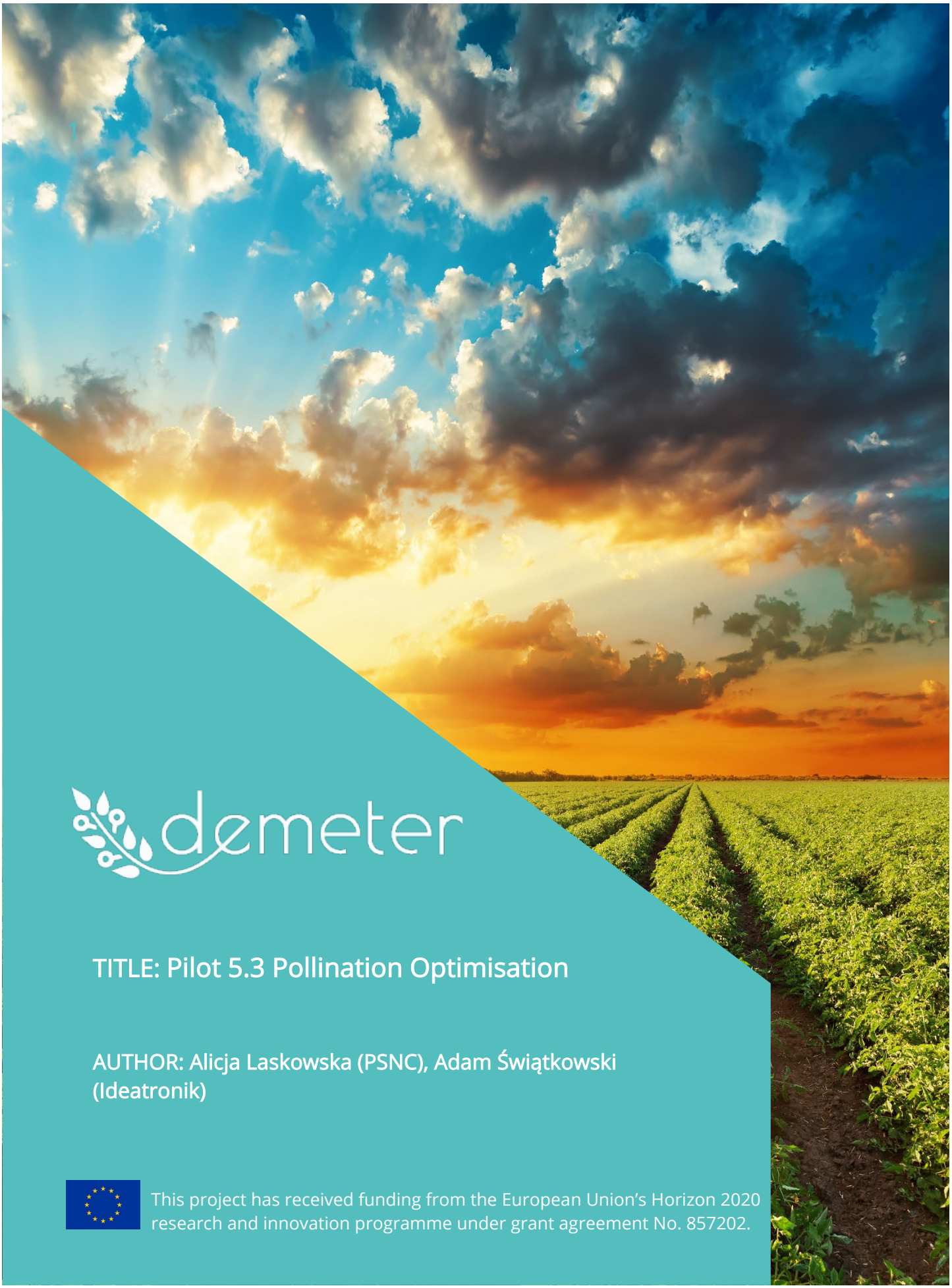

TITLE: Pilot 5.3 Pollination Optimisation

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Pilot 5.3 – Pollination Optimisation

