LAS Deployment and Operation in two experimental sites

Commercialization of an Automated Monitoring and Control System against the Olive and Med Fruit Flies of the Mediterranean Region

FruitFlyNet-ii: STR_B_A.2.1_0043

MEDITERRANEAN SEA BASIN PROGRAMME 2014-2020

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Summary

The objective of this output is to provide information about the various tasks that took place during the reference period (Semesters V-VI) in the two experimental sites of the project aiming to verify the good performance of the e-traps, as well as to test the new functionalities and ensure the good operation of the e-services in the large-area sites. To accomplish the full deployment of the Location Aware (LA) products in the 2nd cultivation period, the olive and Med e-traps were tested in both sites to satisfy all the evaluation criteria set for the full operation. Noteworthy, the *OliveFlyNet* was tested in Greece (BEN) and the *MedFlyNet* in Italy (P02). The results for both types of the e-traps tested in the two experimental fields showed very good performance in terms of battery charge level and signal reception.

The e-services of adults' population distribution map, infestation risk map and spray density map creation were tested by BEN in its experimental site to validate its functionalities in the new environment. A new e-service was developed and tested regarding the automatic digitalization of trees, that is an e-service which facilitates the implementation of the system. An additional e-service which gives the ability to the system to identify the optimum position for placing each trap in each area with olive groves was developed and tested too, so that to rationalize the approaches used. The two new e-services were implemented successfully whereas the updated software was able to produce all the different kind of maps required for the full implementation of the LA e-services.

Finally, a detection and count machine learning test for the case med fruit fly pest was also studied by PP02. Tests related to the automatic recognition of medfly catches in the e-trap were also conducted and showed a very food response.

1. AUA (BEN)

1.1. E-traps

1.1.1. Methodology

The trials for testing the performance of e-traps for the OliveFlyNet were conducted in an olive grove of cv. Manaki (large size drupe), located in Koropi, in a flat agricultural landscape (37° 56′ 11′′N latitude 23° 51′41″ E longitude), Attiki, Greece. The planting system is linear, rows are oriented East-West, and the age of the trees was ca. 40 years. The olive grove was uniform in agronomic conditions (e.g., soil type, fertilization, pruning, and irrigation).

The experimental procedure for testing the performance of battery level and the signal reception the olive e-traps was divided into two periods. The first period was on autumn 2022, when the olive fruit fly appeared in the field, and the second one was during the spring/summer 2023, when the fly was present in the field, and just before the end of the summertime in Greece. During the 1st cultivation period (2022) the used prototype showed some critical points that required a specific optimization action that took place during 2023 to solve them (see D4.2).

For this purpose, three e-traps were tested during the 1st cultivation period (2022) and for two of them the testing was repeated during the 2nd cultivation period (2023). According to the cultivation period the Node ID of each e-trap used, and its corresponding total number of images taken was as follows:

- 1st Cultivation Period -Autumn 2022
  NODE 11: 25.09.2022 to 2.11.2022, number of Images acquired: 62.
  NODE 12: 17.10.2022 to 13.11.2023, number of Images acquired: 48.
  NODE 14: 18.10.2022 to 10.11.2022, number of Images acquired: 41.
- 2nd Cultivation Period – Spring/Summer 2023
  NODE ID 11: 30.6.2023 to 3.9.2023, number of Images acquired: 62.
  NODE 12: 27.4.2023 to 19.7.2023, number of Images acquired: 125.

During each monitoring period ammonium carbonate was used as attractant. The yellow adhesive panel placed in the trap was replaced bi-weekly and the ammonium carbonate was replaced before it finished.

Each e-trap took 2 photos each day, one at 7:00 UTC and one at 13:00 UTC. Readjustments took place either to revise the time, or to check the absence of the signal, or to replace the exhausted battery. They could also happen to take clearer images in terms of shadow or blur image reception. Note that the e-raps, being heavier than the traditional traps, were attached to an outer and sturdier branch, taking care that the solar panel was not covered by the smaller branches and leaves, to avoid the shadow would not allow the battery to recharge.

1.1.2. Results

The results depicted from the following graphs (Figs 1.2, 1.4, 1.5, 1.7) showed very good battery charge level which very rarely was less than 50%. However, in the case of Figure 1.1., the battery level was kept at low levels, however after our visit and placing the solar panel in a sunnier place on the canopy, the battery level was highly increased reaching to 92%.

The percentage of reception of images sent from the e-traps are given in Figs 1.3, 1.6, 1.8. The rates of successfully uploading images to the server was high. The percentages of storing images in the card due to failures in connection was very low (i.e. 9, 5 or 10%).

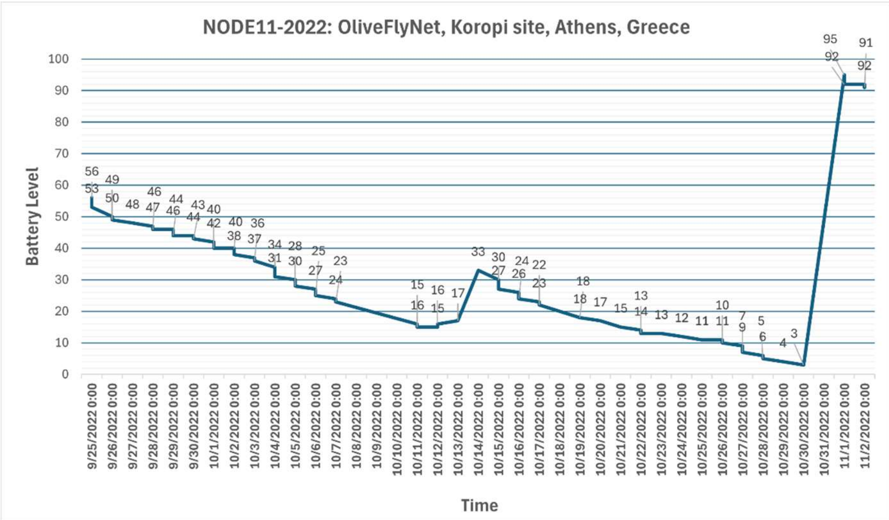


Figure 1.1: Actual percentage of battery charge level of the e-trap of NODE ID: 11, during the testing of the 1st cultivation period (2022).

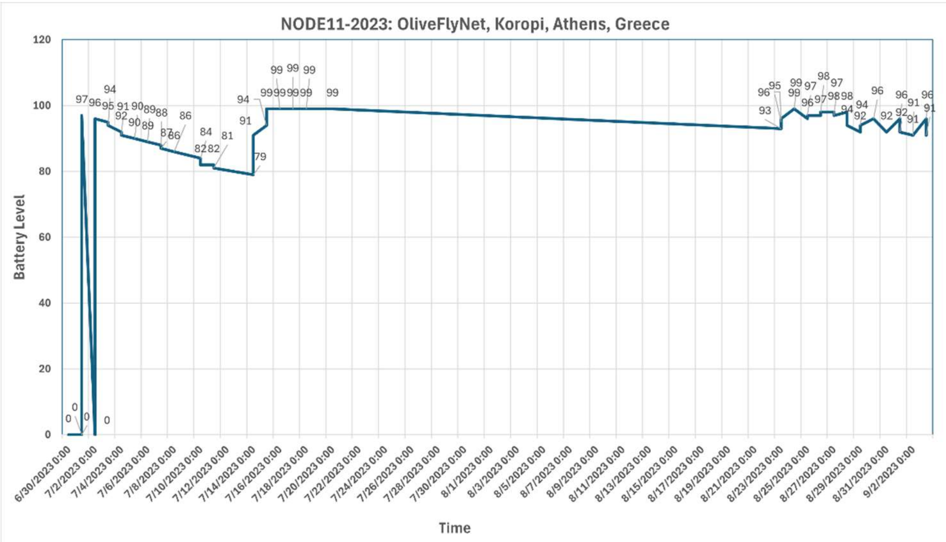
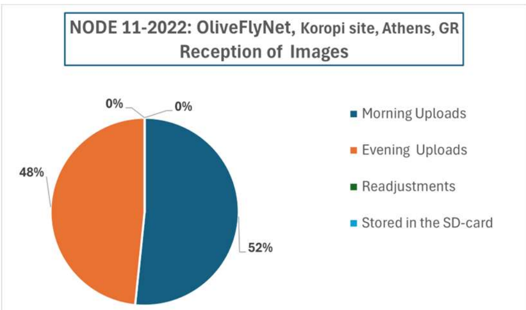
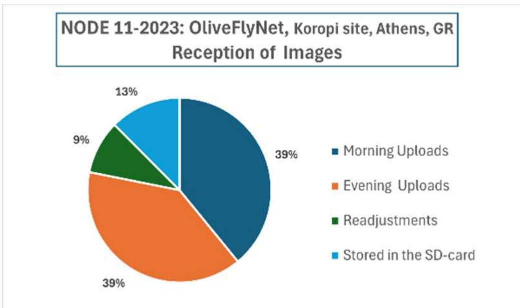


Figure 1.2: Actual percentage of battery charge level of the e-trap of NODE ID: 11, during the testing of the 2nd cultivation period (2023).



(a): 1st Cultivation Period (2022).



(b): 2nd Cultivation period (2023).

Figure 1.3: Percentage of reception of images sent from the e-trap of NODE ID: 11 to the cloud (Morning Uploads, Evening Uploads, Readjustments) and stored in the SD card, because of low signal strength.

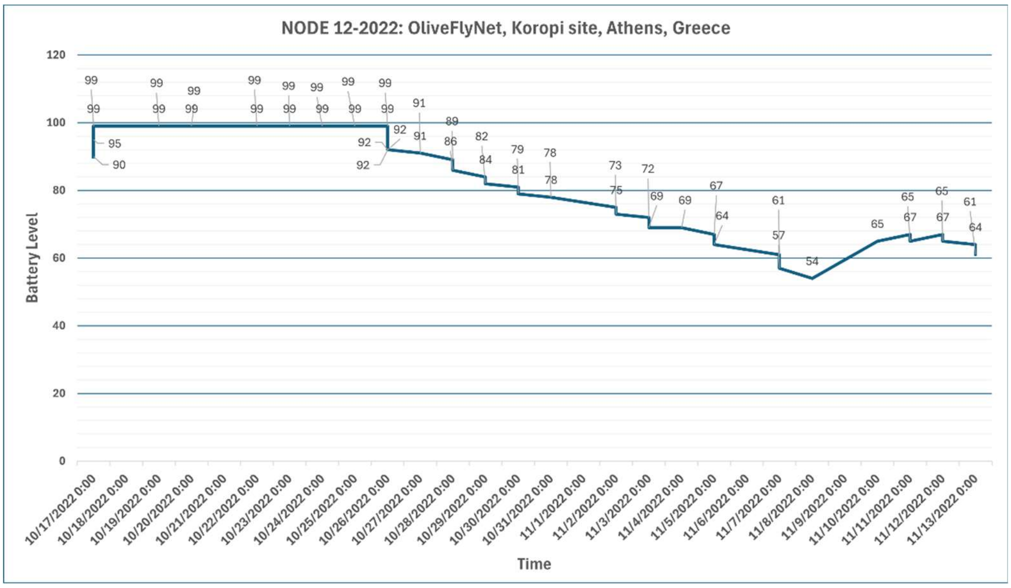


Figure 1.4: Actual percentage of battery charge level of the e-trap of NODE ID: 12, during the testing of the 1st cultivation period (2022).

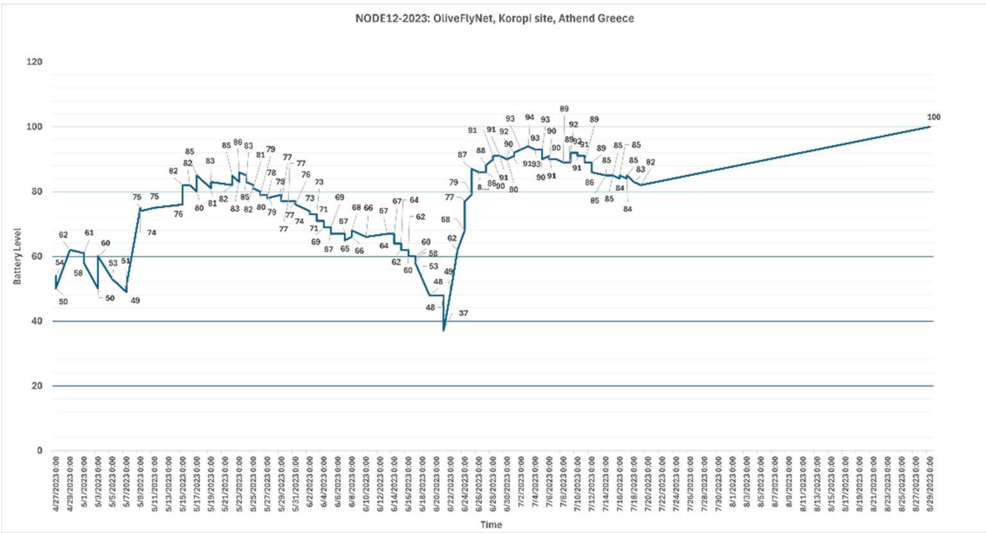
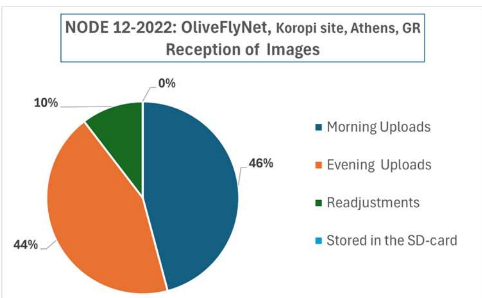
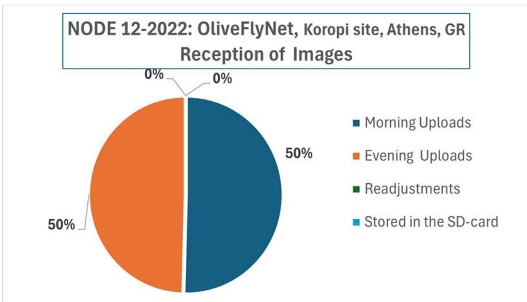


Figure 1.5: Actual percentage of battery charge level of the e-trap of NODE ID: 12, during the testing of the 2nd cultivation period (2023)



(a): 1st Cultivation Period (2022).



(b): 2nd Cultivation period (2023).

Figure 1.6: Percentage of reception of images sent from the e-trap of NODE ID: 12 to the cloud (Morning Uploads, Evening Uploads, Readjustments) and stored in the SD card, because of low signal strength.

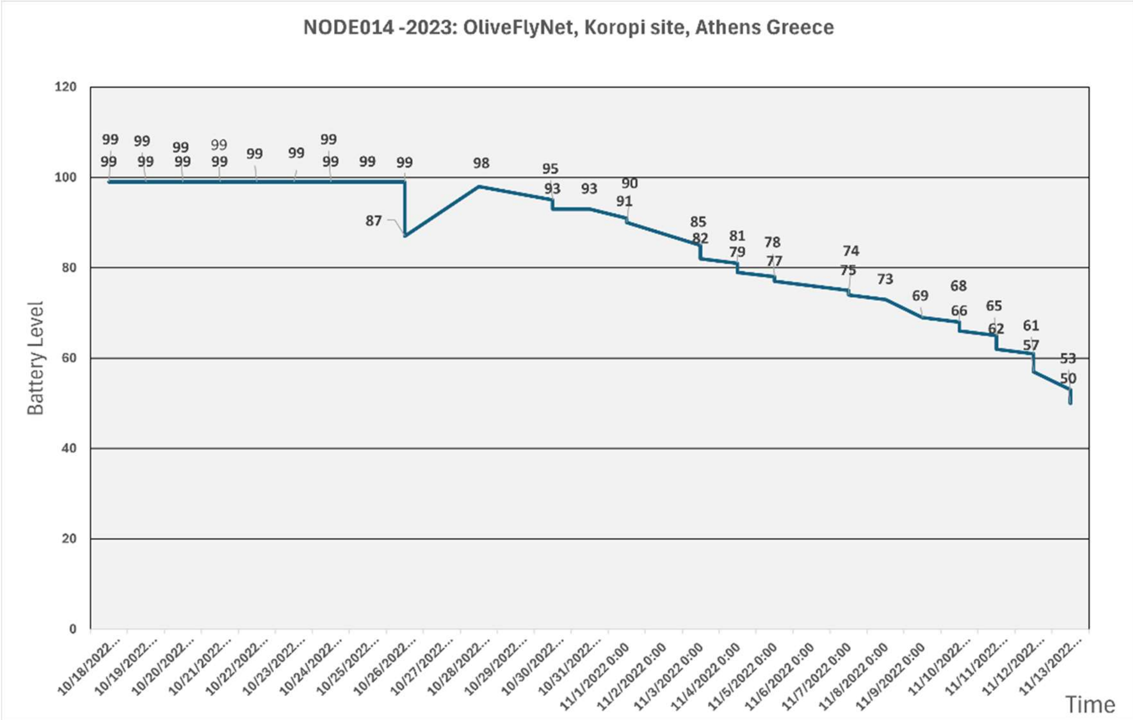


Figure 1.7: Actual percentage of battery charge level of the e-trap of NODE ID: 14, during the testing of the 2nd cultivation period (2023).

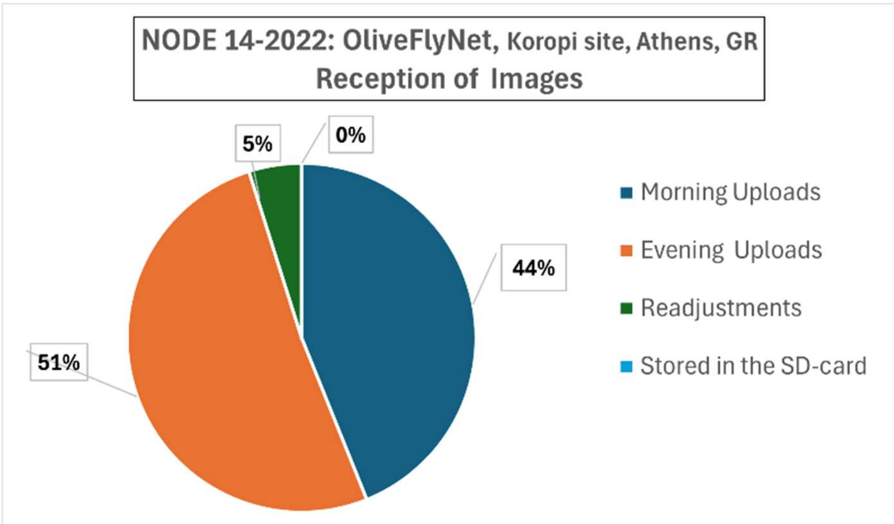


Figure 1.8: Percentage of reception of images sent from the e-trap of NODE ID: 14 (2nd Cultivation period - 2023) to the cloud (Morning Uploads, Evening Uploads, Readjustments) and stored in the SD card, because of low signal strength.

1.2. LAS e-services

The aim of these tasks was to develop the functionalities and e-services of LAS in new software environment (in comparison to the previous project) and then to test new LAS e-services aiming to reduce the workload, the cost and facilitate certain aspects of the LAS implementation, also increasing its efficacy in pest control due to more accurate and scientifically sound methodologies, than the approaches currently in use. The new e-services were related to:

- **The automatic digitization of trees**. Digitization is the first task to be performed for implementing the LAS in a grove since satellite maps are not giving the coordinates of each element. However, digitization is a laborious task when performed manually (i.e. using the mobile GIS tablet visiting each tree in the field).
- **E-services of adults' population distribution map, infestation risk map and spray density map creation**. Advance algorithms and updated geodatabase were tested to estimate the spatial distribution of the olive fly population, the infestation risk for each olive grove and the proposed density of the spraying in the olive groves.
- **Identifying the optimal position to establish each trap**, for more effective monitoring of the olive fruit fly since the current approach is to establish the traps following zig-zag patterns or otherwise based on ad-hoc and non-scientifically based decisions without considering their most representative distribution in the field.

1.3. Manual digitalization of trees

1.3.1. Methodology

The digitization of the experimental orchard includes the digitization of the necessary GIS information layers. Two different approaches were used for the digitization process, also for comparison reasons. The first approach is the manual digitization and the second one is the (new) automatic digitization.

In the manual digitization the information layers were created visually, using the GIS tools and procedures of the QGIS software manually. The digitized information layers created by the manual approach are used as a reference layers. The geospatial layers created with the manual method are shown to the following table:

Table 1.1: The digitized geospatial layers of the experimental site.

Geospatial layer	GIS type	Description
SITE	polygons	The boarders of the experimental site as polygon.
OLIVE TREES	points	The trees of the experimental site.
OLIVE GROVES	polygons	The boarders of each orchard using polygon geometry. Each polygon is assigned by the owner ID.
LANDUSES	polygons	The aim of this layer is to provide spatial information about the areas that must be protected during the spraying process. Also, it provides information that is useful during the spray process.

PROTECTED ZONES	polygons	The PROTECTED ZONES layer is emerging from the LANDUSES layer using the Buffer value of each feature and buffering methodology
SENSORS	points	Distribution of the sensors of the experimental site.
TRAPS	points	Distribution of the traps of the experimental site.

Table 1.2: Digitization approach for creating the geospatial layers of the experimental site.

Geospatial layer	Digitization approaches			
	Manual	Assisted	Semi-automated	Automated
SITE	☑	☑	☒	☒
OLIVE TREES	☑	☑	☑	☑
OLIVE GROVES	☑	☑	☒	☒
LANDUSES	☑	☑	☒	☒
PROTECTED ZONES	☒	☒	☑	☒
SENSORS	☑	☑	☒	☒
TRAPS	☑	☑	☑	☑

1.3.2. Results

The digitized geospatial layers using the manual method are showing in the following maps. The borders of the experimental site are showing in the following figure.

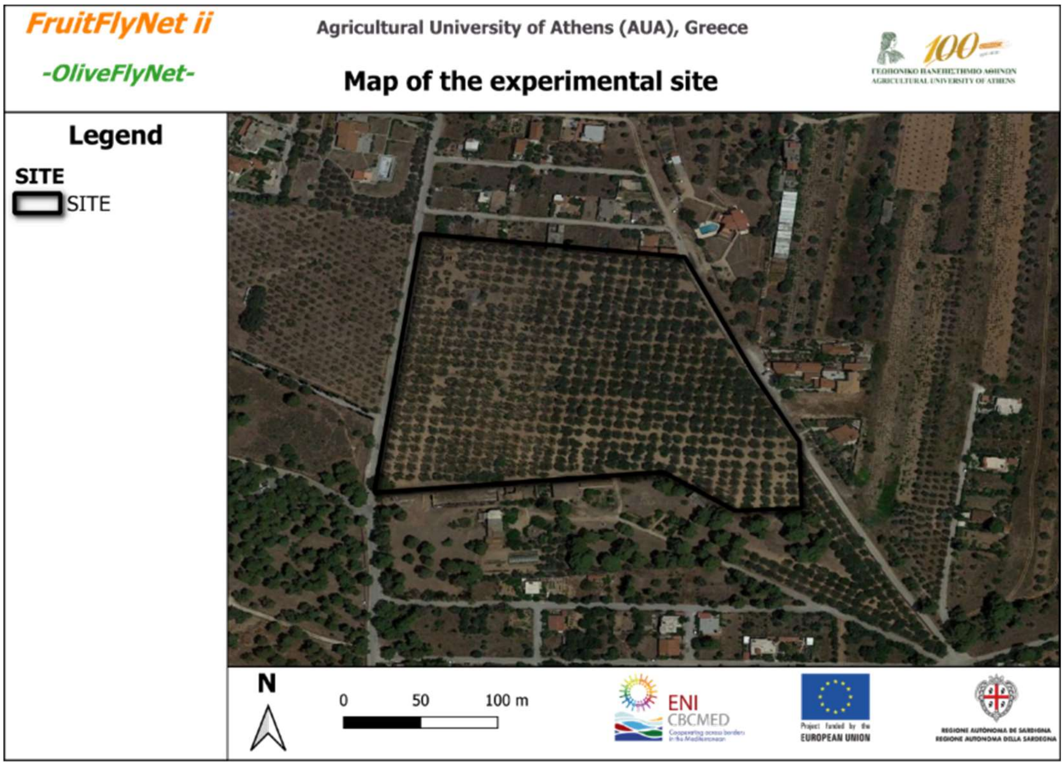


Figure 1.9: Map of the experimental site.

The characteristics of the layer Site of the experimental site is showing in the following table:

Table 1.3: Characteristics of the layer Site of the experimental site of BEN.

Attribute	Value
Area	7ha
Length	1400m

The trees digitized manually using QGIS. The digitized trees of the experimental site are showing in the following figure.

