FINAL DOSSIER

Challenge based Innovation

for Artificial Intelligence

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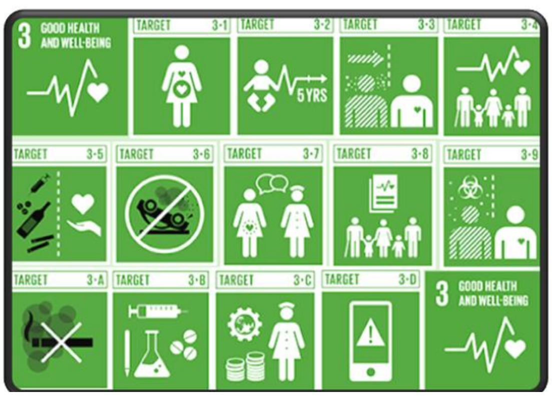
OUTLINE

1. Research report

1.1 The SDG challenges

For our group challenge we were assigned the Sustainability Development Goal 3. After carefully understanding what the goal entails and doing research about the most pressing issues, we as a team decided that we wanted to do something that had a lot of impact, would help plenty of people and something that is often overlooked. After having these clear requirements, coming up with a challenge was not that difficult. The obvious options that affect people's health are air and water and those are usually the ones that are most talked about, but we noticed a third resource that is very important for our health and wellbeing which is soil. Soil constantly gets polluted by air and by water and similarly, once polluted it also contaminates surrounding air and water, creating a never-ending cycle. Soil is responsible for over 90% of the world's water reservoir and food sources, its importance cannot be emphasized enough. Since the industrial revolution, 135bn tones of soil has been lost and over one third of fertile land has been degraded.



1.2 The problem and its implication

Soil pollution is a significant issue because it affects surrounding water and air as well as limiting the amount of fertile land for crops. Some causes of soil pollution are easier to detect like human waste, waste from mining fields and trash fields. Some other causes are not so obvious, like fertilizers which are used to help crops grow, or polluted air and water slowly contaminating surrounding soil. The latter happens very slowly which makes it harder to detect but it is a slow process with long-term repercussions if left unchecked.

Once soil has been contaminated, there are some very effective methods to clean it, but these methods can be very expensive and sometimes leave residues on the soil which may contaminate in different ways. The easiest solution to this crawling contamination problem is prevention.

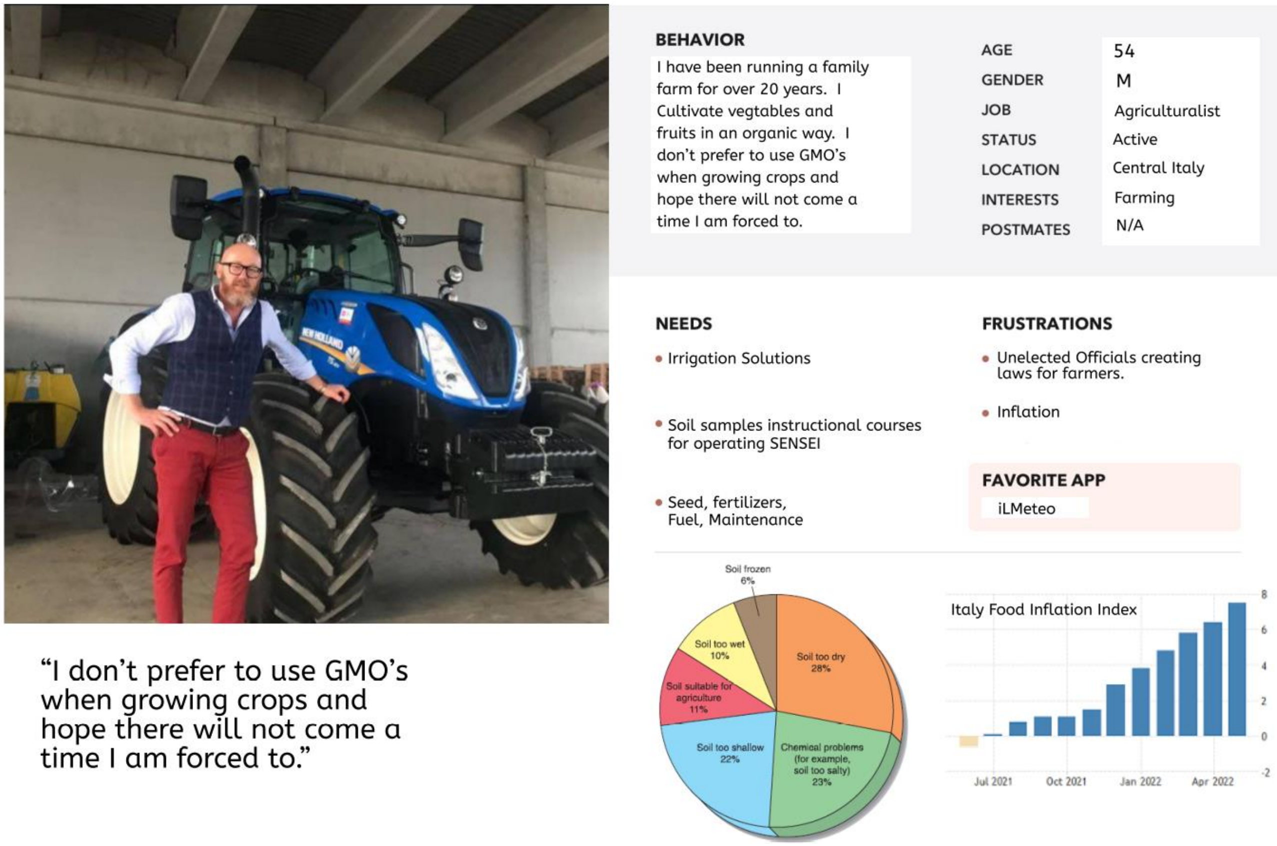
(Iberdrola, 2019)