1 Introduction

DEMETER aims to lead the Digital Transformation of the European agrifood sector based on the rapid adoption of advanced technologies, such as Internet of Things, Artificial Intelligence, Big Data, Decision Support (DSS), Benchmarking, Earth Observation, etc., to increase performance in multiple aspects of farming operations, as well as to assure the viability and sustainability of the sector in the long term. It aims to put these digital technologies at the service of farmers using a human-in-the-loop approach that constantly focuses on mixing human knowledge and expertise with digital information. DEMETER focuses on interoperability as the main digital enabler, extending the coverage of interoperability across data, platforms, services, applications, and online intelligence, as well as human knowledge, and the implementation of interoperability by connecting farmers and advisors with providers of ICT solutions and machinery.

DEMETER focuses on the deployment of farmer-centric, interoperable smart farming-IoT (Internet of Things) based platforms, to support the digital transformation of Europe's agri-food sector through the rapid adoption of advanced IoT technologies, data science and smart farming, ensuring its long-term viability and sustainability.

Twenty real-world pilot projects, grouped into five pilot clusters, are running within DEMETER to demonstrate and evaluate how agricultural innovations and extended capabilities benefit farmers, technology providers, and society. The topics, scope and size of the pilots are diverse, from saving resources, such as water and energy, to a more environmentally compatible crop management with reduced application of fertilisers and pesticides, to improved animal welfare and the tracing of complete supply chains.

This white paper describes the pilot "Pollination Optimisation in Apiculture". This pilot aims to improve the remote monitoring of mobile apiaries to provide decisive information for beekeepers and support cooperation between farmers and beekeepers to protect bees and optimize the pollination of crops.

2 Importance of digital agriculture

Digital technologies can compile large amounts of information and offer site-specific management guidelines to help improve production efficiency, animal welfare or reduce environmental damage. To overcome difficulties in getting farmers to adopt digital technology, the DEMETER pilots define experiments in which stakeholders test technologies and understand their benefits for the management of on-farm and post-farm (supply chain) activities. Cluster 5 aims at a cross-sectorial approach to address the complete food supply chain. The cluster's four pilots focus on four different areas, considering fruits & vineyards, apiculture, cattle and poultry. Pilot 5.3 focuses on pollination optimization and aims at providing not only a digital solution for beekeepers for remote apiary monitoring, but also a cross-sectorial interoperability mechanism connecting farmers and beekeepers.
In an online survey conducted in 2019 as part of the pilot, **the majority of respondents admitted that they use some kind of technology, such as mobile apps, an office suite or services accessible via the Internet at least to save critical information** regarding farm or apiary management. Only about 38% of farmers and 28% of beekeepers admitted that they do not use any digital applications or programs to support their farm or apiary management.

In the same survey, about 50% of beekeepers and only 36% of farmers admitted that they had ever cooperated on pollination. The main reasons for the lack of cooperation from the farmers' point of view include lack of contact to interested beekeepers (55%), fear of accidental bee poisoning (24,7%) and existing apiaries already nearby (22,6%). Beekeepers also point to lack of contact with willing farmers (55,9%), fear of accidentally poisoning bees through improper use of pesticides (50%) and fear of leaving hives unattended e.g., in the context of theft (38%). These factors influencing pollination can be partially overcome with the use of digital technologies. **In the pilot survey, about 72% of beekeepers and about 30% of farmers described the importance of supporting electronic communication between beekeepers and farmers in the scope proposed by the pilot as very important to them**.

