B-GOOD

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GIVING BEEKEEPING GUIDANCE BY COMPUTATIONAL-ASSISTED DECISION MAKING

# LEGACY BOOKLET

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

# A WORD BY THE COORDINATOR

Over the past 4.5 years, the B-GOOD project has given us the opportunity to develop a new perspective for the beekeeping sector in Europe. The use of advanced technologies was herewith not avoided. While this new perspective initially looked very futuristic and perhaps even daring, it has now become really concrete and we notice a growing enthusiasm among the actors in the beekeeping sector. Central themes herein are healthy and sustainable beekeeping. Healthy and sustainable beekeeping means an end to the over-treatment of our bee colonies and letting us guide by the health status of the individual colony. The hive monitoring systems are a crucial chain in this. Healthy and sustainable beekeeping also involves the genetic ability to cope with stressors that bees are exposed to through protective traits and genetic diversity. In B-GOOD, we have helped pave the way for marker-assisted selection. The project has also contributed to the virtual world of dynamic landscapes and the digital twin of the honey bee colony, in particular the ApisRAM model. Risk assessment will soon look completely different and will rely on these novel tools. Finally, the project has nicely mapped out the socio-economic aspects of the sector. The legacy of B-GOOD cannot be underestimated. I am proud that I was able to be part of this.

***Prof. dr. Dirk de Graaf***

B-GOOD coordinator

# PROJECT OVERVIEW

## Project coordinator

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## Duration

June 2019 - November 2023

## Project outcomes

- B-GOOD publications
- Special issue
- Practice abstracts
- B-GOOD Project Outcomes Collection in the Research Ideas and Outcomes (RIO) Journal

## Background

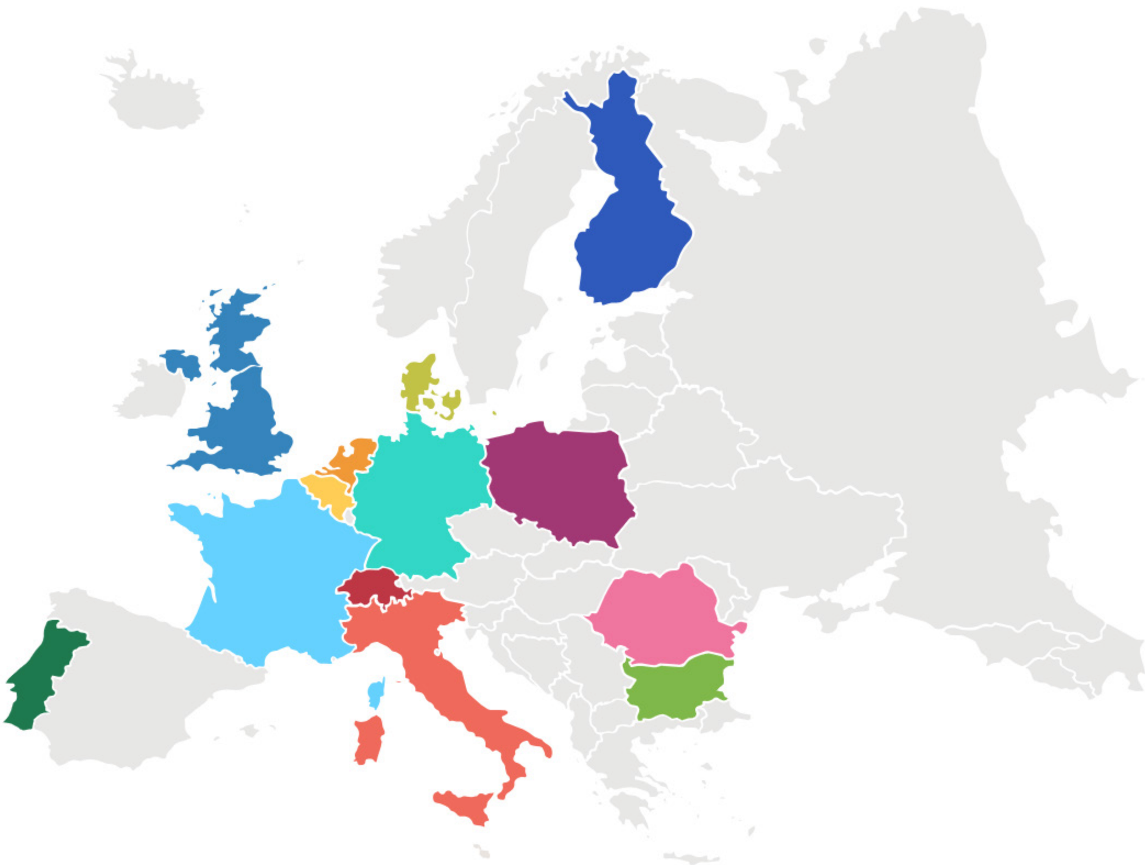
B-GOOD paved the way towards healthy and sustainable beekeeping within the European Union by following a collaborative and interdisciplinary approach. Merging data from within and around beehives as well as wider socioeconomic conditions, B-GOOD developed and tested innovative tools to perform risk assessments according to the Health Status Index (HSI). The work of the project was completed within a series of interlinked work packages, focused on different aspects needed to advance beekeeping knowledge, methods and tools etc. The unique tools developed under B-GOOD included:

- honeybee vibrations-based accelerometers to produce long-term statistics;
- gas and spatially resolved temperature measurements;
- automated bee counters (hive mortality rates, pollen flow, drone/worker discrimination);
- sensors to detect pesticide residues;
- devices to detect honeybee viruses of high health relevance;
- analytical tool for genetic imprint.

## Partners

- Ghent University;
  Sciensano
- Pensoft Publishers
- Aarhus University
- Finnish Beekeepers Association SML
- French National Research Institute for Agriculture, Food and Environment (INRAE)
- Friedrich-Loeffler-Institute;
  Martin Luther University of Halle-Wittenberg
- BeeSources
- Stichting BEEP;
  Stichting Wageningen Research
- Jagiellonian University
- University of Coimbra
- University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca
- University of Bern;
  SCIPROM
- Nottingham Trent University

## Partners map



# CONTENT

# WORK PACKAGES

# WP1 Beekeeping and Health Indicators

## 1 Develop detailed scenarios/protocols for end-users to ensure harmonisation of data and sample collection during and after the project

In the B-GOOD project, we developed detailed work plans and protocols for the beekeepers in the project to be used to collect classical data and coordinate beekeeping activities. Such work plans and protocols ensure harmonisation of data and sample collection. After the project, these documents can be used by beekeepers and scientists to collect data in a similar fashion, to increase standardisation of data collection further and allow for data analyses across projects.

## 2 Facilitate and standardise large-scale data collection on honeybee health indicators across the EU, preferentially in an automated or semi-automated way integrated with the EU Bee Partnership

A broad unique data set was collected on Honeybee Health indicators across the EU in a 3-tiered approach (Figure 1.1), using our work plan and protocols. Data collected consisted of classical measurements as well as making use of automated sensors. For the automated sensors, we collected 4.7 Million data points over 3 years in Tier 1 (8 countries, 64 colonies), 3.9 Million data points over 2 years in Tier 2 (5 countries, 40 beekeepers, 120 colonies), and 3.9 Million data points over 1 year in Tier 3 (12 countries, 58 beekeepers, 174 colonies) (Figure 1.2). After the project, these data will be integrated with the EU Bee Partnership.

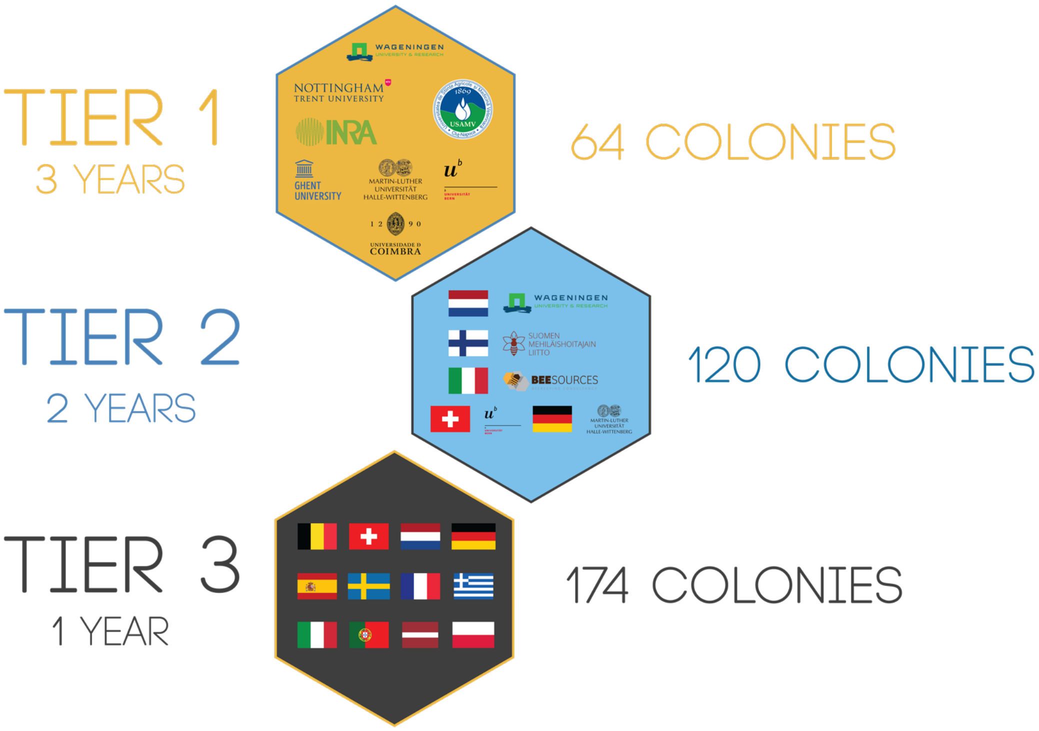



**Figure 1.1.** The B-GOOD 3-tiered approach.

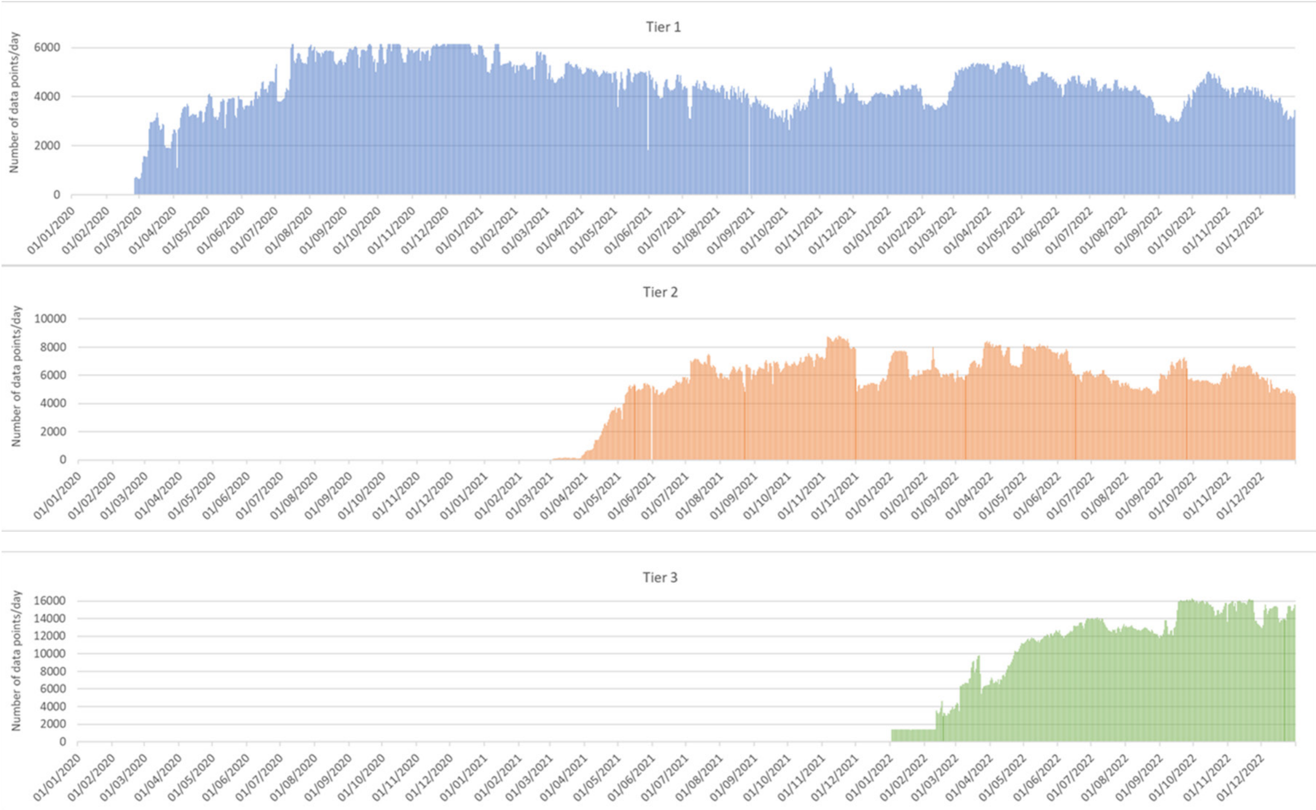



**Figure 1.2.** Number of datapoints per day on Tiers. Graphs were vertically aligned on date. Vertical axes were optimised for the total number of expected data points per day, based on the number of hives.

## 3 Combine ad hoc data input and laboratory analyses in different comprehensive pilot and field studies in different representative EU member states

All beekeepers in all tiers collected bee samples of their colonies three times a year and sent these samples (1800 samples were collected in total) to the two reference laboratories within the project for disease analyses. From there, these samples were forwarded to other laboratories of project partners where analyses on several genetic traits were performed. These data can be utilised for further analyses within the project and be linked to other measurements performed on these colonies (e.g. the classical or sensor measurements).

# WP2 Beekeeping and Innovation

## 1 TaqMan assay

An innovative tool, a TaqMan assay, to detect point mutations associated with the ‘suppressed mite reproduction’ trait in honeybees was developed by B-GOOD partner UGENT. This laboratory test excels in speed and is also cheaper than sequencing-based genotyping. When implemented in a breeding program, it allows the identification and propagation of colonies with protective alleles. This will contribute to the resilience of our breeding stock and over time to the reduction of the treatments against varroa.

## 2 Vibration sensors and generators

Vibration sensors and generators were installed on a collection of 24 honeybee hives by the B-GOOD partner TNTU. This allowed the collection of vibrational signals spontaneously originating from a collection of honeybees, from individual honeybees, and the collection of the response of the colonies to a short vibrational stimulus sent at randomised times in the day. Software was written to analyse the data, providing new honeybee signals of interest, and an estimate of the honeybees’ mobility, and the individuals’ restfulness inside the hive, non-invasively. We showed that failing colonies have a response different to that of healthy ones, months before they collapse.

## 3 Carbon dioxide and humidity sensors

Carbon dioxide and humidity sensors were also installed on a collection of 8 hives by the B-GOOD partner TNTU. This allowed the identification of suitable sensors and their suitable location. We found extraordinarily high levels of CO2 sustained in honeybee colonies, with large daily variations strongly correlating


**Figure 2.1.** (a) SCD30 installed in brood box frame showing propolis coating on the protective mesh. (b) SCD30 (lower) and SCD41 (upper) sensors with a rule to show the relative sizes of the two devices. © Martin Bencsik

with metabolic activity, with their magnitude reflecting the colony size. Furthermore, we also logged the drop of the CO2 variations with colony failure, suggesting that such a drop can be an indicator of colony health deterioration.

## 4 Bee counter

Information on honeybee loss rates at the colony level is crucial for evaluating the magnitude of effects due to stress exposure, thereby ensuring that protection goals for honeybee colonies are met (i.e. threshold of acceptable effects). For that purpose, we developed a highly sensitive and accurate bee counter that provides absolute and real-time quantification of daily activity and mortality rates of worker bees. This will allow the identification of thresholds for abnormal mortality rates, which is relevant for the risk assessment of colony health.

## 5 Lateral Flow Device for virus detection and pesticide detection

In order to discriminate paralysis induced by honeybee viruses from paralysis due to pesticide exposure, prototypes for a cheap and easy-to-use tool for virus detection were set up in parallel to LFD for pesticide measurement. Short peptides from viral protein sequences were used for antibody production against Acute bee paralysis virus and Chronic bee paralysis virus. From both LFD prototypes, Enzyme-Linked ImmunoSorbent Assay (ELISA), western blot analysis and immunosorbent microscopy, B-GOOD has compared the specificity and sensitivity of these serological tools to quantitative PCR.

