SOIL BIODIVERSITY AND FUNCTIONALITY
OF MEDITERRANEAN OLIVE GROVES

# D6.4

# Architecture platform the digital twin

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# D6.4 Architecture platform the digital twin

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## Table of Contents

## Executive Summary

This document outlines the architecture of a proposed platform for generating and managing a digital twin (DT) for Mediterranean olive groves within the SOIL O-LIVE project. In the context of olive groves, the DT integrates various data sources, including IoT sensors, UAVs (drones) with multispectral and thermal cameras, LiDAR, and satellite imagery, to enhance precision agriculture practices.

The system's architecture includes data collection, processing, and visualization modules that facilitate real-time monitoring and decision-making for farmers and agricultural technicians. Through supervised machine learning techniques, the DT predicts future harvest yields, soil conditions, and environmental impacts, allowing for optimized resource management. Additionally, an interactive 3D/4D visualization tool provides an intuitive interface for users, reducing the need for on-site visits. The platform supports various types of olive groves, including organic, traditional, and intensive farming models, ensuring a comprehensive and adaptable system for improving sustainability and productivity in olive cultivation.

## Introduction

A *digital twin* (DT) is defined as a virtual representation of the real world that allows constantly checking its behavior, analyzing it and acting accordingly, both immediately and predicting its behavior in the future. The original concept, originated in the industrial field, has been applied to many other sectors, also in rural areas and agriculture. The DT concept is then framed within Smart Farming and Precision Agriculture.

In the olive grove sector, a digital twin must be capable of managing the life cycle of olive orchards. This involves periodic monitoring of the plantation, analyzing the data obtained and indicating or suggesting the actions to be performed on the site. Two objectives that are in principle opposed to each other should be achieved thanks to the application of a DT: increasing production while preserving the natural environment. Therefore, the olive grove digital twin is an integrated hardware and software system that manages all these different phases considered to be cyclical.

## 1.Data capture and monitoring

Monitoring an olive orchard implies the acquisition of a wide range of environmental variables, from the plant as well as from the air and soil. Numerous types of sensors are today available to capture and send the information remotely. For example: IoT (Internet of Things) sensors can repeatedly measure temperature, environmental or soil humidity, and send them in real time over the Internet. Different technologies and communication protocols such as 5G, allows these devices to feed the digital twin.

On the other hand, the joint use of UAVs (Unmanned Aerial Vehicle) and the multi-sensors attached to them has proven to be a disruptive advancement, revolutionizing aerial data collection and analysis. Examples of these devices are thermal sensors, RGB, multispectral and hyperspectral cameras, or LiDAR (Light Detection and Ranging or Laser Imaging Detection and Ranging). Precision agriculture can take advantage of this technology since they have lightened their weight, improved their performances and lowered their cost.

Finally, satellites provide various types of information across different spectra and sensors, including optical, thermal, radar or multi/hyper-spectral imagery. This type of information is valid to analyze moisture levels or drought stress, meteorological data, as well as numerous vegetation indices that provide information about plant health.

## 2.Data processing

All the data captured from different sensor devices must be integrated with the information coming from other sources, such as chemical analysis from soil and plants. The challenge is to incorporate this heterogeneous multi-temporal and multi-scala data into a *spatio-temporal database.* The information of this data system is managed using the following modules:

- **Decision-make module:** historical data (meteorological and climatological variables, past productions, chemical soil analysis, etc.) will be used to make a forecast applying supervised machine learning techniques (neural networks and SVM). Thus, this module is the brain of the digital twin and tries to estimate relevant future information, e.g., the quantity and quality of the next harvest. Moreover, economic data about the forecast of the olive price will be considered in order to optimize our guidelines to increase the sustainability and profitability of olive plantations.

- **Discriminator module:** After data acquisition and before being stored into the database, this information must be cleaned and transformed into a set of specific variables. Then, the selected variables under study are the input for further analysis which finally will provide valid ranges of these variables for the correct functioning of the olive grove, both soil and plants. This knowledge is the information included in the discriminating model, which must consider the type of olive orchard, soil, the specie of olive tree (arbequina, picual, etc.) and physiognomy of the plant based on the type of trillage or exploitation (classic or extensive). After optimizing this discriminator module, we have an effective tool to determine in real time when these recorded variables are out of the established ranges.