1.3 Interview process

After understanding the challenge and identifying the problem we want to tackle, we decided to conduct field research. This means that we wanted to find and interview persona, who suffered from our identified problem to see what implications it has. Furthermore, we wanted to further understand the needs of our persona. Our main stakeholders are governments, farmers, human beings, and animals. The main persona are farmers. Therefore, we reached out to 15 farmers via WhatsApp, Phone and Calendly/Zoom. We managed to arrange five unrecorded phone calls with farmers from Italy and Germany.

We wrote down several questions regarding our problem and the potential solution before the call. This way, we ensured a structured and results-driven interview process. Every interview was attended by two people, one interviewer and one note taker. After the call, we discussed the content of the interview and documented our findings.

1.4 Selected persona profile



1.5 Interview findings

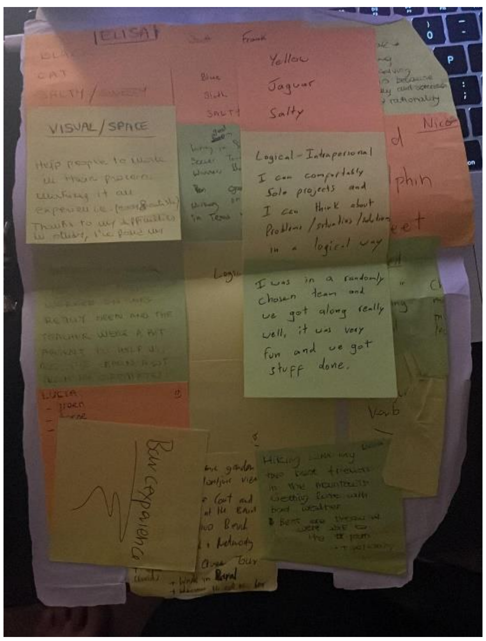
We asked similar questions in every interview while modifying nuances in some interviews which also came from the small talk and flow of conversation. We talked with farmers about their jobs and soil pollution as a general topic. Moreover, the farmers talked a lot about their daily use of chemicals and other substances for their farms, and about the cycles of their farms.

With the interviews, we wanted to find out two things: 1. Is our identified problem real and what are the negative implications, 2. Could our solution be in any from interesting to the farmers? From our interviews, we concluded that farmers indeed have the problem that parts of their field become useless if the soil is polluted by polluted water, wrong use of pesticide or past chemical waste dumping. Especially in developing and emerging countries, this is supposed to be a relevant problem.

2. Conceptual development

2.1 Description of ideation process

During our time at CERN, we were first tasked with coming up with several problems that fall under the SDG 3 that we were interested in. In total we came up with 10 problems from which the majority we did not even like to begin with but there were 4 that we all liked and seemed promising to pursue further. Interestingly they were all regarding different resources like water, air, soil, and health institutions. In the end our decision was narrowed down by elimination.



