Escuela Politécnica Superior de Jaén

Grado en Ingeniería Geomática y Topográfica

UNIVERSIDAD DE JAÉN

Escuela Politécnica Superior de Jaén

Trabajo Fin de Grado

Data capture, processing and generation of Uav products for precision farming

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RESUMEN

El análisis de la información y los datos relativos a una explotación agrícola es de gran utilidad para tomar decisiones para la mejora de la producción y contra las malas prácticas agrícolas. El uso de datos de alta resolución espacio-temporal de una zona facilita un análisis exhaustivo de la explotación a diferentes niveles. El estudio pormenorizado de una explotación concreta implica el manejo de datos precisos sobre la forma de explotación junto con múltiples variables que están interactuando en la explotación. En este sentido, se habla de variables ambientales y de información sobre periodos y acciones de laboreo concretas. Este enfoque está relacionado con la Agricultura de Precisión, donde se analizan las variaciones espacio-temporales de la explotación para mejorar sus beneficios. Este concepto se basa en las nuevas tecnologías de posicionamiento, representación y visualización. Es posible cartografiar una explotación en funcionamiento, extraer y monitorizar pequeñas áreas en lugar de trabajar con valores únicos para toda la explotación a partir de estimaciones promediadas. La gestión adecuada de toda esta información requiere el uso de herramientas geomáticas tanto para la fase de adquisición de datos, como para el procesamiento y generación de productos útiles para la gestión de una explotación.

Palabras Clave : Teledetección, Webmapping, Agricultura de precisión

ABSTRACT

The analysis of information and data relating to a farm is of great use in making decisions for the improvement of production and against bad farming practices. The use of high spatio-temporal resolution data of an area facilitates a comprehensive analysis of the farm at different levels. A detailed study of a specific farm implies the handling of precise data on the way it is farmed together with multiple variables that are interacting on the farm. In this sense, we are talking about environmental variables and information on specific tillage periods and actions. This approach is related to Precision Farming, where the spatio-temporal variations of the farm are analysed to improve its benefits. This concept is based on new positioning, representation and visualisation technologies. It is possible to map a working farm, extract and monitor small areas instead of working with single values for the whole farm from averaged estimates. The proper management of all this information requires the use of Geomatic tools both for the data acquisition phase, for the processing and generation of useful products for the management of a farm.

Keywords : Remote sensing, Webmapping, Precision agriculture

DEDICATION

To my very dear mother

No matter what I do or say, I will never fail to properly thank you. Your care, your watchfulness, and your constant presence by my side have always given me the strength to overcome the various challenges.

Towards my dear father

You have always stood by my side to support and encourage me.
Here that work embodies my appreciation and love.

To my dear brother

Gives your health, happiness, bravery, and most importantly resilience.

And last, I dedicate this memory to everyone who helped me, close and far, to complete my report under ideal circumstances.

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I would like to thank the 1st team at The University of Jaen for their hospitality, the time each member gave to me, and more generally for all the information, bibliographic references, thoughts, revisions that everyone contributed and that helped to fuel this work.

I appreciate this university for introducing me to the world of "precision agriculture" and opening the doors to the newest technologies with which it works.

I also want to thank my professors for the excellent instruction they have given me over these last three years at ESAT University Tunisa.

I want to express my sincere gratitude to Mrs. María Isabel Ramos Galán,

Mr. Juan Manuel Jurado Rodríguez and Mrs. Bouzidi Ines who served as this memory's director.

They allowed me a great deal of creative freedom while guiding me along insightful and insightful paths.

I would want to thank all of my family members who have supported (and will undoubtedly continue to support) my views on self-control.

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LIST OF ABBREVIATIONS

UJA: University of Jaen

ESAT: Higher school of aeronautics and technologies

GPS: Global positioning system

NIR: Near infrared measurment

RGB: Red,Green,Blue

IRT: Infrared thermography

RTK: Real time kinematic

Dem: Digital elevation model

Ndvi: normalized difference vegetation index

Sld: Styled layer descriptor

Shp: Shape file

Js: JavaScript

Css: Cascading Style Sheets

Html: HyperText Markup Language

Ol: OpenLayers

Jpeg: Join photographic expert group

Tiff: Tag image file format

Gsd: Ground sample distance

Gnss: Global Navigation Satellite System

OGC: Open geospatial consortium

WMS: Web map service

WFS: web feature service

GIS: Geographic information system

Uav: Unmanned aerial vehicles

PA: Precision agriculture

I. Introduction

In a Spain that has been qualified as the tenth industrial nation in the world, Andalusia occupies the first place in its agricultural production, with 55 to 70% of the Spanish production, of which 22% is dedicated to the olive.

Faced with the emergence of societal and environmental challenges as well as the growing demand for scarce agricultural workers, drones have evolved into true command and control tools. Thanks to the onboard camera and sensors, the farmer will be able to film a visual inspection of the land to detect weeds or noxious plant damage and also monitor the biomass of his land, measure hydric stress, and map his parcel to determine the other needs of his plants.

For several years, new technologies, which are present in all sectors, have invested in the agricultural market with the goal of assisting farmers in saving time, simplifying their work, and increasing their profits. Currently, 80% of the drone market's sales are dedicated to agricultural use.

So that's the end of the manual calculations. The farmer can now detect the needs of his plants using his drone and treat them accordingly.

Good management requires the use of geomatic-tools such as photogrammetry for the data acquisition phase and web mapping for the publication phase.

The present study is in line with this axis, to generate geomatics products useful for the management of an olive farm using images from drones in a well-defined study area, processing the images and duplicating them with open-source internet services, and publishing them on a web platform in order to optimize the management and improve the daily life of the farmer without even moving.

I. Presentation of the host organization, the University of Jaen

I.1 Presentation of the Office

The University of Jaén is a public higher education institution that fosters the development of a critical, professional, and environmentally conscious citizenry while also adapting to the needs of a changing society through the creation, advancement, and transmission of science, technology, and culture; it also highlights a commitment to personal responsibility as one of its distinctive hallmarks.

The UJA strives to coordinate the work and outcomes of its various organizational units in order to strengthen its position as an innovative university that upholds and encourages the focus on the needs of its target audiences. It pays particular attention to the holistic formation of its students through an educational model that encourages and ensures their intellectual growth and capacity to develop into the professions that a globalized society demands.

I.1.1 History

Founded by the Andalusian Parliament through Act 05/1993 (BOE-A-1993-21845) in 1993 with the stated mission to promulgate and educate future generations of economists, health professionals, engineers, and scientists.

It's regarded as the successor of the ancient University of Baeza, established in 1537 by Pope Paul III in the former Kingdom of Jaen.

more than engineers and firmly establish its position on the local, statewide, and global educational scenes.

To do so, the university will need a dedicated team of people.

The social action, representation, governance, and management of the university are the responsibility of various administrative organs; these can be at the university level or at the level of faculties, schools, or departments. The university's governing bodies can be either individual or collaborative.

I.1.2 Engineering department

The Department of Geographical and Photogrammetric Engineering was established in 1993 in conjunction with the founding of the University of Jaén, which was distinct from the University of Grenade, to which belonged the studies that had been completed prior to this date at the College and, later, the Campus of the University of Jaén, as well as the technical schools of the city (Law 5/1993 of July 1 on the founding of the University of Jaén, BOJA N° 72 of July 6 and BOE of August.

It combines disciplines such as cartography, photogrammetry, remote sensing, topography, geodesis, and computer science to prepare professionals capable of planning, projecting, directing, executing, and managing projects in the fields of engineering and construction, cartography, cadastre, and land management, geographic information systems (GIS), cartographic servers such as Google Maps, and navigation.

Researchers in the Department of Cartography, Geodesy, and Photogrammetry at the University of Jaén have published their work in renowned international journals since the department's founding in 1993.

The following chart in the figure 1 displays the total number of articles from Scopus that Department of Defense researchers have contributed to.

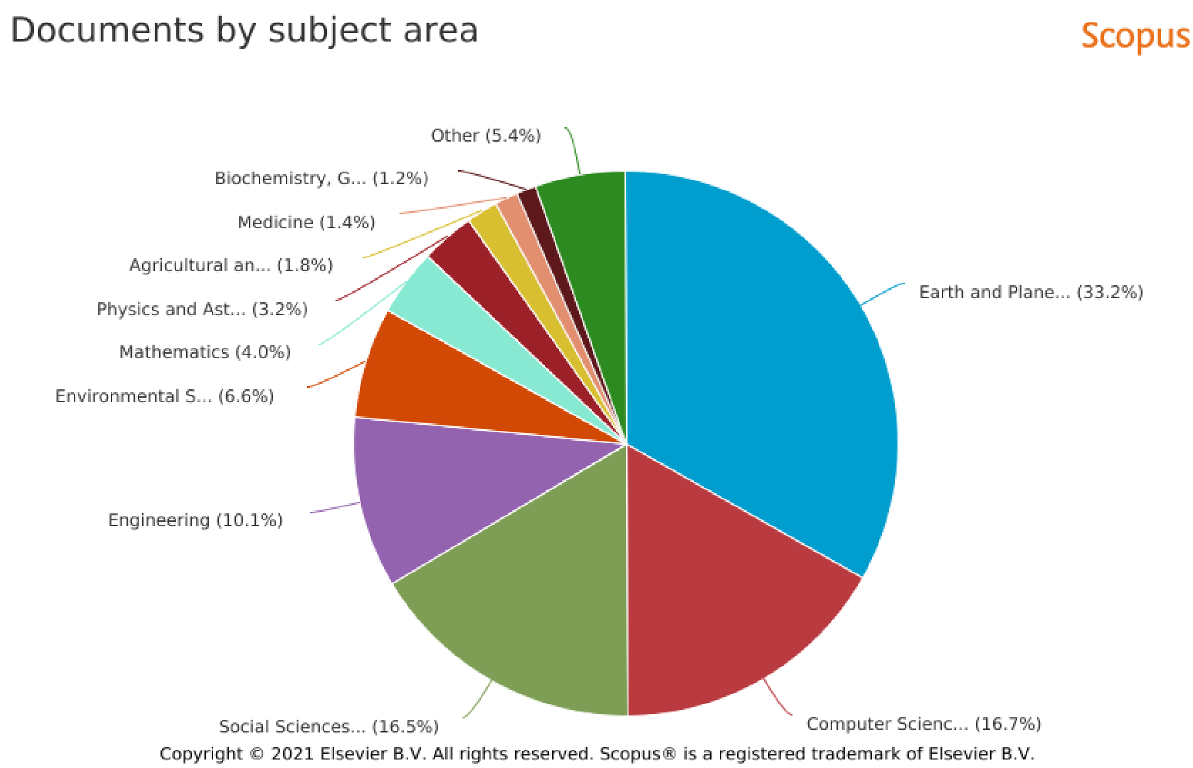


Figure 1: Project realized in the engineering department

Source: https://www.ujaen.es/

I.1.3 The reasons I chose the University of Jaen

It will allow me to benefit from complete and professional supervision during my internship period as a Geomatics and Topography Engineer, thanks to the quality of the modern technologies used, which never ceases to grow due to the massive use of information and communication technologies (ICT), artificial intelligence, and satellite technology in the field of geoinformatics.

The department of carthographic, geodesic, and photogrammetric engineering has more than 38 total stations, 35 GPS, two high technology scans, 45 theodolites, 48 level stations, and drones from different marks(Tableta Nexus 7, Drone Parrot A.R. 2.0, Uas DJI Phantom 3 Pro...), and a much enhanced geographic SIGRA4D simulation tool like we can see in Figure 2. Similar to a topographic map, different colors in this simulator stand for different elevations.

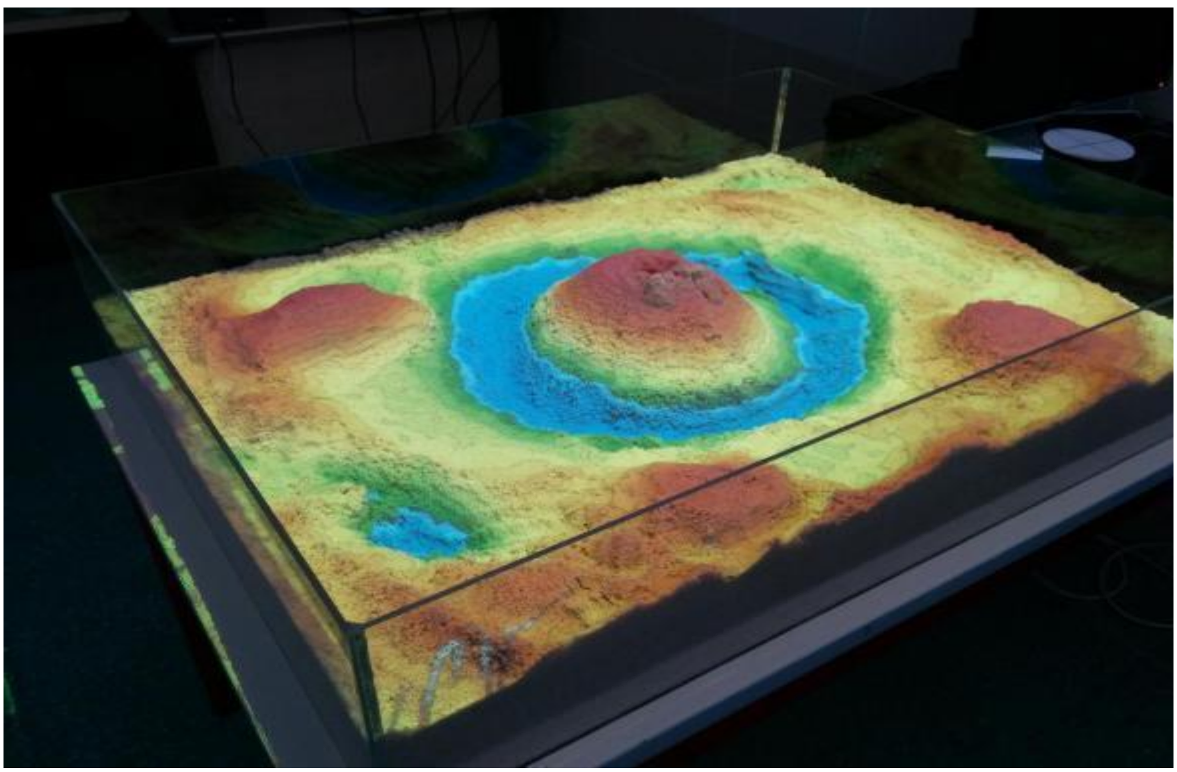


Figure 2: Augmented reality geomatics simulator SIGRA4D

Source: https://www.ujaen.es/

In addition to the resources listed, the University of Jaen offers physical resources in addition to services, which can be grouped into three main blocks: library, ICT and free accessibility and disability services.

II. Project Background

Precision agriculture (PA) is the science of acquiring, processing, and interpreting temporal, spatial, and individual data to improve agricultural yields. PA is a revolutionary concept that has been implemented globally to boost production, minimize labor time, and ensure proper fertilization and irrigation management.

It employs modern technologies such as geomatics to optimize the management of agricultural resources, production, and quality of crops by mixing massive amounts of data and spatial information.

Farmers that employ these tools are frequently pioneers, as tools and software improve and new applications are offered on a regular basis. This is comparable to how computers evolved in the 1980s. Computers were not extremely strong and pricey at first, but after 20 years, they are now ubiquitous. When we see GPS units that are smaller than a mobile phone and have an accuracy of less than 3 meters, all at very low rates, we can imagine that many agricultural consultants will come up with a variety of uses to increase the quality of their recommendations.

II.1 Problem Statement

The olive tree is one of the most important crops in Spain and in many regions with a Mediterranean climate. Its fruit, the olive, is used both for consumption in different ways and for the production of valuable olive oil, which is why it is a crop with high economic potential but which can be attacked by various diseases.

The choice of the topic of this project, "Data capture, processing, and generation of geomatics products for precision farming", is based on the importance of the agricultural sector in Jaen.

Today, the geographical and temporal variability of soils and cultures is thought to be all that agriculture has to offer, although it is frequently overlooked.
The failure of this approach has been attributed to the lack of agronomic knowledge and the costs associated with understanding, controlling, and knowing this variability.
Assessing and managing agricultural output variability at previously unattainable levels of detail and quality for a farmer with an olive oil production of at least one hectare enables him to increase profits, control costs, protect the environment, and obtain the highest-quality olive oil.
Here, geomatics is involved by offering a variety of new technologies in photogrammetry with UAVs. Equipped with high resolution sensors, they measure optical properties of the vegetation cover in order to estimate characteristics that allow the farmer to make the right decisions. This has contributed to the growth of precision agriculture in Spain.
Also, given the importance of the Internet in our daily lives, we have another component of geomatics that comes into play in the publication phase, namely web mapping. In order to publish our production, an interactive map through the web with well-detailed legends.

II.2 Objectives

Different images coming from sensors embedded on drones will be used to generate geomatics products useful for the management of an olive farm. The design, the planification, and the rapid distribution of information at different levels. The development of the data acquisition phase, the processing and exploitation of the ability to visualize a map on a website
These objectives can be achieved with the help of different geomatic tools used during the realization of this project. Hence the need to define their basic concepts and to present the usefulness of these tools in the realization of this work.

II.2.1 Main Objectives

The main objective of this project is to set up an appropriate working methodology to manage an olive farm. For this purpose, different geomatics tools will be used, both for the data acquisition and processing phase as well as for the exploitation of the information.

In this study, the most appropriate methodology is to be able to integrate the concepts of optimization in the use of agricultural resources and an approximation of the prior knowledge of the yield levels of the farm.

In other words, these objectives will be achieved through the use of geomatic applications based on photogrammetric techniques in an integrated manner and applied to a better management of olive crops.

II.2.2 Specific Objectives

As part of enriching my project and in order to unify the knowledge acquired during the engineering degree in geomatics and topography, mainly those related to web mapping, it has been proposed to add a phase of publication on the web, given the importance of the web nowadays, in order to make the information easily accessible to all users, provided they have access to the platform.

II.3 Description of the Project

The project consists of the realization of a presentation that allows the team to cover mainly four modules:

- Design of the flight plan with the various sensors mounted on the UAV.
- Design of data collection campaign for photogrammetric ground control points.
- The processing, analysis, and creation of cartographic products from raster images obtained with sensors maintained on the UAV.
- Design and implementation of a web application to integrate the spatial information in order to jointly evaluate the values obtained by duplicating the results of our product with the official web.

The objective of this project is to generate geomatics products useful for the management of an olive farm, different images coming from sensors embedded on drones will be used. The diagram 1 below depicts the design, planning, and development phases, data acquisition, processing, and exploitation of information.

Information, visualized on a map on a website, has the rapid distribution of information at different levels.

These objectives can be achieved with the help of different tools used during the realization of this project. Hence the need to define their basic concepts and to present the usefulness of these tools in the realization of this work.

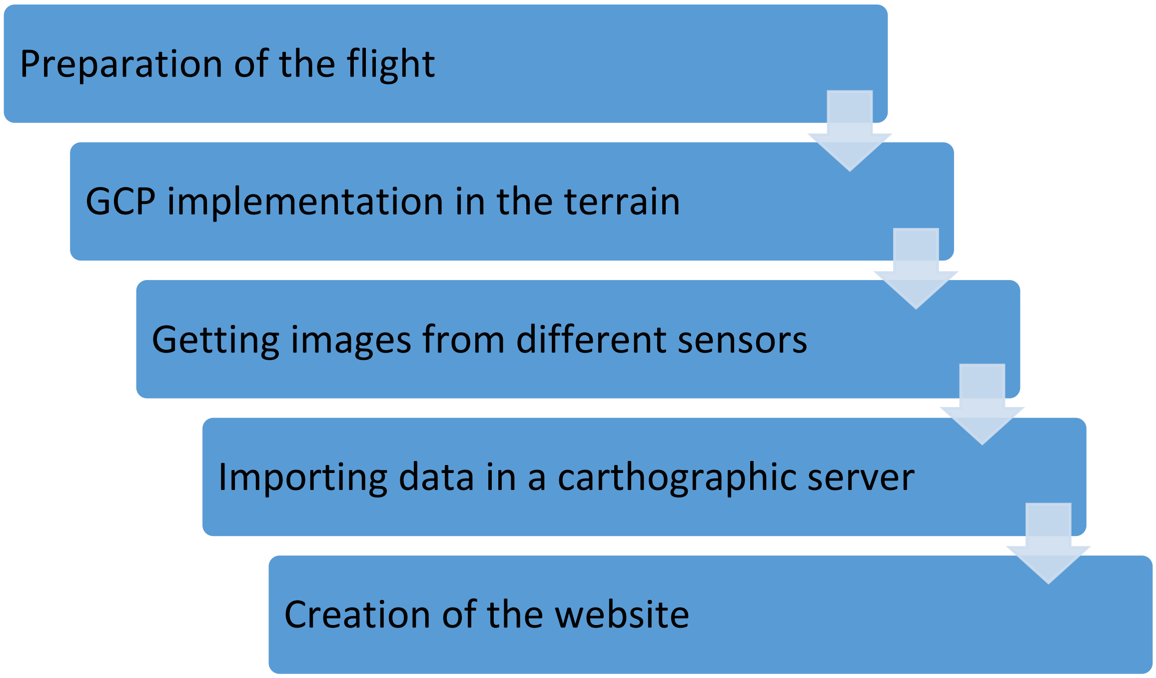


Diagram 1: Work flow

II. Background

II.1 Photogrammetry

II.1.1 Definition

Photogrammetry is the science and technology of the perspective and modeling of contours from aerial images to create a 3D scene without having contact with the object measured in order to determine characteristics such as size, shape, and position of photographed objects.

Photogrammetry was discovered by a French scientist in 1849, who was one of the French armies. He wanted to use landscape photographs not only to observe the terrain but also to measure it.

This is where the first idea of realizing photogrammetry came from.

