countries, and that can be a threat to the honey market. 31: The value of honey in the market is a value that depends very much on the external market... it is a factor... it is not in the European Union... it depends a lot on what is the capacity or not to import from other markets and therefore the value and consequently the income is very dependent on the fluctuation of the external community market. 22: In my opinion there is no not enough control on EU level on alteration. I mean, they have initiated this program, this food fraud program some years ago. They have also made some attempts on the honey market within. But finally, there was not a clear outcome , which is a pity in my opinion. 25: The beekeeper, which might have been able to produce very good uni-floral, special honeys. And they have more difficulties now into in producing this uni-floral honeys which can be sold, sold at high prices. So it will be not a uni-floral honey anymore but just a flower honey , which it's not as high priced as a uni-floral honey for the market . So they will have less profit.	Cogeca, 2020; Jones, 2004; Rossi, 2017). European honey producers have been struggling after production plummeted in 2019 and the price of honey did not rise accordingly. The drop in production was instead compensated by an increase in cheap imports (Copa-Cogeca, 2020). Threats such as the need to maintain, at any cost, competitiveness over other supplier shave caused many of the problems and difficulties that beekeeping faces today. The pressure of competitiveness It can lead to desperate measures such as the treatment of bees with aggressive and inappropriate pharmaceutical products and the reduction of biodiversity in an area or region (Jones, 2004). The proposed Common Food Policy could help the EU beekeeping sector in a number of ways including guaranteeing income for beekeepers by fixing commodity prices, by increasing measures in food quality and safety, by blocking the usage of harmful pesticides and fertilisers, and by implementing measures to increase biodiversity (IPES-Food, 2019).
Improved quality control of bee products (testing for adulteration and contaminants)	Contaminants in honey and honey adulteration put the image of apiary products at risk, which therefore threatens the social and economic viability of beekeepers in Europe	25: We do the quality control for almost all honeys, also imported honey. And I can see that if you get a honey from India or Vietnam or some South American country , you find more	Honey ranks as the third “favourite” food target for adulteration, ranking only behind milk and olive oil (García, 2018).

		residues and contaminants than in honey, than usually in the honeys from the EU. 05: Quality control is not sufficient and that is why we face the problems of adulteration… illegal importations and things like that. And if Danish honey, it's better because I know it's good. I have friends in Denmark and if you say that my honey is good, that I want to sell it, for example, with this and this and this label for 15 euros a kilo. And then from Argentina, that is a new profession with three euros per kilo or one point six. 06: There is a major threat from adulteration of apiary products; not only honey, but all kinds of apiary products suffer from this threat; this has a major impact on prices of apiary products, which is problematic for the authentic and genuine products 09: For instance, when we went, when we detect when we detect honey with antibiotics coming from third countries, the EU immediately bans the import for X months. It was the case with the Brazilian honey a few years ago. No more Brazilian honey enter the EU for six months, I think that's a great punishment. And then they have to be much more careful. And that should be the case with also adulteration of honey.	In the long term, honey adulteration could lead to reduced consumer confidence which could decrease authentic honey sales and shrink the beekeeping industry (Song et al., 2020). Honey adulteration is too common and there are not enough controls, regulation or testing against adulterated honey (Jones, 2004; Thrasyvoulou et al., 2018). The European Union expresses its concern that contaminated bee wax imported from China can often cause health issues for bees (Erdős, 2017).
Improved labelling of bee products (origin and quality)	Appropriate and honest honey labelling is a way to protect consumer confidence in EU honey and therefore protect the livelihood of beekeepers in Europe.	04: You have a slash for non-EU origin (made in EU/non-EU origin). And this this gives you no indication of what where this honey actually come comes from. The problem is, there is an issue with the labelling that does not really allow the quality to distinguish itself from the from the not so good quality in need. In some case, I think it's I think in some cases it's actually not even real, honey.	The decline of bee populations, the progressive increase of imported honey with lower prices and lower-quality has prompted honey adulteration through incorrect labelling of origin and fraudulent admixing with lower quality honeys or with sugar syrups (Soares et al., 2017). The European Professional Beekeepers Association asks for the 'blend of EU and non-EU honeys'

