D5.8

On site farming operations connectivity

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Abstract:	A total number of 3 AgriBIT pilot sites are established in Portugal, Italy, and Greece with tomato cultivation, vineyards, and peach orchards. The customized needs of the diversified pilot sites have led to the selection to specific sensors and technologies to be used and applied in each pilot site. The aforementioned sensors and systems for the on-site farming operations of AgriBIT are described in detail in the current deliverable.		

Document History			
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DISCLAIMER

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Executive Summary

The current deliverable D5.8 entitled "On site farming operations connectivity" contains an elaborate analysis of the pilot sites of AgriBIT project, together with the corresponding farming operations connectivity per pilot. More specifically, chapters of the deliverable as structured as below:

1) **Chapter 1**: provides an overview of the main aims of the deliverable.
2) **Chapter 2**: provides specific information about the pilot sites, such as country, location, cultivation, farm size.
3) **Chapter 3**: presents the tools and sensors to be used in each pilot site.
4) **Chapter 4**: presents a correlation of the farming operations described in chapter 3, and the AgriBIT Use Cases under which, the aforementioned operations are integrated and associated.
5) **Chapter 5**: provides the conclusions of the deliverable.

This way, AgriBIT pilot sites are identified for applying specific operations.

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1. Introduction

The current deliverable constitutes the outcome of AgriBIT task T5.5 “Connection to on-site farming operations”, while the results are taken up by the continuous integration task (T5.3) to monitor and update any needs detected during the pilot operations. Evaluation of the pilot operations will take place within T5.6 “Technical Validation and Testing” in the upcoming project period. The aim of D5.8 is to ensure that all piloting needs are fully covered within the AgriBIT project, regarding connectivity of services to actual machinery, sensors and actuators used on farms.

More precisely, the three pilot sites are located in three different countries, i.e., Greece, Portugal and Italy. Pilot site in Greece contains peach orchards, pilot site in Italy contains vineyards, and pilot site in Portugal contains tomato cultivation. All three pilot sites’ needs and specifications are described in the next chapter.

2. Pilot sites identification

Based on the cultivation of each pilot site, several needs are defined. As each different crop has its own requirements, it is clear that the farming operations needed per pilot side differentiate for covering all needs of the agricultural production of the site.

2.1. Portuguese tomato cultivation

Tomato production constitutes a significant part of the agricultural production of Portugal [1]. In 2021, Portugal was the 4th EU country in area under cultivation of tomato (ha) based on EUROSTAT. In December 2021, Portugal had a total of 17.71 thousand ha of tomato cultivation, which highlights the significance of tomato cultivation for the country.

CCTI, the AgriBIT Portuguese partner, has identified a list of fields in Portugal, where the AgriBIT Portuguese pilot sites will be established. Fields are located in central western Portugal, close to Lisbon (**Figure 1**).

***Figure 1.** Pilot sites in Portugal*

More specifically, 4 distinct fields will be incorporated, accounting for approximately 85 ha. 3 of the fields are located in the valley of Santarem, and one is located in Sao Joao region, close to the valley (**Figure 2**). The valley is an agricultural production area due to the soil and microclimatic conditions of the area.

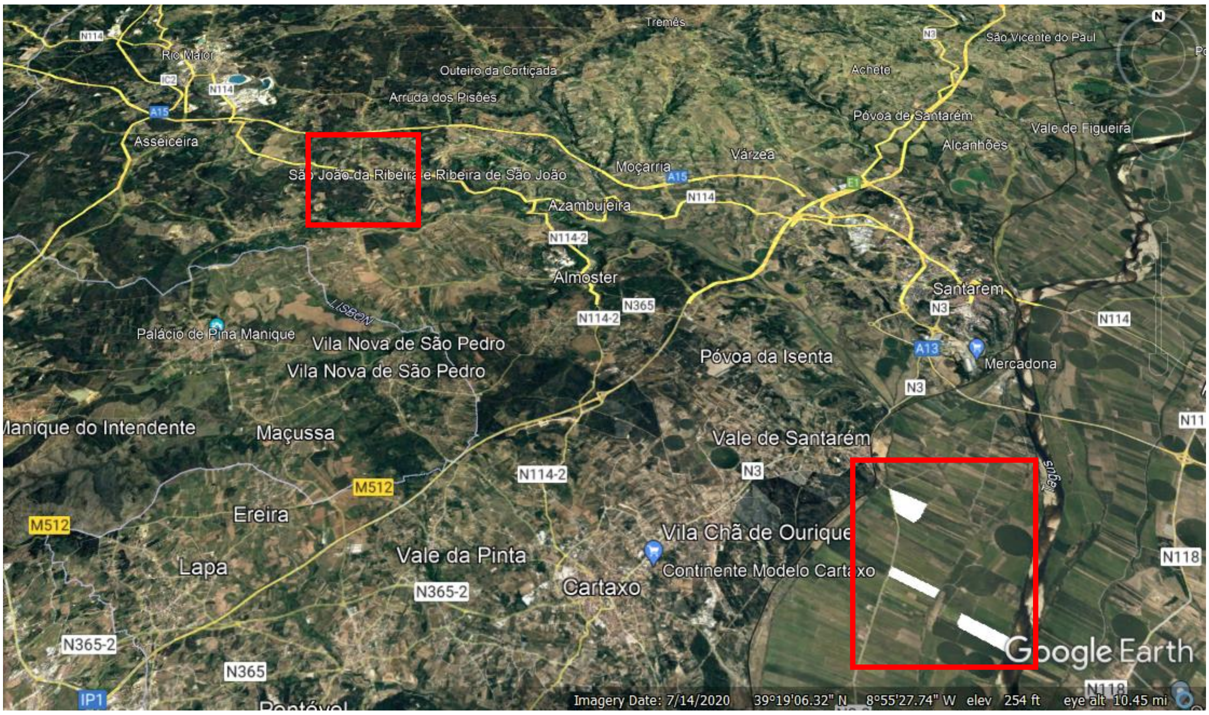

Figure 2. Portuguese pilot sites' scattering

The exact shape of the field outside of the valley is depicted in **Figure 3**, whereas the cadastral file of the field is depicted in **Figure 4**. The field covers a total area of 5.11 ha with 4.63 ha of temporary cultivations.

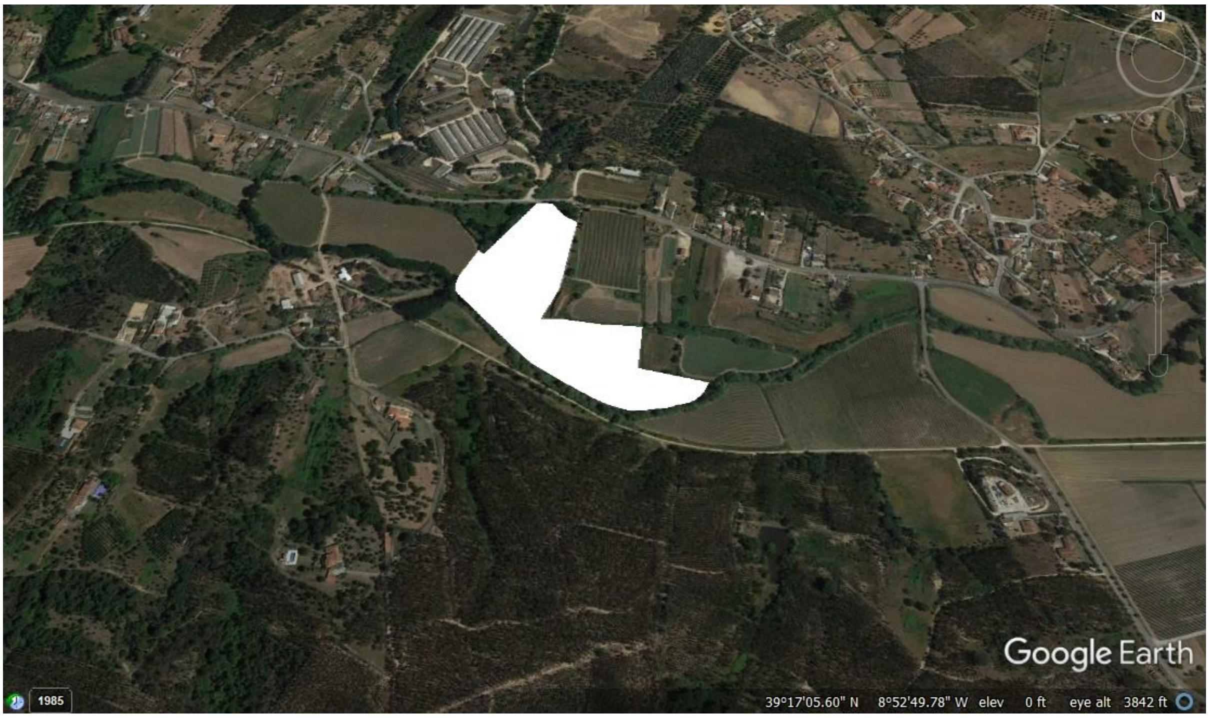

Figure 3. Sao Joao field

__Figure 4__. Sao Joao field's cadastral description

The 3 fields located in Santarem valley are presented in **Figure 5**, and their cadastral files in **Figure 6**, **Figure 7**, and **Figure 8**, while fields cover 19.87, 32.56, and 27.63 ha respectively.