The other key character is Félix Tournachon, also known as Nadar, who, in the 1860s, flew a balloon over Paris and other cities, as it appears in Figure 3, and who, based on his patents, understood the value of aerial photography for both civic and military purposes. Invented in France, photogrammetry was later developed and industrialized in Germany to a high degree.

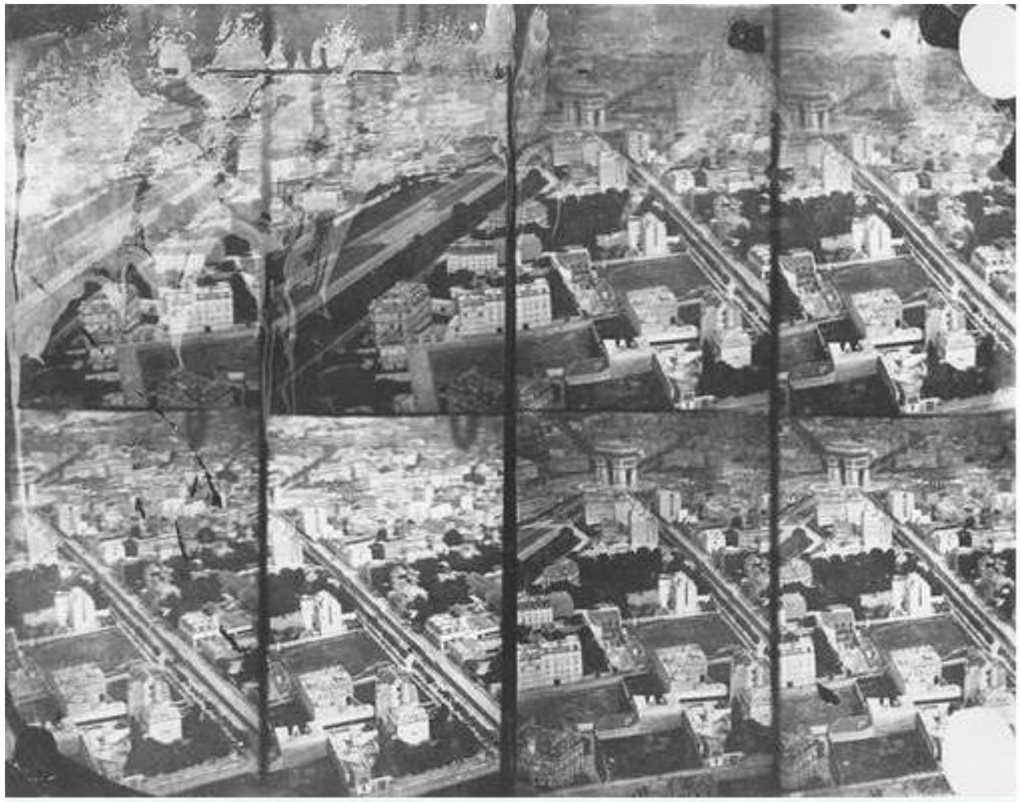


Figure 3: A balloon took the first aerial photograph of Paris

II.1.2 Domain of application

Before entering the different fields of application of photogrammetry, let's talk about the principle of photogrammetry briefly and the different stages concerning this discipline.

In fact, the main principle of photogrammetry is the horizontal and vertical superposition of two images with a high percentage, which causes the creation of a 3D relief that can be easily observed thanks to photogrammetric tools such as restitution on a laptop equipped with a 3D screen using photogrammetric glasses. In fact, it's exactly the principle of the human eye. If you fix an object and try to observe it with one eye and then with the other, you will notice that you cannot observe the object in the same position. That’s exactly the principle of photogrammetry.

Let's discover the photogrammetry product. It allows us to produce a large column of geo-referenced 3D data in a short time and with less money.

II.1.3 Orthophotography

Orthophotography is the assembly of images giving a precise view of a large geographical area. This rendering was obtained using several high-resolution aerial images taken by drones. The assembly of these images allows us to create a map that is both extensive (it is possible to map many hectares) and detailed. As we can see in Figure 4, this image is an example of georeferenced and can be superimposed on a map or a GIS (Geographical Information System) plan.

Figure 4: Example of an output from orthography Images

Source: https://www.brantax.com/aerial-photography/orthophotomaps-and-photogrammetry/

II.1.4 Volumetry

Volumetry is an adaptation of photogrammetry to create a 3D model of land or stock volumes. This technique is principally used in the mining sector, energy production plants, careers, or land management.

Similar to 3D modeling, it allows the extraction of cubes, which are a volumetric measurement of materials as well as tonnages of a delimited space like presented in

Figure 5. The use of the drone allows us to do this job regularly due to its speed and low cost.

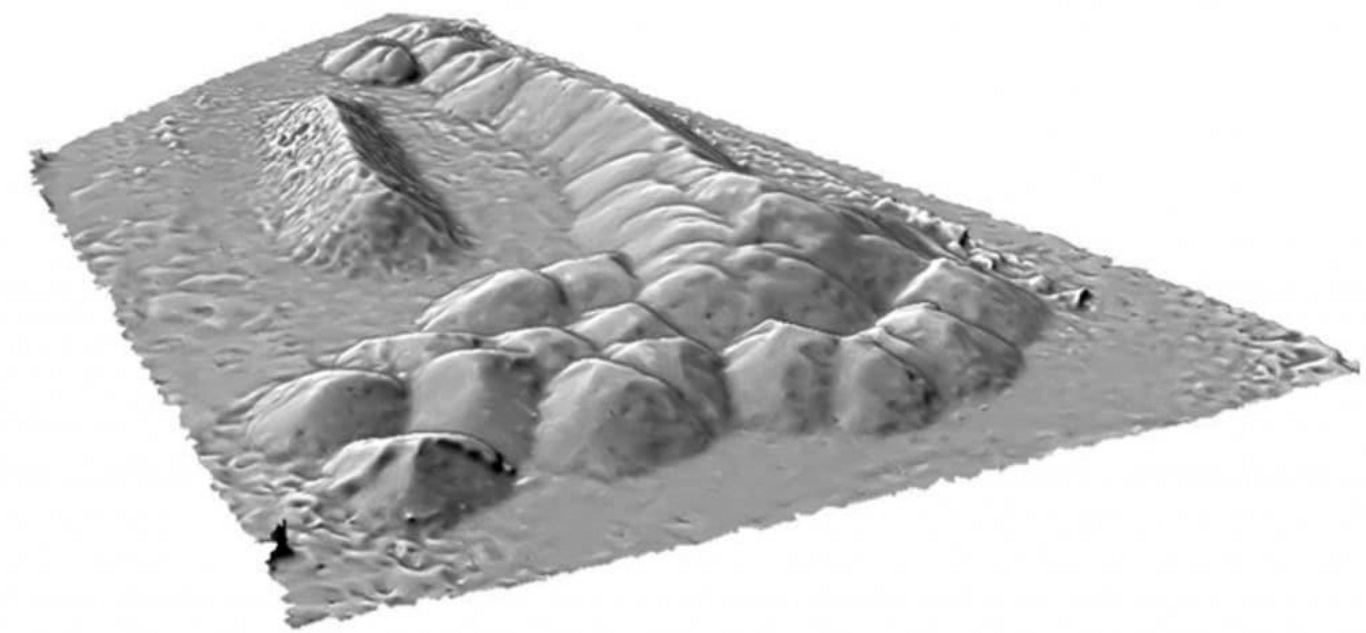


Figure 5: Example of volume extraction from aerial photographs

Source: https://www.researchgate.net/figure/Photogrammetry-model-of-Jwaneng-East-wall-f100mm-distance50m-showing-a-step-path_fig3_269989702

II.1.5 3D Modeling

One of the uses of photogrammetry is 3D modeling. After the discovery of aerial photographs, this technique involves reproducing, thanks to the adapted software, synthetic images representing the photographed area in 3 dimensions. The 3D modeling allows for study support depending on what is sought.

- The evolution of a relief (crevasse, cliff...)
- The construction of a space, such as a road or a waterway, in a specific location.
- The creation of interactive models of buildings, facades, or monuments
- 3D modeling of an archaeological site

As shown in Figure 6, 3D modeling is also very useful in heritage preservation because it allows us to freeze the state of a monument at a specific date.

Figure 6: Example of a 3D model from aerial images

Source: https://www.gim-international.com/content/article/photogrammetry-recent-developments-and-the-way-forward

II.2 UAVs and precision farming.

II.2.1 Definition of UAVs

A drone, or unmanned aerial vehicle (UAV), is an aircraft without a passenger or pilot that can fly autonomously or be controlled remotely from the ground, or fly autonomously using software-controlled flight plans in its onboard systems, which work in conjunction with onboard sensors and a global positioning system (GPS). Here we can see an example of a UAV in Figure 5.

Figure 7: Ortokopter uav fitted with a multispectral camera

Source: https://www.dji.com/newsroom/news/dji-released-its-new-spreading-wings-s1000-octocopter-platform

II.2.2 Domain of application

Now that drones are becoming much more accessible, the number of uses and applications that they may provide is growing. They're starting to use it in a lot more ways than we're accustomed to.

Given that drone development and use have slowed in recent years, businesses are continuing to experiment, explore, and test the boundaries with them to see how a drone may be useful to them.

We'll take a look at five jobs that can be made considerably easier with drones. Many of these applications are now being researched or are already in use, and they have the potential to make a significant difference in the industry.

- Topography

Drones have come a long way in the survey and construction industries, and their capabilities have greatly increased, making them a crucial tool for all surveyors to have in their toolkit.

- Agricultural advances and automation

Producers can make sound decisions to save money and time (for example, precision agriculture), obtain a quick and accurate record of damage, or identify potential problems on the ground.

- Environmental and ecological applications

Quick and inexpensive. Regular flights enable land and water monitoring, road mapping, cadastral mapping, thermal analyses, volcano monitoring, coastline monitoring, or natural resource documentation for geological analyses.

- Emergency management

A drone may be used to inspect damage and access areas that are difficult to reach on foot, as well as provide a far faster and more effective response.

UAVs can capture photographs swiftly for early impact assessment and rescue preparation.

The flight may be carried out over toxic regions without putting the operators in danger or requiring lengthy pre-flight preparations.

- Military operation

The military is perhaps the oldest, most well-known, and most contentious application of drones. In the early 1940s, British and American forces began utilizing primitive drones to spy on the Axis countries. Drones nowadays are far more advanced than UAVs of the past, with thermal imaging, laser range finders, and even the ability to carry out airstrikes. The MQ-9 Reaper is the most well-known military drone in operation today. The aircraft is 36 feet long, has the ability to fly unnoticed up to 50,000 feet in the air, and is armed with a variety of missiles and intelligence-gathering capabilities.

II.2.3 Applications of UAVs in agriculture

The use of drones in the agricultural world is a common practice to collect information at different levels or to access hard to reach areas.

In addition, with mounted sensors, images obtained were and still are widely used in crop analysis.

But the need for better spatial, temporal, and spectral resolution has made the use of drones in agriculture a strong trend in the face of these limitations.

There are two types of drones that can be used in agriculture:

II.2.3.1 Winemakers' Uav

Drones capture data, useful in precision agriculture. This tool is designed to optimize crop yields and inveWinemakers'vide valuable data.

As we can see in Figure 8, an example of a UAV equipped with multi-spectral sensors specifically developed for agriculture, analyzes data in discrete spectral bands. All data is geo-referenced and directly usable by the farmer or environmental manager.

Figure 8: Example of winemarks drone

Source: https://www.terraview.co/how-drones-can-improve-winemaking/

II.2.3.2 Uav in arboriculture

Arborists designate drones for performing spreads or sprays. These allow treating plots of land, sometimes difficult to access, by spraying liquid phytosanitary products or by spreading granules, which can be bio-control products. An example of an arborist drone is shown here in Figure 9.

Figure 9: Example of a drone in arboriculture

Source: https://www.flyingeye.fr/faits-surprenants-sur-les-drones-depandage/

II.3 Precision agriculture

Precision agriculture (PA) is the science of acquiring, processing, and interpreting temporal, spatial, and individual data to improve agricultural crops and to define bad habits.

It is a revolutionary concept that has been implemented globally to boost production, minimize labor time, and ensure proper fertilization and irrigation management.

It employs modern science such as geomatics with the new technologies of satellites, drones, and connected sensors, which are all linked to data collection and processing tools.

This new way will help agricultural producers to get more information about their farms in less time, and to optimize the management of agricultural resources, production, and quality of crops by mixing massive amounts of data and spatial information.

In precision agriculture, there are two phases:

- external subterranean.

External precision agriculture necessitates the use of machines that are both regulatory and environmentally friendly.

Drones and satellite photos are used to monitor plantations.

-Data controlling plates and forms.

- internal subterranean

Internal precision agriculture or subsurface agriculture:

For humidity, temperature, and conductivity, submersible sensors are used.

-Controlling irrigation with deficiency measurements and optimizing crop needs

-Maps of the terrain

Farmers that employ these tools are frequently pioneers, as tools and software improve and new applications are offered on a regular basis. This is comparable to how computers evolved in the 1980s.

According to Justin McAllister, chief technology officer of MicaSense, "there has been a significant growth in sensors that are utilized on drones as well as other agriculture sensors such as soil sample sensors, temperature and humidity sensors, and soil moisture sensors." In the upcoming years, businesses will put a lot of effort into transforming sensor data into knowledge that farmers can utilize.

II.3.1 Sensors

When the issue is the use of drones in agriculture, an essential aspect is the sensors to be used. According to Edwin Pino V. (2019),

Agricultural-type cameras have specialized filters that make them more expensive. Examples of specialized cameras for agriculture are the Micasense Red-Edge and Parrot Sequoia. These cameras are lightweight and designed specifically for drone power. Another important aspect is location on the ground: drones have built-in GPS that gives in-flight location. The currently manageable accuracy on these devices is +/- 3 m.

In Figure 10 below, we present a review of some theoretical fundamentals concerning sensors used in PA.

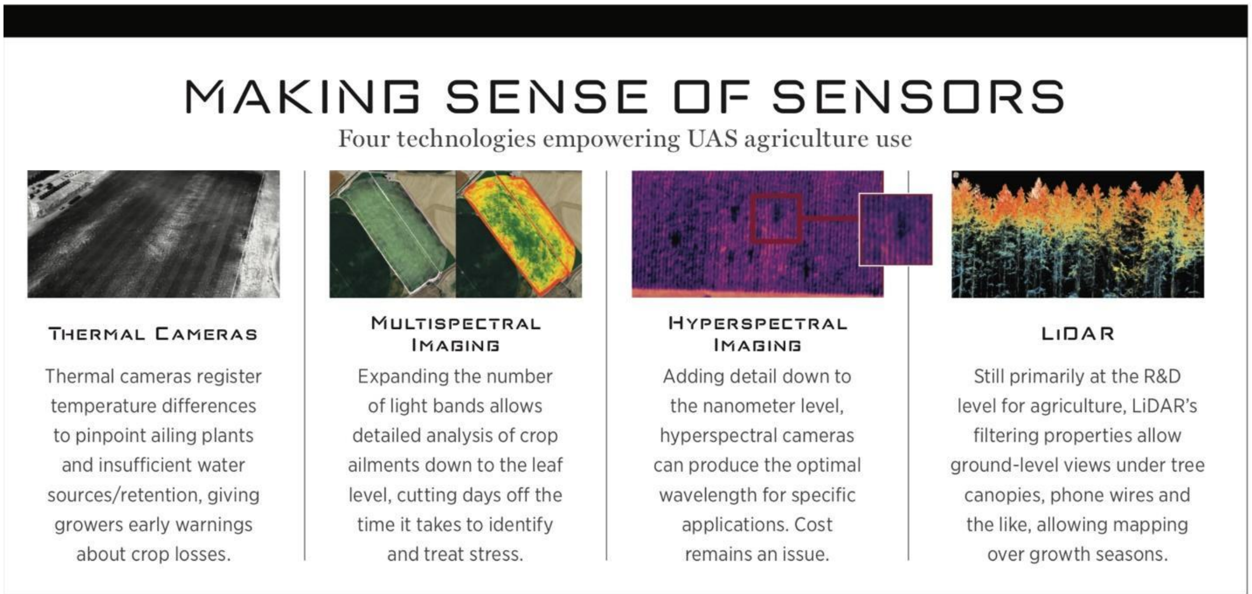


Figure 10: Types of sensors used in PA

Source: https://www.arrow.com/en/research-and-events/articles/top-5-sensors-used-in-agriculture

II.3.1.1 Multispectral Sensors

Multispectral photos display a total of five or six bands in addition to the red, green, and blue spectrum that are typically included in a type of the photo, giving users even more details.

These cameras focus on light frequencies that are similar to what the eye can see as well as bands that it cannot, including near infrared.

If a crop is under stress from illness or lack of water, it will reflect light in a different way. When distinct frequencies are found, producers can determine exactly what is wrong or whether they need to conduct further research when this happens.

The near infrared, or NIR, region of the spectrum, between 700 and 1000 nm, as we can see in Figure 11 below, is also significantly reflected by photosynthesis-active plant leaves. The quantity of NIR that plants reflect diminishes under stress. The ratio of reflected near-infrared radiation to red radiation is employed as a good predictor of plant stress in multispectral imaging systems.

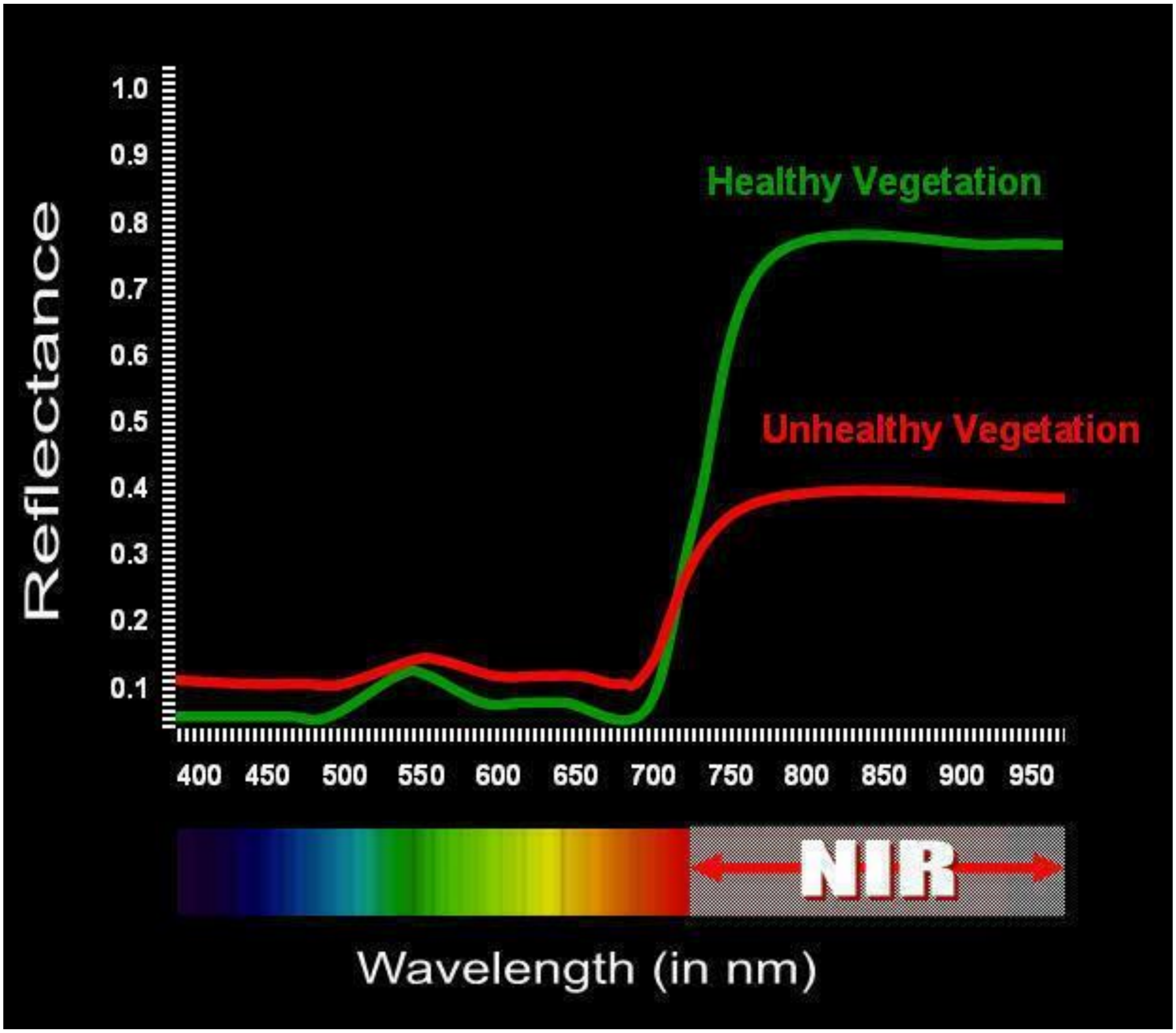


Figure 11: Multispectral camera application notes

Source: https://www.researchgate.net/figure/The-five-drone-sensors-used-in-this-experimentation_fig5_327312873

II.3.1.2 Thermal Sensors

Growers have the capacity to examine drought stress thanks to thermal cameras. When using a thermal or RGB camera, it might be challenging to identify a plant that is having problems until symptoms like withering leaves or brown patches become apparent, as we can see in the figure. 12. Growers have the chance to prevent crop loss since thermal cameras can see temperature variations in the ground that suggest a plant is in peril early in the process.

Additionally, this technology offers farmers useful knowledge regarding irrigation. The temperature of the earth drops as more water is absorbed by it.

According to Jones et al. (2002), the microclimate in crop stands, Lenthe et al. (2007), and variations in transpiration brought on by early infections by plant pathogens, infrared thermography (IRT) is used to measure plant temperature (Oerke et al. 2006). Thermographic and infrared cameras are able to detect infrared radiation that is emitted in the thermal infrared range between 8 and 12 micrometers, and this radiation may then be seen in false color pictures with each image pixel including the temperature value of the measured item. IRT may be applied in plant research at many temporal and geographical dimensions, including airborne and small-scale applications.

