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The BeeSat Project

Pollination plays a crucial role in the preservation of ecosystems, especially in the maintenance of our agricultural abilities and thus in the subsistence of human populations. In a contradictory way, these same agricultural practices and other human behaviors are greatly threatening pollinators providing this valuable ecosystem service. Our project proposes to combine different sources of information to establish maps of relevant and suitable areas for bees. By helping decision making, this knowledge would assist interested parties in enhancing pollination efficiency and help maintain the currently endangered pollinator diversity.

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The BeeSat Project

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Abstract

Pollination plays a crucial role in the preservation of ecosystems, especially in the maintenance of our agricultural abilities and thus in the subsistence of human populations. In a contradictory way, these same agricultural practices and other human behaviors are greatly threatening pollinators providing this valuable ecosystem service. Our project proposes to combine different sources of information to establish maps of relevant and suitable areas for bees. By helping decision making, this knowledge would assist interested parties in enhancing pollination efficiency and help maintain the currently endangered pollinator diversity.

1 Overview of the problem

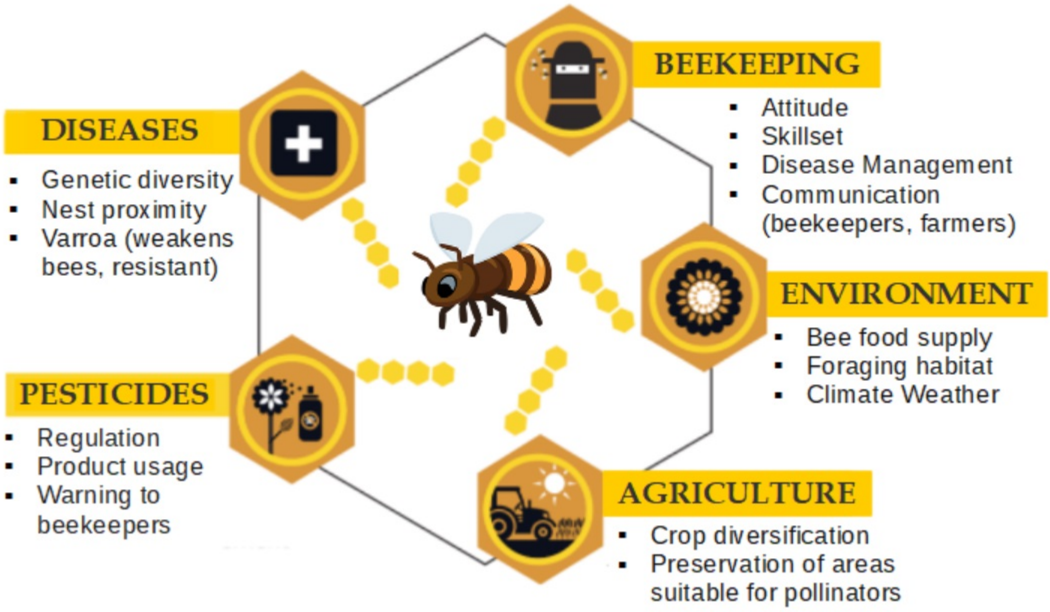
With their status of world's most important pollinator, bees are definitely a booster for the European economy. In its communication document on honeybees' health[1], the European Commission estimated the number of beekeepers in the EU to be around **700,000**, maintaining around **15 million** hives. Since 2010, this number (hives) is however knowing a constant decrease (around 5% over 8 years).

Bees are critically important for the environment and to the economy. It is essential that every step is taken to mitigate the decline of bee populations in the short run and ensure their sustainability in the long run.

Winter losses of bees, which is a good indicator of a hive's health, can be significantly high in European Countries. That is why Europe has invested nearly **5.2 million EUR** in the **EPILOBEE program** specifically aimed at monitoring the mortality of bee colonies.