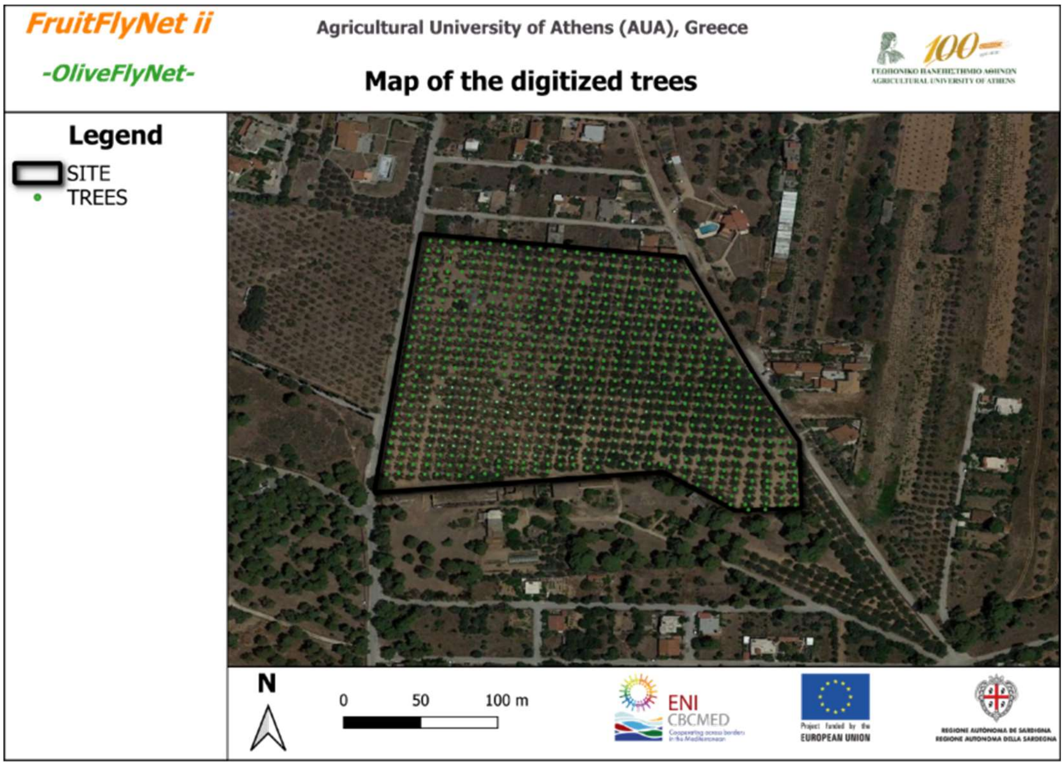


Figure 1.10: Map of the trees of the experimental site.

The characteristics of the distribution of the trees of the experimental site is showing in the following table:

Table 1.4: Characteristics of the distribution of the Trees of the experimental site.

Attribute	Value
Number of trees	673
Observed mean distance:	7.3m
Expected mean distance:	5.9m

Table 1.5: Characteristics of the layer Site of the experimental site

Attribute	Value
Area of Orchard 1	12530,3 m^2
Perimeter of Orchard 1	434,5 m
Area of Orchard 2	12330,0 m^2
Perimeter of Orchard 2	432,9 m
Area of Orchard 3	5234,4 m^2
Perimeter of Orchard 3	255,9 m

The olive groves digitized manually using QGIS. The digitized olive groves of the experimental site are showing in the following figure.

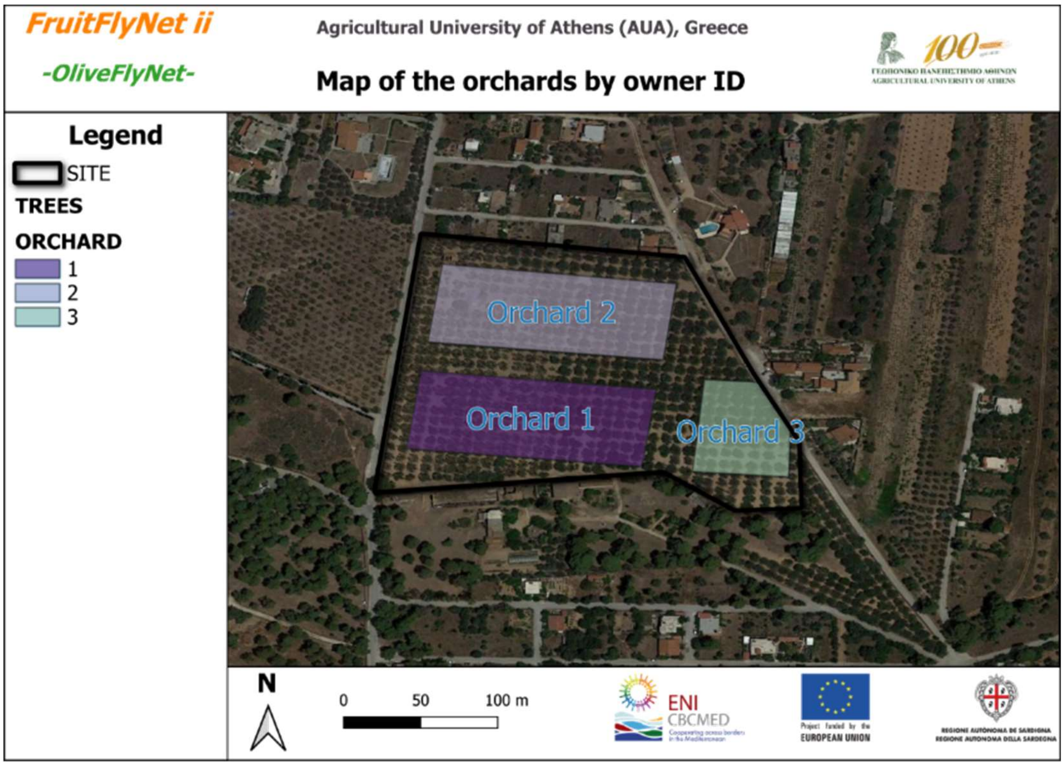


Figure 1.11: Map of the olive groves of the experimental site.

The digitized position of traps of the experimental site are showing in the following figure.

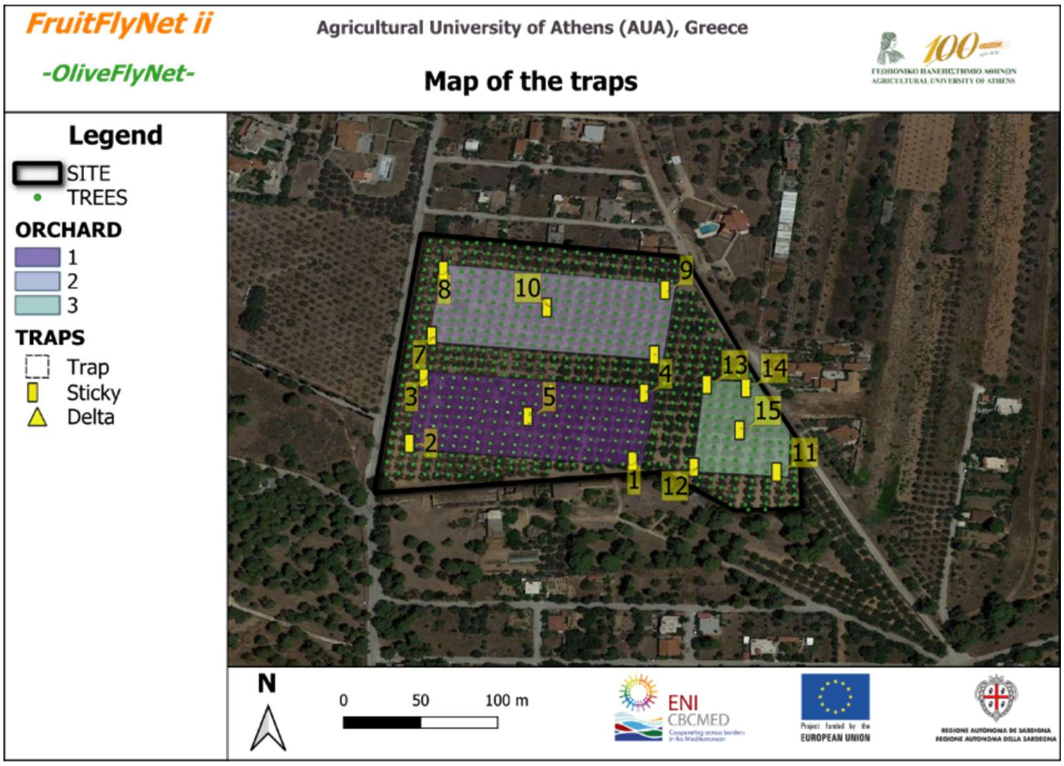


Figure 1.12: Map of the traps of the experimental site.

The digitized land-uses (i.e. areas to be protected and their type) of the experimental site are showing in the following figure.

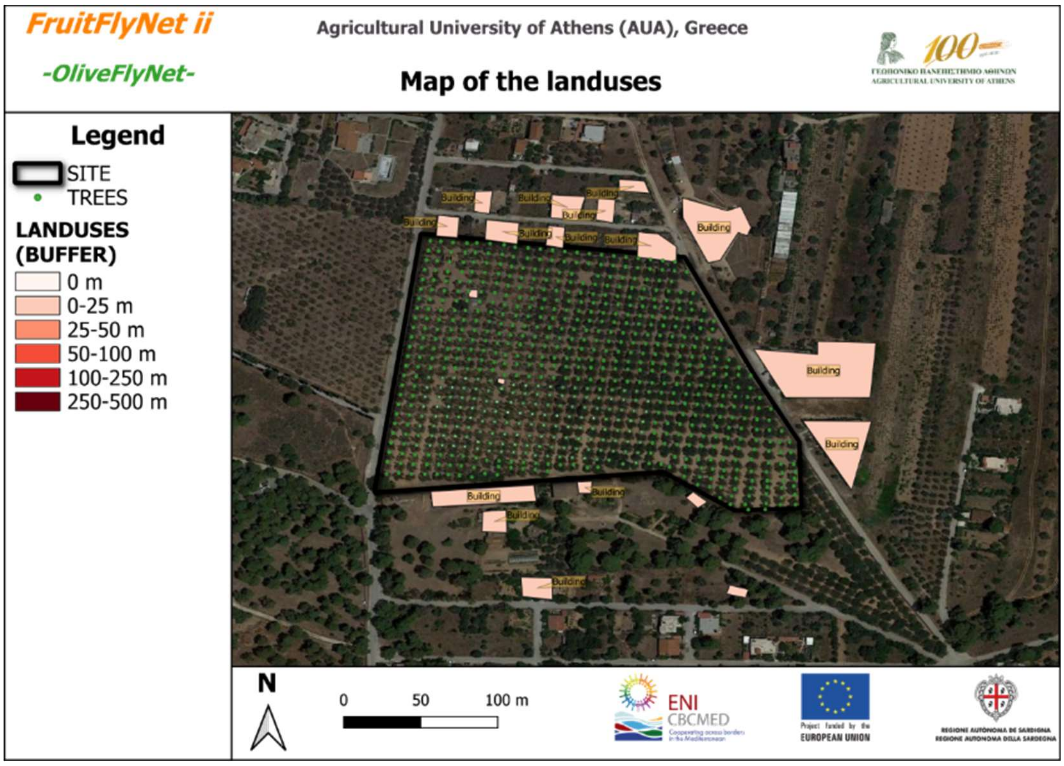


Figure 1.13: Map of the land uses of the experimental site.

The digitized protected areas of the experimental site are showing in the following figure.

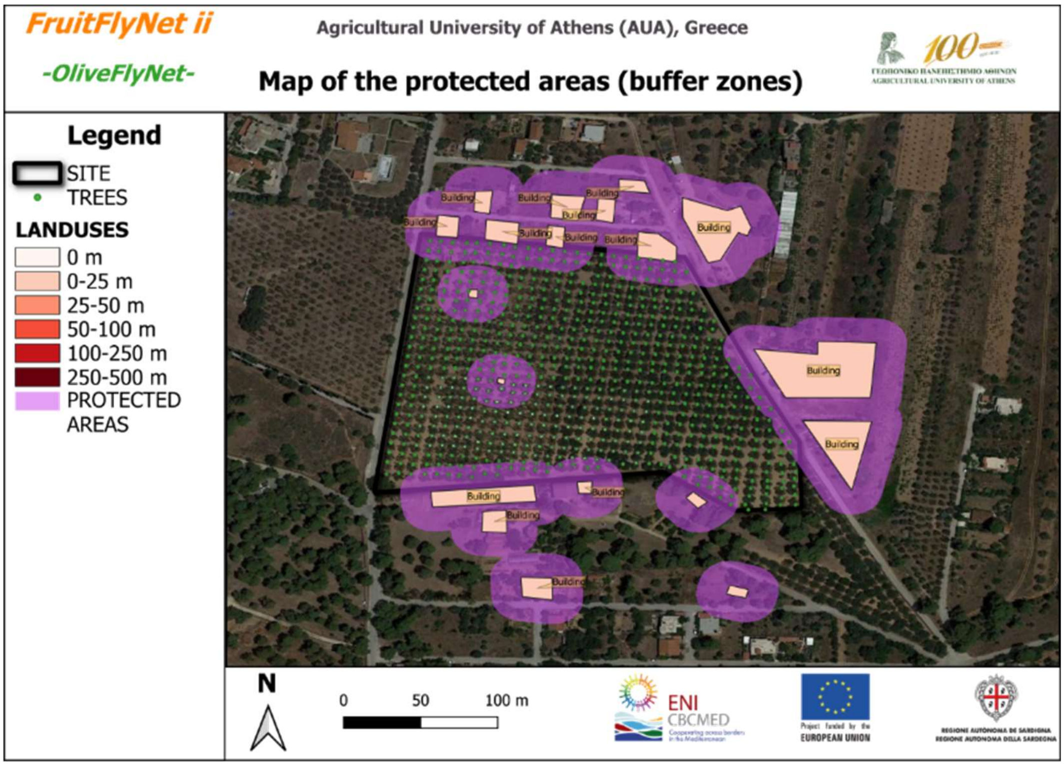


Figure 1.14: Map of the protected areas of the experimental site.

1.3.3. Discussion

Using the manual digitization process the information layers were created visually, using the GIS tools and procedures of the QGIS software. The digitized information provides useful information about the spatial and non-spatial characteristics of the experimental site. Also, from the digitized features it was possible to test and optimize the basic LAS tools for spatial calculations and map creation. However, this was a time consuming and high-cost task and thus its use in commercial LAS prototype is questionable.

1.4. E-services for automatic digitalization of trees

1.4.1. Methodology

In the automatic digitization process, the digitization is performed using the e-services of the LAS (see D3.3- 1.5.1-Digitization e-services). The e-services were used for the automation of digitization of the olive trees. The digitized information layers created with the manual approach are used as a reference layers. For evaluation purposes these layers were compared with the layers created automatically. The aim was to create e-services which can assist LAS to generate faster and more accurate trees layer of the geodatabase for each farmer.
To start with, the evaluation of the e-services of the LAS using the experimental site is the first step. After doing the necessary modifications and optimizations of the e-services, the task will be completed using these services in the wide-area site. The main characteristics of the digitization e-services are shown in the D3.3. The methodology of the automatic digitization of the trees is shown in the following figure:

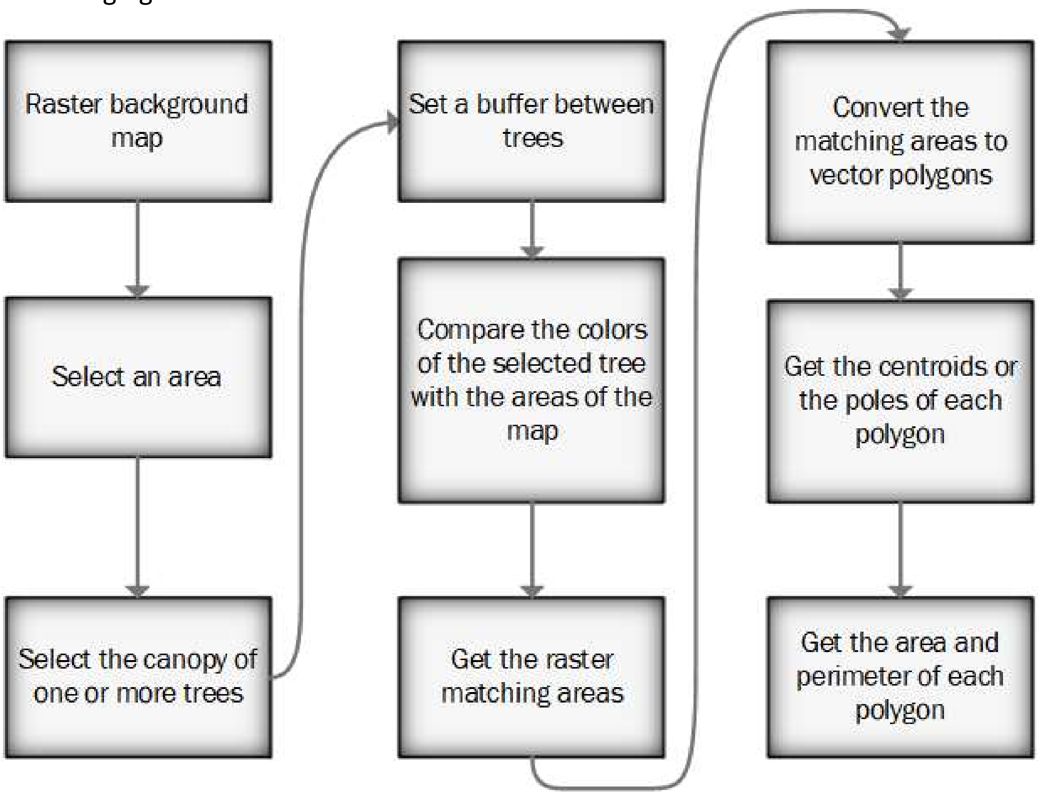


Figure 1.15: Methodology of the automatic digitization of the trees.

The methodology separates the area of the canopy of the trees from the area of the ground using as differential characteristic the colour of the trees in contrast to the colour of the soil surface. The methodology implemented in QGIS and was tested for the trees of the experimental site using different levels of buffer. The selection of the buffer value is rather empirical. It depends on factors such as the spatial distribution of the trees, the distance between nearby trees and the preferred accuracy of the digitization. As raster background maps "Google satellite maps" were used. The selection area was the whole area of the experimental site or the half area of the experimental site. A single tree canopy was selected for each comparison.

1.4.2. Results

The results of the automatic digitization of the trees of the experimental site are shown in the following figures. In the next figure the map generated from the algorithm is shown.

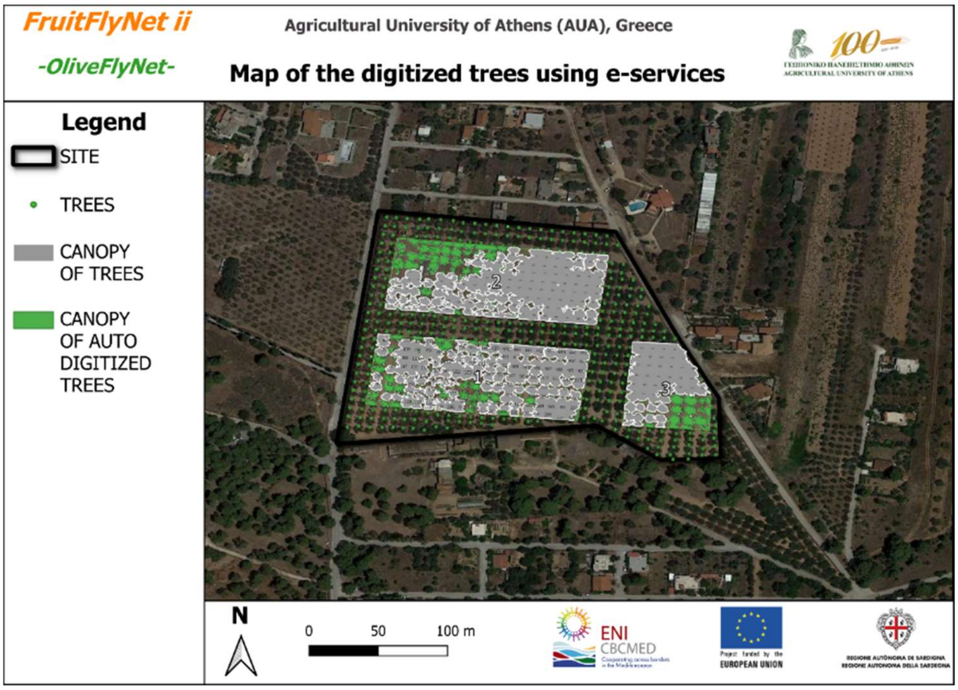


Figure 1.16: Map of digitized trees using e-services (Areas A, B, C: medium buffer)

Next, a medium buffer was used, and the selected area is the area of the experimental blocks or orchards. In the next figure the map generated from the algorithm is shown.

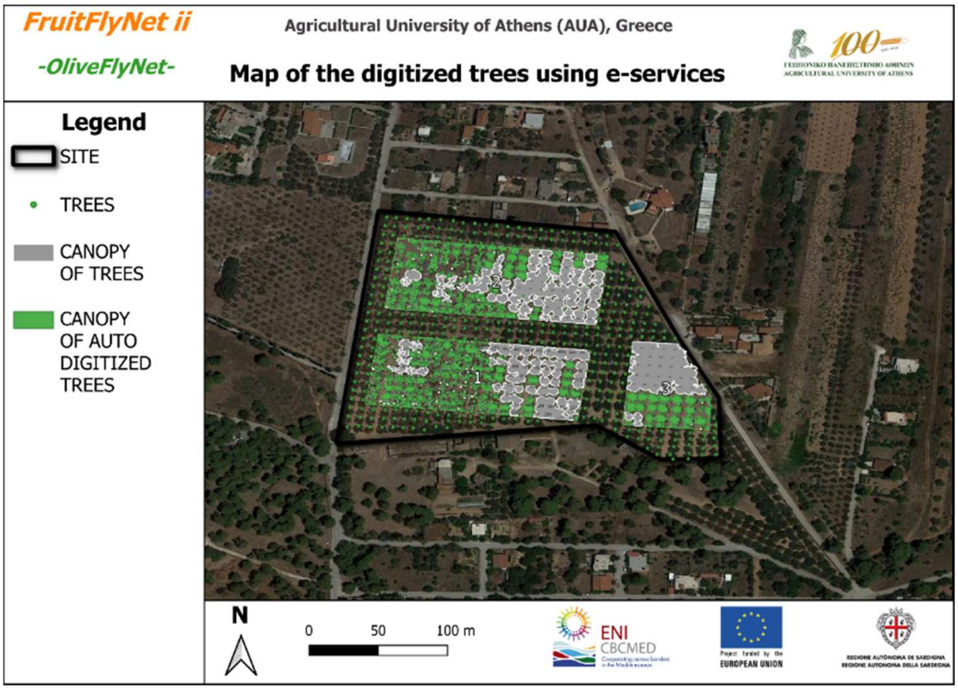


Figure 1.17: Map of digitized trees using e-services (Areas A, B, C: low buffer)

Finally, a low buffer was used, and the selected area is again the area of the experimental blocks or orchards. In the next figure the map generated from the algorithm is shown.

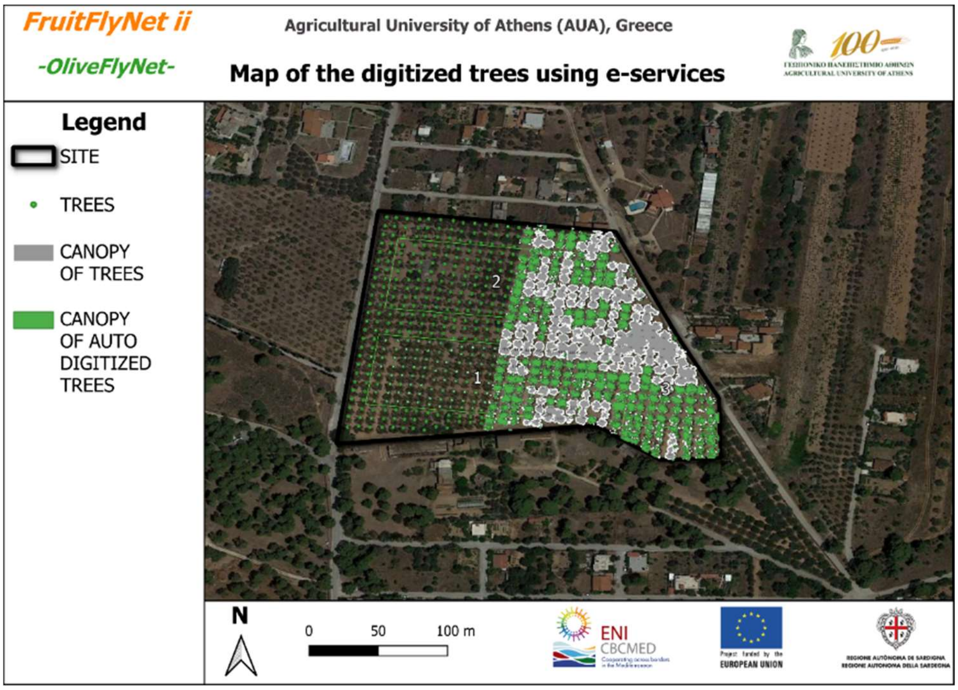


Figure 1.18: Map of digitized trees using e-services (The half experimental area: low buffer)

By entering to the algorithm different input parameters, we can take different output areas. In this case the selected area (input parameter for selected area) is the half area of the experimental site with a low buffer (input parameter for buffer).

1.4.3. Discussion

From the generated maps the algorithm gives better results in the case that the canopies of the trees are separated. In these cases, the border of the trees can be distinguished and the position, the perimeter, and the diameter of the canopy of each tree can be estimated with precision. However, as it turned out from our testing, in the cases that the canopies of the trees touch each other, the only characteristic that can be estimated is the coverage of the trees canopy in the area.