(A) (B)

Figure 12: Visible color and thermal image comparison

https://www.dailymail.co.uk/news/article-8208549/Italian-police-using-heat-sensor-drones-catch-people-coronavirus-lockdown.html

II.3.2 Images Resolution

Resolution is a very important feature used to characterize digital imaging, which is crucial for evaluating the value of drones in precision agriculture today. The next sections discuss the geographical, temporal, radiometric, and spectral resolutions.

II.3.2.1 Spatial Resolution

A pixel is a unit of measurement for the shortest angular or linear distance that a distant sensor may capture from the Earth's surface.

Because a pixel is the smallest unit that makes up a digital image and has identical dimensions on all four sides, it is commonly represented in meters or meters/pixel.

As demonstrated in Figure 13, the highest spatial resolution represents the greatest amount of detail that can be detected on the Earth's surface.

That is, the smaller items on the ground that can be identified. For example, if you have a 5m spatial resolution image, each pixel will be 5x5m, and in theory, plants of lower dimensions cannot be separated from each other in agriculture.

It is possible to observe an object smaller than the resolution because of strong contrast in the picture or a larger object due to poor contrast in the scene by being disguised.

According to Hengl (2006), at least four pixels are required to detect the smallest item. The image must have a resolution of less than 0.25 if the smallest plant in the crop is $1m^2$.

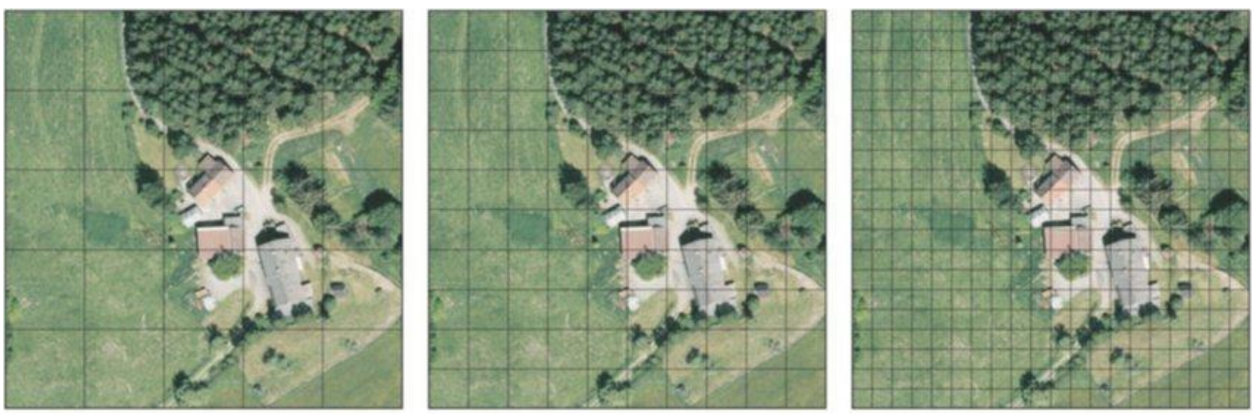


Figure 13: Different examples of the spatial resolution of each observation

Source: https://www.researchgate.net/figure/Different-examples-of-the-spatial-resolution-of-earth-observation-sensors-Larger-pixels_fig12_337087341

II.3.2.2 Temporal Resolution

The frequency or repeat cycle of the sensor returning to the same portion of the Earth's surface is referred to as temporal resolution. The satellite sensor and its orbit pattern are used to derive frequency characteristics. The frequency of plane or satellite flyovers is only relevant in time series, such as in deforestation monitoring.

The intelligence community was the first to use this resolution when repeated coverage indicated changes in infrastructure, unit deployment, or equipment introduction /

modification. When there is cloud cover over a specified object or area, it is reasonable to repeat the collection of that location.

II.3.2.3 Radiometric Resolution

In addition, the temporal resolution is used to calculate the time elapsed between the sensor's consecutive photos of the same ground location. The temporal resolution is mostly determined by the platform; for example, satellites typically have defined return periods, whereas sensors installed on unmanned aircraft systems or airplanes have multiple return times. The return time of satellites is primarily determined by orbital parameters (low vs. high orbit). Landsat has a return period of about 16 days, while other sensors, such as the Moderate Resolution Imaging Spectroradiometer (MODIS), have return times of almost daily.

Let's look at an example from figure 14 above: an image which can have 1 bit of radiometric resolution, or 2^1=2, which means that the information is stored in 0 or 1, with no other possibilities. When the radiometric resolution is increased to 2 bits, the possibilities for storing these zeros and ones increase to 2^2=4 possibilities, and so on until we get an 8-bit image with better detail because the possible values are 256.

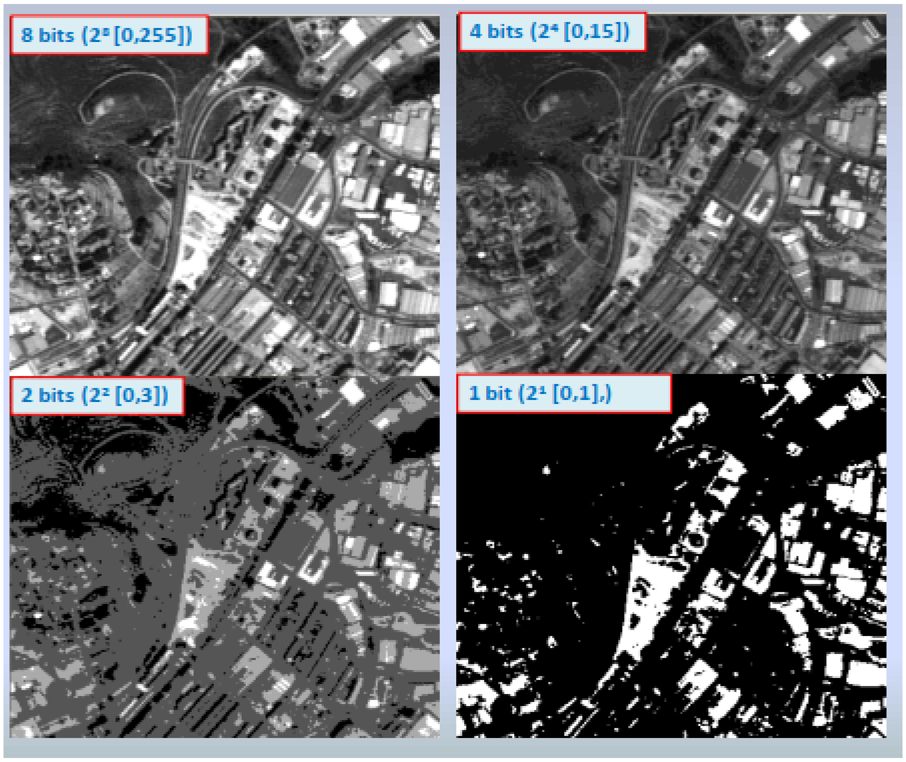


Figure 14: The same image for various radiometric resolutions

Source: https://alfageomatics.com/2019/09/tipos-de-resolucion-en-imagenes-geoespaciales/

II.3.2.4 Spectral Resolution

The number of bands of the electromagnetic spectrum that the sensor can detect is referred to as spectral resolution. The spectral resolution of traditional digital cameras, such as those in our phones, is three since they only store the R, G, and B bands, which are combined to generate the colors of the photos, as we can see in figure 15.

Thus, if a picture is analogous to an Excel sheet grid, an image with three bands of spectral resolution is analogous to an Excel book with three sheets.

However, it is recognized that the electromagnetic spectrum distinguished by the human eye is very small, and that we cannot perceive information and phenomena that emerge in bands of the spectrum that we can no longer see, but we have been able to develop multispectral cameras, which store not only color information but also how things would "look" in bands like infrared or ultraviolet.

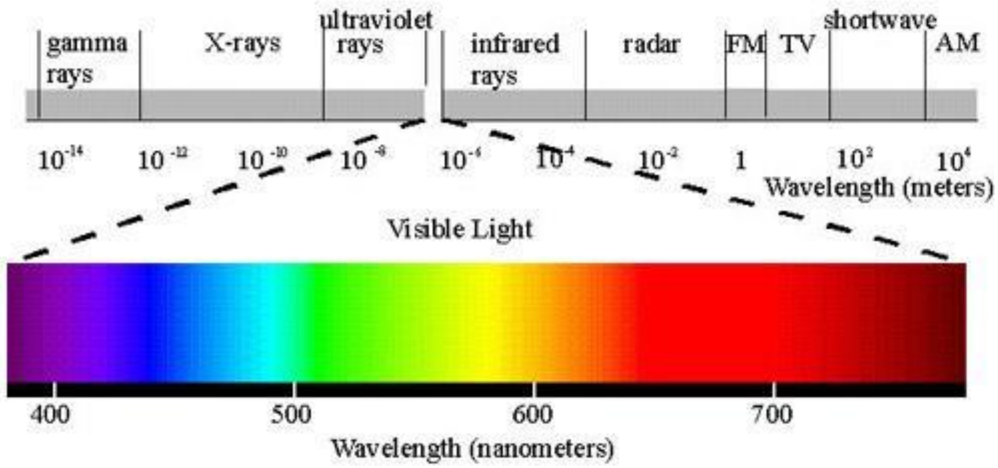


Figure 15: The electromagnetic spectrum covered by the human eye

Source: https://www.aces.edu/blog/topics/crop-production/basics-of-crop-sensing/

II.4WebMapping

II.4.1 Definition

Web mapping is the process of designing, implementing, generating, and delivering geospatial data in map form on the World Wide Web and its products.

It is divided into three levels, based on the capability available:

- Simple webmapping in which only data may be consulted and the visualization is static.
- The term "dynamic" webmapping refers to an online map that is interactive. Simple functions such as zooming, choosing to display layers, and even displaying tooltips are available to the user. This level allows users to access geographic data stored on a map server, such as a cartographic server, such as a database or GIS files, in addition to static maps.
- WEBGIS, which allows for more advanced features such as advanced attribute and spatial queries.

II.4.2 Characteristics

Web mapping is a tool that allows you to incorporate SIG ideas into web pages.

It discusses the evolution of local and Internet networks, the concept of client-server and its characteristics, and the impact of web mapping technologies in incorporating SIG ideas into web pages.

While a SIG is primarily aimed at industry experts, the ability to provide a simple Web browser with visualization or geographic data editing capabilities appeals to a different audience and opens up new possibilities.

The Web cartography, which complements traditional SIG in a variety of areas, is also useful to advanced users.

Non-specialist users who are unfamiliar with other SIG technologies can gain access to the SIG domain through the use of web technologies.

II.4.3 Architecture

The architecture of a Web cartography system is based mostly on four fundamental elements (Fig.16):

- Data is the system's most important component.
- Web cartography software is a server-side program that can generate a dynamic map (simple graphic) from data based on the client's request.
- The Web application's interaction tools: allow the user to manipulate and explore the map (zoom in and out, panoramic), as well as retrieve textual information.
- The web browser: it allows the user (client) to open the Web application and explore the map.

-

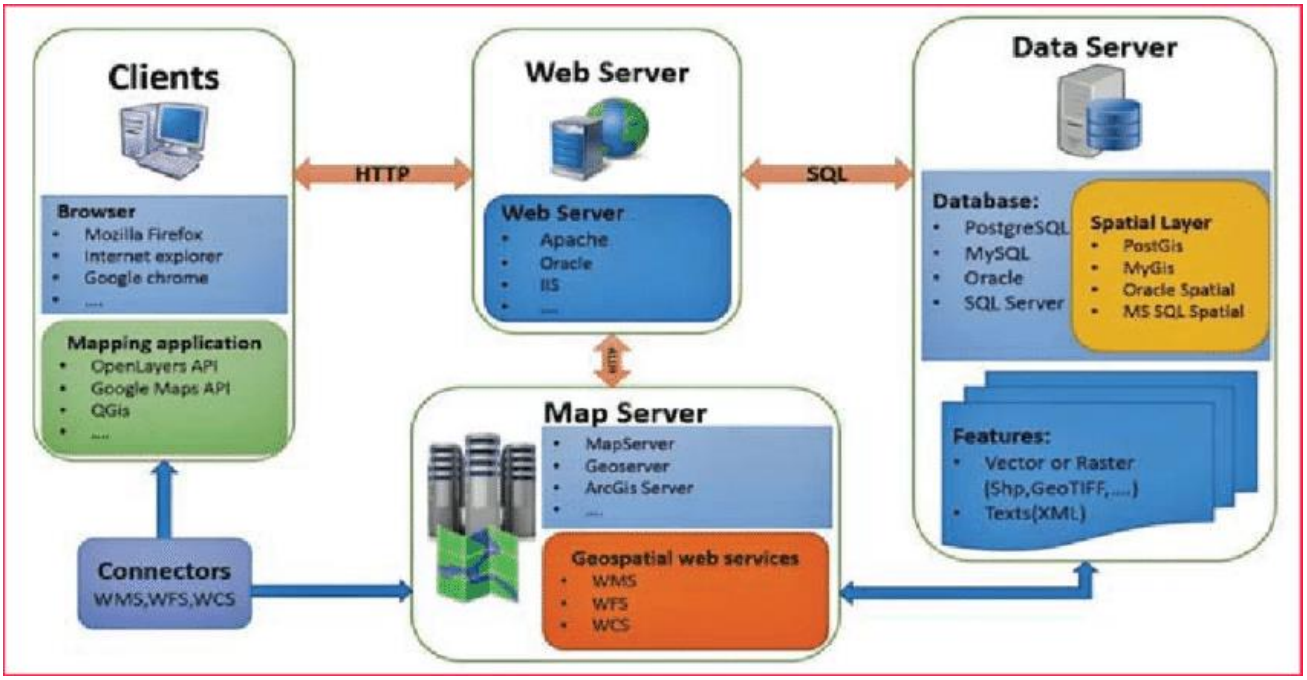


Figure 16: The electromagnetic spectrum covered by the human eye
Source: https://networkencyclopedia.com/web-mapping/

II.4.4 OGC

The Open Geospatial Consortium (OGC) was founded in 1994 and now includes 372 public and private organizations (as of February 2009). Its goal is to define open and interoperable standards within Geographic Information Systems and the World Wide Web. Pursue agreements with different industry companies that allow for the interoperability of their geoprocessing systems and the exchange of geospatial data for the benefit of users.

II.4.4.1 WMS

The Web Map Service (WMS) is an Open Geospatial Consortium “OGC” that was publish first in 1999 as a web service standard that generates dynamic maps from georeferenced data.

This is useful for two things:

Seeing a batch of data and overlaying layers from different servers for additional analysis.

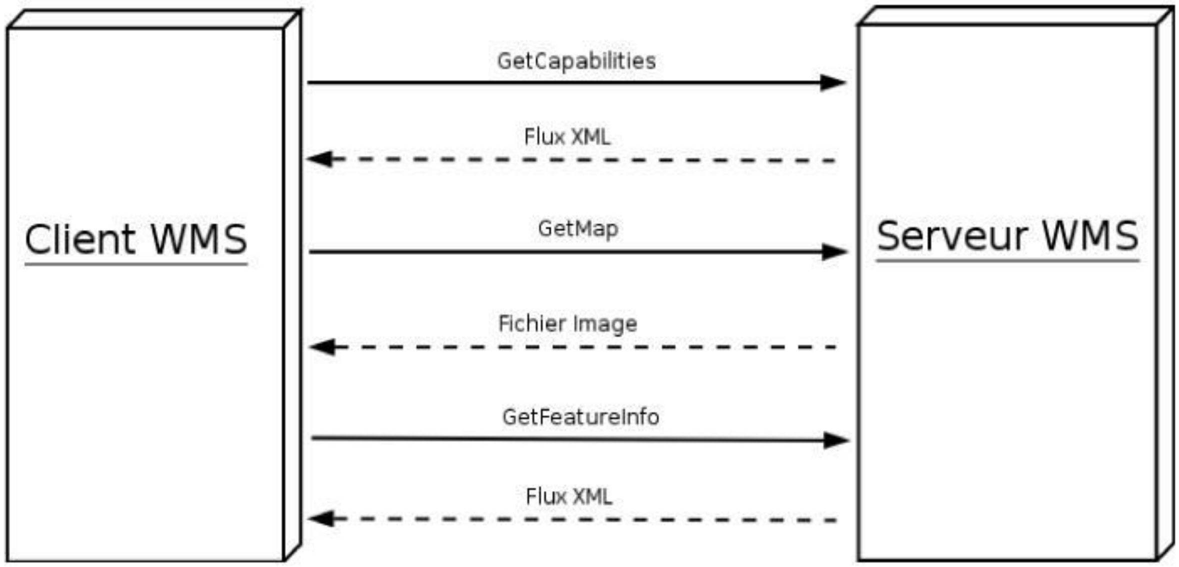


Figure 17: The dialogue between the server and the client WMS

Source: https://georezo.net/wiki/main/standards/wms

The figure 17 above is representing:

GetCapabilities: returns the service's metadata as a proposed covers, associated projections, author...

GetMap: returns the map as an image format based on the input parameters.

GetFeatureInfo: returns information about an object represented on the map.

As shown in Figure 15, there is a dialogue between the server and the client WMS, which will send HTTP (Get or POST) requests to the client via GetCapabilities, GetFeatureInfo, and GetMap, with an XML file as a response by the server on the information side of the map and the display will be done in JPEG, PNG, and GIF formats.

III. Methodology

III.1 Study Area

The study area is located in the province of Jaen on a farm dedicated to the cultivation of rainfed olive groves and where various studies related to the research groups of Computer Graphics and Geomatics (TIC-144) and Microgeodesy Jaen are underway. (RNM-282) from the University of Jaen, as shown in Figure 18 below:

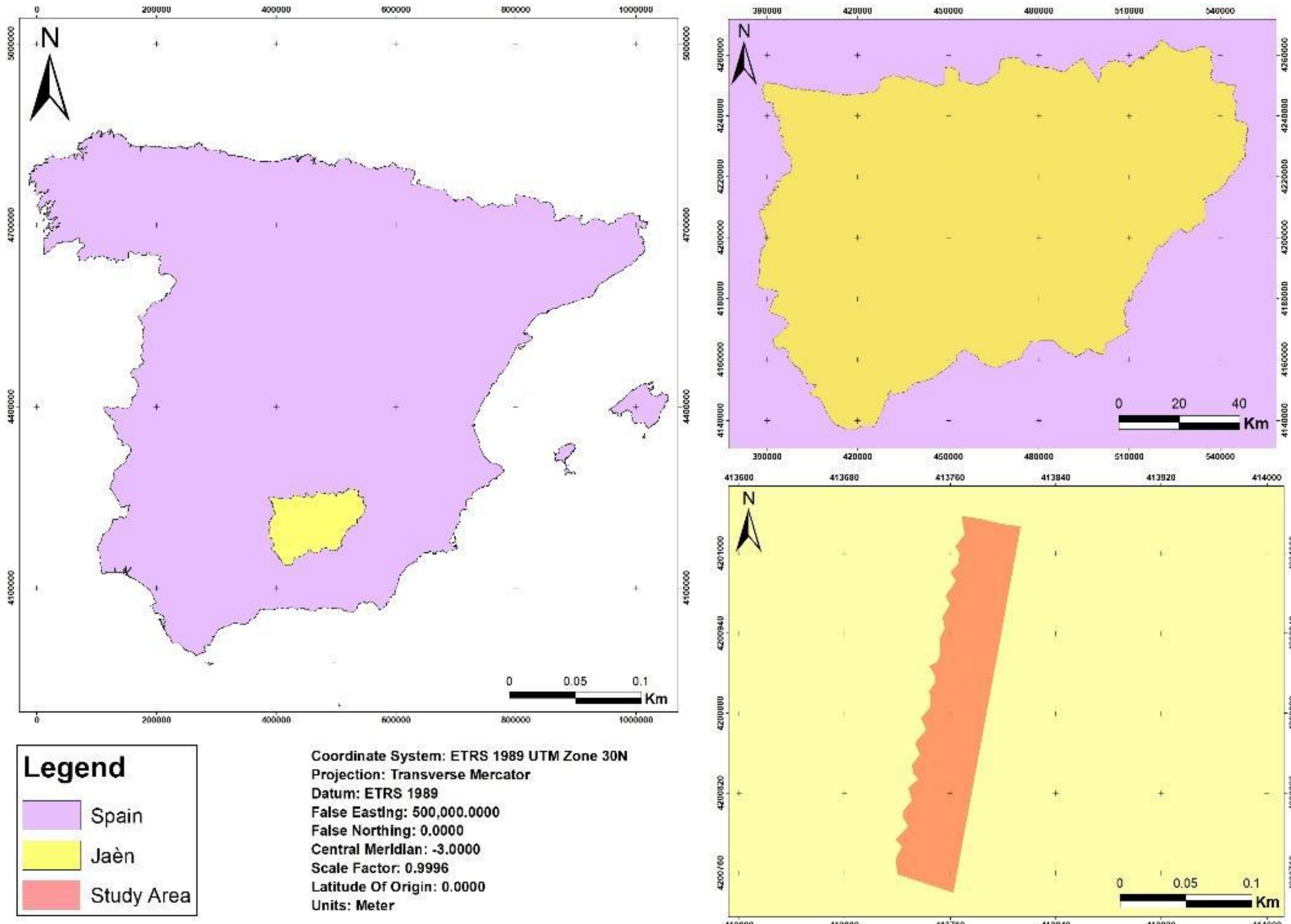


Figure 18: Map of the study area

This is a non-irrigated olive farm, with a SigPac reference visible in Table 1 below. The reason for selecting this work area was to have detailed information about it, as well as the permission of the farm owner to be able to carry out the corresponding flights as well as the rest of the data collection campaigns in the field.

A small area was selected of 1241 m².