As a result of this research and other works, scientists agreed that there are 5 main factors that influence the general health of beehives here represented with their main related issues:

Figure 1: Factors influencing bee's health



Due to a combination of these various parameters, the number of beehives in Europe has been steadily decreasing in the last years. Europe, as well as the whole world, has been captive in a vicious cycle with regards to this problem, and is now trying to revert the wheel. There is indeed a lot of room for improvement in terms of existing beehives, as well as new beehives. Aside from communication, beekeepers needs are mostly focused on 4 areas:

- The **simplicity of installation** for new beekeepers or hives to counteract the recent decline.
- The **improvement of skills and practices**, linked with the fact that the vast majority of beekeepers (96%) are non-professional and have a great need for tools to enable their access to information about better beekeeping practices. Additionally, lack of training not only affects the productivity one's own beehives, but can also affect others that are nearby. Indeed, diseases are one of the biggest threat to bees and bad practices from one beekeeper, resulting in disease spreading, could negatively affect a neighbor.
- The **progress in surveillance of veterinary issues**, linked with the existence of episodic diseases (such as Varroa) affecting the whole of Europe and against which beekeepers need to treat their hives.

[1] COM (2010)714final

However, there is still a lack of harmonized surveillance and as a consequence, a lack of efficient response.

- The **improvement of the resource** available for bees, in quantity and quality (free of pesticides).

In this context, we believe our project idea could bring a significant help to the beekeeper community, and its surrounding communities sharing interest for bees and pollinators status (farmers, private,...).

In this paper we will come back into details on how our project idea proposes to address these different needs. We will propose a cooperative solution that will involve beekeepers, farmers, and satellite data in order to derive an ideal balance between supply and demand for bees and foragers. The rest of the document is organized as follows; in section 2 we expose the socio-economic challenges faced with the decline of bee population, in section 3 we present what the application would be able to do and in section 4 we discuss the data required for the application to work.

2 Socio-Economic challenges and benefits

Beekeepers are, as a matter of fact, part of a much wider issue: the decrease of pollination services. Indeed, as one of the most efficient pollinators, bees play a very important role in European agriculture.

Current situation and economic challenges at stake

It is estimated that pollinators, including honeybees, bumblebees and wild bees, contribute at least **22 billion EUR** each year to the European agriculture industry. They ensure pollination for over 80% of crops and wild plants in Europe. A 2015 study found that bees are responsible for approximately 68% of total pollination services by animals (39% for honey bees, 29% for other bees)[2].

In a contradictory way, the intensification of agriculture and the change in agricultural practices are greatly threatening pollinators providing this valuable ecosystem service. European bees are currently suffering extinction. It is estimated that Europe already lost 10% of species[3]. Considering such a decline, sizeable yearly loss of income is expected in the agricultural industry, as pollination needs are not anymore completely covered.

However, having no direct economic value -except the very exceptional hives renting to farmers for pollination of crops-, this pollination service has been overlooked for decades. We thus end up in the situation we know today with important health and death problems in the various bee communities, endangering both managed honeybees, as well as other bee species (bumblebees, wild bees).

Preserving bees and bee health should consequently make sense for many other actors than just beekeepers, and as we have just seen, mainly farmers. To this end, the economic value of bees should also definitely be better communicated to them.

Outlook of socio-economic benefits from improved pollination services

Beekeepers could see their revenue increase significantly. Indeed, a standard hive can produce up to 30kg of honey per year provided the bees have access to the right food supply and are healthy. This is however currently not always the case and a better management will induce an improvement in these parameters and consequently in the production and quality of end products. Honey production represents the main revenue for beekeepers. But beekeeping services (e.g. renting out bees for pollination) and other products (e.g. propollis or beeswax) still represent a non negligible part of income for beekeepers. In the recent years, these products have also known a growing success driven by the "healthy way of life" trends.

Considering the fact that Europe is currently not self sufficient and only covering 60% of its needs for honey, it is clear that beekeepers could economically benefit from this project idea. On top of this, there are some wider effects of improving pollination that will indirectly affect the wider economy and society, having a collateral effect on the environment, and citizens.

Environmental impacts are a heuristic consequence of better pollination services. Better management of natural resources, food, and pollination will locally improve an environment's resilience. Habitat conservation

[2] source:http://www.pnas.org/content/113/1/146

[3] European Red List of Bees - IUCN

and biodiversity are two key elements of an insect's survival, which means that wild bees would also benefit from the situation. Habitat provides a safe harbor for pollinators favoring their protection and breeding and consequently protecting biodiversity at short and medium term, and improving it at rather long term (genetic breeding induces natural selection of strong genes and populations).