***Figure 5.** Map of Santarem valley fields*

Figure 6. *Cadastral file of field (I) of Santarem valley*

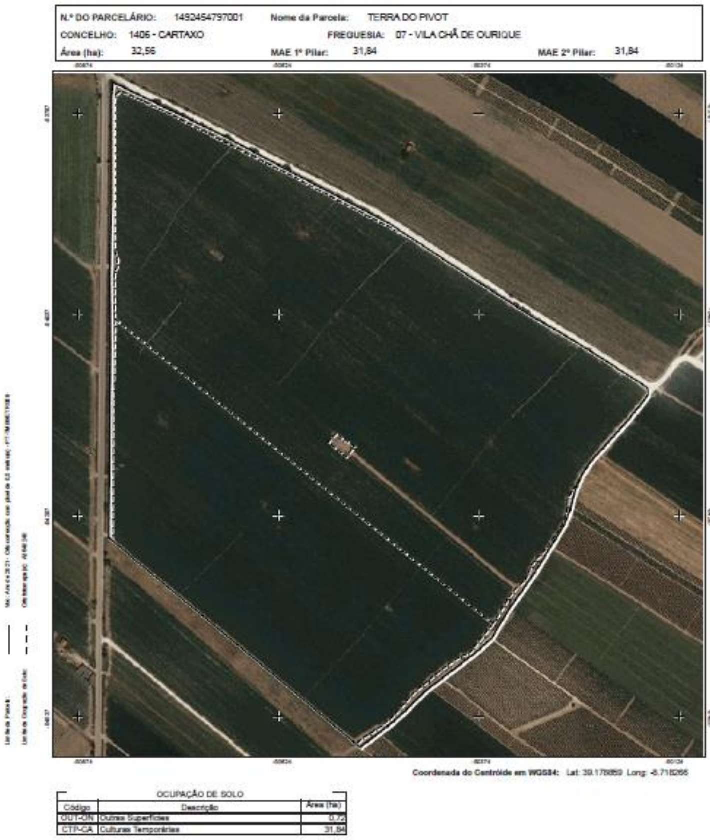

Figure 7. *Cadastral file of field (II) of Santarem valley*

***Figure 8**. Cadastral file of field (III) of Santarem valley*

2.2. Italian vineyards

Vineyards are considered to be a prominent cultivation in Italy. In 2021, Italy was in the 3rd position among the EU countries in areas cultivated with as vineyards, with a total of 718,000 ha [2], constituting almost 23% of the total EU vineyard areas. Spain, France and Italy possess 75% of the total EU wine-growing areas. A wealth of PDO products derive from the wine cultivation in Italy, such as local well-known wines, and various other products such as raisins etc.

AGRICOLUS, the AgriBIT Italian partner, has identified a great number of vineyards in Italy in two areas (**Figure 9**). More specifically, vineyards are located in Umbria region, in central Italy, close to its capital, Perugia, and Turrita, close to Montefalco (**Figure 10**).

***Figure 9**. AGRICOLUS vineyards in Italy*

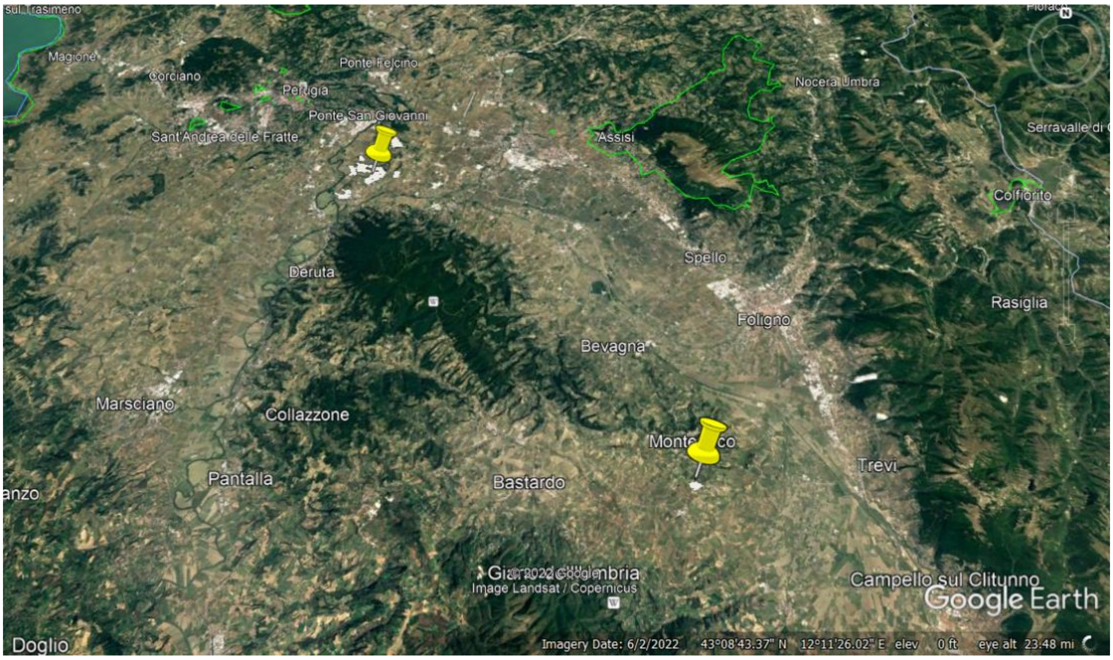

***Figure 10**. Italian vineyards in Umbria*

The aforementioned two areas contain a total number of 21 different varieties cultivated in more than 200 vineyards. All varieties and corresponding number of vineyards are presented in **Table 1**.

***Table 1**. Italian wine varieties and number of vineyards per variety*

Variety	Number of vineyards
Bianco di Torgiano	3
Cabernet Franc	1
Cabernet Sauvignon	9
Chardonnay	8
Colorino	25
Frantoio	27
Grechetto	7
Leccino	28
Merlot	13
Montepulciano	1
Moraiolo	14
Pecorino	1
Pinot grigio	4
Rosso di Torgiano	2
Sagrantino	4
Sangiovese	36
Seminativo	2
Syrah	2
Trebbiano toscano	11
Vermentino	11
Viognier	4

Geographical scattering of the vineyards in Miralduolo and Torgiano (Perugia area) is presented in **Figure 11**, while the respective scattering for Turrita is presented in **Figure 12**.

Figure 11. Vineyards in Perugia area

Figure 12. *Vineyards in Turrita area*

Due to the vast number of available vineyards, for the AgriBIT purposes, 5 vineyards with major cultivated varieties were selected for establishing the pilot sites in Italy. Selected vineyards have 4 varieties, namely Chardonnay, Grechetto, Sangiovese, and Trebbiano toscano. All 5 vineyards (A, B, C, D, E) are located in Perugia area of Umbria (**Figure 13**).