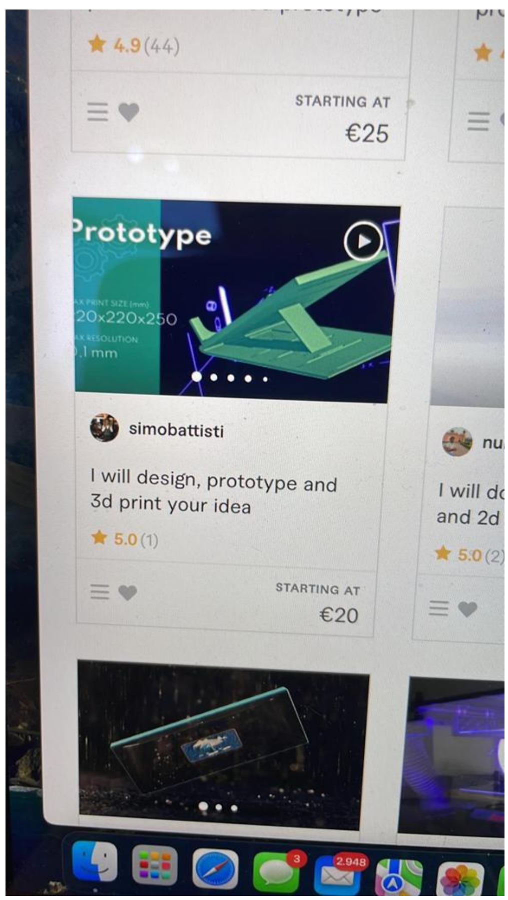
2.2 Different ideas and Attract technologies considered

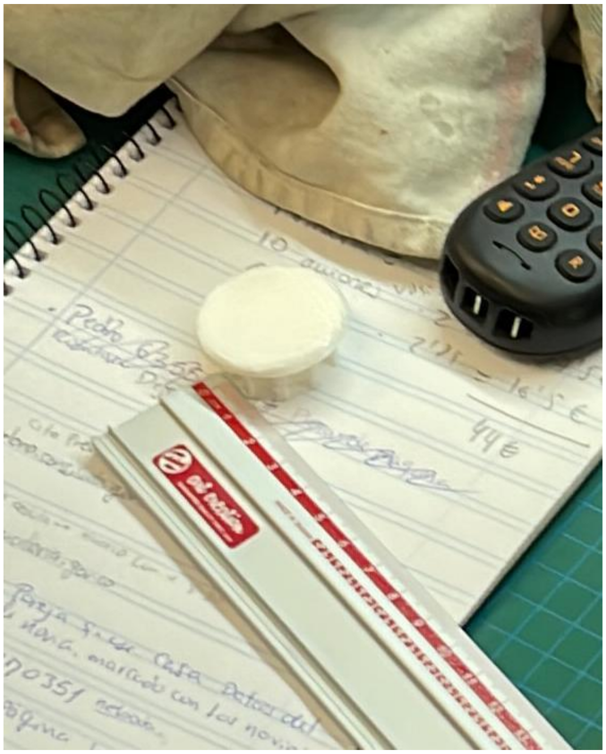
As previously mentioned, we had plenty of different ideas, but we needed to narrow it down through an elimination process. To do this we looked up the technologies available from the ATTRACT project as it was a requirement to use one of them. So, we searched through almost all of them in search of something that could inspire us and is somehow aligned to the issue we wanted to tackle. Eventually we arrived to SENSEI which combined perfectly with our idea to tackle soil pollution and thus we began our research into the topic.