Table 1: Catastral reference of the farm

The Reference SigPac of the Farm				Catastral Reference
Province	**Municipality**	**Polygon**	**Parcel**	
23	40	5	205	23040A00500205HD

Source: https://sigpac.mapama.gob.es/fega/visor/

Furthermore, to verify that the flight can be completed, a query on the free web application ENAIRE Drones is recommended to be checked for flight constraints.

According to ENAIRE, "The application provides on a map the airspaces of interest for drone flight in Spain as air traffic control regions or safety zones to be respected with reference to airports, helicoports, or military locations that may require permission to fly this type of aircraft," according to ENAIRE.

The flight was possible since there were no restrictions in the project area (indicated by the red marker) as shown in Figure 19.

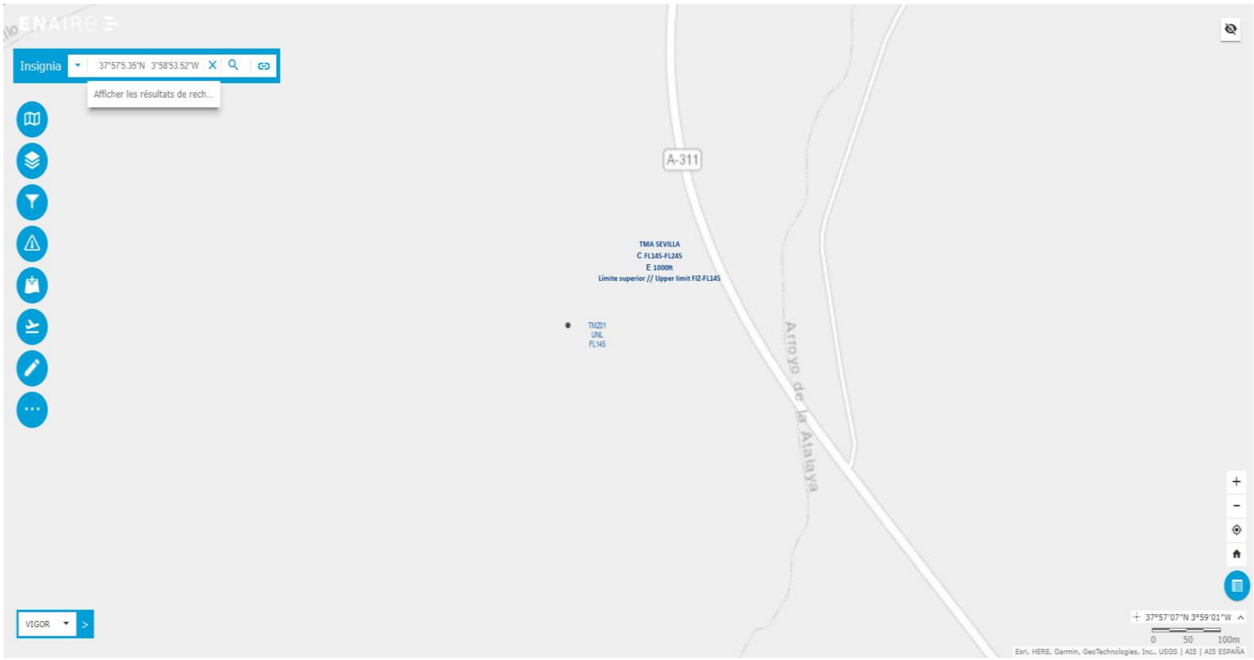


Figure 19: Screen shot of the platform ENAIRE

Source: https://drones.enaire.es/

III.2 Material of the flight

III.2.1 Drone DJI Matrice 300

III.2.1.1 Definition

The Matrice 300 professional drone from DJI presented in figure 20, boasts a video range of up to 15 Kilometres and a battery life of up to 55 minutes. It features six obstacle detection sensors for 360° coverage, and in S mode, it is capable of 82 km/h. It is outfitted with the new OcuSync Enterprise, which has a transmission range of up to 15 km and is capable of sending a 1080p video signal across triple channel 3 and has a maximum carrying capacity of 2.7 kg. AES-256 encryption offers safe data transfer, and real-time automated switching between the 2.4 GHz and 5.8 GHz 4 frequency bands make it possible for more steady flying close to areas with heavy interference.

Figure 20: Drone DJI Matrice 300

Source : https://www.dji.com/es/matrice-300

III.2.1.2 Main flight screen

The new primary flight display (PFD) on the Matrice 300 shown in the Figure 21, is obviously unique because it incorporates flight information such as drone attitude, height, and speed as well as wind direction and speed.

Figure 21: The new flight display on the matrice 300

Source: https://www.dji.com/es/matrice-300

It also functions as a navigational aid by giving the pilot a real-time status of the drone's trajectory as well as more precise location and projection data for the target's starting point.

Additionally, we may record our mission in real time, including the movement of the apparatus.

Likewise, the planning for the trajectory has been enhanced for more flexibility and effectiveness during flight operations.

II.1.2 Characteristics

The characteristic of the drone Matrice 300 is presented In the table 2 below Table 2: Features of the DJI Matrice 300

Table 2: Characteristic of the drone Matrice 300

Max. operating distance (km)	15 km
Flight time Max	55 min
Extra batteries	4 Times
degree of protection	IP45
Operating Temperature	Temperatures range from -20°C to 50°C.

Source: https://www.dji.com/es/matrice-300

II.2 Multispectral Camera

II.2.1 Micasense RedEdge-MX

The MicaSense RedEdge-MX is a multispectral camera that fits into any drone with ease. It can capture up to five spectral bands in a single flight and produces vegetation indexes and color photos.

MicaSense, the industry leader in agricultural drone sensors, introduces the RedEdge-MX, which has far more advanced technology thanks to a new aluminum housing.

This camera has been calibrated for precise and repeatable measurements and is built to work in the most difficult environments, including those with high temperatures (up to 60 °C) to improve lighting calibration.

And it moves quickly, covering a 40 hectare area in just 27 minutes (at 120 meters above ground level and 70% Recovery).

The findings show that the Blue, Green, Red, Red Border, and Near Infrared bands of RedEdge-MX are the best for monitoring the health of cultures.

Figure 22: Camera Micasense RedEdge-MX

Source: https://elvuelodeldrone.com/repuestos-y-accesorios/camara-drone-profesional/micasense-rededge-mx-camara-multiespectral/

II.2.2 Characteristics

The characteristic of the camera RedEdge_Mx are presented in the table 3 below in order to use them in the preparation of the flight plan.

Table 3: Characteristic of the camera Micasense RedEdge-MX

	Multispectral sensor
Focal length (mm)	5.4
Pixel Size (µm)	3.75
Resolution (px)	1280x960
Weight (g)	380 (Including sensors)
Multispecral band	Green (550 nm ± 40 nm) Red (660 nm ± 40 nm) Red edge (735 nm ± 10 nm) Near infrared (790 nm ± 40 nm)

Source: https://elvuelodeldrone.com/repuestos-y-accesorios/camara-drone-profesional/micasense-rededge-mx-camara-multiespectral/

II.2.3 Calibration panel

In order to calibrate your data based on the lighting conditions of the day, taking a snapshot of the calibrated reflectance panel is a crucial step in the data gathering process. It is advised to take a capture of the CRP from a height of about 1 meter before and after each flight, with the panel flat on the ground in an open location. The simplest way to do this is to hold the camera or drone such that the sun is shining directly on the panel without being reflected by your clothing or any nearby objects (Fig.23).

Figure 23: Calibration panel of the multispectral camera

Source: Taken by myself

II.3 Thermographic Camera

II.3.1 Zenmuse H20T

The advanced camera multi-capture device known as the DJI Zenmuse H20T combines four separate data collection sensors: wide-angle, 20X zoom, radiometric temperature, and a precise laser measurer.

Up until very recently, the phrase "many useful charges on a drone" or "several useful charges"

To gather all mission-related data, the DJI Zenmuse H20T came out on top.

"All in one." When mounted to the DJI Matrice 300, it can fly for up to 43 minutes.

This indicates a qualitative decline in the operational effectiveness of the technical inspection areal flight.

Its integrated design and distinctive intelligence provide opportunities for imaging without a previous computer through a variety of technical, commercial, and industrial uses.

All the necessary sensors in one to capture everything, up close and far away, in real colors or thermally. Use the integrated laser distance measuring device to measure distances up to 1200 meters (LRS). The DJI Zenmuse H20T presented in the figure 24, enables rapid advancements in intelligent aerial inspection technology using the DJI Matrice 300 RTK platform.

Figure 24: Camera Zenmuse H20T

Source: Taken by myself

II.3.2 Characteristics

The table 4 below is representing the charachteristic of both of the sensors in the Zenmuse H20T which will be used after in the calcul of the flight plan.

Table 4: Characteristics of the camera: Zenmuse H20T

	Thermographic Sensor	RGB Sensor
Focal length (mm)	13.5	4.5
Pixel Size (µm)	12	16
Resolution (px)	640x512	4056x3040
Weight (g)	828±5	-
Spectral band (µm)	8-14	-

Source: https://www.dji.com/es/zenmuse-h20-series

II.4 Photogrammetric flight planning

Nowadays, photogrammetric projects are widely used for multiple purposes.

A perfect example is the regular updating of a land cover, various objects and linear features, and elevation information layers, as digital orthophotos are needed at the same time.

However, conflicts of objectives appear in these projects, but they can be resolved or at least minimized by a judicious choice of the following parameters:

- Boundaries of the study area
- Climatic conditions (period of the year during which the photogrammetric flight must be carried out)
- Scale of the images (choice of target)
- Overlap
- Scanning resolution

Imaging of the study area was performed using the DJI Matrice 300 UAV using sensors properly installed on it. Below we present three different programs, one for each sensor (multispectral, thermal, and RGB), even if two sensors belong to the same camera.

The calculations will be made using some project requirements that have been previously established in the office, and for this purpose, Google Earth Pro has been used to visualize the project area and measure its approximate dimensions.

II.4.1 GSD (Ground Control Distance)

The GSD is determined by the defined flight height, the focal length of the camera, and the pixel size of the sensor.

It can be defined as the minimum distance on the ground at which two objects can be detected in another way. It represents one pixel on the ground.

The GSD is a measurement that you cannot, in all honesty, pass without it. You run the risk of obtaining a useless card or inaccurate data collection.

To put it in a mathematical way like we can see in Equation 1 below:

$$\mathrm{GSD(cm)} = \frac{\text{Flight Height (mm)} * \text{Pixel Size (mm)}}{\text{Focal Distance (mm)} * 10} \qquad \text{(Equation 1)}$$

According to Real Decretory 1036/2017 (BOE, no 316, 29 de December de 2017), drones can’t fly higher than 120 meters. Therefore, this is something to keep in mind while determining the height of the plane.

Because there is a short focal distance and a detailed analysis of each olive grove is required, the flight height had to be low (50m) so that the GSD could be small as well. With this in mind, with the focal distance of the RedEdge-MX multispectral sensor being 5.4 mm and the pixel size being 0.00375 mm, it was possible to calculate the GSD that would be obtained in the operation below:

$$\mathrm{GSD} = \frac{50000 * 0.012}{13.5} = 44.44\ \mathrm{mm} = 4.44\ \mathrm{cm}$$

II.4.2 The dimension of an image on the ground

The length of the image on the ground is the size of the study area that will be covered by an image in meters, which will be determined by the GSD required and, of course, the flight height. This operation can be used for both the width and height of the image. In general, the dimension of an image is like what we are representing in Equation 2:

$$S(c/l) = s(c/l) * GSD\ (m)$$

(Equation 2)

To put it another way,

Sc = sc*GSD =640*0.044 = 28.16 m

Sl= sl*GSD = 512*0.044 = 22.53 m

Where:

s: The number of pixels in each image's short (c) and long (l) sides (l).

S: Dimension of the image on the ground for the short (c) and long (l) sides (l)

II.4.3 Frontal Overlap

The part common to two photographs is called the overlap stereoscopic.

It is qualified as longitudinal if we consider the overlapping of two successive photographs of the line of flight, which is represented in equation 3:

$$p\% = \frac{(Sc - B) * 100}{Sc}$$ (Equation 3)

Here, the shorter side (Sc) of the picture is used since the reduction of pass, or perpendicular to the direction of flight, is what photogrammetry is looking for. The longer side will therefore be related to the transverse covering.

In fact, both the longitudinal and transverse coverage are often already predetermined based on the project's requirements. They are thus not calculated but rather used in the calculation of other parameters. It is important to remember that these values must be greater than 60% for the longitudinal overlap and 30% for the side overlap.

In addition, it is important to pay attention to changes in the terrain's relief since they might cause overlap to increase or decrease depending on how high the elevation was when the flight was planned. The percentage of recovery is also affected by weather factors, as is the drone's instability brought on by strong winds.

Therefore, 80% longitudinal coverage was specified for this flight.

III.4.4 Side Overlap

The transversal retrieval is the same as the longitudinal retrieval, except it refers to photographs taken over a period of time rather than in one go. It's calculated using the fourth equation below.

$$q\% = \frac{(Sl - B) * 100}{Sl}$$ (Equation 4)

As with the longitudinal, 70% of transverse recovery was defined for this flight.

III.4.5 Area Base (B)

The area base is the distance between two consecutive points on the ground, which will be determined by the longitudinal recuperation. It can be calculated using the fifth equation below.

$$B = Sc * (1 - \frac{p\%}{100})$$ (Equation 5)

With the information we've gathered thus far, we'll need to:

$$B = 28.16 * (1 - 0.8) = 5.63 \text{ m}$$

II.4.6 Distance between previous events (A)

The distance between passes on the ground will be determined by the transversal recovery required by the project, and can be calculated using equation 6 below.

$$A = Sl * (1 - \frac{q\%}{100})$$ (Equation 6)

So, we have:

$$A = 22.53 * (1 - 0.7) = 6.76 \text{ m}$$

II.4.7 Number of models in one pass (Nm)

The number of models produced will be determined by the size of the aircraft and, of course, the value of the longitudinal overlap value. To put it another way, the larger the collection, the smaller the base area and the larger the number of images. Equation 7 is used to calculate the result.

$$Nm = \frac{L}{B} + 1$$ (Equation 7)

Using our parameters, we have:

$$Nm = \frac{100}{8.88} + 1 \cong 13 \text{ Models}$$

II.4.8 Number of photos in one pass (Nb)

The number of photos will be superior by one photo to the number of photos calculated like in the equati. This means:

$$\mathrm{Nb} = \mathrm{Nm} + 1$$

(Equation 8)

So:

$$\mathrm{Nb} = 23 + 1 = 14 \text{ Photos}$$

II.4.9 Number of passes (Ns)

The number of passes is determined by the distance between passes, which is determined by the transverse overlap value. To put it another way, the larger the transverse overlap, the shorter the space between passes and the more passes there are. The same logic applies to the number of patterns. Furthermore, it is determined by the block's width. Equation 9 is used to calculate it.

(Equation 9)

$$\mathrm{Ns} = \frac{\mathrm{Q}}{\mathrm{A}} + 1$$

So we have:

$$\mathrm{Ns} = \frac{50}{9.99} + 1 \cong 12 \text{ passes}$$

II.4.10 Total number of pictures (Np)

The total number of photographs will be calculated based on the number of passes and the number of photographs per pass, as shown below in Equation 10:

$$\mathrm{Np} = \mathrm{Ns} * \mathrm{Nb}$$

(Equation 10)

We obtained:

$$\mathrm{Np} = 21 * 12 = 252 \text{ Photos}$$

II.4.11 Time between Two Photos (tf)

As indicated in equation 11 below, the time between photos is dependent on the size of the base (B) and the speed (m/s) of the flight:

(Equation 11)

$$tf = \frac{B}{V}$$

In our project:

$$tf = \frac{5.43}{2} = 2.71 \text{ m/s}$$

II.4.12 Total Flight Time

The total time spent flying in minutes is determined by the total number of photographs and the time spent between them, and may be calculated using Equation 12 below.

$$T = \frac{2.71 * 224}{60} = 10.13 \text{ minutes}$$

(Equation 12)

II.5 For the camera Zenmuse H20T (RGB Sensor)

In this calcul, we are going to change the parameters of the wide camera RGB displayed above in the table 4.

Table 5: Calculated flight parameters for Zenmuse H20T camera (RGB)

GSD	1.77 cm
Sc	40.56 m
Sl	30.4 m
B	8.11 m
A	9.12 m
Nm	17 photos
Nb	18 models
Ns	10 passes
Np	180 Photos
tf	4.05 m/s
T	12.16 minutes

II.6 For the camera RedEdge-MX

In this section, we are going to change the parameters of the wide camera RGB displayed above in the table 3 in order to calculate the flight plan.

Table 6: Calculated flight parameters for RedEdge-MX

GSD	$\frac{50000*0.00375}{5.4*10}$ = 3.47 cm
Sc	1280x0.0347=44.42m
Sl	960x0.0347=33.31m
p%=80	q%=70
B	44.42x(1-0.8)=8.88m
A	33.31x(1-0.7)=9.99m
Nm	$\frac{130}{8.88} + 1 \cong 16\ Models$
Nb	17 Models
Ns	$\frac{80}{9.99} + 1\ \cong 17\ passes$
Np	153
tf	4.44 m/s
T	11.32 minutes

II.5 Realisation of the flight

II.5.1 GNSS Receptor Used

We used the following materials for the ground control points: The GR-5 receiver (Figure 25), which is a multi-frequency GNSS receiver aimed at the surveying business, The GR-5 can be used. With a full-wave antenna, they receive and interpret many signal types using tracking, dual-frequency RTK, and other functions are also included.

Figure 25: Topcon Receiver GR-5

Source: https://www.topconpositioning.com/fr/

The initial stage was to create a correct distribution of control points across the research area, which was accomplished using an RGB orthomosaic built using data from a previous campaign made accessible by the University of Jaen's Computer Graphics and Geomatics Research Group (TIC-144). It had fairly defined spots, and what we attempted to do in this practice was to put some on the outside and others in the center of the region.

II.5.2 Leica Geo Office

Leica Geo Office is software that enables you to import and use collected data, which in cludes
points that were recorded using a total station, a GPS, a laser scanner, or a drone.
In this project, we used Leica in order to get the coordinates of the ground control points.

II.5.3 Ground control point

The control points are physical reference sites in the research region that can be identified in the photogrammetric flight photographs like the white board presented in figure 26.

Figure 26: Using a white board as a signalizer for control points

Source: Taken by myself

As a result, using a white screw, the plates were claved in the center.

To obtain precise coordinates for control points, in addition to the RTK (Real Time Kinematic) technique equipped on the drone, their geographic coordinates will be determined through our field survey Topcon receiver GR-5, which is connected via GPRS with the RAP (Red Andaluza de Posicionamiento) to obtain precise coordinates.

In total, 10 points were collected above the base from the Leica Geo Office software, which are listed in table n°4 along with their precision.

Table 7: Coordinates of the control points with their respective precisions

Points	Longitude(m)	Latitude(m)	Height (m)	SigmaX (m)	Sigma Y (m)	Sigma Hz (m)
PLAT1	-3. 981641285	37.951465830	318.554	0,008	0,017	0.13
PLAT2	-3.981728446	37.951246304	316.337	0,006	0,012	0.22
PLAT3	-3.981416452	37.951218193	315.101	0,008	0,017	0.12
PLAT4	-3.981801147	37.951048000	314.233	0,006	0,013	0.06
PLAT5	-3.981591892	37.950972210	312.223	0,006	0,012	0.12
PLAT6	-3.981558677	37.950806886	309.028	0,012	0,026	0.12
PLAT-B1	-3.981894292	37.950838675	313.426	0,006	0,013	0.22
PLAT-B2	-3.981911009	37.950553843	307.563	0,006	0,013	-0.02
PLAT-B3	-3.981664388	37.950493966	303.232	0,007	0,014	0.16
PLAT-B4	-3.981669719	37.950243913	298.668	0,006	0,013	0.04

II.6 Flight execution

Some measures had to be considered before determining the day on which the flights would take place. That means, two days before the appointed date of the flight, the area's meteorological data was analyzed to determine the likelihood of rain and the estimated wind speed. Furthermore, we sought to leave early from the University of Jaen so that the flights could take place around noon, when the sun was at its optimum altitude and there was little shade.

Two flights (one for each camera) were completed, and the drone flight planning software used was Mission Planer of the PFD of the matrice 300. Whose role is to establish the previously defined and calculated flight parameters, as shown in Illustration 27 below.

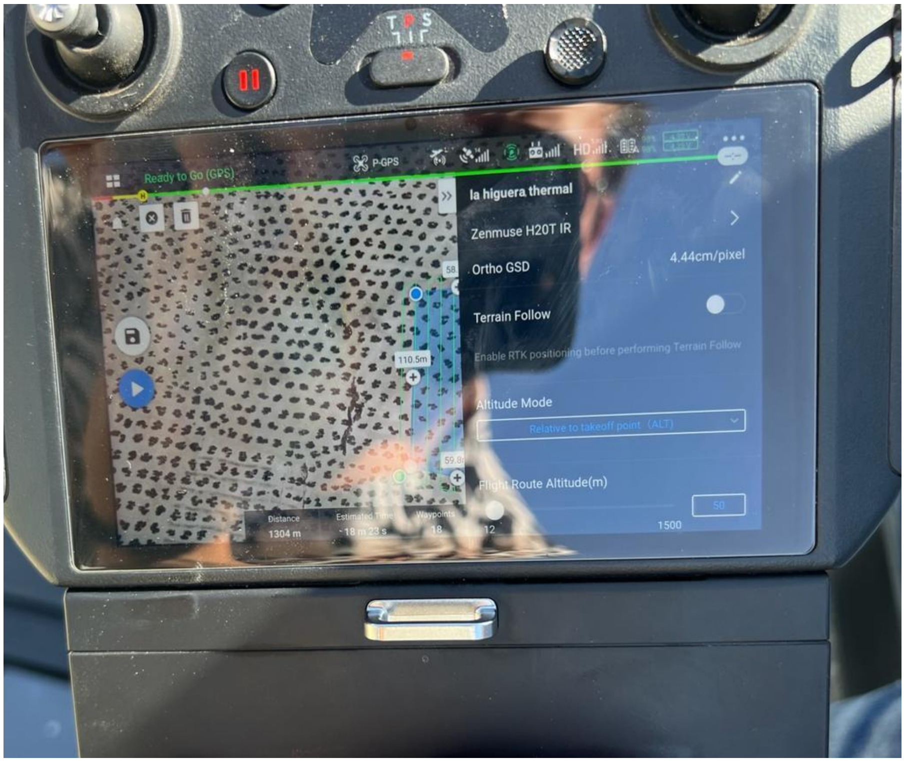


Figure 27: Flight plan with PFD of the matrice 300
Source: Taken by myself

It's important to keep in mind that the drone was controlled by a researcher from the University of Jaen's Computer Graphics and Geomatics Research Group (TIC-144) who was properly certified for this type of work.