		22: I think this discussion on the EU level to properly label the origin and not labelling EU, non-EU but labelling really the origin saying it's Argentine honey or Chinese honey or whatever . So the consumer has the possibility to decide because I mean EU, non-EU 31: The problems that make this labelling a threat are, let us say, European regulations that are very flexible in terms of not identifying the origin of the product, honey in particular. That is clearly a threat to beekeepers themselves at European level. There is then unfair competition associated with the external market and imports and the lack of more functional regulations ... which will protect beekeepers in Europe more.	descriptor on labels to be replaced by an indication of exactly which country or countries the honey used in the final product come from (Association, 2020). It seems that some honey importers do not want to disclose the origin of the product especially when it is imported from third countries. A lack of harmonised honey labelling increase unfair competition, misleading consumers about honey quality and commercial barriers and obstacles in honey trading (Thrasyvoulou et al., 2018). The adopted Regulation No 2017/625 on checks and penalties related to marketing rules in the EU food industry contains measures on the use of labelling which could help to fight adulteration (Commision, 2017; Różański, 2018).
Increased use of hive monitoring technology	Beekeeper's use of hive monitoring technology can help reduce management mistakes thus reducing bee mortality and disease susceptibility. The widespread use of monitoring technology would also promote information exchange between beekeepers and between beekeepers and scientists.	06_1: Well, there has been talks about smart hives and so on and so forth and remote technology since quite a few years. And gain it is as mixed as possible. I go back again nothing is easy about beekeeping. Because what we have learned is that there there's a number of sensors you can put in and around the hive and then some of them are quite soon covered by propolis by the bees and so on and so forth. They cease to function and so forth. So I have some high hopes and faith in this technology , but still we'd like to see them actually working in and around the hive. 03_1_1: We are very happy for money to be spent on [hive monitoring technology]. I think it's an opportunity, but I do think that you have to bear in mind that an awful lot of bee farmers throughout the whole of the UK are digitally challenged. 06: Digitisation provides opportunities, especially for	Hive monitoring technologies have been and are being developed and perfected, minimising the need for manual hive inspection even if the hives are placed in rural areas or forests (Zacepins et al., 2017). Ease of access to these technologies would improve production and bee health due to less intrusive and more precise inspections to the hives, permitting beekeepers opening the hives less times and still keep records and inspections regularly, thus having a less stressful impact on bees and providing more precise decision making options for management choices (Edwards-Murphy et al., 2016). The interconnectedness of applications and data sharing can also provide important platforms for knowledge exchange between beekeepers themselves and between

		the hobbyist beekeepers who can benefit from digital monitoring and limit the need for interventions.	beekeepers and scientists (Neville, 2015).
Improved education / training on hive management for beekeepers	Providing ease of access to quality education and training on beekeeping management, medicine use etc. can reduce colony losses substantially.	05_1: It's a big problem of even education of beekeepers , you know. They don't know and it's I think it's not 100 . It's not only their fault because if no one tell them what to do , how to do that , they are really abandon and think it's even responsibility of veterinarians. 11_1: So everybody wants to have honeybees at home or on the roof of the buildings. And you most of the times they are not trained at all those people. And this is where the problems start. So it's more the training is should be focused on the hobby beekeepers and also on new beekeepers. The one that wants to start beekeeping activity. And they shouldn't start a beekeeping activity without the correct training. 12: I think there are studies which show that the training and professional education of beekeepers is indeed a factor correlated with, positive situation regarding to colony survival of the respective beekeepers. 36: That's very important. I think education. Little bit more education for beekeepers so they know how to manage and not too complex because the managing bee colonies in itself is already pretty difficult and disease management is even more technical sometimes. And beekeepers generally don't want difficult solutions. 03_3_2: Beekeeping club and a some of them, they are doing great, but some of them they are doing, yeah, really bad. And so this is a huge variance in education and it's reflected also by, yeah, the loss of colonies in the end. So that means that	Education level of beekeepers in terms of beekeeping formation seems to be highly correlated with bee mortality. More efforts are needed in beekeeper training to promote good beekeeping practices and achieve early identification of clinical signs of disease. (Jacques et al., 2017). Training for beekeepers is compulsory only in Portugal and Romania. In five countries, (Portugal, Hungary, Romania, Slovakia and Spain) beekeepers need to receive approval by a competent authority before starting the beekeeping activity (Sperandio et al., 2019).