- **Interactive 3D/4D visor**: real olive orchards are 3D, as well as some of the data obtained from some of the sensors attached to a drone, such as LiDAR or the result of fusioning RGB images. Digital twins in the rural environment cannot obviate the 3D representation, allowing among other advantages: (1) to reproduce the morphology of terrain and trees, aspects which are not obtained from a two-dimensional representation. The height, trunk shape, type of tillage or volume are 3D features that are crucial to know the evolution of the plantation. (2) Users of the digital twin will only trust this technology if the way in which they are informed is understandable and accessible for them. This implies reducing the level of abstraction in the way they visualize the plantation remotely, making it as realistic as possible. The objective of reducing the physical visit by technicians to large tracts of land must be compensated with a virtual observation of the physical environment by incorporating enriched 3D models.

## 3.Obtaining and distributing information on the actions to be carried out to the different agents involved

The final objectives of digital twins are the actions directly performed in the olive plantation. In contrast to other DT application frameworks, such as the industry, at the moment the action in the rural environment is carried out by farmers. They act in the olive grove mostly on the basis of the knowledge acquired through generations. Ultimately, they have had access to the services of agricultural companies and technicians. However, a digital twin can help them to make the best decisions at any given moment and act accordingly to improve their farm's performance. In this framework, technicians are also considered important agents in the model. They both are considered the client-side of the system since all the information provided by the system must be translated to apply different actions on the orchard (specific use of fertilizers, phytosanitary products, pruning or irrigation). For that purpose, the development of a mobile application for technicians and farmers can be considered an automatic mechanism for information. In fact, this application is the main bidirectional mechanism of communication with the digital twin. Technicians can avoid visiting the site, being able to check large tracts of land remotely through the digital twin. The farmer receives on his cell phone the information of the plot in a direct and friendly way. In both cases, the 3D plantation visualization is available.

## 4.Case: three types of olive grove farms

The input data is obtained from the three orchards described in the Appendix section. The plots are representative of the type of olive grove cultivation: organic, traditional and intensive. These orchards have been flown with drones (UAV) with different sensors attached, such as the RGB camera (which allows obtaining orthophotos and 3D point clouds) and the thermal and multispectral sensors.

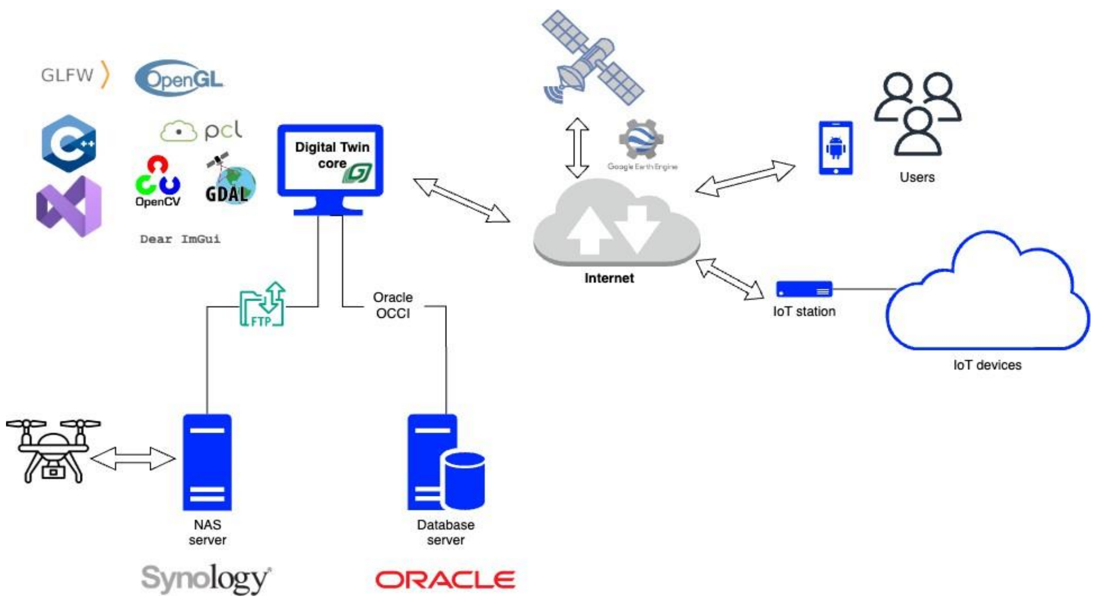



Figure 1: Architecture of the digital twin.

