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DELIVERABLE

Final Smart Farming Application

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Executive Summary

This document presents the functionality and the implementation details of Smart Farming (SF) applications to be used by the advisors, the agronomists and the farmers in the context of the LIFE GAIA Sense project and beyond. This document can be considered as complementary to the initial design specifications of the SF applications contained in deliverable entitled **“Final Application Design and Mockups”** [1]**.** The requirements and the design principles that were specified on that document are the guidelines for the implementation of the actual software services that are described in this document.

As it will be further analysed, two applications have been developed:

• The **“gaiasense web-based application”** that provides access to detailed current and historic environmental information of selected parcels (fields) along with scientific based indications on the associated hazards with regards to irrigation and pest management.

• The **“gaiasense mobile application”** tailored to the needs of users that are on the move while performing various tasks (e.g. farmers visiting different fields and applying various cultivation practices) hence only crucial information summaries are presented to small-mobile devices.

Both applications are based on the gaiasense (http://www.gaiasense.gr/en) - cloud based - information management system that provides to both the web-based and mobile applications, access to the necessary data in support of their overall functionality.

The initial version of this document entitled “Initial Smart Farming Application” was released on 28/6/2019 along with the initial stable release of the two applications. Through the utilisation of the applications significant finding and shortcomings were identified that indicated the need for providing various refinements. Improvements are mainly targeting aspects of user interfacing along with the options for the complementary visualisation of heterogeneous information items in order to give to the end user a more integrated view of the current status of his/her parcels.

This deliverable is considered as an extension of the initial document and describes all the conducted updates for the final release of both application. However, it should be noted that as in any information management system and as the applications will be further utilised shortcomings and bugs are expected to be discovered that will lead to various code updates and functionality improvements.

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1.1	31/01/2020	N . Kalatzis (NP)	Final revised version

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Definitions, Acronyms and Abbreviations

Acronym	Title
AB	Advisory Board
ALs	Action Leaders
CE	Circular Economy
M2M	Machine2Machine
NP	NEUROPUBLIC AE PLIROFORIKIS & EPIKOINONION
SF	Smart Farming
KPI	Key Performance Indicator
SF	Smart Farming
API	Application programming interface
REST	Representational State Transfer
NDVI	Normalized difference vegetation index
JSON	JavaScript Object Notation
IoT	Internet of Things
iCM	Crop management system

1. Introduction

1.1. Project Summary

The main objective of the LIFE GAIA Sense project is to demonstrate Gaiasense, an innovative "Smart Farming" (SF) solution that aims at reducing the consumption of natural resources, as a way to protect the environment and support Circular Economy (CE) models.

More specifically, this project will launch 18 demonstrators across Greece, Spain and Portugal covering 9 crops (olives, peaches, cotton, pistachio, potatoes, table tomatoes, industrial tomatoes, grapes, kiwi) in various terrain and microclimatic conditions. They will demonstrate an innovative method, based on high-end technology, which is suitable for being replicated and will be accessible and affordable to Farmers either as individuals or collectively through Agricultural Cooperatives.

Moreover, LIFE GAIA Sense aims to promote resource efficiency practices in SMEs of the agricultural sector and eventually, contribute to the implementation of the Roadmap to a Resource Efficient Europe. This project will demonstrate a method on how the farmer will be able to decide either to use or avoid inputs (irrigation, fertilizers, pesticides etc.) in a most efficient way, without risking the annual production. The focus is on the resource consumption reduction side of CE, and the results will be both qualitatively and quantitatively, considering the resources' efficiency in agricultural sector.

1.2. Document Scope

This document presents the functionality and the implementation details of the following two Smart Farming (SF) applications:

• The **"gaiasense web-based application"** that provides access to detailed current and historic environmental information of selected parcels (fields) along with scientific based indications on the associated hazards with regards to irrigation and pest management.

• The **"gaiasense mobile application"** tailored to the needs of users that are on the move while performing various tasks (e.g. farmers visiting different fields and applying various cultivation practices) hence only crucial information summaries are presented to small-mobile devices.

This document also provides an overview of the gaiasense (http://www.gaiasense.gr/en) - cloud based - information management system that provides to both the web-based and mobile applications access to the necessary data in support of their overall functionality.

1.3. Document Structure

This document is comprised of the following chapters:

Chapter 1 is the introductory section of this document.

Chapter 2 elaborates on the overall system architecture and the underlying gaiasense framework where the functionality of the two applications is based on. The integration of the scientific models as software modules for extracting the respective advice for pest, irrigation and fertilisation is presented along with implementation technologies utilised.

Chapter 3 describes in details the actual functionality and the respective front-end views of the two applications.

Chapter 4 presents the conclusions and the next steps.

2. System Architecture

2.1. The gaiasense framework

As it was analysed in the document "**Final Application Design and Mockups**" the gaiasense framework (figure 1) follows a layered architectural design approach where the main information flow is realised from the bottom layers to the higher layers. For the needs of the LIFE GAIA Sense project two applications have been developed, on top of this architecture, leveraging on the provided data collection and processing infrastructure.

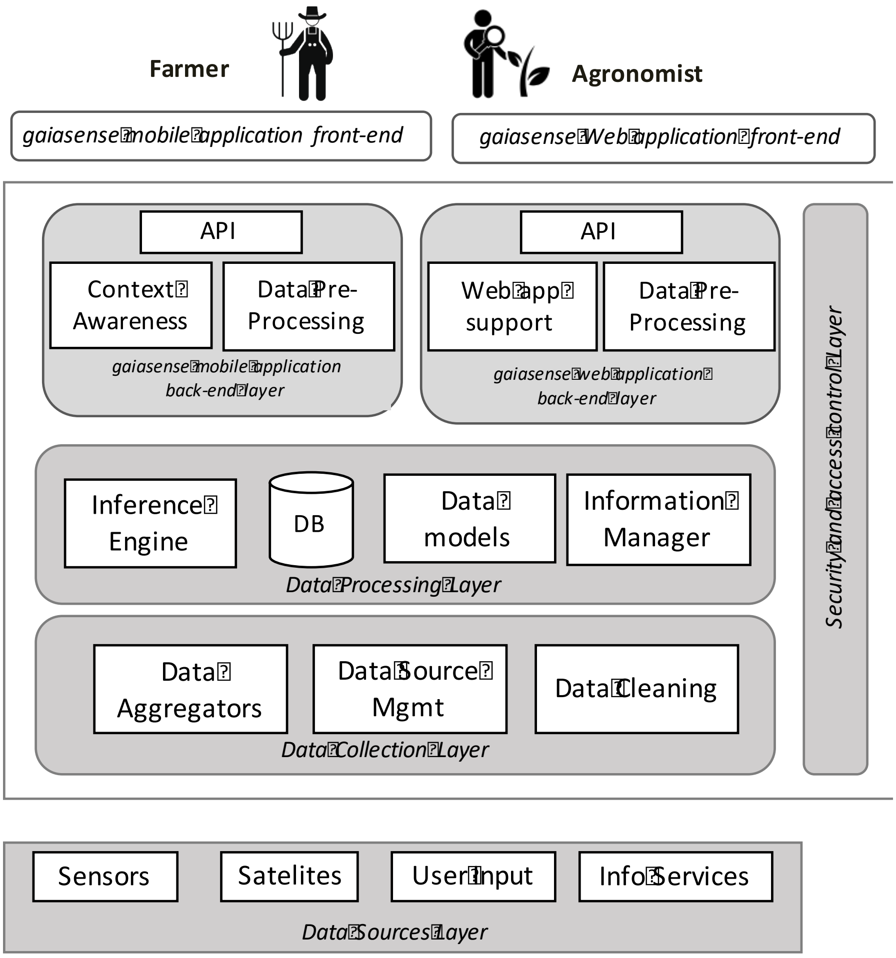

Figure 1. Functional view of the gaiasense framework layered architecture

The **gaiasense web-based application** is tailored to the needs of the agronomists and the advisors and is accessible through resource rich devices (e.g. desktop and laptop personal computers). As it will be described in detail in the following sections, this web-based app provides access to current and historic environmental conditions on the targeted parcels (fields) along with scientific based indications on the associated hazards with regards to irrigation and pest management.