Another important interest of our project, on a strategic level, would be the benefits of good practices adoption regarding knowledge sharing. Typically the reduction in uncertainty of bee presence (on the farmer side) and of food shortage (on the beekeeper side) would bring a high competitive advantage to European beekeepers and farmers. The access to information is very valuable, especially in agriculture, as it reduces uncertainty and helps decision making.

In addition to a rise in environmental resilience, food products like fruits and vegetables would see an increase in quality. A better pollination service, will thus benefit to the wider society (e.g. citizens).

3 The BeeSat Project Idea

As seen earlier, the needs of beekeepers are currently focused on 4 different aspects: the simplicity of installation for new beekeepers and new hives, the improvement of beekeeper skills and practices, the progress in surveillance of veterinary issues, and the improvement of the resources available for bees.

The first objective of our application is to help beekeepers (amateurs and professionals) and farmers know where to position their hives. Indeed, we have seen that bees are most useful when acting as pollinators. Thus, beekeepers (or beekeepers to be) must know where the demand for bees is high and where it is low. Targeting the right areas for beekeeping would improve decision making with regard to hives location and thus facilitate beekeeping. This will greatly participate to the creation of a virtuous cycle between biodiversity and bees. To that end, the main and first feature developed in our application will be to allow the user to visualize a map of the surrounding region indicating the best spots to place a beehive.

In a second step, our application will help already installed beekeepers by increasing their productivity. To do this, we would dispatch more advanced alert systems targeting the hive management itself, not only its positioning. This would mainly address the second and third need above mentioned. With these two axis of work, we hope to increase the number of bees not only via an increase in the number of beehives, but also through an improvement in bee health for existing hives which will in turn reduce bees losses.

Indirectly, and by creating a community around the topic, we also hope that this application, as part of a more general European context, would play a role in raising awareness with regards to some good agricultural and land planning practices, and thus contribute to address the last of the four needs.

Slightly tailored application for different types of users

As mentioned before, our application would target beekeepers (amateurs and professionals) as well as farmers keeping bees for pollination services. However, these different users having different type of beekeeping strategies, our application would propose 3 types of user accesses, linked with slightly different types of services. The table below presents how we propose to differentiate our three types of users.

Table 1: Users characteristics

User Type	Amateur beekeeper	Professional Beekeeper	Farmer & beekeeper
Area available	Limited (garden or equivalent)	Extended (woods, meadows, ...)	Extended (woods, fields, meadows...)
Beehive mobility potential	Static	Possible to move	Possible to move
Input on landcover information	Limited	Limited	Possible

These aspects are of importance when considering the need to match the bees with the resources surrounding the hives. Indeed, an amateur could only use the application to receive a positive or negative feedback regarding the suitability of his garden for bee breeding. On the contrary, a professional beekeeper could use it to determine where is it optimal for him to position his beehives.

The main service: the creation of habitat suitability maps

The potential presence of pollinators, and especially bees, in an area is highly linked to the quantity and quality of available resources from which to feed. The current remote sensing capabilities for studying the land cover and land use changes, together with the development of technologies for precision agriculture have a high potential to enhance decision making in the apiculture professional field.