Then, to begin the execution of the mission, the drone reaches the defined height and moves to the first point of shooting and moves automatically along the defined route, taking pictures at a well-defined speed.

The place where the drone is launched will be the same as the place where it will land, which means that the starting point must be the same point of arrival, and it is important to check the existence of any obstacles so that the GPS receiver works correctly and without interruption.

A very important point to remember is the need to take pictures of the calibration panel of the Mecasense RedEdge-MX multispectral camera before and after the flight, as shown in Figure 28 below.

Figure 28: Capture photo of the calibration photo pre-flight

Source: Taken by myself

III. Methodology

III.1 Image Processing

III.1.1 Software used

- Agisoft Metashape

Agisoft Metashape is a Russian software that allows you to do photogrammetric processing on digital photos (aerial and short-range photography, satellite images) and generate 3D spatial data for use in SIG applications, cultural heritage documentation, and visual effects production, as well as indirect dimensional measurements of objects at various scales.

The software can process images from RGB, thermal, or multispectral cameras, as well as multicamera systems, to extract spatial information in the form of dense clouds, textured polygonal models, and genuinely georeferenced orthomosaiques, calculate vegetation indices, and extract data for agricultural equipment action cards.

Metashape's distributed processing capability allows it to process more than 50,000 pictures on a single cluster. Alternatively, the project can be sent to the cloud to save money on hardware while still having access to all available processing choices. The careful application of a digital photogrammetry technique combined with computer vision methods results in an intelligent automated processing system that, on the one hand, can be managed by a newcomer to the field of photogrammetry, but on the other hand, has a lot to offer a seasoned professional who can benefit from advanced functions such as stereoscopy and computer vision.

III.1.2 Processing Images

Once the flight has been completed, we will have obtained a folder containing

- GPS control points.
- Images of the calibration plane will be post and pre-flight (for the multispectral images).
- RGB and Multispectral Images

All the processes will be done with the software Agisoft Metashape, where they will be quoted and described one by one.

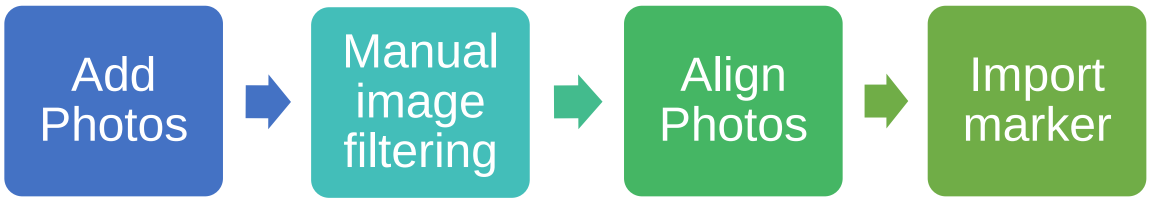


Diagram 2: Agisoft process

After separating the three types of images produced by the camera Zenmuse H20T (RGB, RGB Z, Thermal), the first step is to check the coordinate system of the images depending on the coordinate system of our ground control points which is presented in the table 4 WGS84 and then we add our photos.

Once added, we are asked to check the photos to see if they have poor quality, such as take-off, landing of uav, or wind, and take them off to prevent a high error rate.

Now, we align our photos, In this phase, Agisoft Metashape looks for common points in photographs and associates them. It also determines the camera's position for each image and aligns the camera's calibration parameters.

To better explain, we are going to create the terrain model as we can see in the figure below.

Once the photos have been aligned, the most important step in every photogrammetric project which is adding marker because of the erroneous location and inaccurately predicted camera orientations, the 3D point is really where the rays are closest to intersecting, allowing for more accuracy in the image-processing process.

A marker placed on a single shot simply defines a "rayon" (Fig.29) or a line that extends indefinitely in the direction of the marker's placement on the photo, starting from the location of the camera.

The same marker placed on a second picture defines a different "ray," and where these rayon’s intersect is the marker's "position" in the three-dimensional space.

Figure 29: Placing marker

Source: Taken by myself

Now that the markers are added perfectly in every image, the third step, is to build dense cloud that is based on the estimated camera positions defined by the alignment of photos. Agisoft calculates the depth information for each camera in order to combine them into a single dense point cloud like shown in the Figure 30.

Figure 30: Dense cloud from RGB images

Source: Taken by myself

III.1.3 Quality report for the thermal sensor

Once the process is finished, we can generate a report from Agisoft Metashape, the figure 31 below present the number of pictures superimposed for each orthomosaic pixel. Each pixel must be visible in more than five photographs because the blue areas indicate too little overlap and the red areas indicate too good overlap. This is crucial because, as you can see for this rendering, the whole area is blue, and a weak collision might result in a 3D reconstruction in these areas that is of poor quality.

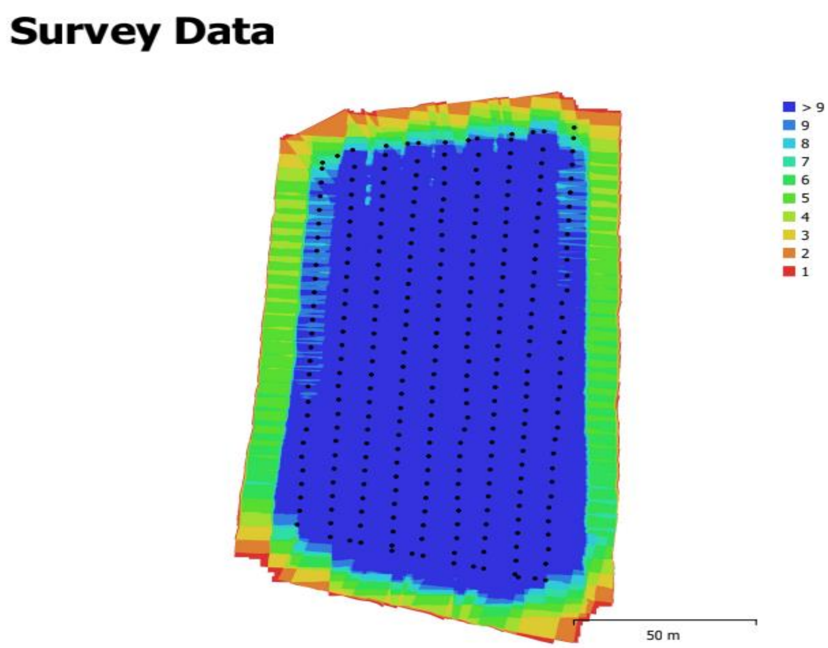


Figure 31: Overlapping Agisoft Metashape report Thermal camera

Source: Taken by myself

Additionally, the quadratic error is shown in Figure 32 and is estimated to be 2.34 cm, which is ideal because it is preferable to not go above the GSD's triple, which in our case is 4.44 cm.

Camera Locations

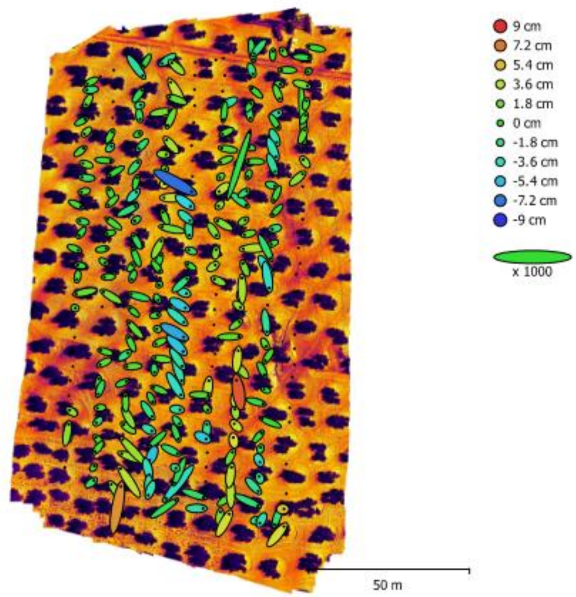


Fig. 3. Camera locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total error (cm)
0.275125	0.348919	2.30315	0.44434	2.34562

Table 3. Average camera location error.
X - Longitude, Y - Latitude, Z - Altitude.

Figure 32: Quadratic error Agisoft Metashape report Thermal sensor

Source: Taken by myself

III.1.4 Quality report for the RGB sensor

The report also includes a picture that shows the number of superimposed images for each orthomosaic pixel. As may be seen in Illustration 33, the entire area is blue for this processing. What is very good.

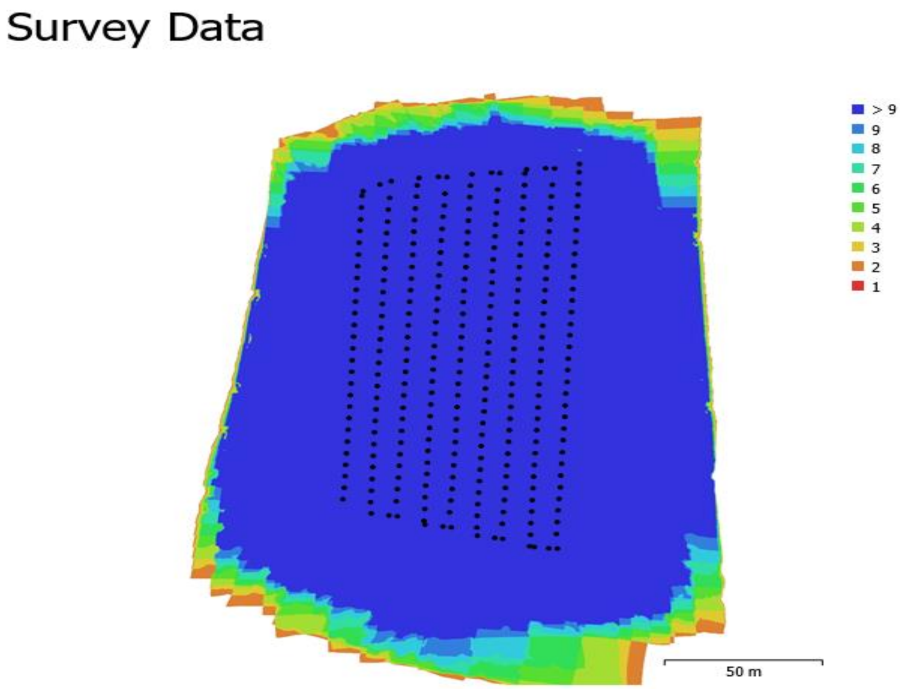
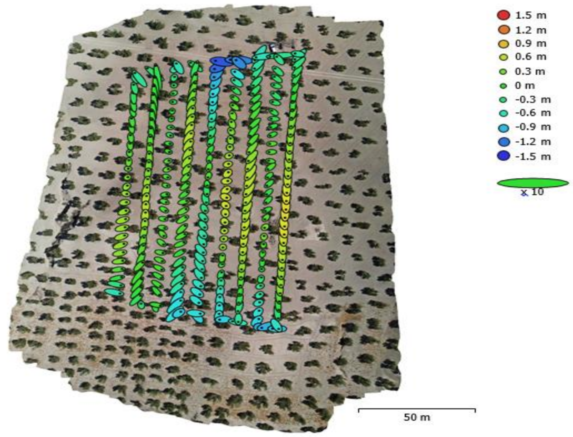


Figure 33: Camera location and image overlap RGB sensor

As represented in the figure 33, the total error is 1.44 cm which considered a very good result.

Camera Locations



Z error is represented by ellipse color. X, Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total error (cm)
1.1761	0.8871	0.9519	1.5334	1.4479

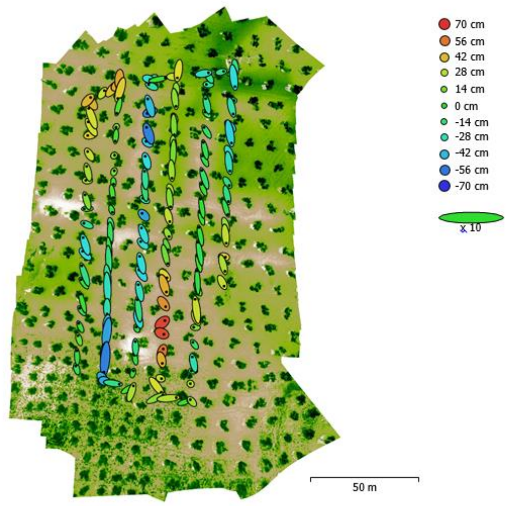
Table 3. Average camera location error.
X - Longitude, Y - Latitude, Z - Altitude.

Figure 34: Camera locations and error estimates RGB sensor

III.1.5 Quality report for the Multispectral sensor

As we can see in the figure 35, the multispectral sensor too generate a very good error 1.34 cm comparate to the triple of the GSD which is 4.44 cm.

Camera Locations



Z error is represented by ellipse color. X, Y errors are represented by ellipse shape.

Estimated camera locations are marked with a black dot.

X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total error (cm)
1.0583	0.8969	0.6066	1.3804	1.3435

Table 7. Average camera location error.

X - Longitude, Y - Latitude, Z - Altitude.

Figure 35: Camera location and error estimated Multispectral sensor

Source: Taken by myself

The report also includes a picture that shows the number of superimposed images for each orthomosaic pixel. As may be seen in Illustration 36, the entire area is blue for this processing.

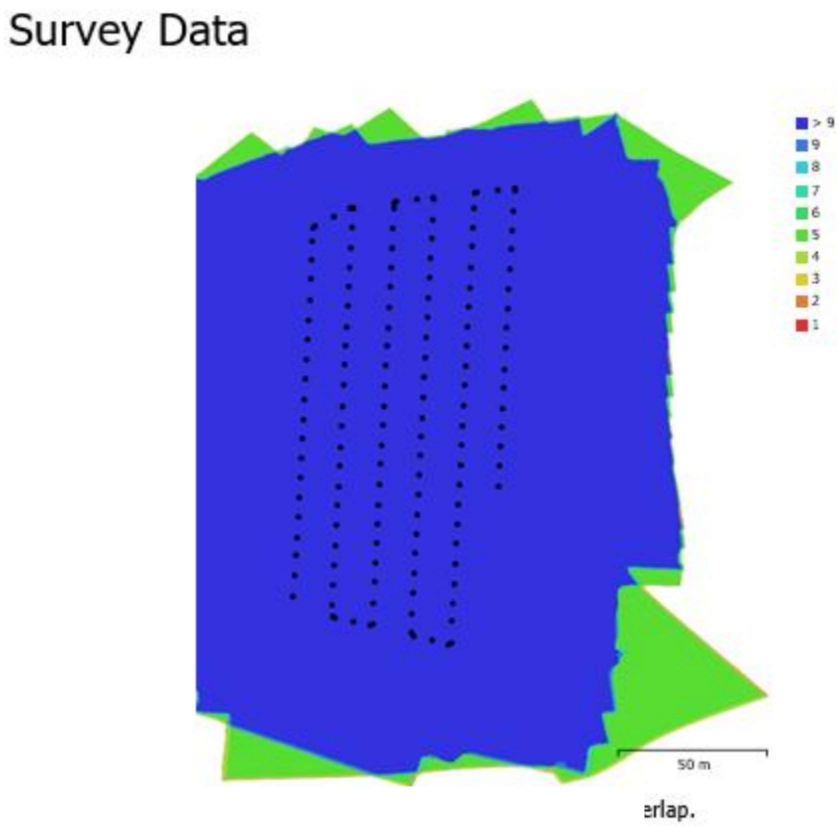


Figure 36: Camera locations and image overlap multispectral camera

III.2 Results

III.2.1 RGB Product

III.2.1.1 DEM

A digital cartography dataset called a "Digital Elevation Model" (DEM) depicts a continuous topographic elevation surface through a grid of cells. The elevation (Z) of a feature at each cell's position is shown (X and Y).

From figure 37 below, we can see that the altitude of the terrain varies between 320 m and 347 m.

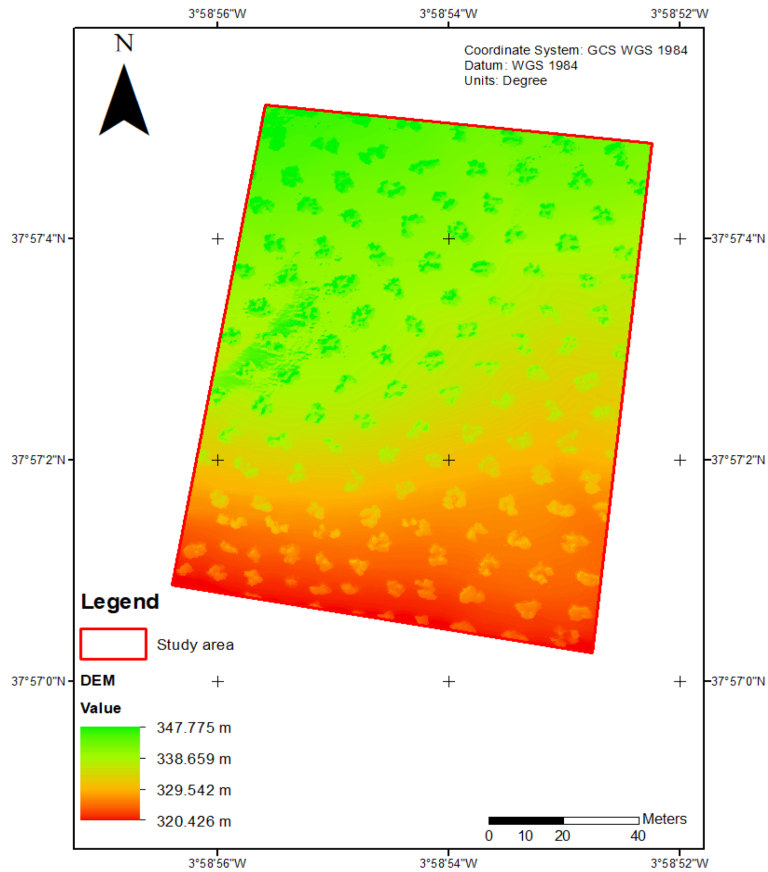


Figure 37: Digital elevation moel from RGB sensor

Source: Taken by myself

III.2.1.2 Orthomosaic

An orthomosaic picture, also known as an ortoimagen, ortofoto, or ortofotografia, is a high-resolution aerial photograph taken by a drone, the use of RGB products is often for visual products, such as the orthomosaic shown in the figure 37 below.

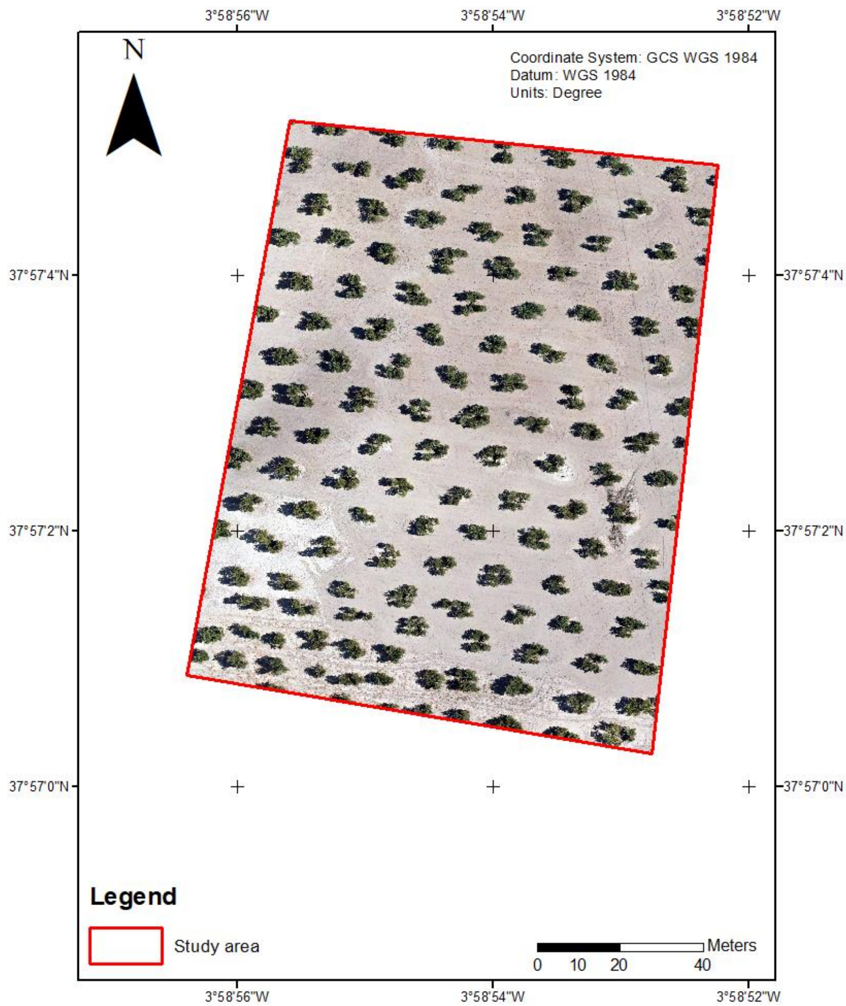


Figure 38: Orthomosaic RGB

Source: Taken by myself

III.2.1.3 Contours

One of a topographic map's core components, contours, it provide us with a wealth of information wherever and whenever we understand how to analyze them. One of a topographic map's core components, contours provide us with a wealth of information wherever and whenever we understand how to analyze them.