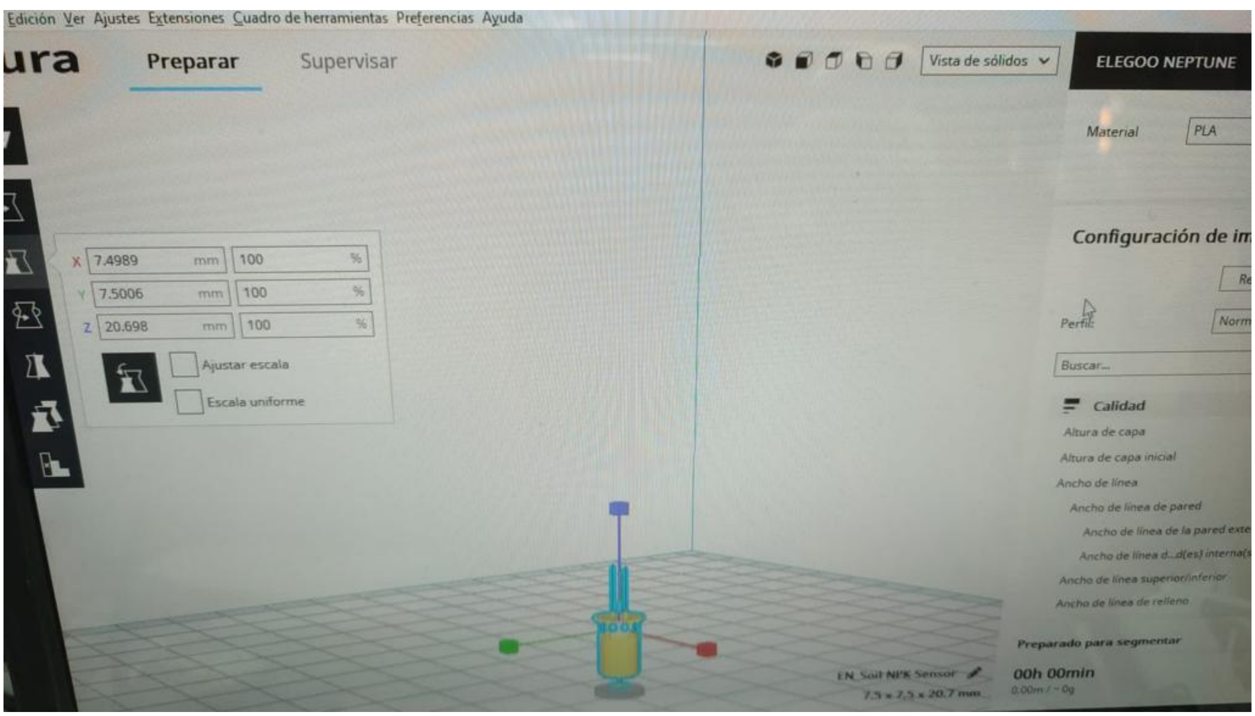
Other technologies that we investigated and caught our attention included Eco Tags, and Sniff Drone. We specifically investigated how we could merge the drone technology from the sniff drone with the SENSEI sensor to create some sort of automated grid placement and recovery which could potentially increase the scalability of the project. We also explored how the Sniff technology could also be capable of detecting the environment the soil is in so that we could have even more data and evidence about the pollution and potential pollution of the soil. In the end we were advised to narrow down the scope of the project as we simply did not have enough time to properly explore all the ideas and technologies we were interested in, but surely our project still has plenty of unexplored areas of improvement and space for evolution.

2.3 First prototypes

For our first prototype we had a clear idea of what we wanted to do which was to make a 3D printed version as it would be a terrific way to sell the idea and it would feel great to physically see materialized what we had worked so hard on for the last few months. We did not have any knowledge on how to make a 3D model, so we used the challenge resources at our disposal to contact and hire a 3D specialist that created a printable version of the sensor. The first iteration was nice, but we wanted to add more to it, so a second revision was needed. Afterwards the model was ready for printing but there were issues at the printing company and the model failed due to technical issues. On the second attempt the model was finally corrected, printed, and was later painted to provide a more professional finish.



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3. Final idea/solution

3.1 The solution

We developed an innovative solution to monitor and predict the quality of the soil combining the new state-of-the-art sensor SENSEI and AI (Artificial Intelligence).

SENSEI (Live, autonomous biosensor modules for environmental monitoring) is one of the technologies proposed by ATTRACT. It was developed in Israel at the Hebrew University of Israel and Shenkar College of Engineering and Design. It consists of a network of live, autonomous biosensor modules that can detect and quantify any organic or inorganic material present in the soil.

Our main idea consists of:

- Creating a network of SENSEI sensors that detect the presence of target materials in the soil.
- Creating a model that predicts soil pollution build up with the help of machine learning.
- Visualization of collected data on a platform.

Thanks to a network of SENSEI sensors, it is possible to monitor the quality of soil in various positions in a target land. Once the sensors are positioned on the soil, the bacteria detect whether organic or inorganic materials preselected are present and in which quantities. The optical signal emitted by bacteria is first converted into an analog signal and then into a digital signal. The communication unit sends the resulting signal to an external server that collects the measurements from all the sensors, and it processes them.