The user will be able to be informed about the potential pest or insect infestations through the scientific models that will be integrated within the "Data Processing Layer". This helps the user to enhance and optimize the process of making timely decisions and precision applications in the crop.

Finally, the user will have a complete overview on the field activities during a growing season though the necessary intuitive visualisations about irrigation and plant protection works carried out, the phenological stages of the plants, and harvest related info.

The **gaiasense mobile application** is tailored to the needs of the farmers and is optimised for utilisation through mobile devices (e.g. smart-phones, tablets). This category of users is expected to be on the move while performing various tasks (e.g. visiting different farms and applying various cultivation practices).

The application is "parcel" oriented meaning that the central information entity that the application is designed upon is the field that the farmer is cultivating. The application visualises only the information necessary to the farmer avoiding complicated details about the underlying scientific models. The focus is on the simplified and user friendly representation of the respective outcomes. This implies that a relative minimalistic approach is followed, especially when compared with the information richness of the "gaiasense web-based application".

Both applications follow an incremental development approach where initially a set of core functional services are provided that are constantly improved according to user recommendations and feedback. Improvements are expected to both user-experience aspects of the service but also on the advanced knowledge extraction elements of the provided services.

2.2. Integration with existing services

For the needs of the LIFE GAIA Sense project, a set of additional, existing services will be configured appropriately in order to be utilized and integrated with the newly developed applications. These services are:

The "Intelligent Management Crop – (iCM)" is a multifunctional platform that can properly manage a group of producers or a single farm. This service has been created to assist farmers to comply with regulatory frameworks i.e. Multi-Compliance Rules and the requirements arising from the various Quality Systems i.e. Agro, Globalgap, PDO / PGI, Organic Agriculture. Particularly, it provides the ability to access and manage a set of information and files relating to Regulatory Frameworks and the various Quality Systems in the form of a Producer Log-Book / Output Register.

The reports issued by this application help the producer monitor the crop and evaluate the results from previous years. It also allows correlations between, specific cultivation practices or inputs and the product produced (quantity and quality product). Apart from monitoring, ICM is a very powerful tool for drawing conclusions about the agricultural practices and products used (fertilizers, water etc) as well as for decision-making regarding the optimization of the economic result.

The agronomists who have access to the required information over the internet, are given the opportunity to have the overview of the parcels and provide instructions according to the Regulatory Requirements as well as the requirements of the Quality Systems very efficiently. In this way, full and continuous monitoring of the Quality Systems is achieved by recording all processes and minimizing the time spent by the visiting agronomist on field visits and observations.

The existing version of the iCM system, developed by NP, was only capable to handle information originating from agricultural fields located in the geographical area of Greece. Given that the LIFE GAIA Sense pilot fields are also located outside Greece (Portugal and Spain) it was necessary to implement additional software modules and translations in order to make the iCM available to non-Greek agronomists and farmers.

The application called "**Field Collect**" is an innovative tool useful for farm advisors and producers. It was implemented with the purpose of detailed planning and control of the trapping process but also of monitoring the population and insect spreading within a crop. Growers have the ability to record the entomological attack directly on the field with the help of a smartphone and exploiting this data to control effectively the damage caused by plant's enemies while reducing the amount of pesticides

released on the ground. An additional menu of the application is the recording of the phenological phase of crop at the time of insitu control. Furthermore, Field Collect has been integrated with the recording of soil samples taken from points within the field, as well as with irrigation measurements.

2.3. Integration of scientific models and information flow

One of the core objectives of the LIFE GAIA-Sense project is the development of pest, irrigation and fertilization prediction models. The scientific models are initially expressed as computational algorithms, then they are coded as software components which are integrated within the gaiasense framework and made available to the end-users through the LIFE GAIA Sense applications. The initial scientific analysis and the development of the models will be realized under actions "B3.1 Development and customisation of specialised pests/diseases prediction models", "B3.2 Development and customisation of specialised irrigation models", and "B3.3 Customisation of specialised fertilisation models".

The specified architecture (Figure 1) adopts an approach where each model is considered as an autonomous and self-contained software module. All these modules are following a common method for data input/output through harmonized Application Programming Interfaces (APIs) [3] which supports the dynamic interaction with the rest of the gaiasense framework components. Each model can be plugged and unplugged with the platform with a minimum configuration effort without affecting the overall functionality of the system. For example, pest management models accept as input a predefined set of data (e.g. current and historic environmental data, phenological stages, history of past pest infestations) and produces risk limits (%) for each target disease and degree days sum limits for predicting targeted insect flights. Figure 2, illustrates in a conceptual manner the parallel utilization of different pest and disease estimation models along with the flow of information from the deployed sensors to the farmer.

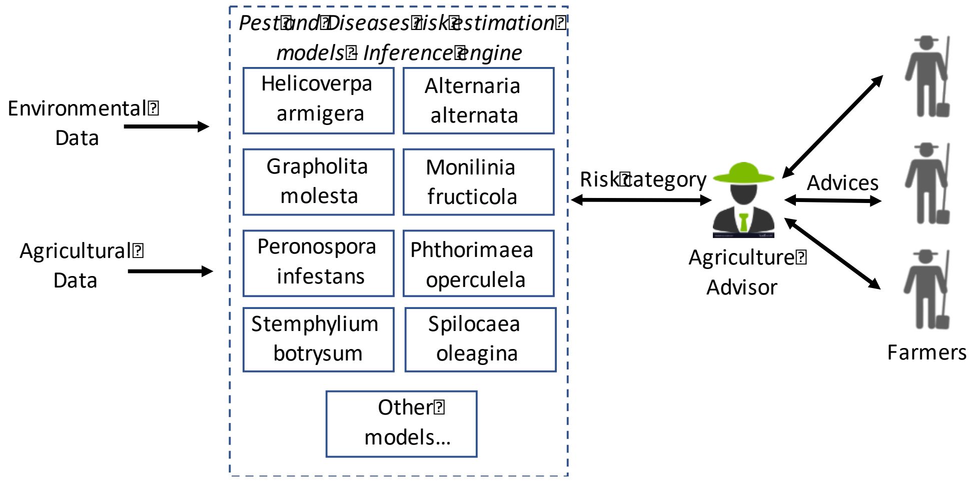

Figure 2. Integration of pest management scientific models and conceptual flow of information

For an adopted rational water management strategy to be effective, it should be based on direct and accurate determination of the irrigation time and the optimal amount of irrigation. The determination of the irrigation time will be achieved by introducing critical water scarcity values derived from the time-gradient analysis of the soil moisture profile along the active root and hydrodynamic parameters of the plants. For this purpose, precise knowledge of the spatial distribution of the active bedrock is required in conjunction with the continuous recording of soil moisture. In addition, the excellent irrigation dose is the one that maintains the entire plant root system at moisture levels higher than

the water stress start point and, on the other hand, limits water losses due to run-off beyond the active bed area. Figure 3 presents the respective information flow environmental data monitoring, processing of information through the proper irrigation model, extraction of irrigation needs and generation of the final irrigation advice.

