CropTracker: Applying HYGER technology in agriculture

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Abstract

Introducing CropTracker, a solution aimed to optimize water efficiency, enhance crop growth, and pave the way for future advancements in agricultural technology. The idea is to fly a drone with a hyperspectral camera that uses HYGER technology to capture images in the visible and infrared spectrum. After being processed, these images can give powerful insights about crops to farmers like the health or water content of the plants. With these insights, the farmer can act accordingly, increase harvest and reduce water waste. HYGER technology is an advanced infrared detection unit using high-purity black germanium. It offers high sensitivity, low noise, cost-effectiveness, and exceptional performance in detecting near-infrared (NIR) and short-wave infrared (SWIR) wavelengths.

1 What is HYGER

HYGER is a highly efficient infrared detection unit based on high-purity black germanium technology. This detector converts light to an electrical signal so that one can measure and determine the incoming photon intensity and wavelength quantitatively. Instead of the traditional approach of using a thick anti-reflection coating on a flat surface, in this case a nanotexture is applied which results in a fully absorbing surface at a wide range of wavelengths and provides efficient light trapping paths inside the substrate. These approaches lead to a GE sensor element with superior sensitivity in near-infrared (NIR) and low-energy x-ray detection.

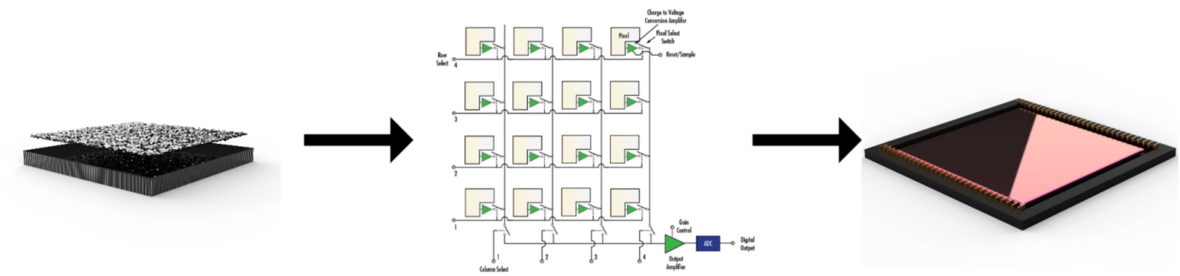

Figure 1: HYGER detection unit. CMOS procedure. Sensor obtained as an array of HYGER units.

2 Benefits of HYGER

Some of the main benefits of HYGER are the high sensitivity, low noise, low cost of manufacturing, CMOS compatibility and no need for traditional pn-junction formation or AR coatings. As mentioned previously it can absorb light at a range of wavelengths from 0.4 to 1.8 µm. However it performs especially well in the infrared spectrum. More concretely in the Near-Infrared (NIR) and Short Wave Infrared (SWIR).

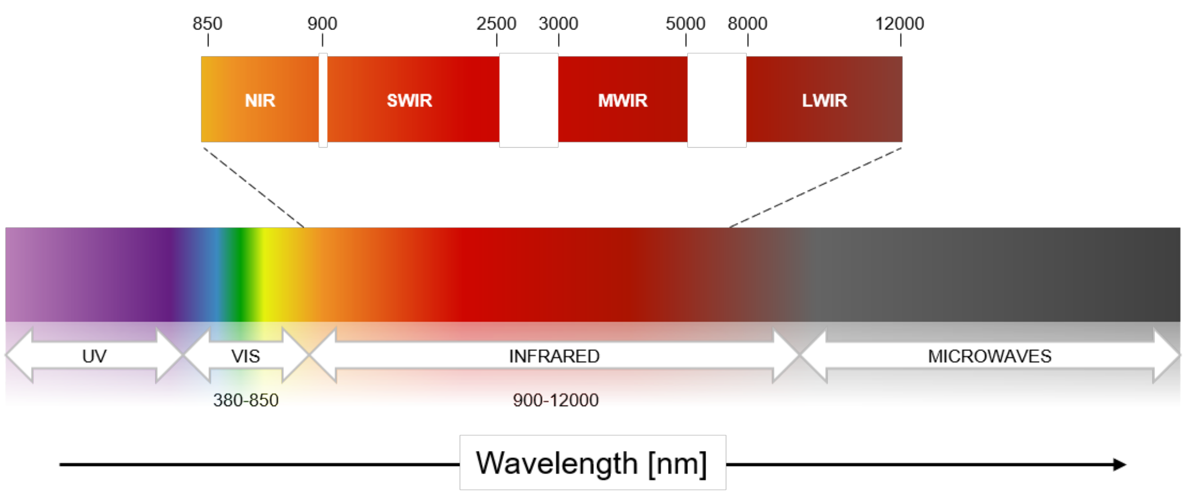

Figure 2: Wavelengths diagram.

3 Design Process

3.1 Phase 1: Exploring Potential Applications for HYGER

In the initial phase of our design process, our team embarked on an extensive research journey to explore the diverse range of applications that could benefit from HYGER technology. We focused on sectors including medical, automotive, industrial, and agricultural, aiming to uncover areas where HYGER could truly make a difference.

3.1.1 In-Depth Research and Analysis

- Our exploration began within the medical sector, where we delved into the potential applications of HYGER technology. This involved a comprehensive study of the latest advancements in vascular tomography, PET/MRI, and other pertinent medical imaging techniques.
- We also monitored the automotive industry, and examined how HYGER could be integrated into LIDAR technology to enhance autonomous driving systems and collision avoidance mechanisms.
- Looking towards the industrial sector, we sought to identify ways in which HYGER could enhance existing applications related to quality control, monitoring, and optimization of manufacturing processes.
- Finally, we immersed ourselves in the agricultural sector, investigating the potential of HYGER to revolutionize crop monitoring, disease detection, and water management practices.

3.2 Phase 2: Refining the Scope to Specific Applications

During Phase 2, our focus shifted towards narrowing down this wide range of possibilities to four specific applications: vascular tomography, PET/MRI, LIDAR, and Agriculture (NDVI). Our objective was not only to identify these applications but also to evaluate the social impact and value proposition that HYGER could offer in each context.