By adopting advanced machine learning models that read the collected data, we can obtain estimations on the quality of soil over time. Based on the quantity of a certain material detected in the soil, the model predicts the buildup of this material, hence the buildup of the pollution in the soil.

Overall, the main steps to follow are:

1. Position the sensors on the field

2. On our platform, save the exact GPS location of each sensor.
3. Each sensor can detect up to 10 organic or inorganic materials (already pre-selected during the manufacturing of the sensor).
4. The application will build an interactive map where for each sensor it will display the data read by sensors.
5. Our AI will process the data and will deliver predictions on the quality of the soil.
6. Possible to share and save this data

Any farmer will be able to read real time data on the measurements collected by sensors and to visualize future predictions on the quality of soil. An example is present in the next subsection.

3.2 Design elements

Our SENSEI technology-based sensor prototype consists of three components. At the bottom, there are several pillars for stabilization and to stick the sensor into the soil.

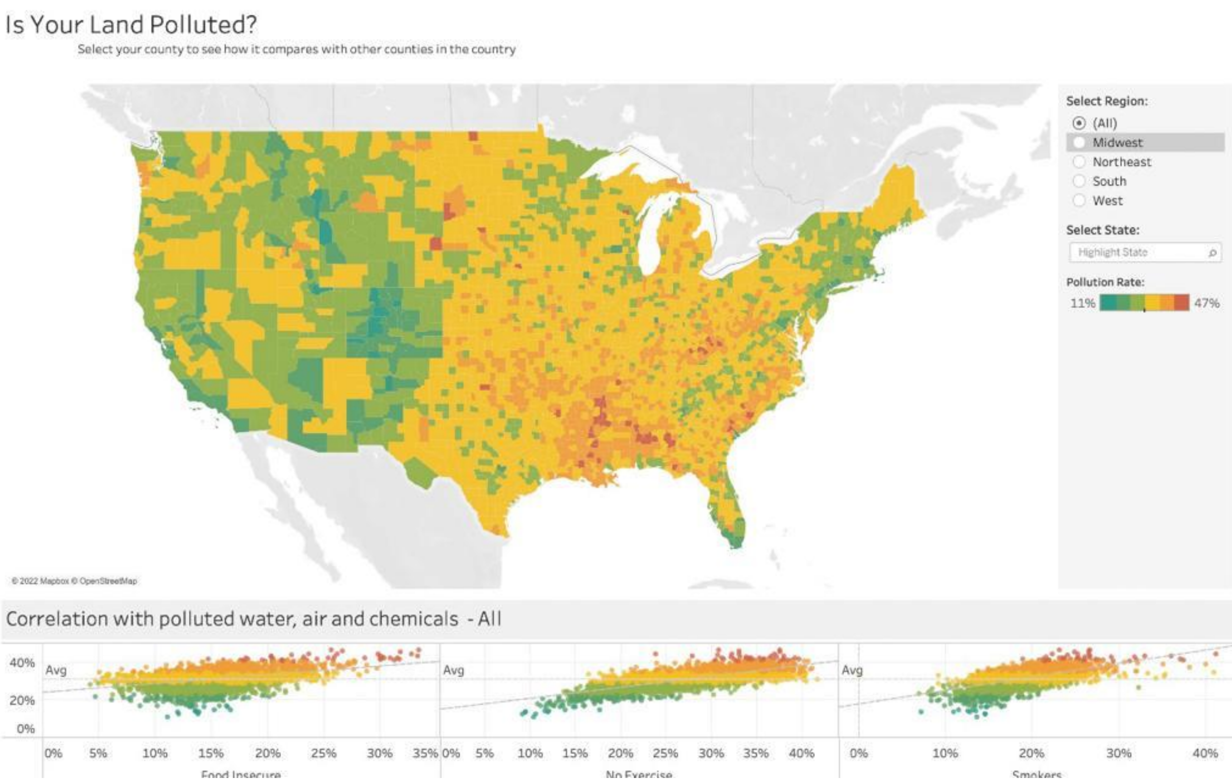
On top of the bottom pillars, there are entrance ports in which the soil will be filled in combination with water. Inside the sensor, the soil and water can then react with the bacteria.