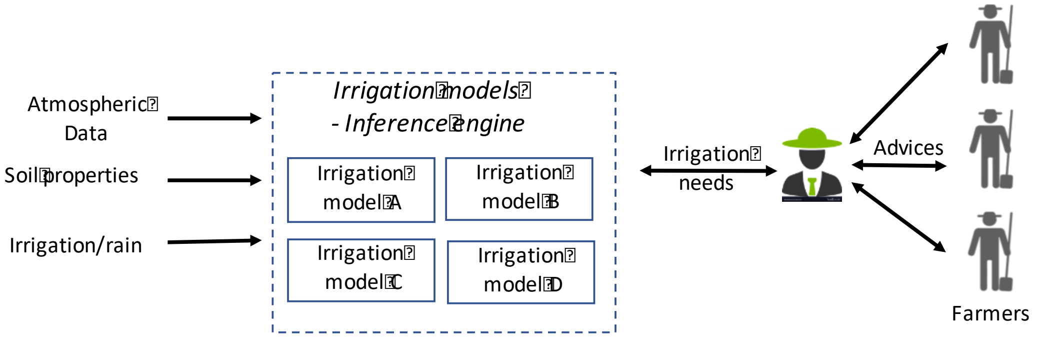

Figure 3. Integration of irrigation scientific models and conceptual flow of information

2.4. Implementation technologies

The following table presents the various technologies utilised for the realisation of the described services. Within the table each architectural layer presented in Figure 1 is associated with the technologies utilised for the implementation of the respective components.

Table I. Technologies utilised for the realisation of the software applications.

A/A	Layers	Technologies
1	Data sources layer	This layer mainly consists of stand-alone services (e.g. ICM, FieldCollect) that utilise various combinations of technologies and can even be external to gaiasense framework (e.g. Copernicus Sentinel). However, the integration with the rest of the gaiasense framework is realised through standardised data transfer technologies such as: HTTP- REST-API [2], JSON.
2	Data collection layer	Scripts implemented in Python 2.7
3	Data processing layer	Relational database system: PostgreSQL 11.2 Implementation of scientific models: Java 8 Implementation of Data Management: Java 8
4	gaiasense mobile application back-end	Apache HTTP Server, Java 8, REST-API
5	gaiasense web application back-end	Apache HTTP Server, NodeJS 10.15, REST-API
6	gaiasense mobile application front-end	Javascript ES2017 (ES8), PHP 7.1

7	gaiasense web application front-end	Javascript ES2017 (ES8), PHP 7.1

The data collected from the fields are maintained and processed in NEUROPUBLIC S.A. data center located at the company's premises in Piraeus Greece (https://www.neuropublic.gr/en/infrastructure/cloud-data-center/). The back-end services of the two applications (gaiasense mobile & web based applications) utilised by the farmers and farmer's advisors are also hosted in NEUROPUBLIC S.A. server systems.

3. Services description

In this section the functionality of the implemented services is descripted. Initially, screenshots from the various pages of the “gaiasense web application” are presented along with the supported functionality. In a similar manner, a presentation of the “gaiasense mobile application” follows.

3.1. The “gaiasense Wep application”

The gaiasense web application is accessible on-line through the Internet while the overall services are offered through the web browser. Users can access the application at:

- https://gaiasense.neuropublic.gr/smartfarming/views/login.php

Although all standard web browsers can be utilised, the application is optimised for use with either Internet Explorer 10, Mozilla Firefox or Google Chrome. At the Login page (Figure 4) the user should provide a valid username and password in order to get authenticated and proceed with the utilisation of the application. User is able to select between English and Greek language.

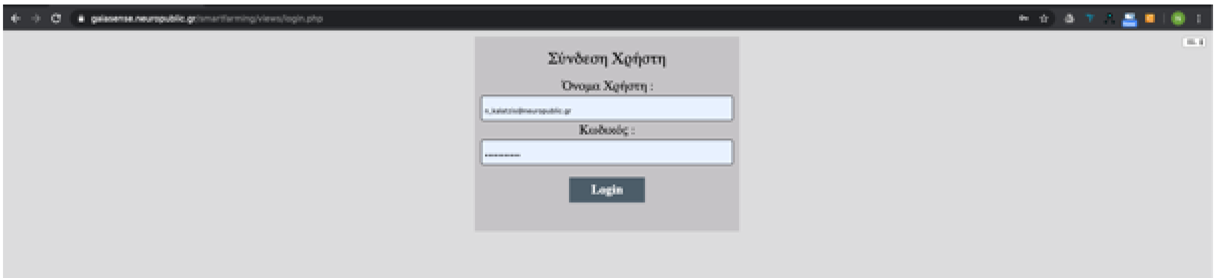

Figure 4. The “gaiasense web application” - Login page

Upon successful login, a list of the IoT stations are presented that the user (e.g. advisor) authorised to view (Figure 5). Each telemetric station (gaiatron) is associated with an area of cultivated parcels. The gaiatrons are listed on the left of the screen where also an indicative name of the associated area is presented. Upon selecting a station the respective measurements are presented in a table format.

These records have been collected by the stations and have been processed and maintained by the gaiasense framework. The user has the option to issue queries with time range related criteria in order to access records from specific time periods. On top of each column an indicative label describes the type of the information presented (e.g. Date, leaf wetness, soil moisture, etc.) Each row of the table corresponds to a different snapshot of measurements that took place within an hour.

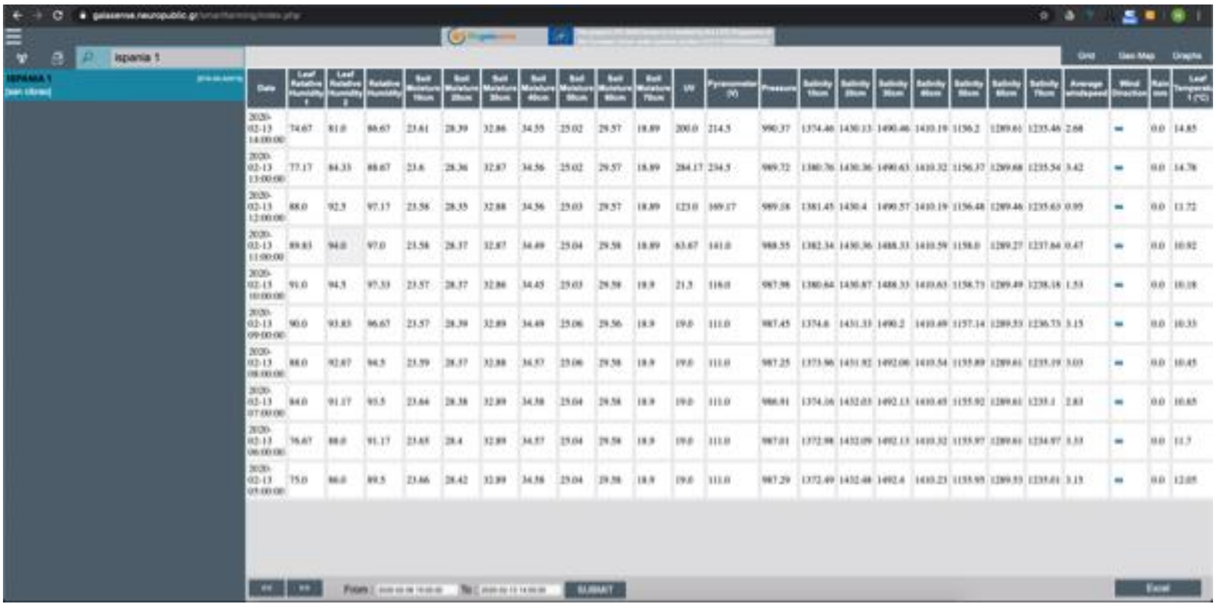

Figure 5. Web application - Environmental measurements in Grid format

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The user is able browse through the data collection and to export selected datasets to a spreadsheet file format (e.g. .xls). It should be noted that this view presents a rich set of data including data types that may not be easily comprehensible from non-experts. The following table II presents a list of data types and their respective units.