A contour is a line that may be shown on a map that connects all points that have the same condition, which is often the height above sea level or depth like presented in the figure 39 below.

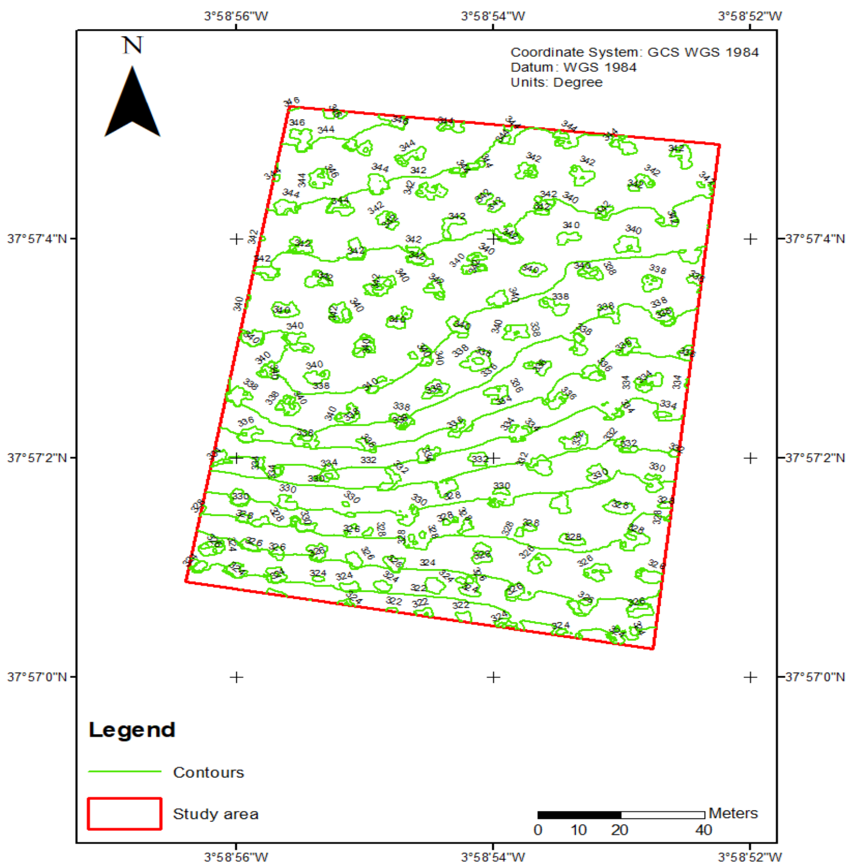


Figure 39: Contours from RGB camera

Source: Taken by myself

III.2.2 Multispectral product

III.2.2.1 NDVI

By contrast, the normalized vegetation index (NDVI) measures vegetation. It is used in agriculture to assess the strength and quantity of vegetation through studies of remote sensing measurements.

NDVI, introduced by Rouse et al. (1974), is the most widely used and recognized vegetation index in academic and professional circles. Calculation methods include the equation:

$$\text{NDVI} = \frac{NIR - R}{NIR + R} \quad \text{(Equation 13)}$$

Where:

NIR stands for near infrared spectrum value.

R is the spectral value of the red band.

This index is used to evaluate the strength of various cultures, and its values can range from -1 to 1. This means that vegetation will be considered to be more prevalent the closer it is to 1, while areas devoid of vegetation, such as water, will correlate to values below (Fig.40).

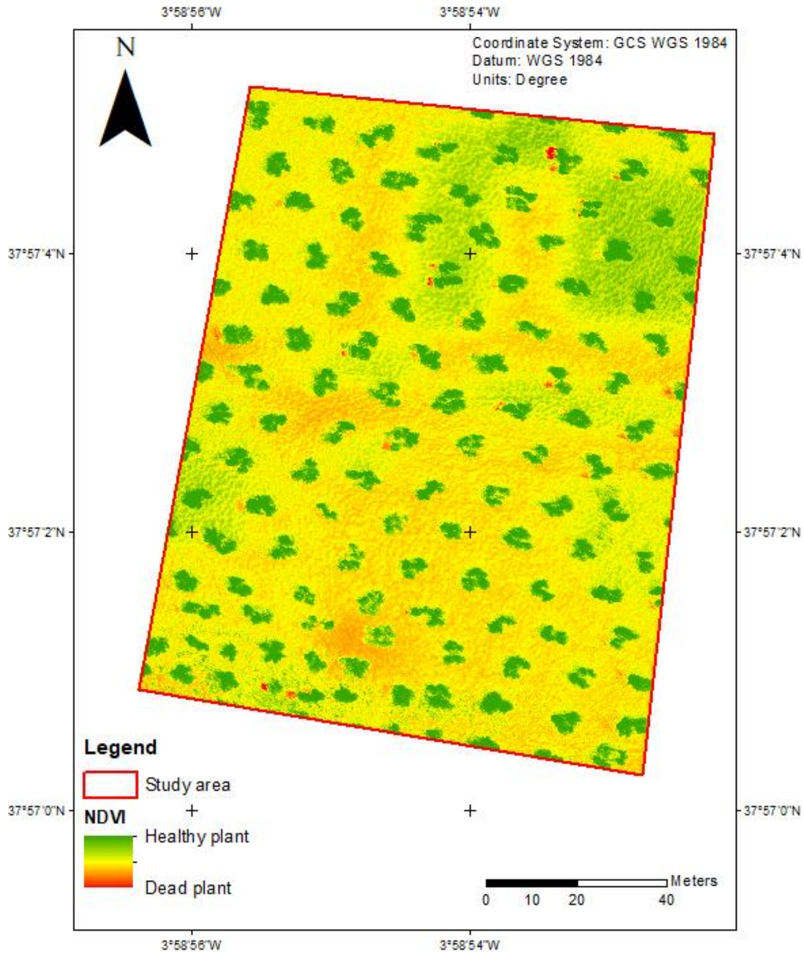


Figure 40: NDVI

III.2.3 Thermographic product

And to finish, in the figure below, we present the ortomosaic of the thermographic images but the problem that agisoft metashape does not allow to export the value of the temperature, suddenly its will be a representative image.

And to have an idea on the report of this image, we have consulted the software dji software analysis tools which is free to use, allows us to carry out analyzes on the thermographic images at least, we have an idea on the value of the temperature as shown in the figure 41 below.

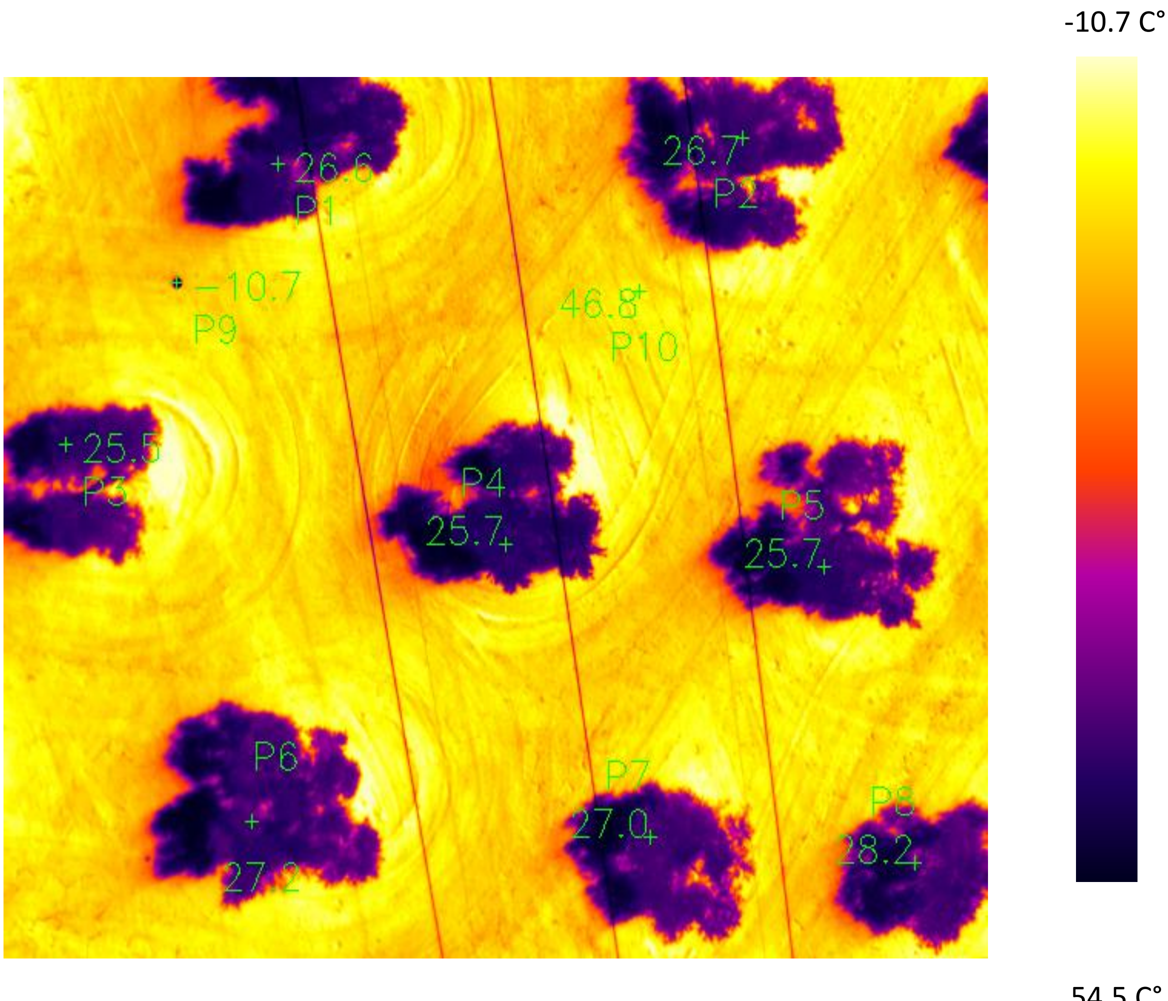


Figure 41: temperature report produced by DJI thermal analysis tool

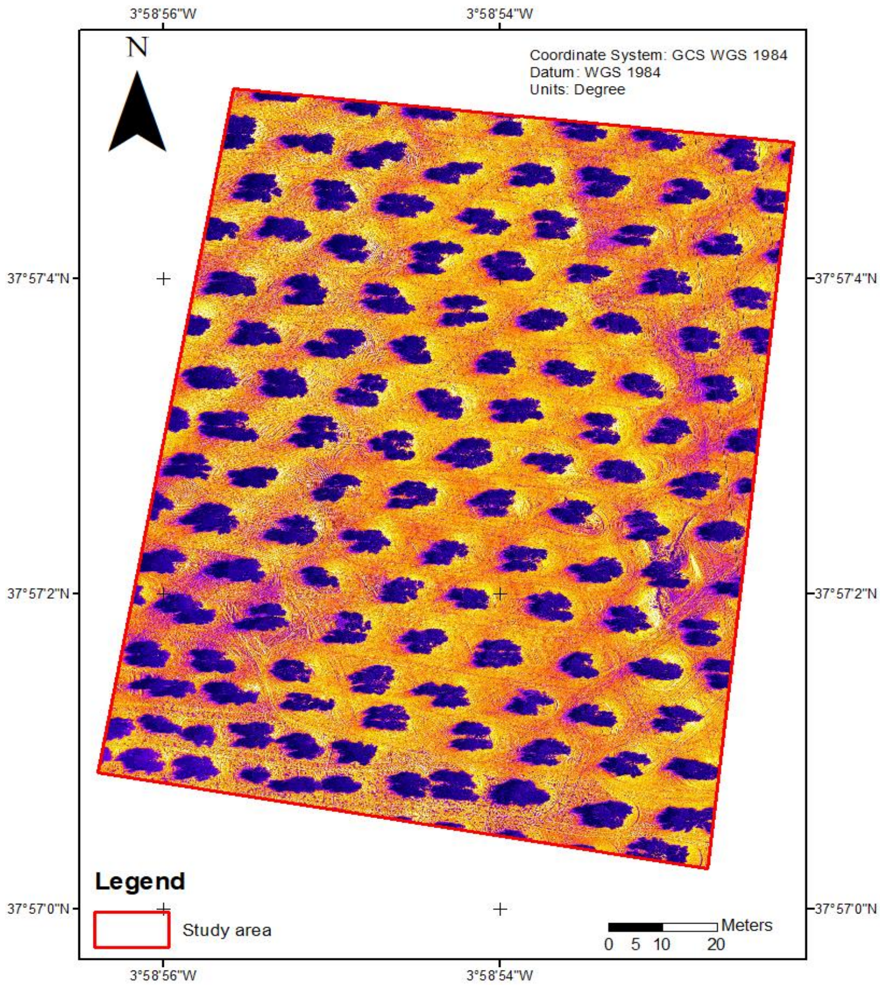


Figure 42: Thermographic images from thermal sensor

III.2 Web

A website can be a very wise investment, both now and in the future. With the help of this resource, a sizable audience may be reached for a low investment. The tendency is particularly prevalent in Spain, where publishing data online is now seen by businesses as a means of expansion.

The website is a great option to successfully approach them. Regarding price, effectiveness, and timing, it provides significant benefits. To stay ahead of the competition, a site must be well-designed and optimized.

III.2.1 Languages

- OpenLayers

OpenLayers allows you to quickly and easily create an interactive map on any web page. It can show you map tiles, vector data, and markers from any source. OpenLayers was created to encourage the use of all types of geographic data. And it's completely free.
OpenLayers displays geospatial data in any current web browser on a desktop or mobile device. It can handle a wide range of data and screen sizes, and it was built using the most up-to-date navigation technologies such as HTML5, WebGL, and CSS3. These are the languages that we'll need to make a webmapping application.

- Geoserver

A GeoServer is a web server that allows users to provide maps and data in a variety of formats to standard clients such as web browsers and geographic information systems (GIS). WMS, WFS, WCS, WPS, Tile Caching, and other standards-based interfaces are used to publish data.
GeoServer comes with a browser-based administration interface and connects to multiple data sources on the back-end.

- Bootstrap 5

Bootstrap is the most popular front-end framework. It simplifies and accelerates the creation of websites by incorporating HTML and CSS into a based design, and it can also use JavaScript plug-ins to add dynamism to the web.

- Jquery

jQuery is a free JavaScript library that makes it easier to create and navigate online applications. In particular, it makes HTML Document Object Model (DOM) manipulation, Asynchronous JavaScript and XML (Ajax), and event handling easier, which also incorporates JavaScript functionality by altering CSS properties to produce effects like fade-ins and fade-outs to website elements.
It has been the most popular JavaScript library for web development in recent years.
A web developer only needs to reference the jQuery JavaScript file within the HTML of a webpage to use jQuery. Some websites maintain their own local copy of jQuery, while others just use Google's or the jQuery server's library. For instance, a webpage might load the jQuery library by including the following line in the portion of the code.

- Apache Tomcat 9.0.

Apache Tomcat (also known as Jakarta Tomcat or simply Tomcat) is a project that aims to bring together the best-of-breed developers around the world. It was created in an open and collaborative setting and it is available under the Apache License version 2.

It's a Java Servlet, JavaServer Pages, Java Expression Language, and Java WebSocket implementation that is free.

- QGIS

QGIS is an open-source multiplatform software published under the GPL license. It allows users to access a wide range of extensions as well as collect, store, and visualize geolocated data in the form of maps and maps.

- HTML

HyperText Markup Language, the most user-friendly language for developers, is a kind of descriptive computer language.

It is a tag-based language used for structuring web pages. It is an essential step for a piece of content to be posted online and reach its readers.

- CSS

A Cascading Style Sheet (CSS) is a style sheet language used for describing the presentation of a document written in a markup language such as HTML.

- JavaScript

JavaScript is a lightweight scripting development language, and more specifically, an object-oriented scripting language. It is found mainly in Internet pages. It allows, among other things, to introduce on a web or HTML page small animations or effects.

- PHP

Hypertext Preprocessor is a server scripting language and a powerful tool for making dynamic and interactive Web pages. It is used by 78.9% of all websites with a known server-side programming language.

- MySQL

MySQL is an open-source relational database management server, used to create and manage databases based on a relational model.

MySQL has some advantages that make it very interesting for developers. The most obvious one is that it works with relational databases, that is, it uses multiple tables that interconnect with each other to store the information and organize it correctly.

- Wamp server

WampServer is a WAMP-based web development platform that allows PHP scripts to run locally. Because it is localized on your machine and not connected to the internet, it also allows you to test all WordPress functions without risk.

- Visual studio code

Visual Studio Code is an open-source text editor that is simple to install, lightweight, and powerful. It comes with built-in support for JavaScript, Typescript, and Node.js, as well as a robust ecosystem of extensions for other programming languages (such as C++, C#, Java, Python, PHP, and Go), and runtimes (such as.NET and Unity).

III.2.2 Welcome page

It is no longer necessary to prove the relevance of landing page design. An effective landing page allows you to boost your site's visit time and conversion rate, create more leads, and build a qualified database.

And to do it, we have to download a free template from bootstrap, then we have to do our personal modifications (text, image, color, and button).

II.2.2.1 Functionality

In this part, we are going to explain the functionality of the welcome page and each button and interface.

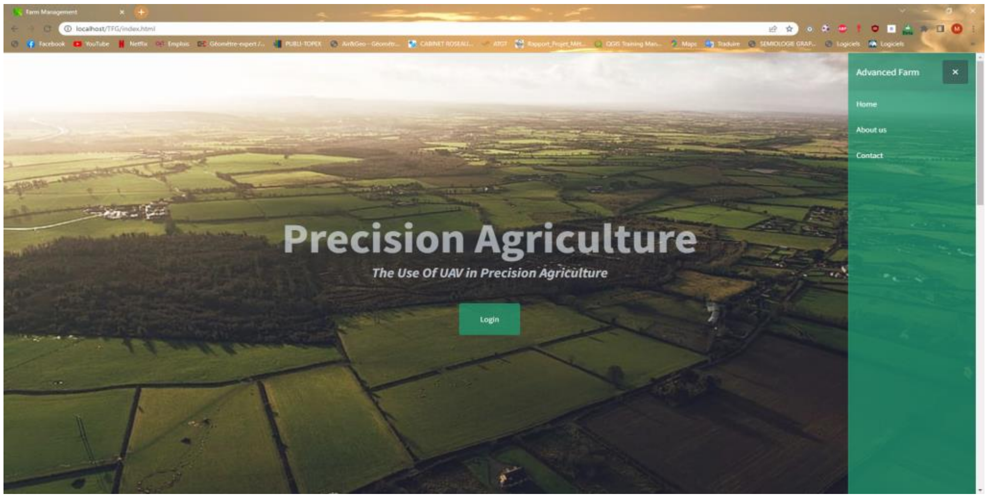


Figure 43: Screen shot of the land page of the platform

In Figure 43 above, we have a vertical bar including three buttons, which are presented in Figure 44. We are going to explain now what the functionality of each one is.