An antenna is built on the top of the sensor to send the data gathered from the soil location to a centralized receiver which will be processed by our machine learning software.

Below, you can find two pictures of the prototype:

For the visualization of the gathered data, we derived a farmer-friendly dashboard that can be used to monitor and predict soil pollution.

Below, you can find a screenshot from the dashboard.



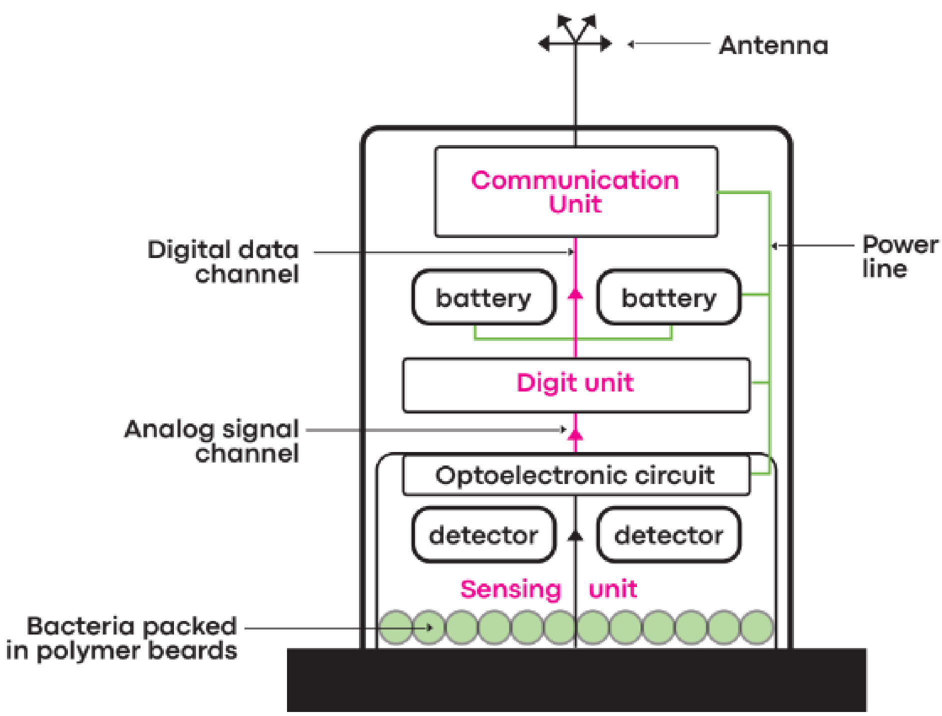
3.3 Business proposition

For the business proposition, the product could be licensed or sold to farmers and/or governments to better monitor fields and soil pollution as these two parties are most interested in our solution. However, we could also imagine a non-commercial distribution and usage of the solution in the future or it could be subsidized by the government.

This idea has as its main purpose the need to raise awareness regarding the seriousness of soil pollution, delivering quantitative and qualitative data. Environmental organizations and governments are the ones interested in paying for this unique service.

3.4 Technical specifications

In the figure below, it is schematized the structure of the SENSEI sensors.



It is divided into different units:

- Sensing unit: the core sensing elements of the technology are live bacteria that are genetically engineered to respond to the presence of a target compound in their microenvironment by the emission of a bioluminescent signal. The bacteria are embedded in an optoelectronic circuit that is installed in a module designed to operate autonomously outdoors. The optoelectronic circuit converts the optical signal into an analog signal.
- Digit unit: it receives from the sensing unit the analog signal and it converts it into digital.
- Batteries: they keep the sensor active.
- Communication unit: essential to send the detected measurements to an external unit that collects all data.

