6. Data linking for bee health

6.1 Focus of the use case

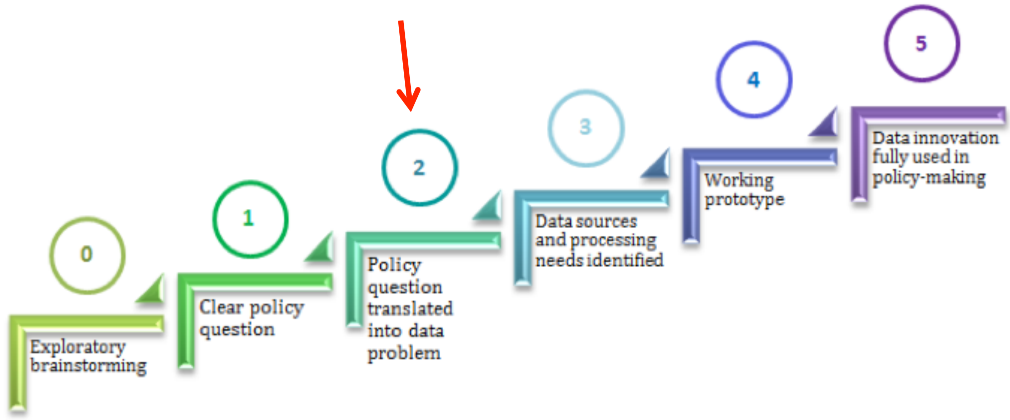
This use case considers the opportunity to develop shared data and visualization tools related to the health of bees for improved policymaking in a variety of areas, including agricultural policy, economic policy, and science policy.

Over the past 10 to 15 years, beekeepers have been reporting unusual weakening of bee numbers and colony losses, particularly in Western and Southern European countries including France, Belgium, Switzerland, Germany, the UK, the Netherlands, Italy and Spain. No single cause of declining bee numbers has been identified. However, several possible contributing factors have been suggested, acting in combination or separately. These include the effects of intensive agriculture and pesticide use, starvation and poor bee nutrition, viruses, attacks by pathogens and invasive species – such as the Varroa mite (*Varroa destructor*), the Asian hornet (*Vespa velutina*), and the small hive beetle (*Aethina tumida)* and environmental changes (e.g. habitat fragmentation and loss).

The policy implications of bee health are enormous. From the economic point of view, both agricultural employment and food security more broadly are intricately tied to the ability of bees to pollenate crops, and the inability of bees to pollenate crops can result in price increases for the consumer in additional to job losses all across the food supply network. From an environmental point of view, bee health is not only a bellwether for changes in the environment which may also effect other organisms, but bee behaviour is highly predictable and can be used to measure, for instance, changes in seasonality over time, flora diversity in rural and urban settings, migration of invasive species, and other topics.

This use case focuses on the opportunity that the collection of multi-level data related to bee health can improve policymaking at local, national and European levels. From a design perspective, this use case can be considered to have reached step 2: the policy question is translated into a data problem, but the data sources and processing needs and opportunities need some further consideration. As we will discuss below, we have built a demonstrator based on the bee health problem as part of this project, but one of the issues that became clear in the building of the demonstrator was the lack of available data to build a fully working prototype.

Figure 12 Scale for assessing the maturity of use cases



6.2 The rationale

Since the mid-1980s, biodiversity conservation on farmland has been approached largely through incentivising land managers to carry out specific farming practices through payments under agri-environment schemes, mostly within the framework of EU rural development policy. In some situations, results-based payment schemes have been shown to have a significant potential for delivering targeted and verifiable biodiversity outcomes in a cost-effective way. The evidence suggests that results-based schemes are particularly advantageous where management measures need to be tailored to local, or even farmholding specific, conditions to produce optimal results for biodiversity (IEEP, 2014). For pollinators such as bees too, these measures are relevant because research demonstrates a strong positive correlation between plant species diversity in grasslands and pollination (Albrecht et al, 2007) and pest control functions (Balvanera et al, 2006).

6.3 The policy context

Past and present research and risk assessments relating to honeybee health have identified the importance of multiple stressors and the need to take a holistic approach to the understanding of colony decline and bee health. The resultant policy objectives in the area of bee health therefore include the development of a deeper understanding of the importance and inter-relation between multiple stressors, as well as the early detection of distress and colony health impairments.

Ultimately, these insights should be to design more efficient and targeted interventions for risk managers. The ultimate outcome is to reverse the observed colony decline.

Policy and legislation on apiculture targets consumer health (honey quality, labelling, pollutants), agricultural output (bees provide essential pollination for crops) and apicultural production (of honey, beeswax, pollen, propolis, etc). Biodiversity policy also plays a role for apiculture as both wild and cultivated bee populations continue to struggle, but is not specifically targeted towards bees. Regulations for allowed plant protection products (e.g. EC Regulation 1107/2009) are actively updated based on the latest knowledge on their ecological impact, including that on pollinators such as bees.

