

ENTOMATIC

A novel IPM tool



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1. Introduction

1.1 What is the ENTOMATIC project?

ENTOMATIC addresses a major problem faced by EU Associations of Olive growing SMEs: the Olive fruit fly (*Bactrocera oleae*). This insect pest causes yearly economical losses estimated to be almost €600/ha. **ENTOMATIC** aims to develop a novel stand-alone field monitoring system comprising: a fully autonomous trap with integrated insect bioacoustic recognition embedded in a wireless sensor network and supported by a spatial decision support system.

The ability to quantify and make a precise control of Olive fly populations in a cost-effective way, has been a long desired goal in the Olive sector. The potential offered by **ENTOMATIC** has SME-AGs and their associated SMEs keen on its development. The expected benefits are the reduction of damage to olive fruit and oil production and to promote the sustainable use of pesticides

Via **ENTOMATIC**, olive producers will be able to track pest population and geographical status and receive advice on precision pesticide application.

1.2 What is our solution?

The ENTOMATIC system aims to offer EU Olive SME-AGs an advanced IPM system for *Bactrocera oleae*, based on an innovative trap capable of automatically counting each insect trapped, identifying the species based on bioacoustic analysis and send the data wirelessly. The proposed system will also be able to function autonomously during the whole fruiting season, have an operative life-time of at least 5 years and be adapted to handle other fruit flies.



FIGURE 1. ENTOMATIC SYSTEM

IPM relies on the accuracy of the pest population monitoring technique. Without gathering information of pest dynamics and related ecological factors it is almost impossible to execute the appropriate pest control at the right location and time. Studies in Greece and Spain using extended monitoring programmes with a combination of different state-of-the art traps, more frequent inspections of traps, extensive manual count and species identification of captured insects, and manual processing of collected data shared between regional and national authorities, demonstrated that the fruit losses provoked by the Olive fruit fly could be reduced in more than 50%, with a 60% reduction of insecticides and 60% increase of extra virgin oil.

Obviously the cost, the effort and complexity of laborious massive manual inspections and manual treatment of data is not affordable for producers. It is evident that existing IPM systems do not fulfil the need of the Olive industry as these are not autonomous or collect and send data automatically. Moreover, EU regulations aim to promote low pesticide-input farming and urge the establishment of novel and better IPM techniques and crop specific standards. With the recent developments in microelectronics, communications and bioacoustic analysis, finally a cost-effective solution may be developed with the expertise of the subcontracted RTDs UPF, TEIC, IMMS and AVIA.

Our aim is to develop an easily accessible system, which enables automatic and cost-effective IPM for *Bactrocera oleae* for all end users. In addition, the proposed system can be a powerful tool in the hands of regional/national authorities to enforce legislative requirements, which need data collection on a regular basis to achieve a sustainable use of pesticides. The ENTOMATIC system will enable the Olive SME-AGs and their members to improve their production, reduce the amount of pesticides used and reduce the labour cost associated with spraying activities and inspection of traps. Based on published studies, the experience of the consortium SME-AGs and SMEs and interviews with several producers, the participants expect a reduction of the Olive fruit fly damage, a reduction of spraying costs and an increase of productivity, using ENTOMATIC.