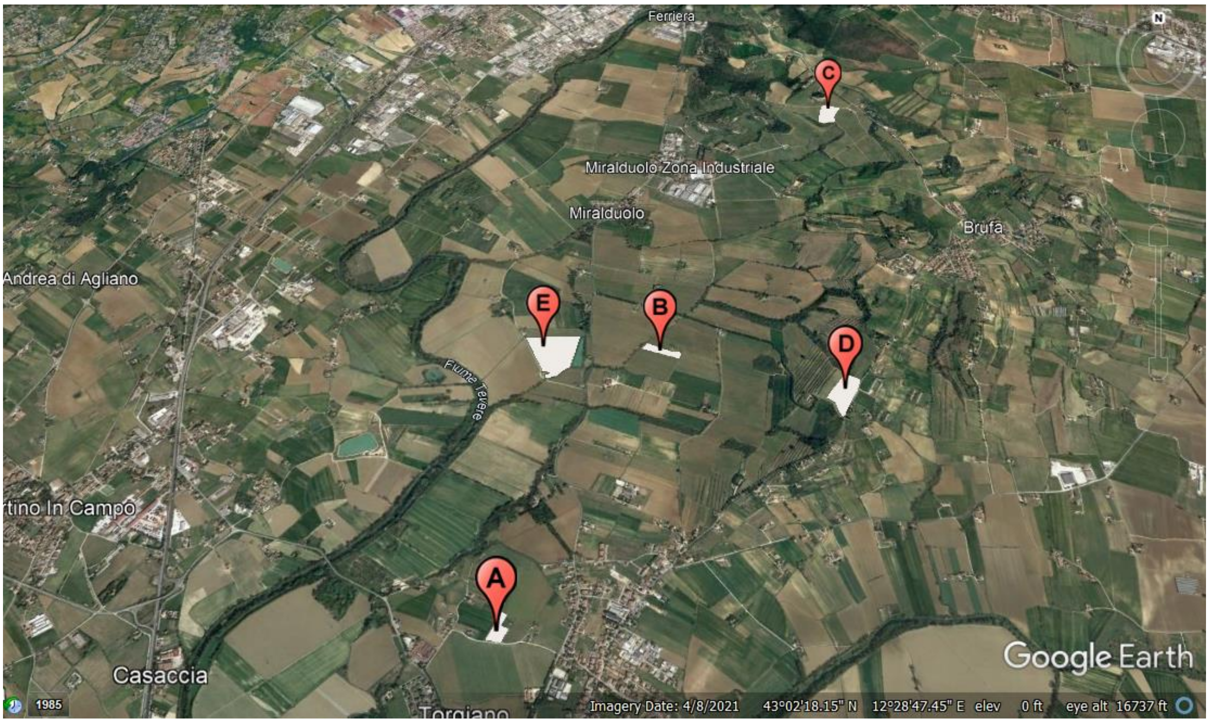

Figure 13. Selected vineyards in Perugia

In **Figure 14**, a more detailed and closer insight of the shape and size of the vineyards is presented for all identified and selected vineyards.

Figure 14. *Identification of selected vineyards*

Further characteristics and details of the pilot site vineyards, regarding the field morphology, soil compound, variety particularities, as well as other features are presented in **Table 2**.

__Table 2.__ Characteristics of vineyards pilot site fields

Pilot site / Characteristics	Chardonnay (Field #4)	Grechetto (Field #3)	Sangiovese (Field #3)	Sangiovese (Field #35)	Trebbiano toscano (Field #2)
Wine color	White	White	Red	Red	White
Requirement for special treatments	No	No	No	No	No
Irrigation	Drip irrigation (from July, irrigation wets 10% of the surface area) + additional emergency irrigation if necessary	Drip irrigation (from July, irrigation wets 10% of the surface area) + additional emergency irrigation if necessary	No	No	Drip irrigation (from July, irrigation wets 10% of the surface area) + additional emergency irrigation if necessary
Soil characteristics	• Coarse skeleton: 74g/kg • Sand: 40% • Clay: 35% • Silt: 25% • Ph: 8,2 • Total N: 0,7 g/kg • Organic C: 6,75 g/kg • CSC: 15,7 meq/100g	• Coarse skeleton: 74g/kg • Sand: 40% • Clay: 35% • Silt: 25% • Ph: 8,2 • Total N: 0,7 g/kg • Organic C: 6,75 g/kg • CSC: 15,7 meq/100g	• Coarse skeleton: 74g/kg • Sand: 40% • Clay: 35% • Silt: 25% • Ph: 8,2 • Total N: 0,7 g/kg • Organic C: 6,75 g/kg • CSC: 15,7 meq/100g	• Coarse skeleton: 74g/kg • Sand: 40% • Clay: 35% • Silt: 25% • Ph: 8,2 • Total N: 0,7 g/kg • Organic C: 6,75 g/kg • CSC: 15,7 meq/100g	• Coarse skeleton: 74g/kg • Sand: 40% • Clay: 35% • Silt: 25% • Ph: 8,2 • Total N: 0,7 g/kg • Organic C: 6,75 g/kg • CSC: 15,7 meq/100g

Slope	No	No	No	No	No
Planting and cropping spacing	• Planting: 2m x 1m • Crown height: 1.55 m • Crown width: 2.5 m • Root depth: 3 m	• Planting: 2m x 1m • Crown height: 1.55 m • Crown width: 2.5 m • Root depth: 3 m	• Planting: 2m x 1m • Crown height: 3.20 m • Crown width: 2.5 m • Root depth: 3 m	• Planting: 2m x 1m • Crown height: 3.20 m • Crown width: 2.5 m • Root depth: 3 m	• Planting: 2m x 1m • Crown height: 1.55 m • Crown width: 2.5 m • Root depth: 3 m
Agricultural operations	• October: pruning • Pruning name: "Double Guyot" • March: weed control, no weeding, yes harrowing and inter-row diggers • Mid-March: pesticide treatments • By 30 June: head tying • After June: topping • September: grape harvest • February: lethamic or	• October: pruning • Pruning name: "Double Guyot" • March: weed control, no weeding, yes harrowing and inter-row diggers • Mid-March: pesticide treatments • By 30 June: head tying • After June: topping • September: grape harvest • February: lethamic or	• October: pruning • Pruning name: "Cordone speronato" • March: weed control, no weeding, yes harrowing and inter-row diggers • Mid-March: pesticide treatments • By 30 June: head tying • After June: topping • September: grape harvest • February: lethamic or	• October: pruning • Pruning name: "Cordone speronato" • March: weed control, no weeding, yes harrowing and inter-row diggers • Mid-March: pesticide treatments • By 30 June: head tying • After June: topping • September: grape harvest • February: lethamic or	• October: pruning • Pruning name: "Double Guyot" • March: weed control, no weeding, yes harrowing and inter-row diggers • Mid-March: pesticide treatments • By 30 June: head tying • After June: topping • September: grape harvest • February: lethamic or

	urea fertilization	urea fertilization	urea fertilization	urea fertilization	urea fertilization
Neighboring installed stations	Station name: "lungarotti torgiano entrata" - distance from the field: 0 m (on the border)	Station name: "lungarotti miralduolo renaglio" - distance from the field: 0 m (on the border)	Station name: "lungarotti brufa" - distance from the field: 0 m (on the border)	Station name: "lungarotti san rocco" - distance from the field: 218 m	Station name: "lungarotti palla laghetto" - distance from the field: 0 m (on the border)

2.3. Greek peach orchards

Peach production constitutes a major cultivation of the agriculture in Greece, especially in Northern Greece, in Pella area of Macedonia close to Thessaloniki (**Figure 15**). Peach cultivation in Greece allows delivering of fresh fruit, canned peach products, and peach puree. In 2018, Greece was the 3rd EU country in peach production, with 810.49 thousand tonnes [3].

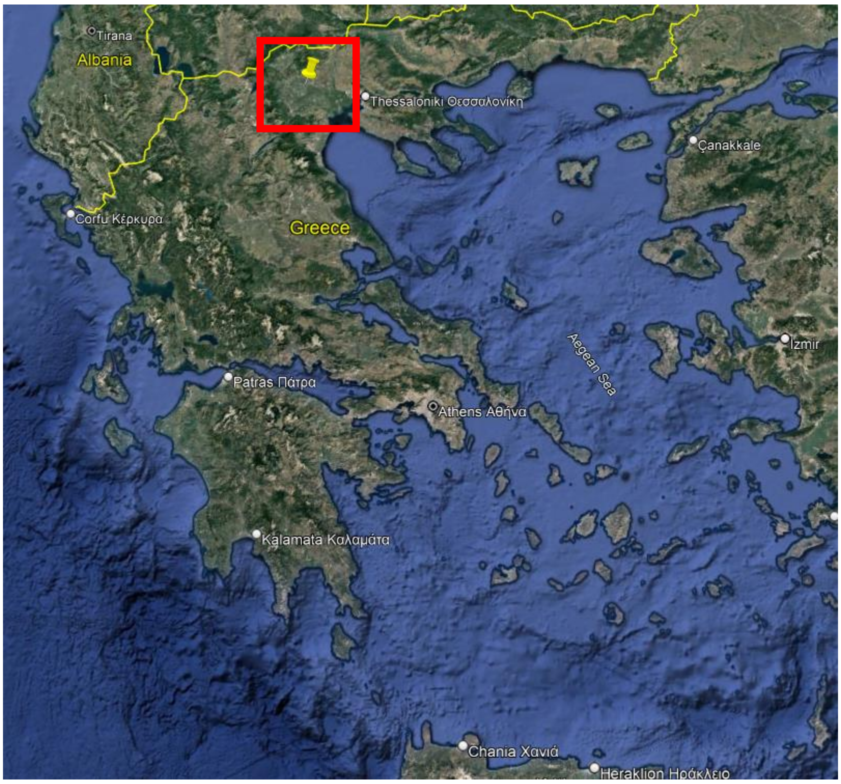

Figure 15. ACP peach orchards in Greece

For the AgriBIT pilot site needs, a total of **119 orchards** were identified in the entire region of the selected valley. The orchards account for 73.42 hectares in total and are distributed in various areas of valley, as depicted in yellow color in **Figure 16** below. The average orchard size is 0.62 ha, with sizes varying between 0.1 and 1.95 ha. Apart from peach orchards, some nectarine orchards are also incorporated into the fields list. Fields have cultivations for fresh fruit and for further processing.