3 Pilot Overview

The main challenge tackled by the pilot is to protect the honeybees to ensure optimal pollination services for crop production. Pollination is the highest agriculture contributor to yields worldwide, contributing far beyond any other management practice (Why bees matter, FAO, 2018). Furthermore, honeybees are the most economically valuable pollinators of crop monocultures in the world (Klein, 2007). Significant differences in the number of bee colonies per 1 km2 across different regions may indicate that they are not optimally located for pollination. This can result in lower crop yields and a lack of sufficient and varied food for bees. The lack of cooperation between farmers and beekeepers may also lead for example to accidental poisoning of bees. According to a recent report (The beekeeping sector in Poland in 2020), in 2020 nearly 26,000 colonies were affected by the poisoning due to use of plant protection products.

The main goal of the pilot project is **to improve the remote monitoring of mobile apiaries** to assist beekeepers in looking after apiaries **and to foster cooperation between farmers and beekeepers** by developing a unified communication mechanism connecting farm and apiary management systems.

Attempts in this direction can be observed in some countries (e.g. Germany, UK), where, for example, services for ordering pollinators or exchanging information between farmers and beekeepers on the use of insecticides in crops have been created. However, these services require both farmers and beekeepers to register in these services and update the data manually. The approach proposed in the pilot is to build a reusable web service that allows to exchange data between different apiary and farm management systems used by beekeepers and farmers in everyday work, thus reducing the needed effort from the end user perspective.

Figure 1. Mobile apiary located on a rapeseed crop (photo by Mateusz Sikora)

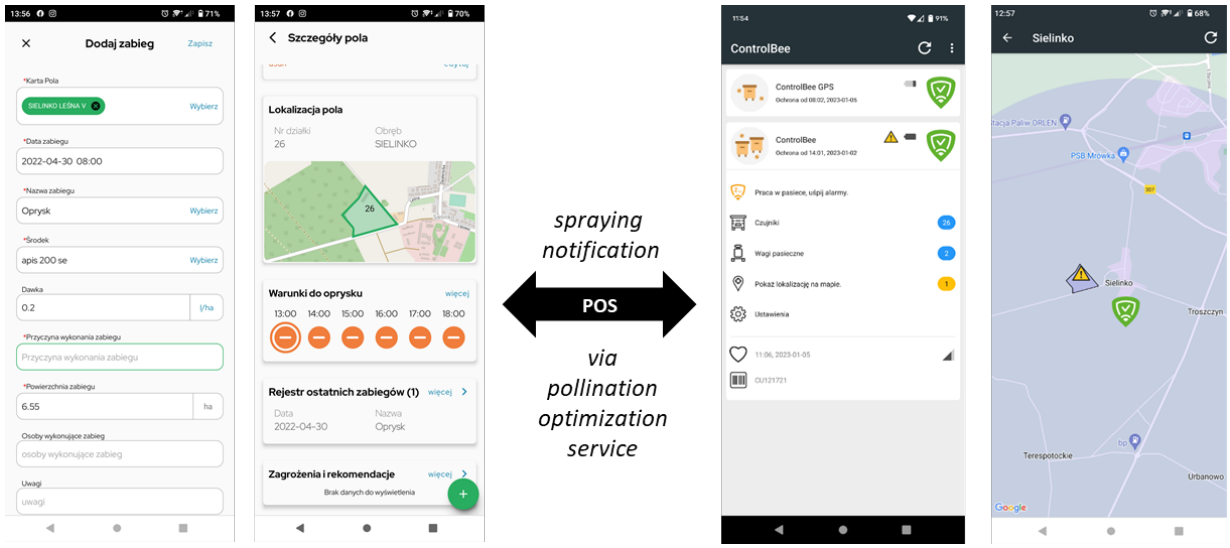
In this pilot, the **Poznań Supercomputing and Networking Center** (PSNC), **Wielkopolska Agricultural Advisory Center** (WODR) and **IDEATRONIK** (ControlBee) make a joint effort to develop a solution to support the optimization of pollination by honeybees, supporting beekeepers and farmers.