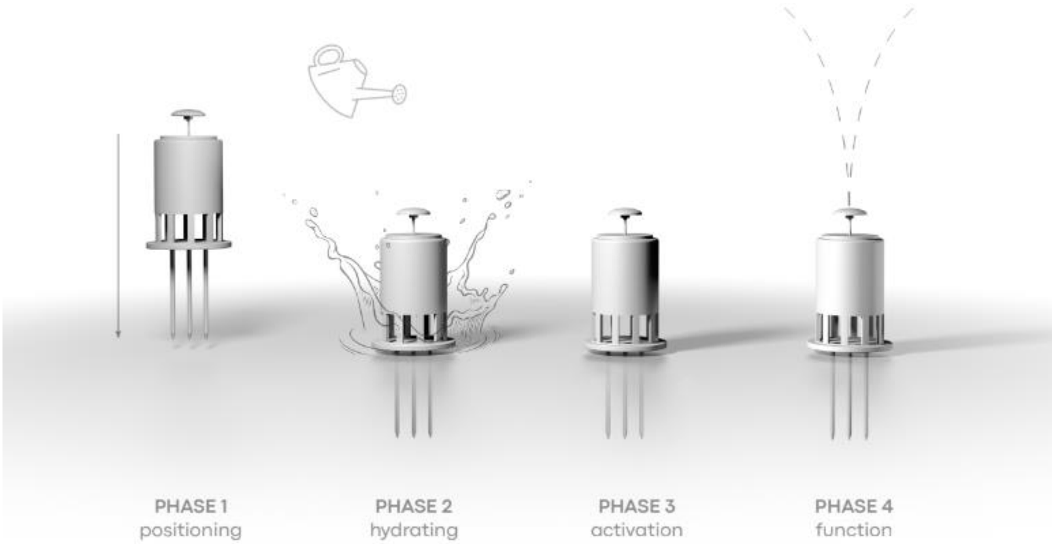
The communication unit must be robust to the outside environment and be able to survive long periods of time independently. We searched in the market for the most recent antennas adopted in the agriculture field and we found an interesting solution developed by MobileMark. It is very robust against environmental changes (it resists extreme temperatures and water) and animal attacks.

In the table there are the technical specifications of the antenna.

Name	**HD4-2400**
Company:	MobileMark
Frequency:	2400-2485 MHz
Gain:	4 dBi peak
Vertical Beamwidth:	57° Elevation
Horizontal Beamwidth:	360° Azimuth
Polarization:	Vertical
Max Power:	10 Watts
High of antenna:	1.3 cm
Diameter of antenna:	6.9 cm
Operating Temp:	-40° to +80°C

To install the sensor on the ground there are several steps to follow:

1. Position the sensor under the ground, only the antenna must stick outside the soil. The apertures of the body of the sensors permit the soil to enter inside and to react with the bacteria.
2. To obtain a more heterogeneous mix of materials, some water is added to the soil.
3. The GPS coordinates of the sensor are saved, and it is activated.
4. It starts functioning.



3.5 Impact

Our solution could potentially be a strong driver of reducing soil pollution. If governments and farmers use the solution to better monitor and predict pollution, they can take measures accordingly to prevent the misuse of certain chemicals or misusage of farming principles. The fight against soil pollution will also positively impact and reduce the pollution of air and water. This will bring us one step further reaching the SDGs and reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination worldwide.

3.6 Outlook

We researched our problem in-depth, validated that our problem exists, and farmers would potentially be interested in such a solution. From a machine learning and AI perspective, the solution should also be feasible over time. However, at this point it is hard to estimate when the Sensei technology will be mature enough to be applied and used as sensors. Therefore, the future development of our solution strongly depends on the progress of the SENSEI team.

3.7 Learnings and key takeaways

Challenging – Rewarding – Fun

The journey with CBI4AI and Attract has been incredibly challenging, rewarding and fun. From the beginning, we were thrown into the "cold water" and had to work our way through the challenge, various problems and find a solution. Working in an interdisciplinary team was a wonderful experience as we had complementary skills and personality traits which ensures the best outcome as we analysed the challenge and problem from different perspectives. We really valued that we could learn so much from the others and grow together. Sometimes, the communication was difficult because we speak different "languages" and have different priorities. Therefore, it was important to coordinate this well between each other. Furthermore, working with these unknown, attract technologies which were partly not even fully developed was challenging. It was not easy to find a suitable technology to tackle our problem. During this process, we managed to leave our comfort zone and dive deep into various technologies while exploring our problem and its implications in depth.

We had three key learning: Our first key learning was that teamwork and communication is key, we understood how crucial it is that to let people speak and express their opinion and while being respectful. Due to our complementary skills, it is even more important to actively listen and give room to each other. Secondly, we were impressed with how rapid innovation is – many innovative technologies such as Sensei are emerging rapidly, and it is important to monitor them and keep up with the latest tech trends. Finally, we were amazed by how "easy" it is to find a problem, develop a potentially suitable solution and prototype. The most important thing is to just keep having a good structure and a good team.

A happy team :)