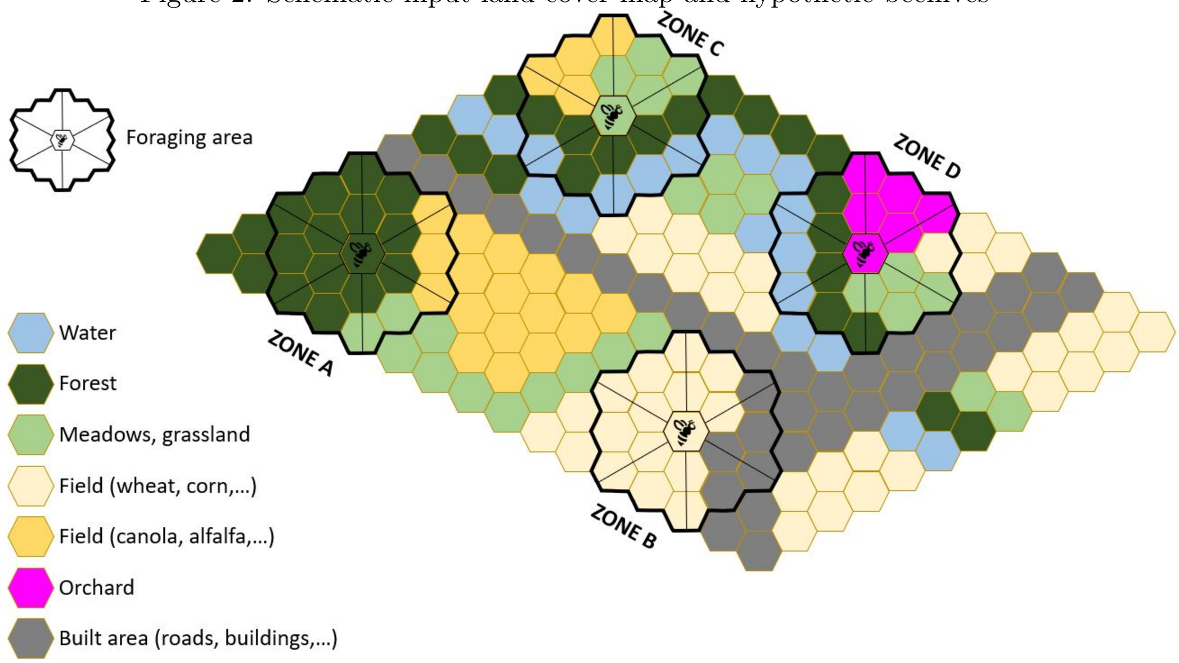
Indeed, it is now possible to access information on land cover types thanks to their specific spectral signatures, and also allows to retrieve information on the state of vegetation (growing, blooming,etc.) thanks to indexes such as the NDVI index. This land cover is an excellent indicator of the quantity of food available for bees. Therefore, the BeeSat project idea is to use these data as an input to create habitat suitability maps for bees, covering their potential foraging area.

This part will focus on explaining the theory behind our application's maps. The data aspect will be further developed in the next chapter.

In order to derive relevant habitat suitability indexes, satellite images would be evaluated against 3 criteria that are of use to bees (see figure 2):

- The **presence of water** to provide access to a clean drinking area,
- The **presence of protective areas** (tree hedges or forest,...) acting against wind or as pesticides buffers and providing early bloom flowers, and most importantly
- The **floral resources** (crops, grassland, trees, etc.). Due to its important variability, the floral resource parameter should itself be consolidated with regards to various parameters:
  - The **type of plant considered:** on one hand, corn, rice, wheat,... would rank as very low value land cover types as they are not pollinated by bees; on the other hand, fruits, vegetables, nut crops, canola, mustard, clovers,... would give a very high land cover value as they are particularly appreciated by bees;
  - The **diversity of these plants in the area of interest:** an area with only one type of resource would be rated lower than an area with a higher diversity as it would provide a more diverse forage opportunity;
  - The **blooming period:** having an area with both canola and mustard would induce a high score as canola blooms in spring/summer and mustard blooms later in tame around end summer/fall. On the contrary having an area with a very short time frame of blooming would reduce the score.