First, we build a **technology to support remote monitoring of apiaries**, using and improving a prototype IoT system (ControlBee owned by IDEATRONIK) for this purpose. Such a monitoring solution allows us to better supervise apiaries set up in farmers' fields for pollination purposes as well as monitor hives and bees welfare during the wintering without disturbing the bees. The apiary monitoring solution is deployed and tested in Poland in 4 apiary farms of different sizes located in the Wielkopolska region. Each apiary is equipped with: an apiary control unit, hive scale(s), shock and humidity sensor, autonomous shock sensors with GPS location and 25 shock and temperature sensors.

Figure 2. Improved apiary monitoring solution (photos by Mateusz Wigura, Mateusz Sikora)

Secondly, we develop a prototype **data exchange component for apiary and agricultural management systems** used by farmers and beekeepers, called a pollination optimization service. The pollination optimization service (owned by PSNC) is the central part of the pilot solution providing a unified communication mechanism (via a programming API) for farm and apiary management systems. It allows for management and exchange of the beekeeping and farm information important for pollination, including apiaries' real-time location, hives data (e.g. weight), and farming activities like planned sprayings (based on the information from farmers). The service allows for example: to estimate the number of bee families needed to effectively pollinate a particular crop, facilitating contact with beekeepers interested in transporting hives to honey crops, and to inform beekeepers about planned sprayings and alerting farmers about apiaries within the flying distance.

Finally, the ControlBee apiary management system and **the Polish nationwide farm management system** (eDWIN Virtual Farm) **have been integrated** to exchange information via the pollination service. The eDWIN Virtual Farm management system, developed jointly by Wielkopolska Agricultural Advisory Center and Poznań Supercomputing and Networking Center, is part of a new national Internet Platform of Consulting and Decision Support in Integrated Plant Protection[1], released last year, and is a public service provided to all Polish farmers free of charge. Thanks to the integration with the pollination optimisation service the eDWIN farming system promotes more pollinator friendly agricultural practices e.g. by reminding farmers to use plant protection products in accordance with best practices.



Spraying planning in farm management system (eDWIN WG)

Spraying notification in apiary management system (ControlBee)

Figure 3. Exchange of information on sprayings between the farm and apiary management systems.

4 DEMETER Integration

The pilot takes advantage of some of the enablers provided by the DEMETER project. One of the key ones is **EstimateBeehive** which is a domain specific enabler that provides an estimated number of beehives required to optimally pollinate a crop field. Moreover, the pilot uses the **Agricultural Information Model (AIM)** together with Data preparation and integration enablers to enhance semantic interoperability of the pollination optimization service and the integrated systems and enable semantic mapping of data with other services. Thanks to these enablers key concepts of the solution (e.g. crop type names) are described with AGROVOC taxonomies to easily and properly map them between the different services and systems (e.g. for integration with the EstimateBeehive enabler).
Finally, **core DEMETER technical components and enablers** such as: Stakeholders Open Collaboration Space (SOCS), DEMETER Enabler Hub (DEH), Brokerage Service Environment (BSE) and Access Control Server (ACS), together with related data model enablers for security, privacy and data management, are used to enable sharing information about the pilot activities, partners and services/endpoints with providers and consumers of other components in DEMETER ecosystem.