Table II. Data types monitored by GAIAtron Station's.

Variable(s) and (Units) measured
Temperature (C°)
Relative Humidity (%)
Barometric Pressure (mBar)
Wind Direction (°)
Sun Radiation - Pyranometer (Volts)
Rain Collector (0.2 mm increments- Auto Emptying)
Wind Velocity (km/h)
Leaf Temperature (C°)
Leaf Wetness Sensor (Binary -wet/dry)
Leaf Relative Humidity (%) (at two different locations of the field)
Soil Moisture (%) (at 7 different depths)
Soil Salinity/Conductivity (dS/m) (at 7 different depths)
Soil Temperature (C°)

In order to make the presentation of the measured data more intuitive the "gaiasense web application" supports the visualisation of data in the form of graphs. The user may select the "Graphs" option on the top right menu and then provide the respective criteria (e.g. measurement type, time range, etc.) for creating the graph. Recorded measurements are presented as time series with a time step of one hour. Multiple graphs can be visualised on the same axis allowing the comparison and the identification of various causalities e.g. rain events and soil moisture.

In addition, this page support the visualisation of selected events related to irrigation, pest management, harvests, plants phenological stages, etc. Upon hover on the event symbol more info appears in a pop-up info box. An indicative example is illustrated in Figure 6.

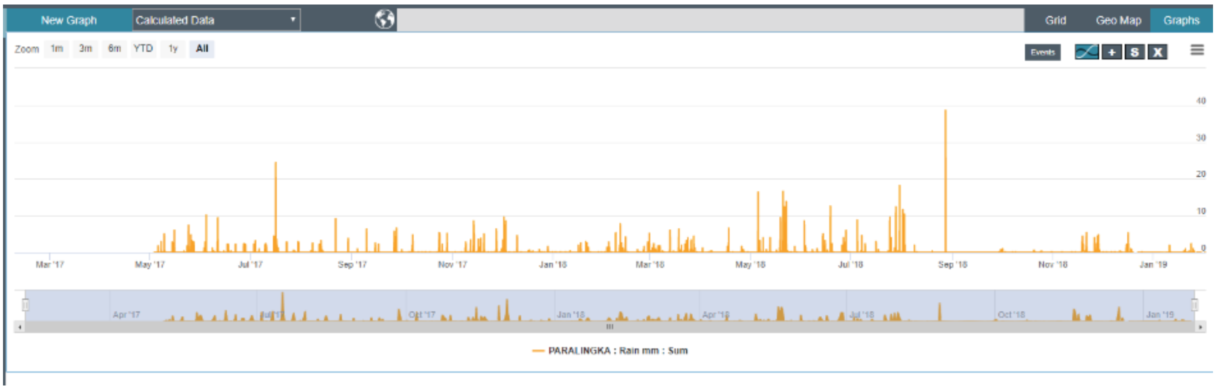

Figure 6. Web application - Environmental measurements in Graph format.

The "gaiasense web application" supports the combined representation of recorded environmental parameters with pest infestation calculated outcomes. Figure 7 displays the calculated risk for Spilocaea infestation along with the related parameters (e.g. leaf relative humidity, leaf temperature). As it was expected and show in the figure, there is a clear relation between increased leaf moisture and increased risk for Spilocaea infestation.

Figure 7. A graph representing combined graphs referring to the calculated risk of Spilocaea infection

By selecting the "GeoMap" option on the top right menu a map is presented with gaiasense pins located at the places where stations are installed. The user has the option to select a pin and view a set of information associated with the station (Figure 8).

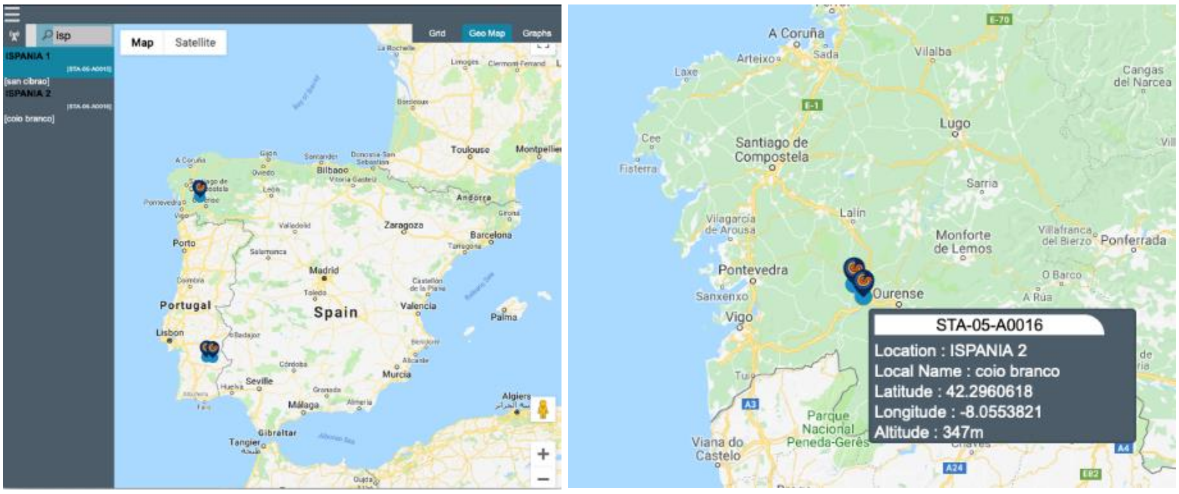

Figure 8. Web application - Geo-Map showing the location of IoT sensing stations.

Various configuration options for the application are available by selecting the three horizontal bars at the top left menu item. User can switch languages (English or Greek), log-out and quick navigate to home page (Figure 9).

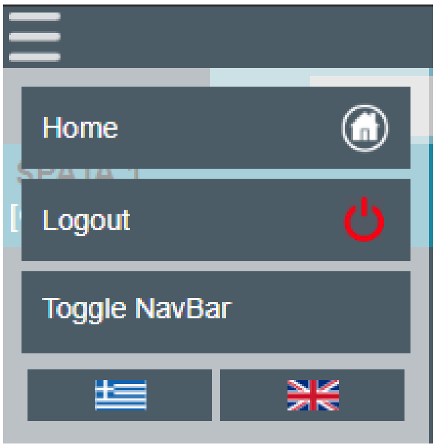

Figure 9. Configuration menu

3.2. The Gaiasense mobile application

3.2.1. Design rational

Currently there are three main approaches when developing a mobile app[1]:

1. Native apps
2. Hybrid apps
3. Web apps[2] as responsive versions of website to work on any mobile device.

Each approach has advantages and disadvantages however given that mobile devices are constantly getting more powerful in terms of processing power, storage, and connectivity the third approach is getting more attention from the developers' community. As it is stated in a report from Google[3], Web apps are evolving to a new mobile app development paradigm called Progressive Web apps (PWA) demonstrating the following benefits:

"Progressive Web Apps are user experiences that have the reach of the web, and are:

- *Reliable - Load instantly even in uncertain network conditions.*
- *Fast - Respond quickly to user interactions with silky smooth animations and no janky scrolling.*
- *Engaging - Feel like a natural app on the device, with an immersive user experience.*

This new level of quality allows Progressive Web Apps to earn a place on the user's home screen."

There are many commonly used technologies to create progressive web apps. All PWAs require at minimum a service worker and a manifest[4] file. The "Farmer's assistant" confronts with these requirements however further improvements are currently ongoing especially with regards to off-line functionality. In addition, and as the application will be operational further feedback is expected from the users and hence additional improvements on lay-out design and use experience will be conducted. However, continuous coding refinements are expected as in any production software development project (identification of bugs, optimisation of processes, refinement of graphs, etc.).