3.2.1 Selection of Specific Applications

- Vascular tomography emerged as a highly promising application, in which HYGER could transform non-invasive imaging techniques for assessing cardiovascular health, potentially leading to earlier disease detection and improved patient outcomes.
- By combining HYGER with PET/MRI technology, we enhanced imaging capabilities that could facilitate precise medical diagnoses and more effective treatment strategies.
- Within the automotive industry, the integration of HYGER into LIDAR systems held significant potential for advancing object detection, mapping, and navigation systems, ultimately bolstering road safety and the development of autonomous vehicles.
- Moreover, we recognized the immense value of HYGER in the realm of Agriculture (NDVI), where it could revolutionize the monitoring of plant health, enabling farmers to optimize their agricultural practices and contribute to sustainable food production.

3.2.2 Assessing Social Impact:

- Vascular tomography utilizing HYGER technology could revolutionize cardiovascular disease management by enabling early detection and intervention, potentially saving lives and improving overall patient well-being.
- The integration of HYGER in PET/MRI systems has the potential to elevate the accuracy of medical diagnoses, leading to more targeted treatments, improved patient outcomes, and a reduction in healthcare costs and dose exposure.

- Leveraging HYGER in LIDAR applications has the power to enhance road safety, minimize accidents, and pave the way for a future of efficient autonomous transportation, thus positively impacting both individuals and society as a whole.
- In the agricultural domain, the utilization of HYGER in NDVI (and other indexes) applications could empower farmers to optimize water usage, reduce waste, improve crop yields, and contribute to sustainable agricultural practices, ensuring food security for future generations.

3.3 Phase 3: Focus on Agriculture Application

During the subsequent phase, Phase 3, we directed our attention to the Agriculture application of HYGER, centering our efforts on problem definition, developing a business model canvas, and conducting an impact analysis with a particular emphasis on water waste reduction.

3.3.1 Problem Definition

- The first step we took involved recognizing the need for a precise and efficient method to monitor and manage water usage in agriculture, addressing the challenge of water scarcity and sustainability.
- Our goal was to leverage HYGER technology to develop a solution that would empower farmers to optimize their irrigation practices,conserve water resources, and minimize water waste, ultimately promoting efficient and responsible water management.

3.3.2 Business Model Canvas

To plan our path forward, we carefully studied the market and looked at important people and factors. We made a detailed plan that showed what we offer, who our customers are, how we make money, and the important partnerships we need for our HYGER-based NDVI solution to work well. Here is the business model canvas we created.

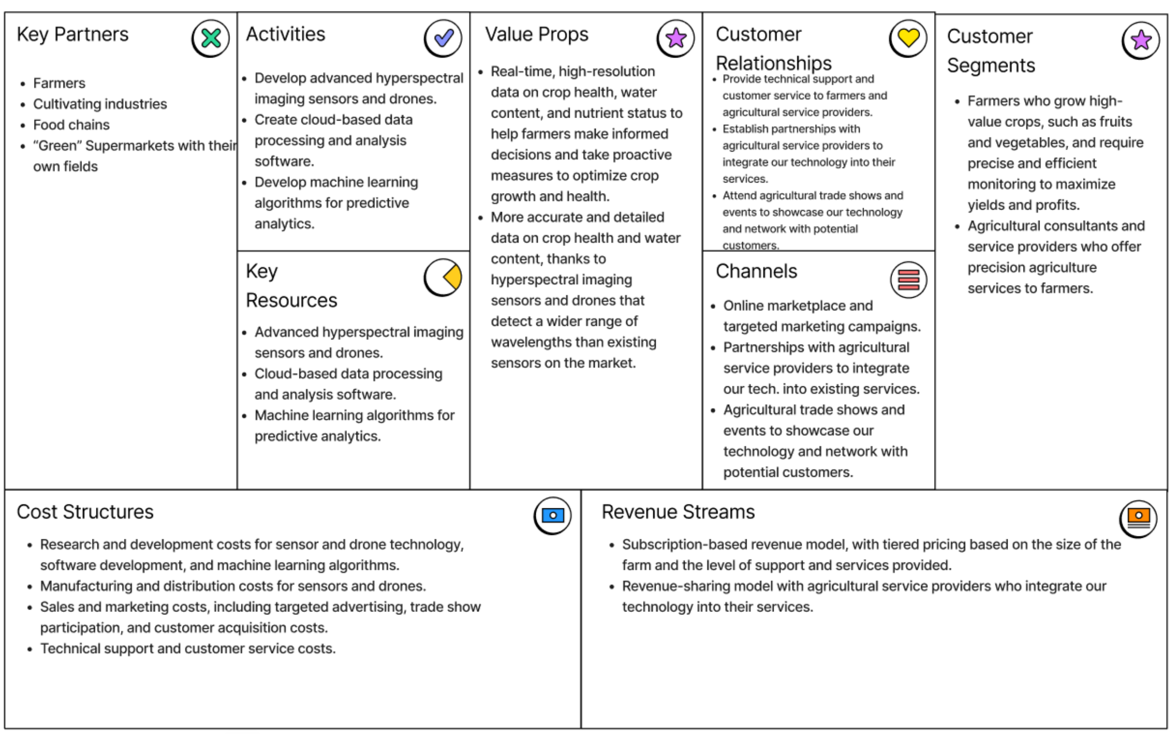

Figure 3: Business Model Canvas

3.3.3 Impact Analysis (see section 8)

- Our impact analysis focused specifically on the potential reduction of water waste through the utilization of HYGER in NDVI-based water management systems. By providing real-time data on crop water requirements, we aimed to facilitate informed decision-making and optimize water usage, thereby minimizing waste.

- Throughout the analysis, we quantified the potential water savings, estimated the environmental benefits, and evaluated the economic viability of the solution, ensuring its holistic sustainability and viability in the agricultural sector.

By carrying out some specific research, centering on the Agriculture application with a water waste reduction perspective, our aim was to develop a practical and sustainable solution that leverages HYGER technology to benefit the agricultural sector, contributing to efficient resource utilization and environmental preservation.