Nectarine varieties cultivated are the following:

- Big top
- Red gold
- Ali top
- Platimoon
- Key suite
- Luciana
- Big bang
- Orion

Peach varieties cultivated are the following:

- Andross
- Catherina

- Everts
- Fortuna
- Sagittaria
- Gladys
- Ι.Φ.Δ.-Α37
- Lolyta
- O' Henry
- Royal glory
- Royal summer
- Royal gem
- Sweet dream
- Sweet scarlet
- Spring bell
- Symphonie
- Fayette

Figure 16. *Distribution of Greek orchards*

All fields of the AgriBIT pilot sites are included in the .kmz file available in the following link:

https://agribit.agenso.gr/pilot_sites/it_pt_gr.kmz

3. On-site operations

The diversified AgriBIT pilot sites, as presented in the previous chapter, are introduced to have specific needs, due to the divergence of cultivations, areas, climatic conditions and agricultural practices exercised at each pilot site. For this reason, different sensors, and corresponding services are required at each pilot site for the optimization of the production process and the maximization of the yield, avoiding any possible losses. In the sub-chapters below, the needs of each pilot site are presented, together with the on-site operations to be performed.

3.1. Portuguese tomato cultivation

Due to the nature of tomato cultivation, tomato pilot sites require performance of measurements of environmental parameters such as Relative Humidity, Wind Direction, Wind Speed, Temperature, Precipitations, Wind gust, UV, Light intensity, atmospheric pressure, and soil moisture. The main reasons behind the aforementioned measurements are crop monitoring, and environmental and soil monitoring. Crop monitoring allows an effective management of the crop in terms of application of agricultural practices.

Soil moisture measurements are required for avoiding any excess of soil moisture, that could leave to the development of diseases, and especially root fungal rots which cause a decline of the crop, soil borne pathogens that may hinder in soil, and bacteriological diseases that are find favorable environment in soil matrices with high moisture.

3.1.1. AGENSO nodes, weather stations, and soil moisture sensors

Under this framework, AGENSO will deliver 2 weather stations (**Figure 17**) and 2 soil moisture sensors (**Figure 18**) for the Portuguese pilot sites, so that the aforementioned measurements can be performed. These systems will function through the Ardeusi.gr system of AGENSO (https://about.ardeusi.gr/en/ardeusi/) via GPRS/4G protocols. Ardeusi.gr provides a 3-year energy autonomy through the use of a small solar panel, allowing the reduction of energy consumption within an energy efficiency framework. The Ardeusi.gr system nodes support GPS feature.

Figure 17. *AGENSO weather station*

Figure 18. *AGENSO soil moisture sensor*

The technical specifications of the weather station are the following:

- Temperature: -40˚C - +60˚C
- Humidity: 10% - 99%
- Rainfall: 0 – 9999 mm

- Wind speed: 0 – 180 km/h
- Wind gusts speed: 0 – 180 km/h
- Wind direction
- Sunlight: 0 – 2370w/m2
- UV radiation: 0 – 13 (UV index)
- Atmospheric pressure: 300 – 1100 hPa

The soil moisture sensor's technical specifications are the following:

- Measurement of volumetric water content
- High precision: (±0.03 m^3/m^3)
- Waterproof, anti-corrosion sensors, able to operate for up to twenty (20) years
- Cable length 5m

Both the weather station and the soil moisture sensor function through the Ardeusi.gr system node (**Figure 19**).

Figure 19. *Ardeusi.gr system node*

The node has the below mentioned technical specifications:

- Small size (11.5cm x 9cm x 5.5cm), can be installed practically anywhere
- Photovoltaic panel (13cm x 11cm) for making the system fully autonomous energy-wise
- Integrated rechargeable battery
- Ability to charge from a USB charger or a power bank
- Maximum system autonomy up to three (3) years, without using any power source (dependent on sampling rate)
- Plug-and-play system, no customization needed
- Easy installation from farmers
- Connectivity to mobile phone network through the integrated SIM card
- Ability to operate in over than 100 countries
- Integrated GPS for positioning
- Ability to disable operation and trace its position in case of theft
- IP67 certification: water and dust proof

In addition to that, Ardeusi.gr online platform allows data visualization, five-day weather forecast, task calendar, display of historical data, data export to Microsoft Excel, default sampling rate of 30 minutes, and creation of personalized notifications based on rules set by the user, as well as sending email notifications.

3.1.2. Caudalimeter/flowmeter

Moreover, apart from the aforementioned systems, further systems will be exploited in tomato pilot sites. More precisely, a water counter will be used for monitoring the water flow in the irrigation pipe system, aiming to allow the identification of water consumed during the production of tomato.

Flowmeters (**Figure 20**) are composed by a caudalimeter, that measure water flow (pulse meter, 1 pulse/m3) DN15 or DN20, and a data logger to collect and transmit data to the server with the following specs:

- Ultra-low power wireless data logger
- 2G / 4G modem
- Internal 3.6V 13Ah Lithium Thionyl Battery
- 4 digital input 0-30V
- Operating Temperature -40'C to +65ºC
- Protection IP67

The data is sent to a server and it is accessible through an FTP server. The data is transferred via .csv file.

Figure 20. *Water flow meter*

3.1.3. Pest traps

Tomato cultivation is also susceptible to pests' infestation during the growing season. As a result, apart from the flow meter to be installed in the Portuguese pilot sites, field cameras will be installed in the pilot sites for insect monitoring. Field cameras will provide 6 photo captures per day, while cameras will be accompanied by traps where pests will be trapped prior to capturing the image (**Figure 21** and **Figure 22**). This will allow an efficient insect monitoring and scouting. Thus, pest management will be facilitated, allowing the application of integrated pest management solutions of different types of insects.

Figure 21. *Pest traps (i)*

Figure 22. *Pest traps (ii)*

The system is composed by:

- RGB (Red Green Blue) Camera - 12Mpixel, Auto-focus
- Data logger to collect and transmit data to the server with the following specs:
- 4G modem
- Internal 12V 7Ah Battery (rechargeable)
- 10W Solar Panel and power controller
- Image collecting capability (up to 200 images/day)
- Operating Temperature -15ºC to 55ºC
- Protection IP67

The data is sent to a server and it is accessible through an FTP server. The data is transferred via .jpg files, with the time stamp in its name.

Data from both the water flow meter and the field cameras will be ingested on the field via Demarcator online application as manually input data in various points of interest (PoIs) into the field. This way, user will be able to access specific information for each separate part of the pilot site.

3.1.4. Analog Devices MVP based custom sensor node

This section describes sensing technologies of RFSAT Limited that are applicable for in-situ sensing of environmental parameters, including climate, soil and air parameters and pollutants. The most applicable sensor node is a results of an ongoing collaboration with Analog Devices (Limerick, Ireland)[1], the world renowned semiconductor chip manufacturer, which has resulted in the joint development of a novel sensor node based on a new Analog Device MVP sensor board see **Figure 23**.

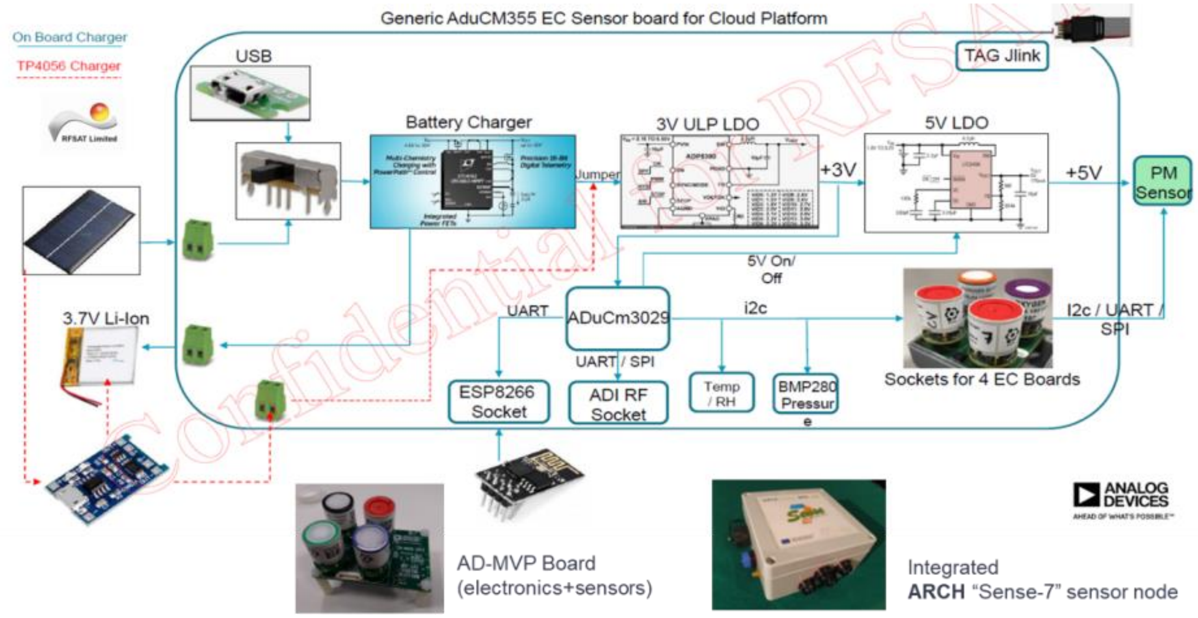

Figure 23. *Sensor node based on Analog Device MVP board*

RFSAT has been a proud first tester of this board offered on complimentary bases for testing in the AgriBIT project. This board uses a generic AduCM355 EC sensor board suitable for cloud IoT applications. In the context of AgriBIT project, a sensor is designed to measure local climate parameters (temperature, humidity, and pressure) in addition to HS_4, CO, SO_2 and NO_2. All sensor elements are "calibrated", i.e. their accuracy has been verified by manufacturers and certified to be within 1PPM for at least two years.