## 5.System architecture

In order to provide a solution to all of the challenges described above, we propose the system architecture depicted in Figure 1. The DT core is an application implemented in C++ called GEU. This native application is connected to a Network-Attached Storage (NAS) server with high storage capacity in which most raw data is stored. The Oracle database, on the other hand, stores the rest of structured data regarding plots (municipalities, tree geometry, etc.), UAVs flies (flight plans, location in the NAS of raw data and tables with processed information) as well as meteorological information or the results of different types of soil and plant analyses.

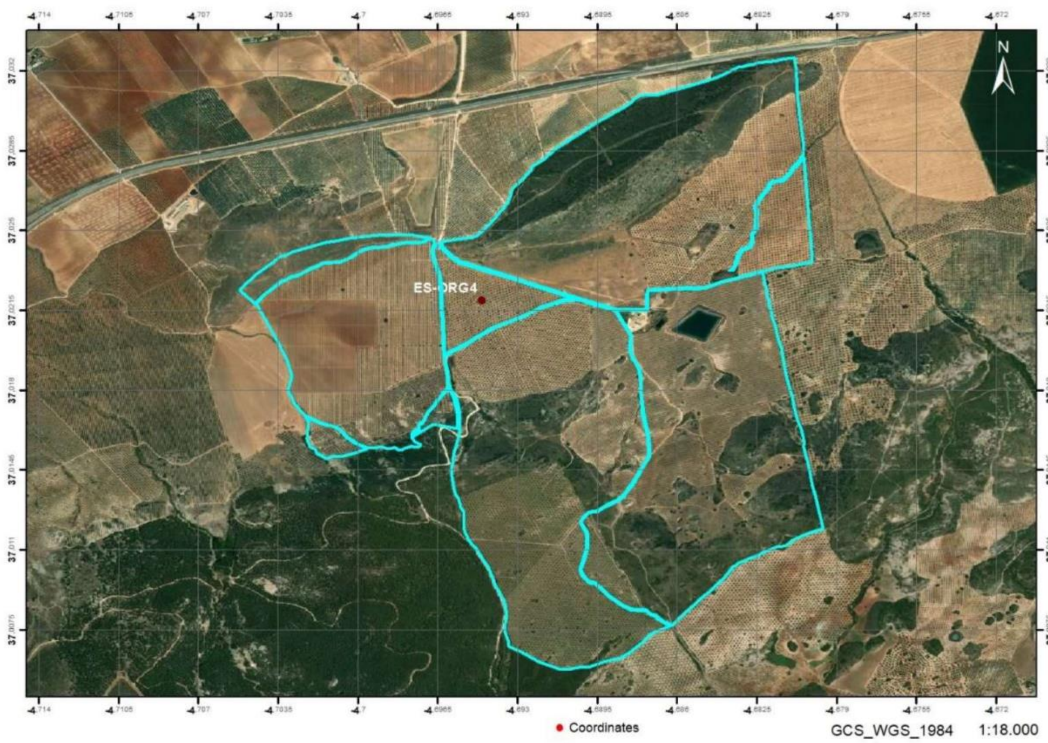
Clients such as farmers or technicians are connected to the system via smartphone applications connected to the system through the Internet. IoT devices located in different plots are also part of the input dataset, feeding the system through the network. Satellite information is also analyzed and incorporated into the system, as well as the rest of heterogeneous information.