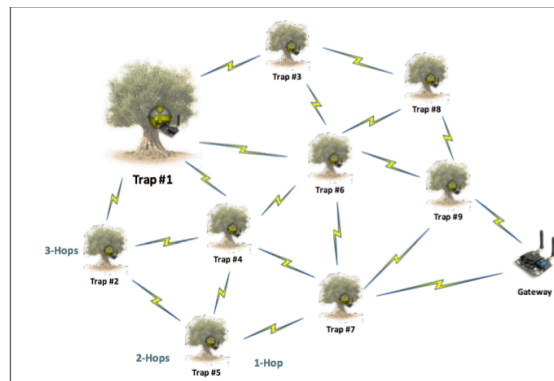


FIGURE 2. MESH NETWORK OF TRAPS

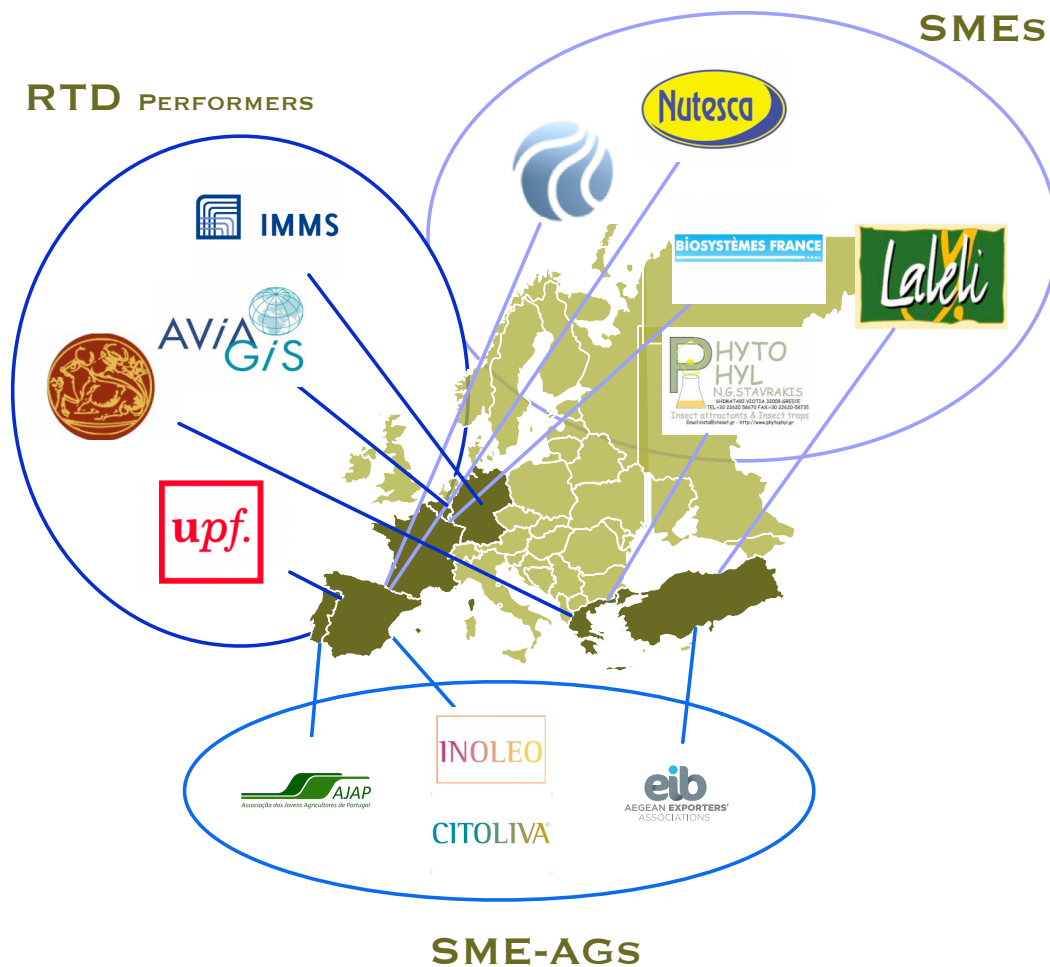
The ENTOMATIC trap units are easily installed in olive trees by the end-users. According to modern IPM procedures for the deployment of Olive fruit fly traps, for small holdings and in field of uneven topography a density of 2-4 traps/ha will be used. One ENTOMATIC trap will be deployed for every two hectares of large scale fields of homogeneous lands. Within the same field the traps form a low-power mesh network, capable of wirelessly communicate between each other to finally send the collected data to the ENTOMATIC Gateway.

This gateway, equipped with a meteorological station, transmits the field data to the ENTOMATIC Monitoring & Management Central (using a link like GPRS/GSM or Wi-Fi). This central is hosted by a Cloud Provider, which makes the collected processed data available on internet. The end-users can use the on-line platform as an easy to access the IPM tool, using just a common laptop, a smart-phone or a tablet PC.

ENTOMATIC will enable the possibility to set-up of a European Network for Integrated Olive fruit fly Pest Surveillance, adaptable for other flying insect pests. The ENTOMATIC systems in each Olive growing SME are connected to their respective SME-AG. The information collected by each SME-AG cluster provide Pest information at regional and national scales, giving authorities a powerful tool to understand at a higher level the impacts and risks imposed by the presence of the pest. EU countries using the ENTOMATIC system can share their data at a transnational level.

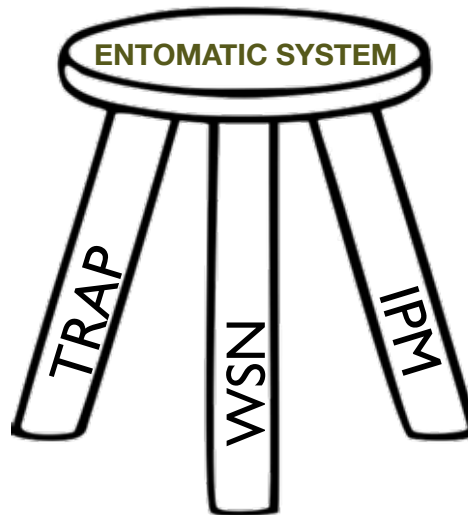
1.3 Who is working in this project?

The consortium is composed of SME-AGs of Olive Producers from the EU and Turkey, and lead-user SMEs expert in Pest Management solutions. These will lead the specification, validation, protection, and use of the results generated by the selected RTD providers expert in Entomology, Decision Support Systems, Bioacoustics, Electronics, Signal Processing, IT solutions, Wireless Communications and Prototyping.



2. ENTOMATIC system

2.1. ENTOMATIC system: what we offer?



The major novelties that ENTOMATIC is offering is based on three main concepts:

- **The ENTOMATIC trap** units are easily installed in olive trees by the end-users. According to modern IPM procedures for the deployment of Olive fruit fly traps, for small holdings and in field of uneven topography a density of 2-4 traps/ha will be used.
- Within the same field the traps form a low-power mesh network, capable of wirelessly communicate between each other to finally send the collected data to the ENTOMATIC Gateway. This gateway, equipped with a meteorological station, transmits the field data to the ENTOMATIC Monitoring & Management Central
- This central is hosted by a Cloud Provider, which makes the collected processed data available on internet. The end-users can use the on-line platform as an easy to access the IPM tool, using just a common laptop, a smart-phone or a tablet PC.

2.2. ENTOMATIC trap: how it works?

Flies (males and females), attracted by the combination of baits and lures, seek an entrance into the trap, and are detected by a photointerrupter. Since the fly may have erratic movements or even leave the trap, the count is only processed when it passes by the second photo-interrupter. As soon as this happens, the Bioacoustic Identification system starts recording the audio signals produced by the fly.