Such an MVP sensor offers wireless transmission capabilities and power autonomy with solar panels. The MVP offers better power optimisation as compared to its competitors, such as Libelium P&S[2] and waspmote[3], hence has proven to be more reliable during high overcast periods, e.g. during last autumn and winter period, when Libelium had to be ultimately plugged into mains. The additional advantage of such a solution is a smaller form factor, thus visually less obstructive in the field.

3.1.5. Multi-gas based on M5Stack/M5Stick

An interesting development made for AgriBIT project uses a generic M5Stack/M5Stick[4] (**Figure 24**) embedded devices. Those devices are ESP32-based boards and can be easily programmed and flexibly reconfigured to custom needs using Arduino Studio. The most important advantages of those devices over their predecessors above are:

- Very small form factor with long battery life for mobile sensing
- Embedded screen for simultaneous graphics and text display

[1] Analog Devices Ireland: https://www.analog.com/en/about-adi/corporate-information/regional-headquarters/directions-to-analog-devices-international.html

[2] Libelium Plug & Sense: https://www.libelium.com/iot-products/plug-sense/

[3] Libelium waspmote: https://www.libelium.com/iot-products/waspmote/

[4] M5Stack and M5Stick: https://m5stack.com/

- Grove connectivity for I2C and SPI sensor boards

The custom development for AgriBIT project focusses on building a universal plug-and-play sensor board, considering a vast range of interests from pilot sites in AgriBIT project for different types of sensors. As such the board has been programmed to automatically detect connected sensors as well as chose from the range of pre-configured wireless networks to send its data to cloud IoT platforms. For testing purposes support for BME680 (temperature, humidity, and pressure), particulate matter (PM1.0, PM2.5, PM10), SI1145 (visible light with UV index), VEML6070 (UV light sensor) has been implemented. Additional sensors measuring soil water level etc. are also supported. Note that **Figure 24** shows the M5Stack version with BME 680 sensor, displaying measured parameters with gas resistance corresponding to CO_2 levels as added value. Similar developments were pursued that took advantage of even smaller M5Stick device and similar plug-and-play capabilities connected to the SI1145 sun light sensor and BME280 environmental sensor, the white box plugged on the right to its proprietary port.

Figure 24. *Gas sensor nodes based on M5Stick/M5Stack embedded platforms*

Note that except for M5Stick special port, multiple sensor elements can be connected through Grove connectors (both I2C and SPI interfaces are supported). By using Grove HUB one port can be populated with three other sensors, thus extending the range of parameter value that can be measured simultaneously. The firmware built by RFSAT offers an added-value of automatically adapting to the type(s) of sensor(s) connected, also permitting dynamic exchange of sensors connected to its I2C and SPI ports. The node senses removal of a sensor element and after few seconds waiting time it switched to a search mode. Once sensor is identified and communication re-established, the periodic acquisition and upload of sensor values to cloud IoT servers is resumed. In similar manner change of communication interfaces is accomplished, with dynamic switching among known Wi-Fi networks.

3.1.6. Raspberry-PI based sensors with Turta IoT HATs

In order to increase the number of connected sensors the Raspberry-PI embedded computer has been investigated. However, this meant higher power consumption and hence a need to remove the display as a way to reduce high power consumption of the RASPI board. The use of Grove HATs enables up to 15 simultaneously connected sensors (with some compromise regarding I2C and SPI connectivity), which may be beneficial for applications requiring a large number of parameters to be monitored simultaneously. **Figure 25** shows a smaller version of the Grove HAT board with only eight ports built in collaboration with Turta.io, but with additional sensors embedded directly onto the board. Initially, the latest standard-size RASPI-4 was selected for testing (left), which has proven to work well in mains powered mode. However, its power consumption has proven too high to be powered from a battery of the same size as the computer itself, even in shall mode (i.e. without X-Windows GUI).

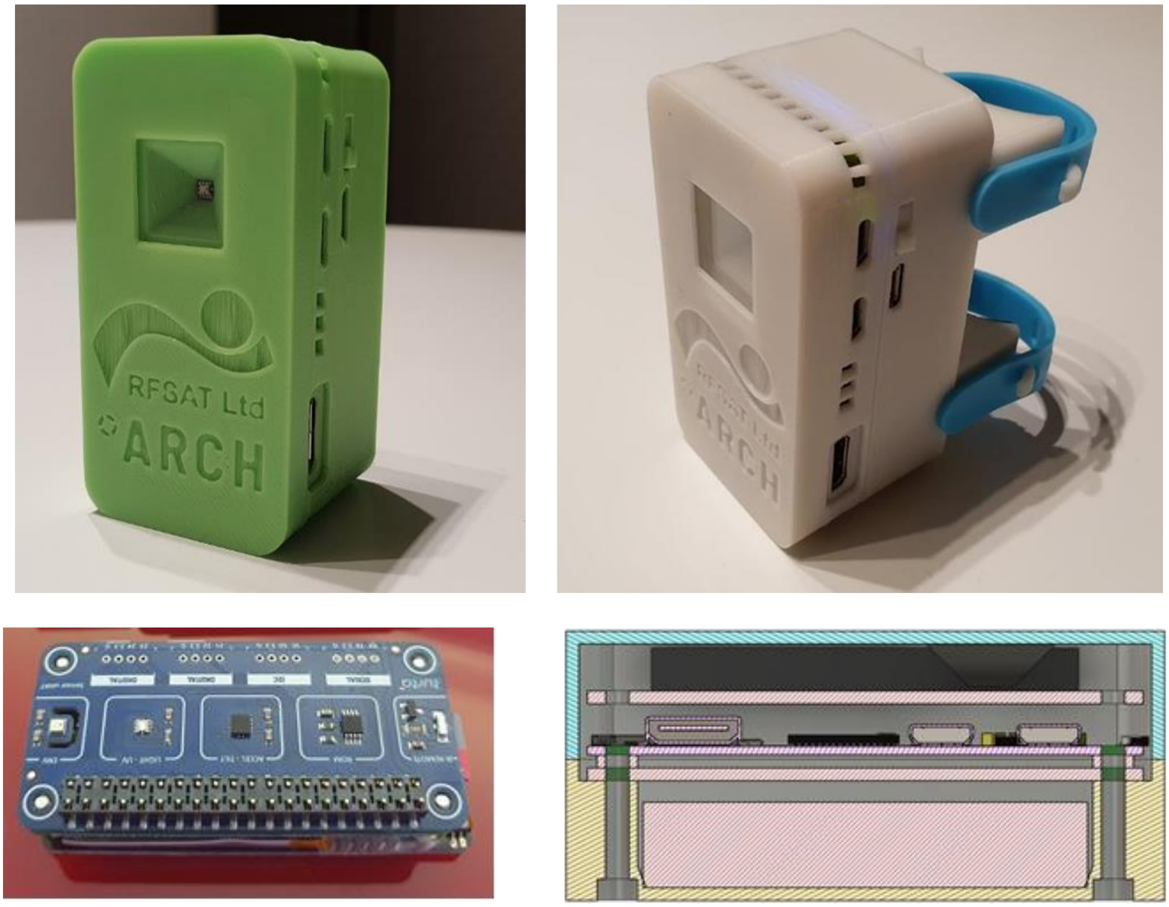

Figure 25. *Sensor nodes based on Raspberry-PI with Turta-IoT2 HAT, showing fabricated prototypes (top) and sensor interiors (bottom)*

The figure shows both the real hardware and the design of the case built for deployment at selected pilot sites. With embedded UPS battery HAT, main power option as well as mount option for bicycle/motorbike handles, it can be used both for fixed deployment as well as for mobility application. In the formed case it offers a capability to directly link with pre-configured Wi-Fi access points. In the latter case, communication can be done either to the smartphone via Bluetooth, Wi-Fi direct or USB cable (incl. charging) using it as a long-haul communication interface to the remote IoT server, such as ThingSpeak IoT server (shown in **Figure 26**), and for direct access to displaying acquired sensor data. An option is also possible to connect the mobile GPRS and GNSS add-on card thus it becoming a self-contained mobile sensor node for deployment on e.g. agricultural vehicles as shown in **Figure 27**.