4 HYGER in agriculture

As we have seen HYGER can detect SWIR and NIR light waves reflected by land surfaces. NIR-SWIR wavelengths can provide rich information about chlorophyll levels, moisture, soil minerals, and proteins. [1] Using these images detected we can obtain different information, but how can it be applied to agriculture? Using vegetation indexes which are indicators that describe different parameters such as the greenness, moisture or water levels in crops. [2] The most relevant are explained below:

- NDVI

  The Normalized Difference Vegetation Index (NDVI) is used to determine the density of green on a patch of land.

  When sunlight strikes objects, certain wavelengths of this spectrum are absorbed and other wavelengths are reflected. Chlorophyll strongly absorbs visible light (from 0.4 to 0.7 µm), the leaves cell structure reflects near-infrared light (from 0.7 to 1.1 µm).

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

  where NIR: Near Infrared and RED: Visible Red Light

  When analyzed through time, NDVI can reveal where vegetation is thriving and where it is under stress. It is generally effective at characterizing spatial variability in plant health, providing a snapshot of the good and bad parts of a field. [3, 4, 5]

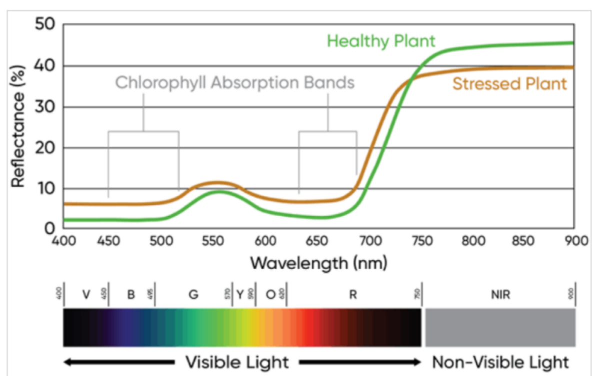

Figure 4: Generalized electromagnetic radiation reflectance profiles of healthy and stressed plants

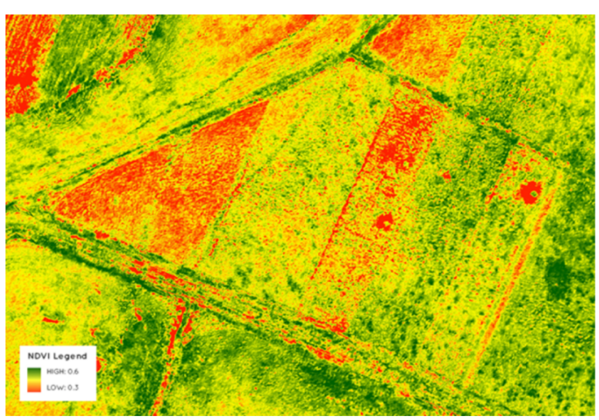

Figure 5: Graphic representation of NDVI index over a field. In green, areas where plants are healthier and in red, plants that are less healthy

- NDMI

  The Normalized Difference Moisture Index (NDMI) detects moisture levels in vegetation using a combination of near-infrared (NIR) band, picks up the bright reflectance off the leaf internal structure, and short-wave infrared (SWIR) band that is sensitive to the vegetation water content and the mesophyll structure of leaves. It is a reliable indicator of water stress in crops. [6]

$$NDMI = \frac{(NIR – SWIR)}{(NIR + SWIR)}$$

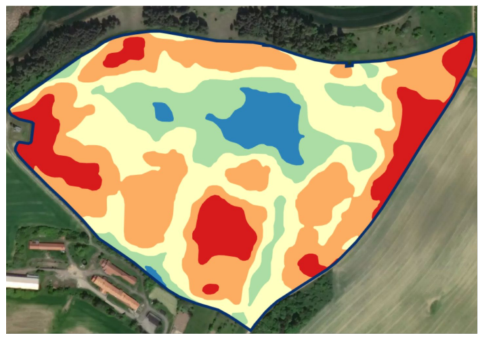

Figure 6: Graphic representation of NDMI index over a field. In blue, areas where moisture is higher and in red, those where it is lower

- NDWI

  The Normalized Difference Water Index (NDWI) is mainly used to detect and monitor slight changes in water content of the water bodies. It can be especially useful in crops that require huge amounts of water such as rice or soybeans.

  The NDWI, is calculated using the GREEN-NIR (visible green and near-infrared) combination, which allows it to detect subtle changes in water content of the water bodies. [7]

$$NDWI = \frac{(Green – NIR)}{(Green + NIR)}$$

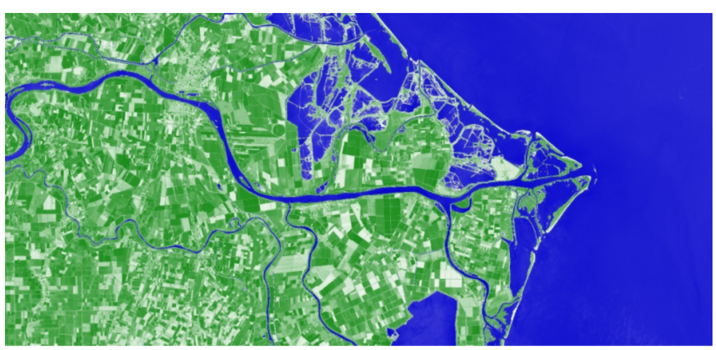

Figure 7: Graphic representation of NDWI index over a coastal area. In blue, areas where there is a high water content and in green, areas with crops

Figure 8: Vegetation bands reflectance depending on the state of the leaf

5 Our proposal: CropTracker

Our main objective is to enhance water efficiency and optimize crop growth using hyperspectral imaging technology. The idea of CropTracker is to use a drone that implements a hyperspectral camera that is composed of a HYGER sensor and a regular camera to be able to capture data from the visible and the Infrared spectrum. This data can be processed as hyperspectral images which can later be used to obtain powerful insights about the crops using the different indexes: NDVI, NDMI and NDWI. This information will then be stored in the Cloud where we could merge it with external data such as weather forecasts, soil mapping, topological data, etc. Here is where AI and machine learning come into play. By leveraging machine learning models or AI algorithms, the data stored in the Cloud can be analyzed to derive valuable insights for farmers. These models can be trained to recognize patterns, correlations, and anomalies within the data. For example, machine learning algorithms can be employed to identify specific crop diseases or predict irrigation needs based on historical data and current conditions.