1.5. E-services of adults' population distribution map, infestation risk map and spray density map creation

1.5.1. Methodology

The automatization of the creation of the maps of adults' population distribution map, infestation risk and spray density are based on the e-services of the LAS (see D3.3- 1.5.1-Digitization e-services, D3.3-1.5.3 Pest monitoring, D3.3-1.5.4 Infestation risk and D3.3-1.5.5 Spraying process). The user can select the trapping layer (trapping data) and insert the preferred date. The e-services using the traps layer, the site layer, the olive groves layer and the user's inputs should find in the geodatabase the insect captures for the selected date and calculates from the available spatial data the insect population, the values of the DSS for the infestation risk and the spaying density. From these values the e-services should produce the adults' population distribution map, infestation risk map and spray density map and assign the status of the index of the infestation risk or spraying density to each tree of the selected area. All these maps are the tools to be used by the farmers to apply sprayings. The running all the above functions in the new software environment had to be tested in this Activity in the experimental site of BEN. The assignment of spraying density per tree (and not in an area of the grove with many trees, as in the previous project), is an improvement of significant value facilitating the spraying process and increasing the spraying precision in the field. Each e-service should be possible to be executed separately or all together (one after the other). In the second case the produced maps of the density spraying are used only if a decision for spraying has been taken. Otherwise, these maps have only advisable value. The methodology of adults' population distribution map, infestation risk map and spray density map creation are shown in the following figure:

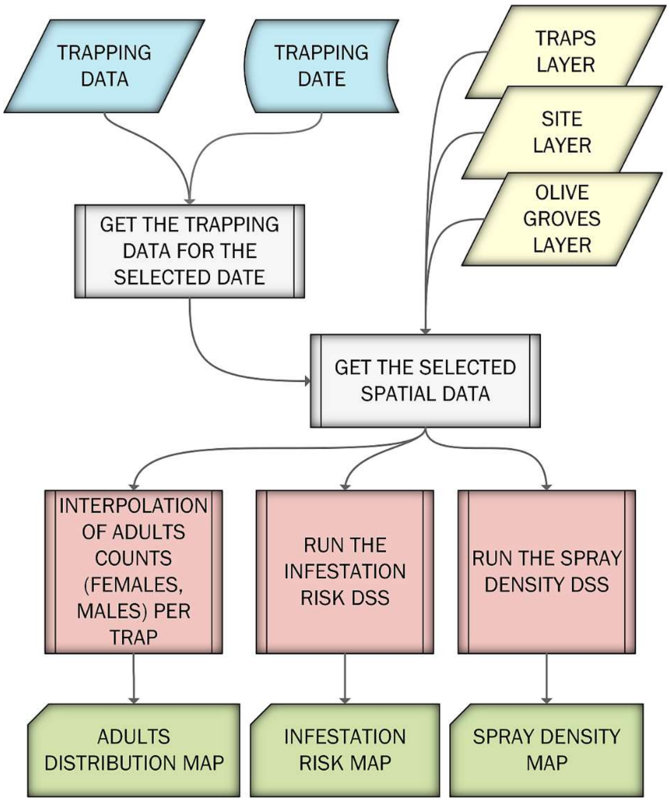


Figure 1.19: Methodology of adults' population distribution, infestation risk and spray density maps creation.

1.5.2. Results

1.5.2.1. Maps creation using past data of traps' captures

For testing and evaluation purposes of the software and the functionalities of LAS and the production of maps, previous data of olive fruit fly captures when 15 traps had been placed in the experimental site were used. The results of the e-services for the creation of maps of the adult population, the risk of infestation, and the spray density from the geodatabase of the experimental site are shown in the following figures. The maps of the spatial distribution were created using the IDW algorithm of the QGIS software. The spatial distribution of the adult population for the trapping data for the date 2015-07-03 is shown in the following figure.

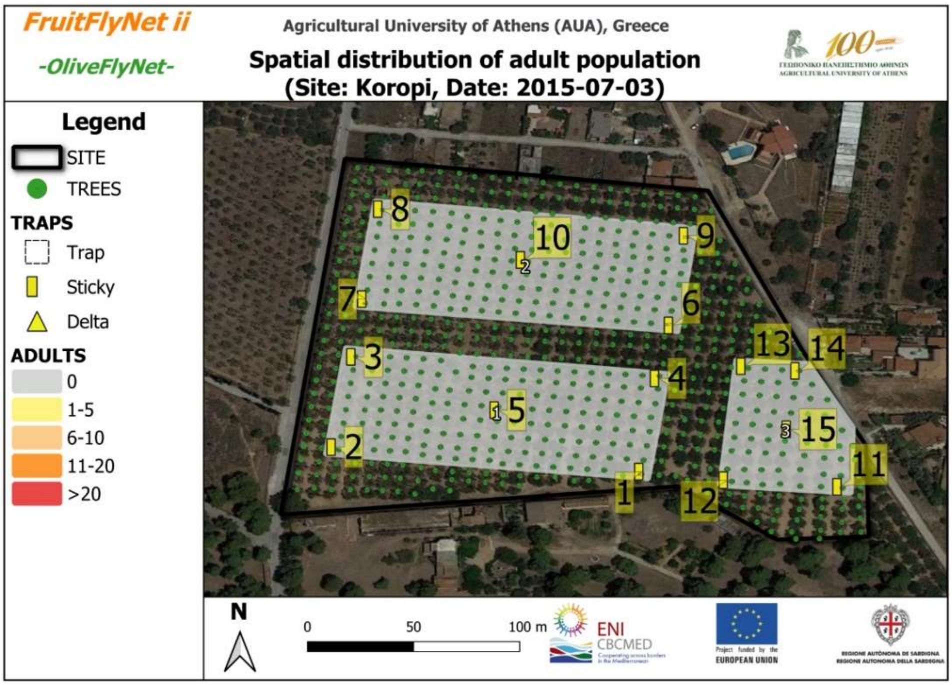


Figure 1.20: Spatial distribution of adult population (Date: 2015-07-03).

In this case there is no coloured areas of the spatial distribution of the insect population, due the absence of the insect in the area (there were no captures) and correctly the produced map shows zero level of adults in the whole area.
The infestation risk map for the trapping data for the date 2015-07-03 is shown in the following figure.

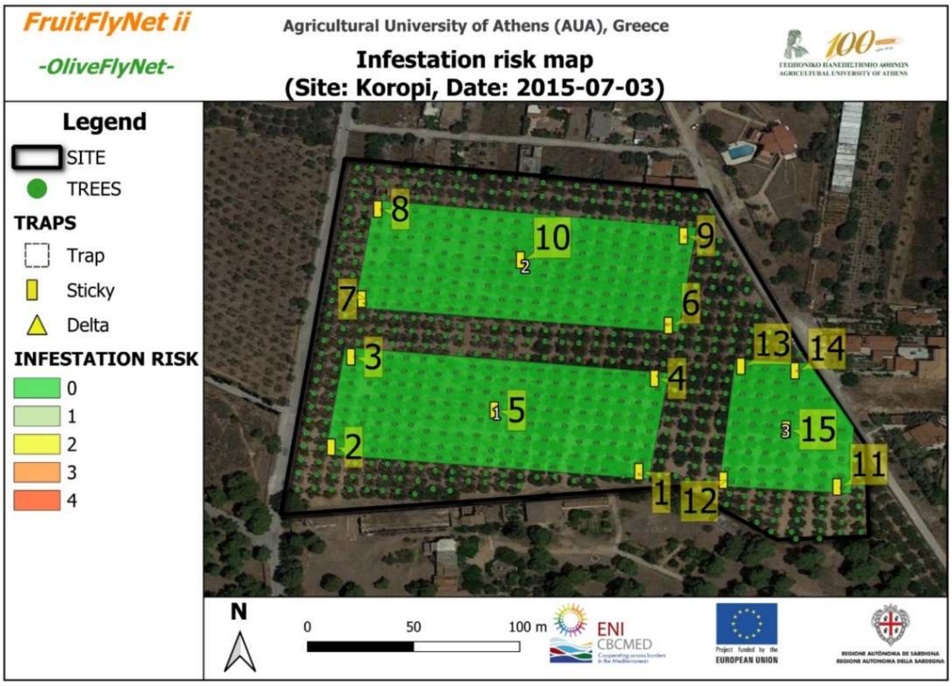


Figure 1.21: Infestation risk map (Date: 2015-07-03)

Due the absence of the insect in the area there is no risk, so the map for the selected areas was colored green (Infestation risk=0).

The proposed spraying map for the trapping data for the date 2015-07-03 is shown in the following figure. The map is used only if a decision for spraying has been taken.

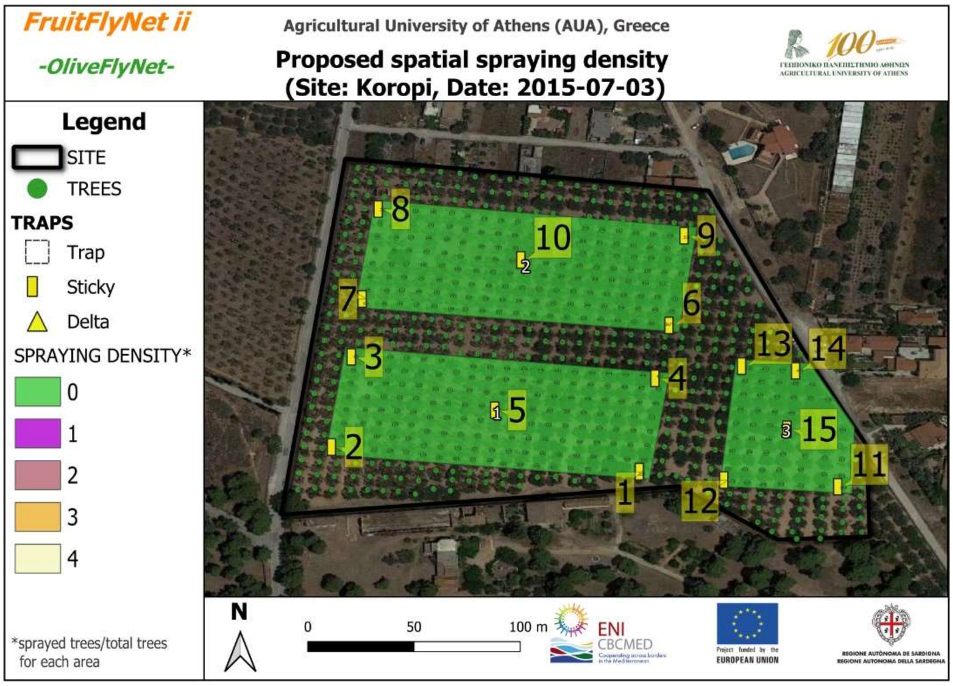


Figure 1.22: Proposed spraying map (Date: 2015-07-03)

As there is no infestation risk in the area, there is no proposed area for spraying and the map for the selected areas was coloured green (spraying density=0).

The spatial distribution of the adult population for the trapping data for the date 2015-08-04 is shown in the following figure.

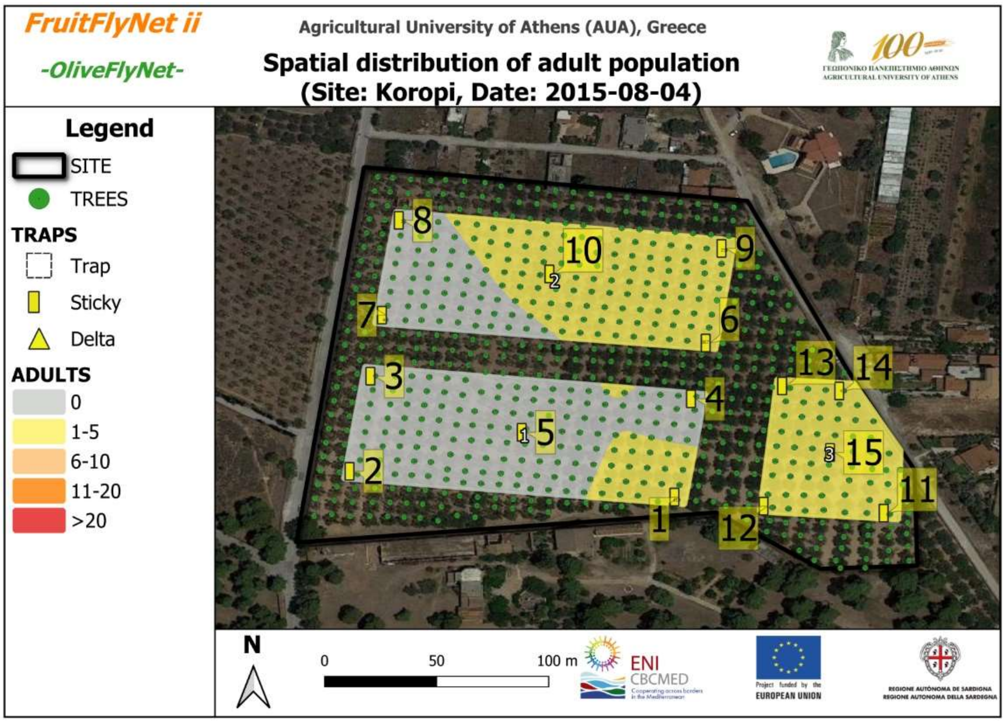


Figure 1.23: Spatial distribution of adult population (Date: 2015-08-04)

The infestation risk map for the trapping data for the date 2015-08-04 is shown in the following figure.

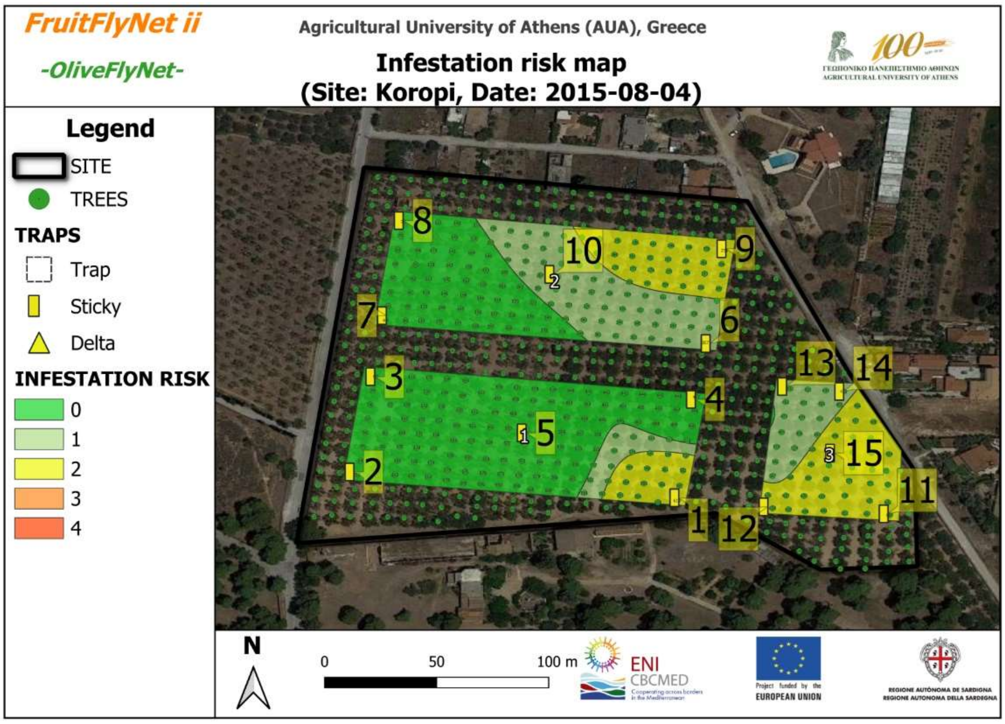


Figure 1.24: Infestation risk map (Date: 2015-08-04)

The proposed spraying map (i.e. spray 1 out of 4 trees in the purple area) for the trapping data for the date 2015-08-04 is shown in the following figure. The map is used only if a decision for spraying has been taken.

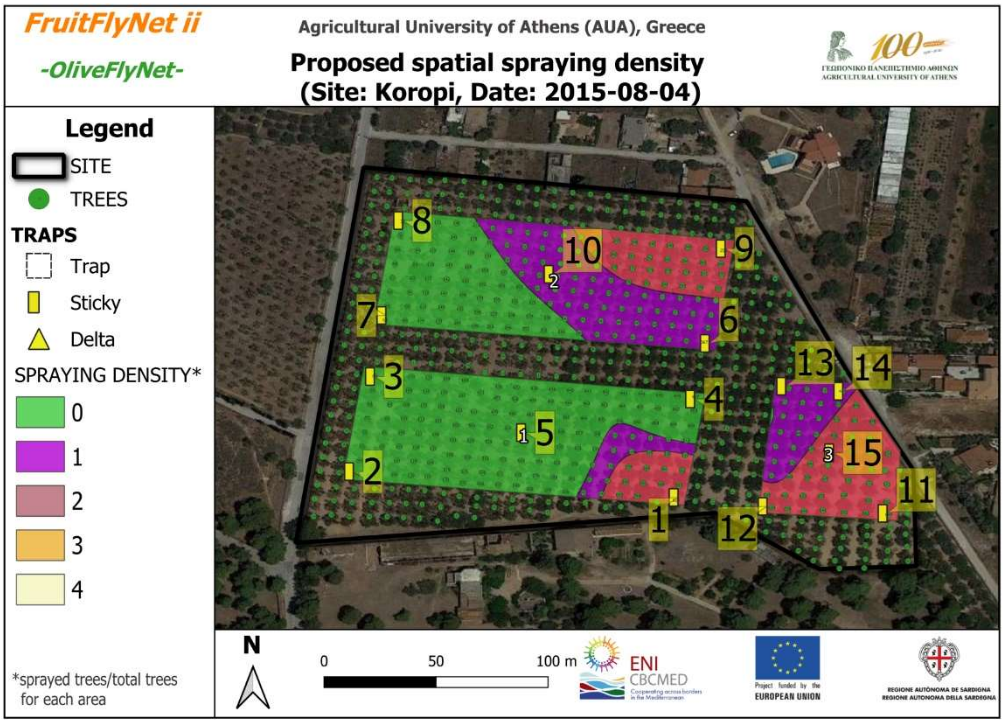


Figure 1.25: Proposed spraying map (Date: 2015-08-04)

The spatial distribution of the adult population for the trapping data for the date 2015-08-07 is shown in the following figure.

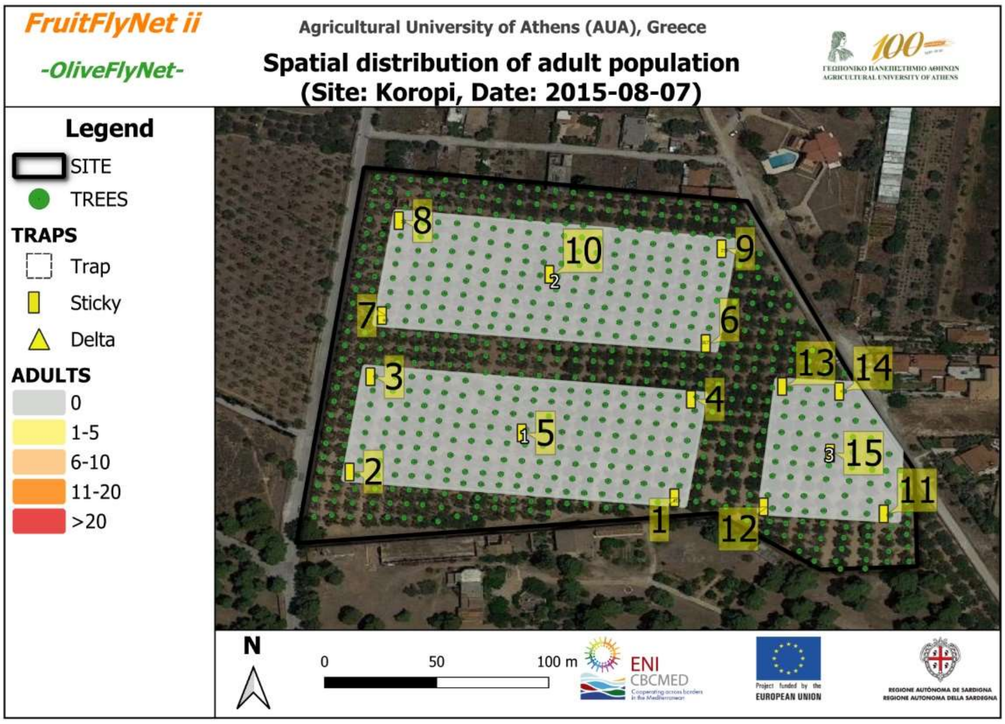


Figure 1.26: Spatial distribution of adult population (Date: 2015-08-07) (no captures).

The infestation risk map for the trapping data for the date 2015-08-07 is shown in the following figure.

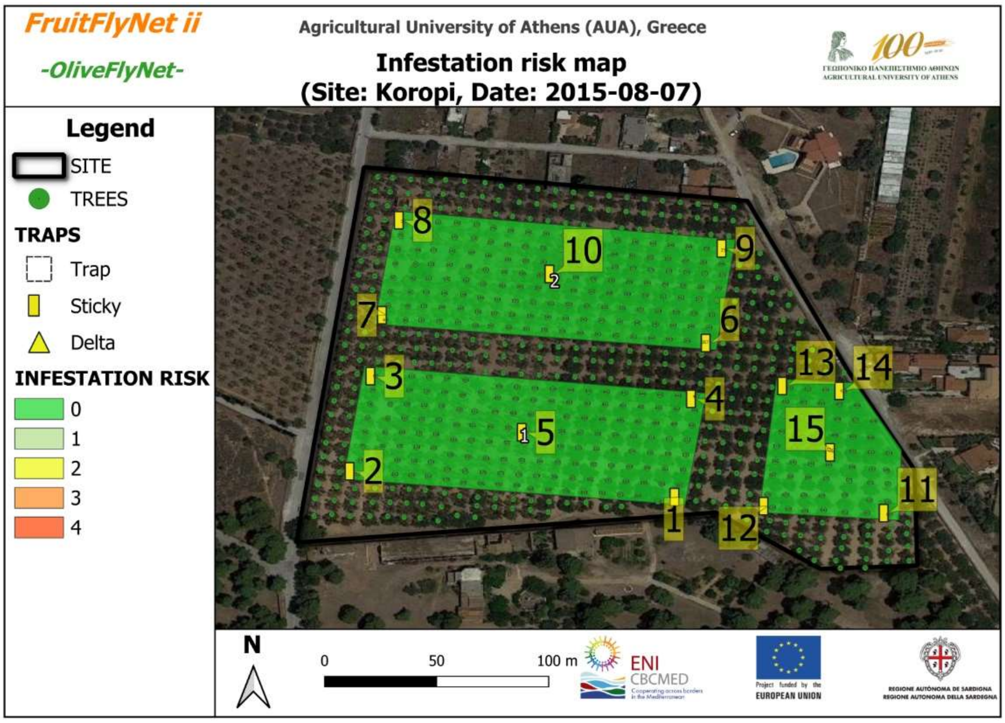


Figure 1.27: Infestation risk map (Date: 2015-08-07) (no infestation risk).

The proposed spraying map for the trapping data for the date 2015-08-07 is shown in the following figure.

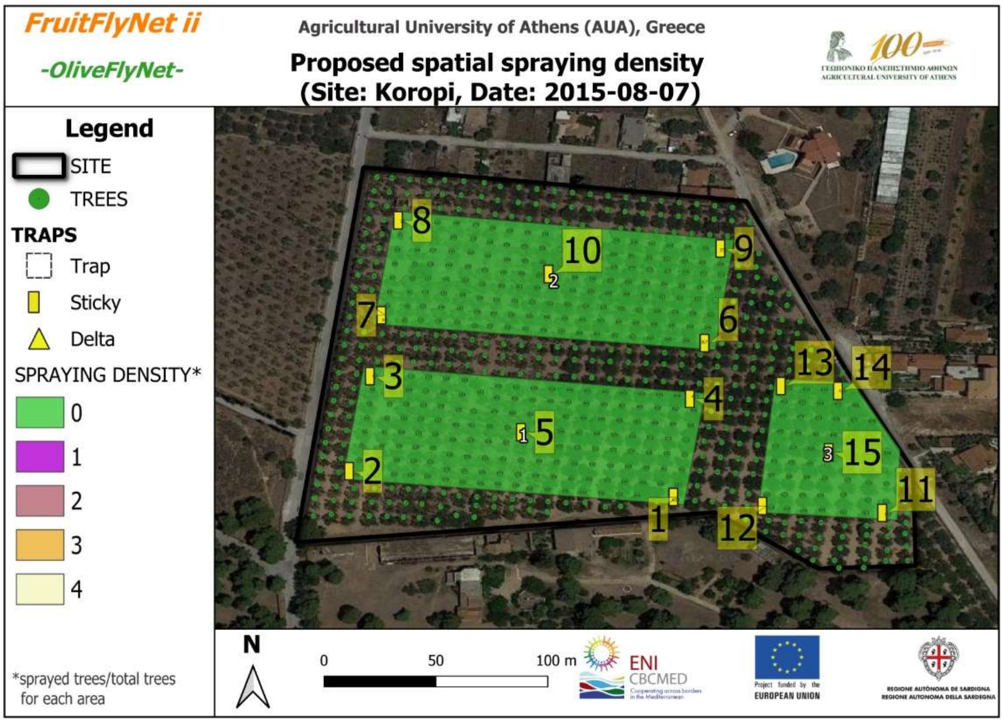


Figure 1.28: Proposed spraying map (Date: 2015-08-07) (no spraying areas)

The spatial distribution of the adult population for the trapping data for the date 2015-08-14 is shown in the following figure.