Figure 26. *Sensor values from RASPI-Zero sensor as recorded by ThingSpeak IoT platform*

In order to push the RASPI technology capabilities to its limits, the RASPI-Zero-W has been investigated. Due to its significantly smaller size, the number of Grove connected sensors had to be reduced to four (4), though at a benefit of much lower power consumption of the board itself, making it a promising choice for mobile application. With addition of the UPS-HAT[5] and a 1200 mAh battery, the integrated sensor was able to work for several hours on battery.

5 https://www.amazon.de/gp/product/B07RDNT8CY/ref=ppx_yo_dt_b_asin_title_o08_s00?ie=UTF8&psc=1

The ongoing collaboration between RFSAT and Turta.IO from Turkey has led to the development of the Turta IoT HAT[6], which has been evaluated by RFSAT for possible evaluation by pilots. The latest version is an upgrade following evaluations by RFSAT and contains four Grove-type connectors for connecting I2C, SPI and serial connected sensors. At the same time, it contains light-UV and BM280 environmental and agricultural sensors. The resulting sensor node has a very small form factor of only 65mm x 30mm x 20 mm, including the uHAT and UPS boards. The sensor can be easily programmed under Linux using Python using provided libraries. This device is currently tested sending sensor data to RFSAT cloud IoT repositories Cloud and on-premise IoT Platform deployments.

3.1.7. Mobile environmental sensors

Following up on the sensor described in the previous section, it is very attractive for operating in a mobile scenario for collecting data from larger areas, especially over large fields without the need to deploy larger number of sensors. Therefore, additional development of such sensors has been pursued by RFSAT, as shown in **Figure 27**.

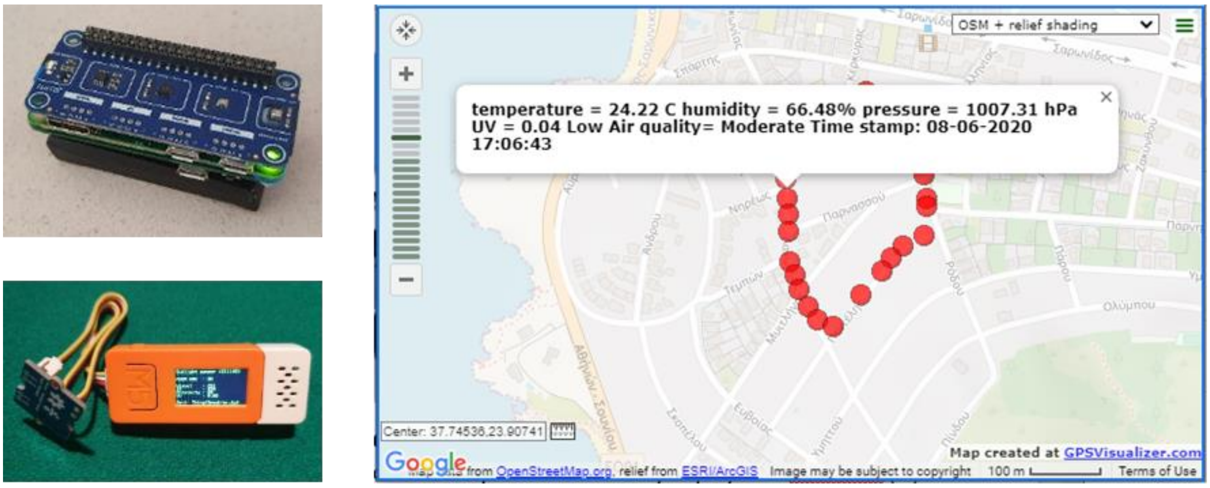

Figure 27. *Mobile sensors: (left) RASPI and M5Stick versions, (right) tracking sensors via Web application*

Sensor developed by RFSAT adds a Global Navigation Satellite System (GNSS) position sensing with General Packet Radio Service (GPRS) mobile data communication capabilities to send data to the IoT platform deployed by RFSAT. A screenshot from RFSAT server showing the route and collected sensor data is shown in **Figure 28**. This prototype combines Battery/UPS (8hrs+operation) with GNSS operating in autonomous mode (1.2m accuracy). Alternative design uses M5Stack (incl. display) with embedded GPS and up to 3 simultaneously connected Grove sensors.

3.1.8. RFSAT repository on ThingSpeak cloud IoT platform

The ThingSpeak[7] IoT platform from Mathworks™ (**Figure 28**) is a powerful cloud service platform for capturing, processing, and distributing sensor information. Having the Matlab engine embedded into its core system, it offers possibilities for rapidly coding and testing scripted functions that gather and analyse sensor information. Such capabilities have been used by RFSAT not only for working with its own sensors, but also for fast testing of gathering and processing responses received from APIs provided by Open IoT sensor platforms and repackaging received measurements into the format required by WEB services to be offered by ENG for uploading sensor data to the AgriBIT repository.

[6] Turta sensor uHAT: https://docs.turta.io/raspberry-pi-hats/sensor-uhat

[7] ThingSpeak: https://thingspeak.com/channels

RFSAT has also deployed its own proprietary industrial embedded fan less server for processing all sensor data prior to sending those to the AgriBIT repository, being especially useful for acquisition of relevant data locally prior to deployment of official AgriBIT repository by ENG. Nevertheless, ThingSpeak has remained a rapid testing and development system, not to mention having in its repository over 6 years' worth of environmental data and corresponding to more than 650.000 records from RFSAT office locations that started being collected before AgriBIT project has started.

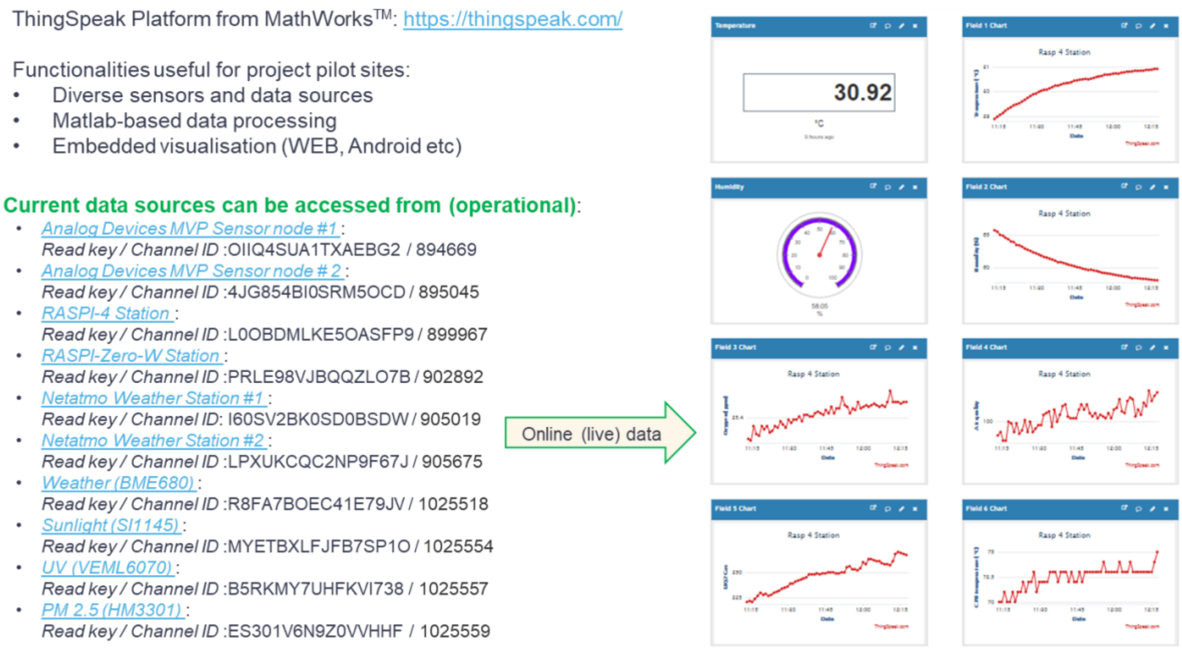

Figure 28*. RFSAT repository of sensor data on ThingSpeak IoT platform*

3.1.9. Thinger.io IoT platform

The Thinger.io[8] is an Open Source IoT platform development project, offering IoT platforms to be co-developed and deployed either in Cloud on on-premises. Advantage of this system is low computing requirements, allowing it to be deployed even on a Raspberry-PI. **Figure 29** shows such a deployment on a Raspberry-PI v4 for collecting sensor information from custom sensors described earlier.