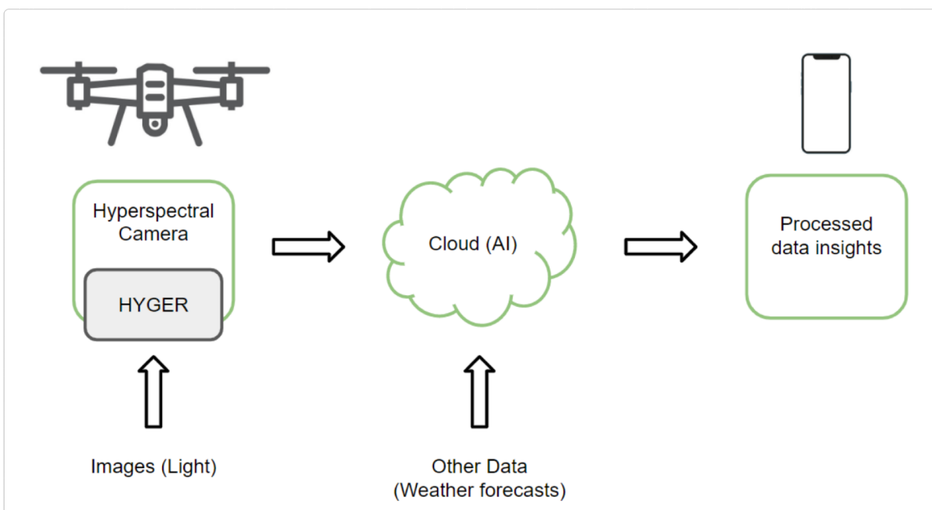

Figure 9: Architecture of CropTracker

This idea has been validated by Jordi Corbera during the interview we conducted. He even pointed out that the use of drones was a great idea to bring the benefits of precision agriculture to smaller farmers and field crops: *"Drones/UAVs, are really useful when working in projects in relative small areas* $< 300/400$ *hectares"*.

The purpose of AI in this context is to augment the farmer's decision-making process by providing actionable insights. The machine learning models can help automate the analysis of vast amounts of data, enabling quick and accurate identification of crop health issues, optimal watering schedules, or even predictions of potential crop yield. These insights empower farmers to make informed decisions, optimize their agricultural practices, and ultimately enhance crop productivity and resource management.

In order to make all this valuable data accessible and understandable to farmers, we have considered using an intuitive app platform with an engaging user interface. Farmers can easily download this app on their mobile devices or tablets and have instant access to information about their crops. The app has all the knowledge derived from the hyperspectral imaging and AI analysis.

Within the app, farmers can find precise information about water content within each crop and the optimal amount of water needed for irrigation or fertilizer usage. Also, monitor the health of their crops, detect any signs of diseases or pests, and receive recommendations for appropriate treatments. Furthermore, the app provides insights into product yields, enabling farmers to estimate potential harvests and plan their operations accordingly.

The user interface of the app is designed to be user-friendly and visually appealing. It presents the data in a clear and easily understandable manner, using graphs, charts, and visualizations. Farmers can navigate through different sections of the app, access historical data, set up personalized notifications, and track the progress of their crops over time. This will allow farmers to be able to use the power of hyper-spectral imaging and AI without requiring specialized technical knowledge.

We interviewed Carlos Burillo, an elder farmer from la Plana Tarragona who has been cultivating olive trees, tomatoes, potatoes, lettuce, and all kinds of plants and flowers for many years. His opinion was very important to assess the difficulties and benefits that he might think of having by using this app and accommodating to new technologies. In this sense he also validated the idea with facts like: *"As we progress, farmers are increasingly adapting to technology. I find the application you have shown me to be quite clear and promising. However, like any change, there are certain details that I would need to get used to. Nevertheless, I am excited to explore how this tool can improve our agricultural practices"*

Figure 10: 3D render of a drone over a field

6 Branding

For the visual communication, we designed our own logotype. The logo is the H (from Hyger), hidden into the shape of a leaf, as we are working with agriculture.

Primary Logotype

Figure 11: Primary logotypes

Secondary Logotype

Figure 12: Secondary Logotypes

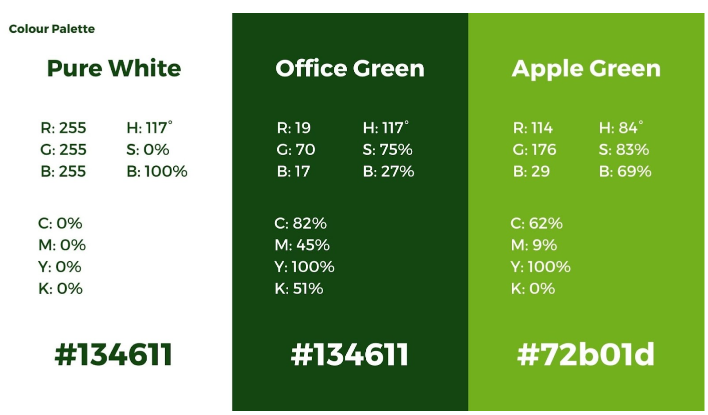

Figure 13: Color palette

7 Prototyping

When deciding how to prototype our idea, we first needed to establish the architecture of our proposal. Once we had this part covered, we discussed different options for our prototype. At CERN we learned that there are many different reasons for prototyping. Our main focuses with the prototypes lay in two areas;

- Communicating our idea to the scientists, and the audience of the presentation.
- Testing the efficiency and functionality of our idea with our target.

7.1 Video

We decided to make a video, as this is a very visual and clear way of showing the agricultural sector without the audience having to be there. We started off by writing a storyboard for the video in our Figma board.