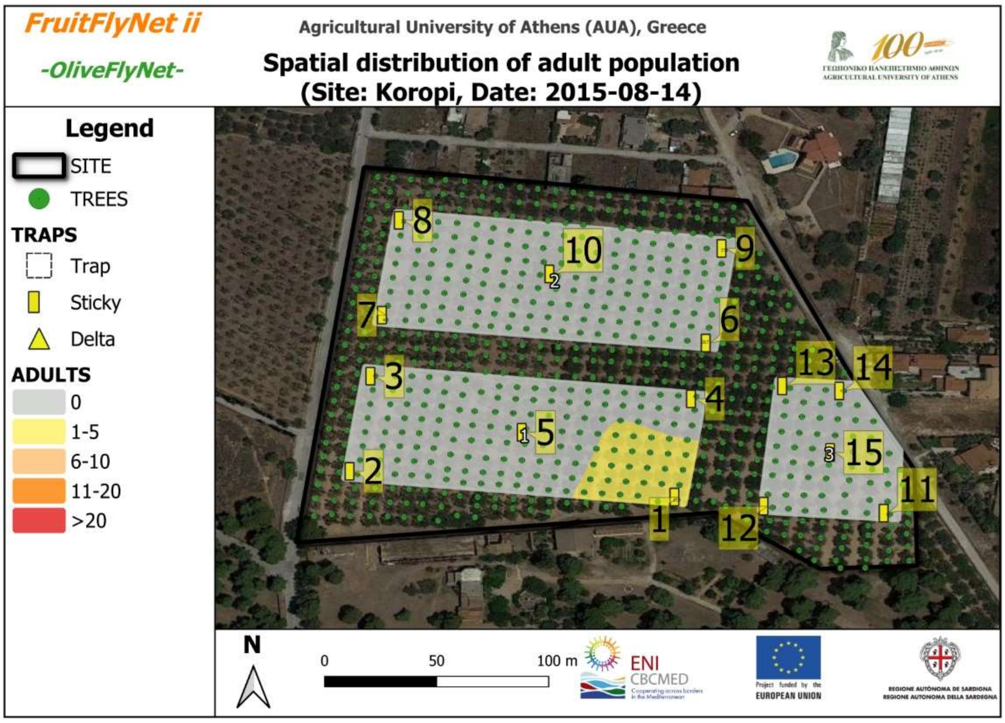


Figure 1.29: Spatial distribution of adult population (Date: 2015-08-14)

The infestation risk map for the trapping data for the date 2015-08-14 is shown in the following figure.

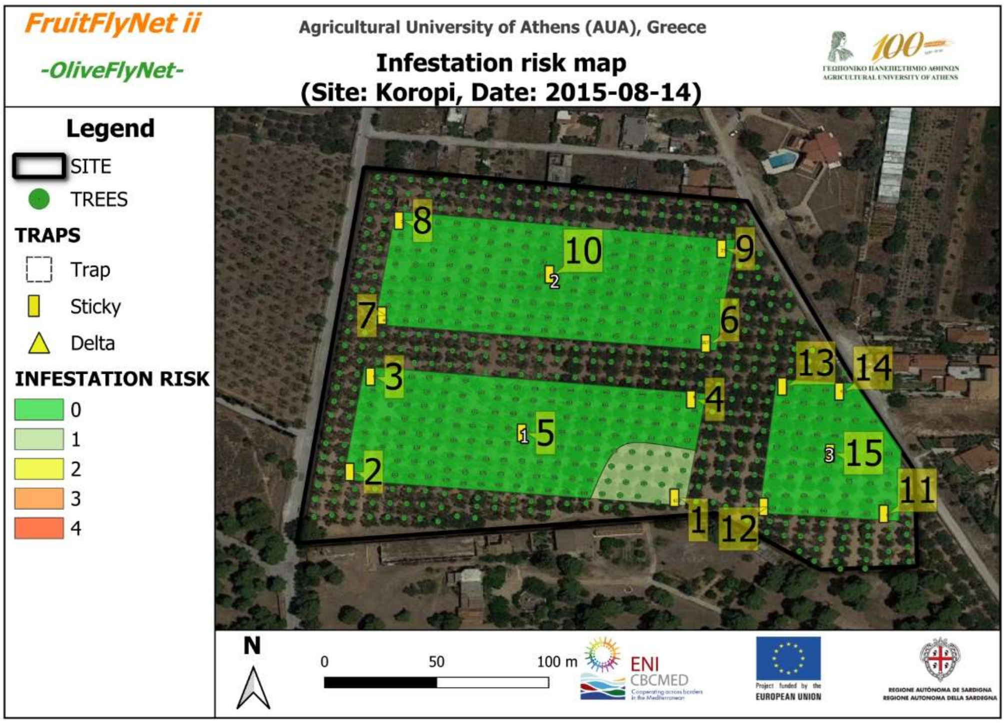


Figure 1.30: Infestation risk map (Date: 2015-08-14).

The proposed spraying map for the trapping data for the date 2015-08-14 is shown in the following figure. The map is used only if a decision for spraying has been taken.

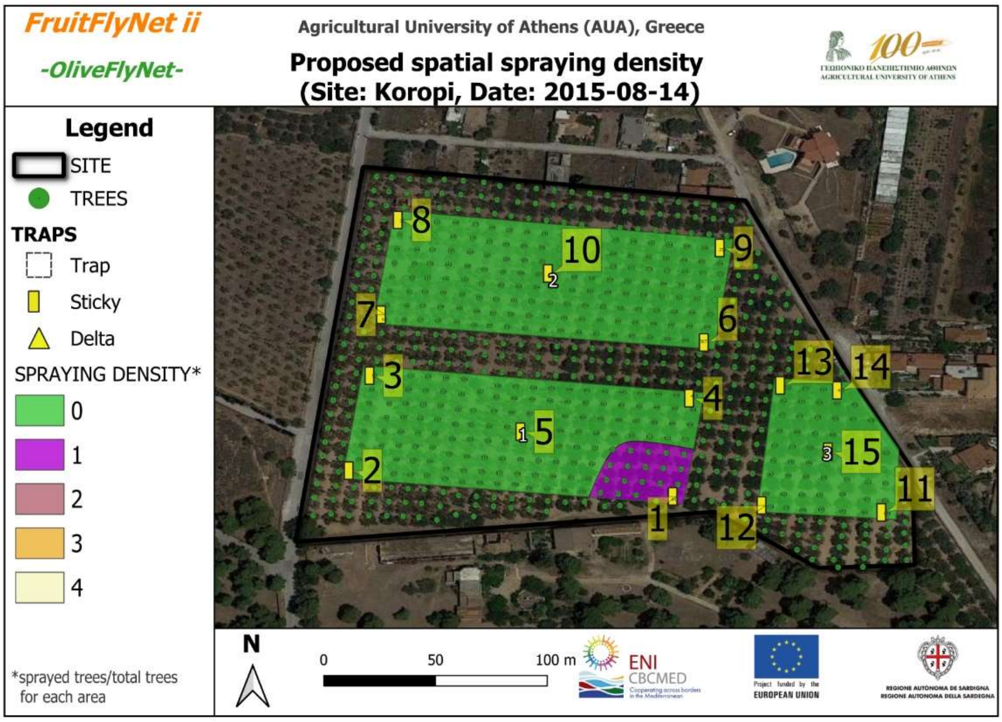


Figure 1.31: Proposed spraying map (Date: 2015-08-14).

The spatial distribution of the adult population for the trapping data for the date 2015-08-19 is shown in the following figure.

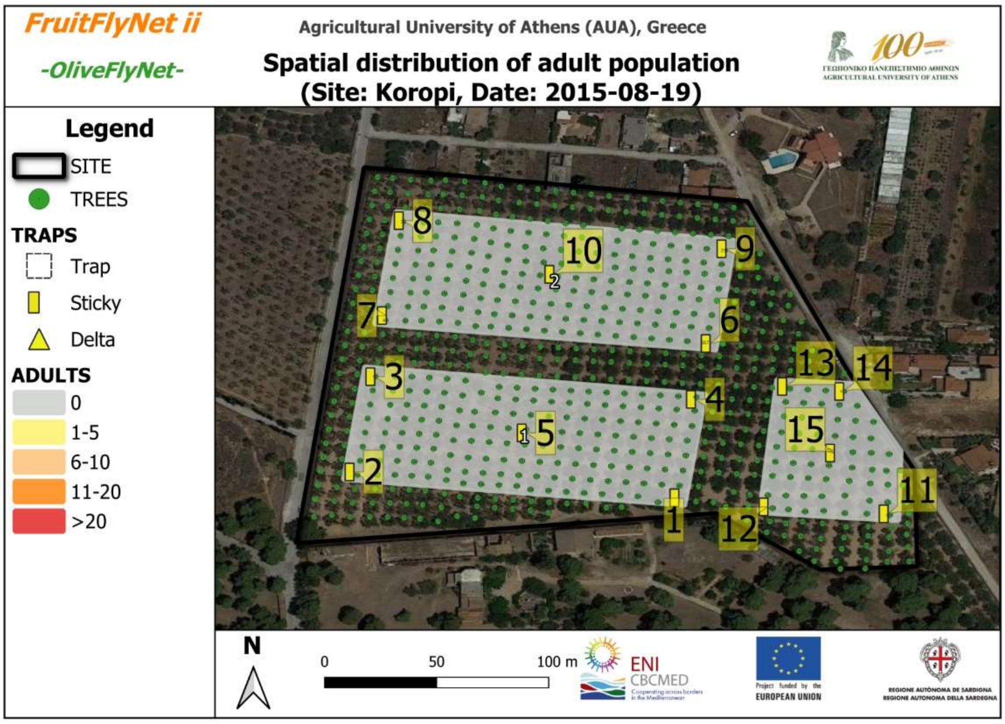


Figure 1.32: Spatial distribution of adult population (Date: 2015-08-19).

The infestation risk map for the trapping data for the date 2015-08-19 is shown in the following figure.

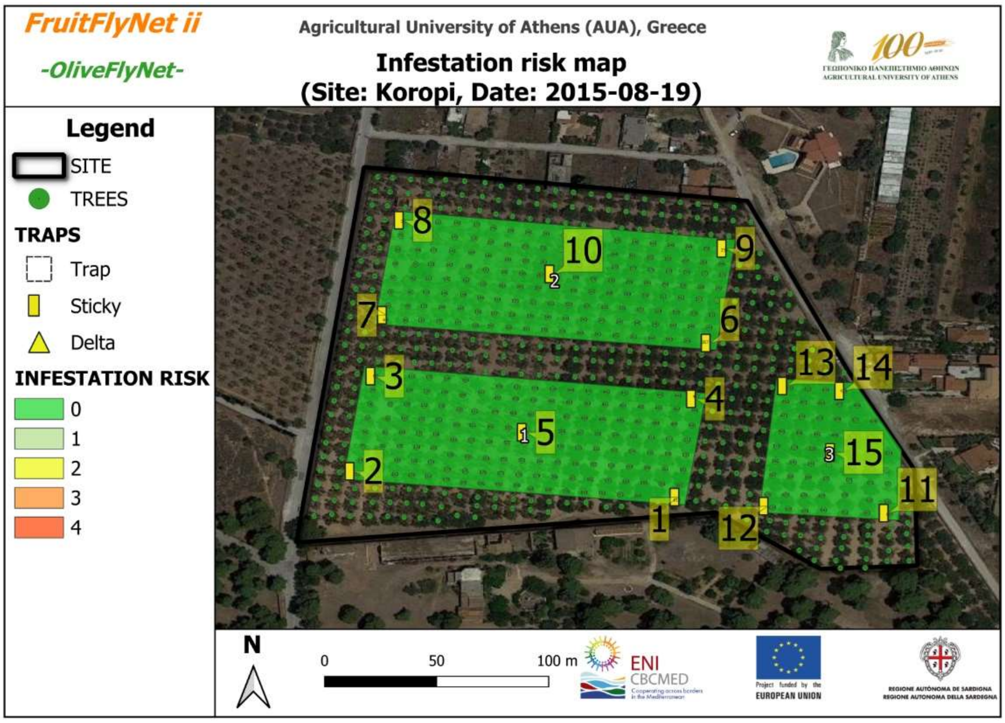


Figure 1.33: Infestation risk map (Date: 2015-08-19).

The proposed spraying map for the trapping data for the date 2015-08-19 is shown in the following figure. The map is used only if a decision for spraying has been taken.

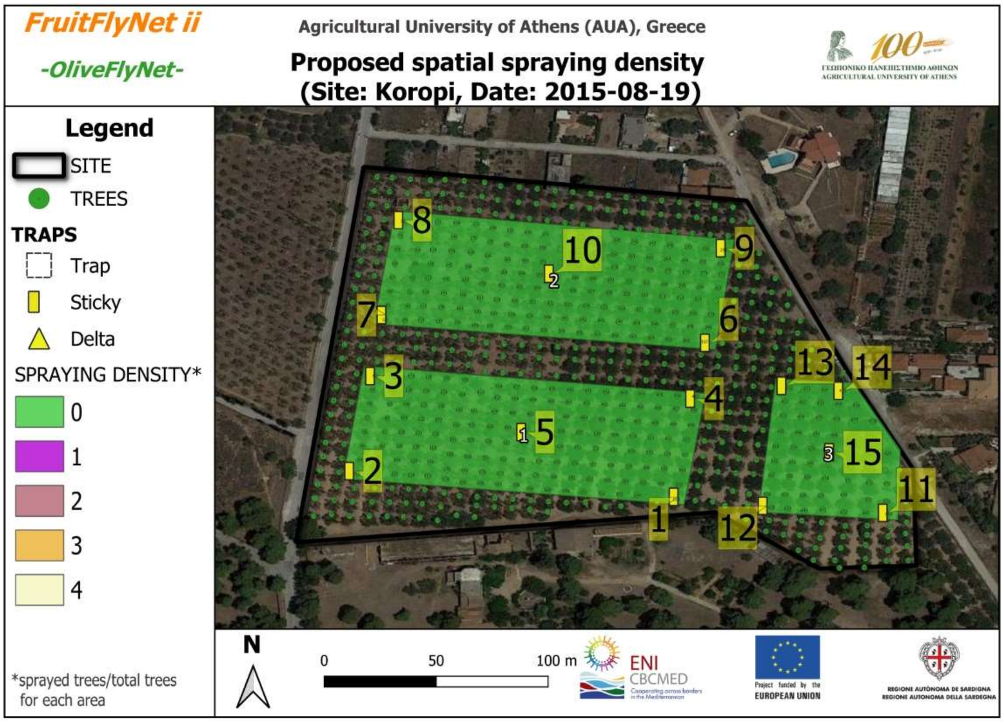


Figure 1.34: Proposed spraying map (Date: 2015-08-19)

The spatial distribution of the adult population for the trapping data for the date 2015-08-25 is shown in the following figure.

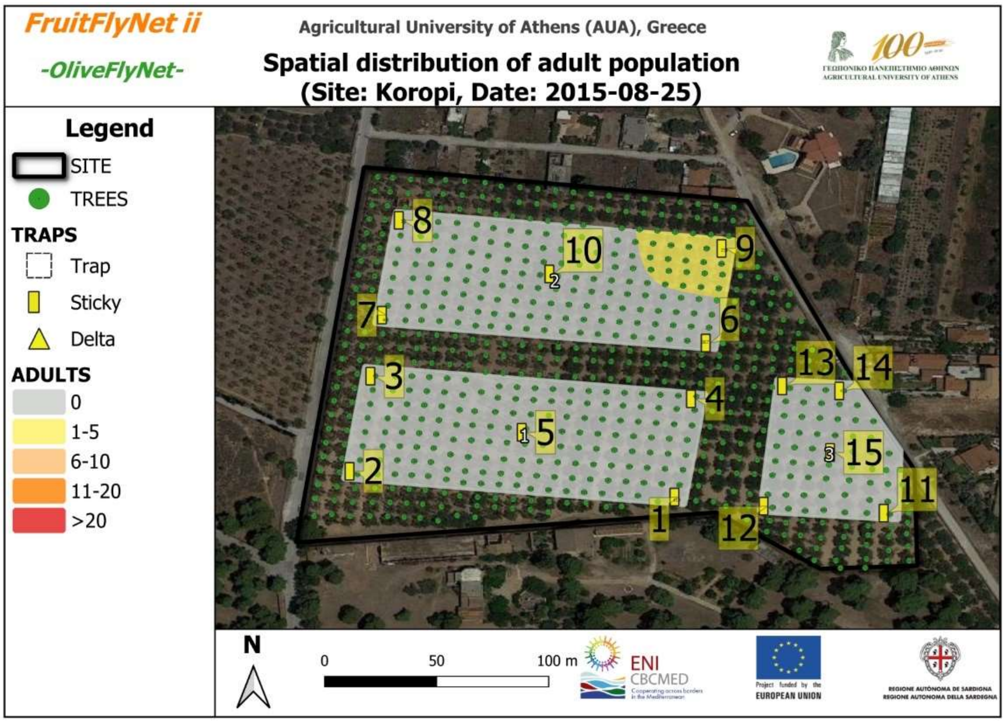


Figure 1.35: Spatial distribution of adult population (Date: 2015-08-25).

The infestation risk map for the trapping data for the date 2015-08-25 is shown in the following figure.

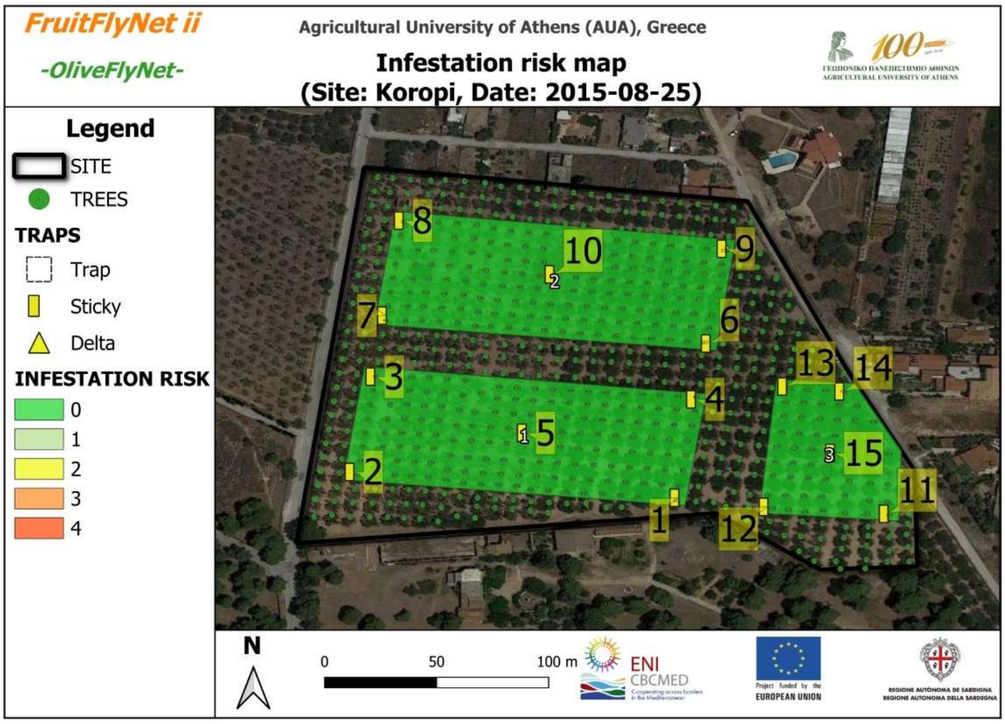


Figure 1.36: Infestation risk map (Date: 2015-08-25).

The proposed spraying map for the trapping data for the date 2015-08-25 is shown in the following figure.

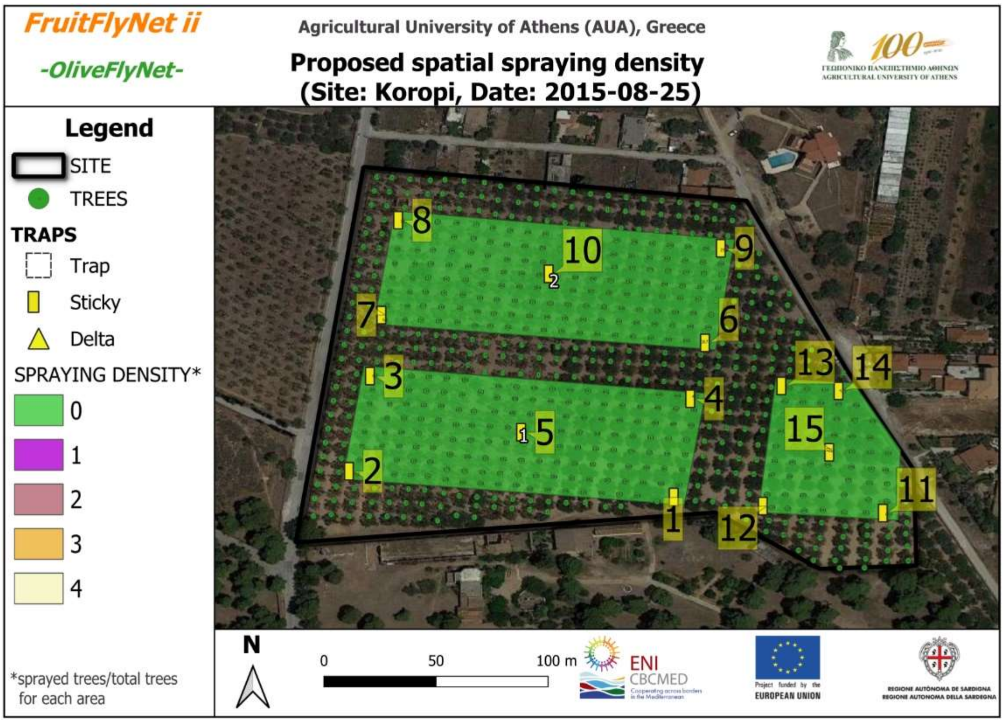


Figure 1.37: Proposed spraying map (Date: 2015-08-25).

The spatial distribution of the adult population for the trapping data for the date 2015-08-29 is shown in the following figure.

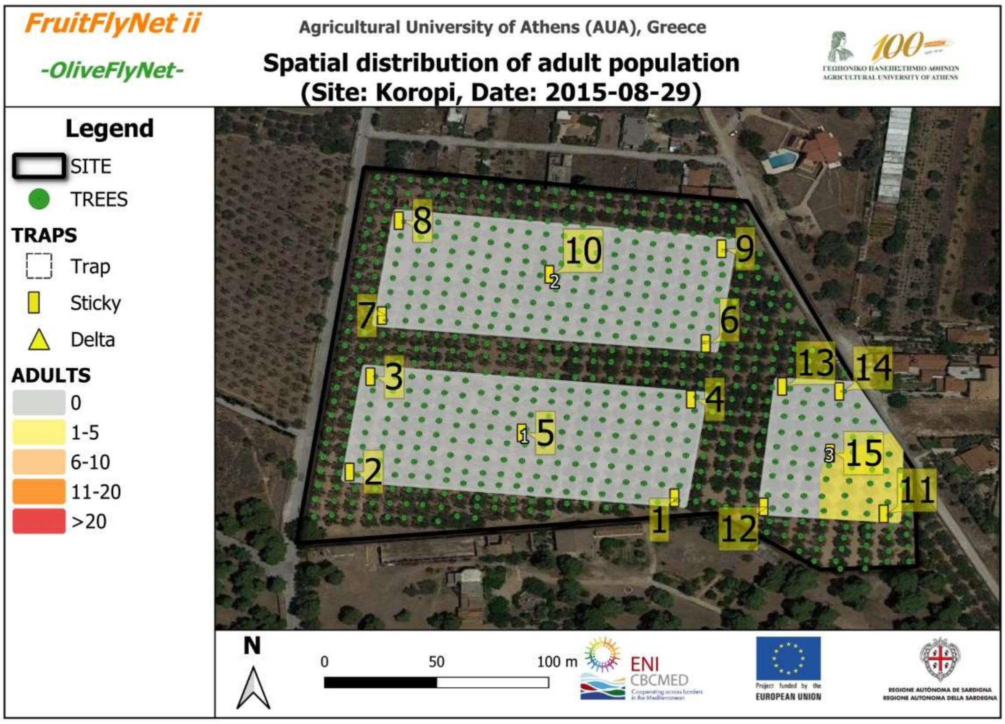


Figure 1.38: Spatial distribution of adult population (Date: 2015-08-29).

The infestation risk map for the trapping data for the date 2015-08-29 is shown in the following figure.

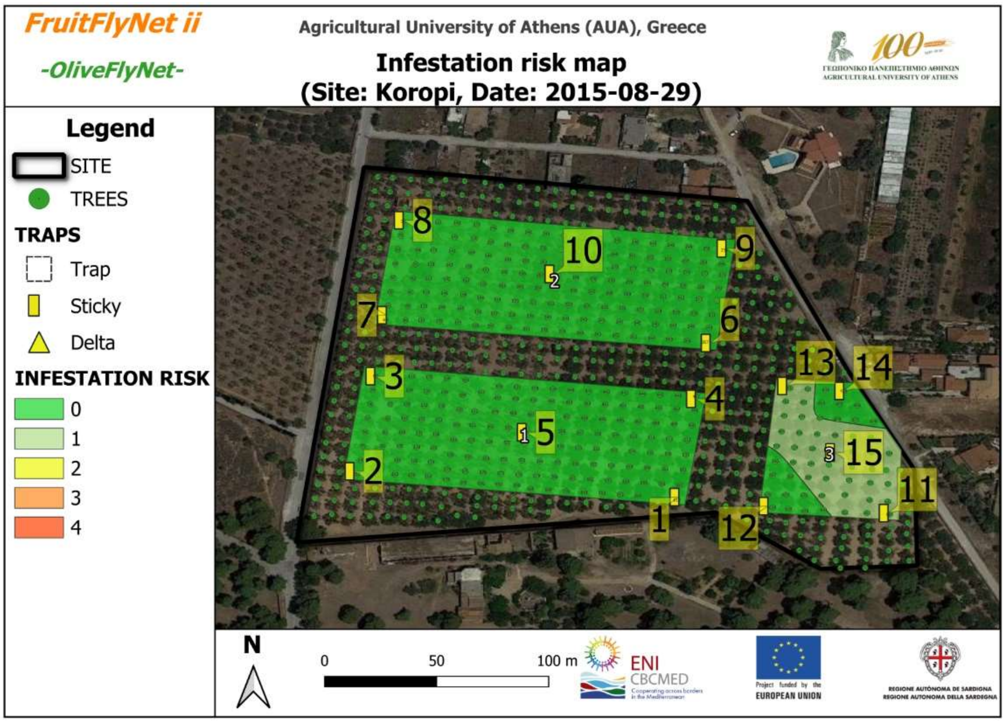


Figure 1.39: Infestation risk map (Date: 2015-08-29).