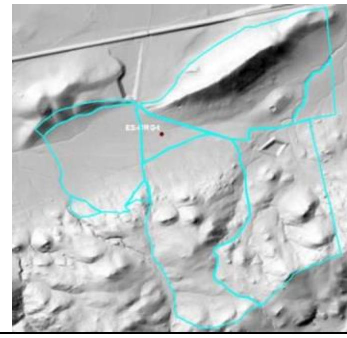
# Appendix

## ES-ORG4.- SPAIN Organic

LOCATION

| | |
|---|---|
| Id Plot | ES-ORG4 |
| Orchard name | La Torre |
| Cadastral ref | 29015A09100029-30/29015A09200046-47/29015A10100009-41/29015A10300001/29015A 10500001 |
| Country | Spain |
| Nuts[21] level 2 | Andalucía |
| NUTS level 3: Province | Málaga |
| LAU[22] name | Antequera |
| Latitude (centroid) WGS84 | 37,02194580290 |
| Longitude (centroid) WGS84 | -4,69454337660 |

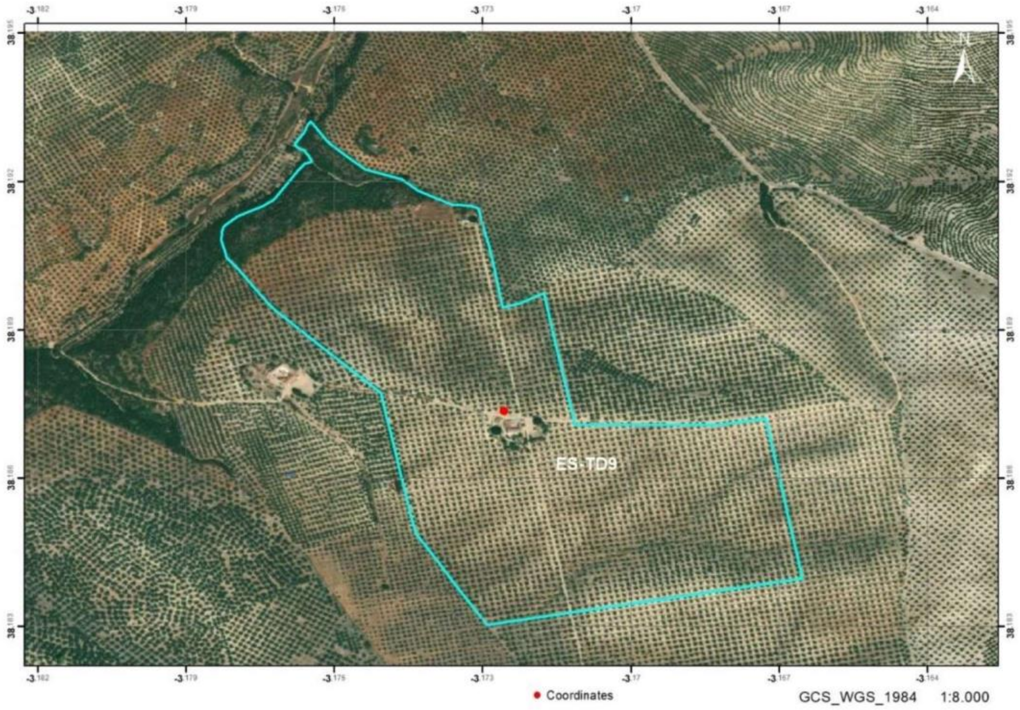


| GEOGRAPHICAL CHARACTERISTICS OF THE PLOT | | |
|---|---|---|
| Area (ha) | 380,3 |  |
| Mean elevation | 447 | |
| Mean slope (%) | 12 | |

| | |
|---|---|
| Cultivation method | Organic |
| Olive tree variety | Hojiblanca |
| Age | 22 |
| Tree density/ha | 100 |
| Organic | Yes |

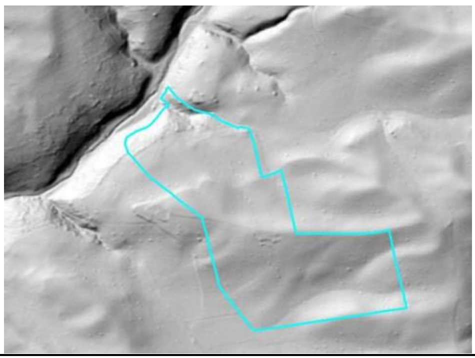
# ES-TD9.- SPAIN Traditional

| LOCATION | |
|---|---|
| Id Plot | ES-TD9 |
| Orchard name | Los Robledos |
| Cadastral ref | 23079A030000060000QZ |
| Country | Spain |
| Nuts[7] level 2 | Andalucía |
| NUTS level 3: Province | Jaén |
| LAU[8] name | Santisteban del Puerto |
| Latitude (centroid) WGS84 | 38,18735684740 |
| Longitude (centroid) WGS84 | -3,17255745234 |




link to map:

| GEOGRAPHICAL CHARACTERISTICS OF THE PLOT | |
|---|---|
| Area (ha) | 49,1 |
| Mean slope (%) | 18,05 |
| Mean elevation | 595 |