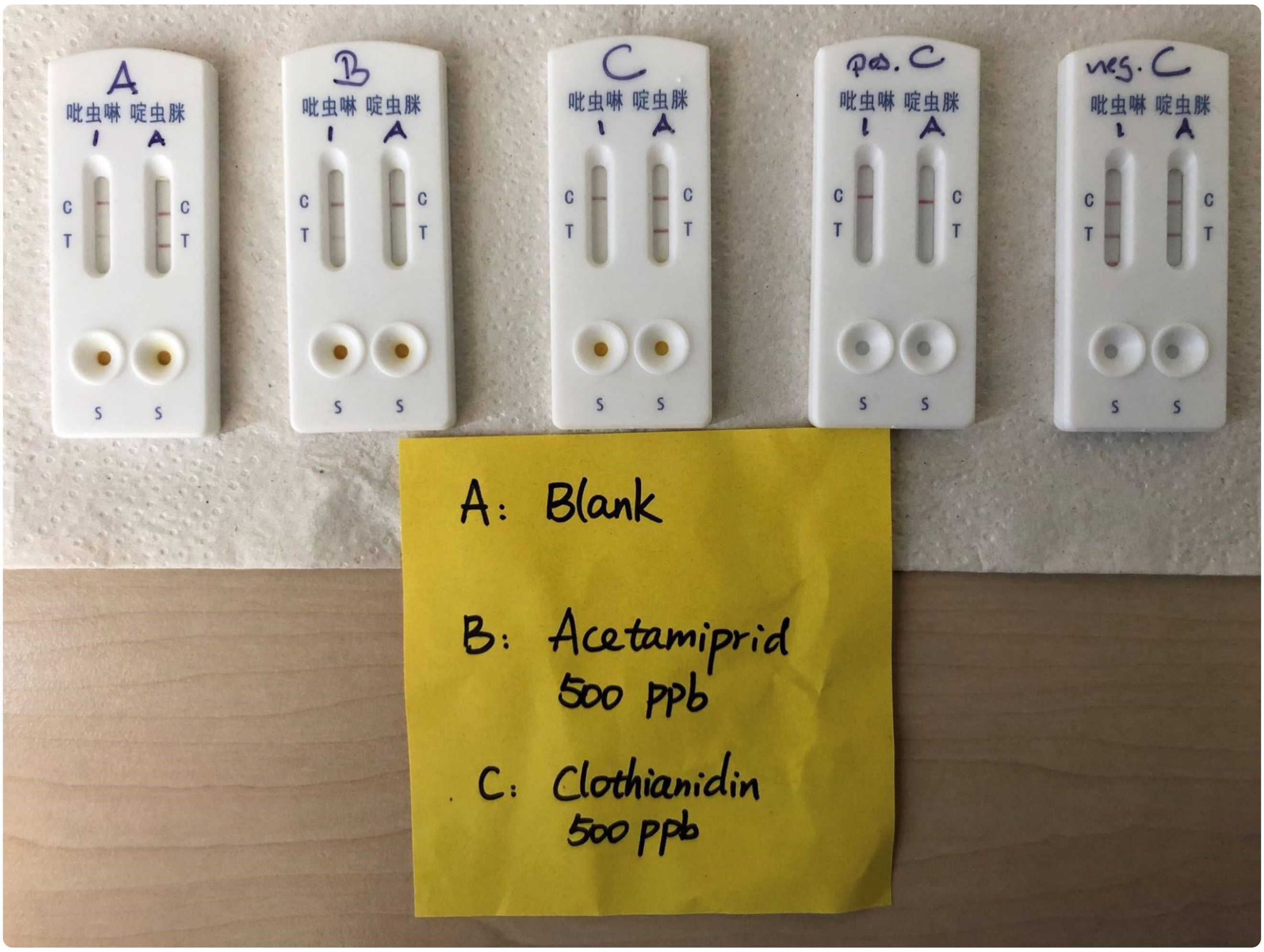



**Figure 2.2.** An LFD test for pesticide detection during a B-GOOD workshop in May 2021. © Marc Schäfer

# WP3 Ecology and Environmental Drivers

## 1 Mapping floral resources in Europe

In the B-GOOD project, we developed a methodologic approach to access and map the availability of floral resources across Europe (Figure 3.1). The methodology is centred around five key components: (1) habitat classification (BIOEUNIS), (2) plant composition per habitat, (3) bee-friendliness value per plant species (BF Value), (4) bee-friendliness index (BF Index), and (5) bee-friendliness habitat score (BF Habitat score).

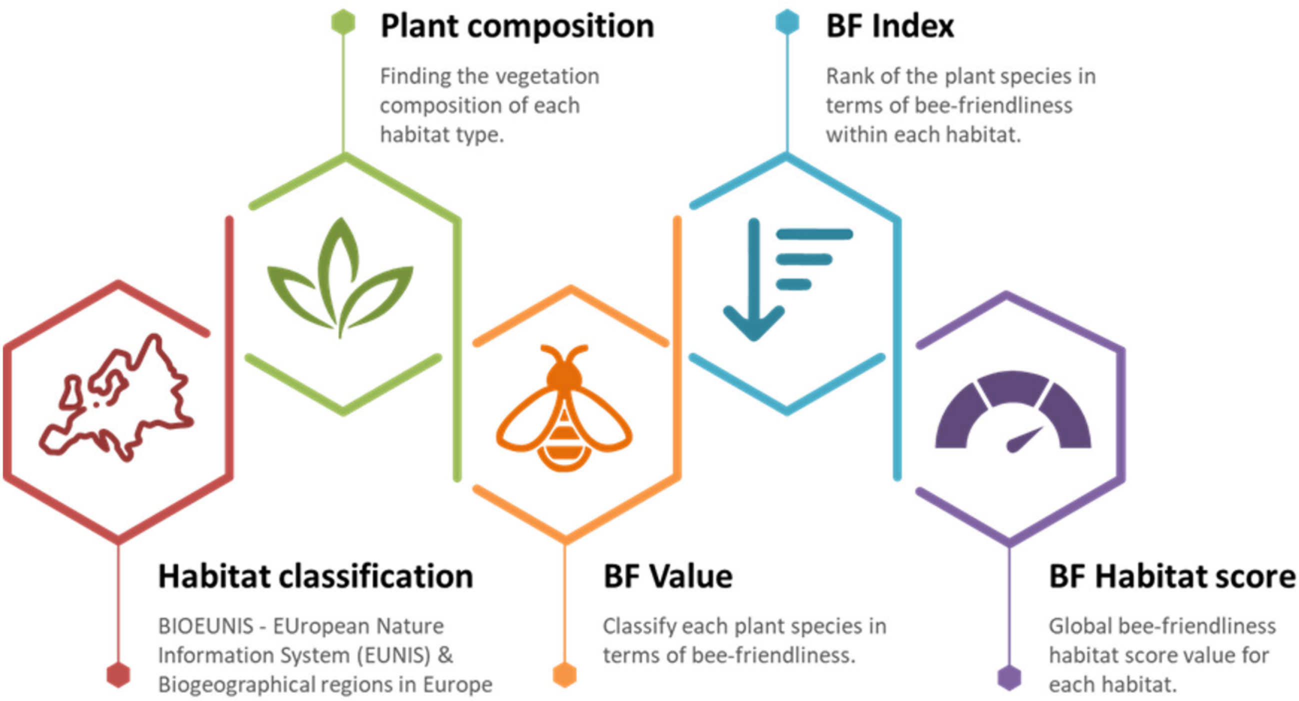



**Figure 3.1**. Methodology overview to access floral resources in Europe.

The development of a spatially explicit habitat classification and typology system, the BIOEUNIS, seamlessly integrates the biogeographical regions of Europe with EUNIS Level 2 habitats. This integration results in the identification of 379 distinct BIOEUNIS habitats (Figure 3.2). These habitats collectively encompass a wide spectrum of ecosystems, each offering a unique floral resource composition that significantly influences the foraging patterns of honeybees. For each BIOEUNIS habitat, we calculate the detailed floral composition (occurrence and cover) based on the European Vegetation Archive (EVA) database. A total of 8029 different plant species were identified as the most representative plant species across all BIOEUNIS habitats. For each one of these plant species, the BF Value was estimated by combining information from different bee-friendly plant species databases. Moreover, we developed and calculated the BF Index using a trait community-weighted mean (CWM) approach, allowing us to assess the contribution of each plant species to bee-friendliness within each BIOEUNIS habitat. In addition, to assess the overall value of each BIOEUNIS habitat in terms of bee friendliness, we developed and calculated the BF Habitat score (Figure 3.3). The BF Habitat score represents the potential value of the habitat to be bee-friendly, primarily reflecting the potential presence of food resources for honeybees in that habitat.

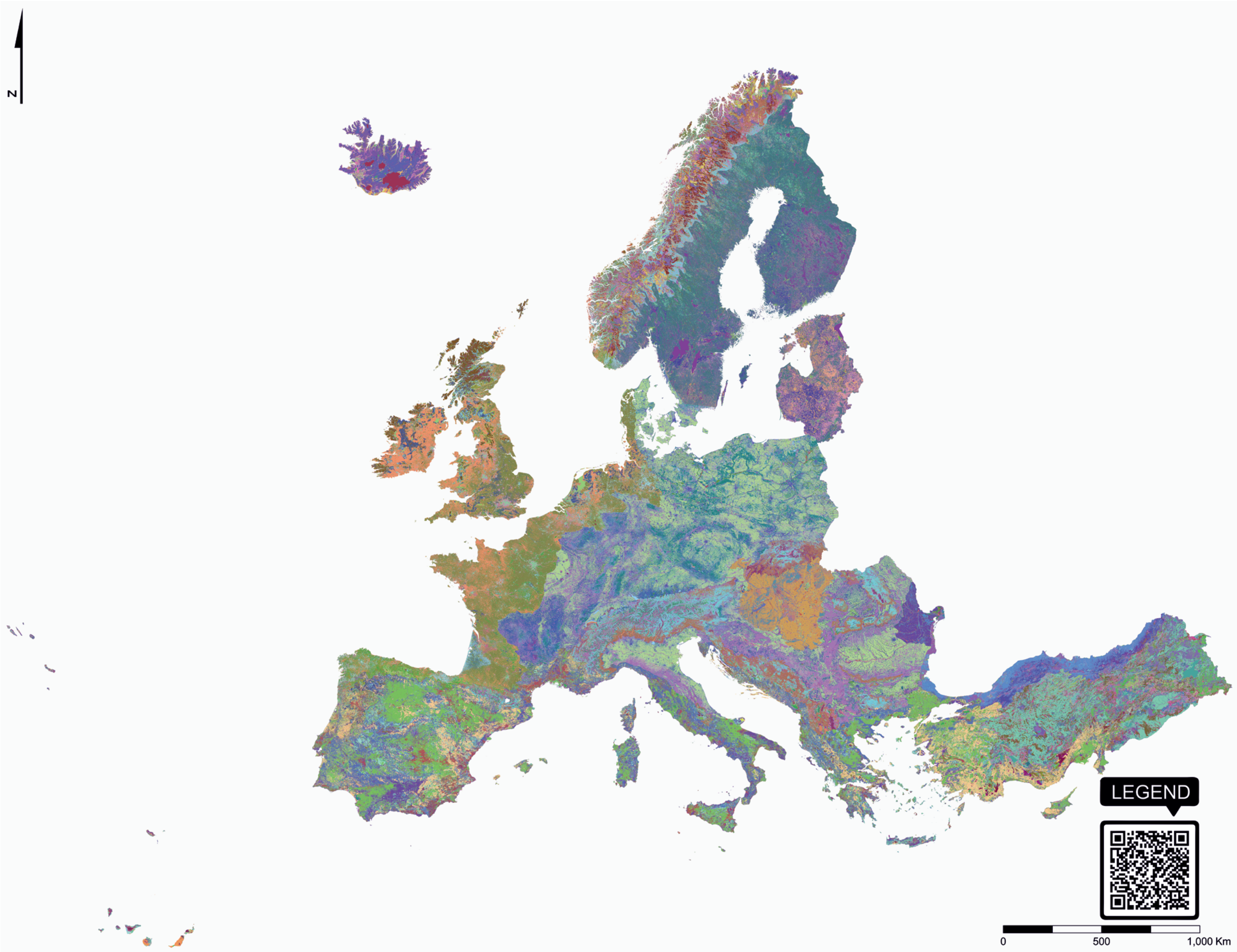



**Figure 3.2**. Map of BIOEUNIS habitats.

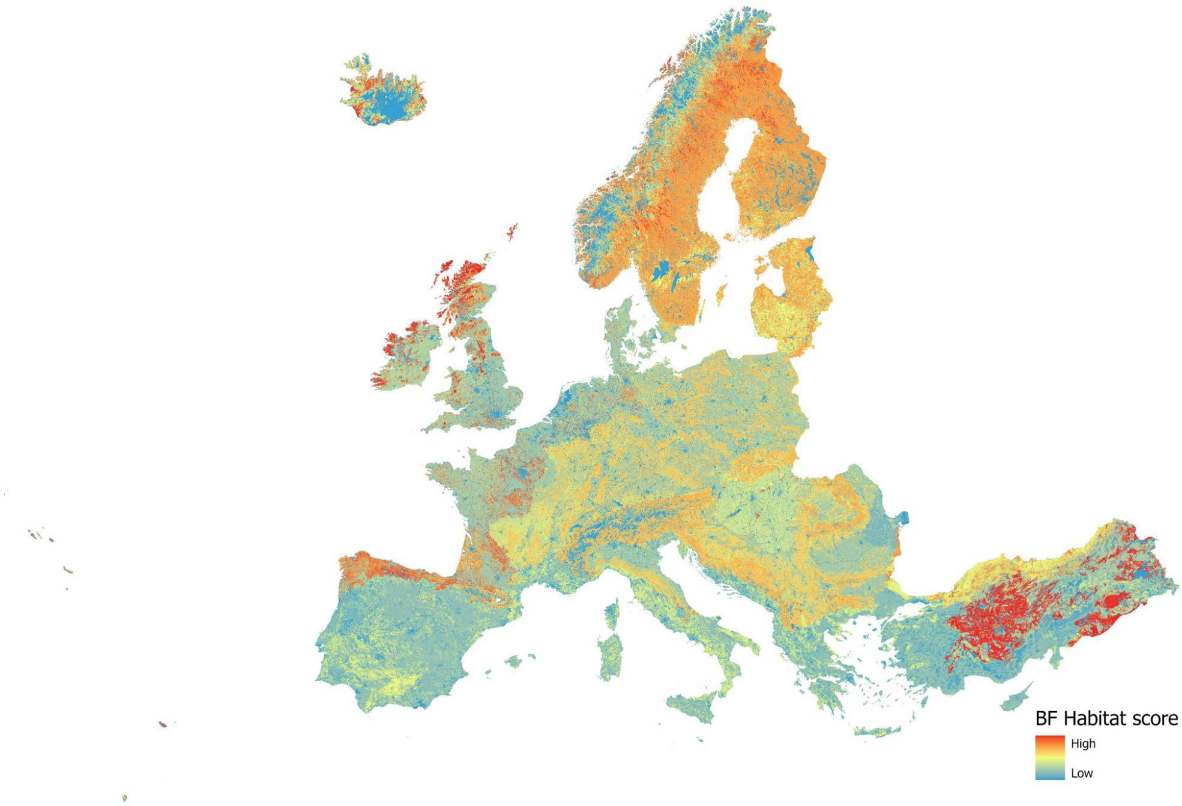



**Figure 3.3.** Map of bee-friendliness habitat score (BF Habitat score).

# 2 Database on the pollen, nectar, and sugar production and the flowering phenology of plants

Access to food resources of adequate quantity and quality is crucial for the development, health and fitness of pollinators, including honeybees. To predict the quantity and quality of food available to pollinators in different landscapes over time, it is necessary to collect detailed data on pollen, nectar and sugar production per unit area and the flowering phenology of plants. Within the B-GOOD project, we have built a comprehensive database that is the first compilation of data on the different food resources produced by 1612 plant species belonging to 755 genera and 133 families, including cultivated and wild plants, annuals and perennials, animal- and wind-pollinated plants, and weeds and trees growing in different ecosystems and under different environmental conditions. The database consists of 103 parameters, collected by us and extracted from the available literature, describing pollen, nectar and sugar production, honey yield, timing and duration of flowering, flower longevity, density of plants and flowers in different habitats, weather conditions, geographical location, habitat type and syntaxonomy. Our dataset provides a unique opportunity to test hypotheses related to pollinator ecology and conservation, food web functioning, nutrient cycling, and plant ecology.

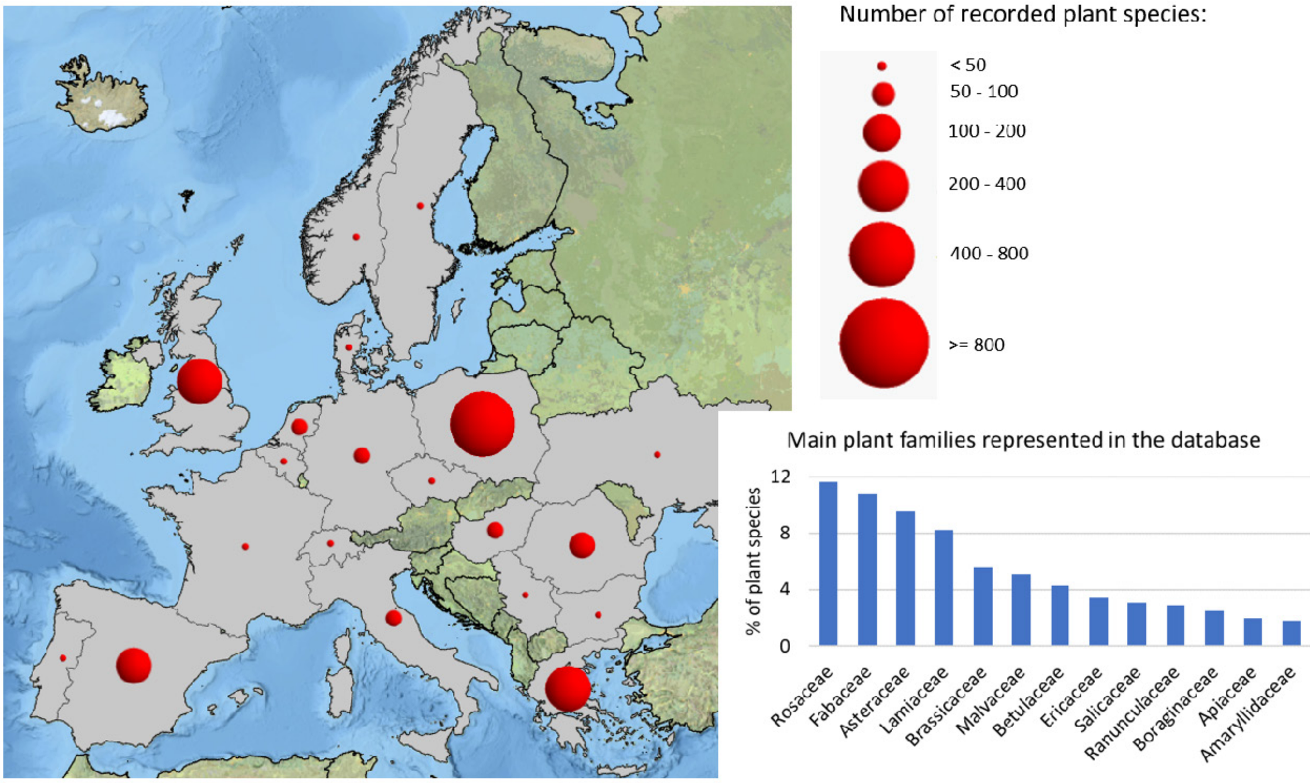



**Figure 3.4**. Data on pollen, nectar and sugar production and flowering phenology were obtained from different pedoclimatic zones. Most of the data were available for plant species and communities present in Central Europe, especially in Poland, where research on floral resources has a long tradition.