The proposed spraying map for the trapping data for the date 2015-08-29 is shown in the following figure. The map is used only if a decision for spraying has been taken.

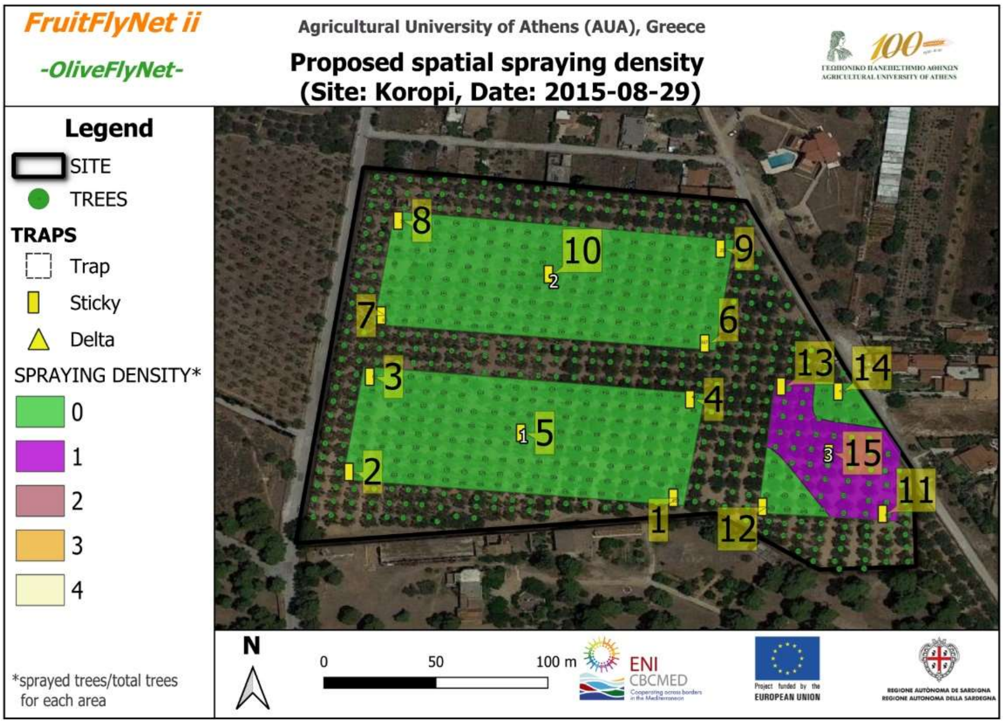


Figure 1.40: Proposed spraying map (Date: 2015-08-29).

The spatial distribution of the adult population for the trapping data for the date 2015-09-08 is shown in the following figure.

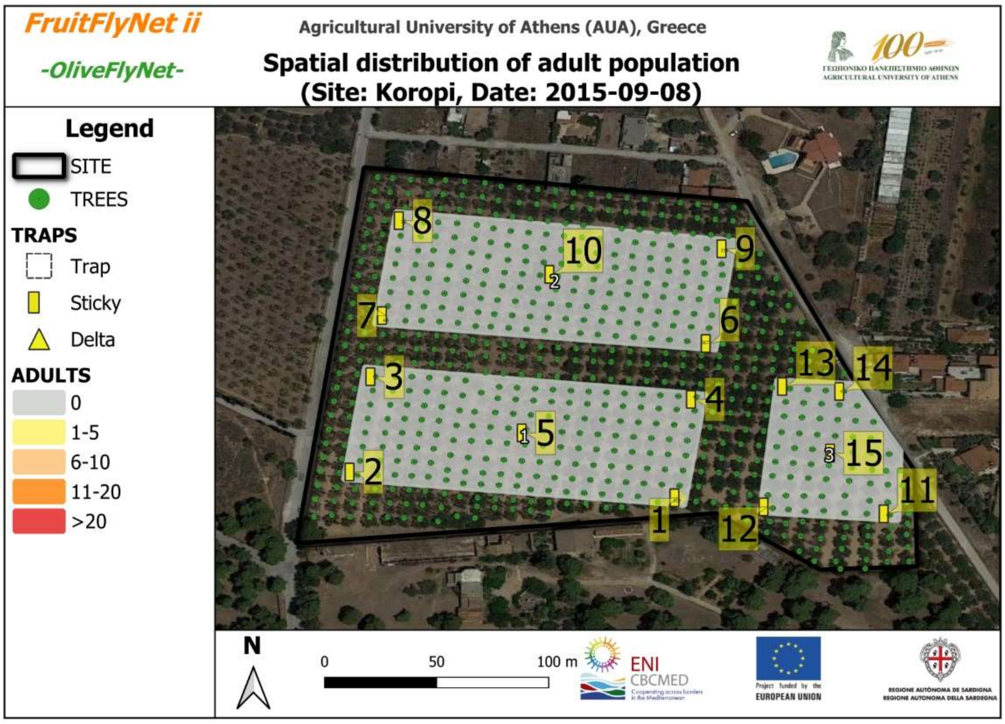


Figure 1.41: Spatial distribution of adult population (Date: 2015-09-08).

The infestation risk map for the trapping data for the date 2015-09-08 is shown in the following figure.

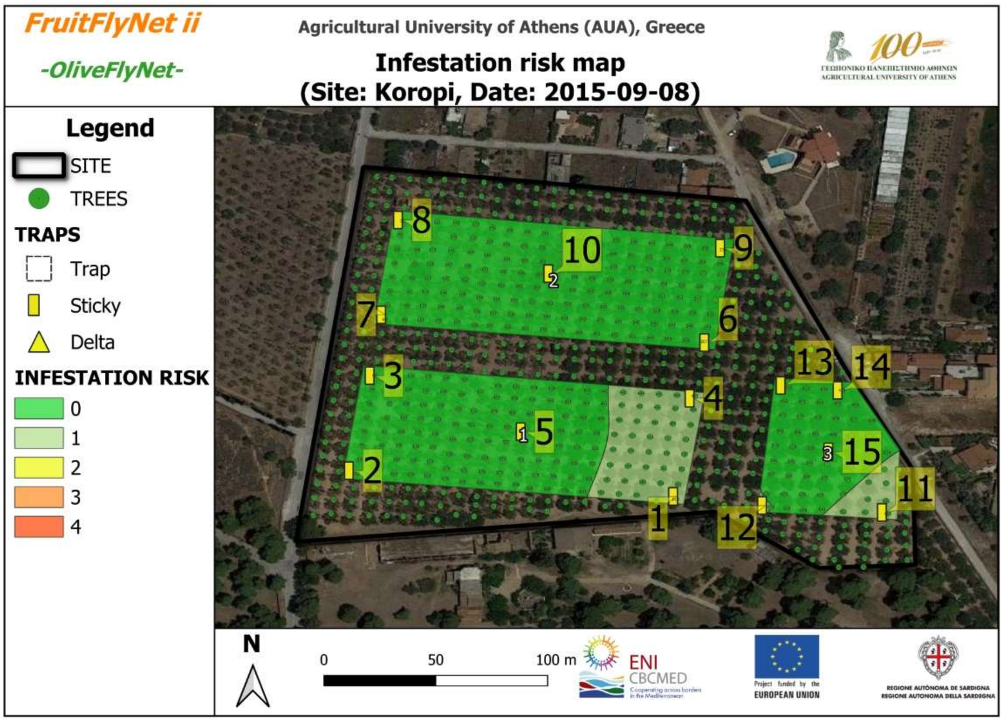


Figure 1.42: Infestation risk map (Date: 2015-09-08).

The proposed spraying map for the trapping data for the date 2015-09-08 is shown in the following figure. The map is used only if a decision for spraying has been taken.

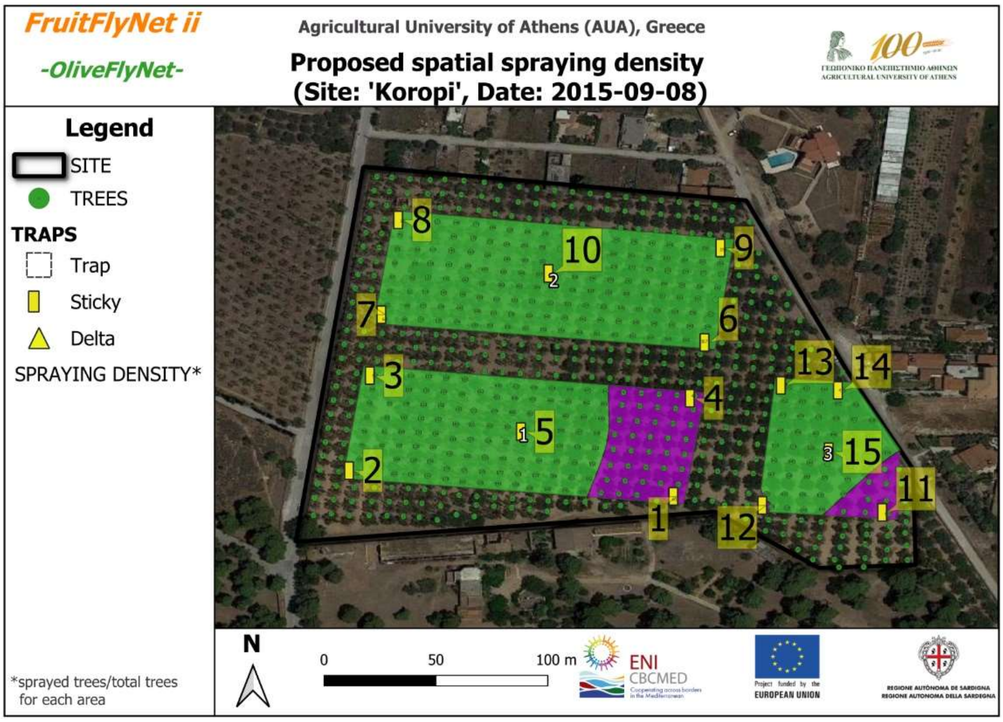


Figure 1.43: Proposed spraying map (Date: 2015-09-08).

The spatial distribution of the adult population for the trapping data for the date 2015-09-13 is shown in the following figure.

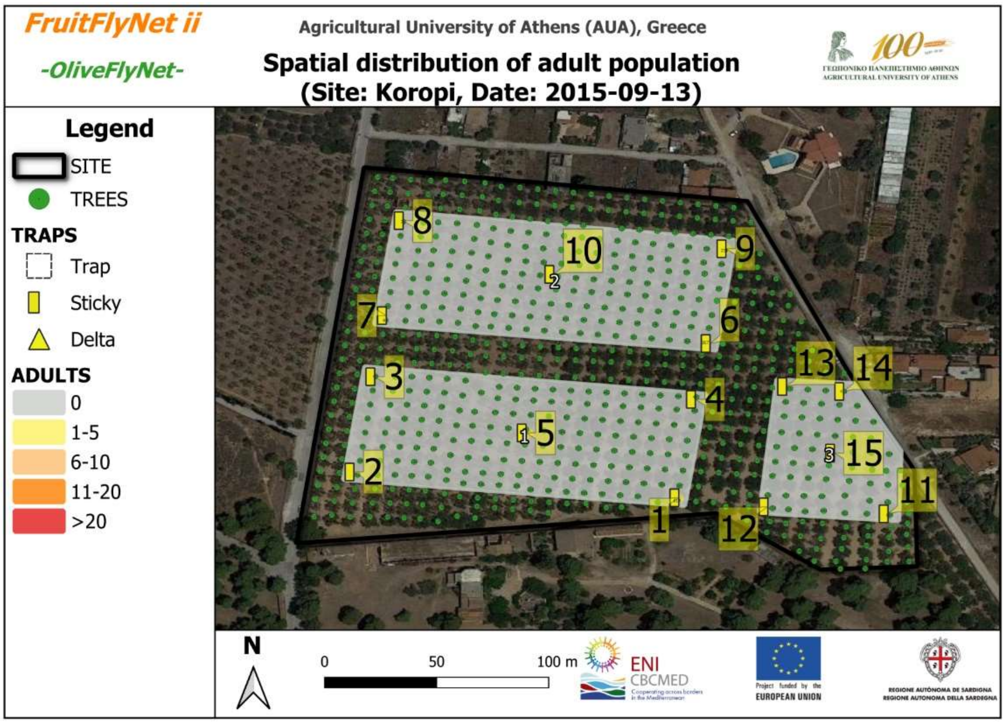


Figure 1.44: Spatial distribution of adult population (Date: 2015-09-13).

The infestation risk map for the trapping data for the date 2015-09-13 is shown in the following figure.

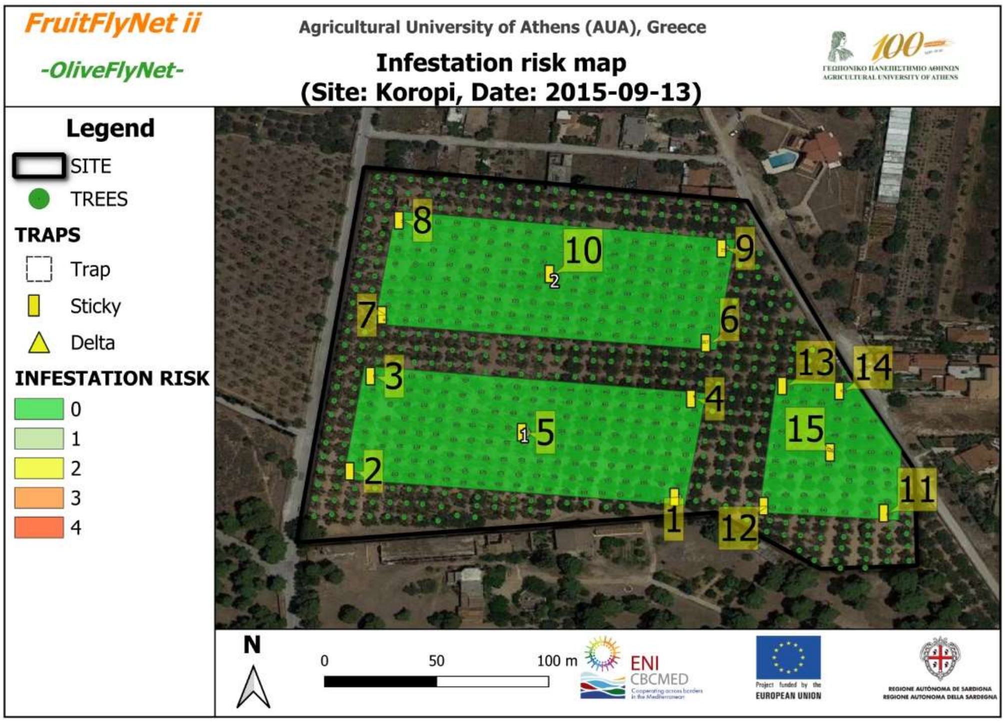


Figure 1.45: Infestation risk map (Date: 2015-09-13).

The proposed spraying map for the trapping data for the date 2015-09-13 is shown in the following figure.

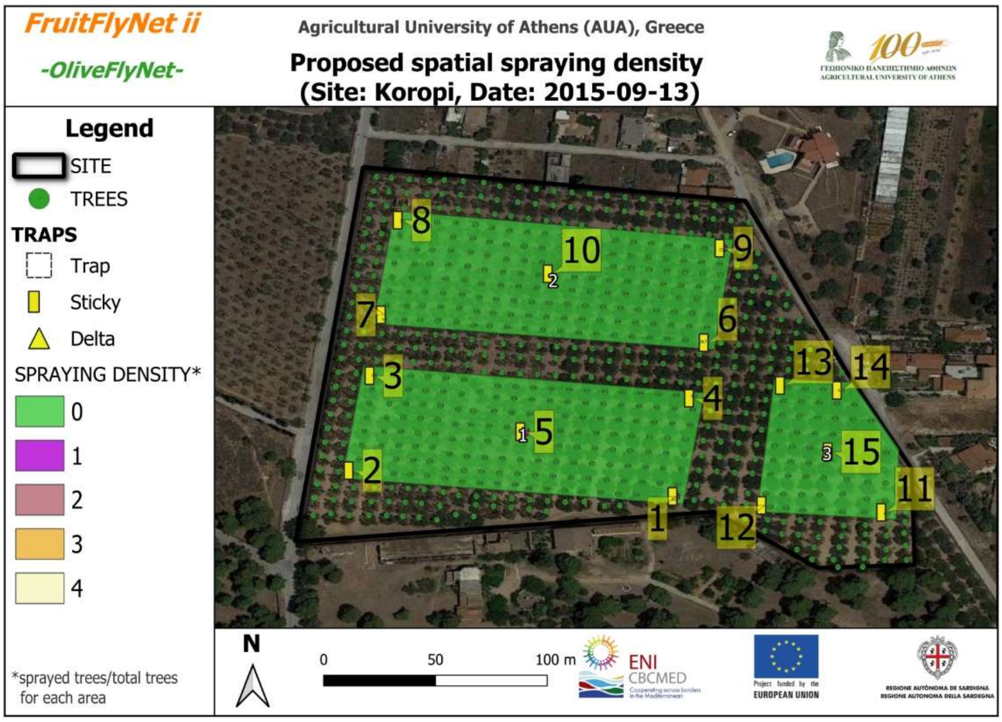


Figure 1.46: Proposed spraying map (Date: 2015-09-13).

The duration of the creation of risk maps using the e-services of the LAS requires only a few seconds as shown in the following table. In the table the duration of the whole process, including that of the execution of the internal libraries of QGIS. Therefore, the duration does not increase when more data are elaborated.

Table 1.6: Duration of the e-services of risk map creation.

Date of trap counting	Duration of the e-services for risk map creation (in seconds)	Duration of the e-services (execution all services) (in seconds)
2015-07-03	9.75	38.60
2015-08-04	9.90	75.31
2015-08-07	9.73	38.10
2015-08-14	9.74	52.52
2015-08-19	9.75	39.98
2015-08-25	9.85	46.67
2015-08-29	9.93	49.81
2015-09-08	9.87	58.14
2015-09-13	9.77	55.49
Mean duration*	**9.81**	**50.51**

*

1.5.2.2. Maps creation using simulated traps' captures.

Using the past data, it was not possible to test all the cases of the e-services results. For this reason, we created simulated scenarios using artificial data. The data for the simulated scenarios A1 and A2 are shown in the next table.

Table 1.7: Data for the Simulation A1 or A2.

Trap ID	Males	Females	Sum
1	5	2	**7**
2	2	1	**3**
3	0	1	**1**
4	1	1	**2**
5	0	0	**0**
6	1	0	**1**
7	2	2	**4**
8	3	1	**4**
9	1	1	**2**
10	0	0	**0**
11	6	4	**10**
12	3	12	**15**
13	2	3	**5**
14	2	3	**5**
15	0	0	**0**
Sum	**28**	**31**	**59**

The spatial distribution of the adult population for the trapping data for the Simulation A1 is shown in the following figure.

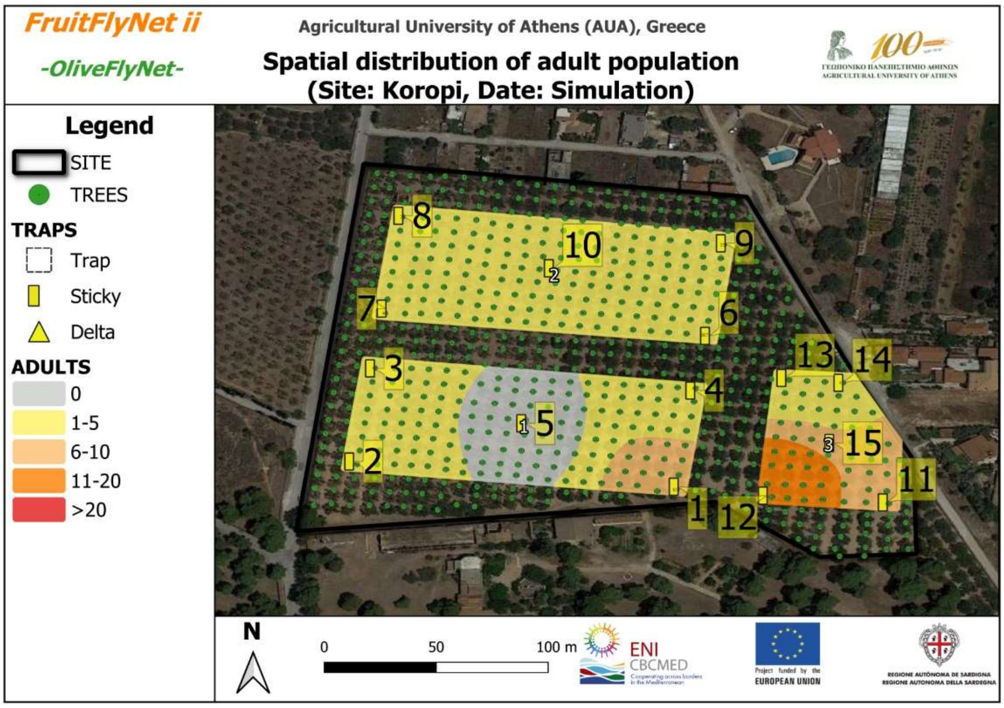


Figure 1.47: Spatial distribution of adult population (Date: Simulation A1).

The infestation risk map for the trapping data for the Simulation A1 is shown in the following figure.

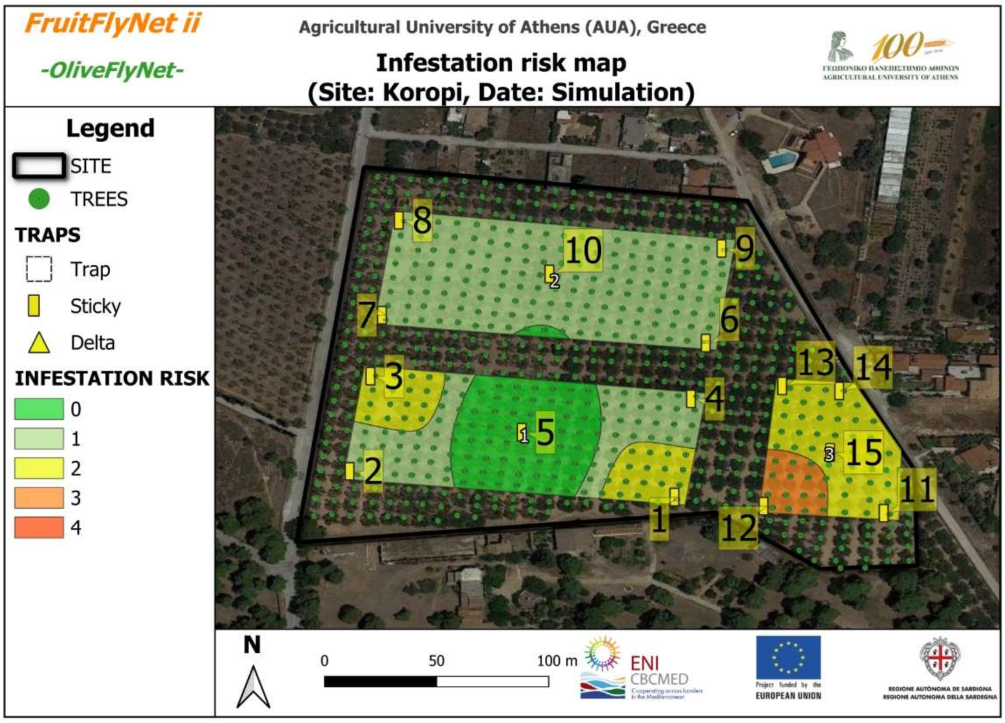


Figure 1.48: Infestation risk map (Date: Simulation A1).

The proposed spraying map for the trapping data for the Simulation A1 is shown in the following figure. The map is used only if a decision for spraying has been taken.

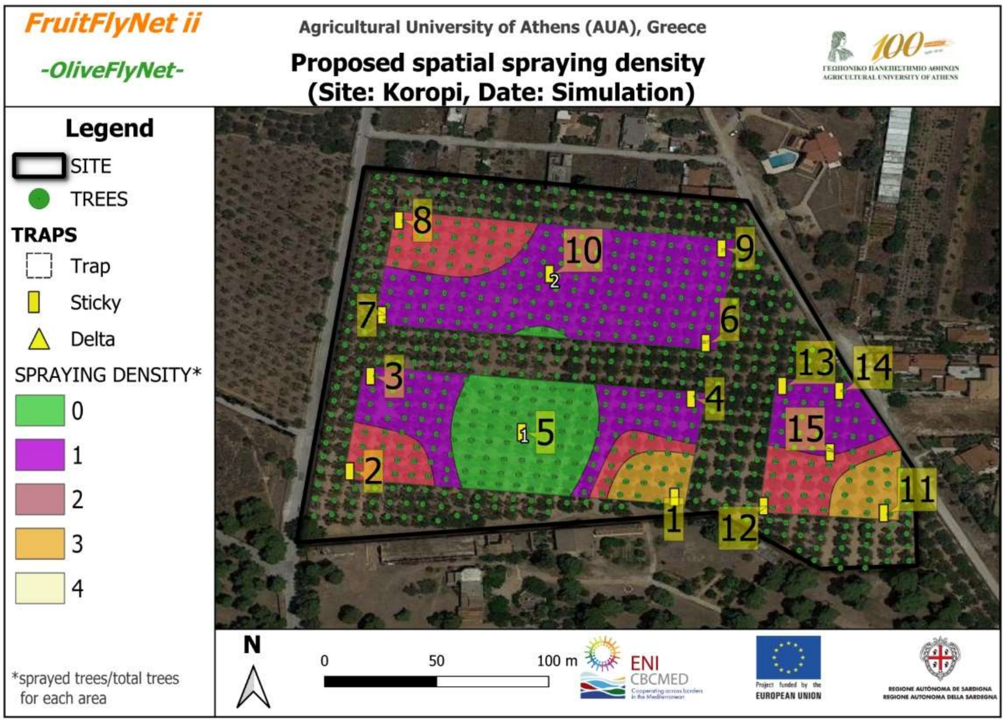


Figure 1.49: Proposed spraying map (Date: Simulation A1).