It should be noted that it is not expected the app to be utilised by users that are not registered with the gaiasense smart farming framework of services and this is a reason why the app is not provided through app stores.

Access to the mobile and desktop services are granted only to users that are in contact with the gaiasense advisors. Data and warnings provided by the apps are always supported by the respective interpretation of the advisor as this is a fundamental principle of the gaiasense smart-farming-as-a-service approach.

[1] https://thinkmobiles.com/blog/popular-types-of-apps/

[2] https://www.gartner.com/en/information-technology/glossary/mobile-web-applications)

[3] https://developers.google.com/web/progressive-web-apps

[4] https://en.wikipedia.org/wiki/Progressive_web_application

Directions on how to install the app on the mobile device:

1. The first time the user is accessing the "Farmer's assistant" service through this link: https://gaiasense.neuropublic.gr/farmerassistant
2. The user selects to save the webpage on the desktop of his/her mobile device.
3. A "Farmer's Assistant" icon is then available on mobile device. Afterwards, the app will be initiated through this icon. (no need to open the browser and type the url address).

3.2.2. Mobile application presentation

This section presents the various views of the "gaiasense mobile application". This service is accessible through this web address:

https://gaiasense.neuropublic.gr/farmerassistant

or as a stored application on a mobile device.

The lay-out of the applications and the overall design is optimised to be accessed and utilised through mobile devices like smart-phones and tablets. However, the application is also accessible through desktop devices. After a successful login, the user is redirected to the landing page of the application.

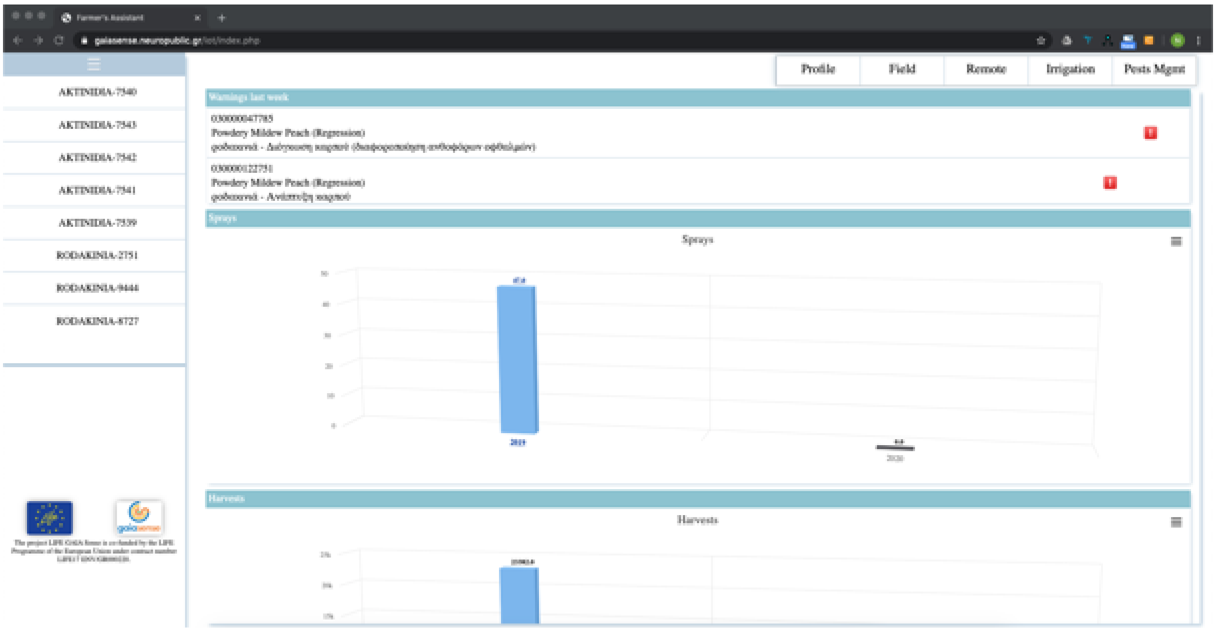

Figure 10. Mobile application – Landing page - Dashboard presenting important warnings and spraying KPIs

As it is depicted at the application screenshot of Figure 10 the landing-page is a dashboard where the most recent and important warnings are presented related with pest management and/or irrigation warnings. In addition, various Key Performance Indicators (KPIs) that are the outcome of a real-time calculation of the overall inputs. As it is depicted in figure 10 and 11 the bar-charts allow the further analysis of the aggregated data providing to the user a finer grained analysis of how the various data are distributed.

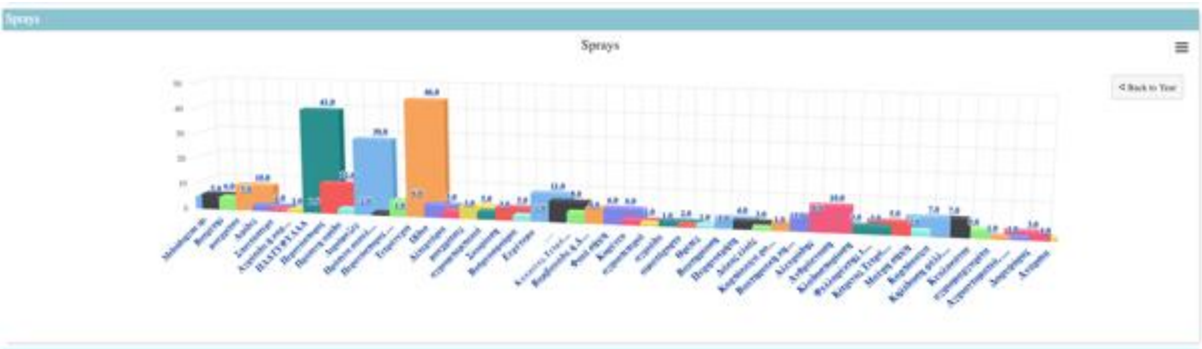

Figure 11. Analysis of utilised chemicals per pest or disease.

It should be noted that although this functionality is provided by the application it is the users (farmers and agronomists) that needs to provide the necessary data to the proper detail level in order to aggregate them and support the respective visualisations. Hence, the system can adapt to the level of detail of the provided information and provide the respective visualisations. (Figure 12 & 13)

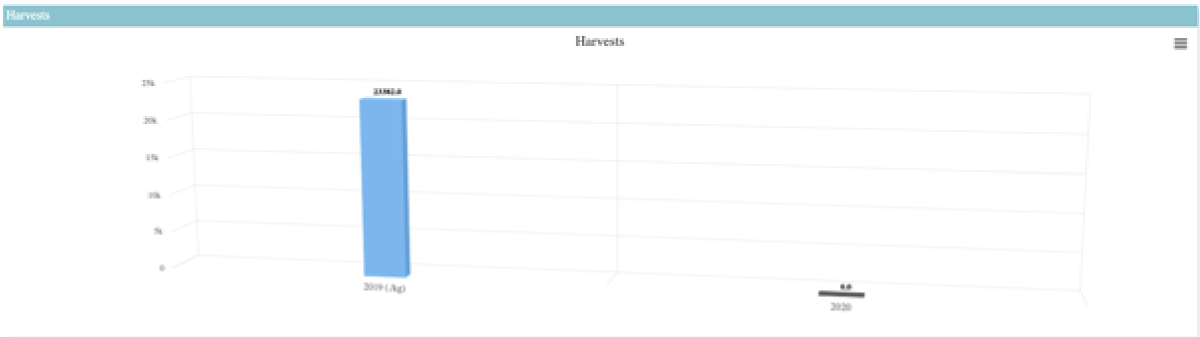

Figure 12. Mobile application – Landing page - Dashboard focusing on Harvests KPIs