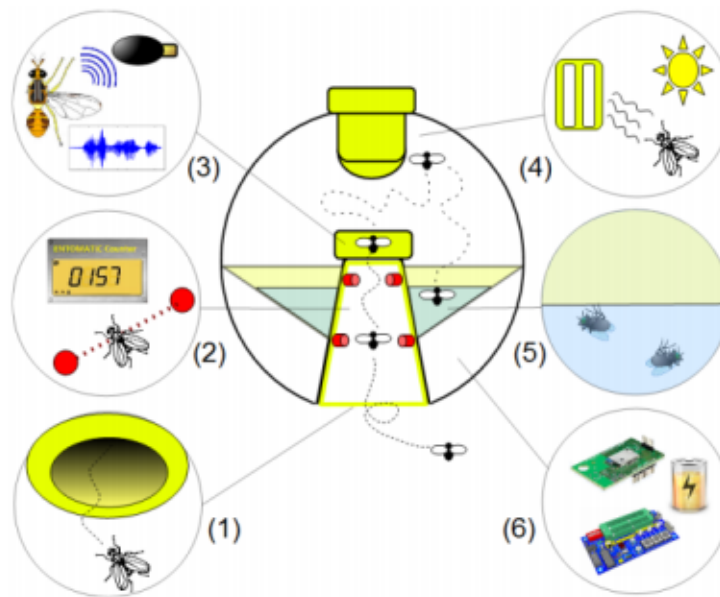


FIGURE 3. SCHEME OF TRAP FUNCTIONALITY

The digital signal processing at the trap will identify if the species entering is *Bactrocera olea* or not. The fly will not return where it came from, since it will be lured to the pheromone bait and by the sunlight or to the liquid food lure where it will eventually drown and die. All the electronics (signal processing, communications, power, etc.) are placed at the bottom part of the trap.

2.3. ENTOMATIC WSN: how we connect the traps

ENTOMATIC traps are equipped with a radio module that will act as the communication tool.

The network global logical topology chosen for the ENTOMATIC project is a two-tier hierarchical topology, where upper tier nodes are used to process and send the collected information to the central servers while lower tier nodes are used to perform the sensing tasks in the proximity of the target.

As for the way the lower tier nodes transmit its data to the gateway within a WSN, there are different topology options: point-to-point, bus, star, ring or circular, mesh, tree, hybrid, or daisy chain. In the current project, the lower tier nodes will use a **mesh** network, where messages can be transmitted through different paths from a source to a destination.

Mesh networks provide high reliability, as messages can still be successfully transmitted through alternative routes in case any of the links or the nodes experience problems in terms of processing or connection.

Lastly, the link between the upper tier nodes and the central servers will be performed through a point-to-point connection by using a cellular technology.

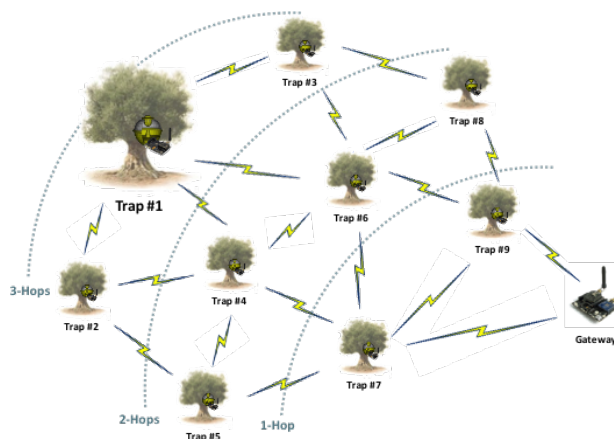


FIGURE 4. DETAIL OF THE PHYSICAL TOPOLOGY FOR THE ENTOMATIC PROJECT

2.4 ENTOMATIC IPM TOOL: How we process the data?

The Entomatic pest management tool relies on olive fly counts made by a tailored trap that includes a bioacoustic sensor. The SDSS includes an indication when sensors should be switched on again to capture the onset of olive fly counts and to perform the first olive fly control measures of the year. The period in which olive flies are active is strongly correlated with olive growth for which altitude and temperature are important environmental predictor variables. Based on data captured in Italy and Spain, a model was established that provides insight in when to expect olive flies to become active.

The SDSS can be considered in three parts: (i) The *B. oleae* spring onset model (ii) The control decision tree and (iii) Additional analysis on the ENTOMATIC Web app. The *B. oleae* spring onset model serves as an early warning system to notify farmers when to turn on the traps in early spring. It runs from the 1st of January and constantly record the change in daily temperature in each of the orchards. When a critical, threshold temperature (TT) is reached the model calculates the growing degree days (GDD) for the orchard and gives an estimate of when the first peak of *B. oleae* is expected.