The spatial distribution of the adult population for the trapping data for the Simulation A2 is shown in the following figure.

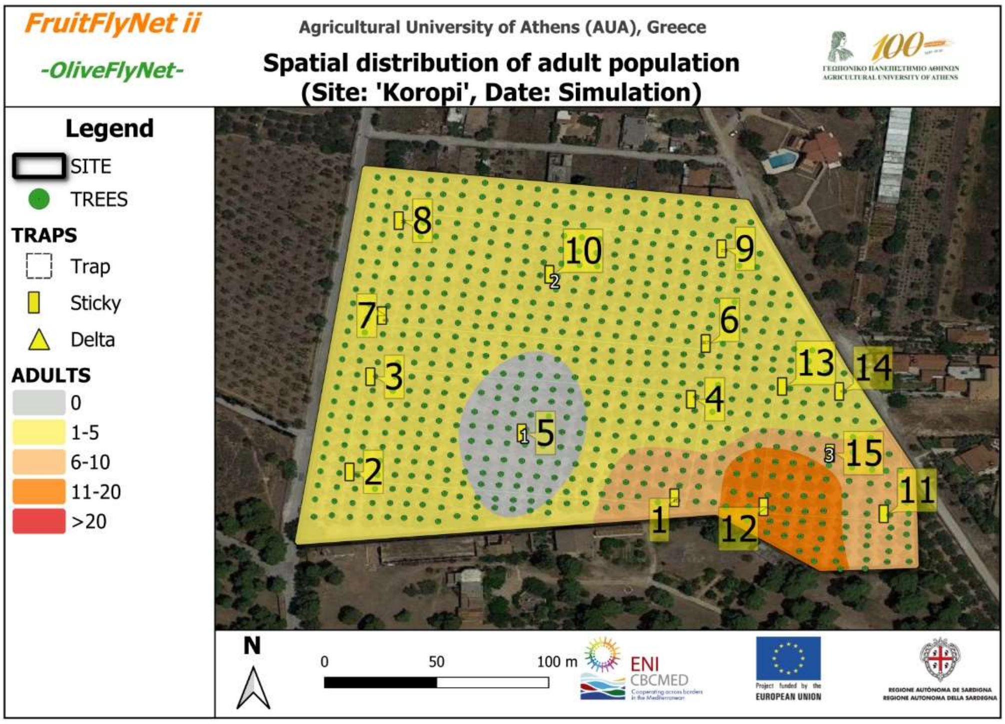


Figure 1.50: Spatial distribution of adult population (Date: Simulation A2).

The infestation risk map for the trapping data for the Simulation A2 is shown in the following figure.

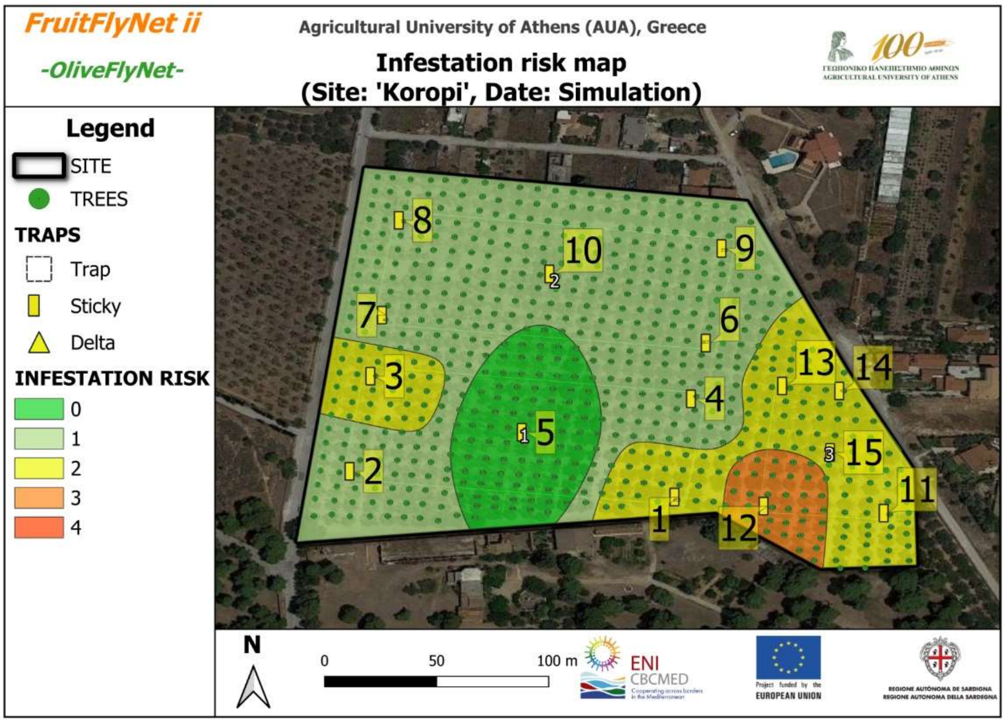


Figure 1.51: Infestation risk map (Date: Simulation A2).

The proposed spraying map for the trapping data for the Simulation A2 is shown in the following figure. The map is used only if a decision for spraying has been taken.

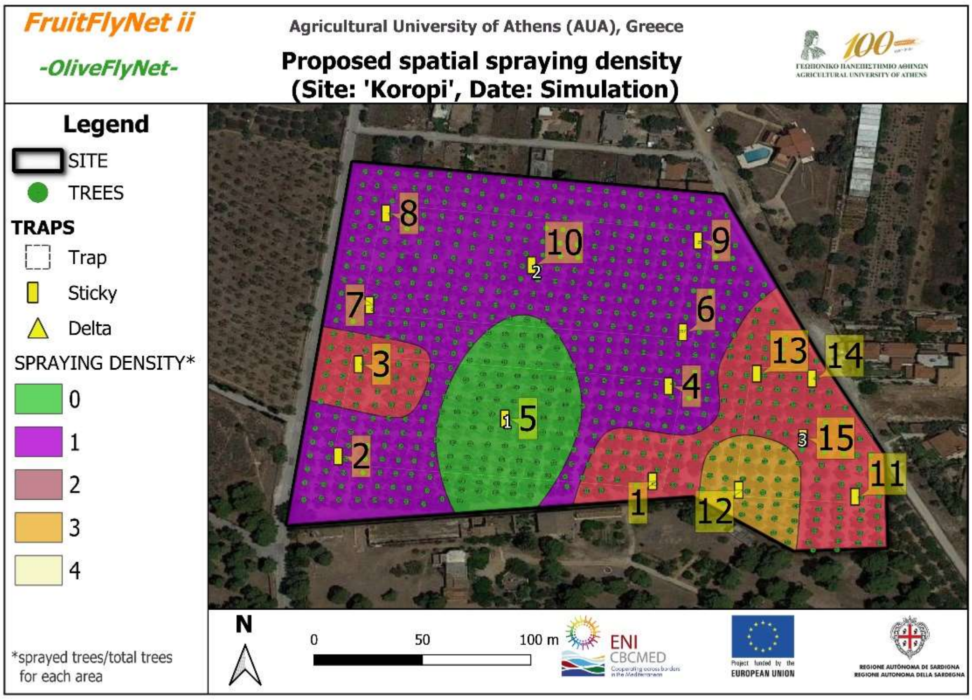


Figure 1.52: Proposed spraying map (Date: Simulation A2).

The data for the simulated scenarios B1 and B2 are shown in the next table.

Table 1.8: Data for the Simulation B1 or B2

Trap ID	Males	Females	Sum
1	2	5	7
2	1	2	3
3	1	0	1
4	1	1	2
5	0	0	0
6	1	0	1
7	2	2	4
8	1	3	4
9	1	1	2
10	0	0	0
11	4	6	10
12	12	3	15
13	3	2	5
14	3	2	5
15	0	0	0
Sum	**31**	**28**	**59**

The spatial distribution of the adult population for the trapping data for the Simulation B1 is shown in the following figure.

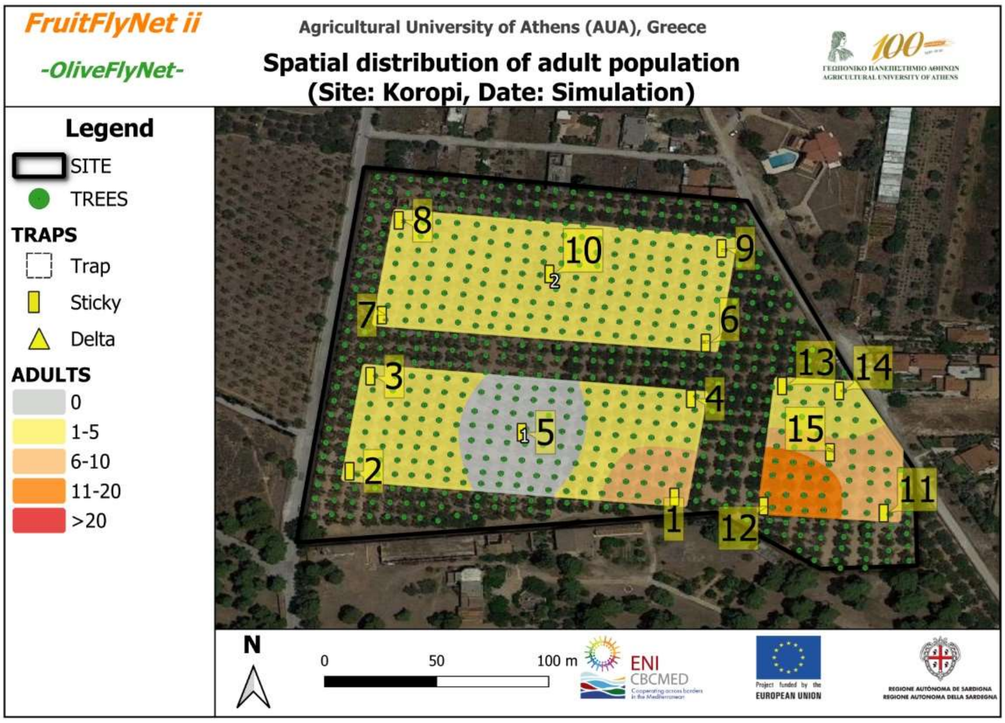


Figure 1.53: Spatial distribution of adult population (Date: Simulation B1).

The infestation risk map for the trapping data for the Simulation B1 is shown in the following figure.

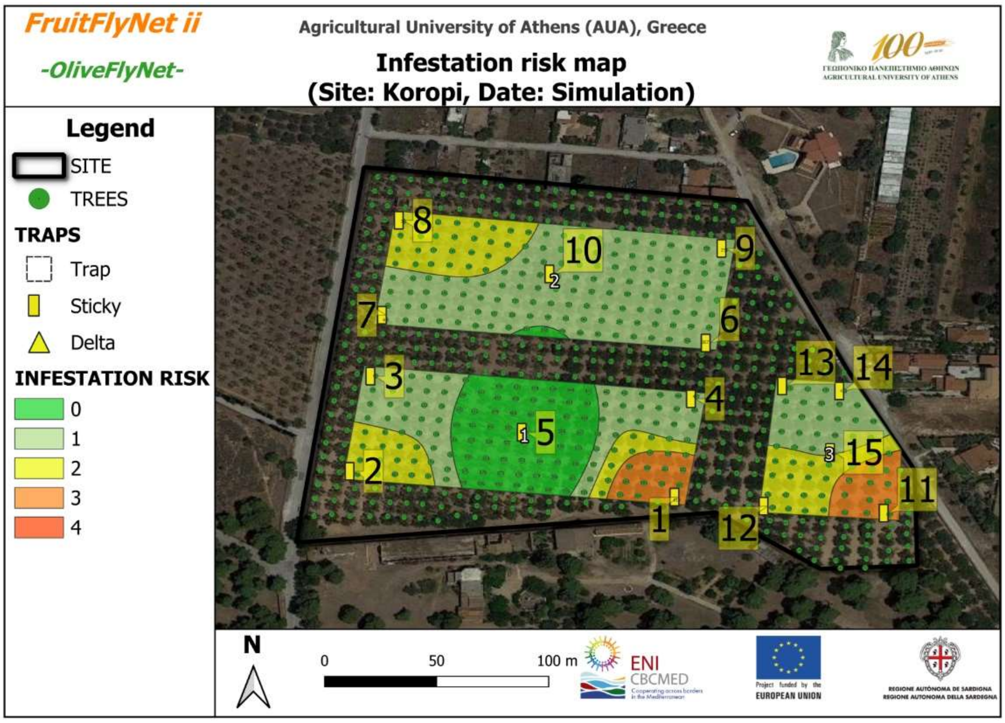


Figure 1.54: Infestation risk map (Date: Simulation B1).

The proposed spraying map for the trapping data for the Simulation B1 is shown in the following figure. The map is used only if a decision for spraying has been taken.

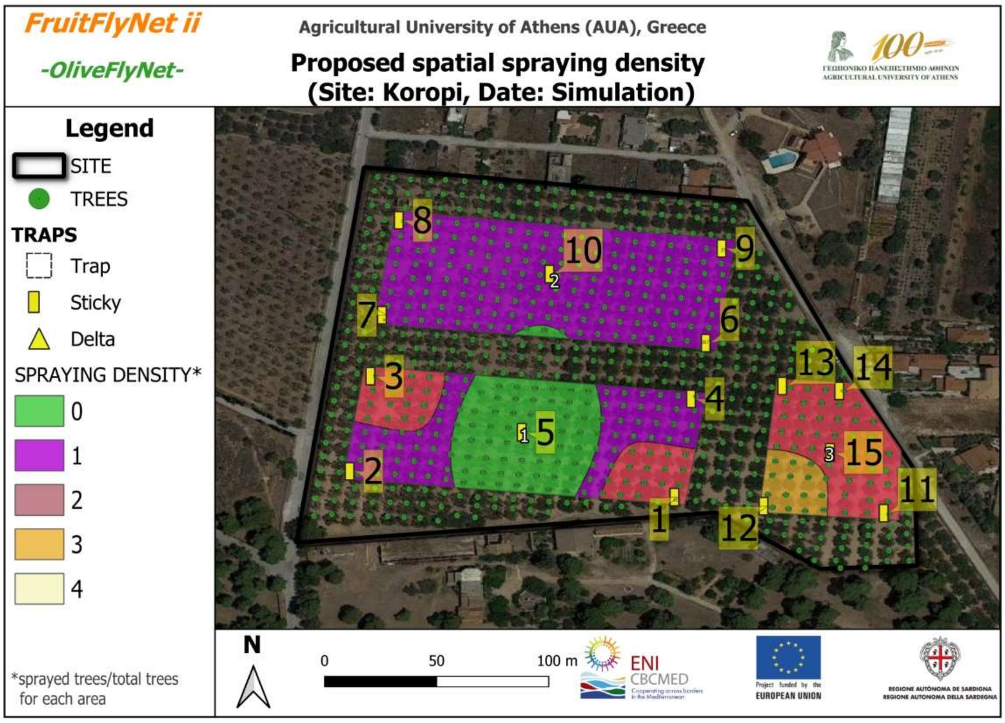


Figure 1.55: Proposed spraying map (Date: Simulation B1).

The spatial distribution of the adult population for the trapping data for the Simulation B2 is shown in the following figure.

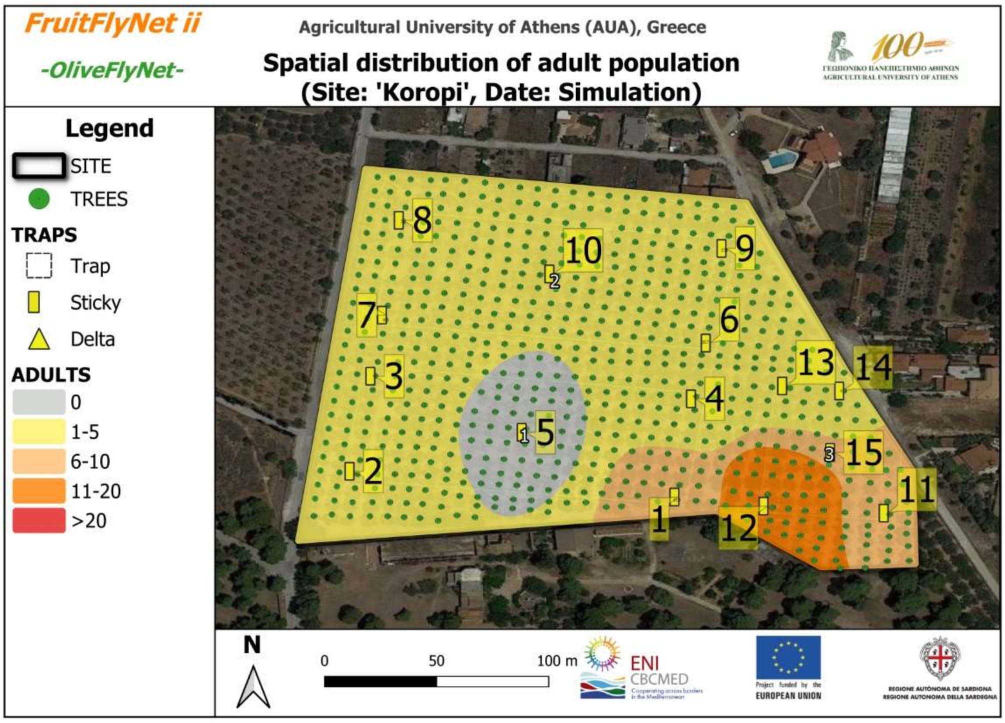


Figure 1.56: Spatial distribution of adult population (Date: Simulation B2).

The infestation risk map for the trapping data for the Simulation B2 is shown in the following figure.

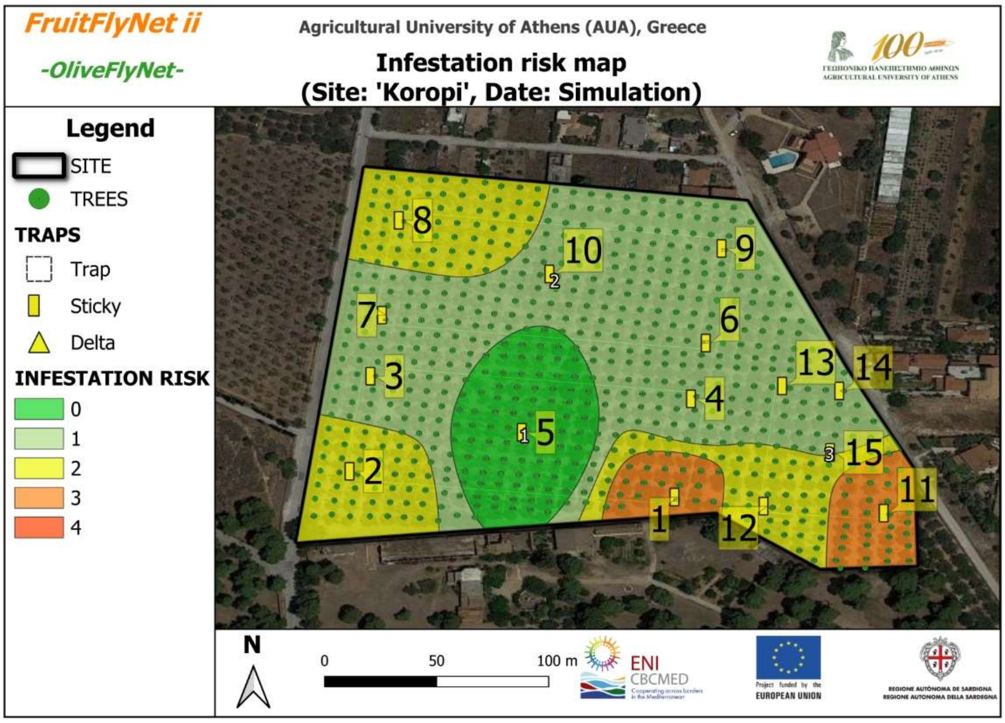


Figure 1.57: Infestation risk map (Date: Simulation B2).

The proposed spraying map for the trapping data for the Simulation B2 is shown in the following figure. The map is used only if a decision for spraying has been taken.

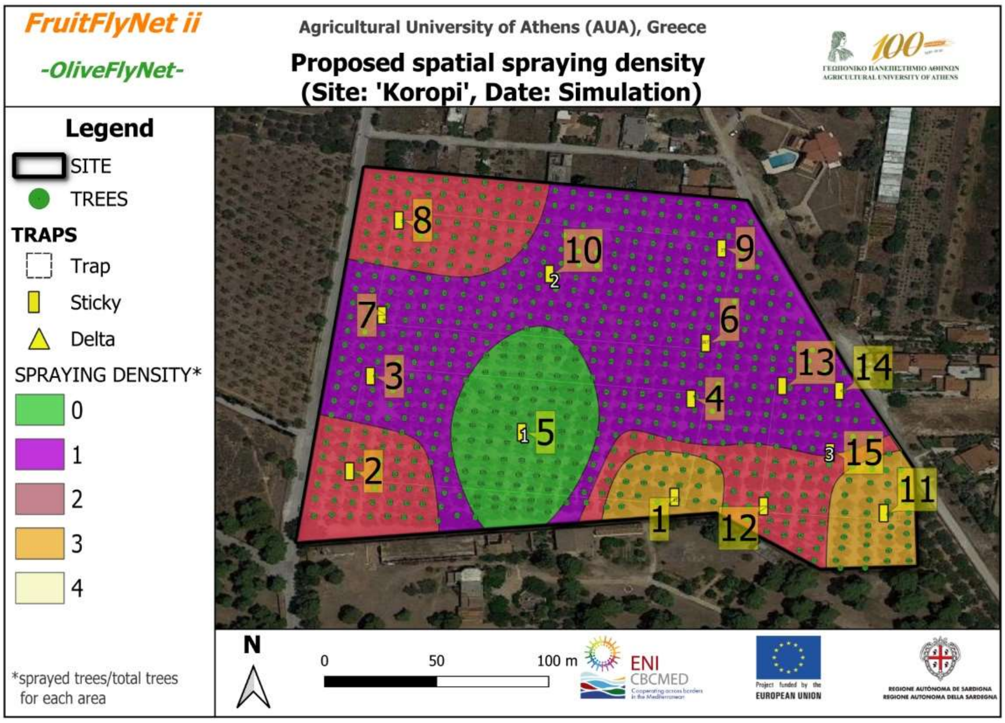


Figure 1.58: Proposed spraying map (Date: Simulation B2).

The data for the simulated scenario C (high pest numbers) are shown in the next table.

Table 1.9: Data for the Simulation B1 or B2.

Trap ID	Males	Females	Sum
1	6	15	**21**
2	3	6	**9**
3	3	0	**3**
4	3	3	**6**
5	0	0	**0**
6	3	0	**3**
7	6	3	**9**
8	3	9	**12**
9	3	3	**6**
10	0	0	**0**
11	12	9	**21**
12	36	9	**45**
13	9	8	**17**
14	9	6	**15**
15	0	0	**0**
Sum	**96**	**71**	**167**

The spatial distribution of the adult population for the trapping data for the Simulation C is shown in the following figure.

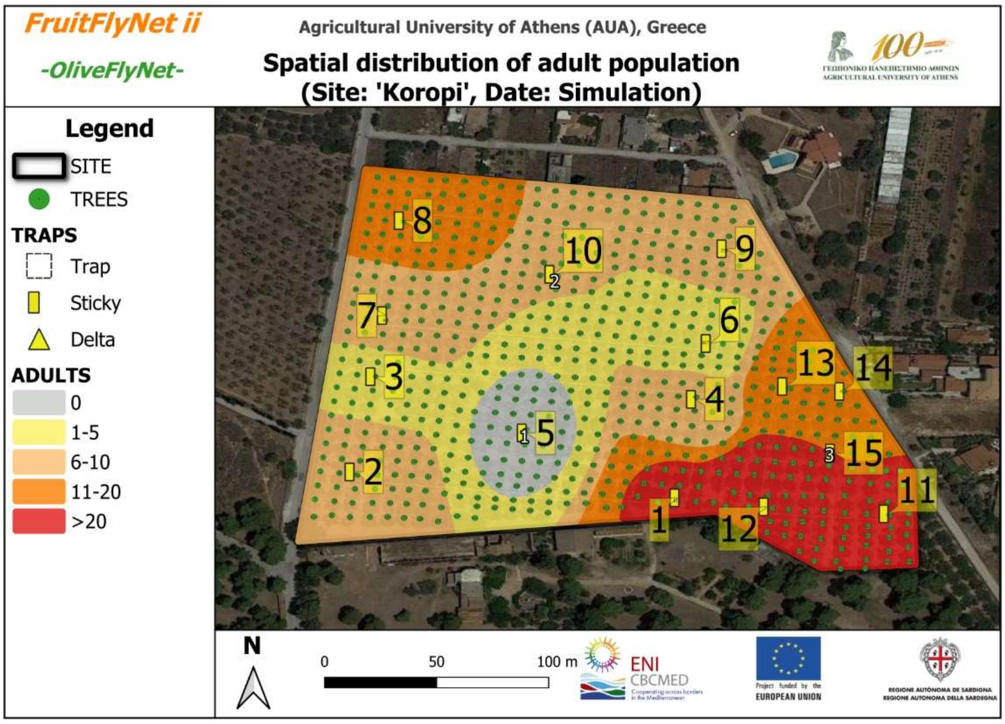


Figure 1.59: Spatial distribution of adult population (Date: Simulation C).