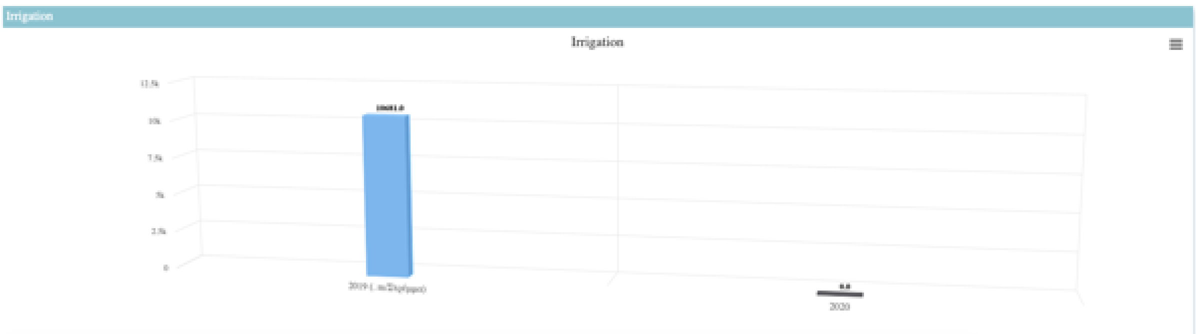

Figure 13. Mobile application – Landing page - Dashboard focusing on Irrigation KPIs

At the left side of the landing-page the list of parcels that are administered by the user is presented. Selecting one of this parcels and clicking the Profile item of the main menu the user is able to view the respective polygon on a google-maps. By clicking on the respective pin an info box is presented with more details on the parcel and the respective ongoing cultivation. (Figure 14)

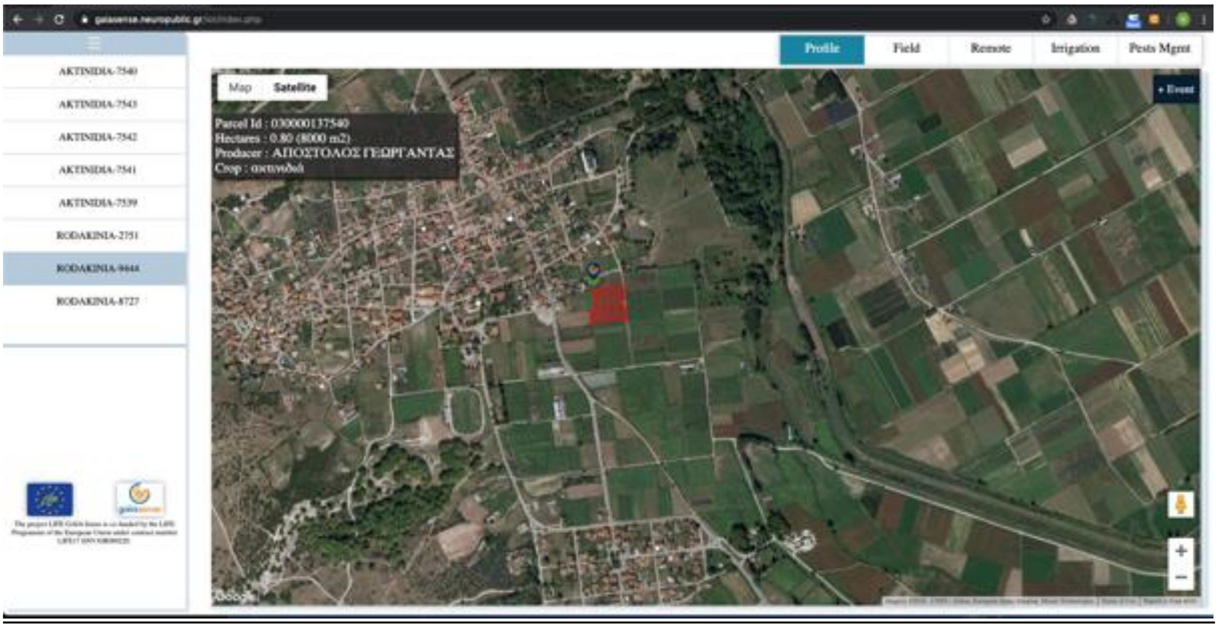

Figure 14. Mobile application – Visualisation of the polygon of the selected parcel

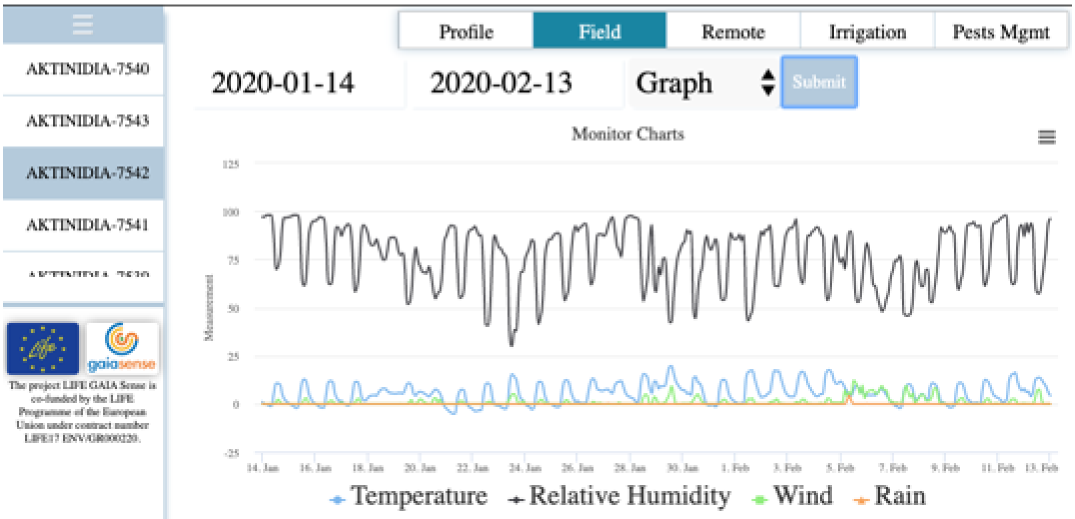

Figure 15. Mobile application – Current and past conditions in selected Parcel

When selecting the second menu item, entitled “Field”, a graph is presented visually rendering selected indicative data types over a predefined period of one month (Figure 15). Although the gaiasense platform collects and maintains a larger number of data types only the most indicative are presented to the farmers in order to avoid overwhelming them with redundant information. The user is able to select a different time period than the preselected one month.

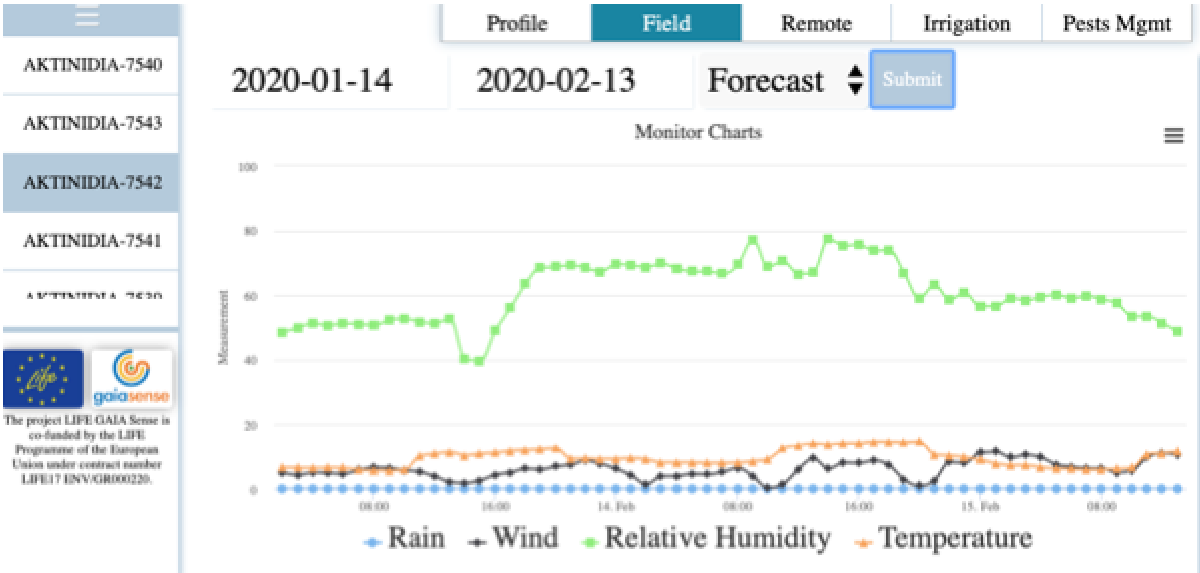

Figure 16. Mobile application - Extreme weather forecasting page.