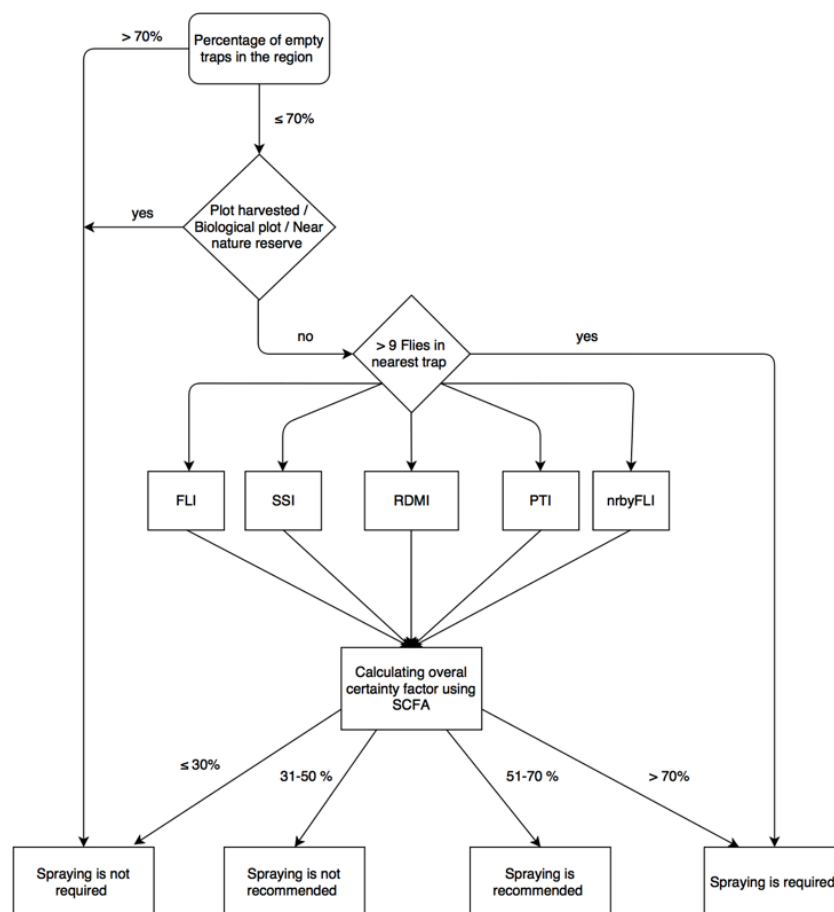


FIGURE 5. FLOWCHART FOR THE CONTROL DECISION TREE MODEL

2.5 ENTOMATIC WEB: How we show the data?

The Entomatic web application gives users access to a variety of tools that are grouped in five different web pages: (i) administration, (ii) pest management, (iii) analysis, (iv) network performance and (v) configuration.

A software layer has been developed for receiving data from the traps in the field, and database architecture has been defined for the storage of data gathered.

This module is able to read data received from the field and store it, after pre-processing it, in the system database. This module also incorporates the ability for the software to perform system checks, detect failures in nodes and sensors, troubleshooting guide, auto-calibration and to incorporate “plug and play” devices. A user friendly graphical interface has been developed for the user to interact with all the above described modules.

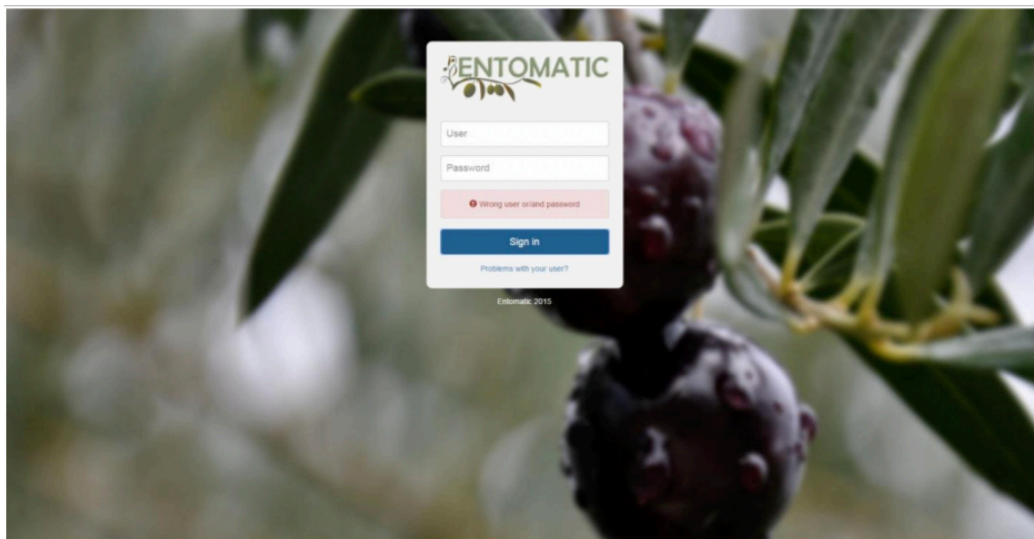


FIGURE 6. SCREENSHOT OF THE WEB APP

3. How we install the traps?

3.1. Autonomous trap

This first version of the trap it has been developed to cover isolated areas or areas with low density of traps at the same area. This trap includes a GSM module itself in order to directly connect to the database server. Hence this kind of trap could be placed at remote places where the installation of a meshed solution is not allow due to environment's characteristics.

The installation of the traps is has only three steps:

1. Place the trap at the olive tree.
2. Press the red button outside the trap. You will hear a beep. The autoconfiguration has started.
3. Wait until you hear two more beeps. This second beep indicates that the trap has established a connection with the server. The data collected (number of flies, temperature and humidity) will be automatically sent by the trap.



FIGURE 7. DETAIL OF THE RED BUTTON OF THE TRAP

3.2. Mesh network of traps

This solution is based on the previous architecture presented before. In an orchard or areas of orchards that has a high density of traps monitoring the olive fly population benefits the use of this solution.

The installation of the second version, the one that includes a gateway that collects the information obtained by the traps, has more steps, but it is, again, a plug & play solution, really easy to perform.

This connection is divided in two steps.

3.2.1. Gateway Connection

1. Place the gateway in a central area and as high as possible. The gateway has to have inside its range the whole network of traps.
2. Initialized it following these steps (see Figure 8):
 - i. Press the right button and then wait until the blue led is on (see Figure 9).
 - ii. Press the left button and then wait until the green led is on (see Figure 10).
 - iii. The gateway is ready to look for traps.