The most relevant policy for apiculture is the European support for national apiculture programmes set out in EC Regulation 1234/2007 and further detailed in EC Regulation 917/2004. This policy provides up to 50% of national expenses on apiculture support, capped at the European level around €33m, divided over Member States proportional to the national bee population sizes. Eligible support actions are:

1. Technical assistance to beekeepers and groupings of beekeepers;
2. Varroasis control;
3. Rationalisation of transhumance (colony migration);
4. Measures to support laboratories carrying out analyses of the physicochemical properties of honey;
5. Measures to support the restocking of hives in the Community; and
6. Cooperation with specialised bodies for the implementation of applied research programmes in the field of beekeeping and apiculture products.

The bee health demonstrator that is developed in our project[47] can give a meaningful contribution to actions 2, 3 and 6. Further development of the demonstrator could benefit from actions 1 and 6. Additional (European) support is present in the form of an array of research and innovation programmes, many of which take into account a multiple factor approach to assess colony mortality.

6.4 The data process: from data collection to analysis and visualisation

The associated data problem concerns primarily the monitoring and ex post evaluation phase of the policy cycle. In addition, insights can feed back into policy design and policy adaptation.

Low-cost sensor technologies have existed for some time to monitor honeybee colonies. Typical target parameters include acoustic signals (intensity and spectrum), temperature, humidity, and, in some cases chemical signals. Sensors are typically attached to a beehive, and some manual calibration is likely necessary to adjust each sensor to the specificities of the beehive. A more recent approach is fitting tiny sensors to bees themselves.[48]

While such sensor technologies exist, they have been deployed typically in relatively small, regional or local experiments, and mostly not connected to a common data infrastructure. A large-scale cross-EU honeybee monitoring infrastructure could allow real-time, or near real-time monitoring of colony health and number indicators, across various climatic regions.

The potential benefits of such a platform include the ability to detect large-scale patterns, trends and correlations in multi-dimensional data sets and across varying geographies that have hitherto been inaccessible. Modern approaches to data analytics could facilitate new types of hypothesis generation and verification beyond the current state of the art.

Earlier detection of colony stress is potentially possible, e.g. through machine learning approaches in detection of patterns in the sensor data. Furthermore, the effectiveness of policy interventions can be tested against real time data collected through the monitoring infrastructure.

Data streams should be made available as standardized open data to facilitate involvement of the broad scientific community, and the design of the entire process should involve all stakeholders, including beekeepers themselves in the feasibility phase.

Data sources

Based on current research, legislation, and data availability, three different scales have been identified at which a data-driven approach could be beneficial for policy evaluation.

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[47] The publication of the demonstrator will be announced via www.data4policy.eu
[48] http://www.csiro.au/en/News/News-releases/2015/Honey-Bee-Health

Microscale

The microscale concerns individual hives, and related data collected through sensors and direct observation. Such microscale sensor data would not be directly relevant for policymakers at the European level. However, mandatory reporting of colony infections could be done through a data platform, and support measure #2 (varroasis control) would benefit from geographically logged infection reports. Platforms (not yet in existence) would allow for filling in standardised colony surveys linked to the hive that contains the sensor equipment. Measured observables would then be linked to visual and laboratory inspections, which would allow for varroasis control and aggregated scientific analysis of sensor data with survey data. To this end, support measure #1 (technical assistance) would allow for support for installing monitoring equipment in hives.

Precision apiculture systems could be integrated in crowdsourcing, user-generated content platforms (e.g. users entering information on what crops grow near the hive, flowering periods, environmental disturbances). Such platforms would be able to integrate data from beekeepers, to be used for analysis at higher geographical, and organizational scales. For example, beekeepers can log what kind of intervention they applied to what hive and when, combined with their assessment of the results in a standardised survey. This allows for analysis of effective practices on aggregated level. At the same time, open data concerning weather, pesticide usage, and land use can be imported into apiculture systems, to provide beekeepers with analytics tools to better understand the state of their beehives in context.

Mesoscale

The mesoscale concerns groups of hives that are in each other's interaction radii. This means that bees from hives within the same mesoscale group can interact with each other (compete for food, rob hives, transmit pathogens) and are influenced by the same environmental factors (food availability, pollution, pesticides and weather). Typically the hives in the same mesoscale group would fall within a 5 km radius as bees forage for at most 3-4km around their hive.

Since the mesoscale reports on the location and context of groups of hives, the most relevant support measure at this scale is #3 (rationalisation of colony migration). Colony migration practices are not logged, and beekeepers are not formally informed of movements and presence of other beekeepers' hives. Colony migration introduces costs for fuel and risk of loss of colonies (Deloitte, 2013) while arguably an optimal spread of hives throughout foraging areas maximises pollination and minimises food competition among pollinators.

As bee health can be a proxy indicator for environmental factors, health information about colony clusters may indicate food scarcity or environmental decline. Food scarcity is indicated through steady decline of hive weight combined with continued foraging activities for a cluster of hives. Environmental degradation may be indicated by hive mortality throughout the cluster without indications of scarcity (e.g. evidence of nearby acres with flowering crops).