In the same page the user is able to select from the dropdown menu the “Forecast” option and to view a graph with predicted values of Temperature, Wind speed, Humidity and Temperature. (Figure 16)

When selecting the second menu item, entitled “Remote”, earth observation related metrics are presents. Currently time series of NDVI values are visualised through a graph as it is illustrated in Figure 17.

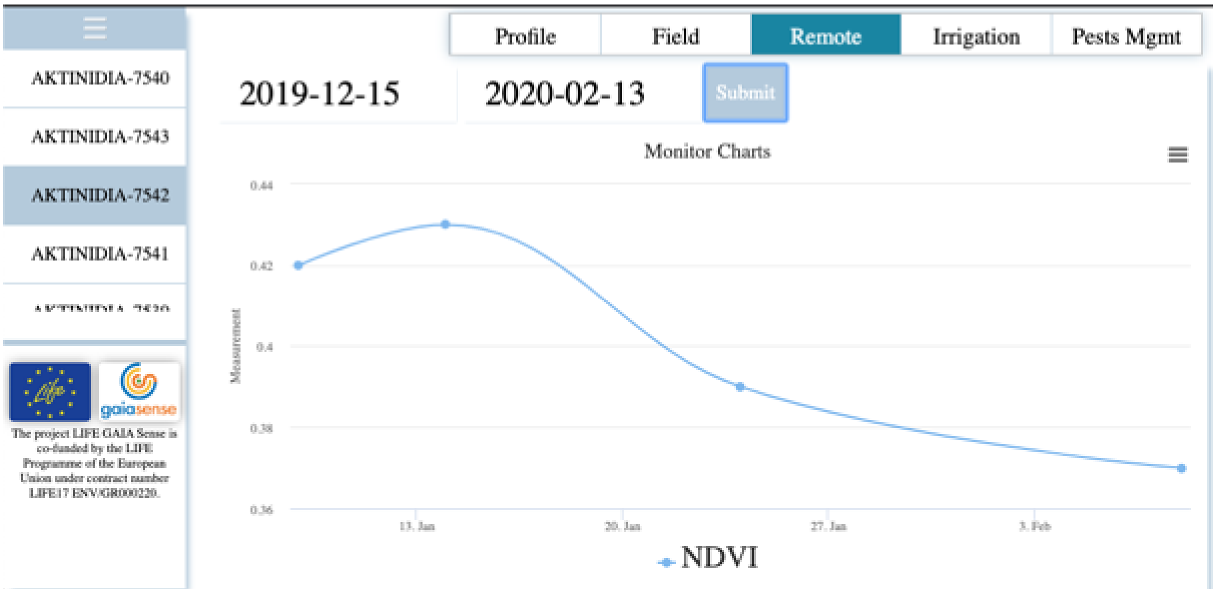

Figure 17. Visualisation of NDVI measurments for the selected parcel.

The “Irrigation” menu item presents environmental information that are related to the irrigation process of the parcel (e.g. soil moisture, rain events, and irrigation events) (Figure 17). At the profile page the user is able to submit information about an irrigation action that has taken place to one of the parcels that he/she administers (Figure 18).

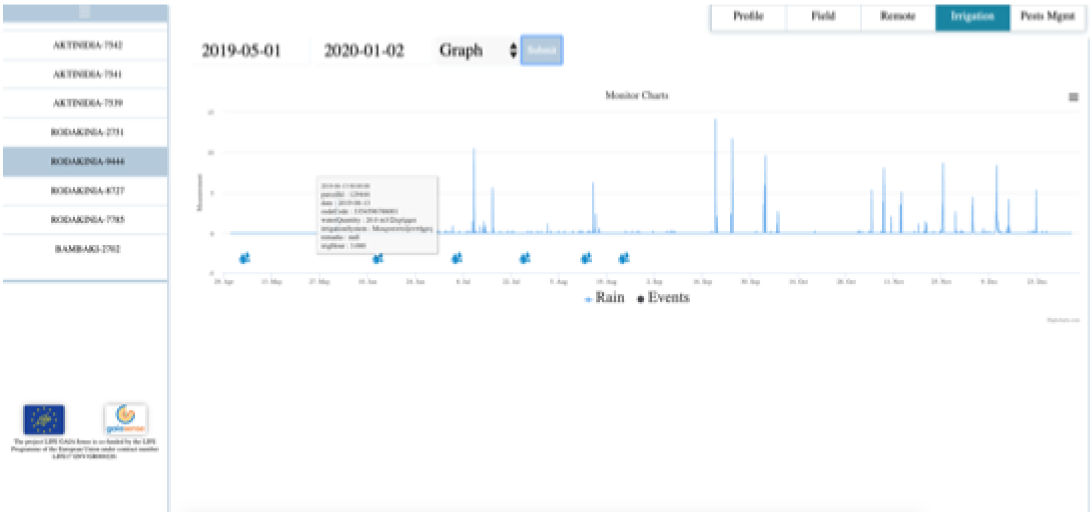

Figure 18. Mobile application - Irrigation page.

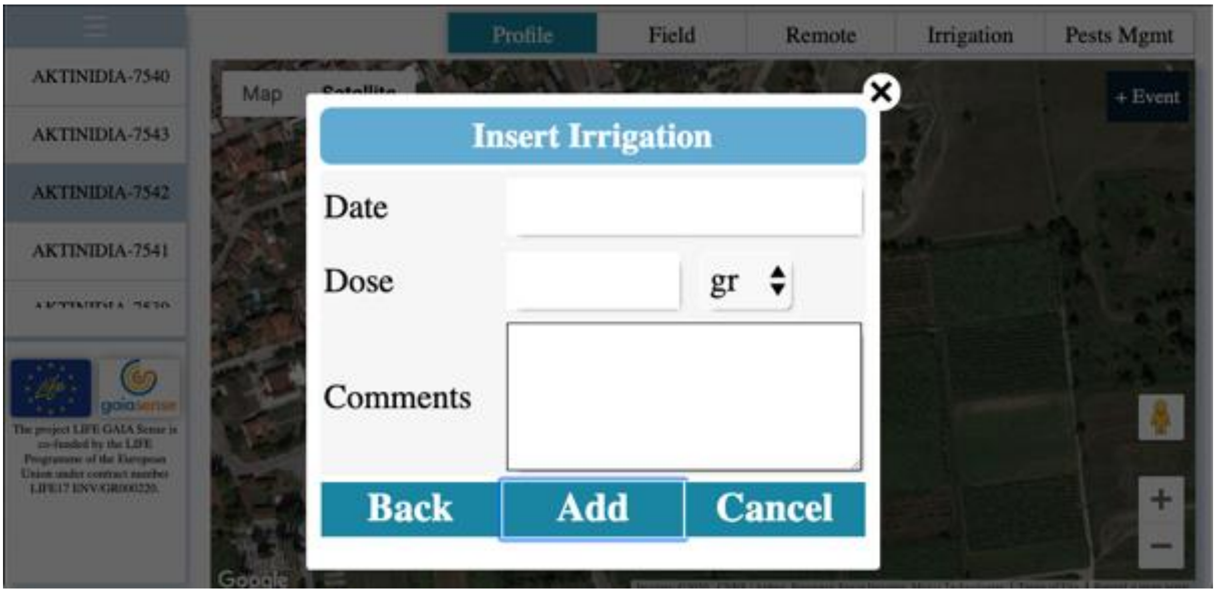

Figure 19. Mobile application - Irrigation Action page.