The figure shows data sources collected by the platform and on the platform WEB interface. Note that all the custom RFSAT sensors are capable of sending their data simultaneously to the proprietary ThinkSpeak/Thinger.io platforms of RFSAT and the ENG repository, when it becomes available.

The specific functionalities that have been identified as useful for AgriBIT project pilots are:

- On-premise server deployment by RFSAT with option of replicating it at pilot sites
- Support for range of sensors and data sources, practically any one shown earlier
- Tested on: M5Stack/M5Stick, Raspberry PI and Zero etc.
- Offers embedded WEB-based visualisation and online data analytics
- Supports API based access for integrating into own applications

8 Thinger.io: https://thinger.io/

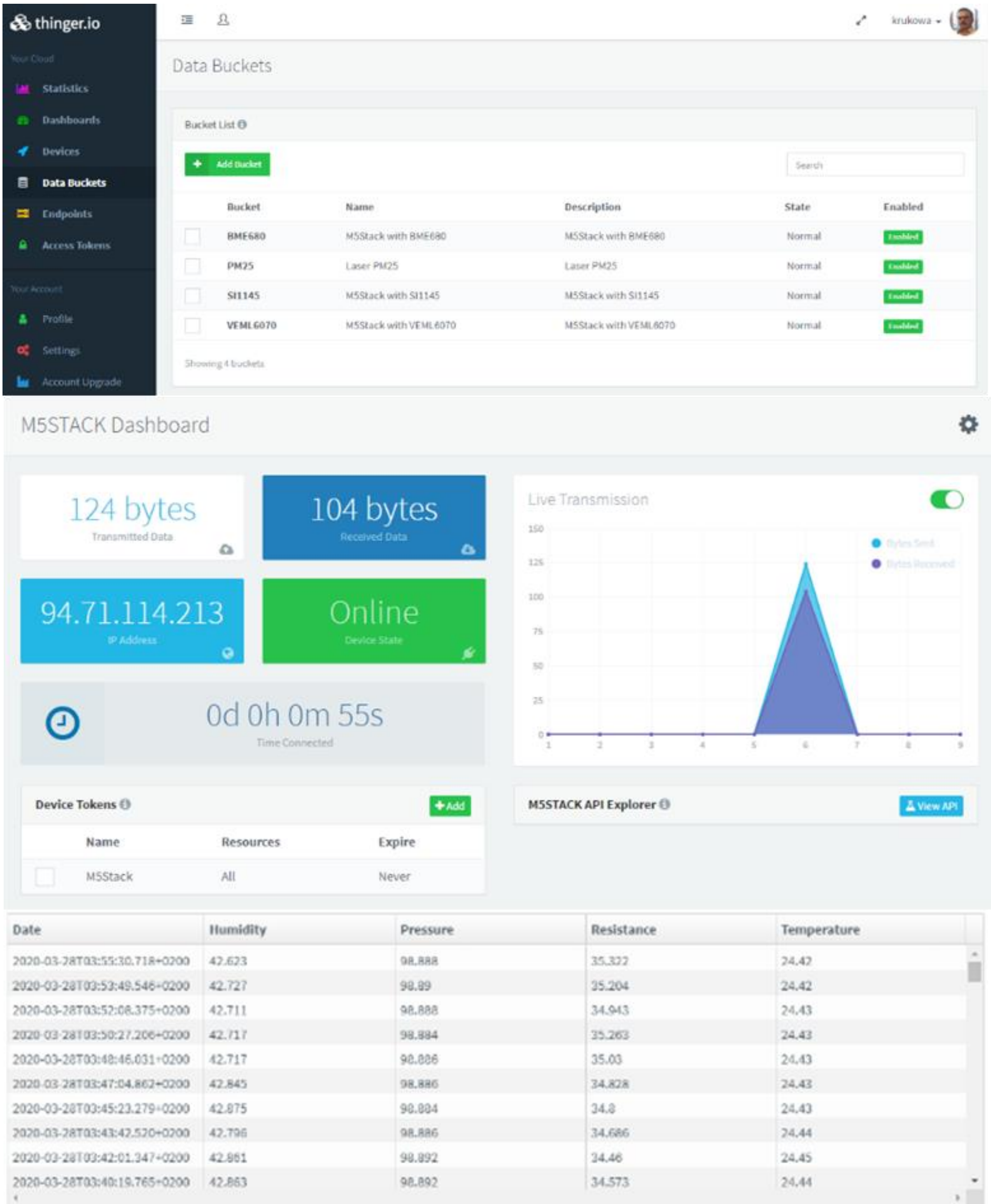

Figure 29. *RFSAT repository of sensor data on the Thinger.io IoT platform*

The entire equipment and sensors to be used in the Portuguese pilot sites will be stationary due to the nature of the annual crop nature of tomato production. All sensors and equipment are presented in detail in **Table 3**.

Table 3. Portuguese pilot site sensors

Sensor	Pilot site/ country	Measurements	Stationary/ mobile	Communication protocol	GPS/GNSS	Data ingestion	Energy autonomy
Weather station	CCTI/ Portugal	• Relative Humidity • Wind Direction • Wind Speed • Temperature • Precipitation • Wind gust • UV • Light intensity • Atm. pressure	Stationary	GPRS/4G	✓	Ardeusi.gr	3 years
Soil moisture sensor	CCTI/ Portugal	• % Soil moisture content	Stationary	GPRS/4G	✓	Ardeusi.gr	3 years
Field camera	CCTI/ Portugal	• Insect images capturing	Stationary	3G	Manual location input in Demarcator	Demarcator app	Internal 12V 7Ah Battery (rechargeable) by a 10W Solar Panel
Water counter	CCTI/ Portugal	• Water quantity	Stationary	GPRS/4G	Manual location input in Demarcator	Demarcator app	Internal 3.6V 13Ah Lithium Thionyl Battery
Custom field node	CCTI/ Portugal	• Temperature • Relative Humidity • Atmospheric pressure • Pollution (NO_2, SO_2, CO, H_2S)	Stationary	TBC	Pre-geo-coded in app	MVP system by RFSAT	Equipped with solar panel

3.2. Italian vineyards

In the case of Italian vineyards pilot sites, meteorological monitoring is required for allowing an efficient management of the cropping production, together with pest and disease monitoring, whereas soil moisture measuring will also take place, and a brix sensor will be used.

3.2.1. AGENSO nodes, weather stations, and soil moisture sensors

More specifically, measurements of environmental parameters that will be performed contain parameter such as Relative Humidity, Wind Direction, Wind Speed, Temperature, Precipitations, Wind gust, UV, Light intensity, and atmospheric pressure. The aforementioned measurements, together with soil moisture measurement will be performed by Ardeusi.gr system, exactly as in the Portuguese pilot sites with tomato cultivation (see paragraph 3.1.1. **AGENSO nodes, weather stations, and soil moisture sensors**).

This is expected to play a crucial role in crop management, irrigation management, disease and pest management, and in application of agricultural practices in general. Within this framework, AGENSO will deliver 2 weather stations and 2 soil moisture sensors for the Italian pilot sites, in order to enable the measurement of the aforementioned parameters.

3.2.2. Existing weather stations

In addition to that, Italian pilot sites, have an already established system of 6 weather stations by Netsens for measuring Relative Humidity, Wind Direction, Wind Speed, Temperature, and Precipitations. The existing weather station network will continue to function. More specifically, weather stations' model is MeteoSense 4.0 and operates by exploiting GSM communication protocols. More information about the aforementioned existing weather stations can be found in https://www.netsens.it/meteo/stazioni-meteo-professionali-20, while some of their specifications and characteristics are:

- Communication: 2G / LAN / MODBUS RTU
- On board memory: SD card
- Interfaces: 12 I/O (expandable), USB, RS232, RS485
- Power supply: fixed network or solar panel with rechargeable battery and extended operation even without radiation
- Case: ABS UV resistant, IP56 rated; on request IP66 steel housing
- Operating temperature range: -30 +70 °C

3.2.3. RFSAT custom field nodes

Moreover, for the purposes of the pilot sites, RFSAT will provide the same custom field nodes for measuring temperature, relative humidity, atmospheric pressure; equipped with pollution sensors such as in the case of Portuguese pilot sites (see paragraphs 3.1.4. **Analog Devices MVP based custom sensor node**, 3.1.5. **Multi-gas based on M5Stack/M5Stick**, 3.1.6. **Raspberry-PI based sensors with Turta IoT HATs**, 3.1.7. **Mobile environmental sensors**, 3.1.8. **RFSAT repository on ThingSpeak cloud IoT platform**, 3.1.9. **Thinger.io IoT platform**).