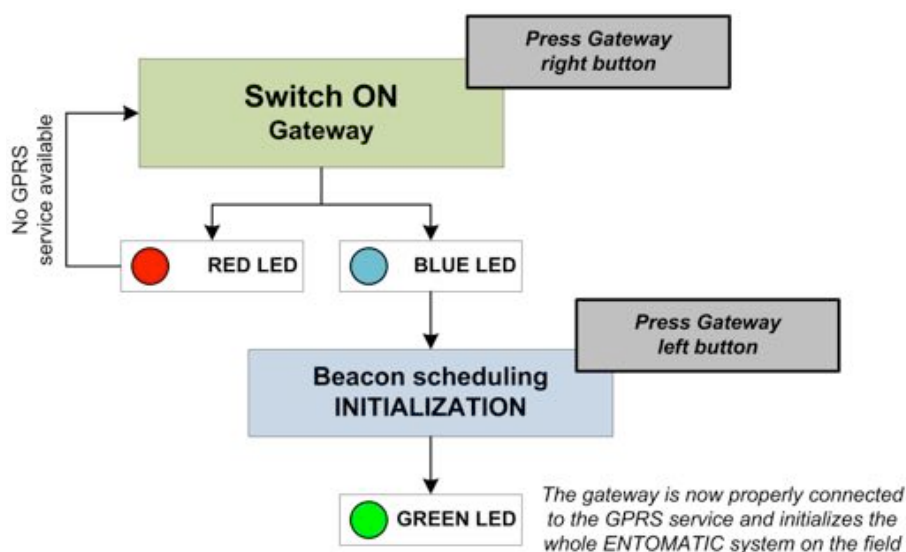


FIGURE 8. DIAGRAM OF THE GATEWAY UNIT INITIALIZATION

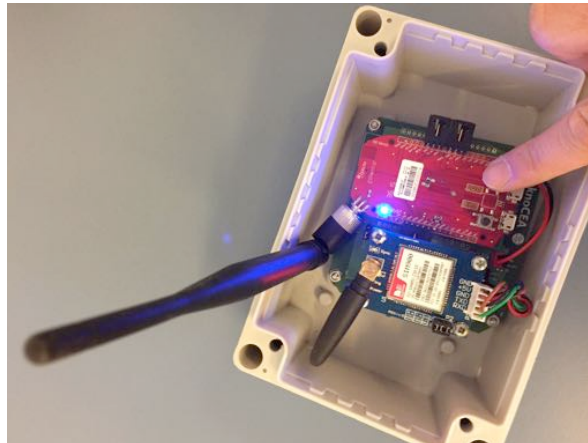


FIGURE 9. DETAIL OF THE FIRST STEP TO CONFIGURE THE GATEWAY (RIGHT BUTTON AND WAIT UNTIL BLUE LED IS ON)



FIGURE 10. DETAIL ON THE SECOND STEP TO CONFIGURE THE GATEWAY (LEFT BUTTON AND WAIT UNTIL THE GREEN LED IS ON)

3.2.2. Trap Connection

Once the trap unit, it must be fastened tight on a tree. Swinging is not a problem but a direct hit would cause false alarms due to propagation of vibrations. The trap is designed to be operated in the field; i.e., away from any electromagnetic interference caused by mobiles, routers, and/or tablets. The procedure (see Figure 12) to connect the traps is described at the following steps.

1. Place the trap at the olive tree. The propagation conditions inside the tree will be the final one and it is important to set from the beginning.

2. Press the red button outside the trap (see Figure 7). You will hear a beep. The autoconfiguration has started.
3. Wait until you hear two more beeps. This second beep indicates that the trap is ready to be connected with the radio module.
4. Press the right button (see Figure 11) of the radio module placed inside the trap and wait until the green led is on.
5. The trap is now ready to collect data and send it to the gateway.



FIGURE 11. DETAIL ON THE CONFIGURATION OF THE TRAP (ONCE THE RED BUTTON IS PRESSED, PRESS THE RIGHT BUTTON AND WAIT UNTIL THE GREEN LED IS ON)