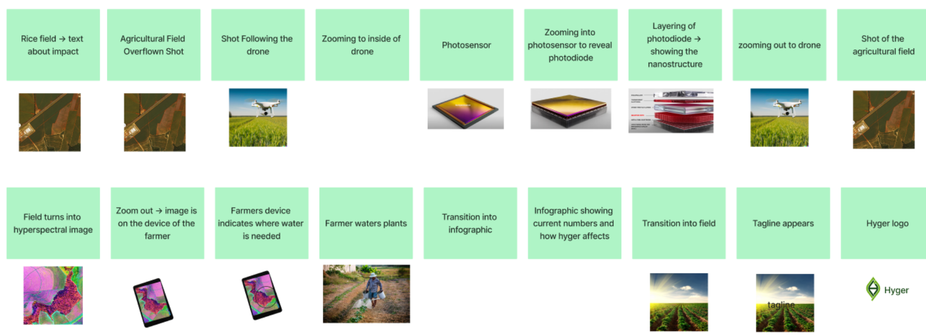

Figure 14: Storyboard

We then established that CGI would be the easiest way to create some of these shots, and so we rendered some shots through KeyShot at IED. We then paid someone on Fiverr in order to get the agricultural field renders we wanted. The person we paid modelled the whole rice field according to our needs, and we gave him a script to know which shots were needed.

Figure 15: 3D Render

After this delivery, we liked the shots but they were not self explanatory enough. Because of this, we hired someone else on fiverr and passed them all the shots we had so far. This person then used 2D animation in order to turn it into a coherent video with voice over.

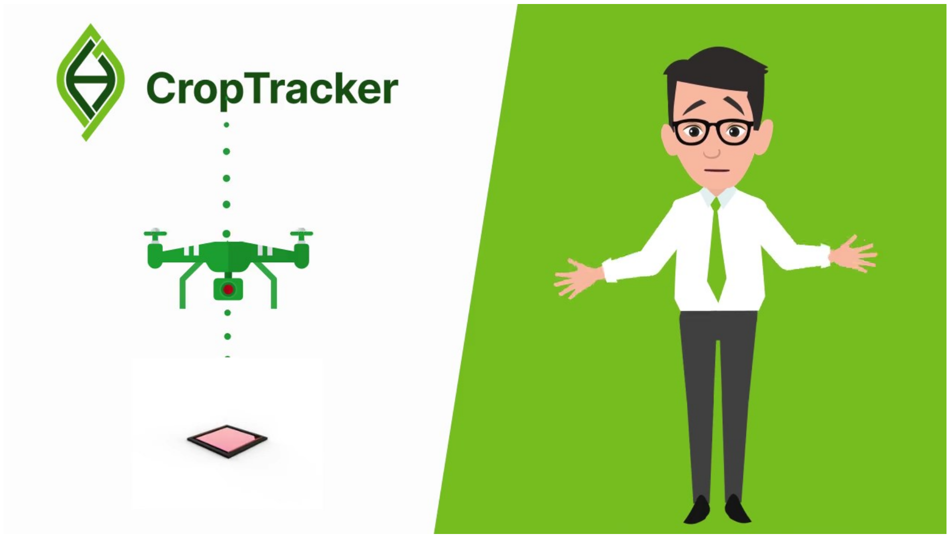

Figure 16: Screenshot of the video

7.2 Visual Poster

As we knew we would have a table at the presentation, we also wanted to have a poster in order to grab the attention of the public, and invite them to walk over. The aim of the poster is to show the main idea, but spike curiosity for more explanation. This was the poster we first made:

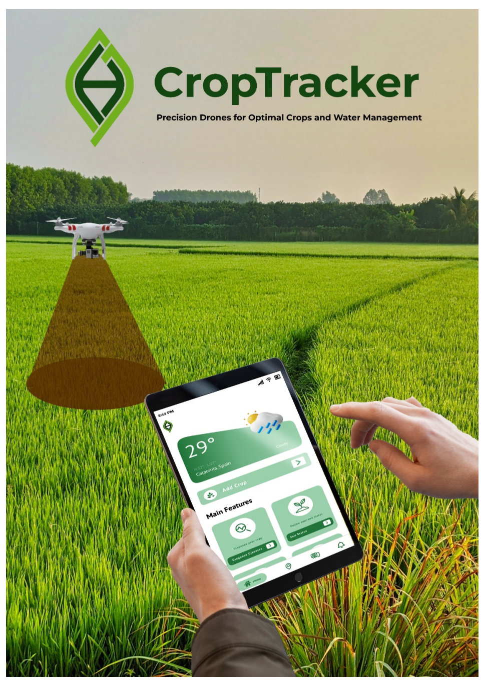

Figure 17: Our poster design

In the end we still had budget left, and decided to hire someone to see if the poster could be better. This resulted in these two posters:

Figure 18: Externalized poster designs

7.3 Informative Panel

We also wanted for the public to be able to understand our project on a deeper level, even without having seen the presentation. The video explains the main idea, but with the panel we wanted to go more into the technicalities. We wrote a text of 1000 words, explaining the project in depth, and provided the images with it. This package, we sent out to someone who did the graphic design of the panel. We printed it in A1, and hung it up at the table. See figure 19