# 3 'Floral resource models' and an online tool for calculating floral resources

Floral resources are the foundation for insect pollinators, on which we rely for food and ecosystem functioning. Mapping floral resources across a landscape and knowing how they change throughout the year is crucial for identifying 'hungry gaps' where food supply does not meet pollination demand. It can also help inform landscape planning and management decisions to better support and protect pollinators. In the B-GOOD project, we have developed models and tools to access daily pollen, nectar and sugar production levels and their changes throughout the year. As these 'floral resource models' need to be dynamic across the EU, the floral phenology of 'bee-friendly' plants was analysed in relation to growing degree days. Floral phenology models were then combined with information on the composition of 'bee-friendly' plants within different habitat types, data on pollen, nectar and sugar production per floral unit, and habitat-specific density of floral units per unit area. This allows nectar, sugar and pollen production to be assessed at species level and then up-scaled to habitat and landscape levels. Our 'floral resource models' have been incorporated into the landscape component of the Animal, Landscape and Man Simulation System (ALMaSS) and linked to the ApisRAM honeybee colony model. We also developed an online tool to calculate floral resources for different habitat types and locations across Europe using European daily meteorological data (E-OBS) from the Copernicus programme.

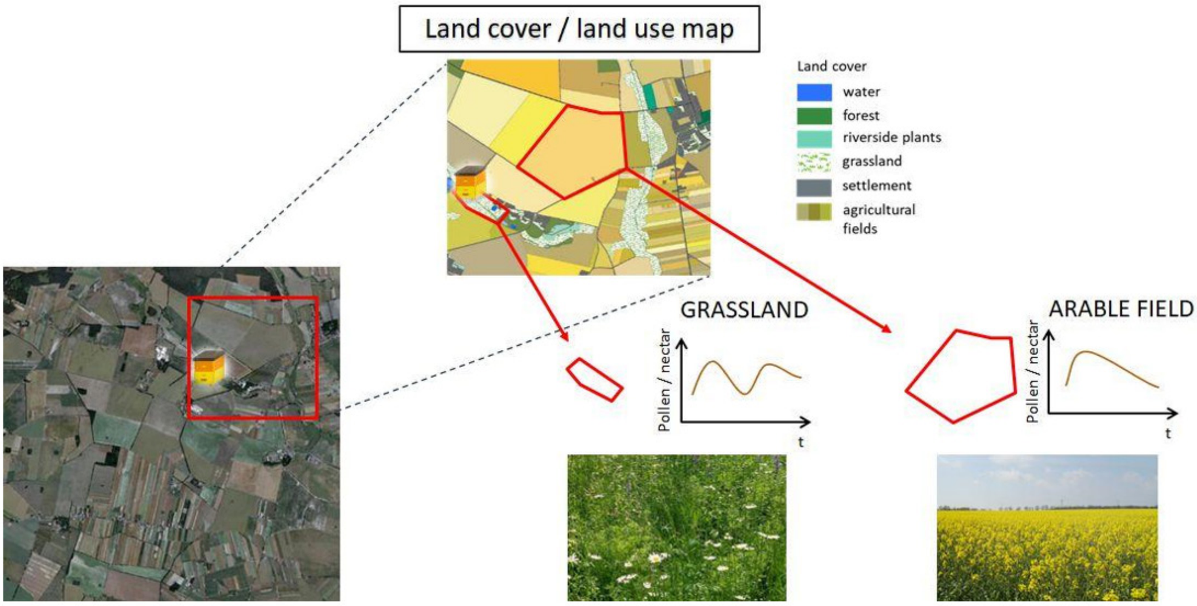



**Figure 3.5**. Detailed mapping of land use/land cover and associated habitat types. The composition of 'bee-friendly' species for each landscape element/habitat unit was derived from phytosociological studies and the literature. Estimates of pollen, nectar and sugar production throughout the year were made separately for each 'bee-friendly' plant species and then up-scaled to habitat and landscape levels.

# 4 Landscape suitability map

The Landscape Suitability Map for honeybees across Europe was developed in B-GOOD and involves the integration of multiple critical variables. This product aims to provide a comprehensive assessment of the suitability of different habitats and landscapes for honeybees across Europe by incorporating both intrinsic and extrinsic factors.

One of the most important steps to achieving this goal is the evaluation and quantification of the food resources available for honeybees across Europe. The use of the BIOEUNIS habitats together with the information on BF Value, BF Index and BF Habitat score allows detailed spatial information about the floral resources available for honeybees across Europe.

By incorporating this data, the suitability map considers the spatial availability of these habitats, which is pivotal in understanding the broader landscape context. In addition to intrinsic habitat considerations, external variables play a crucial role in shaping honeybee suitability. Thus, by incorporating climatic data, water availability, and altitude derived from various sources and models, the Landscape Suitability Map captures the nuanced interplay between honeybee presence and environmental conditions, offering a more holistic representation of habitat suitability for honeybees. Integrating these diverse datasets and variables requires advanced geospatial analysis and modelling techniques. Through a fuzzy logic-based spatial analysis, the suitability map can effectively depict varying degrees of suitability for honeybees across different regions of Europe, helping stakeholders identify priority areas for conservation and habitat enhancement. ***Ultimately, the Landscape Suitability Map for honeybees serves as a powerful tool for informed decision-making and strategic planning***. By considering a comprehensive array of variables, from habitat availability and climatic conditions to water sources and altitude, this map provides a nuanced understanding of the factors influencing honeybee distribution.

# WP4 Socio-Economic Drivers

## 1 Stakeholder and beekeeper interviews and surveys

In the course of B-GOOD, we conducted a series of in-depth interviews and cross-sectional surveys with a diversity of actors involved in the European beekeeping sector. First, 41 in-depth interviews were conducted with stakeholders in industry, policy-making, academia, non-governmental organisations, apiary product quality inspection, beekeeping service providers, and beekeepers. Of those stakeholders, 28 also completed a semi-quantitative SWOT-scoring survey. Following this exploratory research phase, we completed our data collection with large-scale quantitative stakeholder (n=504) and beekeeper (n=844) surveys. The sample of beekeepers is very diverse and covers Western, Eastern, Southern and Northern European regions, as well as hobbyist and professional beekeepers. The focus has been to provide a detailed analysis of beekeeping management practices related to the management of queens and colonies, comb replacement and wax recycling, administration and record keeping, hive monitoring, environment management and monitoring, equipment management, and health and welfare monitoring, which led to the introduction of a Good Beekeeping Management Practice (GBMP) index. Furthermore, honeybee colony outputs (e.g. the production of honey and other apiary products) as well as honeybee colony winter loss rates have been analysed and compared across regions and beekeeper types. Finally, specific efforts have been made to assess the external validity of the study sample through comparing average honey yields per hive per country and reported honeybee colony winter loss rates per country with secondary data accessed from other sources.

## 2 Strengths, weaknesses, opportunities and threats facing beekeeping in Europe

The results from the exploratory stakeholder interviews have been translated into key attention points for policy, strategy and business model development with potential to contribute to future healthy and sustainable beekeeping. Based on a SWOT analysis that identified five strengths, five weaknesses, nine opportunities and nine threats, we have outlined five key attention points for 'offensive' policy and strategy development, three key attention points for 'defensive' policy and strategy development, five key attention points for 'clean-up' policy and strategy development, and three key attention points for 'crisis' policy and strategy development. Topics that emerged for further study related amongst others to getting a better insight into the diversity among beekeepers, the impacts they experience from climate change, and their interest in adopting digital hive monitoring technology.

## 3 Diversity among European beekeepers

Based on an analysis of beekeepers' motivations for keeping honeybees, five distinct types of beekeepers were identified and profiled. Motivations ranged from merely a passion for honeybees and nature to an economic interest in the production of apiary products and related business opportunities. Associated beekeepers' orientations towards honeybees and beekeeping (referred to as 'affect' versus 'utility') have been used as segmentation variables to identify five segments or distinct types of beekeepers, which have consecutively been profiled and characterised in terms of socio-demographics and beekeeping managerial characteristics. The five segments have been referred to as Urban-explorer, Average-cool, Passionate-hobbyist, Passionate-skilled and Professional.

# 4 Experienced and perceived impacts from climate change

Insights and data from the stakeholder interviews and beekeeper survey were used to assess the extent to which stakeholders and beekeepers perceive and experience the impacts of climate change on their beekeeping operations, and whether and to what extent they had to adapt their beekeeping practices (Van Espen et al., 2023). The analysis confirmed that climate change is clearly perceived to be impacting beekeeping in Europe, although the impacts differ substantially from region to region. Climate change is therefore likely to create winners and losers within the European beekeeping sector. Among the possible losers are mainly beekeepers located in Southern Europe and professional beekeepers who experience the strongest impacts from climate change (Figure 4.1). Major impacts concern changes in local weather conditions and food resource availability. More severe perceived impacts from climate change are associated with lower honey yields and higher colony winter loss.

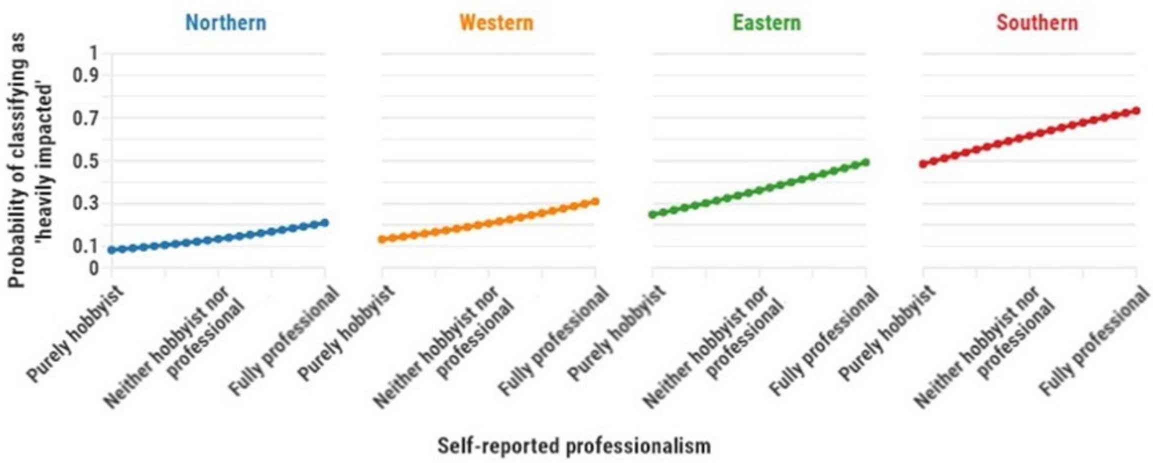



**Figure 4.1**. Probability of European beekeepers feeling heavily impacted by climate change, from purely hobbyists to fully professionals and across European regions (%, n=844, 2022) (Van Espen et al., 2023).

# 5 Interest in adopting digital hive monitoring technology

An analysis of beekeepers' use and interest in adopting digital hive monitoring technology revealed that the proportion of European beekeepers currently using some kind of digital monitoring (21%) is still low, and when using this technology, it is mostly limited to the monitoring of a single parameter (mostly hive weight) and implemented on a very limited number of hives. Their main motive is to facilitate hive management (Figure 4.2). The use of digital hive monitoring differed significantly between EU regions, type of beekeeper (professional vs. hobbyist, and associated size of the beekeeping operation), number of years' experience as a beekeeper, and social embeddedness through active involvement in the board of beekeepers' associations. The data of the beekeeper survey suggested that the so-called 'social tipping point' where a minority group of early adopters of a technology (typically 25% of the population) initiate a cascading change of social behaviour, is within reach in the European beekeeping sector. The analysis further revealed that personal attitudes towards the technology are the main driver of adoption, whereas social norms (i.e., influences of opinions of others) and facilitating conditions such as skills, availability and accessibility of the technology also play a role – albeit minor – in driving hive monitoring technology adoption.

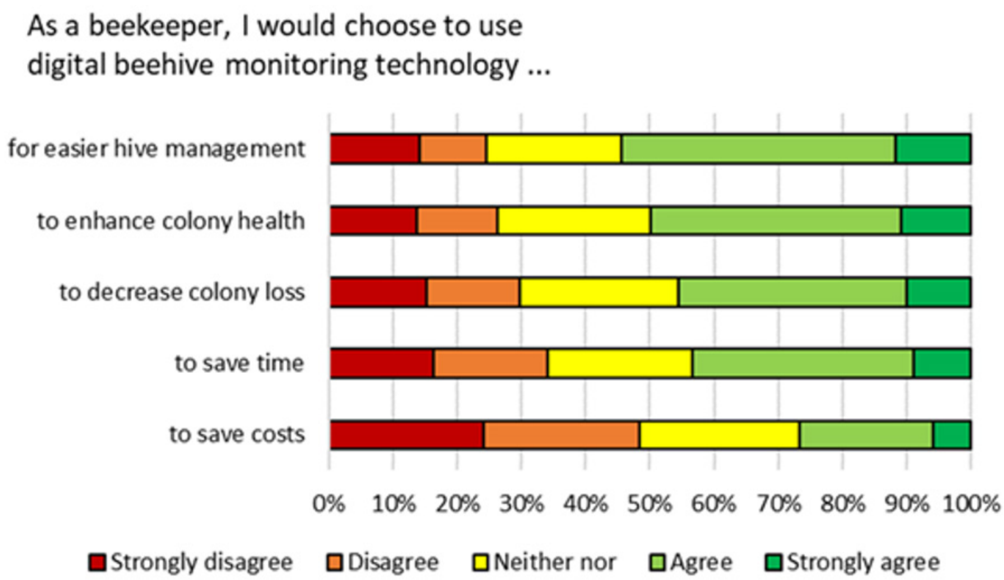



**Figure 4.2**. European beekeepers' motives for using digital beehive monitoring technology (%, n=844, 2022).

# WP5 Data Analysis and Decision Making

## 1 Data Analysis for automatic colony monitoring data

Within an apiary with multiple hives equipped with automated mass measurements, a signature was identified by B-GOOD researchers, allowing the scientists to pick out colonies that exhibited abnormal behaviour, and these colonies were also assessed, by visual inspection, to be in poor health. We have thus shown that by focusing on a particular aspect of the mass variations of a honeybee colony, collected automatically and non-invasively, it is possible to indicate to the beekeeper specific hives that require attention.

## 2 Machine learning methods for colony health prediction

Machine learning is a field that empowers computers to perform various tasks by learning from data. In the context of beekeeping, machine learning based models, such as neural networks, have been developed to predict the health status of bee colonies using data from BEEP automatic monitoring and inspections. These advanced models offer beekeepers valuable tools for improving the management of their bee colonies.

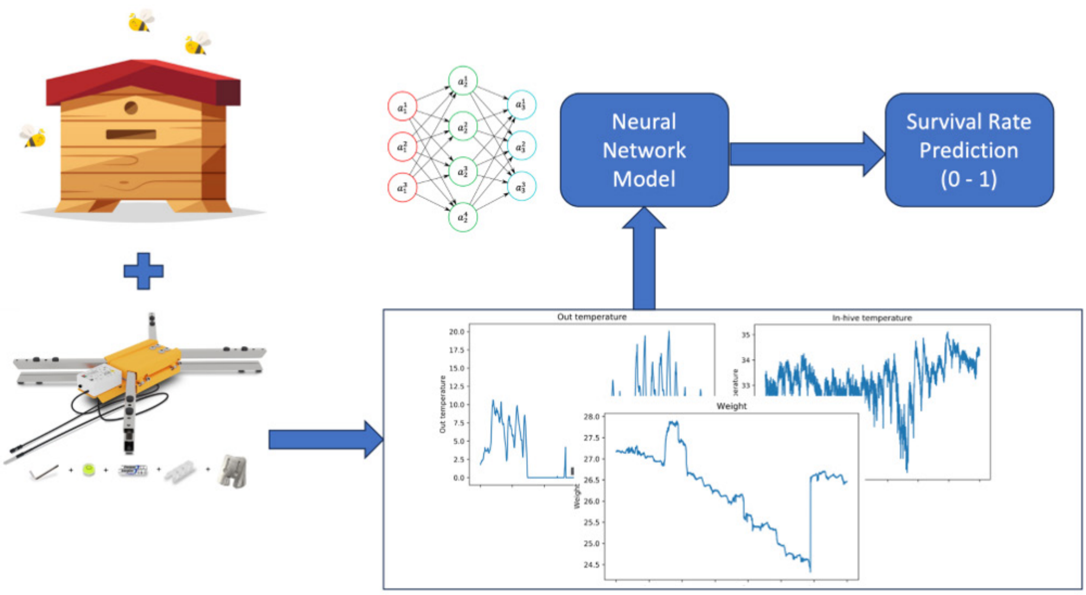



**Figure 5.1**. Machine learning based model for colony survival prediction.

## 3 Dynamic landscape and flower resource model for ALMaSS

In the context of the Animal, Landscape, and Man Simulation System (ALMaSS), dynamic landscapes are computer-generated representations of real-world landscapes that undergo changes over time. In the B-GOOD project, dynamic ALMaSS landscapes were specifically created to model landscapes in the UK and Belgium. Additionally, within ALMaSS, a dynamic flower resource model was developed to simulate the availability of nectar and pollen resources. This model enables the simulation of bee populations and their interactions with the changing landscape and floral resources, providing valuable insights into the impact of landscape management on these important pollinators and their ecosystems.