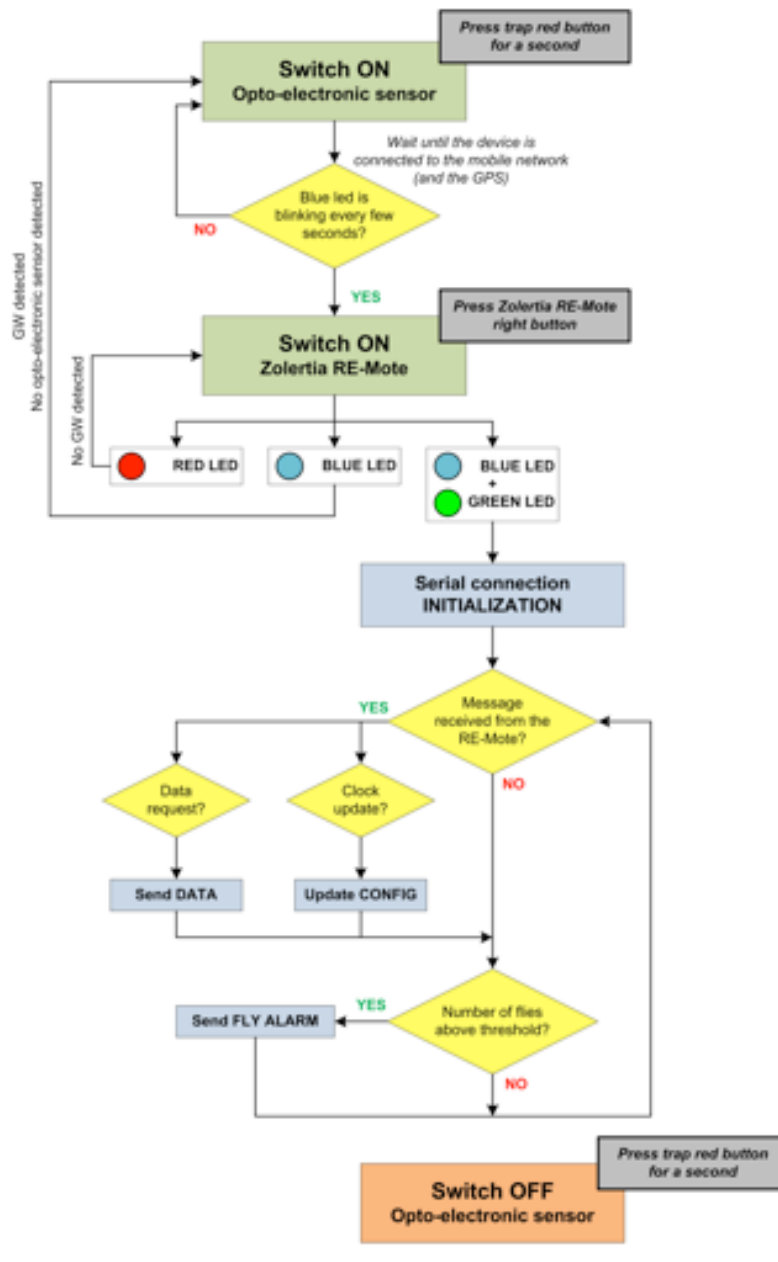


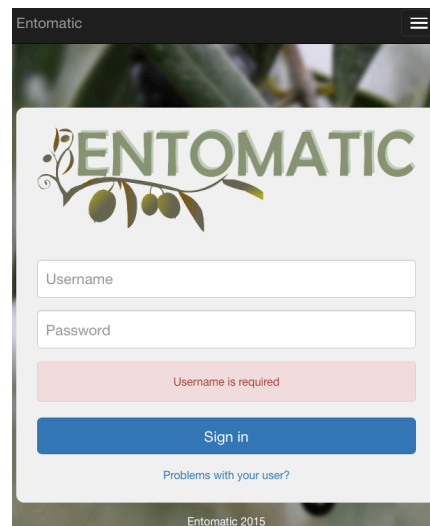
FIGURE 12: DIAGRAM OF THE COMMUNICATIONS PERFORMED BY THE TRAP UNIT

4. How we control the traps and visualize the data?

4.1. Visualizing the data at the web app

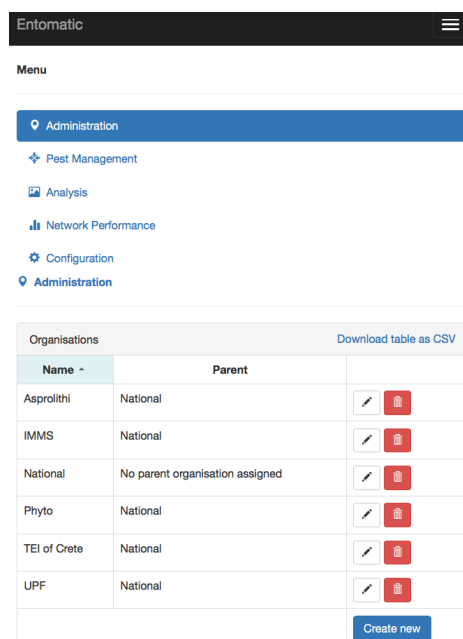
The basic steps to visualize the data are summarized in the following points.

1. Login with your user and password at the web page test.entomatic.upf.edu















The image shows the login page of the Entomatic web application. It features a header with the 'Entomatic' logo and a navigation menu icon. The main content area contains a login form with two input fields: 'Username' and 'Password'. Below the 'Password' field, there is a red error message that reads 'Username is required'. A blue 'Sign in' button is positioned below the form. At the bottom of the form, there is a link that says 'Problems with your user?'. The footer of the page indicates 'Entomatic 2015'.

2. Select *Administration* from the main menu



The image displays the 'Administration' menu and a table of organizations. The menu is located at the top of the page and includes options for 'Administration', 'Pest Management', 'Analysis', 'Network Performance', 'Configuration', and 'Administration'. The 'Administration' option is highlighted. Below the menu, there is a table titled 'Organisations' with a 'Download table as CSV' link. The table has two columns: 'Name' and 'Parent'. The data rows are as follows:

Name	Parent	
Asprolithi	National	 
IMMS	National	 
National	No parent organisation assigned	 
Phyto	National	 
TEI of Crete	National	 
UPF	National	 

At the bottom right of the table, there is a blue button labeled 'Create new'.

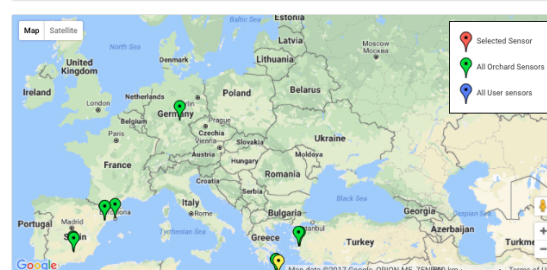
- If you belong to many organisations they will appear at this menu. Select the corresponding organization to see the traps associated.
- Once selected, scroll down to see the users associated to the association selected. Select your own user.
- Once selected the user, scroll down down again and you will observe a table with the different orchards available.