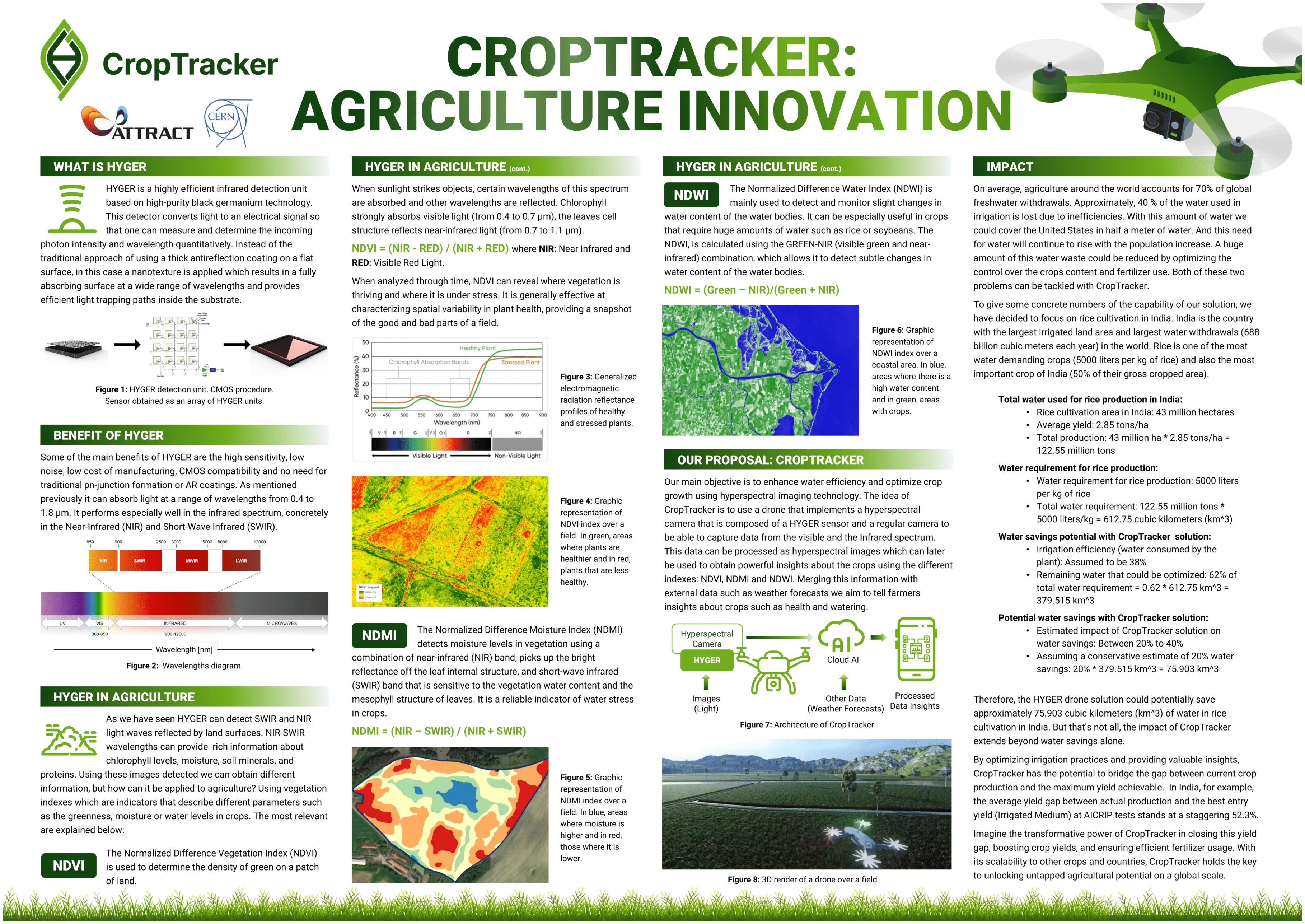

Figure 19: Informative Panel

7.4 Interactive Interface

If our idea would become reality, the information would have to reach the farmer in some kind of way. Our idea would be to have an app that provides the farmer with all the data, as well as the recommendations. We decided to prototype a clickable interface, with the help of Figma. With Figma, you can test UX/UI designs, without having to actually launch the app yet.

The farmer needs the information to be clear and accessible. We aim to include; information about the irrigation, whether water is needed, the weather precipation, any pests that have been detected and soil data. Apart from that, the farmer should also be able to provide information to the AI as well. This means that we want the farmer to easily be able to map out his field and register when new crops are planted.

We used a template and adjusted it, in order to create our first setup of this interface. The goal is to have it be realistic enough to show to farmers, and receive their feedback about functionality and necessities.

In figure 20 you can see some screenshots of the user interface. To try out the entire interface use this link;

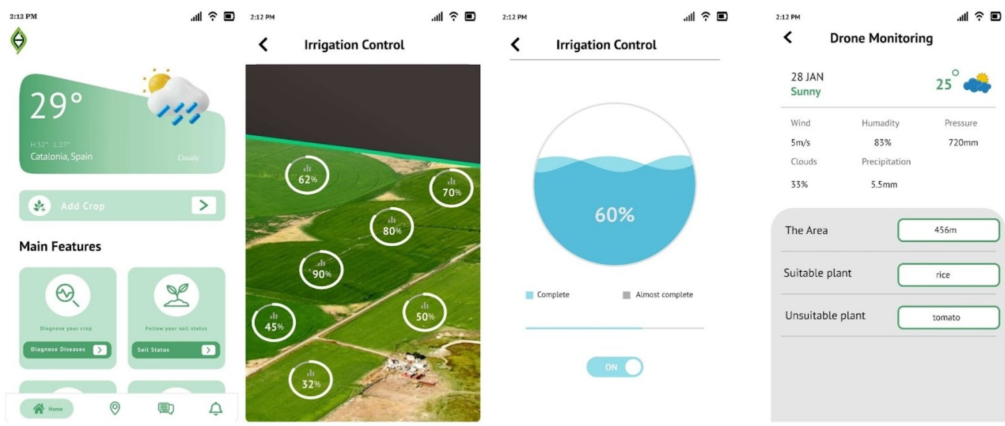

Figure 20: User Interface Prototype

8 Impact

On average, agriculture around the world accounts for 70% of global freshwater withdrawals. Approximately, 40% of the water used in irrigation is lost due to inefficiencies. With this amount of water we could cover the United States in half a meter of water. And this need for water will continue to rise with the population increase. [8, 9] A huge amount of this water waste could be reduced by optimizing the control over the crops content and fertilizer use. Both of these two problems can be tackled with CropTracker.

The variability of the potential impact of our solution is very big, but we estimate it can be between 20% - 40%. To give some specific numbers of the capability of our solution, we have decided to focus on rice cultivation in India.