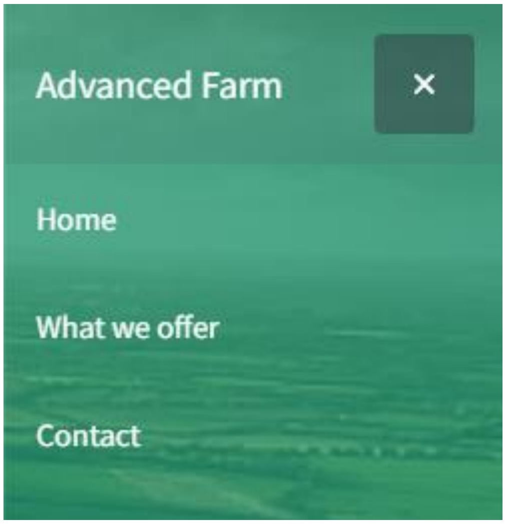


Figure 44: Vertical menu bar

1- What we offer

On clicking on what we offer, we find a small section containing some description about the reason for the creation of our platform, as we can see in Figure 45 below:

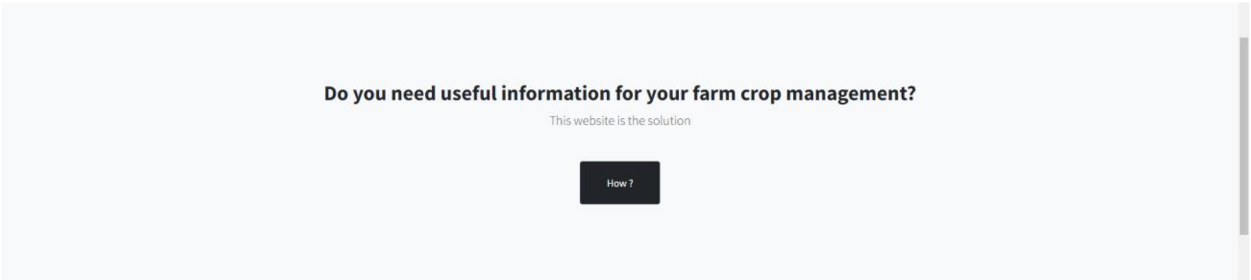


Figure 45: The section what we offer in the platform

2- How

On clicking on the black button, you have a short description of our product, like the use of drones in precision agriculture, the product that we are going to produce, as we can observe it in figure 30:

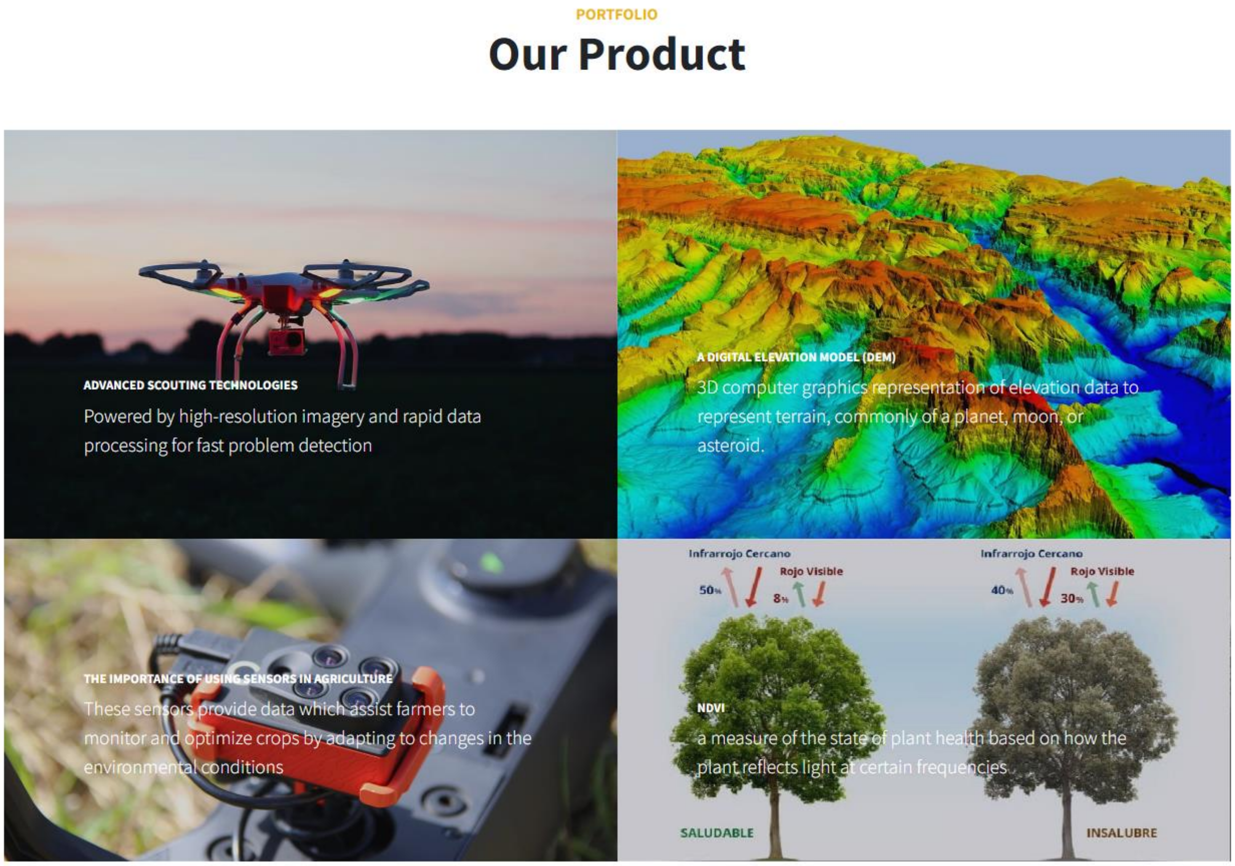


Figure 46: Our product

3- Contact

The last button is consecrated to give the users of the platform information about my social media links, as we can see in figure 31 below:

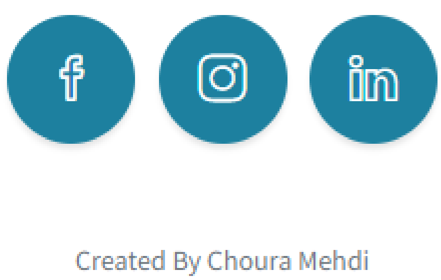


Figure 47: Contact links

Each button is a link to my social media account.

II.2 Login/Signup Page

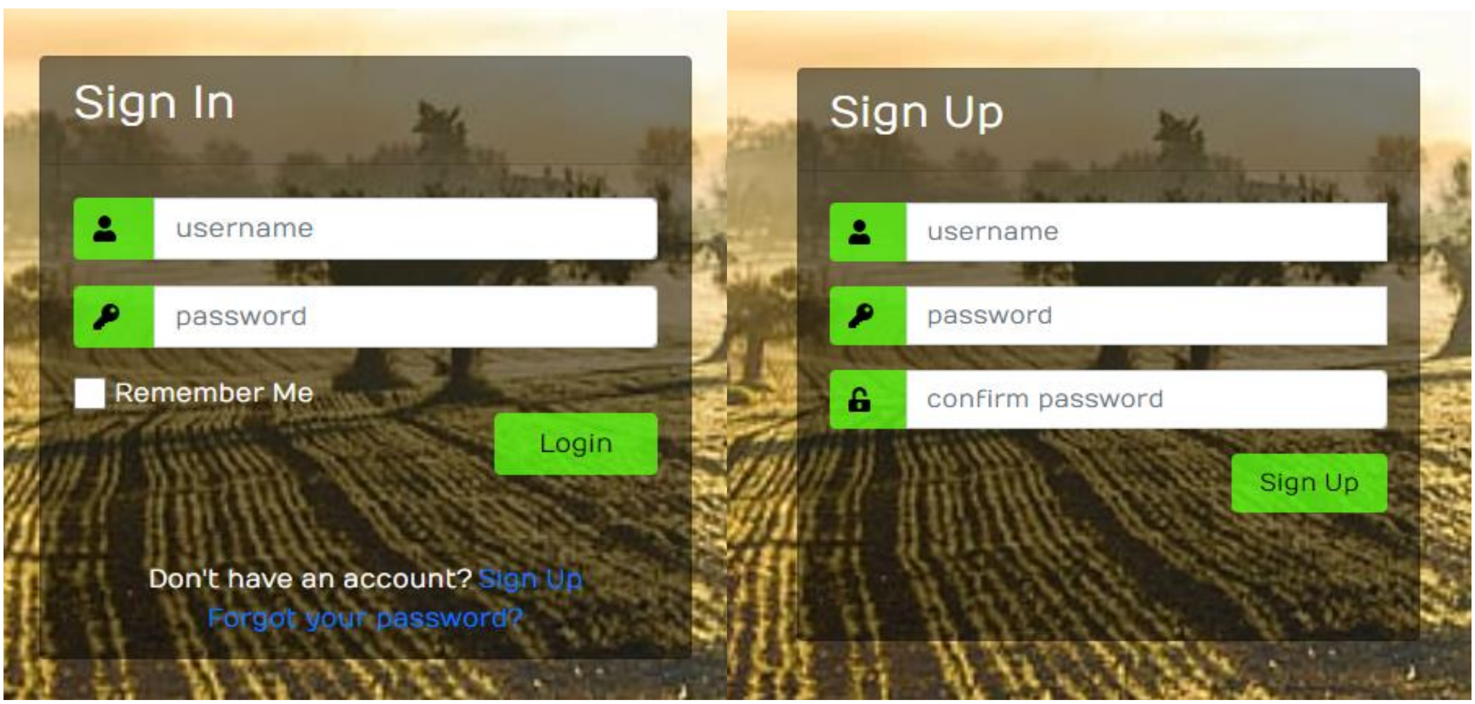
The internet is a game of numbers. You can reach more people once you have more visitors and members on your platform.

Of course, I'm not suggesting that we physically touch them, but rather that we reach out to them through advertisements and other means.

Clearly, our connection screen is not the reason for the agriculturists' visit.

We'd like them to get through it as quickly as possible. The best way to ensure this is to keep things as straightforward as possible.

Now, we are going to come back to the first button on the welcome page, which is named "Login." This button’s role is to navigate to the next page, which is created for the farmer’s personal account, as we can see in the figures below 32 and 33:



In today's web applications, user authentication is very frequent. It's a security feature that prevents unauthorized users from accessing member-only areas and features on a website, especially when we are going to produce personal information about a farm’s crops.

That’s why we have to create a database for the farmer in order to have permission to access the map interface of his farm.

First of all, we are going to create our table in the PhpMyAdmin Platform. To access it, you have to put in 'root’ as a username and an empty password, as we can see in the figure below.

We'll design a registration system in this section that allows the farmer to establish new accounts by filling out a web form. However, we must first create a database to house all of the user data.

Then, we created a table named "users" with four columns, as represented in figure 34:

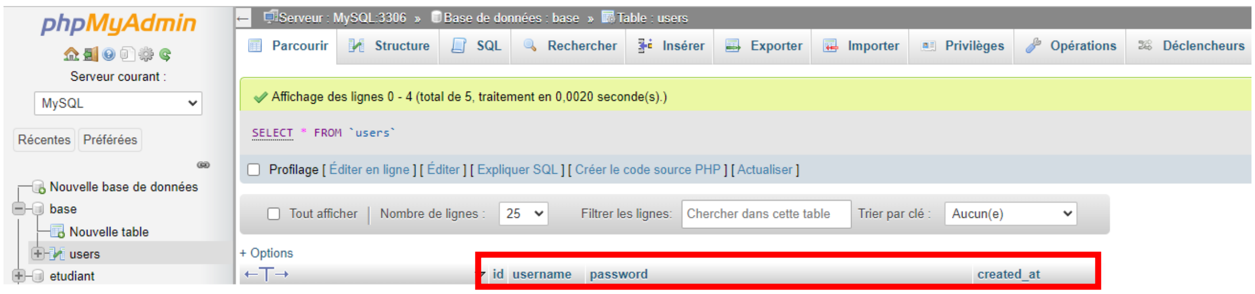


Figure 38: PhpMyAdmin data base

IV. Web mapping

III.1 Creation of the map

The first step to creating the map is to download the frameworks that we will need to build our web map, which are (Bootstrp 5.1.3, OpenLayers 6.13.0, jquery-ui 1.12.1). We will explain in the sections below exactly what the needs of each one are.

After the preparation of the tools, we now have to build our html page, which we are going to call all the JavaScript and CSS files, and create buttons according to the needs of the farmer.

In the figure below, we can observe the results of our map in figure 35.

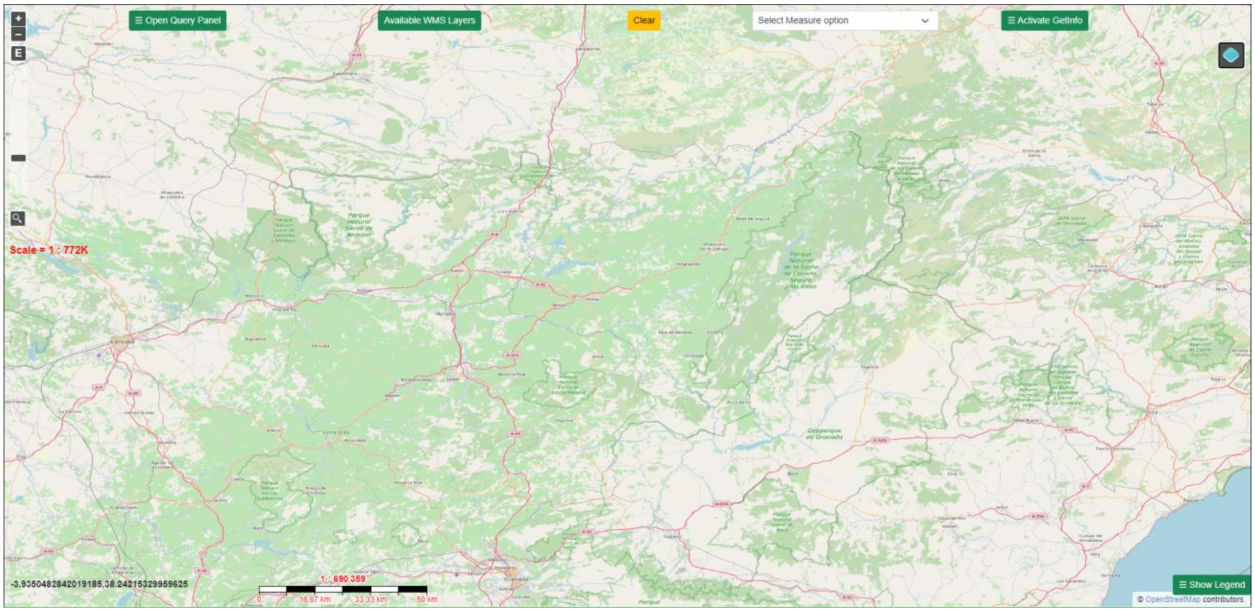


Figure 39: Screenshot of the map

III.1.1 Functionality

In this section, we are going to explain every button's functionality:

1- Zoom

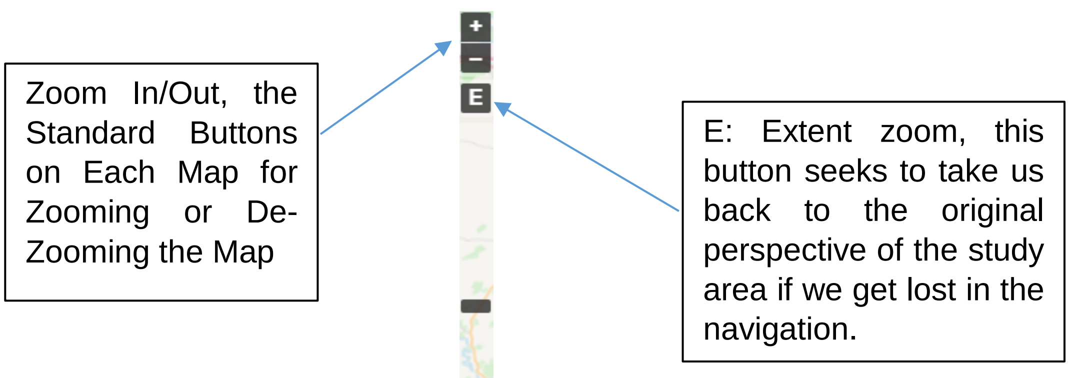


Figure :

2- Open Query Panel

When we click on the Open Query panel, we have two types of options that allow the farmer to run any type of query he wants based on our layers:

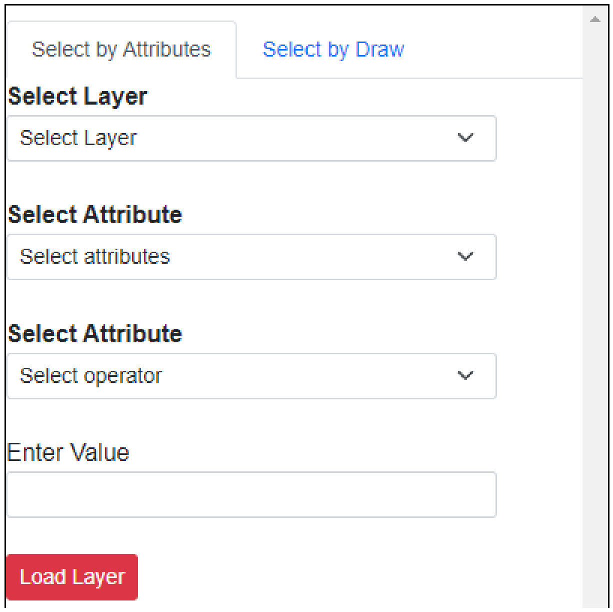


Figure :

The first one is the query based on the layer's attributes, represented in figure 37 above. Here, the farmer is prompted to select the layer on which he wants to submit requests, the desired attribute, and, of course, the requested value, all of which are shown in figure 38 below.

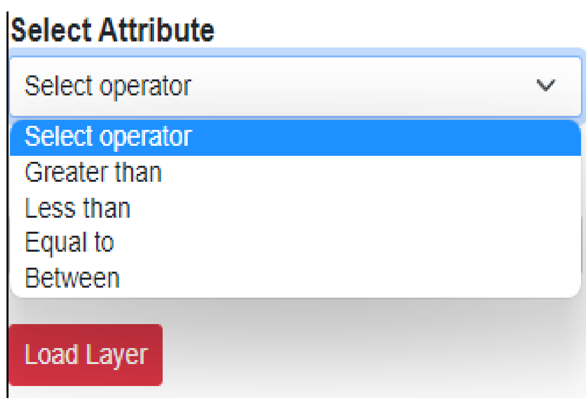


Figure 43: Selection mathematical operation

Also, the farmer can effect his selection by drawing a shape with a different type of geometry on the map, as we can see in figures 39 and 40 below.

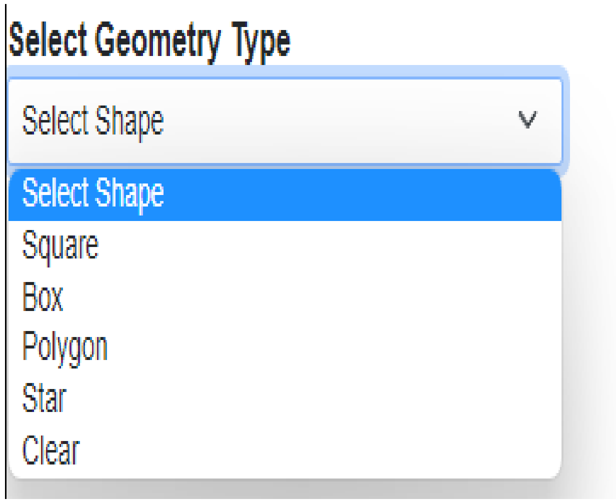


Figure 45: Geometry type of selection

3- Adding WMS Layers

This button on the top of the map, is a button that allows us to get all the feature stored in previously in GeoServer, this button is created to post our rasters done by Agisoft Metashape like OrthoPhoto, DEM, Contours and also to post the WMS from different official Spanish websites like IGN, in order to superimposed with our products.

4- Clear

The button clear, is used to clear all the operation did on the map, it's like the button of refresh the website.

5- Measurement

Here we can effect measurement on the map with different type.

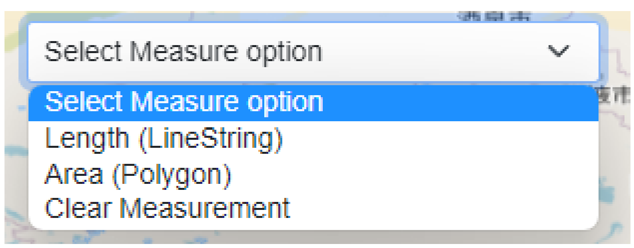


Figure 46: Measurment option

As we can see in the figure 41 above, our website offer two types of measurement, the first one is “Length” used to measure the length of the farm, distance between the trees…

6- Activate Get-Info

We need to activate the get-info button in order to get the information of the layers displayed on the map to get all the information available in the layers by a simple click on the map.

7- Layer switcher

A very helpful tool for organizing our visor's layers is the "layerswitcher" button found on our web-based map viewers. This button allows us to toggle between activating and deactivating each cap as we can see in the figure 42 below.

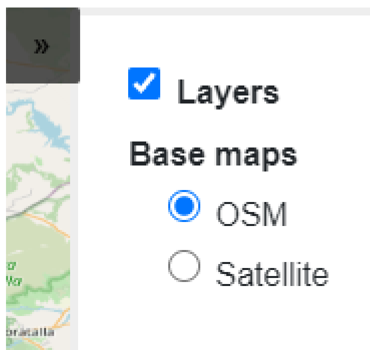


Figure 47: Layer switcher

8- Legend

One of the most important functionality of the map, is the legend while we are creating a website containing for a user that normally he don’t have idea about geomatics product, so we have created this button in order to get the legend with each layer added.

9- Scale

The distance in the real world is represented by the scale of the map, which is the value of one distance unit on the map.

The values are expressed as a graphing scale bar and are displayed in mm to km varies depending on zoom like represented in the figure 43.

Figure 48: Linear scale bar

10-Mouse Position

In the below figure 44 shows the coordinates of the cursor's pointer as the user moves or slides the cursor across the map in the WGS84 projection. This is made feasible by event listeners who continuously update the coordinates x and y as the mouse moves.

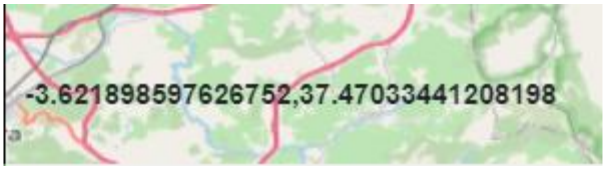


Figure 49: Mouse position (Longitude,Latitude)

III.3 Adding data to geoserver

The ability to publish and share geographic information online with a large audience is one of the most significant capabilities of web mapping. An essential and effective way to communicate farm information to farmers is through the sharing of our geospatial data. First and foremost, we must add our product to Geoserver in order to publish it using the "Add WMS Layer" button that has already been developed in our platform.

III.3.1 WMS

After connecting to Geoserver, the first step is to create the "Workspace". The newly created one and all of the services it offers, including the WMS, are shown in figure 45. These services will be used when the data is shown on the web map viewer.