Orchards				Download table as CSV
Name ^	Creation Date ^	Amount of Sensors ^	Action	
Chania	11-11-2016	15	View Sensors	
Orchard	01-08-2016	0	View Sensors	
				Create new

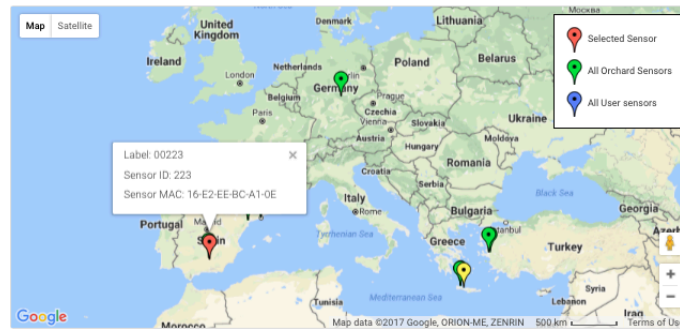
- Select view sensors from the preferred orchard. A table with the available traps will appear. moreover, a map with the exact location of the traps also appears.

Sensors							Download table as CSV
ID ^	Label ^	Mac	Gateway ID	Latitude	Longitude		
215	00215	16-E2-EE-BC-A1-06	102	38.4646	27.3676		
219	00219	16-E2-EE-BC-A1-0A	102	37.8306	-3.45996		
223	00223	16-E2-EE-BC-A1-0E	102	37.8309	-3.45872		
225	00225	16-E2-EE-BC-A1-10	102	35.5193	24.0437		
226	00226	16-E2-EE-BC-A1-11	102	41.1485	0.805692		
227	00227	16-E2-EE-BC-A1-12	102	37.9955	-3.47571		
229	00229	16-E2-EE-BC-A1-14	102	35.5193	24.0437		
230	00230	16-E2-EE-BC-A1-15	102	41.1485	0.80566		
231	00231	16-E2-EE-BC-A1-16	102	35.5193	24.0437		
232	00232	16-E2-EE-BC-A1-17	102	35.5193	24.0437		

Gateways					Download table as CSV
ID ^	Mac	Latitude	Longitude		
102	A1-18-A1-BB-A8-00	35.3722	24.4564		



7. By selecting each trap, below the map, one could observe a table with all the data captured by the trap.



Map showing sensor locations across Europe. A pop-up window displays the following information for a selected sensor:

- Label: 00223
- Sensor ID: 223
- Sensor MAC: 16-E2-EE-BC-A1-0E

Legend:

- Selected Sensor (Red pin)
- All Orchard Sensors (Green pin)
- All User sensors (Blue pin)

Last sensor readings Download table as CSV

BatteryLevel
 Humidity
 Luminance
 B.oleae
 Insects
 Temperature
 Olive Fly
 B.ole

Date	Temperature	Insects	B.oleae	BatteryLevel	Olive Fly	Humidity	B.ole	Luminance
18/10/2017 - 21h01	14.2	3		76	3	100.0		
18/10/2017 - 18h00	12.9	2		77	2	0.3		
17/10/2017 - 21h00	17.0	0		79	0	75.1		
17/10/2017 - 10h13	19.0	0		82	0	59.4		
16/10/2017 - 20h55	19.0	3		83	3	43.3		
16/10/2017 - 17h56	28.7	2		84	2	28.7		
15/10/2017 - 20h56	24.5	2		86	2	36.5		
15/10/2017 - 17h57	28.0	2		86	2	32.6		
14/10/2017 - 20h57	23.8	1		88	1	41.8		
14/10/2017 - 17h58	28.0	1		89	1	36.5		

Previous **1** 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 Next

This data is able to be downloaded as a CSV file in order to be proceeded offline.

For more information please see the video on our youtube channel or our web page entomatic.upf.edu/training

4.2. The recommendation system

One of the main innovations of the ENTOMATIC system is the introduction of a pest management tool that provides to the user recommendations based on the ENTOMATIC Spatial Decision Support System (SDSS) designed.

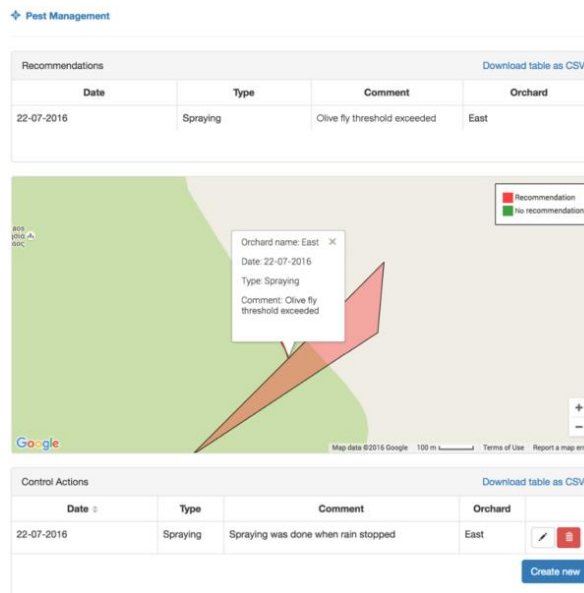


FIGURE 13: PEST MANAGEMENT SECTION

The Recommendations-section shows following information:

- **Date:** the date on which the recommendation was generated. The Entomatic system runs an algorithm each day to decide whether new recommendations should be given;
- **Type:** the type of control action that is recommended at the moment;
- **Comment:** a brief text describing why a certain recommendation was given;
- **Orchard:** the orchard to which a recommendation applies.