The infestation risk map for the trapping data for the Simulation C is shown in the following figure.

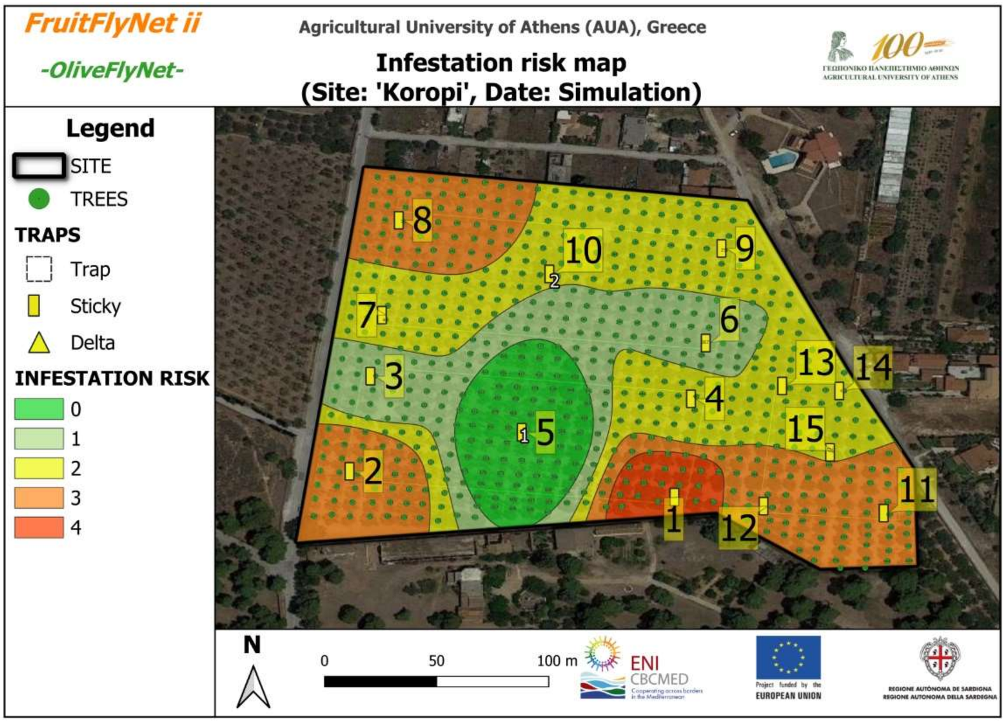


Figure 1.60: Infestation risk map (Date: Simulation C).

The proposed spraying map for the trapping data for the Simulation C is shown in the following figure. The map is used only if a decision for spraying has been taken.

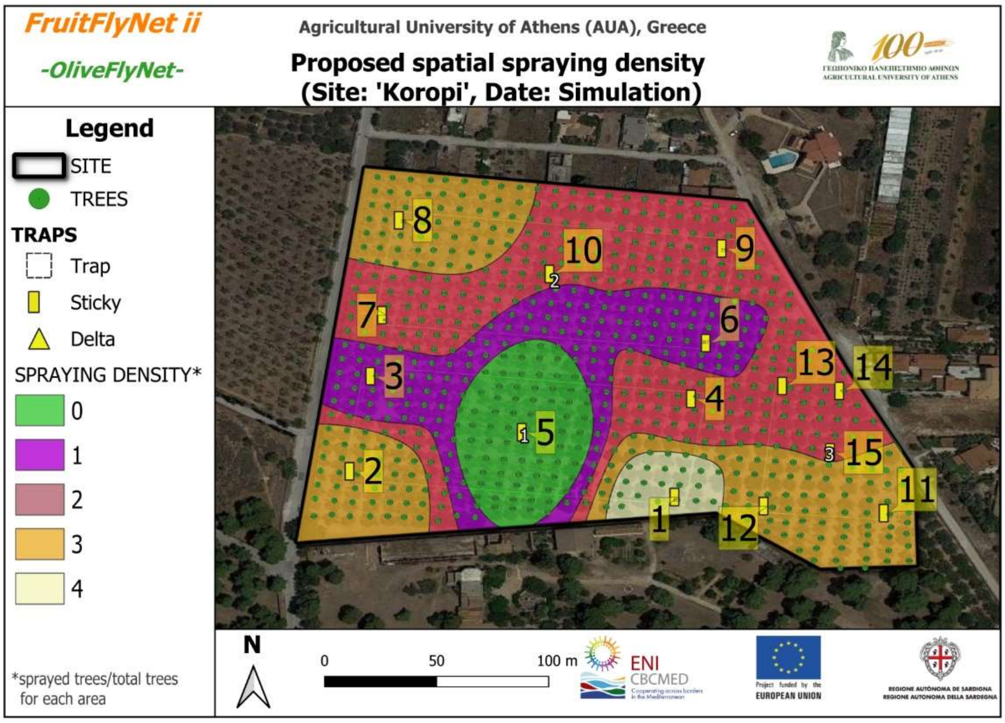


Figure 1.61: Proposed spraying map (Date: Simulation C).

1.5.3. Discussion

The simulations produced maps for the distribution of the insect population, the infestation risk and the spraying distribution. In this way we tested the functionality of e-services under variable pest level and pest distribution scenarios. The results showed that the algorithms are functioning well for all the cases they are designed for. Therefore, the updated β

1.6. E-services for traps distribution

1.6.1. Methodology

To define the optimum distribution pattern of the given number of traps in an olive grove and to replace the empirical approaches in use so far, we implemented spatial methodology procedures using the QGIS software. The first step is to select the target area and the trees of that area, mainly by selecting the olive groves' (owners) layer and the respective trees' layer from the geodatabase. The next step is to provide the total number of traps which we are going to be established in the selected area. The accuracy of the spatial distribution of the traps is affected by the RND value that the user enters to the algorithm. The RND value is the number of random points that distributed in the selected area. Larger RND values may increase the accuracy of the distributed trap network but also may increase the execution time of the algorithm. The outcome of the algorithm is the creation of two layers of points and two layers of polygons. The point layers are the theoretical trap layer and the proposed trap layer. The theoretical trap layer gives the optimum distribution of the traps in the selected area, while the proposed trap layer gives the distribution of the traps in the selected area at a tree level (i.e. giving also the tree on which each trap should be placed). The polygon layers are the voronoi distribution of the theoretical and proposed layers. The methodology of the automatic design of the distribution of the traps is shown in the following figure:

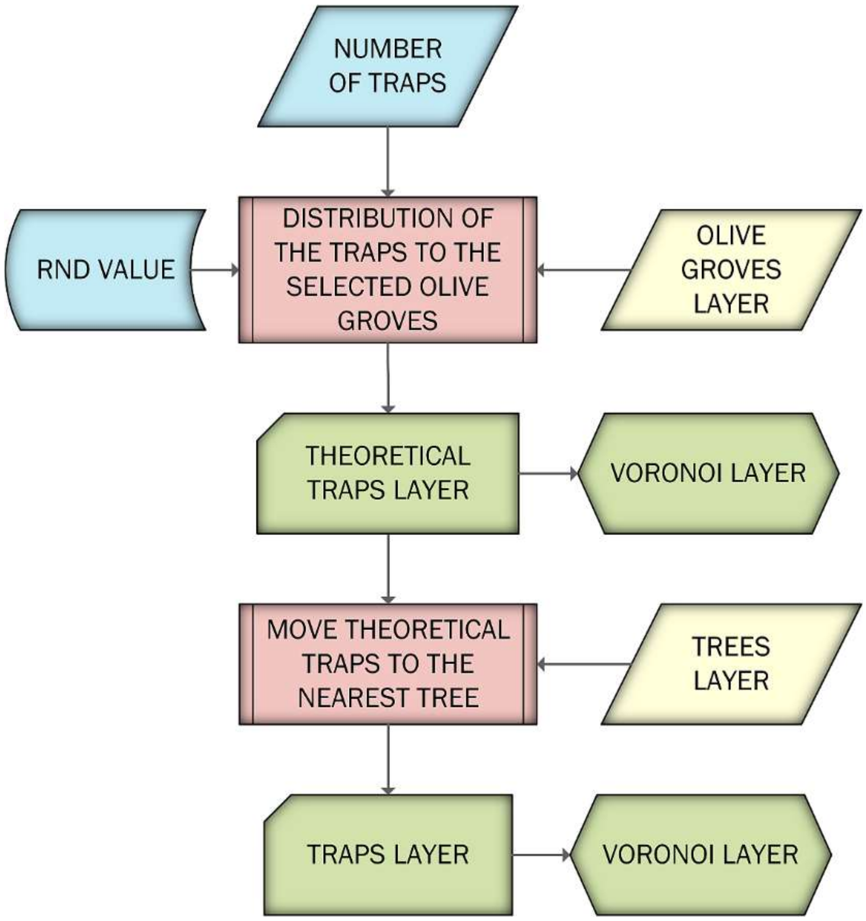


Figure 1.62: Methodology of automatic design of trap network distribution

1.6.2. Results

The algorithm of the design of the distribution of the traps was executed for the experimental area of Koropi by selecting different olive groves (i.e. parts of the experimental site) and using various combinations of preferred traps numbers and RND values. The theoretical trap distribution for 5 traps and RND value equal to 1000 for the Area 1, is shown in the following figure.

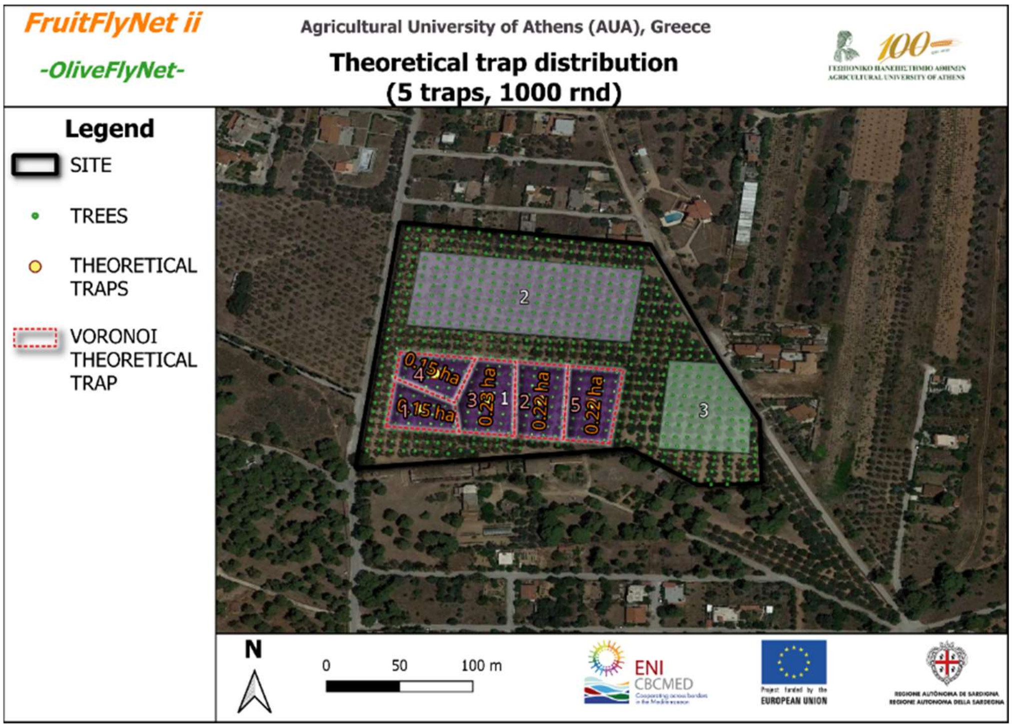


Figure 1.63: Theoretical trap distribution (Orchard 1, 5 traps, 1000 rnd).

The proposed trap distribution for 5 traps and RND value equal to 1000 for the Area 1, is shown in the following figure.

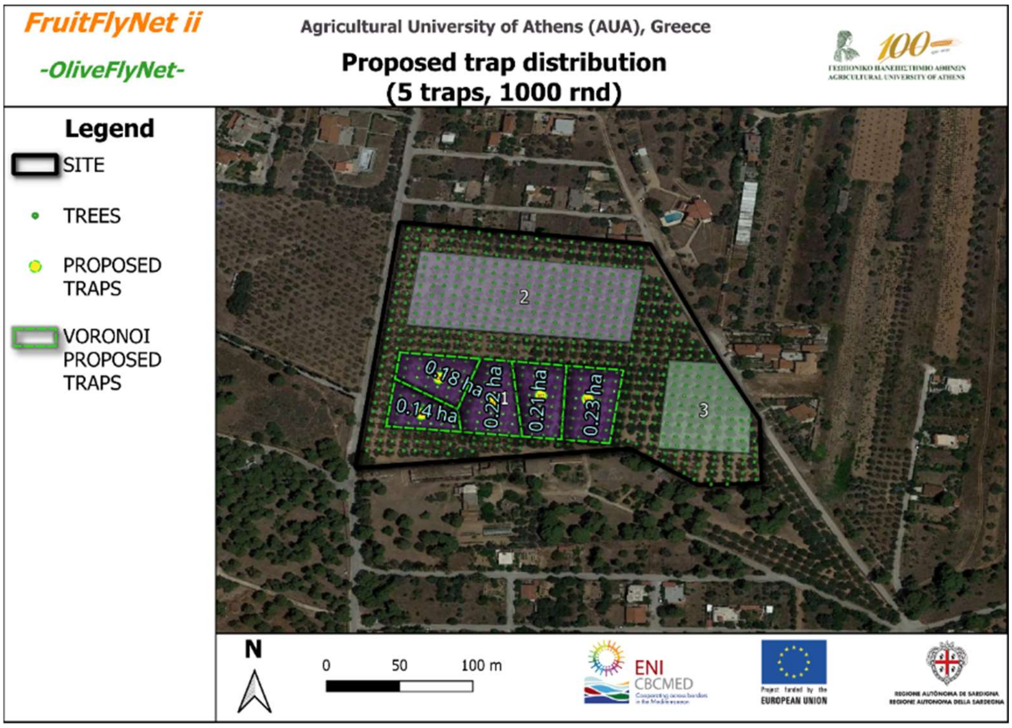


Figure 1.64: Proposed trap distribution (Orchard 1, 5 traps, 1000 rnd).

The theoretical trap distribution for 5 traps and RND value equal to 1000 for the Area 2, is shown in the following figure.

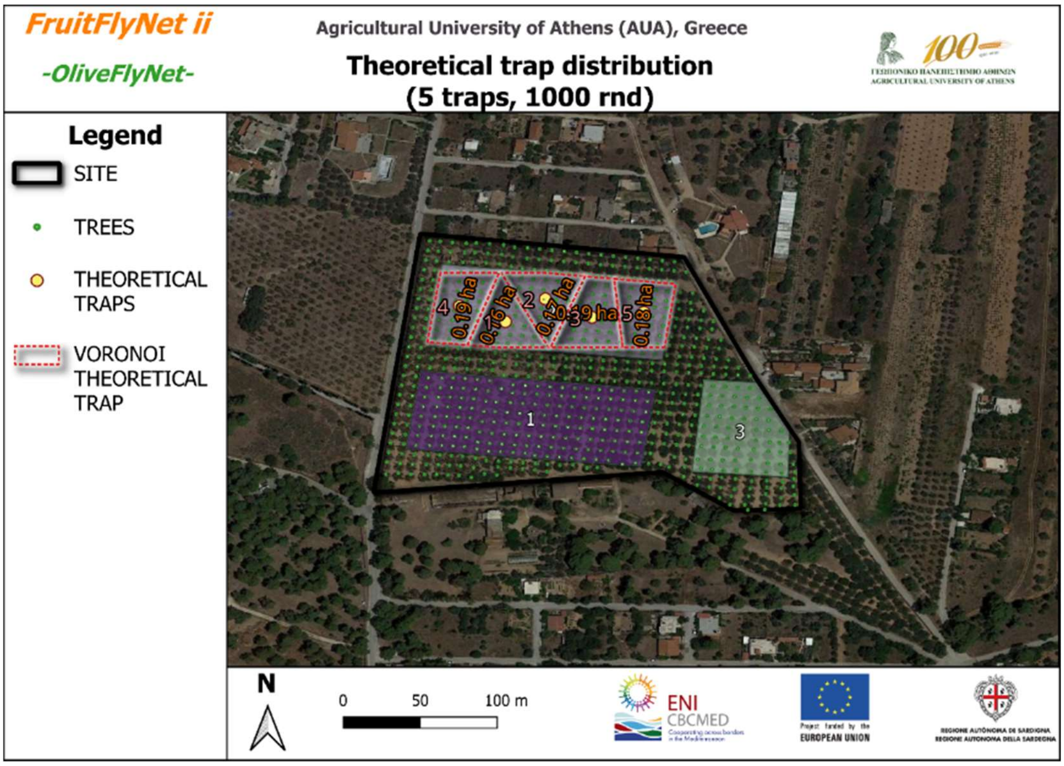


Figure 1.65: Theoretical trap distribution (Orchard 2, 5 traps, 1000 rnd).

The proposed trap distribution for 5 traps and RND value equal to 1000 for the Area 2, is shown in the following figure.

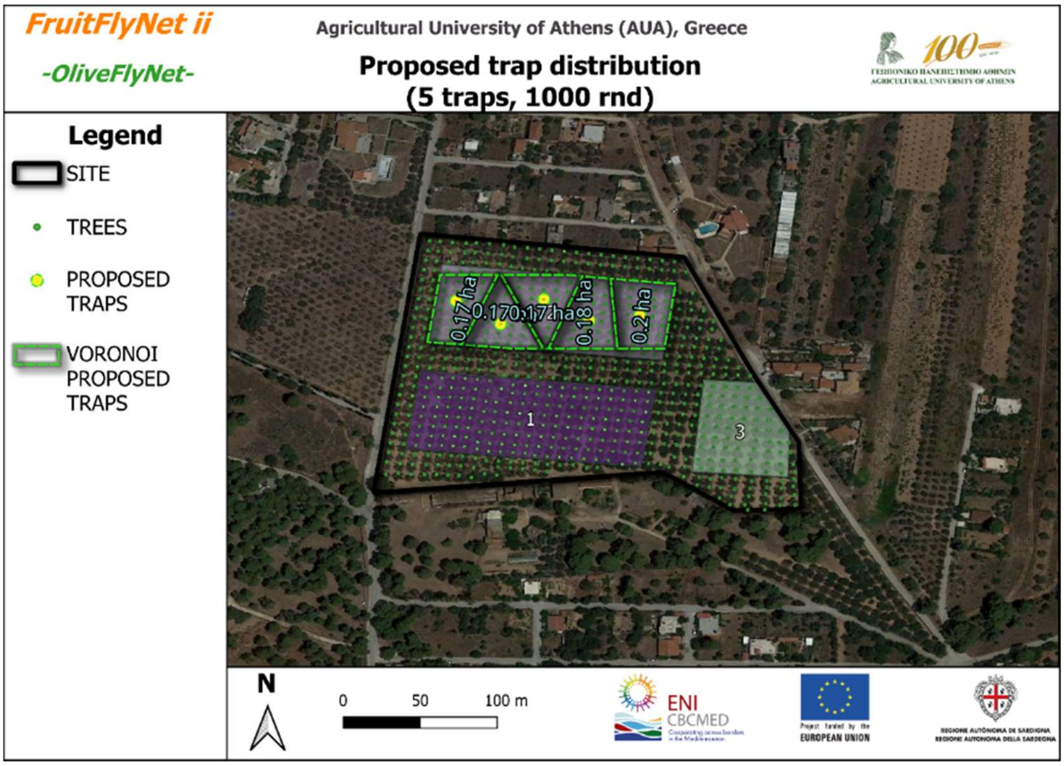


Figure 1.66: Proposed trap distribution (Orchard 2, 5 traps, 1000 rnd).

The theoretical trap distribution for 5 traps and RND value equal to 1000 for the Area 3, is shown in the following figure.

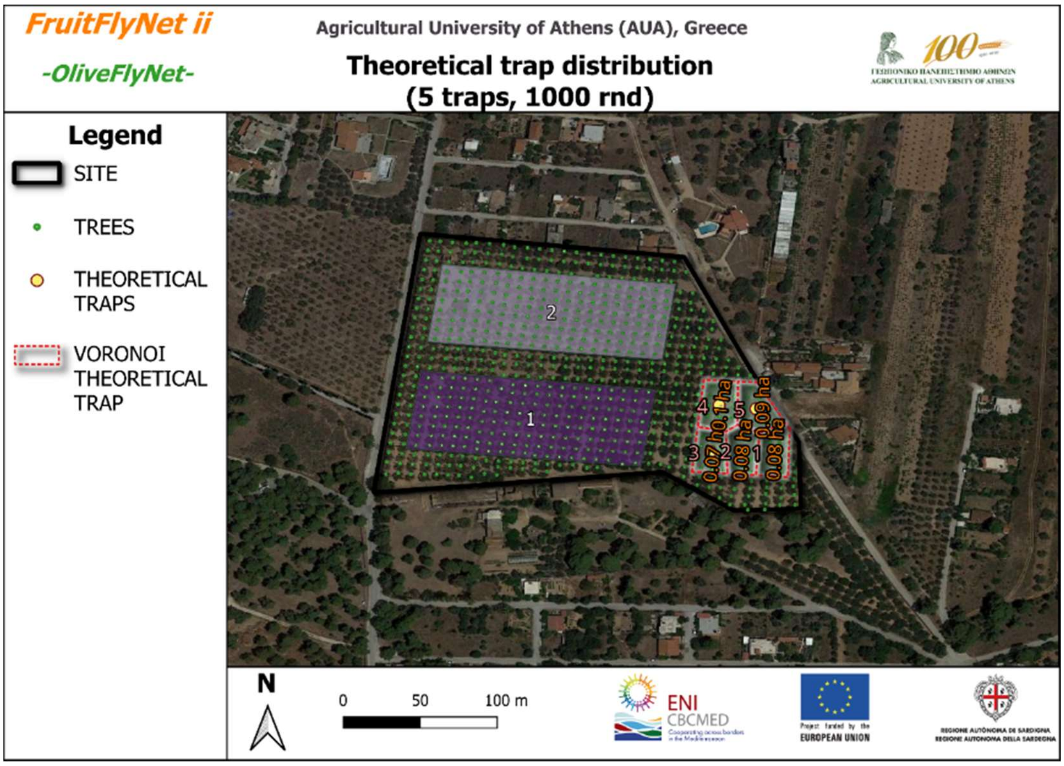


Figure 1.67: Theoretical trap distribution (Orchard 3, 5 traps, 1000 rnd).

The proposed trap distribution for 5 traps and RND value equal to 1000 for the Area 3, is shown in the following figure.

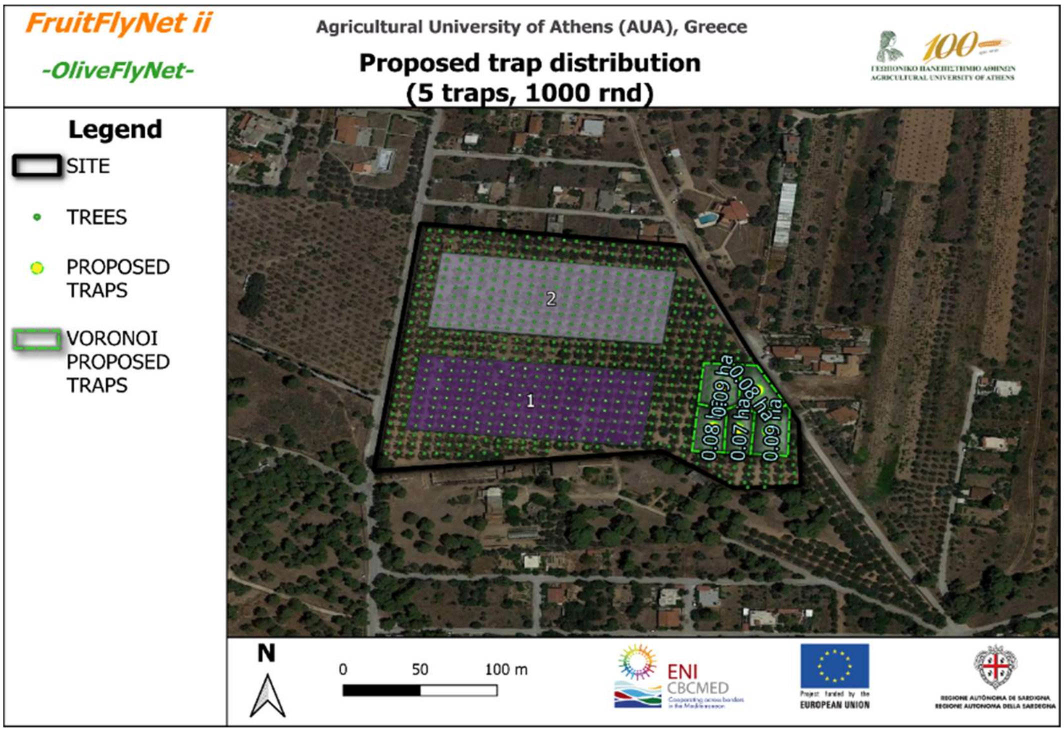


Figure 1.68: Proposed trap distribution (Orchard 3, 5 traps, 1000 rnd).

The theoretical trap distribution for 15 traps and RND value equal to 1000 for the Area 1, 2 and 3, is shown in the following figure.