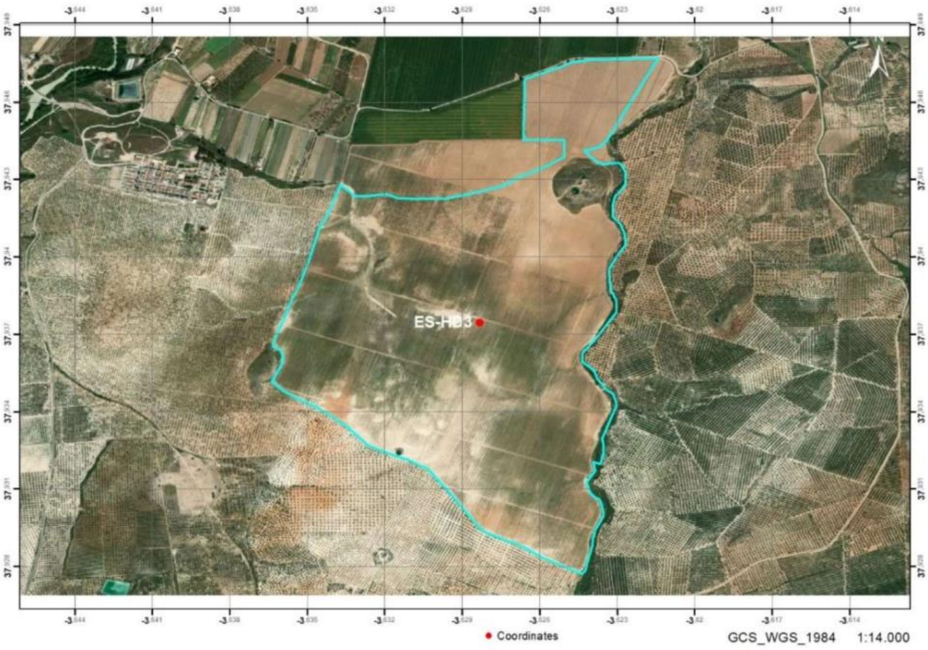


| | |
|---|---|
| Cultivation method | Traditional |
| Olive tree variety | Picual |
| Age | 80 |
| Tree density/ha | 100 |
| Organic | No |

## ES-HD3.- SPAIN HIGH DENSITY

### LOCATION

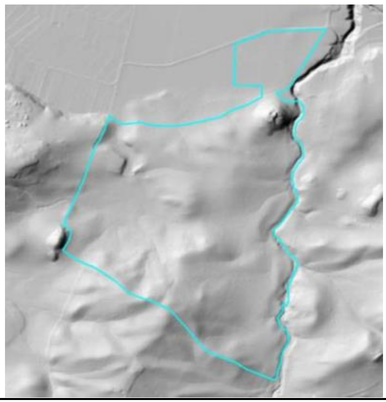
| | |
|---|---|
| Id Plot | ES-HD3 |
| Orchard name | Racioneros |
| Cadastral ref | 23100A01700094/ 23900A01800108/ 23900A01800107 |
| Country | Spain |
| Nuts[13] level 2 | Andalucía |
| NUTS level 3: Province | Jaén |
| LAU[14] name | Jaén |
| Latitude (centroid) WGS84 | 37,93744223590 |
| Longitude (centroid) WGS84 | -3,62829938887 |




link to map:

### GEOGRAPHICAL CHARACTERISTICS OF THE PLOT

| | |
|---|---|
| Area (ha) | 152,3 |
| Mean slope (%) | 3-13% |
| Mean elevation | 275 |



| | |
|---|---|
| Cultivation method | Intensive |
| Olive tree variety | Sikitita |
| Age | 2,5 |
| Tree density/ha | 200-400 |
| Number of trunks within the olive tree | 1 |
| Organic | No |