India is the country with the largest irrigated land area and largest water withdrawals (688 billion cubic meters each year) in the world. In addition, agriculture is the primary source of living for 70% of the India population. Within agriculture, rice is the dominant irrigated crop, accounting for approximately 30 percent of the total irrigated area. Also, rice is one of the most water demanding crops (5000 liters per kg of rice) and also the most important crop of India (50% of their gross cropped area) [10, 11]. Moreover, almost 90% of rice production comes from irrigated ecology and rainfed shallow lowlands, both in great need of precise water management. [12]

Precisely quantifying the potential impact of this solution on water savings is a complex task due to the multitude of variables involved. Generalizing its effects is challenging as it heavily depends on the specific circumstances of each case. The impact may differ significantly between crops that already employ efficient irrigation methods and those that do not. Additionally, variations in water demand, pest prevalence, soil nutrient availability, rain frequency, temperature, and even the specific crop varieties, can further influence the outcomes. Therefore, it is essential to consider the unique characteristics and conditions of each agricultural scenario when evaluating the potential water-saving benefits of this solution.

Therefore, in order to give some context and number of magnitude of water savings CropTracker could provide, we have pursued a research on different papers and publications from the FAO and Indian organizations such as NARS. From these studies we found out some statistics and values to calculate, approximately, how much water is India using/wasting for their rice production. We are considering homogeneous behaviour over all crops and considering an "average" of every factor.

India plants rice over an area of about 43 million ha. Their yield level varies a lot depending on the place, however the average is around 2.85 t/ha (which is low compared to countries like Australia 8.25 t/ha). Therefore, the production is approximately 122.55 million t. Now, considering the previous water requirement of rice, 613 km$\hat{3}$ is the average used water. But how much of this water could be saved? To calculate this we will make several assumptions. Irrigation inflow requirements can be described by means of crop evapotranspiration **(T)**, evaporation **(E)**, seepage and percolation losses **(S and P)**, and surface runoff **(SRO)**. From all of these factors, our solution can not help to reduce T, as it is the water actually consumed by the plant (needed to grow). This is called irrigation efficiency, which for India is roughly 38%. Then we could only impact the other 62%, in this case, 368 km$\hat{3}$. [12, 10, 9]

Finally, we have to estimate how much of that water would our irrigation monitorization by drone be able to save. From the state of the art, we know that actions like implementing modified schedules to minimize evaporation, decreasing water usage during land preparation, adopting alternative rice planting practices, implementing techniques to reduce water consumption during crop growth, improving strategies for water distribution, etc could all be done with our drone. And this accounts for more than 20% of the water saved. Therefore, the HYGER drone solution could potentially save approximately 75.903 cubic kilometers (km$\hat{3}$) of water in rice cultivation in India.

But that's not all, the impact of CropTracker extends beyond water savings alone. By optimizing irrigation practices and providing valuable insights, CropTracker has the potential to bridge the gap between current crop production and the maximum yield achievable. In India, for example, the average yield gap between actual production and the best entry yield (Irrigated Medium) at AICRIP tests stands at a staggering 52.3%. Imagine the transformative power of CropTracker in closing this yield gap, boosting crop yields, and ensuring efficient fertilizer usage. With its scalability to other crops and countries, CropTracker holds the key to unlocking untapped agricultural potential on a global scale.

9 Reflection of Learning - Challenges and Difficulties

Throughout our project journey, we faced and overcame many big challenges. These experiences taught us a lot and helped us understand HYGER technology better. In this section, we will talk about three main challenges we faced: choosing the right applications, understanding the technical aspects of HYGER and its pros and cons, and keeping good communication and progress within our team.

1. Choosing the right applications:
   At the beginning, it was hard to decide which applications of HYGER technology to focus on. There were so many possibilities, and it was overwhelming. To tackle this, we did thorough research and analysis. We looked at things like market demand, impact on society, and feasibility. We used a methodical approach to prioritize the applications that aligned with our project goals. It took careful thought, but we managed to narrow down our focus to the most promising areas.

2. Understanding the technical aspects of HYGER and its pros and cons:
   Another big challenge was understanding HYGER technology in depth and knowing its advantages and disadvantages. We had to dive into scientific literature, talk to experts, and have long discussions within our team. By immersing ourselves in the technical details, we were able to grasp the complexities of HYGER. This knowledge helped us effectively explain its benefits and limitations in our proposal and presentations. It also allowed us to identify potential challenges and find solutions for them.

3. Communication and progress within our team:
   Good communication and keeping a steady pace of progress were crucial for our project's success. We had to manage our workflow, coordinate tasks, and make sure we were moving forward consistently. To address this, we set up clear channels of communication, had regular team meetings, and used tools like Figma, Google Drive, and Teams for collaboration. These measures created a supportive and open team environment, where we could address any issues quickly. By communicating effectively, we made sure everyone was on the same page, motivated, and working towards our shared goals.

Through these challenges, we gained valuable insights and developed important skills. We improved our decision-making abilities and learned how to prioritize and make informed choices. We also acquired technical knowledge in the field. Additionally, the focus on good internal communication created a sense of unity and synergy within our team. It helped us overcome challenges together.

To sum up, the challenges we encountered in selecting applications, understanding the technical aspects, and maintaining good communication taught us valuable lessons. They tested our problem-solving, critical thinking, and teamwork skills. We faced these challenges with determination, adaptability, and a strong commitment to doing our best. The knowledge we gained from these experiences will surely help us succeed in future design and innovation projects.

10 Annex - Interview Notes

10.1 Jose A. Lázaro - Electronics professor at UPC

Advised to make a comparison of different material photodiodes Relevant specs to look at: Noise Figure for $\lambda = 1550$ and Dark current.

Thorlabs for Photodiodes specifications

Hamamatsu for Avalanche photodiode information

10.2 Santiago Marco - Photodiodes researcher at IBEC. Professor at UB

Experience in chemical sensing. Especially in gas sensing. Each gas has an absorption band and using the specific LASER/LED it is possible to detect it. Normally filters are used so we receive a low amount of photons (Photodiodes) SNR is very important. To reduce SNR they usually use light pulses.

Check Gas Sensing Solutions company for more details (John Fuller, CEO of GSS)

Contact: Mauricio Moreno (UB optoelectronics professor)

10.3 Jordi Corbera - Head of the Earth Observation area at the Cartographic and Geological Institute of Catalonia. Jordi is an ecologist as well as a biodiversity expert.