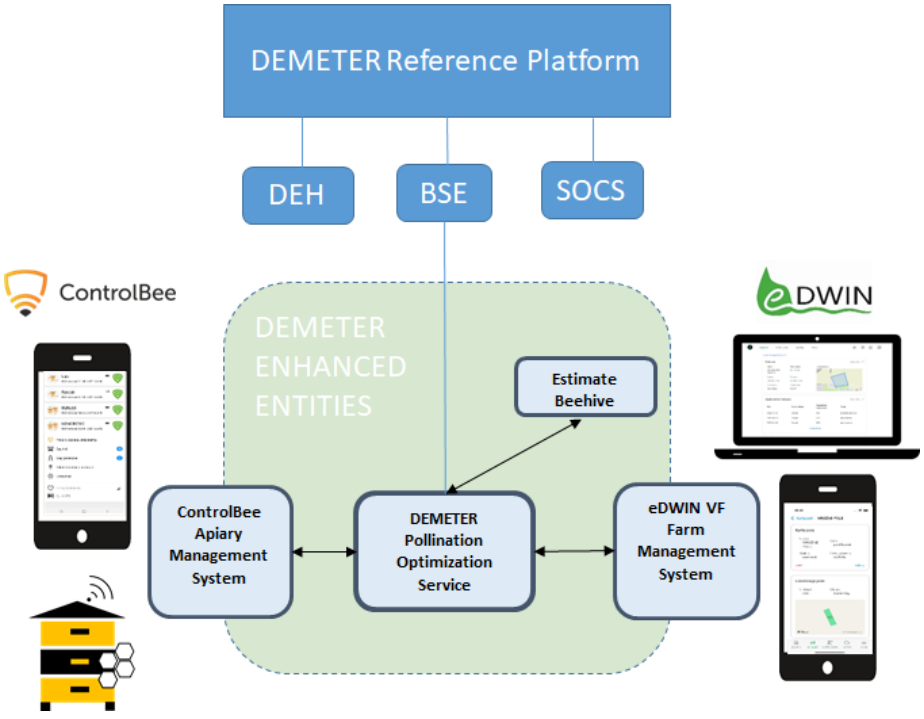


Figure 4. Flow of communication and DEMETER integration

5 Feedback from farmers

Farmer and beekeeper communities have been engaged in the pilot since the beginning of the project. First interactive workshop conducted in January 2020 involving both groups, allowed to identify the end users' needs and define the expected scenarios of the pilot solution. Also, very **valuable feedback to the pilot requirements has been provided by the pilot surveys** conducted in 2020 among 68 beekeepers and 447 farmers. The surveys also verified the interest in the planned functionality of the pilot solutions, helping to determine the priorities and requirements of the minimum viable product of pollination optimisation service. Moreover, **beekeepers, farmers and agriculture advisors are involved as part of the team** and involved in the collaborative design, development and testing of the solution and its components by participating in workshops, interviews, meetings, direct communication, providing data etc.
The prototype solution for apiary monitoring has been deployed in pilot round 1 in four apiary farms and since then has been extensively tested by pilot beekeepers.

Figure 5. Sensors deployment and testing at apiaries (photos by Mateusz Wigura, Piotr Głowacki, Mateusz Sikora)

Thanks to the feedback from the beekeepers the hardware IoT solution for apiary monitoring has been redesigned and redeveloped to better support the needs of the beekeepers (e.g. battery issues have been solved). The apiary management system has been enriched with new functionalities for monitoring the conditions in the apiary and integrated with pollination optimisation service. Also, the UI design is being refined based on beekeeper feedback, such as how to best visualise monitored hives conditions or spraying information, to allow beekeepers to better assess its impact on the apiary.
Moreover, the feedback received from end users involved in the pilot allowed for building and improving the pollination optimization service. The users provided valuable input for defining the rules for exchanging the information between systems and real cases for testing its implementation.

6 Benefits

The digital solution proposed by the pilot aims at optimizing pollination by honeybees by: advising farmers on estimated pollination needs for their crops, fostering cooperation between beekeepers and farmers by enabling them to find a pollination partner, notifying nearby beekeepers of planned sprayings; and finally, by supporting beekeepers in remote monitoring of hives to decrease their fear of leaving hives unattended, when transported to fields or during wintering.

Figure 6. Wintering bees (photos by Mateusz Sikora and Jędrzej Wigura)

Therefore, the main benefits expected by the pilot to be achieved by the farms using the solution are **the increased well-being of bees, better gains for beekeepers transporting bees for pollination and improved yield in crops for farmers**. The KPIs defined for the pilot, listed in the table below, reflect only some of the goals and expected benefits from the use of the solution.

- **Improving pollinated crop**: An increase in rape yield from fields optimally occupied by bee colonies of at least 10 % compared to the previous years

(before DEMETER piloting, when the crops were not optimally occupied). Data has been collected from pilot farms. The values presented in the figure below shows data from an example pilot farm that did not have any stationary or mobile apiary nearby before the pilot, and it was set up in the pilot.