3.2.4. Brix sensor

Moreover, apart from the aforementioned systems, an additional sensor will also be used. A brix portable sensor will be used to monitor the sugar (sucrose) into the grapes. This will allow an estimation of the final alcohol percentage, and the quality of the grapes produced. Brix sensors are in general small, hand-held devices that are portable and allow on situ measurements in an easy and fast way.

Data from the brix sensor be ingested on the field via Demarcator online application as manually input data in various points of interest (PoIs) into the field. This way, user will be able to access specific information for each distinct pilot site part.

The equipment and sensors to be used in the Italian pilot sites will be stationary and mobile due to the nature of the perennial crop nature of vineyards. All sensors and equipment are presented in detail in **Table 4**.

Table 4. Italian pilot site sensors

Sensor	Pilot site/ country	Measurements	Stationary/ mobile	Communication protocol	GPS/GNSS	Data ingestion	Energy autonomy
Weather station	AGRICOLUS/ Italy	• Relative Humidity • Wind Direction • Wind Speed • Temperature • Precipitation • Wind gust • UV • Light intensity • Atm. pressure	Stationary	GPRS/4G	✓	Ardeusi.gr	3 years
Soil moisture sensor	AGRICOLUS/ Italy	• Soil moisture % content	Stationary	GPRS/4G	✓	Ardeusi.gr	3 years
Existing Weather station network	AGRICOLUS/ Italy	• Relative Humidity • Wind Direction • Wind speed • Temperature • Precipitation	Stationary	GSM	N/A	SMS or email notification by Netsens	Rechargeable battery
Brix sensor	AGRICOLUS/ Italy	• Grape sucrose % content	Mobile	N/A	Manual location input in Demarcator	Demarcator app	N/A
Custom field node	AGRICOLUS/ Italy	• Temperature • Relative Humidity • Atm. pressure • Pollution (NO_2, SO_2, CO, H_2S)	Stationary	TBC	Pre-geo-coded in app	MVP system by RFSAT	Equipped with solar panel

3.3. Greek peach orchards

In the case of Greek peach orchard pilot sites, meteorological monitoring is required, together with soil moisture monitoring, pollutants' monitoring (as in the previous pilot sites), and leaves' chlorophyll monitoring.

3.3.1. AGENSO nodes, weather stations, and soil moisture sensors

Measurements of environmental parameters that will be performed contain parameter such as Relative Humidity, Wind Direction, Wind Speed, Temperature, Precipitations, Wind gust, UV, Light intensity, and atmospheric pressure. The aforementioned measurements, together with soil moisture measurement will be performed by Ardeusi.gr system, exactly as in the previous pilot sites with (see paragraph 3.1.1. **AGENSO nodes, weather stations, and soil moisture sensors**).

This is expected to play a crucial role in crop management, irrigation management, disease and pest management, and in application of agricultural practices in general. Within this framework, AGENSO will deliver 2 weather stations and 2 soil moisture sensors for the Italian pilot sites, in order to enable the measurement of the aforementioned parameters.

3.3.2. RFSAT custom field nodes

For the purposes of the pilot sites, RFSAT will provide the same custom field nodes for measuring temperature, relative humidity, atmospheric pressure; equipped with pollution sensors such as in the case of Portuguese pilot sites (see paragraphs 3.1.4. **Analog Devices MVP based custom sensor node**, 3.1.5. **Multi-gas based on M5Stack/M5Stick**, 3.1.6. **Raspberry-PI based sensors with Turta IoT HATs**, 3.1.7. **Mobile environmental sensors**, 3.1.8. **RFSAT repository on ThingSpeak cloud IoT platform**, 3.1.9. **Thinger.io IoT platform**).

3.3.3. Portable chlorophyll meter

Moreover, apart from the aforementioned systems, an additional sensor will also be used. A chlorophyll portable sensor will be used to monitor the % content of green leaves in chlorophyll. This will allow the estimation of the leaves; growing parameters, and will serve as an indicator for plant health of the crop and the plants' condition in general.

The chlorophyll meter to be used, more precisely, atLEAF CHL STD model (https://www.atleaf.com/atLEAF_CHL_STD#) is a powerful, handheld, easy to use device for noninvasively measuring the relative chlorophyll content of green leaf plants (**Figure 30**, [https://www.atleaf.com/images/chlstds.png]).

Figure 30. *atLEAF CHL STD chlorophyll meter*

The % plant relative chlorophyll concentration is measured by inserting a leaf into the device aperture. Green leaves of up to 3mm thickness are suitable for further analysis. Then, the device functions by pressing a single button. Moreover, the device offers:

- Display of up to 64 measurements stored in the device's memory
- Deletion of the most recently performed measurement
- Deletion of all measurements
- Performance of instrument calibration

The technical specifications of the selected chlorophyll meter are described in detail in **Table 5**.

Table 5. *Technical specification of atLEAF CHL STD chlorophyll meter*

Technical specification	Description
Measuring System	Optical density difference at 2 wavelengths (640nm and 940nm)
Keys	4 keys to operate all functions; simple, one-key operation to perform measurements only
Display	2 lines x 16 characters
Data Memory Capacity	64 measurements
Power Source	2 AA (1.5V) batteries
Battery Life	5,000-30,000 measures, depending on use and batteries type
Time to perform a measure	Less than 1 sec
Dimensions (W x D x H)	6.9 x 2 x 1.8 inches (175 x 50 x 45 mm)
Weight	5.8oz (165g), not including batteries
Auto power off	after 1 minute of inactivity

Data from the chlorophyll meter be ingested on the field via Demarcator online application as manually input data in various points of interest (PoIs) into the field. This way, user will be able to access specific information for each distinct pilot site part.

The equipment and sensors to be used in the Greek pilot sites will be stationary and mobile due to the nature of the perennial crop nature of peach orchards. All sensors and equipment are presented in detail in **Table 6**.

Table 6. Greek pilot site sensors

Sensor	Pilot site/ country	Measurements	Stationary/ mobile	Communication protocol	GPS/GNSS	Data ingestion	Energy autonomy
Weather station	ACP/Greece	• Relative Humidity • Wind Direction • Wind Speed • Temperature • Precipitation • Wind gust • UV • Light intensity • Atmospheric pressure	Stationary	GPRS/4G	✓	Ardeusi.gr	3 years
Soil moisture sensor	ACP/Greece	• Soil moisture % content	Stationary	GPRS/4G	✓	Ardeusi.gr	3 years
Chlorophyll meter	ACP/Greece	• Chlorophyll content (%) of green leaf plants	Mobile	-	Manual location input in Demarcator	Demarcator app	2 AA (1.5V) batteries for ~ 5,000-30,000 measures
Custom field node	ACP/Greece	• Temperature • Relative Humidity • Atm. pressure • Pollution (NO_2, SO_2, CO, H_2S)	Stationary	TBC	Pre-geo-coded in app	MVP system by RFSAT	Equipped with solar panel

4. Conclusions

The current deliverable describes all three AgriBIT pilot sites in Portugal, Italy, and Greece. Concrete information is provided regarding the location and the specifications of the fields that constitute the pilot sites. In addition to that, sufficient information is provided with respect to the needs of each distinct pilot site, and a detailed description of the sensors to cover these needs is performed. This way, the AgriBIT consortium aims to ensure that all piloting needs are fully covered, based on the differentiated customized needs of each cultivation in each region with the use of various sensors.

List of Abbreviations

Abbreviation	Explanation/Definition
PDO	Protected designation of origin products
UV	Ultraviolet
GPS	Global POsitioning System
FTP	File Transfer Protocol
MVP	Manual Voltage Processor?
UPS	Uninterruptible Power Supply
GSM	Global System for Mobile Communication
LAN	Local Area Network
RTU	Remote Terminal Unit

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[2] https://www.statista.com/statistics/1247482/vineyard-surface-area-europe/

[3] https://www.statista.com/statistics/578383/peaches-production-volume-europe/

Internal Deliverable Review Form

Project Acronym	AgriBIT
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Topic	Answer	IF "No", classify as "Major" or "Minor" issues	Comments
1. Is the content and structure of the deliverable in accordance with the DoA?	Yes No	Yes	
2. Is the content of the deliverable scientifically relevant?	Yes No N/A	Yes	
3. Is the content of the deliverable useful for the subsequent work on the project?	Yes No N/A	Yes	
4. Is the deliverable suitable to be submitted to the EC?	Yes No	Yes	
If not:			
4.1. Does it need formatting adjustments?	Yes No	No	
4.2. Does it need content adjustments?	Yes No	No	
4.3. Does it need to be significantly refined (e.g. content improvement, structure changes, etc.)?	Yes No	No	
Additional comments			