Experience in Agriculture sector in Fertilization management. (France, 800k hectares, Visible, NIR)

SWIR Bands - some experience using sentinel to images to analyze anomalies in vegetation by using SWIR Sentinel bands

In terms of agriculture, the use of SWIR bands are quite useful in terms of determining water content, moisture, and irrigation. Would be a good proxy in particular because nowadays, in order to evaluate water content and vegetation you can use variables like evapoconspiration.

Experience with people working in sector In france, we provide service to fertilization management Collect spectral data and introduced into a model run by IVAS to provide surveys on France But for here, it wasn't user driven. But in France, it was organized into a huge and powerful farmer organization. In Spain, this sort of structure is quite weak compared to France. recommended to focus in farmers in a particular zone.

Also experience in public sector - worked for agriculture department - climate action department to provide current service based on Sentinel 2 to provide each agriculture parcel and crop with specific indexes of crops always using visible NIR. Evaluate water content so we move to SWIR bands

Water saving - recommendation: Really interesting to focus on agriculture but also, we have request from government for other activities such as surveillance NDMI index using SWIR and NIR band

Sentinel 2 satellite uses: SWIR bands at 20m we have 2 or 3 bands in SWIR spectral range and we use a lot not only in terms of agriculture but also in terms of water content Its also used in some models for water quality or entropization of water (when theres algae, and poor quality of water) this detects chlorophyll

Important in terms of remote sensing: Spatial resolution - but a good image or observation is not in terms of better spatial resolution but rather radiometric and good SNR In experience its more important the radiometry than the spatial resolution. Prefer good radiometry over spatial resolution.

2 main manufacturers of sensors: Specim (Finland) and Iitres (Canada) for SWIR. They operate

some of these sensors and ran a test 2 months ago with a SWIR sensor. (These are usually really expensive even for satellites. There are options like Prisma (Italy) and EMAP (DLR_GERMANY))

Using Drones: UAVs, are really useful when you work in projects in relative small areas ¡300/400 hectares

More applications for SWIR: Mineralogy - SWIR bands are very competent New soils and mineral extractions, SWIR bands are very useful Detection of Methane Detection of Materials on rooftops

He says this because for agriculture, it is multi-factorial environment so it is quite difficult to provide solution with just data from SWIR but need models from many different sources (soil models, meteorological data, growing data, etc)

Nowadays any person can train a dataset and run an algorithm to produce a map. Not validated but really nice so be careful on that since we need real growing data.

For SWIR bands, in the trade-off between Spatial resolution and spectral resolution try to achieve a good balance. When using NIR and SWIR integration, you should analyze the spectral response and how this can change in time Instead of 2 bands at 5m, prefer 6 or 7 bands at 2m.

Final recommendation. In terms of detectors, the current state of tech in SWIR has two. Sensors achieve 1.7 and 2.5. Many sensors arrive to 1.7 but not so many to 2.5. Try to assure 1.7 is okay in terms of asbestos response or methane response.

10.4 Carlos Burillo - Farmer from Tarragona

Experience and Knowledge of the Farmer:

More than 20 years of experience in agriculture. Specially cultivating olive trees, tomatoes and all kinds of plants and flowers. Actually also has potatoes and lettuce crops. Approximately, the fields are around 280 ha, being olive trees the bigger one (almost 160 ha).

The main challenge for him is to deal with weather changes, price elevations and lack of knowledge about pests and fertilizers.

He is currently participating in different courses or lessons that agriculture associations do to teach farmers how to deal with specific problems and pests. He would really appreciate an app that is able to tell him what to do in each case.

Knowledge and Technological Experience:

He has limited experience with agricultural applications and technology. He relies more on experience, intuition, and traditional farming methods passed down through generations. However, he is open to exploring new tools and techniques that can potentially improve his farming practices.

Evaluation of the Application:

He was interested. Having access to information about the health of plants and other agricultural aspects could certainly be beneficial. As long as the application is user-friendly and provides accurate and relevant insights, he would be interested in exploring it further.

His main concern would be the ease of use and practicality of the technology. He would need assurance that incorporating technology does not complicate or disrupt his farming practices. It should be accessible and not overly burdensome to implement. If it is very expensive he is not willing to pay it alone. However he pointed out that farmers work together and many times they put money to buy a common beneficial technology. In this case, this would also be possible.

List of Figures

References

[1] Princeton: Agricultural inspection using swir camera technology. https://www.princetonirtech.com/applications/agricultural-inspection-in-swir?lang=en. Accessed: 2023-05-06.

[2] Eos: Agriculture band combinations — overview. https://eos.com/es/make-an-analysis/agriculture-band/. Accessed: 2023-05-10.

[3] Nasa: Earth observatory. https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php. Accessed: 2023-04-30.

[4] Pioneer: Remote sensing applications in crop production. https://www.pioneer.com/us/agronomy/Remote-Sensing-Applications-in-Crop-Production.html. Accessed: 2023-05-03.

[5] Usa government: Vegetation indices. https://www.usgs.gov/special-topics/remote-sensing-phenology/science/vegetation-indices. Accessed: 2023-05-05.

[6] Eos: Ndmi (normalized difference moisture index). https://eos.com/make-an-analysis/ndmi/. Accessed: 2023-05-10.

[7] Eos: Normalized difference water index. https://eos.com/make-an-analysis/ndwi/. Accessed: 2023-05-10.

[8] Aquastat - fao's global information system on water and agriculture. https://www.fao.org/aquastat/en/overview/methodology/water-use. Accessed: 2023-05-17.

[9] Water for sustainable food and agriculture. https://www.fao.org/3/i7959e/i7959e.pdf. Accessed: 2023-05-20.

[10] Brinding the rice yield gap in india. https://www.fao.org/3/x6905e/x6905e09.htm#BRIDGING%20THE%20RICE%20YIELD%20GAP%20IN%20INDIA%20E.A.%20Siddiq*. Accessed: 2023-05-16.

[11] Rice production in the asia-pacific region: issues and perspectives. https://www.fao.org/3/x6905e/x6905e04.htm. Accessed: 2023-05-14.

[12] India rice area, yield and production. https://ipad.fas.usda.gov/countrysummary/Default.aspx?id=IN&crop=Rice. Accessed: 2023-05-18.