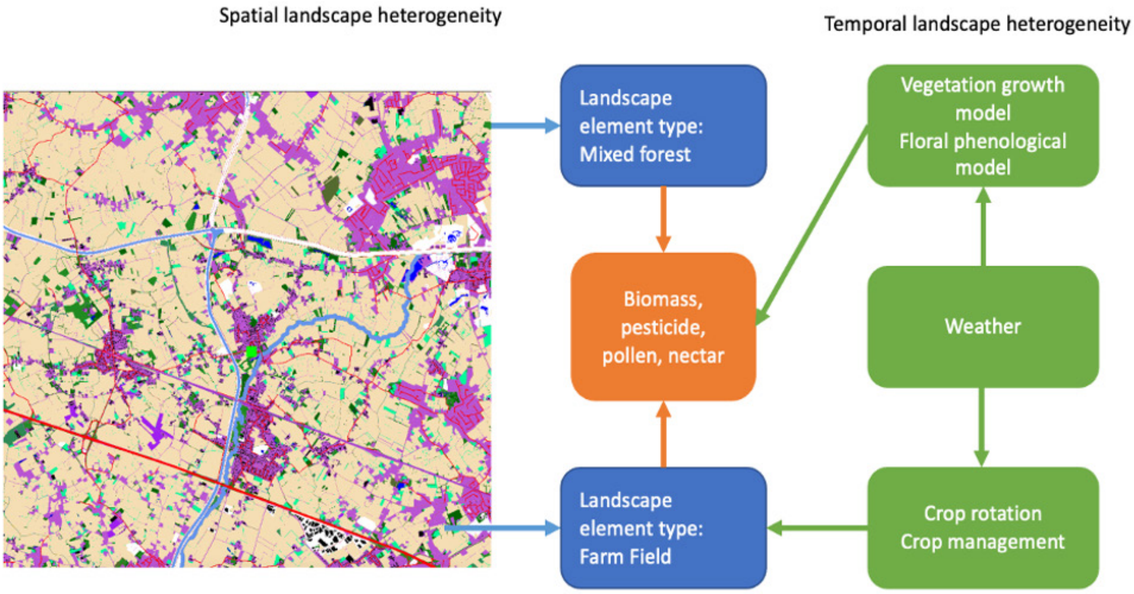



**Figure 5.2**. The dynamic ALMaSS landscape model with flower resources.

# 4 ApisRAM further development

ApisRAM stands as a highly innovative and intricate model for honeybee colonies, aiming not only to simulate individual bees within a colony, but also to capture their interactions and behaviours in fine detail. Within the scope of the B-GOOD project, *Apis*RAM has been further refined, with particular emphasis on enhancing the foraging model. This refined foraging model seeks to realistically simulate the interactions between the model bees and the dynamic landscape model integrated into ALMaSS to enable the analysis of impacts landscape management on honey bee colonies.

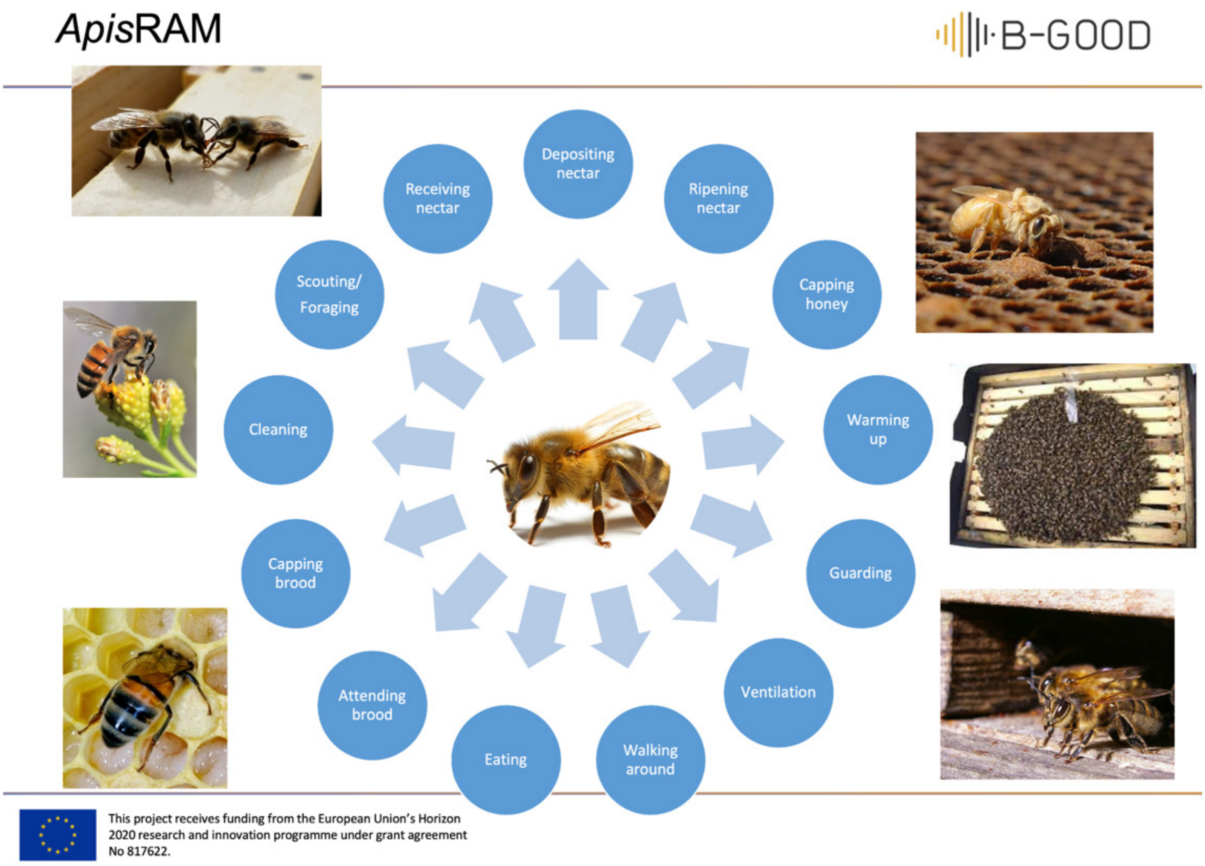



**Figure 5.3**. The activities of workers in *Apis*RAM model.

# WP6 Operationalization and Application

## 1 Open research platform for beekeepers and researchers

BEEP is a research platform with digital tools, aiming to support beekeepers in their role as caretakers. The online system offers an overview of all colonies, inspections and apiaries. The BEEP base sensor system allows for automatic measurements. Bee researchers can invite beekeepers to their citizen science project for high-quality data collection.

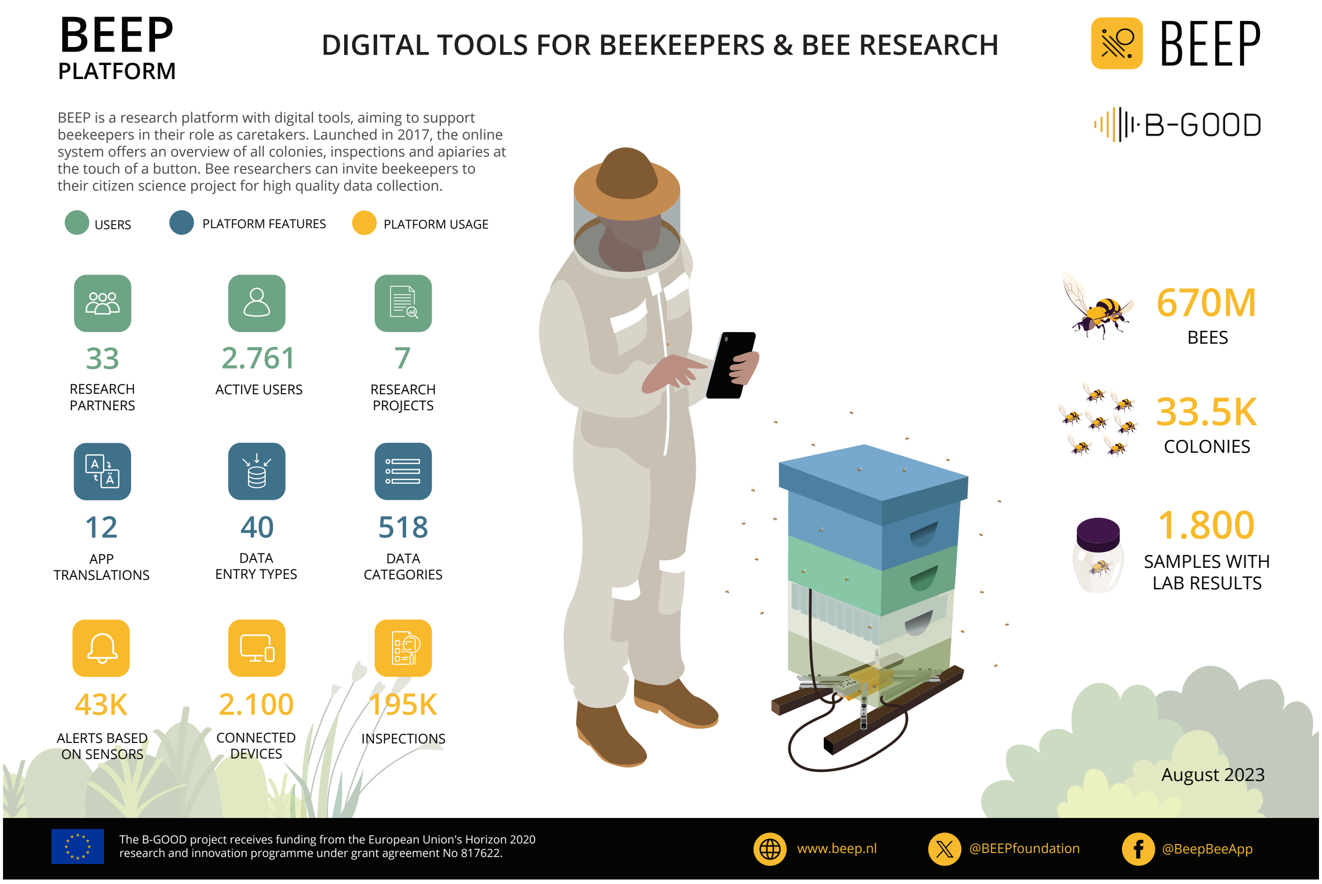



**Figure 6.1**. The BEEP platform.

## 2 Decision support for honeybee colony health

Advanced data analytics allow for setting alerts on events such as a bee swarm. And warnings based on predictions such as the trend in colony weight compared to other colonies or your own algorithm or prediction model. The alerts and warnings enable users of the platform to take care of the colonies when it is required. And the colonies are less disturbed by manual inspections.

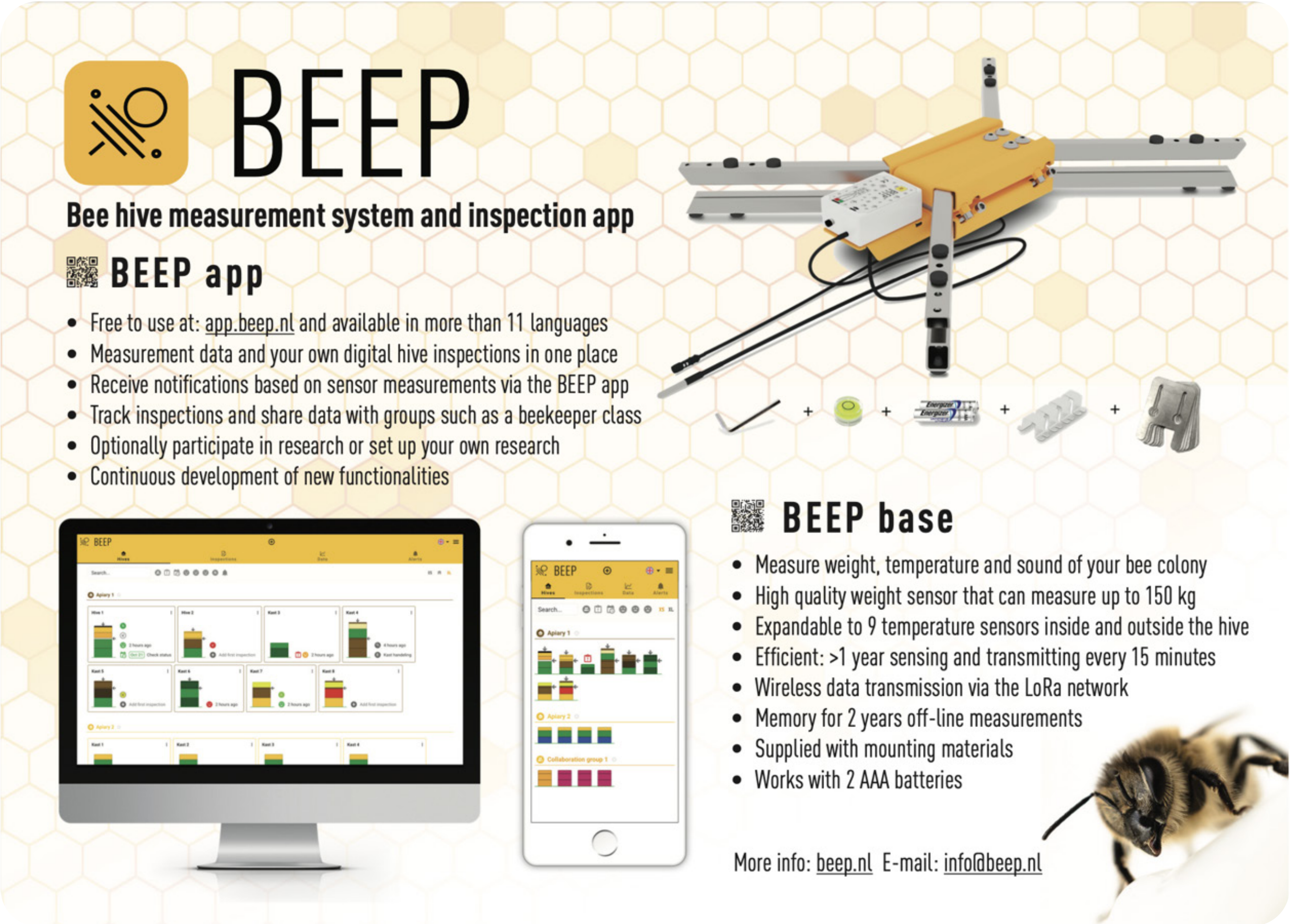



**Figure 6.2**: The BEEP hive measurement system and inspection app.

## 3 Data portal for easy management of datasets

To keep an overview of datasets and share these with partners for research purposes, a data portal website was designed, built and implemented. It has a fine-grained permissions feature while all partner organisations in the consortium can see all available datasets. That way, it forms the central data repository to (towards the end of the project) publicly share the datasets.

# WP7 Communication and Exploitation

## 1 Communication: building a diverse network and delivering outputs to all corners of society

Effective science communication plays a huge role in the successful implementation of a project, bridging the gap between different areas of expertise. In its four and a half years of action, B-GOOD has developed a strong and diverse network of scientists, practitioners and other interested parties. With the help of a unique project identity and a modern website, B-GOOD has communicated all relevant project outputs and developments, making sure they reach the different corners of society. The project utilised various tools, such as tailored promotional materials, introductory and training videos, infographics, newsletters and market stands. Furthermore, the project utilised its social media channels on X, Facebook and YouTube by introducing innovative social media campaigns, such as B-GOOD faces, B-GOOD partners, beekeepers stories & the B-GOOD photo contest campaign.