Moreover, each user can introduced manually an action performed. This means that if a spraying action or any other action has been taken, each user can record all of them at the control action section. This report of all actions performed can be downloaded as a csv file.

4.3. Analysis

The web platform offers opportunities to analyse sensor readings both in space and time.

In the Data parameters-section the data can be loaded for analysis, based on a timeframe and sensor selection. The sensor selection is done for the own data by selecting one orchard or one sensor. After clicking one of these radio buttons, the name of the orchard or sensor can be selected from the drop-down list. The data the user wants to compare his own data too, can be selected either based on a range around the selected own data, or by giving a number of nearest sensors that must be taken into consideration. After clicking the “Load Data” button, the map and graph are updated.

The map shows the total number of captured olive flies on the last full day, the number of days since the last olive flies were captured or a combination of both metrics. When “Combination” is selected, the number of olive flies captured on the last day that olive flies were captured, is given using different colours, the number of days since the last olive flies were captured is represented by a range of different opacity levels.

The graph shows a time-series of boxplots that represent the distribution of sensor reading values that were registered for the day given on the X-axis or the period around it. The amount of days for which data is aggregated in one box depends on the length of the timeframe that was selected to keep the graph easy to interpret.

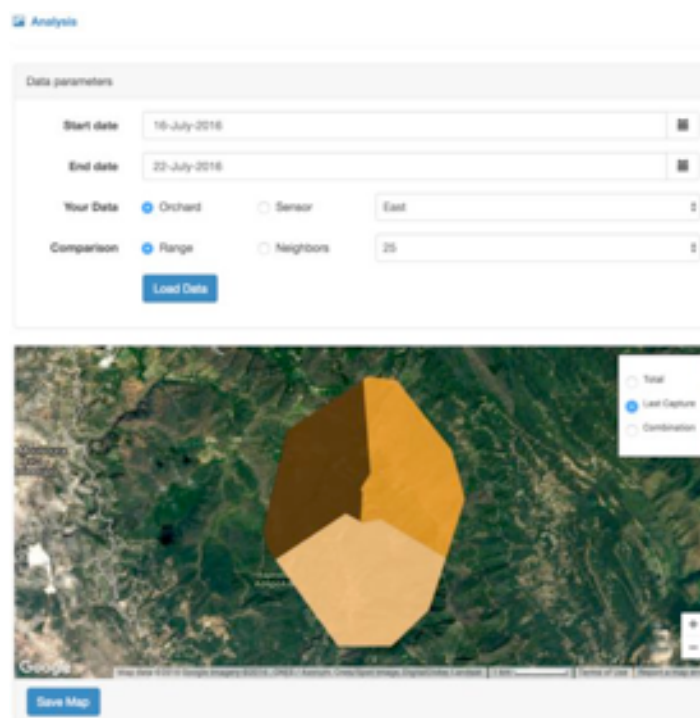


FIGURE 13: THE ANALYSIS SECTION.

4.4 Network Performance

In the network performance page users can monitor the status of their sensors in terms of e.g. battery level. When the battery voltage drops below a certain level, the user receives a warning so he/she knows that batteries need to be replaced.

The “Deactivated type” is a special case of alarm and shows that data was received for a measurement type that is deactivated. The value column specifies the measurement type the alarm is referring to.

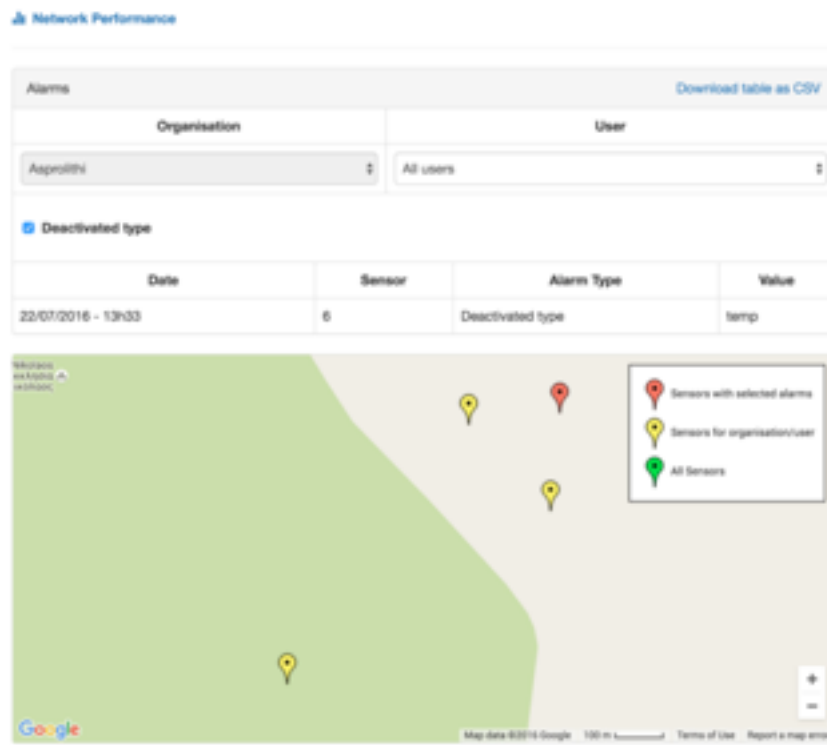


FIGURE 14: NETWORK PERFORMANCE SECTION

For more information please visit



entomatic.upf.edu



[cordis.europa.eu/
project/rcn/](http://cordis.europa.eu/project/rcn/)



[www.twitter.com/
entomatic_](https://www.twitter.com/entomatic_)