		uneducated or beekeepers that are not organised also and then maybe trained themselves, by, by YouTube videos and not even literature, but just keeping bees and trying you know. And yeah, most of the time you see there that they will face some problems.	
Increased promotion of beekeeping as a valuable service, both environmentally and economically	Promoting beekeeping as a valued service can help the public to understand the importance of this practice, and hence advocate support for beekeepers.	03_2: And the whole piece of increasing awareness around bees means that, you know, increasingly those people that use pesticides, farmers and growers, you know, are more aware of the risks to bees 43: Developing and establishing strategy for the most important beekeeping related challenges and problems such as, bee fraud, increase awareness of importance of bees as pollinators, bee problems related to pesticide use and the use of bee products for food and health, particularly 03_1_1: It's growing together with the people's awareness on the capacities of the bees for food, for beauty or other and in medicine	The ecosystem services that honeybee pollination provides has a relatively high financial value (Vrabcová & Hájek, 2020). In general, the value of honeybees and beekeeping to agricultural production is under-appreciated and probably hugely undervalued. The value of honeybees and beekeeping to agricultural productivity needs to be assessed regularly (perhaps once every five years) in all countries where beekeeping and pure honey production is important (Kevan et al., 2007).
Stricter regulations on beekeeper and beehive registrations	Currently in Europe, beekeeper registration is compulsory in only 20 countries, with only 15 having a centralised national database. Improving requirements for beekeeper registrations would give relevant indications on the need for renewal of honeybee livestock in each European country, and improve the ability to conduct research.	36 One thing is legislation on importation of queens and foreign stock. I think we should limit this. We should very much control the actually did genetic build-up of colonies and people drag the colonies around too much 03_1_1 Reliable registration and subsidised varroa treatment.	The industry would be served if beekeeping registration was uniformly implemented across member states (Chauzat et al., 2013). We can only speculate about the coverage of the beekeeper national registration systems, and the way of data collection differs (Brodschneider et al., 2019).

Appendix 4. Ethics approval letter—Stakeholder interviews

FACULTEIT PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN

ETHISCHE COMMISSIE

Wim Verbeke

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Secretary of the Ethischal Commission

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DATUM
17 januari 2020

ONS KENMERK
2019/122/Wim Verbeke

The Ethical Commission gives approval for the following research project:

B-GOOD stakeholder interviews on healthy and sustainable beekeeping in the EU (WP4 – Task 4.1 – Study 1)

Researcher: Wim Verbeke

T. Marchant
(Voorzitter)

G. Roets
(Secretaris)

UNIVERSITEIT GENT

Appendix 5. Ethics approval letter—Stakeholder survey

FACULTEIT PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN

ETHISCHE COMMISSIE

Dana Freshley

Griet Roets
Secretaris van de Ethische Commissie

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T 09 264 62 93

DATUM
24 december 2020

ONS KENMERK
2020/126 Dana Freshley

De Ethische Commissie verleent gunstig advies aan het project:

B-GOOD stakeholder perceptions in sustainable beekeeping management (WP4 -Task 4.1 - Study 2)

Onderzoeker: Wim Verbeke

T. Marchant
(Voorzitter)

G. Roets
(Secretaris)

UNIVERSITEIT GENT