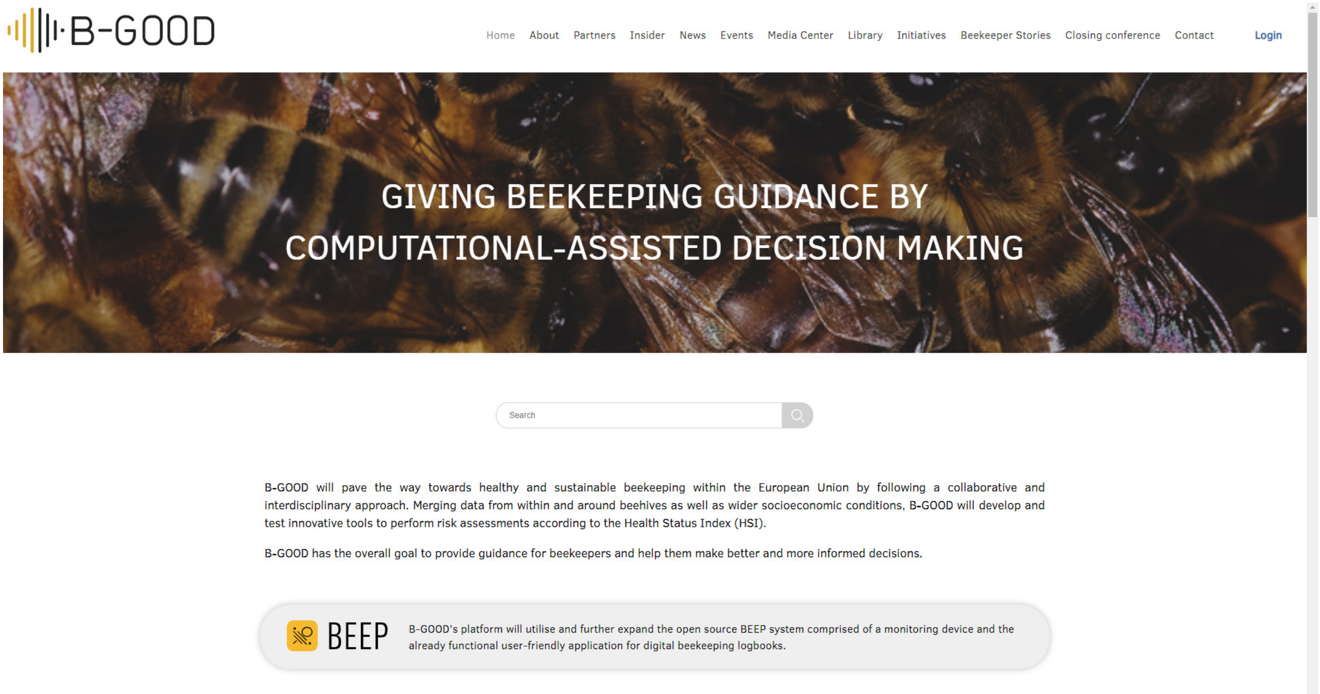



**Figure 7.1**. The B-GOOD website.

## 2 Dissemination: making results understandable to all stakeholders

In B-GOOD, we believe in making research information FAIR (findable, accessible, interoperable and reusable). This is why we strive to make our publications easily understandable and available to all our stakeholders, from researchers to beekeepers. The project has developed a significant number of practice abstracts which were made available on the EIP-AGRI platform. These concise and clear pieces of knowledge aim to present B-GOOD results to one of the key project target groups – the practitioners. In the course of the project, a plethora of captivating articles have been published in Open Access journals (see references). To make these accessible to a wider audience, we have created short graphical summaries, describing the question addressed in the studies, its importance, and the main results and societal relevance. You can find the B-GOOD graphical abstracts in the second part of this document.

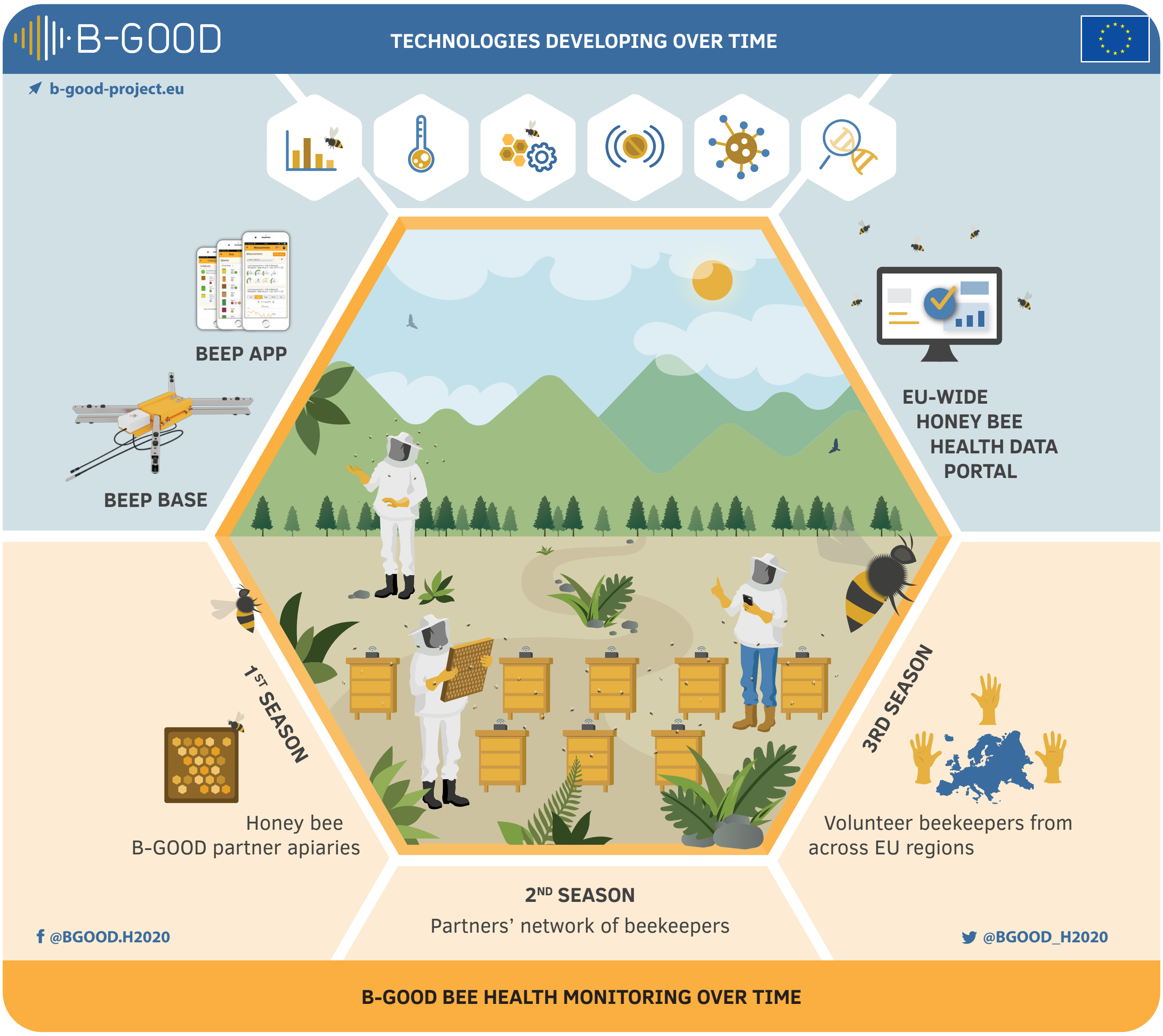



**Figure 7.2**. B-GOOD in a nutshell – an infographic.

# 3 Exploitation: outlining the future of B-GOOD key exploitable results

Exploitation activities focus on making concrete use of project outputs, either for commercial, societal, or policy support purposes. To increase the exploitation of the project's results, B-GOOD maintained a continuous and in-depth dialogue with its multi-actor forum members, involving them in a co-design process and eliciting their unique expertise. In addition, the project organised several training activities and beekeeping courses, where practitioners got the opportunity to put theory into practice. B-GOOD has also utilised the free services provided by the European Commission – the project initiated discourse with the Horizon Results Booster service, discussing and outlining the future of several key exploitable results (i.e. the BEEP platform, LFDs, etc.) with the appointed external experts. Furthermore, the future of B-GOOD has been secured with the newly funded Horizon Europe project Better-B, the overall aim of which is to improve the resilience of beekeeping to abiotic stresses such as climate change, habitat loss and hazardous chemicals.

# WP8 Multi-Actor Co-Development

## 1 Engaging multiple actors for co-development

A core component of the B-GOOD project was its multi-actor approach. It was designed to integrate the expertise and interests of a wide range of relevant actors, helping to foster knowledge exchange to guide the development of innovative and practical solutions for the beekeeping community to keep their honey bees healthy. A keystone of B-GOOD's multi-actor approach was the establishment of a Multi-actor Form (MAF). This forum enabled B-GOOD partners to interact directly with a variety of key actors, from beekeepers to EU authorities. The B-GOOD MAF initially targeted and engaged with key actors at EU and national levels representing different


**Figure 8.1**. Images from the future of managing colony health workshop at the B-GOOD consortium meeting (June 2022). © Marten Schoonman

**Figure 8.2**. Images from the market stands at B-GOOD consortium meeting (June 2022). © Marten Schoonman

sectoral interests, e.g. authorities (agriculture/environmental/health), practitioner associations (beekeeping, farming and industry), as well as environmental NGOs (environmental/wildlife/pollinators). The 'grassroots' reach of the MAF was extended by including beekeepers involved in the project (Tier 2 and 3 beekeepers). MAF members were invited and actively participated in all consortium meetings. They enabled project partners to inform MAF members of project activities and results, both through presentations and 'market stands', as well as actively seeking their feedback through question and answer sessions. In addition, several workshops (both for in person and online participation) were held at consortium meetings. These workshops were used to explore a number of themes and gain input from MAF members to guide project activities e.g., how digital hive monitoring technology could improve hive management for more healthy and sustainable beekeeping. MAF activities were beneficial in promoting interactions between the project partners and interested external actors, facilitating knowledge exchanges and fostering B-GOOD project developments that are relevant and have a lasting legacy for the beekeeping community.

## 2 Learning platform for knowledge exchange

An aim of the B-GOOD project was to develop a dynamic learning platform for knowledge exchange and feedback. Integral to this has been the establishment and convening of the MAF and involvement of key actors in direct exchanges with project partners (as described above). The B-GOOD website, along with social media channels and dissemination activities conducted within WP7 (Pensoft and Bern University) have also been instrumental as mechanisms for informing and supporting knowledge exchange with MAF members, as well as other interested parties in B-GOOD developments. The B-GOOD website has acted as a resource hub for a wider audience, helping to ensure dissemination of project activities and results, as well as beekeepers' individual perspectives and challenges on keeping honey bees (Figure. 8.3) to foster learning and understanding by wider audiences.


**Figure 8.3**. A beekeeper's individual perspective on keeping honey bees and current challenges, one of a series published on the B-GOOD website.


**Figure 8.4.** The B-GOOD Open Science Collection in RIO Journal.

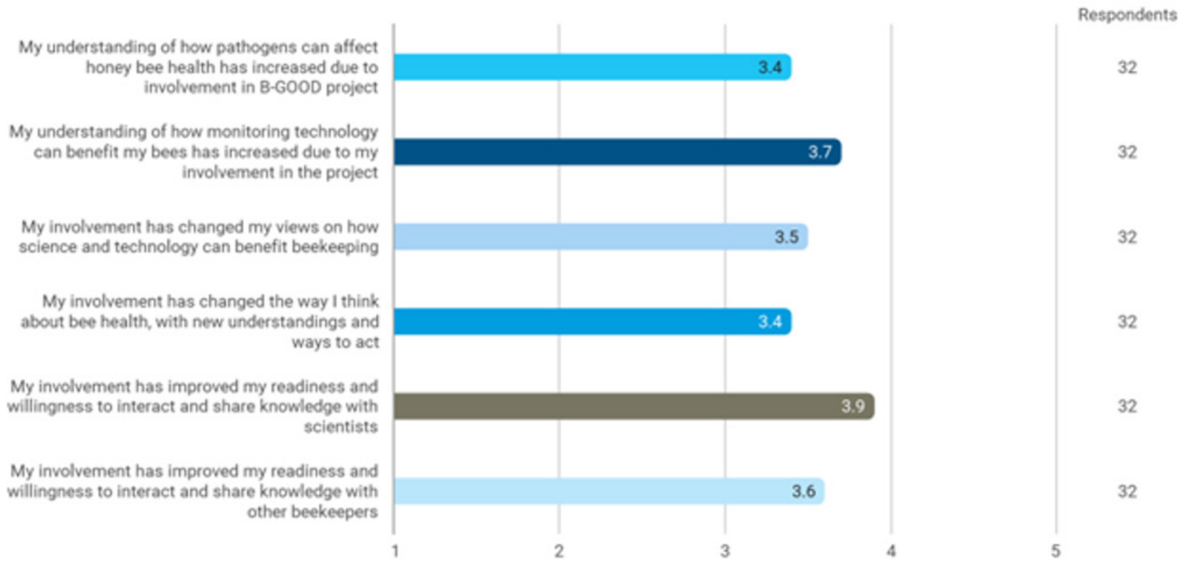



**Figure 8.5**. Mean scores for beekeepers involved in the project, and their agreement with a series of statements on 1 – 5 scale, 1 = strongly disagree to 5 = strongly agree.

In addition, the B-GOOD website offers a library providing open access to B-GOOD results and scientific publications, as well as providing links to other beekeeping related initiatives e.g., EU Bee Partnership. The B-GOOD website (https://b-good-project.eu/) will continue to be a source of information, disseminating scientific learning from the B-GOOD project. In addition, the Research Ideas and Outcomes (RIO) platform maintains an open collection of the project's scientific articles and other documents, ensuring a long lasting legacy of access to project results.

## 3 Evaluation of actor experiences in project

A series of quantitative surveys carried out to assess beekeepers expectations and experiences during their involvement in the B-GOOD project. Responses from beekeepers highlighted that access to scientific information was a strong expectation, well as gaining knowledge to benefit their own beekeeping management. Subsequently, beekeepers' responses indicated their involvement in the project had strengthened their 'readiness and willingness to share knowledge with scientists', as well as their understanding of how monitoring technology can benefit their beekeeping (Figure 8.5.)

Acting on feedback gained at consortium meetings and responding to survey results, consortium efforts were stimulated to inform beekeepers and other key actors of relevant results e.g. at consortium meetings. All project partners have supported the active involvement of MAF members by ensuring talks, presentations and workshops were tailored to an external audience and to stimulate dialogue with them. The continued interest and participation of MAF members in the B-GOOD project culminated in positive attendance of many at a final beekeepers event (held in the Netherlands, September 2023) and the B-GOOD final conference (Slovenia, October 2023). As part of these events feedback will be further sought about their experiences and learning from participating in the project, helping guide the legacy outputs of the project.

# GRAPHICAL ABSTRACTS

In the spirit of delivering practice-relevant research outputs, B-GOOD issued a graphical abstract for its key published research papers, focusing on the publications' main outcomes with practical value. This section of the booklet contains B-GOOD's 15 graphical abstracts produced thus far. These materials provide concise recommendations on the benefits to the stakeholder, if the generated knowledge is implemented.

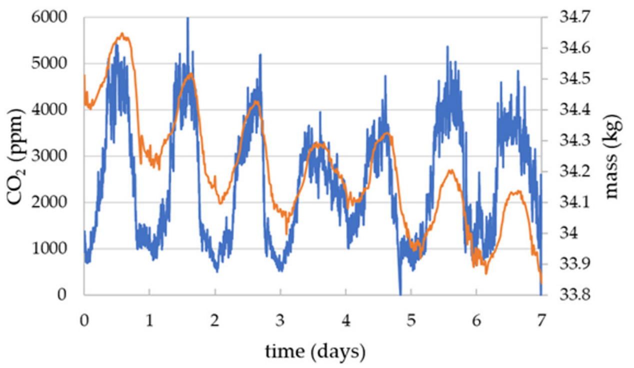
# A MONITORING SYSTEM FOR CARBON DIOXIDE IN HONEYBEE HIVES: AN INDICATOR OF COLONY HEALTH

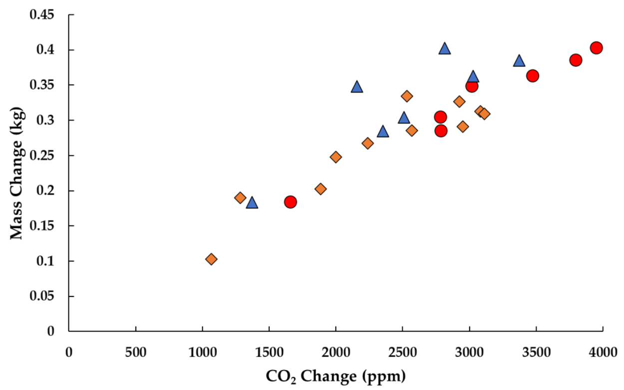
## Background

Over the years, numerous studies have shown the importance of different gases to the health of honeybee colonies, however, much of the data have used expensive laboratory-based analysis or using controlled environments. The lack of availability of low cost, small, and highly specific gas sensors continue to be a limitation in this area of study. Recent developments in small nondispersive infrared (NDIR) sensors have made measurement of carbon dioxide in honeybee hives attainable with a temporal resolution allowing multiple measurement a minute.

## Objective

To monitor long-term carbon dioxide levels in honeybee hives and compare this data to hive mass data.



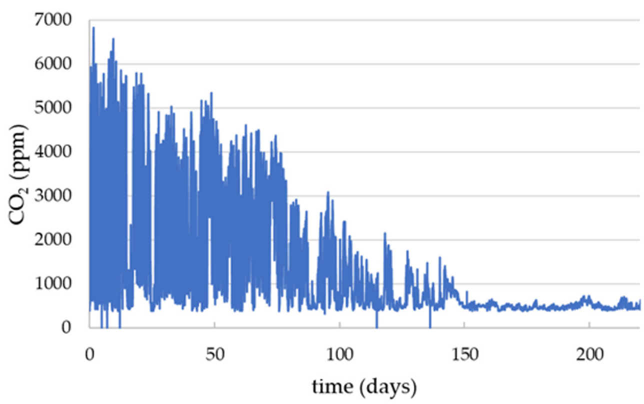

The figure to the left shows typical $CO_2$ values (blue line) over a week with peak values over 5000ppm.

Note that in fresh air the ambient $CO_2$ values typically are around 450ppm.

The orange line shows the hive mass data for the same period where the number of foraging bee leaving the hive each day can be estimated.

The figure to the left plots the daily mass change against the maximum daily $CO_2$ change to suggest that $CO_2$ can give an idea of the strength of the colony.

The link between $CO_2$ and colony strength is clearly demonstrated in the figure (below) which shows $CO_2$ values over more than six months for a colony that failed at around 150 days.