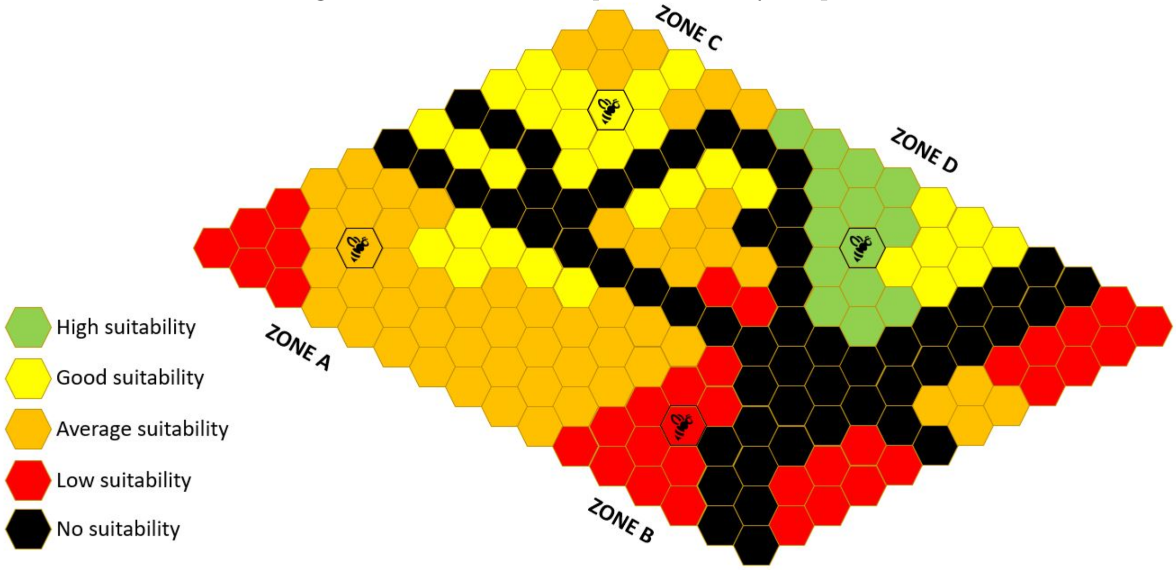
Figure 2: Schematic input land cover map and hypothetic beehives



On the figure 3, we can, as an example find the suitability index of the 4 zones displayed in figure 2.

- **Zone A** has floral resources in quite limited quantities and has no very easy access to water, it would be an average suitability score
- **Zone B** has a very poor food resource, no access to water and is next to a road, it would be rated with low suitability score
- **Zone C** has access to a good food supply, as well as water and forest area, and would thus be given a good suitability score
- **Zone D** has also good food supply, water and forest area; but in addition it has access to an agricultural area (orchard) that would highly benefit from the presence of bees. It is given a very high suitability score.
- The roads and river are areas where it is impossible to install beehives and are thus rated as non suitable.

Figure 3: Schematic output suitability map



And then?

In the second version of our application, we would develop different types of alerts for the different types of users. Indeed due to seasonal change, which could be followed thanks to monthly land cover maps, our application could inform beekeepers as to how much food is available for bees in a given area.

For amateur beekeepers, who do not have the possibility to relocate their hives, the app could send them regular updates as to how much food is available for bees in their area. They could thus be informed as to if they need to feed their bees or not, and receive alerts as soon as the surrounding resources become scarce.

On the other hand, professional beekeepers or farmers, who have the possibility of moving their beehives, could be warned of the existence of more productive areas in their surroundings to where they could bring their hives for higher productivity. For example, if they see that this season, the current location of their beehive is in an area that is poor in food for bees (due to different agricultural rotation cycles for example), and that a nearby farm is rich in resources, this beekeeper will be able to relocate his bees and save them from possible starvation.

Crowd-sourcing information: improving knowledge sharing to improve decision making

As we envision it, the early stage application will contain two other features for collecting information: one to locate hives in order to create a layer of existing colonies and one to validate land cover information. Thanks to the location system, users will be able to locate their hives geographically. This feature combined with the suitability maps, will then allow them to inquire where the hives are and where they are needed.

Table 2 represents a simplified version of the action matrix that will constitute the decision process of the algorithm. Once a sufficient amount data has been recorded, the app should use these inputs to generate an indicator of risk. As a matter of simplicity, only some situations are displayed in this graph: High vs Low coverage and suitability.

Table 2: Coverage vs Suitability matrix

		COVERAGE	
		High	Low
SUITABILITY	High	Balanced Situation	Under-crowding: Risk of deterioration of the natural resource
	Low	Overcrowding: Risk of famine	Balanced Situation

Typically, a zone with "High" suitability index and with "Low" coverage (no hives) should be pinpointed by the app as 'hotspot' for new hives. In this case there is an excess of supply and fewer pollinators which could induce a degradation of the land, flower cover, and productivity in the case of cropland. That could for example happen in our previous zone D. On the contrary, a relatively "Low" suitability area with "High" coverage should be pinpointed by the app as 'already fully exploited' or even 'risky'. Survival of the bees would indeed be at risk and due to the drastic decrease of the hives' output, the beekeeper could also find himself in a risky economic situation (it has already occurred in the surroundings of London for example).