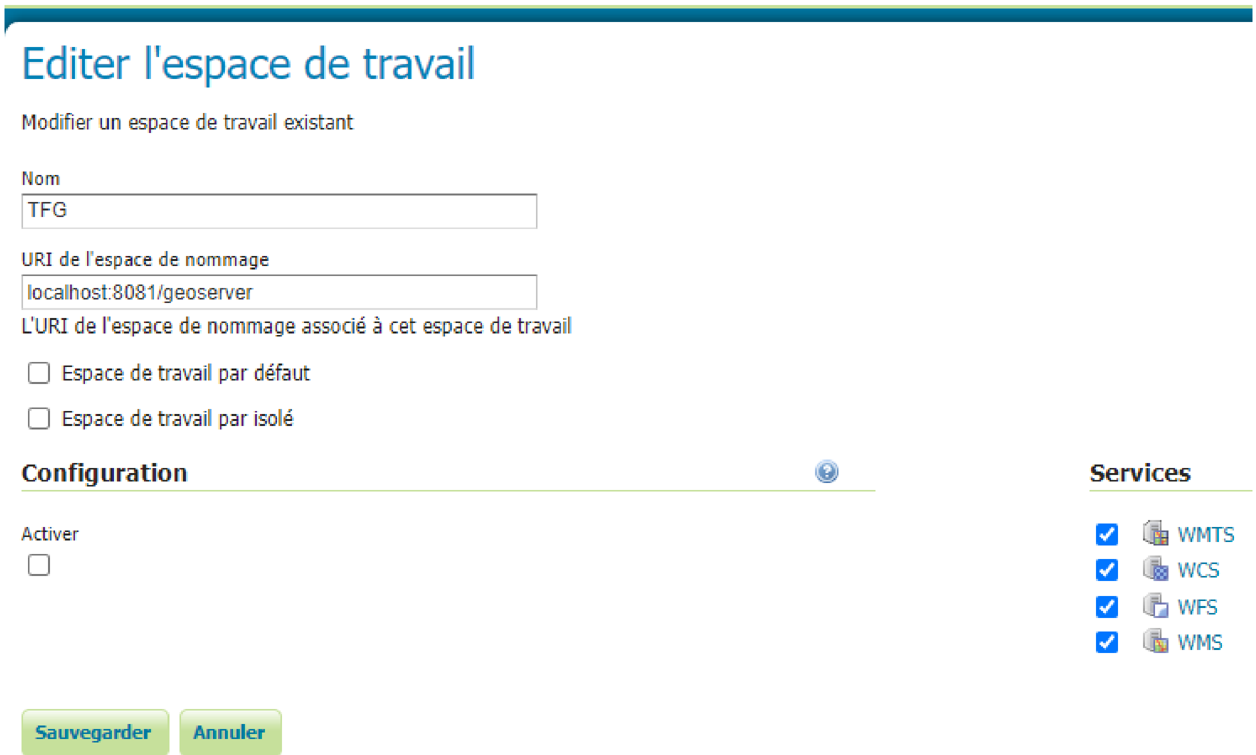


Figure 50: Creation of a new workspace

Then, we are invited to publish our raster by creating a new resource and adding a new “GeoTiff”, as we can see in figure 46 below:

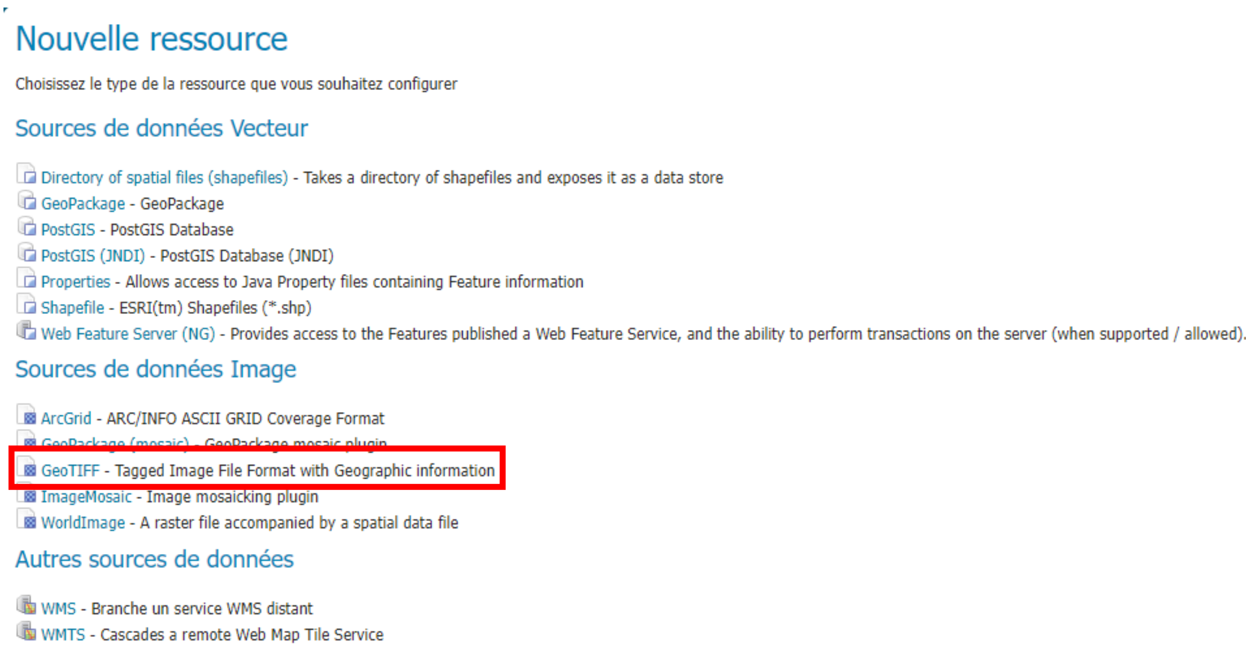


Figure 51: Adding raster to Geoserver

As a result, we will get a layer preview with a different publication method, as shown in figure 47 below.

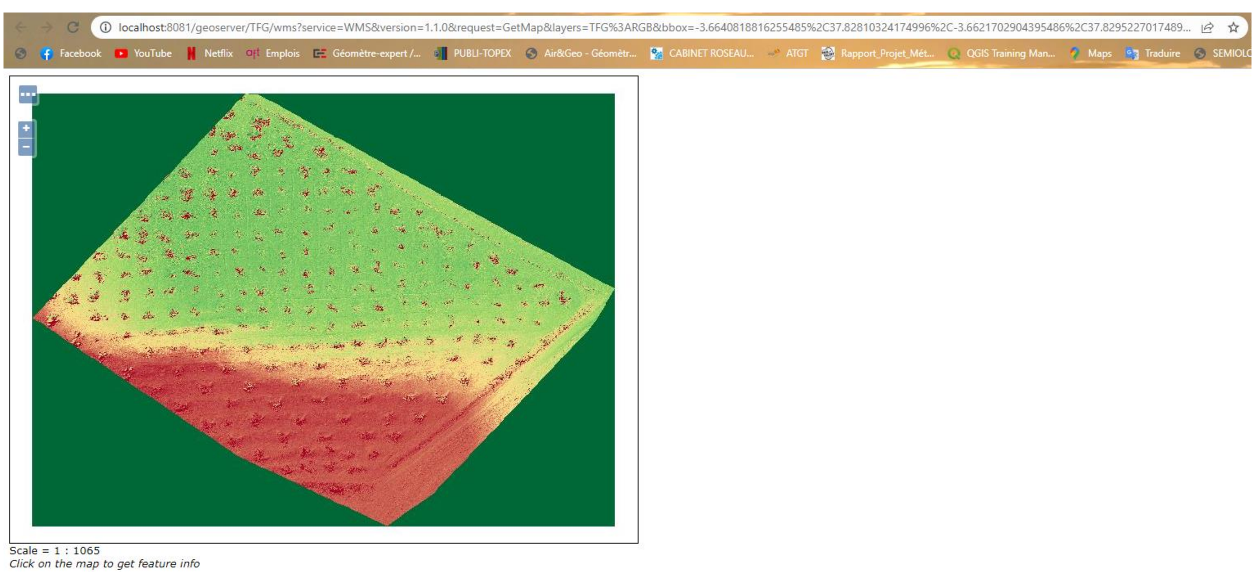


Figure 52: Raster Publication as an open layer form

III.3.2 Vector layers

In the same workspace “TFG”, we have to add our shapefile with the same way of adding a raster layer as we can see in figure 48 below.

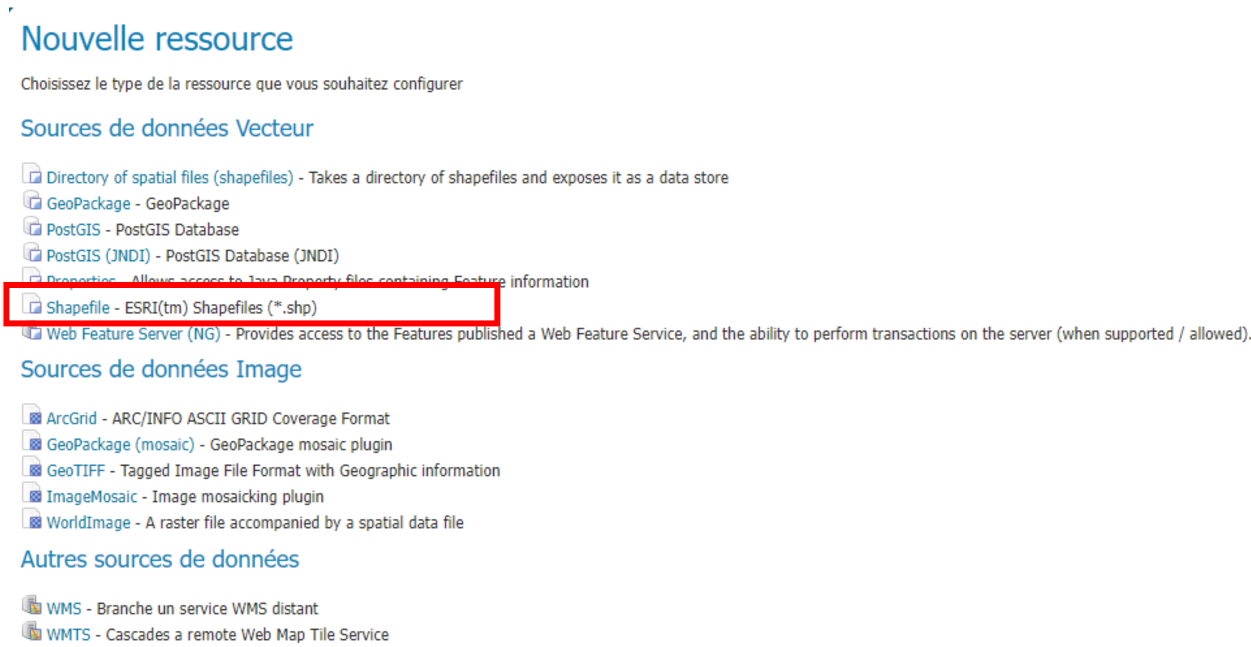


Figure 53: Adding SHP to Geoserver

Here, we are going to present a different way of integrating SHP into our platform using open layers.

In our JavaScript file, we have to insert a simple code obtained from the official website of OpenLayers, where we have to define the src of the layer, as we can see in the red box in Figure 49 below.

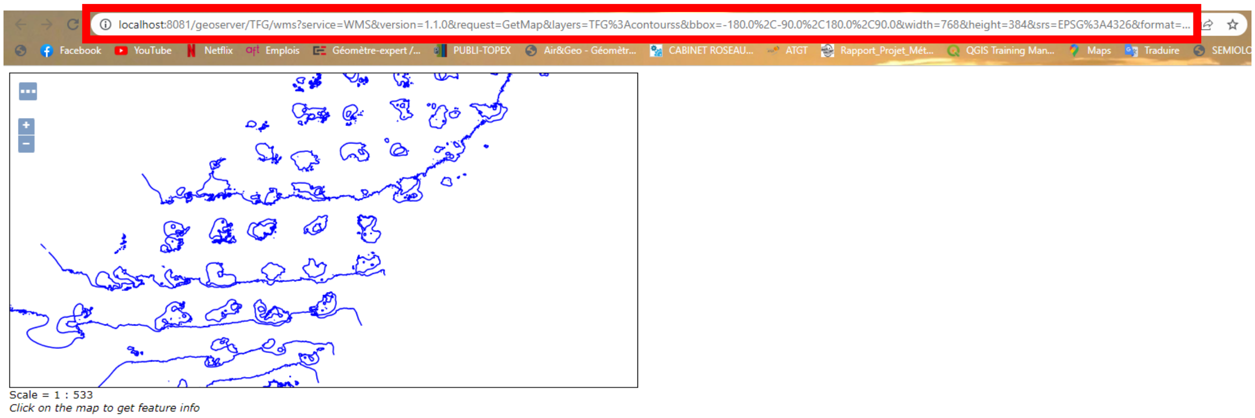


Figure 54: result of the vector publication

III.4 Style editing

This section will detail the style editing of our layers, which is one of the most important steps in our project in order to preserve a comprehensive product for the farmer with a distinct legend to our product.

Here, we are going to use Qgis as a first step because it offers the possibility to export the style of the layer as an SLD file, which allows us to publish it in Geoserver.

In Figure 50 below, we have defined the classification of the NDVI raster with graduation color from the dead plants presented with the red color until the green color, which represents the very healthy plants in our farm.

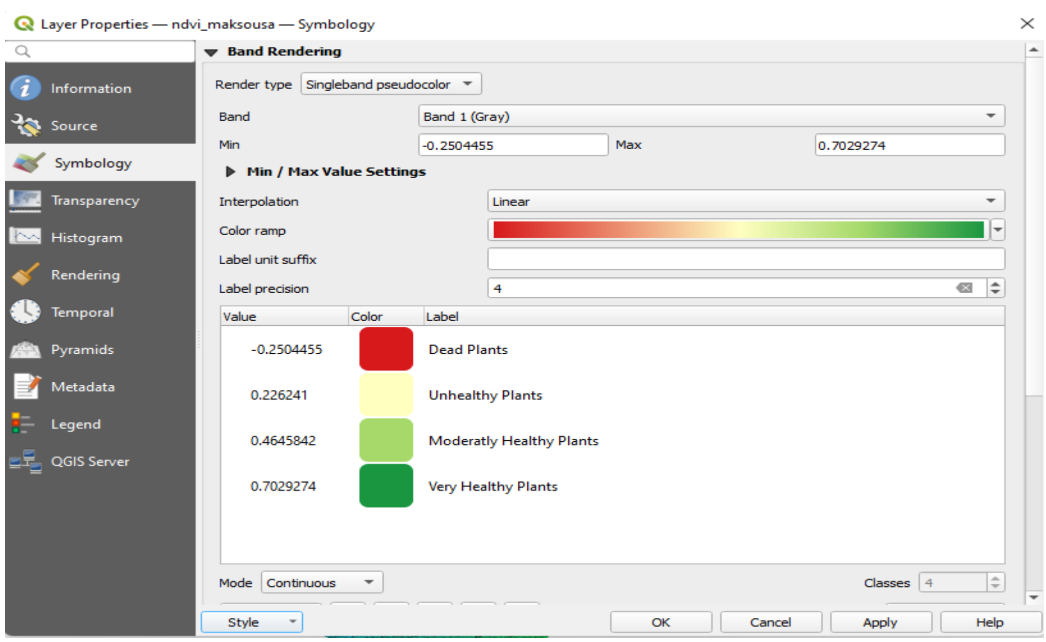


Figure :

While the symbology is created and exported as an SLD file, we will directly import it to Geoserver as shown in Figure 51 below.

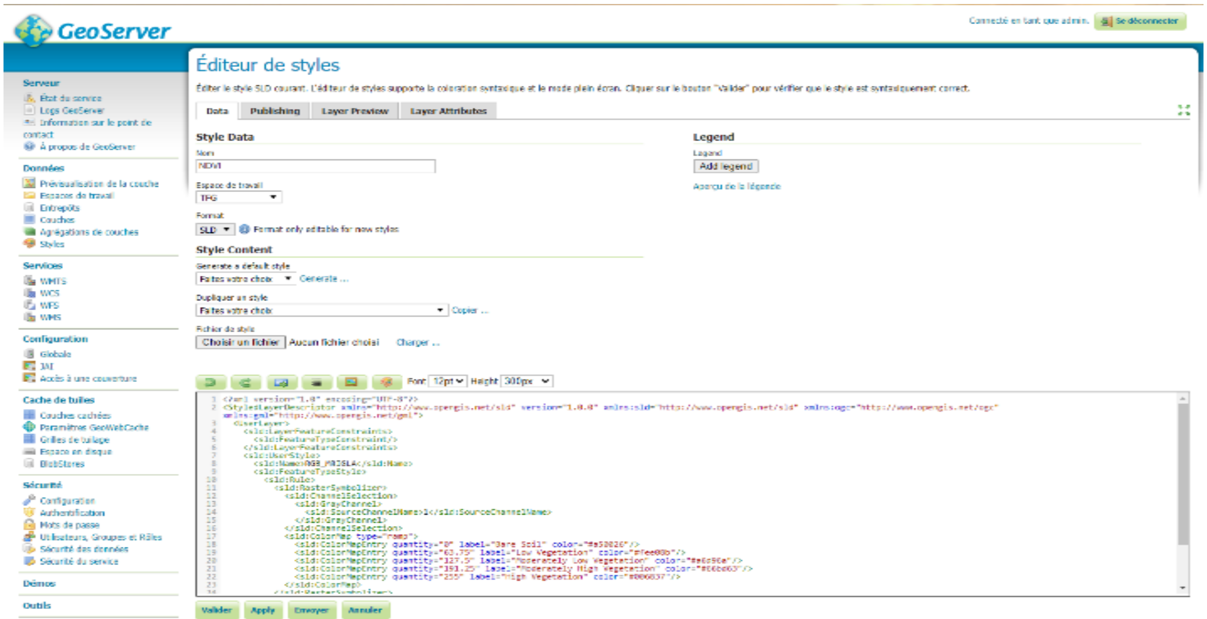


Figure :

III.5 Results

And now that the layers are added to the map, we observe in the figure below the superposition of NDVI, contours, and DEM layers. We obtain crucial information with a simple click every meter on the farm, like the height of the olive trees from the contours, and of course, with the digital elevation model and the vegetation index from the multispectral sensors (fig.52).

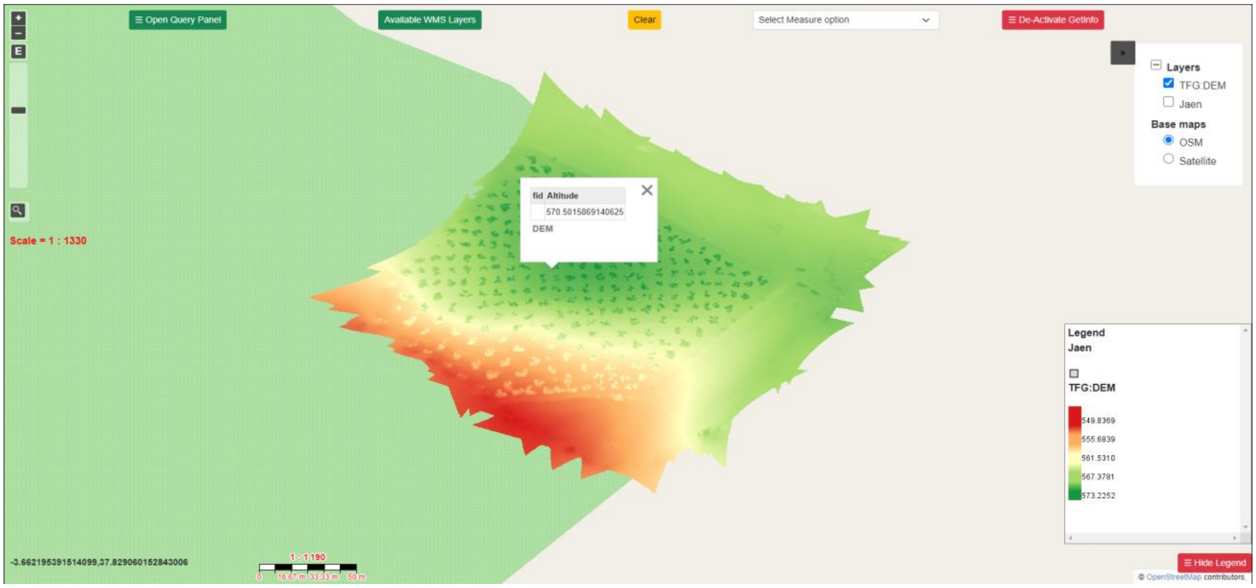


Figure 57: The result of the publication on the platform

VI. Conclusion

This final project aims to implement a management system for a farm in Jaen, Spain using mostly Agisoft Metashape during the image processing phase, Geoserver and openlayers during the online publishing phase. It cost me the opportunity to incorporate the majority of my degree-related knowledge, demonstrating the coherence of what I learned during the topography and geomatic engineering program and my ability to apply my domain to a significant domain, which is olive crops in Jaen.

The use of the various sensors built into drones is becoming more and more crucial for farmers because they will no longer have to walk around their farms surveying soils, crops, and buildings. Farmers now have the best surveillance and inspection technology for their farms.

Starting with visible RGB sensors that provide a direct aerial view of the environment and enable instantaneous but unanalyzed diagnosis. These sensors are also the best to build the degetal elevtion model, which provides the best visual representation of the terrain that can be used to determine altitudes and extract contours.

Regarding the multispectral camera, which is less well-known but plays a significant role in this project because it allows for precise diagnosis of each plant's health and provides a vegetation index for every centimeter of the field. These details are crucial for the farmer to make decisions regarding irrigation, fertilization, and harvesting operations, among others.

The thermal sensor is the third sensor used at the base to monitor the physiological state of the plants by measuring the temperature of the leaves, which is closely related to the rate of transpiration of the cultures.

It is necessary to have theoretical knowledge in many geomatics fields for all steps, starting with the flight plan and ending with the extraction of orthophoto, digital elevation models, NDVI, and contours.

As has been shown in each section of this work, this is a key concept in the fields of geomatics and topographic engineering. A good engineer will never deliver a substandard product.

Moving on to the second phase of the project, data publication, for which we have chosen to create a website with personalized access that will always be available and especially that the farmer who is not specialized in geomatics does not need, for example, a GIS software to visualize or make requests on his farm's information.

In addition to offering a visualization of all the images produced superimposed, with a simple click, he will be able to extract all the necessary information, including the vegetation index, the altitude, the temperature of the leaves,

As a perspective for this project, I propose integrating the "IOT" (Internet of Things), which is a new agricultural technology. It refers to the use of various interconnected sensors installed in the ground or directly on trees in order to convert every component and action involved in agriculture into real-time data that can be noted. A real-time picture of what is happening in the field may be obtained from the data gathered by the IOT sensors.

As a result, farmers will be able to determine when their crops are mature as well as how much water is being used, whether an irrigation system is required, the condition of the soil, and whether further fertilizer or other inputs are required.

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