## Take-home messages

- The current generation of NDIR carbon dioxide sensors are well suited to the task of monitoring in honeybee colonies.
- $CO_2$ in honeybee colonies rise and fall daily and achieve levels way above those conducive to human health.
- Daily changes in $CO_2$ can give information about the number of foraging bees in the hive and hence the colony strength.

## Sources


Bencsik, M.; McVeigh, A.; Tsakonas, C.; Kumar, T.; Chamberlain, L.; Newton, M.I. A Monitoring System for Carbon Dioxide in Honeybee Hives: An Indicator of Colony Health. *Sensors* 2023, 23, 3588. **https://doi.org/10.3390/s23073588** CC-BY

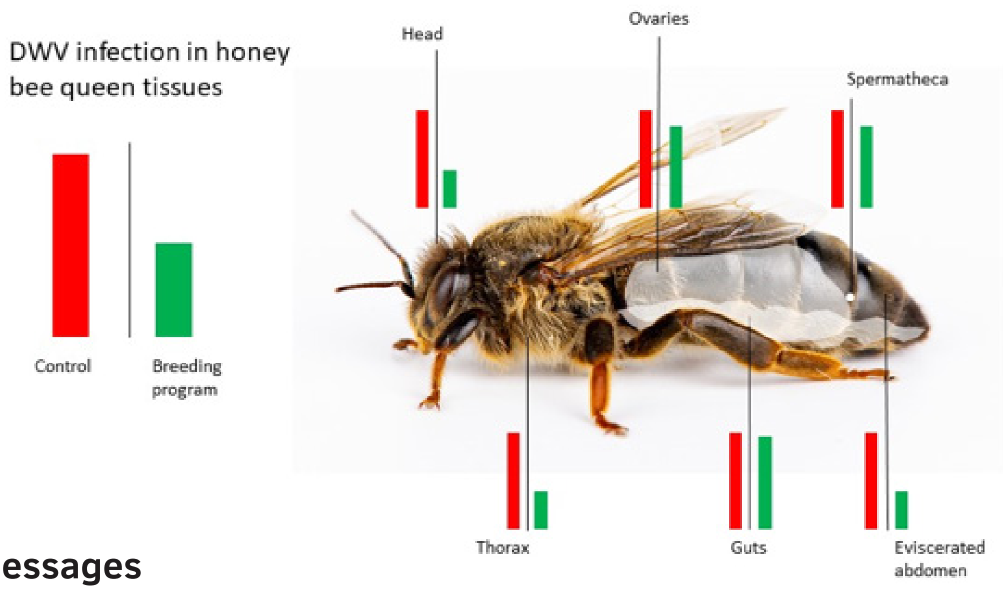
# BREEDING FOR VIRUS RESISTANCE AND ITS EFFECTS ON DEFORMED WING VIRUS INFECTION PATTERNS IN HONEYBEE QUEENS

## Background

Viruses, and in particular the deformed wing virus (DWV), are considered as one of the main antagonists of honeybee health. The 'suppressed in ovo virus infection' trait (SOV) described that control of a virus infection can be achieved from genetically inherited traits and that the virus state of the eggs is indicative for this.

## Objective

This research aims to explore the effect of the SOV trait on DWV infections in queens descending from both SOV-positive and SOV-negative queens. Twenty queens from each group were reared and from each queen the head, thorax, ovaries, spermatheca, guts and eviscerated abdomen were dissected and screened for the presence of the DWV-A and DWV-B using qRT-PCR.




## Take-home messages

- By breeding for virus resistance, major improvements can be achieved in a limited number of generations.
- All honeybee queens were infected with both genotypes of DWV, thus the SOV trait does not result in a clearing of the viral, but rather in downscaling the infection level.
- The SOV trait can act as an important tool to strive towards a stable co-evolution between honeybees and their pathogens.
- As the SOV trait has a genetic background, further research on the genetic markers associated with the trait could contribute to unraveling the underlying mechanisms of SOV.

## Sources

Bouuaert, D.C.; De Smet, L.; de Graaf, D.C. Breeding for Virus Resistance and Its Effects on Deformed Wing Virus Infection Patterns in Honey Bee Queens. *Viruses* 2021, 13, 1074. https://doi.org/10.3390/v13061074

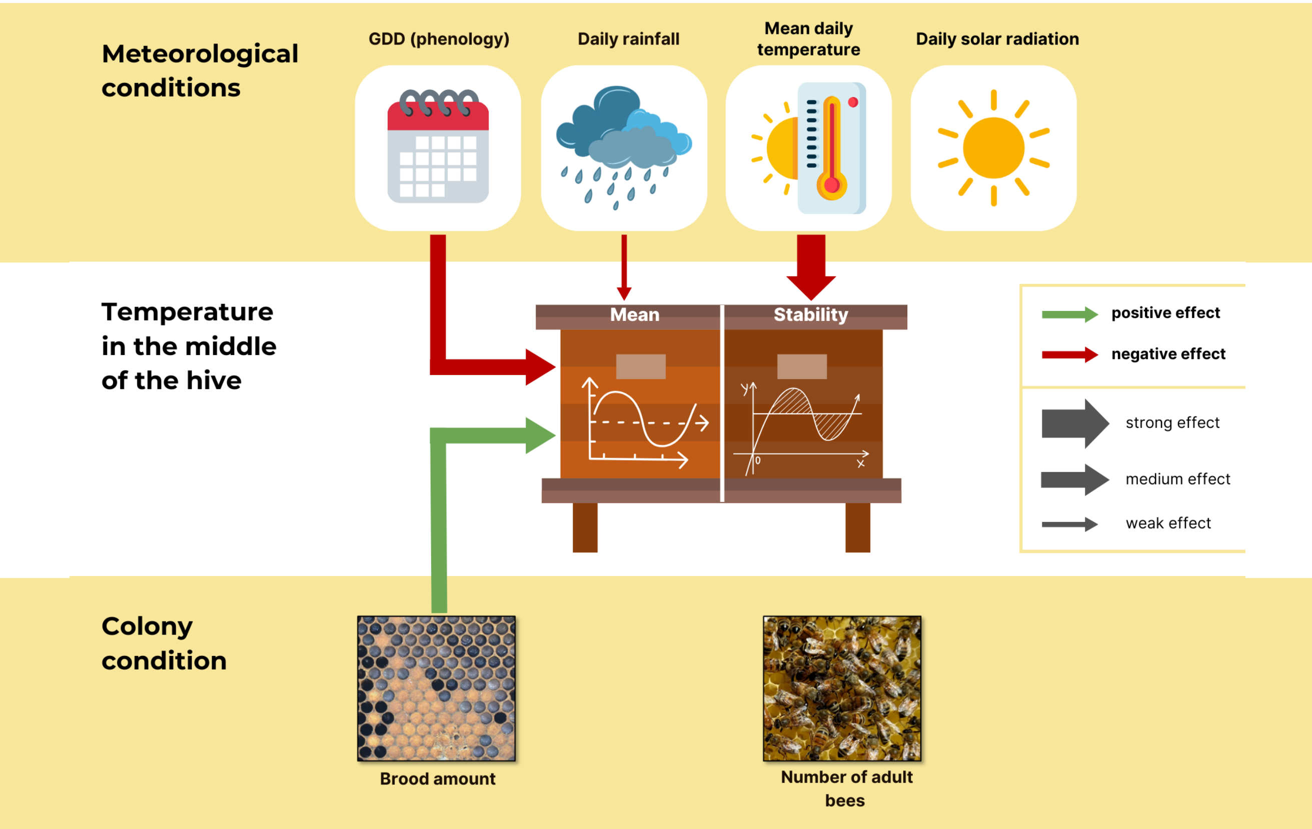
# BROOD THERMOREGULATION EFFECTIVENESS IS POSITIVELY LINKED TO THE AMOUNT OF BROOD BUT NOT TO THE NUMBER OF BEES IN HONEYBEE COLONIES

## Background

To ensure the optimal development of brood, a honeybee colony needs to regulate its temperature within a certain range of values (thermoregulation). However, little is known about the factors that may influence the effectiveness of this thermoregulation.

## Objective

To monitor long-term carbon dioxide levels in honeybee hives and compare this data to hive mass data.




## Take-home messages

- Mean brood temperature is positively linked to the amount of brood.
- Brood temperature variability is not influenced by the size of the colony (number of bees or brood amount).
- However, the relationship between brood amount and mean temperature was too weak for clearly discriminating colony population size based solely on the brood thermoregulatory effectiveness.

## Source

Godeau Ugoline, Pioz Maryline, Martin Olivier, Rüger Charlotte, Crauser Didier, Le Conte Yves, Henry Mickael and Alaux Cedric, "Brood thermoregulation efficiency is positively linked to the amount of brood but not to the number of bees in honeybee colonies", 2023, *Peer Community Journal*, 3(e42). https://peercommunityjournal.org/articles/10.24072/pcjournal.270/

# DETECTION OF AN OUTLIER IN A HONEYBEE MINI-APIARY USING UNSUPERVISED MACHINE LEARNING ON CUMULATIVE MASS DATA

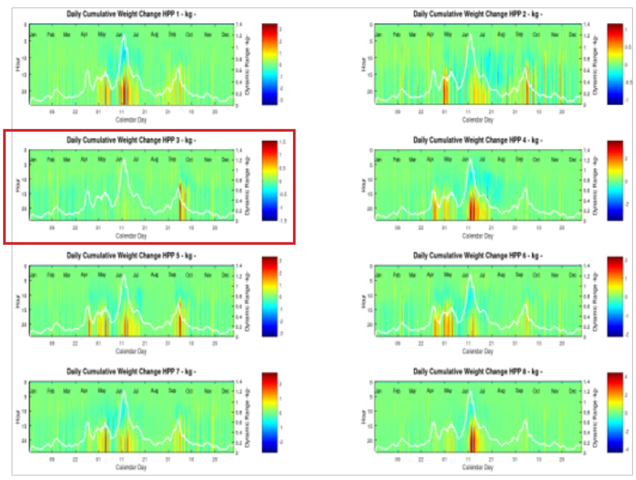
## Background

Placing a scale on one colony in an apiary to assess the nectar flow of the entire apiary has been used for many years by beekeepers. In previous work, it has also been found that the time-course of the mass shows within-day variations directly relating to foraging behaviour. If several colonies have scales, we show that an outlier hive can be determined using an unsupervised machine learning technique, Principal Component Analysis, on a 7-day subset of cumulative mass data, reset to zero every 24 hours (within-day variations).

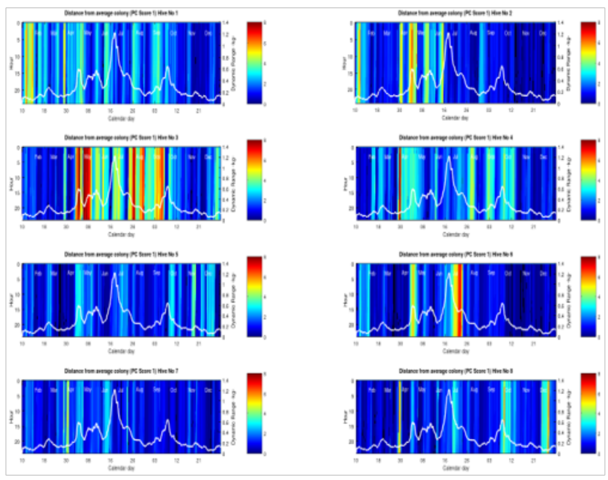
## Objective

Development and validation of a model that predicts the health status of singular colonies by highlighting those that show different mass variation to the average colony within the apiary.

**Within-Day Variations**



**PCA Results**



= Failing Colony

## Take-home messages

- Successfully predicted meaningful outliers due to major colony stressors, i.e. queenlessness, Nosema and Varroa. Does not require subjective definition of health.
- Algorithm outputs stronger results in summer compared to winter because of the high dynamic range of the apiary. Winter output requires sub-set of data longer than 7 days.
- Can be used in future work with supervised machine learning to detect specificity of the feature pertaining to a particular colony disorder.
- Provided a non-invasive technique for predicting unhealthy colonies that becomes increasingly effective as more colonies participate in the subset.

## Source

Detection of an outlier in a honey bee mini-apiary using unsupervised machine learning on cumulative mass data, Chamberlain Luke, Xiaodong Duan, Martin Bencsik, Christopher Topping, Dirk de Graaf, *in preparation.*

# HERITABILITY ESTIMATES OF THE NOVEL TRAIT 'SUPPRESSED IN *OVO VIRUS* INFECTION' IN HONEYBEES (*APIS MELLIFERA*)

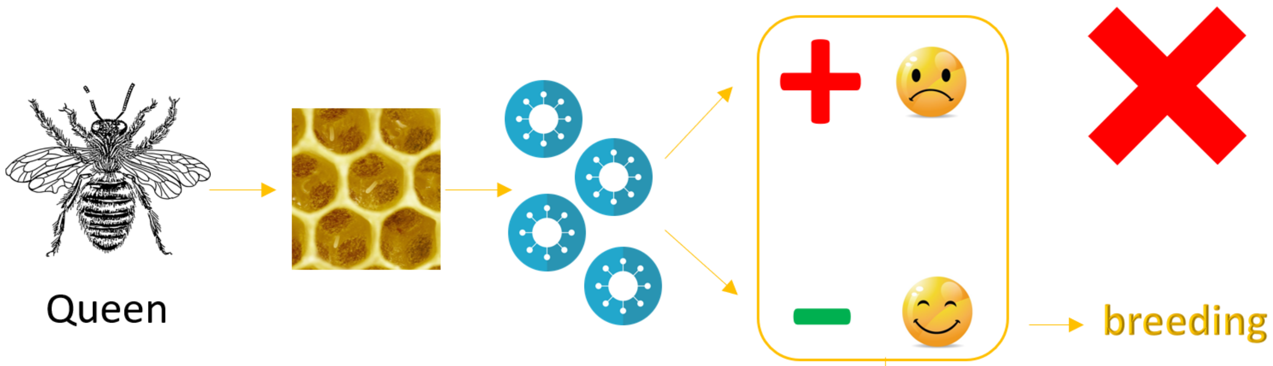
## Background

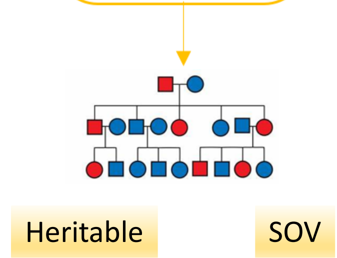
Honeybees suffer the last decades from abnormal high-colony death rates. The Varroa mite and the viruses it transmits are the bees' most important biological threats. So far, this dual infection is mostly focused on the control of the Varroa mite.

The virus infection of a queen can influence her performances and represents an important source of infection for her progeny by vertical transmission. In 2012, Ghent University started a sanitary control of the breeding queens from Flemish beekeepers in the North of Belgium following a non-destructive approach. First, the presence of bee viruses in freshly laid worker eggs was monitored, later we switched over to drone eggs to map the vertical transmission of bee viruses, before finally estimating the heritability.

## Objective

This research aims to estimate the heritability of the virus status of the eggs. We hypothesised that queens that could clear a visceral virus infection and consequently deposited virus-free eggs would pass this predisposition of protective anti-viral immune responses on to their descendants.




## Take-home messages

- A new trait that renders honeybee eggs free of virus infection was discovered.
- This novel trait is called 'suppressed *in ovo* virus infection' (SOV).
- The trait is heritable through the genotype of the queen.
- Estimated heritability is moderate with a value of about 0.25.
- Implementation into breeding programs is recommended.

## Source

de Graaf, D.C., Laget, D., De Smet, L., Claeys Bouuaert, D., Brunain, M., Veerkamp, R.F. & Brascamp, E.W. Heritability estimates of the novel trait 'suppressed in ovo virus infection' in honey bees (Apis mellifera). Sci Rep 10, 14310 (2020). https://doi.org/10.1038/s41598-020-71388-x

# HIGH-THROUGHPUT METHOD FOR GENOTYPING HONEYBEE VARIANTS ASSOCIATED WITH VARROA RESISTANCE

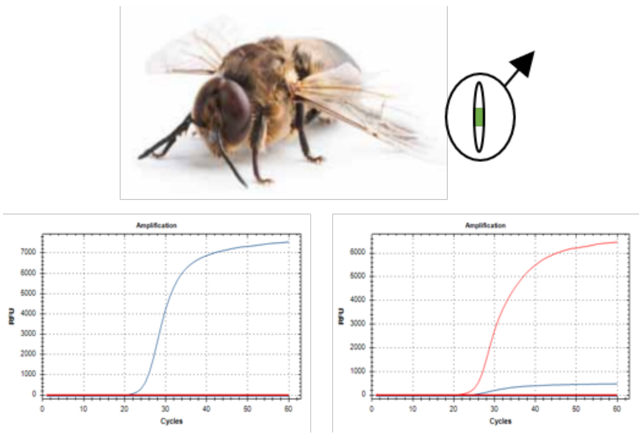
## Background

The varroa mite is one of the main causes of honeybee mortality. An important mechanism by which honeybees increase their resistance against this mite is the expression of suppressed mite reproduction. This trait describes the physiological inability of mites to produce viable offspring and was found associated with eight genomic variants in previous research.

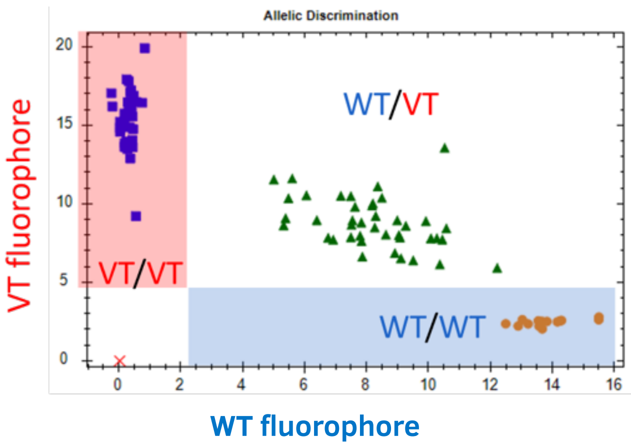
## Objective

Development and validation of a model that predicts the health status of singular colonies by highlighting those that show different mass variation to the average colony within the apiary.