And then?

As mentioned before, in the second version of our app, we would like to develop different types of alerts. Regarding the aspect of crowd sourcing, we would use the app to allow user to signal problems or upcoming chemical usage (on the side of farmers). Indeed, controlling bee pests and diseases is seen as an essential factor for successful beekeeping over the years. Generating a warning for pests attack periods (Vespa velutina, Aethina tumida) would have a very high added value for beekeepers in an affected area, as they could treat and protect their hives before it is too late.

4 Sources of the data and data types

The application aims at combining 2 major sources of data. In situ data should report the presence of bees and their location to determine the supply side of the algorithm, where are the bees? Satellite data, about crops and vegetation repartition, where are the crops, what kind of vegetation is present in which area.

In situ data

Supply of bees can be pointed by beekeepers on a map (e.g. Urban Bees[4]). Users will have the ability to pinpoint their hive location with a high degree of precision. Beekeepers will have the opportunity to report an estimate of the size of each hive, their age, whether they have been treated for pests, etc. The application aims to offer the most inputs possible because the data is very valuable especially once a critical mass of users have adopted the model. In this case in particular, the more you know about hive location, the less likely

[4]http://www.urbanbees.co.uk/maps/

the competition between hives. Data should be transparent to allow for an optimal organization between beekeepers. Many maps are available for such applications and despite Google maps being widely used, more open maps exists such as ZeeMap, or Open Street Map.

In general honeybees would fly to a maximum distance of 6km from their hives. In consequence, the baseline idea of our project would be to rate supplied areas depending on the 6km radius circle surrounding it. Once a hive will be notified, the application will estimate the foraging range and it will be made publicly available to all users.

High scale, satellite level data

The other source of data is about satellite data. There is a bigger challenge here which is to be able to retrieve and interpret satellite data so that they can be accurate and useful for users. The choice of data source should be made in accordance with the application's needs. It requires data sufficiently precise to be able to compute indexes such as NDVI and vegetation type. Moreover, the instruments need to be able to capture images in visual and near infrared wavelength. The OSCAR database regroup most of the Earth Observation current(and future) satellites in orbit alongside with their instruments, parameters and data sources. We know from academic sources (Hofmann et al. (2017) [1], West et al. (2017) [2]) that 60m (or better) resolution allow for vegetation differentiation and NDVI estimation. By consulting the database, we have identified some candidates. Unsurprisingly, the sentinels are identified as very good candidates for this mission.Sentinel 2A and 2B are already active and provide images with a resolution between 10 to 60m every 10 days on average. Primary objectives include Land cover, Leaf Area Index (LAI), Normalized Difference Vegetation Index (NDVI) and Vegetation type. Other candidates such as EnMAP and ResourceSat could provide additional data[5].

5 Conclusion

The BeeSat project is aiming for an efficient integration of existing methods for measuring land cover and biodiversity and cooperative societal actions in order to improve actions taken to support ecosystem services, in this case, pollination.

A first version of our application would focus on evaluating land areas suitable for beehive installation and maintenance. However, many dimensions are still to be taken into account to compute a robust suitability index and the growing literature will provide a precious source of information for statistical modeling. Our project idea is expected to improve over time, as refinement of inputs data and methodologies are made available. A more advanced version of the app would include more features such as indicator of pesticide use, alerts for diseases or high level of predation in order to trigger a human response (by notification system).

Taking into account the prevailing importance of bee pollination services for agriculture, this paper presentation of our Beesat project idea deliberately covered only the consideration of rural or semi rural areas. However, studies recently proved that cities are increasingly becoming safe harbours for bees. Consequently the BeeSat project would also aim at assessing habitat suitability for bees in urban areas, where urban public gardens, common gardens in residential areas, or even green areas on industrial sites, are becoming of increasing importance for bees survival.

[5]https://www.wmo-sat.info/oscar/gapanalyses?variable=172)

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