For the agri-environment schemes discussed above, a results-based remuneration exists for farmers to apply certain practices that promote environmental targets, such as biodiversity. The effect of practices that promote biodiversity can be measured by monitoring the status of colonies in fields that have these schemes applied versus similar fields that do not. Besides possibly basing the remuneration on an indicator that contains, among others, bee population data, one could also assess what practices in results based agri-environment schemes yield best results.

Macroscale

The macroscale is the largest scale for analysis available in a potential apiculture platform. Logical groupings for the macro scale would be the regional and the country level. Many statistics are available at this level, although there is significant variation in national policy between European Member States. Here it can be added already that the scales encompass the range of policymaking interventions that data can allow: for example, if a European-level policy initiative is aimed at a subnational region (for example, Oxfordshire), then tools should be able to aggregate micro- and meso-level, and come down from the macroscale of the national level down to a more regional level.

At the macroscale, analytics tools that don't yet exist could allow policymakers and the general public to explore relevant aggregated data on the state of beehives, and related factors discussed above, to discuss relevant policies and evaluate their impact. An integrated data platform would afford the combination and visualization of relevant open data, freely available through the internet, with crowdsourced information on beekeeping, as discussed above. In the long term, a collaborative sense making platform can be envisioned, where the general public would be able to interact and construct their own analysis and visualizations, to foster public discussion on practices and policies.

The table below summarises the most important aspects at each scale.

	Scale		
	Micro	*Meso*	*Macro*
Policy and regulation	• technical assistance • varroa infection control	• transport and migration regulations for bee populations • rationalisation of hive relocation • honey impurities and labelling requirements • mandatory reporting of selected pathogens (varroa) • Measurements for local biodiversity policy effects	• pesticide usage and control • agricultural output by pollinated crops • honey production • measures to support restocking of hives • cooperation with specialist bodies for the implementation of applied research programmes in the field of beekeeping and apiculture product • support for laboratories on honey analysis
Scientific Research	• precision apiculture	• studies of largescale • ecosystems	• impact of pathogens, pesticides, and climate
Data	• weight, hive temperature and acoustic sensors • local climate sensors • beekeeper survey data	• beekeeper survey data • local biodiversity data	• pesticides import/export and use • weather, climate • land use and crop selection
Users and stakeholders	• bee keepers • farmers • researchers	• bee keepers • farmers • researchers • policymakers	• researchers • policymakers

6.5 Reflections on challenges and next steps

The bee health use case is being developed as a demonstrator as part of this project. We are developing an interactive demonstration of some of the ideas set out in this use case. The principal goal will be to show how merging big data sets at different spatial and temporal resolutions can lead to a clearer understanding of the factors affecting bee heath, and better prediction of the effects of possible changes in policies. The demonstrator will have screens showing relevant data at different levels: micro (hive-level, such as hive activity/status, ambient environmental variables), meso (local neighbourhood and regional, such as local weather, crop status, competing hives, pesticide use) and macro (national and EU-wide, such as land use, pesticide use policy). These should enable analysts (hive keepers, local and regional advisors, researchers and national government experts) to understand how integration of diverse but interrelated big data sources can enhance understanding and decision-making. The demonstrator will be built as a stand-alone website which imports data from selected relevant sources and shows visualizations of the interrelationships between them. Given the very limited resources available, it should be stressed that this will not be a prototype, i.e. it will not be built as the first stage in the development of a deployable application. Rather, its goal will be to illustrate what is possible and which approaches can be taken to the design of a future deployable system.

Beyond this small demonstrator project, visualizing and making accessible data at various scales can be of potential use in many ways to enable policymakers to make decisions and to interact with different stakeholders. A number of concepts and data-driven approaches explored in the field of bee health are also of relevance for other societal challenges and policy areas.

Further reading

European Food Safety Authority topic "**bee health**": http://www.efsa.europa.eu/en/topics/topic/beehealth

http://ec.europa.eu/food/animals/live_animals/bees/index_en.htm

EPILOBEE (https://sites.anses.fr/en/minisite/abeilles/epilobee) was a pan-European voluntary surveillance programme involving 17 member states.

MUST-B is an ongoing European project (2014-2019) on risk assessment on multiple stressors in bees that will produce annual updates in the area of bee health (http://ec.europa.eu/dgs/health_food-safety/dgs_consultations/docs/summary_20141029_bee_health_pt2_en.pdf)

Build the Buzz (http://buildthebuzz.co.uk/) is installing up to 400 sensor arrays in bee colonies across the UK by spring 2016 as the first system in the world to gather systematic data about bee health at a national level. Arnia director George Clouston describes the idea of establishing sentinel apiaries, which can be systematically tracked and monitored over time to enable stronger and more reliable data to improve both the act of beekeeping, but also the science and policy related to bee health. There is the potential to learn from this project with an eye toward scaling this up to a pan-European or international level in the future.

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