**Genotyping drones**



**Genotyping workers**




## Take-home messages

Implementation in breeding programs:

- Will allow the identification and propagation of colonies with protective alleles;
- Paves the way for marker-assisted selection in breeding programs;
- Will lead to the reduction of varroa treatments;
- Contributes to the resilience of breeding stock.

## Source

Claeys Boúúaert, D., Van Poucke, M., De Smet, L. et al. qPCR assays with dual-labeled probes for genotyping honey bee variants associated with varroa resistance. *BMC Vet Res* 17, 179 (2021). https://doi.org/10.1186/s12917-021-02886-x

# ‘PURRING BEE’ SIGNALS – A NOVEL HONEYBEE VIBRATION DETECTED USING ACCELEROMETER SENSORS

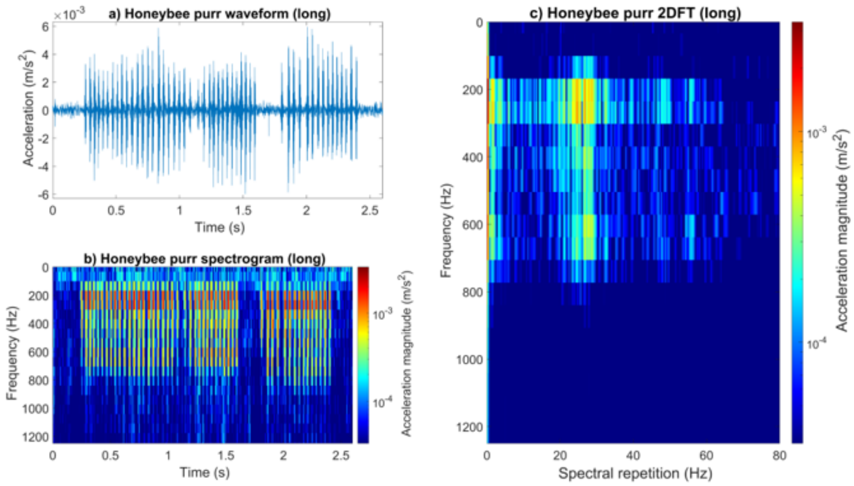
## Background

Honeybees have a large frequency perception range for substrate-borne vibrations (150–900 Hz) and are known to actively build and shape the comb of their hives to promote vibration transmission.

Several honeybee vibrations are known to science, but only a handful have so far been explored and characterised in detail, e.g. the dorso-ventral-abdominal-vibration. Recognising and monitoring a range of honeybee vibrations has the potential to improve our understanding of colony status and activity, which can in turn benefit honeybee colony management, as well as provide interesting fundamental science.

## Objective

We have discovered a novel honeybee vibration that we have coined the ‘purring bee’ signal, as a result of its acoustic features that resemble a high-pitched cat purr. Our objective is to define the features of this vibration and employ machine learning to automatically detect instances of purring bee signals in long-term colony vibrational measurements (for the purpose of identifying patterns in pulse production).




An example of a two-second-long purring bee signal as a waveform (a), spectrogram (b), and two-dimensional-Fourier transform (2DFT) (c).

The vibration repeats itself regularly many times (see the battlements in ‘b’) and the 2DFT (c) is the ideal tool for visualising this spectral repetition frequency (Hz). Here the spectral repetition can be seen at 27 Hz.

## Take-home messages

- We have discovered and characterised a completely novel honeybee vibrational signal.
- Honeybee purring signals are most commonly 0.2 seconds long, but have been recorded up to 20 seconds in length, and they most commonly have a spectral repetition frequency of 22-27 Hz.
- Purring bee signals can be artificially stimulated by gently pressing on a bee’s wing joints.
- We have developed a machine learning technique that discriminates purring bee signals from other common bee vibrations, for the purpose of automatic detection in long-term datasets.
- This exploration will provide long-term statistics on purring bee signal production, perhaps revealing its function under natural conditions.

## Source

Hall, H., Bencsik, M, Characterisation and automatic detection of a novel honeybee vibrational pulse: the ‘purring bee’ signal (manuscript in preparation)

# REMOTE, AUTOMATED DETECTION OF HORNETS AT THE HIVE USING FLIGHT SOUNDS AND MACHINE LEARNING

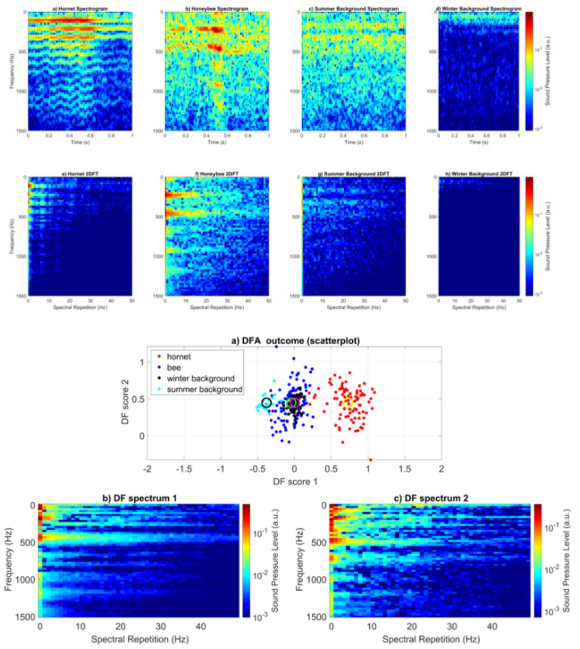
## Background

The Asian hornet (*Vespa velutina*) has recently invaded and spread across Europe and the UK, posing a threat to honeybees: a key prey species for hornets. Current methods of hornet identification for management and control purposes are expensive and/or complex.

Remotely monitoring hornet presence at apiaries would offer fast and simple identification, allowing beekeepers to take quick action. Acoustic monitoring is inexpensive (using microphones) and it is expected that hornet flight sounds will contain features specific to the species for reliable identification.

## Objective

Investigate hornet flight sounds as a remote detection strategy using microphones and machine learning to discriminate these from those commonly encountered at an apiary (honeybee flight sounds, background noise).




The four groups that contributed to the training database:

- Asian Hornet (a, e)
- Honeybee (b, f)
- Summer background (c, g)
- Winter background (d, h)

Each group has specific acoustic features that aid discrimination between the groups. Top and bottom rows are one-second-long spectrograms and 2DFTs, respectively.

Machine learning identified acoustic features that demonstrated high variation between the four groups.

The scatterplot (a) shows the outcome of this discrimination. Asian Hornet (red points) is well discriminated from honeybee and background. Discriminant function images (b, c) show the features that contributed to discrimination (red = strong contribution, blue = weak contribution).

## Take-home messages

- Hornet flight sounds are distinguishable from the other three groups, thanks to using 2DFTs.
- Hornet and honeybee flight sounds contain repeating frequency components, originating from their hovering, that benefit the discrimination process.
- When testing data that did not contribute to the building of the training database, Asian hornets were correctly detected 98.7% of the time.
- This machine learning algorithm has excellent potential for use in detecting hornets at apiaries.

## Source

Hall, H., Bencsik, M., Capela, N., Repeating frequency components in hornet hovering flight sounds promote remote detection in an apiary setting (manuscript in preparation)

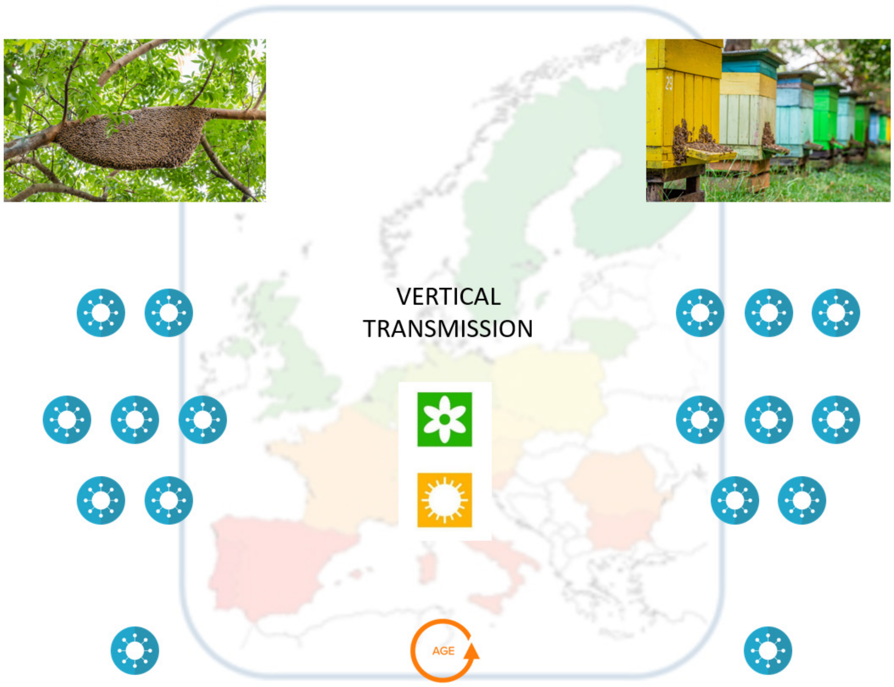
# VIRUS PREVALENCE IN EGG SAMPLES COLLECTED FROM NATURALLY SELECTED AND TRADITIONALLY MANAGED HONEYBEE COLONIES ACROSS EUROPE

## Background

Monitoring virus infections is an important selection tool in honeybee breeding. A recent study showed an association between the virus-free status of eggs and an increased virus resistance to deformed wing virus (DWV) at the colony level.

## Objective

In this study, eggs from both naturally surviving and traditionally managed colonies from across Europe were screened for the prevalence of different viruses, along with an analysis of the effects that queen age and sampling season have on infection patterns in these eggs.




## Take-home messages

- Vertical transmission of DWV was higher in naturally surviving than in traditionally managed colonies.
- Older queens showed significantly lower infection loads of DWV in both traditionally managed and naturally surviving colonies, as well as reduced DWV infection frequencies in traditionally managed colonies.
- Frequencies of DWV and BQCV in honeybee eggs were lower in summer than in spring.
- Honeybee queens have the potential to reduce the degree of vertical transmission over time.

## Source

Claeys Bouuaert, D.; De Smet, L.; Brunain, M.; Dahle, B.; Blacquière, T.; Dalmon, A.; Dezmirean, D.; Elen, D.; Filipi, J.; Giurgiu, A.; et al. Virus Prevalence in Egg Samples Collected from Naturally Selected and Traditionally Managed Honey Bee Colonies across Europe. *Viruses* **2022**, 14, 2442. https://doi.org/10.3390/v14112442

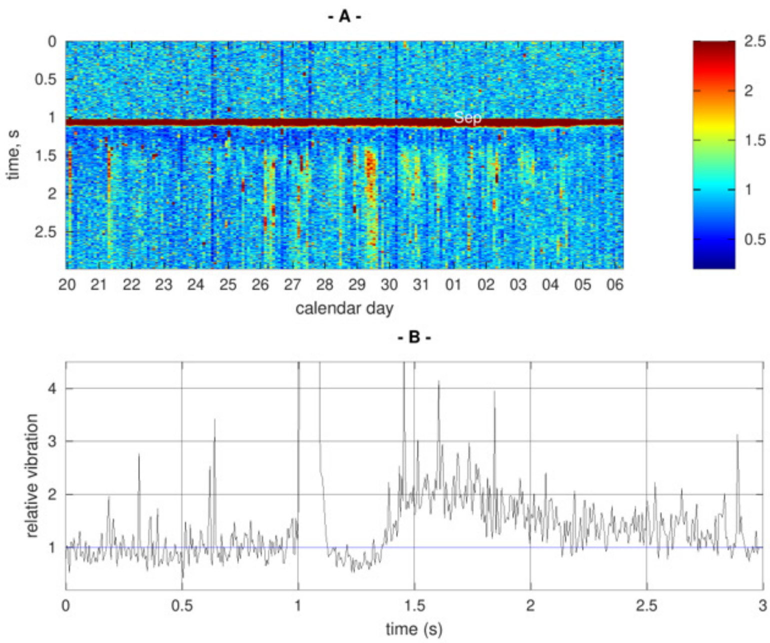
# QUANTITATIVE ASSESSMENTS OF HONEYBEE COLONY'S RESPONSE TO AN ARTIFICIAL VIBRATIONAL PULSE: NON-INVASIVE MEASUREMENTS OF COLONY'S OVERALL MOBILITY AND RESTFULNESS

## Background

European honeybee colonies establish themselves in natural and man-made dark cavities, and cannot usually be seen unless the beekeeper inspects the hive by opening it invasively. Although the traffic of bees at the entrance of the nest gives an indication of its status, in the wintertime all foraging can cease for weeks or even months, and it is not even possible to tell whether the colony is alive or dead. In the past, many beekeepers have been simply knocking on their hives, with their hand, to check and listen for a positive buzzing response, indicating the liveliness of the colony.

## Objective

Development, testing and validation of a quantitative, automated method to knock on a honeybee colony, and measure and interpret the corresponding bees response.




**A:** A collection of three-second-long accelerometer recordings, in late August and early September 2021, with the time of the recording on the horizontal axis, the colour of the pixel intensity conveying the vibrational magnitude relative to that found before the stimulus, and the time relative to the artificial stimulus on the vertical axis. The colour coding has been adjusted to optimise the visualisation of the bees reaction, causing a clipping of the much stronger signal recorded during the application of the short pulse (red horizontal line), which is taking place exactly one second after the start of each recording extract.

**B:** A plot of a particular recording taking place on August 29, 2021 with a remarkably strong colony response.

## Take-home messages

- First implementation of a quantitative, automated 'hive knocking' experiment.
- The short-lived, weak (20%) drop of signal following the knock is a measurement of the colony's overall mobility.
- The long-lived, strong (300%) enhanced signal following the knock has an exponential decay and seems to correlate with the colony's 'restfulness'.

## Source

In preparation.

# QUANTITATING THE LOCAL HONEYBEE HIVE FRAME LOAD USING VIBRATIONAL MODES

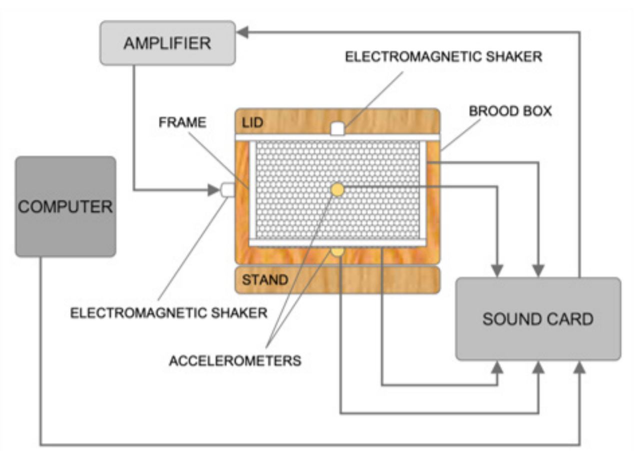
## Background

Honeybees are important pollinators, but their management requires intensive labour. Manual inspection is the most widely used management method, but it is time-consuming, expensive, and stressful for bees and beekeepers. Automatic beehive monitoring is a newer technique that uses sensors to measure the hive environment. It is more efficient and less stressful for bees than manual inspection.

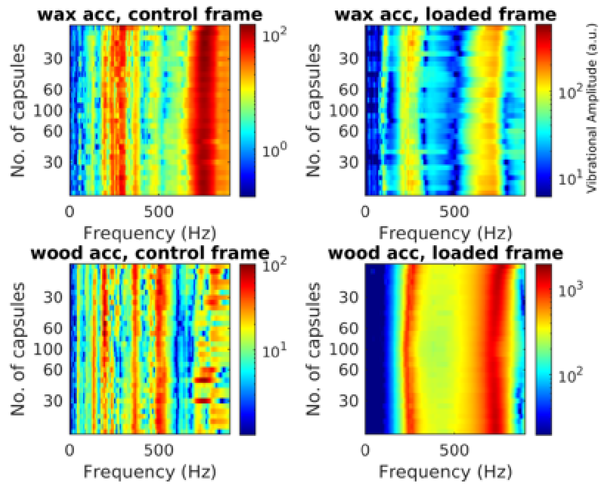
## Objective

Building a system using vibrational modes measurements combined with machine learning, to extract and quantitate the local frame load. Calibrating the system, using capsules loaded with sand and flour to load individual honeycomb cells one by one.

**System Architecture**




**Vibrational spectra of (i) control and (ii) loaded Brood box frames**




## Take-home messages

- The Beekeeper will know the mass density load of his frames without having to open the hive.
- Sensing the mass density might allow the assessment of the content (honey/pollen/brood).
- Will inform the beekeeper when to feed their hives in winter, knowing the amount of Honey remaining in the colony.
- Provides promising economy of (i) inspection efforts (ii) winter food supply.

## Source

Bajare S, Bencsik M, McVeigh A, Capela N, Lumsdon M, 'Quantitating the local honeybee hive frame load using vibrational modes' *in preparation*.