- **Response time to infringements**: Reduction in the time from the occurrence of the problem in monitored hives to intervention by beekeeper. Before adapting the pilot solution it could take up to 7 days (due to rare visits to apiaries on crops at a considerable distance). Thanks to the notification system (triggered by: change of location, internal temperature, shock) the beekeepers are immediately alerted and can make an on-site intervention within 24h or ignore the alert depending on its perceived severity.
- **Survival rate of monitored bee families requiring intervention**: The survival rate of bee colonies in which an effective intervention was undertaken in the winter, thanks to monitoring, is over 25%. This indicator reflects the expectation that at least 1 in 4 hives requiring intervention during winter will be saved thanks to monitoring. Data is to be collected in April 2023.
- **Hive sensor data availability**: Collection of data samples from sensors running in hives and connected to the apiary management system. This isa technical metric which indicates whether a solution meets connectivity requirements. The improvement in connectivity in pilot round 2 has been achieved due to re-design and re-development of the hardware solution in the project.

KPI	TIME BOUND	TARGET	BEFORE PILOT	VALUE - PILOT ROUND 1	VALUE - PILOT ROUND 2
Improving pollinated crop yields	Yearly	10%	29,5 dt	32,7 dt (+11%)	36 dt (+22%)
Response time to infringements	Yearly	< 2 days	up to 7 days	1 day	1 day
Survival rate of monitored bee families requiring intervention	Yearly	> 25%	n/a	n/a	TBC April 2023
Hive sensor data availability	Monthly	> 90%	n/a	80% in 2020 75% in 2021	95% (IV-VIII 2022)

The **benefits of realizing the pilot for its technical partners** depend on their mission and role in the project. For PSNC, which is a research and infrastructure centre with a mission of applying the science in practice by building innovative prototypes and introducing unique solutions using state-of-the-art knowledge and innovative technologies, the pilot is an example of such an experimental project. Also, in the

pilot the AIM model, which is also developed in PSNC, was enhanced and tested in a new domain: apiculture. The solution developed in the pilot complements the eDWIN Virtual Farm platform, which is developed and operated jointly by WODR and PSNC. For WODR, which is an agricultural advisory centre, the pilot allows it to create and test a new kind of innovative agriculture service for its clients, both farmers and beekeepers and promote more pollinator friendly agricultural practices. Finally, for IDEATRONIK which owns the ControlBee solution, the project provides an opportunity to extensively test and improve its products and services for electronic apiary monitoring and increase their interoperability with other systems. With the improved and increased offerings, IDEATRONIK will increase revenue from sales of its products to beekeepers as early as 2023 and beyond.

7 Conclusion

Honeybees are the most economically valuable pollinators of crop monocultures and pollination is the highest agriculture contributor to yields worldwide, contributing far beyond any other management practice. The pilot provides a digital solution for beekeepers and farmers to support the optimization of pollination by honeybees.
For this purpose, the pilot contributes with the following digital innovations:

- an improved IoT system for remote monitoring of apiaries to better supervise apiaries set up in farmers' fields for pollination purposes, as well as monitor hives and bees' welfare during the overwintering,
- a proof-of-concept of a unified communication mechanism connecting farm and apiary management systems supporting collaboration of farmers and beekeepers, integrated with national farm management and an advisory system for farmers (and enhancing its functionality) and apiary management system,
- a more pollinator friendly farming system - thanks to the integration with the pollination optimisation service the eDWIN farming system promotes more pollinator friendly agricultural practices.

The digital solution aims at fostering cooperation on pollination by advising farmers on estimated pollination needs for their crops, fostering cooperation between beekeepers and farmers by enabling them to find and contact a pollination partner and exchange information on planned sprayings and used plant protection products. The solution can be further scaled by integrating other systems and incorporating more categories of notifications e.g. weather alerts.

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