The "Pests mgmt" menu item presents a table containing the potential pests and diseases that are threatening the selected parcels and the calculated warning level (Figure 19). At the profile page the user is able to submit information about a pest management action (e.g. spraying with a pesticide) that has taken place to one of the parcels that he/she administers (Figure 20).

Figure 20. Mobile application - Pest management advice page.

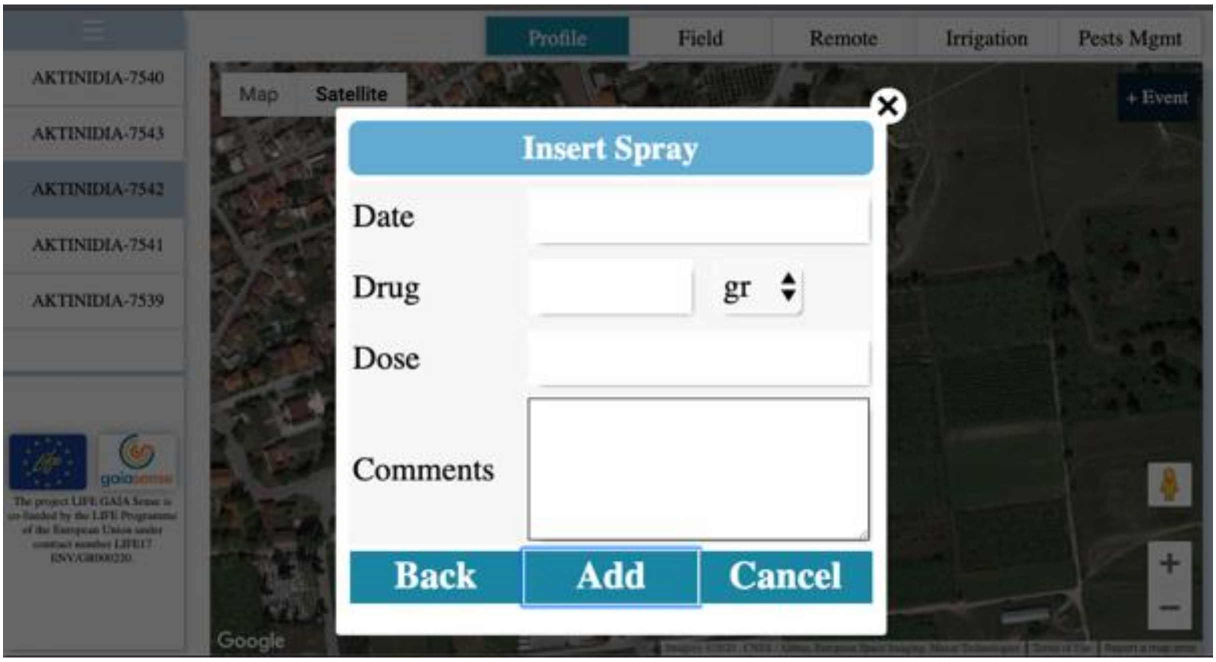

Figure 21. Mobile application - Pest management action page.

Finally, when clicking on the three horizontal bars a configuration menu is presented to the users where various parameters can be edited (Language and Time zone) (Figure 21).

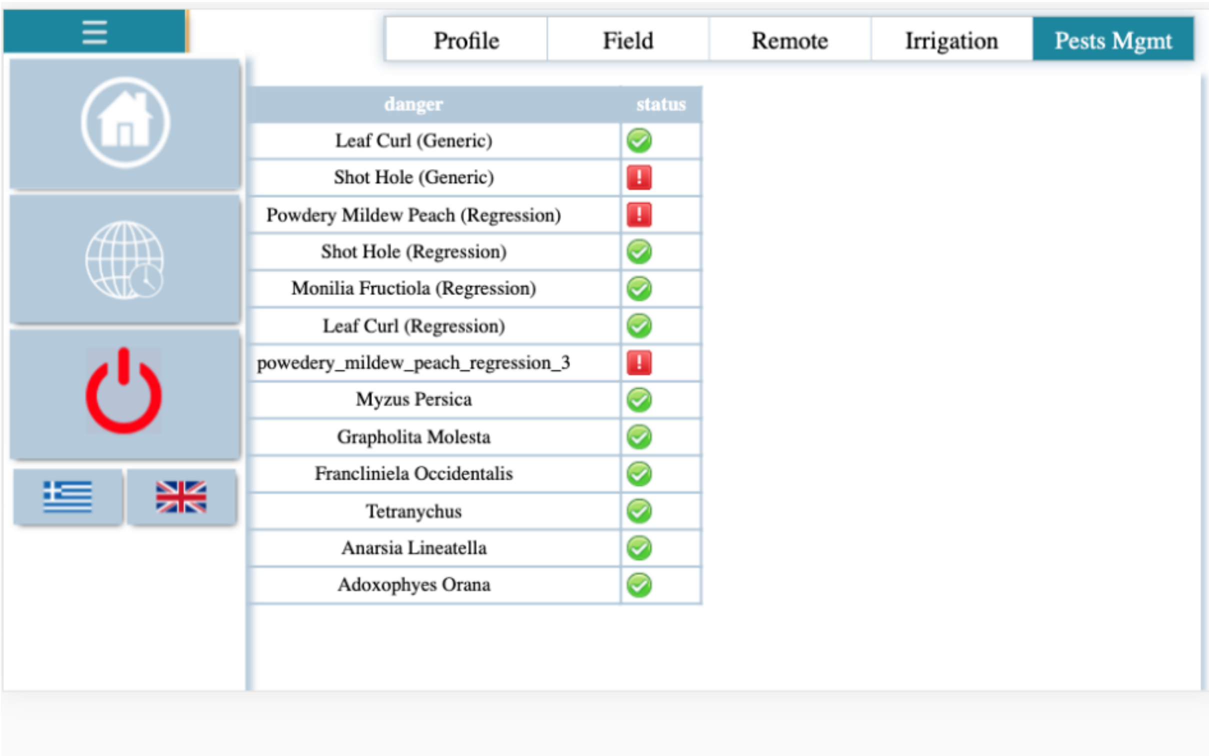

Figure 22. Mobile application – Configuration menu items.

4. Conclusions

This document presented the functionality and the implementation details of the **"gaiasense web-based application"** and the **"gaiasense mobile application"**. The first fully functional versions for both of these two applications are already released and the services are in use by selected users. Feedback from the users will be utilized by the development team in order to further improve and optimize the usability of the applications.

In addition, the scientific models and algorithms that are the core entities for processing the collected data in order to provide pest management, irrigation and fertilization advice are expected to further be refined and integrated within the backend system. The final outcomes on the LIFE GAIA Sense applications design and development will be documented at the deliverable entitled "Final Smart Farming Application" to be released at the end of this year.

5. References

[1] Deliverable: Final Application Design and Mockups, LIFE GAIA Sense project, January 2019

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