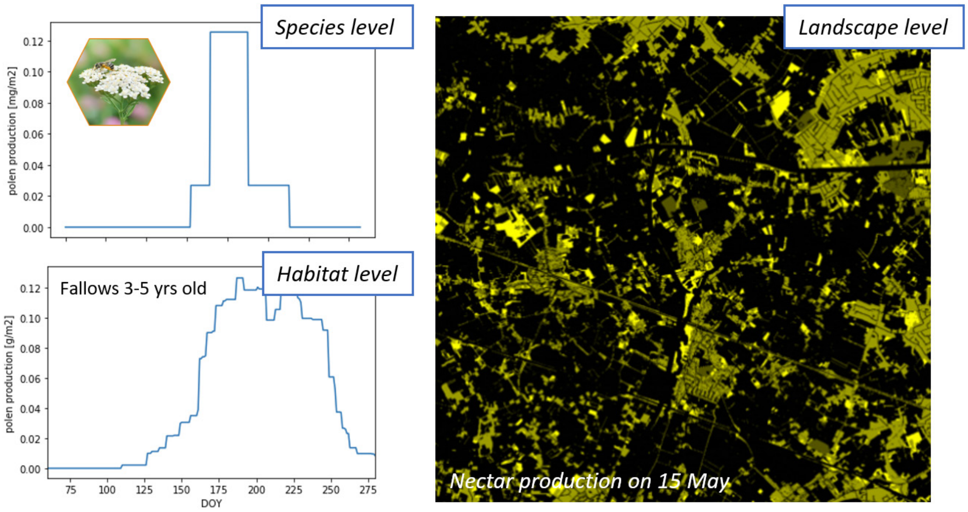
# A MODELLING FRAMEWORK FOR CALCULATING DAILY NECTAR, SUGAR AND POLLEN AVAILABILITY ACROSS HABITATS AND LANDSCAPES

## Background

Together with nectar, pollen is one of the most important food sources for pollinators and contributes to the soil-plant-pollinator pathway of nutrient cycling. Access to balanced food resources is essential for the development, health, and fitness of pollinators. However, changes in the landscape and the associated loss of potential pollinator habitat result in the inaccessibility of key plant species that allow pollinators to thrive.

## Objective

Our aim was to develop models and tools to assess the daily production of pollen, nectar and sugar and their changes throughout the year in different landscape elements/habitat types and crops important for bees across Europe.




## Take-home messages

- Our models integrate information on the composition of 'bee-friendly' plants in different habitat types with data on nectar, sugar, and pollen production per flower unit, number of flower units per unit area, and floral phenology models.
- This allows evaluation of nectar, sugar and pollen production first at the species level, and then upscaling to the habitat and landscape levels.
- Mapping of floral resources and knowing how they change throughout the year could help identify 'hungry gaps' when food supply is not meeting pollination demand. It could help to better understand how farmland, or the landscape in general, can be made more hospitable to pollinators, benefiting the many crops and wildflowers that depend on them.

## Source

Ziółkowska, E.; Walczyńska, A.; Jachuła, J.; Filipiak, M.; Wrzesień, M.; Mikołajczyk, Ł., Sowa, G. A modelling framework for calculating daily nectar, sugar and pollen availability across habitats and landscapes, *in preparation*.

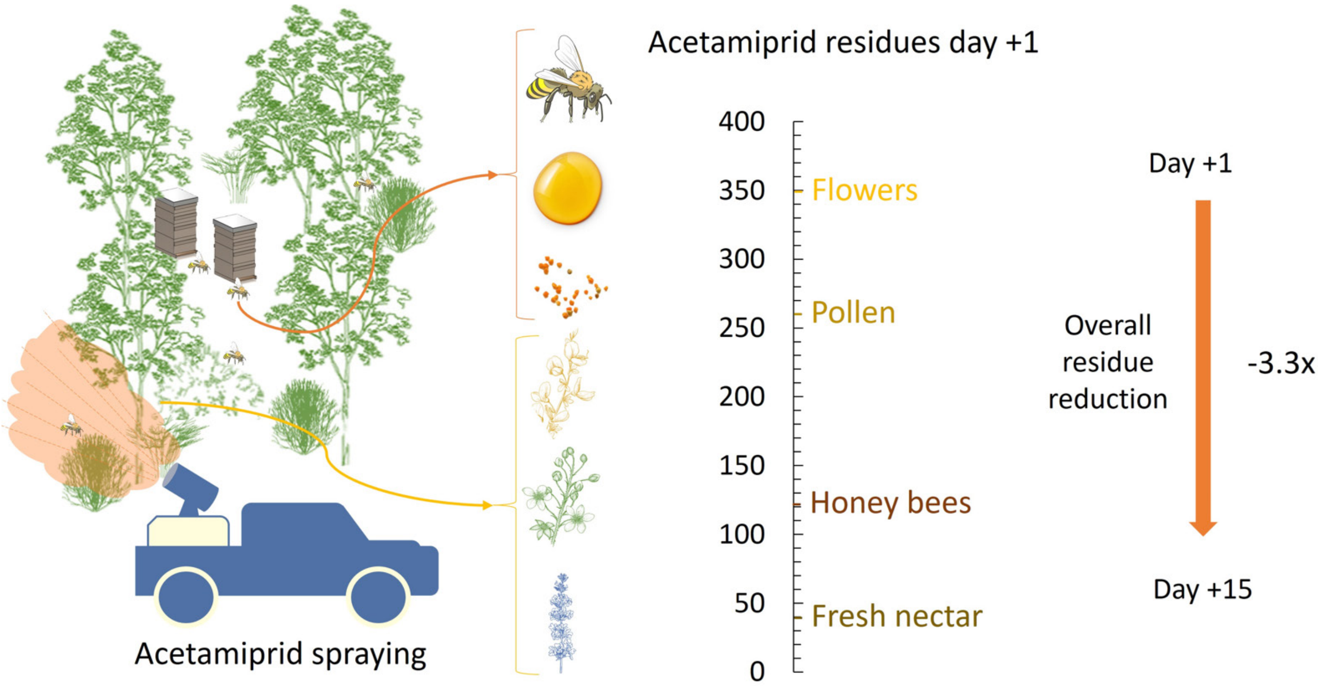
# EXPOSURE AND RISK ASSESSMENT OF ACETAMIPRID IN HONEYBEE COLONIES UNDER A REAL EXPOSURE SCENARIO IN EUCALYPTUS SP. LANDSCAPES

## Background

Colonies are exposed to neonicotinoids and these chemicals have been indicated as one of the causes for colony losses. Acetamiprid is the only neonicotinoid applied outdoors in the European Union, nonetheless, there is still lack of data regarding bees' exposure to acetamiprid in real world scenarios.

## Objective

Measure exposure of honeybee colonies to acetamiprid after a spraying event to calculate their possible negative effects. Test novel methods for the detection of neonicotinoids in colony samples.




## Take-home messages

- Acetamiprid residues were found in samples collected outside the spraying area.
- The amount of residues transported into the colonies increased with the size of the sprayed area.
- According to the calculated Exposure to Toxicity Ratio (ETR) values, spraying up to 22% of honeybees foraging area does not harm the colonies.
- Colony products can be used as a valid tool to monitor colony accumulation of acetamiprid.
- The use of Lateral Flow Devices (LFDs) can be a cheap, fast and easy tool to apply in the field.

## Source

Capela, N., Xu, M., Simões, S., Azevedo-Pereira, H. M., Peters, J., & Sousa, J. P. (2022). Exposure and risk assessment of acetamiprid in honey bee colonies under a real exposure scenario in Eucalyptus sp. landscapes. *Science of the Total Environment, 840*, 156485. **https://doi.org/10.1016/j.scitotenv.2022.156485**

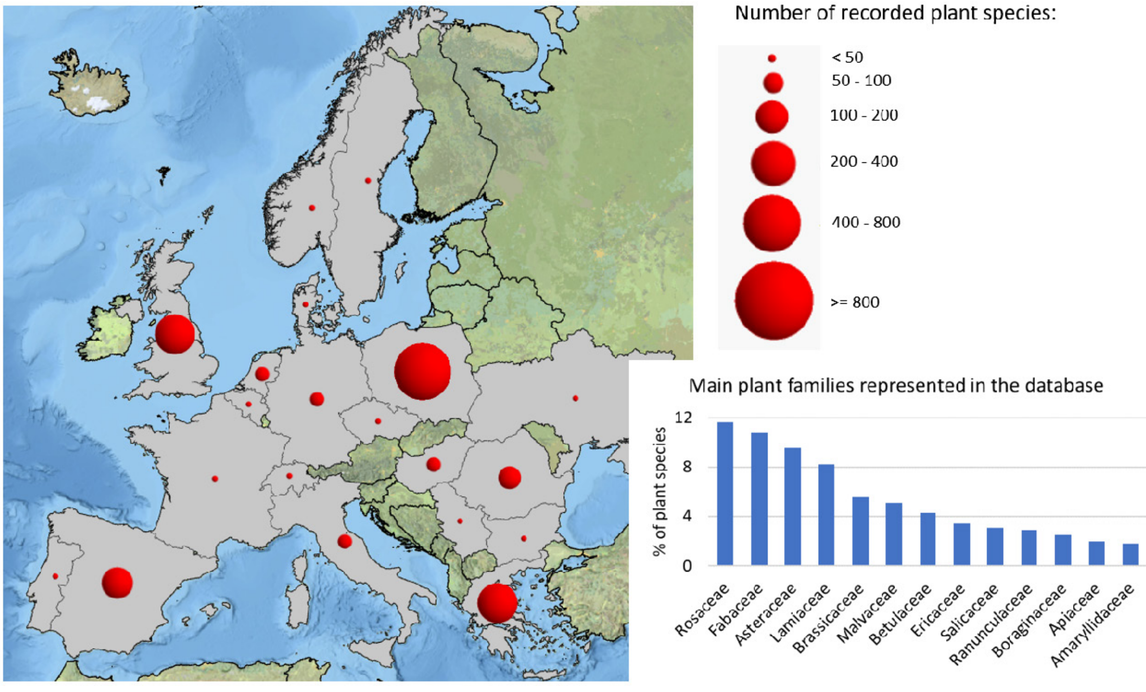
# PHENOLOGY AND PRODUCTION OF POLLEN, NECTAR, AND SUGAR IN 1612 PLANT SPECIES FROM VARIOUS ENVIRONMENTS

## Background

Access to food resources of adequate quantity and quality is essential for the development, health and fitness of honeybees. Beekeepers around the world are facing high colony losses due to, among other things, a reduction in available food resources.

## Objective

Our goal was to collect detailed data on the pollen, nectar, and sugar production per unit area and the flowering phenology of plants necessary to predict the quantity and quality of food available to pollinators in various habitats and landscapes over time.




## Take-home messages

- Our database represents the first compilation of data on the various food resources produced by 1612 plant species belonging to 755 genera and 133 families.
- The dataset consists of 103 parameters related to the traits of plant species and geographical and environmental factors, allowing for precise calculations of the amounts of nectar, pollen, and energy provided by plants and available to consumers in the considered habitat or ecosystem on a daily basis throughout the year.
- Our database provides a unique opportunity to test hypotheses related to the functioning of food webs, nutrient cycling, plant ecology, and pollinator ecology and conservation.

## Source


Filipiak, M.; Walczyńska, A.; Denisow, B.; Petanidou, T.; Ziółkowska, E. Phenology and production of pollen, nectar, and sugar in 1612 plant species from various environments. *Ecology* 2022, 103, e3705. **https://doi.org/10.1002/ecy.3705**

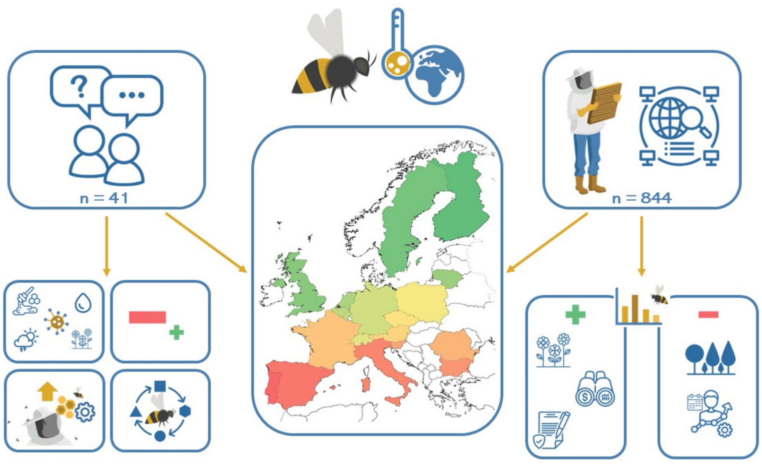
# BEEKEEPING IN EUROPE FACING CLIMATE CHANGE: A MIXED METHODS STUDY ON PERCEIVED IMPACTS AND THE NEED TO ADAPT ACCORDING TO STAKEHOLDERS AND BEEKEEPERS

## Background

The beekeeping sector is suffering from the detrimental effects of climate change, both directly – due to drought stress, altered seasonality, heavy rain events and increasing mean temperatures – and indirectly – through climate change induced fluctuations in other (plant and animal) species. Despite numerous studies conducted on this subject, large-scale research incorporating stakeholders' and beekeepers' perspectives has remained elusive.

## Objective

To assess the extent to which stakeholders involved in the European beekeeping sector and European beekeepers perceive and experience the impacts of climate change on their operations, and whether they had to adapt their practices accordingly via a mixed methods study including in-depth stakeholder interviews (n = 41) and a pan-European beekeeper survey (n = 844).

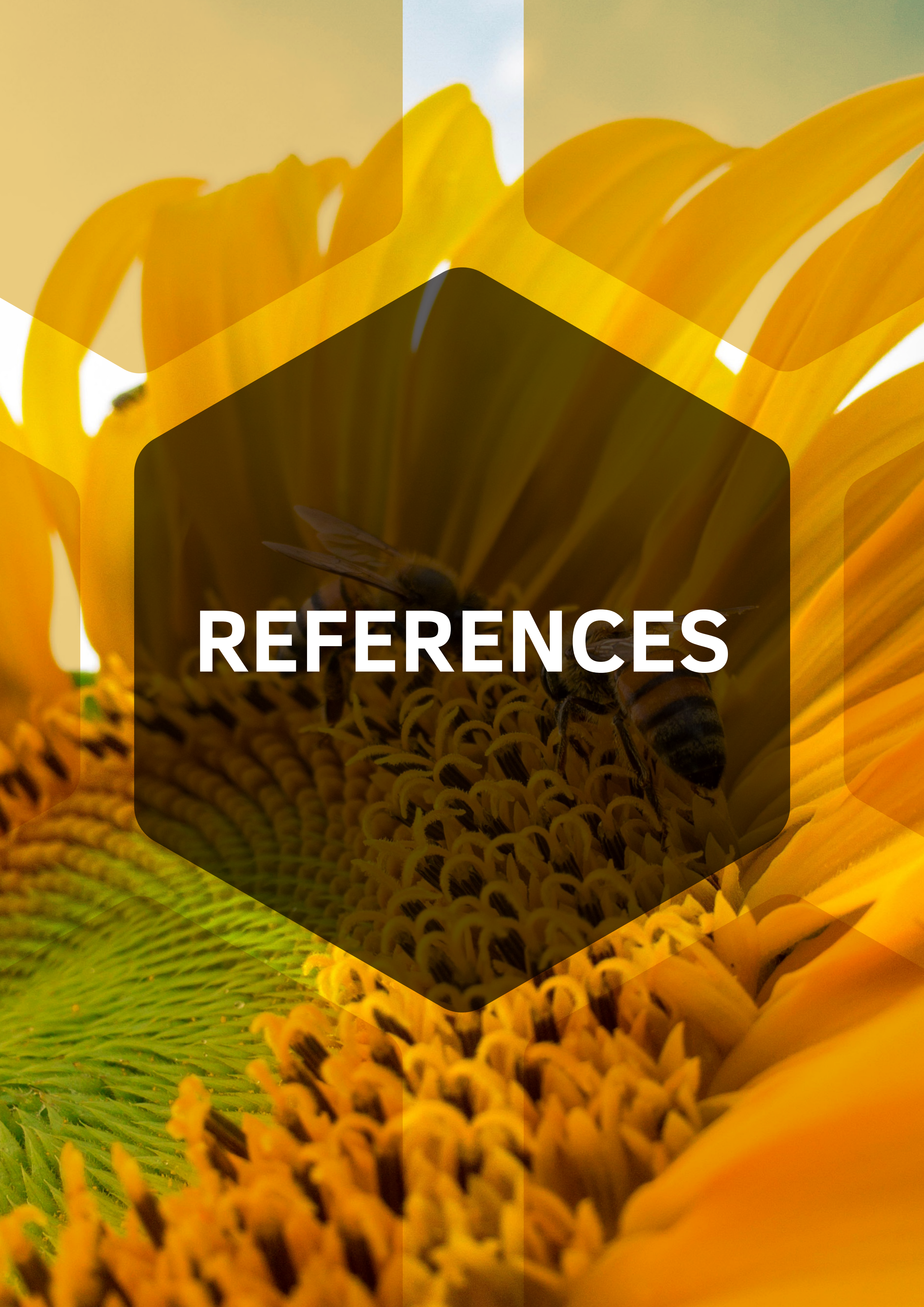



## Take-home messages

- Climate change is clearly perceived to be impacting beekeeping in Europe.
- Climate change impacts are likely to create winners and losers within the beekeeping sector.
- Major climate change impacts concern local weather conditions and food resource availability.
- Climate change impacts are associated with lower honey yield and higher colony winter loss.
- Southern, professional and 'forest' beekeepers are more likely to classify as heavily impacted by climate change.

## Source

Van Espen, M., Williams, J. H., Alves, F., Hung, Y., de Graaf, D. C., & Verbeke, W. (2023). Beekeeping in Europe facing climate change: A mixed methods study on perceived impacts and the need to adapt according to stakeholders and beekeepers. *Science of the Total Environment, 888*, Article 164255. https://doi.org/10.1016/j.scitotenv.2023.164255



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