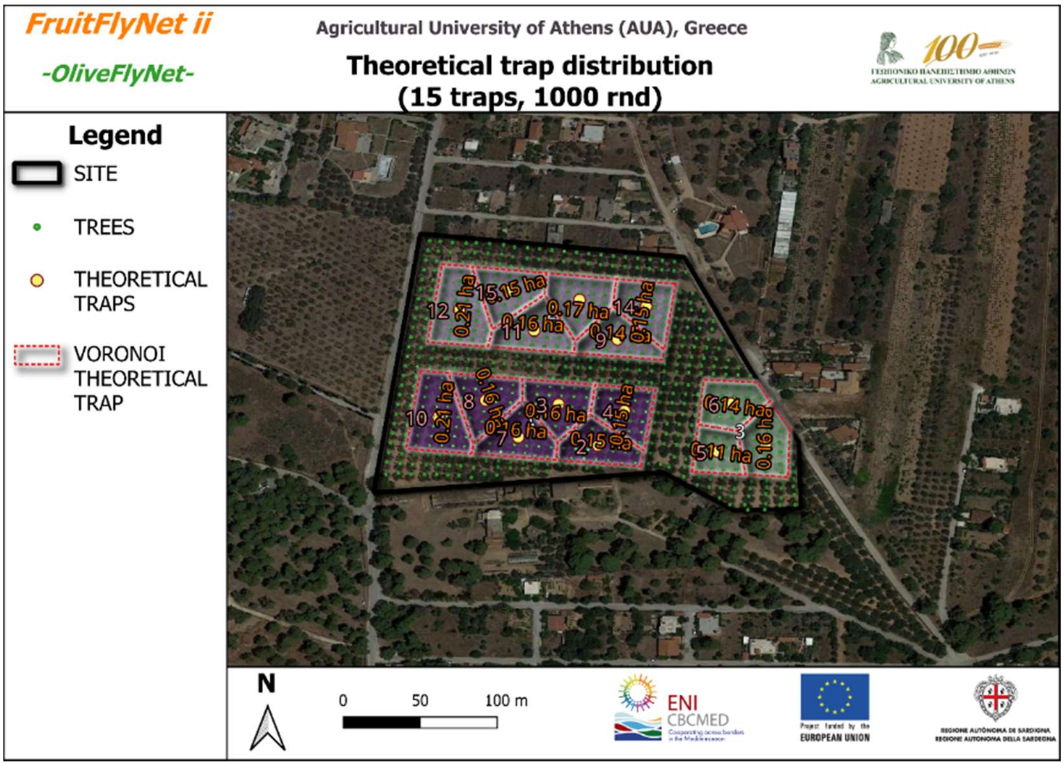


Figure 1.69: Theoretical trap distribution (Orchard 1-3, 5 traps, 1000 rnd).

The proposed trap distribution for 15 traps and RND value equal to 1000 for the Area 1, 2 and 3, is shown in the following figure.

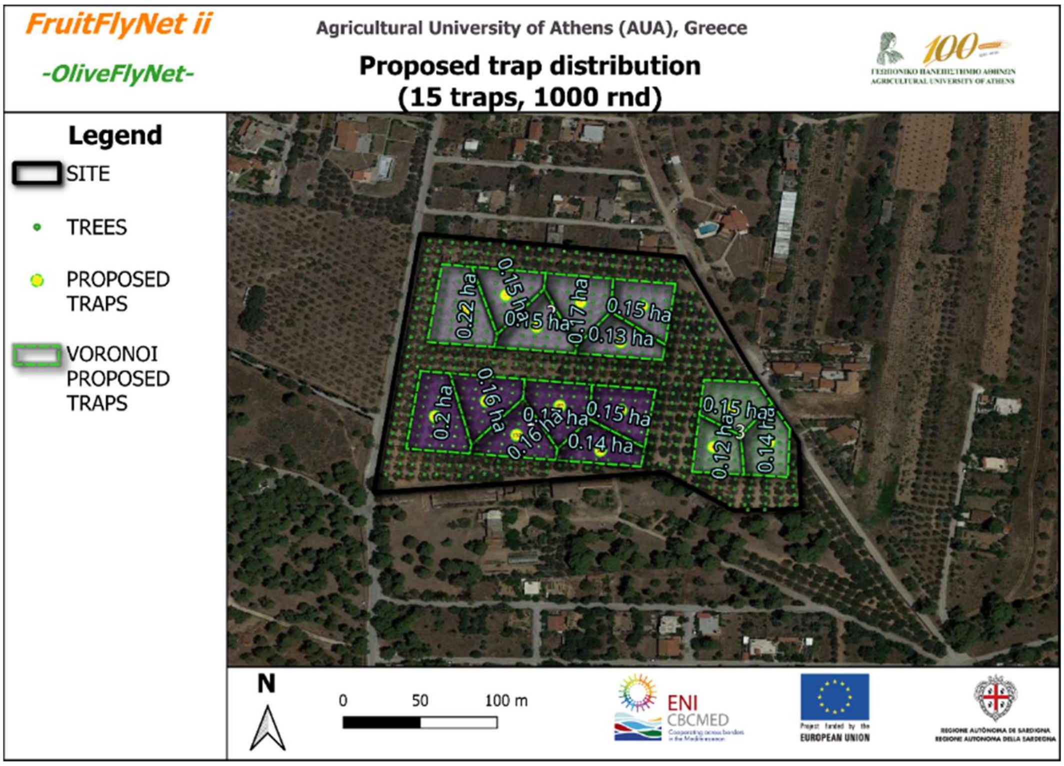


Figure 1.70: Proposed trap distribution (Orchard 1-3, 5 traps, 1000 rnd).

The theoretical trap distribution for 15 traps and RND value equal to 3000 for the Area 1, 2 and 3, is shown in the following figure.

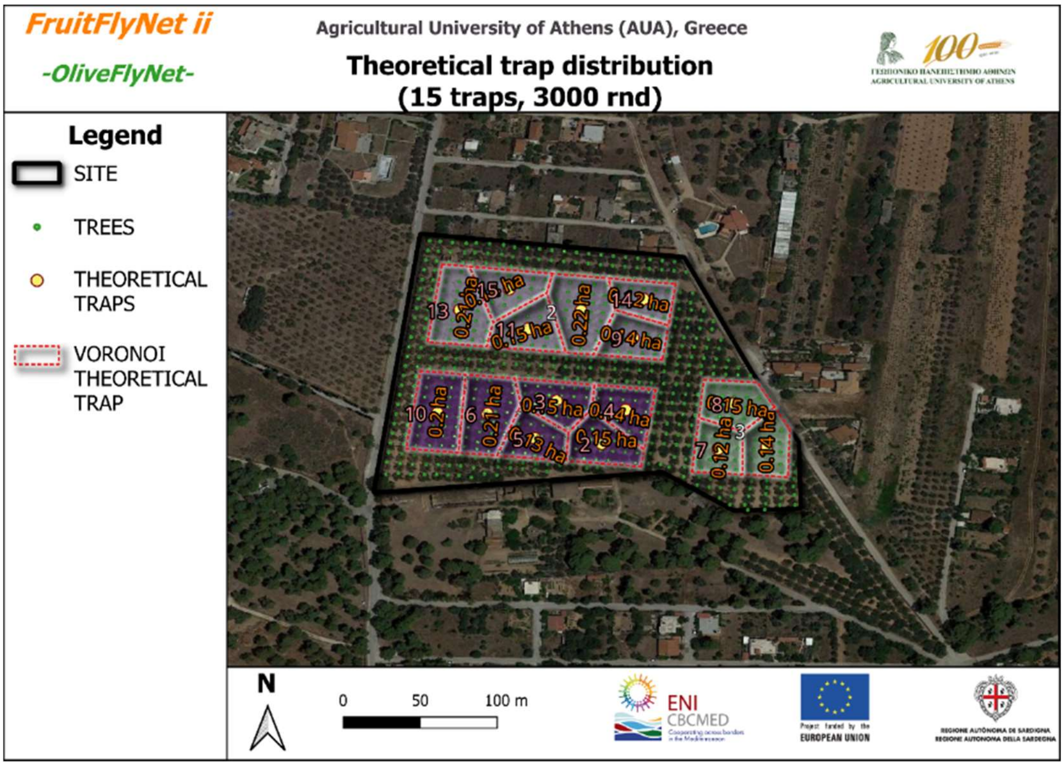


Figure 1.71: Theoretical trap distribution (Orchard 1-3, 5 traps, 3000 rnd).

The proposed trap distribution for 15 traps and RND value equal to 3000 for the Area 1, 2 and 3, is shown in the following figure.

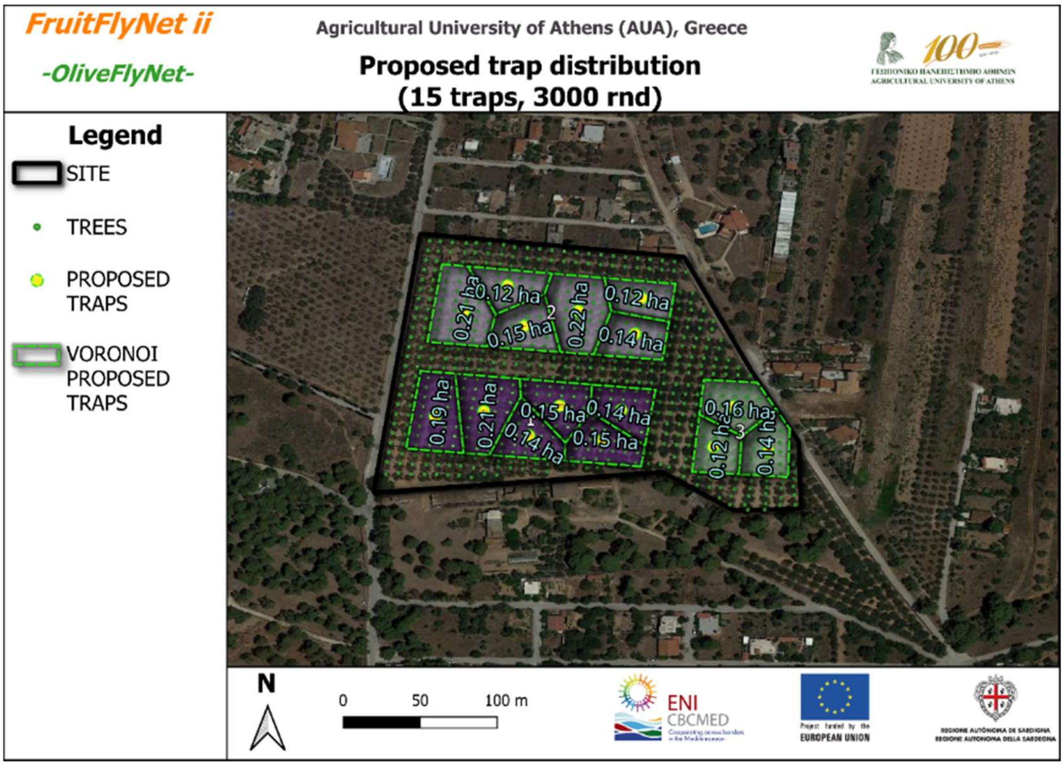


Figure 1.72: Proposed trap distribution (Orchard 1-3, 5 traps, 3000 rnd).

The theoretical trap distribution for 15 traps and RND value equal to 5000 for the Area 1, 2 and 3, is shown in the following figure.

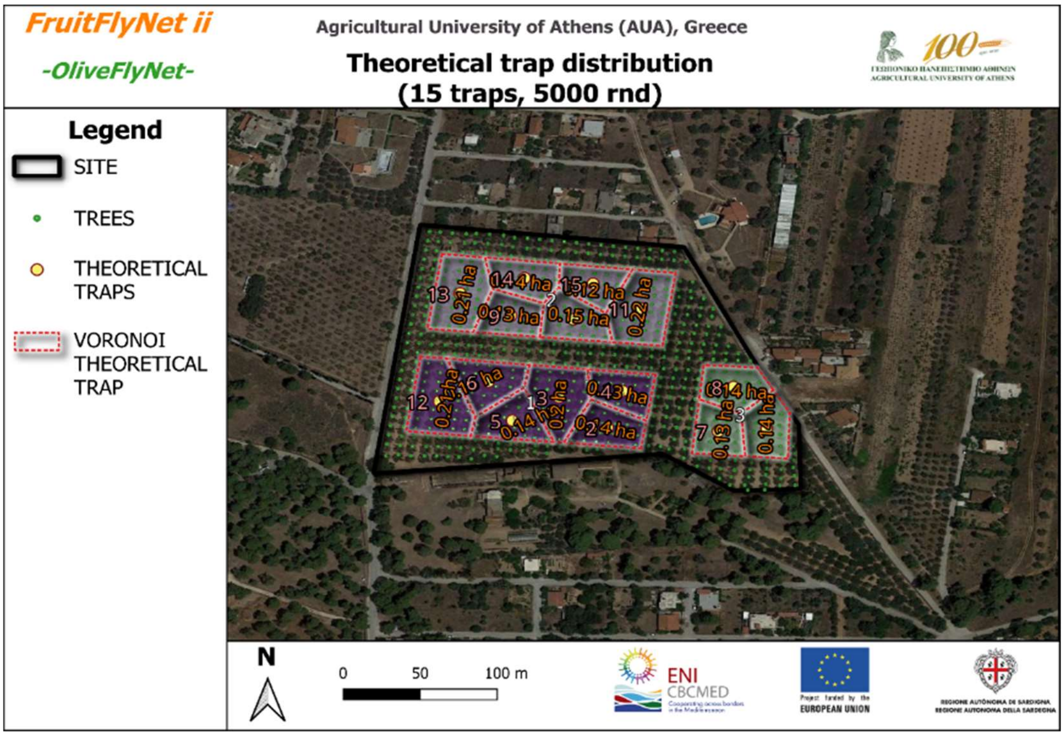


Figure 1.73: Theoretical trap distribution (Orchard 1-3, 5 traps, 5000 rnd).

The proposed trap distribution for 15 traps and RND value equal to 5000 for the Area 1, 2 and 3, is shown in the following figure.

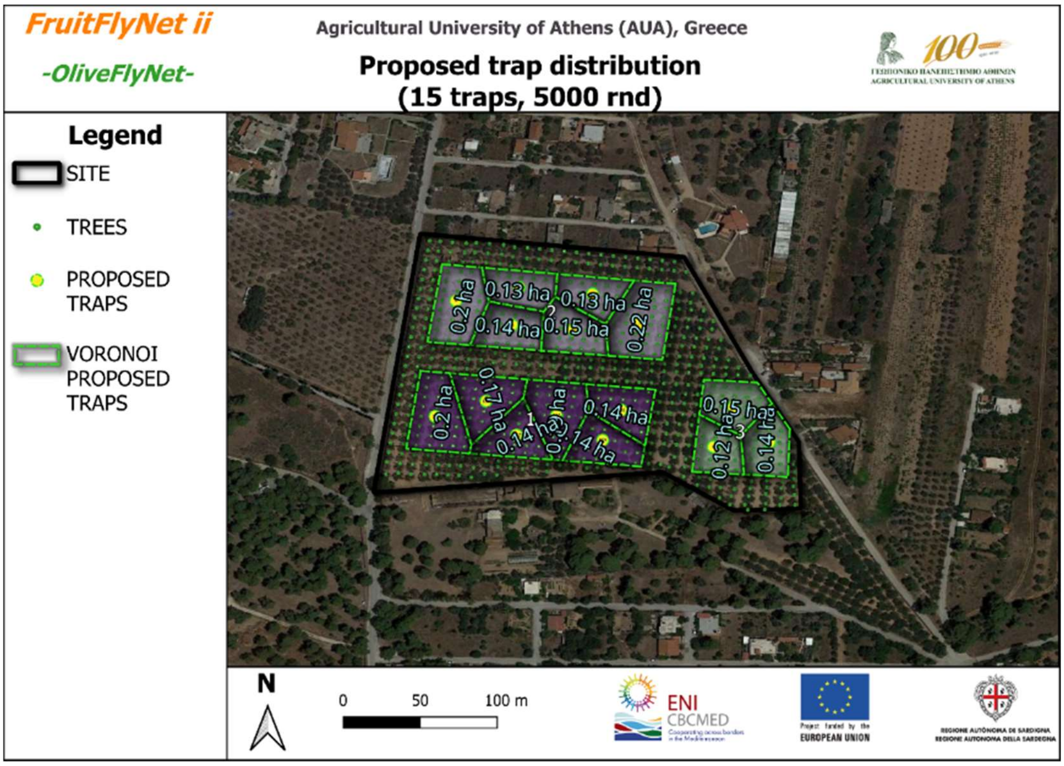


Figure 1.74: Proposed trap distribution (Orchard 1-3, 5 traps, 5000 rnd).

The duration of the e-services of the trap distribution for the above scenarios is shown in the following table.

Table 1.10: Duration of the e-services of trap distribution.

Parameters	Duration of the e-services of trap distribution (in seconds)
Preferred traps 5, RND value 1000	5.42
Preferred traps 5, RND value 1000	5.54
Preferred traps 5, RND value 1000	5.41
Preferred traps 15, RND value 1000	5.59
Preferred Traps 15, RND value 3000	5.51
Preferred Traps 15, RND value 5000	5.50

1.6.3. Discussion

The algorithm of the automatic determination of the optimum trap positioning in a given field was tested in the experimental site of Koropi (BEN) under different scenarios. Minor differences of the Voronoi polygons of the theoretical and proposed traps (the size and the location of the Voronoi polygons) indicates that the spatial distribution of the proposed traps is fully accepted for the purpose of monitoring and the management of the olive fruit fly. The algorithm responds well in low but also in high RND values with rapid execution and can be used effectively in other scenarios of trap number and shape or size of the area, such as that of the wide-area site.

2. UNIMOL (PP2)

2.1. Methodology

In 2023, the automatic recognition of Medfly catches in the e-trap was developed and tested, to verify if this service could be incorporated into the Medflynet LAS prototype.

The images used for these tests were obtained in part from e-traps positioned into cages, where medflies were released, and in part from images got from e-traps located in the experimental peach orchard located in Campomarino.

The process for establishing an automatic recognition of medflies trapped in the e-traps followed 4 steps:

1. data augmentation, so as to increase the number of samples within the dataset;
2. -object detection, where the object is the single trapped fly detected in the image (Figure 2.1);
3. -segmentation, i.e. the extraction of the detected object (Figure 2.2);
4. -classification of the extracted objects in two categories: medfly/other (Figure 2.3).

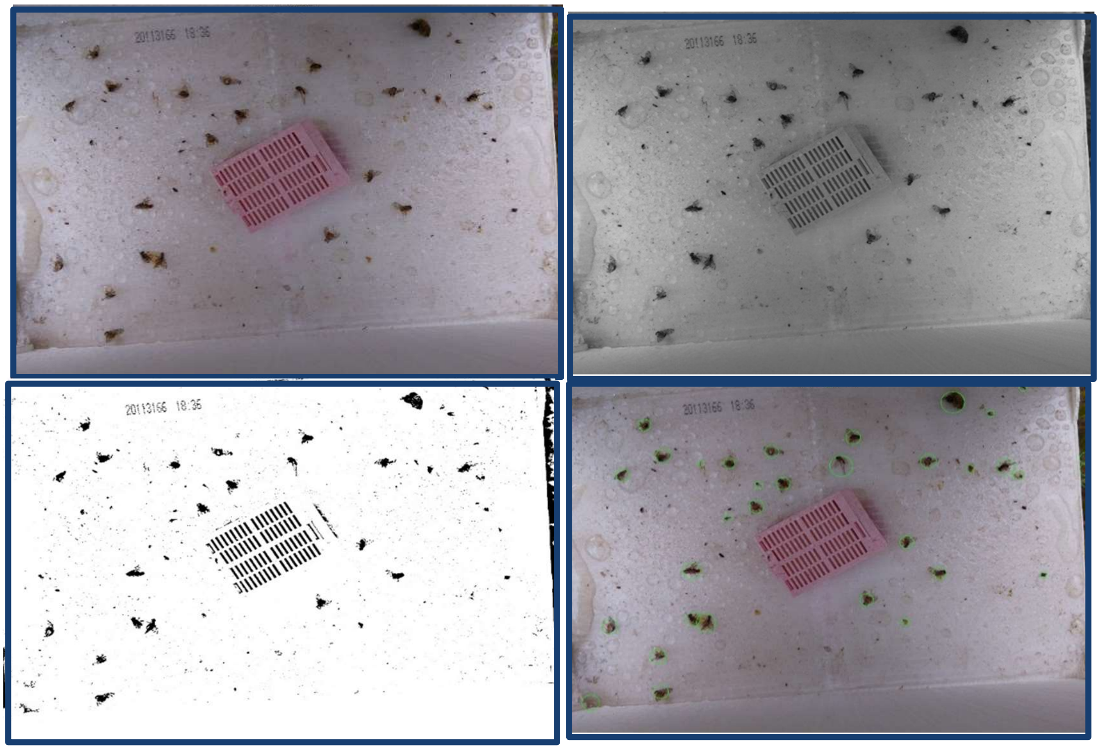


Figure 2.1: Various steps of image transformation for the detection of the single objects (green circles).

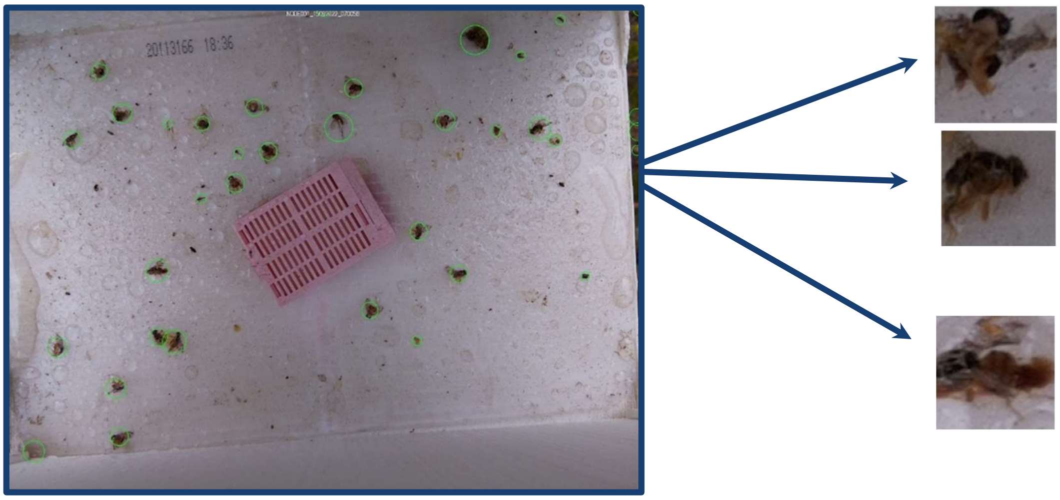


Figure 2.2: Process of the extraction from the image of the recognized objects**.**

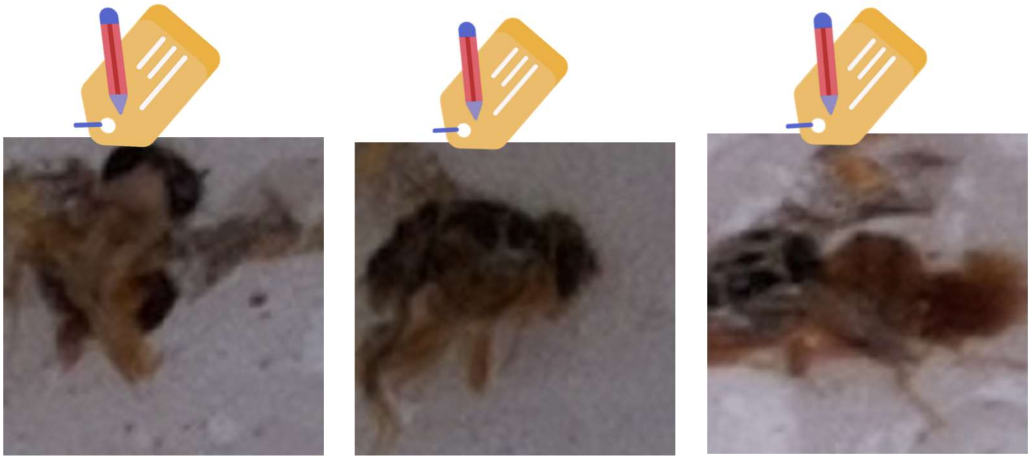


Figure 2.3: Classification of the extracted objects in different categories

These images can then be used as a dataset for training the image classification model, which must be able to distinguish between *Ceratitis capitata* specimens and other insects/objects.
Four models were compared for classification: Convolutional Neural Network (CNN), Random Forest (RF), K-Nearest Neighbours (KNN) and Support Vector Machine (SVM).

2.2. Results

The training dataset was composed of the following extracted objects: *Ceratitis capitata*: 2341; other objects: 423.
The following results were obtained from the comparisons made in the training phase:

CNN:
Accuracy: 0.9973958333333334
Precision: 0.9979959919839679
Recall: 0.996309963099631

RF:
Accuracy: 0.9177816077003123

Precision: 0.9198304594655475
Recall: 0.8995458588333426

KNN:
Accuracy: 0.913410726673604
Precision: 0.9144946259906053
Recall: 0.913410726673604

SVM:
Accuracy: 0.9396368799861256
Precision: 0.9397507687209712
Recall: 0.9396368799861256

Ten images that were not used in the training phase served for validation tests. The best results were obtained with the Convolutional Neural Network and are hereafter reported in The following Table.

Table 2.1: Results of the validation tests carried out using Convolutional Neural Network.

IMAGE ID	N. of *Ceratitis capitata* visually counted	N. of *Ceratitis capitata* detected by CNN
1	0	2
2	3	4
3	5	8
4	6	5
5	10	9
6	11	8
7	17	30
8	19	18
9	29	16
10	49	47

The results showed promising possibilities to apply automatic counting of trapped flies in the e-trap, however additional training sessions are required in order to get a high performance. For this reason, even if significant progress has been made, it was not possible to incorporate the trained algorithm in the prototype executed in the large sites.

At this stage, it seems difficult the possibility to distinguish males from females, making more difficult the application of the method to the olive fruit fly.