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DELIVERABLE

Application of Smart Farming (SF) advice in Portugal

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Executive Summary

The purpose of the deliverable *Application of Smart Farming (SF) advice in Portugal* is to provide all the information about the application of the fertilization, irrigation and pest/disease management advice in the Use Case of CONFAGRI that participate in the project.

The scientific models utilized for the provision of advice related with pest/disease management, irrigation, and fertilization were developed as part of the milestone “Initial specialised scientific models ready”. The inputs used for the adjustment of the models, refer to extensive field work which covers observation (phenology stages, infection rates an location, number of pests captured in traps, etc), sampling (soil, water and plant issue samples) and the whole range of agricultural application on the field (plowing, spraying, irrigating, fertilizing, plant trimming, harvesting etc) using a complete growing season, which started in January 2020 and ended in December 2020.

Role	Name (Organisation)
Deliverable Leader:	CONFAGRI
Contributors:	Domingos Godinho António Baião Gonçalo madeira
Reviewers:	V.Geitona (GAIA
Approved by:	Domingos Godinho

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1.0	30/12/2020	All (CONFAGRI)	Final version
1.1	30/12/2021	All (CONFAGRI)	Revised Version
1.1.S	30/12/2021	All (CONFAGRI)	Summary

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Definitions, Acronyms and Abbreviations

Acronym	Title
AUTH	ARISTOTELIO PANEPISTIMIO THESSALONIKIS (Aristotle University of Thessaloniki – Special Account of Research Funds)
CE	Circular Economy
GAIA	GAIA EPICHEIREIN ANONYMI ETAIREIA PSIFIAKON YPIRESION
NP	NEUROPUBLIC AE PLIROFORIKIS & EPIKOINONION
SF	Smart Farming
COSTEIRA	VIÑA COSTEIRA SCG
CONFAGRI	Confederação Nacional das Cooperativas Agrícolas e do Crédito Agrícola de Portugal CCRL
NATURA	Network of nature protection areas in the territory of the European Union
LASITHI	Enosi Agrotikon Synetairismon Oropediou Lasithiou
gaiatrons	NP’s telemetric stations

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

The main scope of this deliverable is to describe the pest/disease management, irrigation and fertilization SF advices that were applied to the Use Case of CONFAGRI (see also deliverable "Documentation of use case existing agricultural practices and restrains, requirements, needed interventions and KPIs"). The document also provides a high-level overview of the scientific models operation along with the means utilized for rendering their output. The deliverable was revised to statistics concerning how many of cultivating practices were the result of a SF advice and overall cost reductions. Revised material from the previous version (see First report from the application of the Smart Farming advice in Portugal v.1.0) can be found in paragraph 1.3 and Chapter 5

1.3. Document Structure

This document is comprised of the following chapters:

Chapter 1 provides introductory information about this deliverable.

Chapter 2 elaborates on the actual scientific models that have been utilized for the needs of the Use Case of CONFAGRI

Chapter 3 describes the collection of data used for the adjustment of the scientific models.

Chapter 4 depicts the procedure of issuing the Smart Farming Advice

Chapter 5 focuses on the actual application of the Smart Farming advice.

2. The scientific models

In order to enable the development of services for irrigation, pest/disease management and fertilization for the producers of the Use Case of CONFAGRI , scientific predicting models have been developed and adapted to the microclimate and crop requirements of each region. The models were fed with data from a network of telemetric stations installed in the field collecting atmospheric and soil measurements, as well as data provided by the producers and agronomists involved, including information related to inputs - outputs but also to all those parameters whose values identify the specificity of each production unit in the vast variety of cases.

2.1. Irrigation management

To propose a useful water management advice, we need to ensure direct and accurate determination of the optimal irrigation time and amount of irrigation. Determining the irrigation time is 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. The optimal irrigation dose is determined as the sum of daily water absorption values from the crop after the last irrigation. Also, given the high solubility of nutrients in the water, a significant change in nutrient concentrations should be expected with the adoption of a new water management strategy. To control the above hypothesis, the kinetic of nutrient elements at different depths along the plants' active roots need to be recorded continuously. To this end, the gaiasense system provides soil moisture and soil salinity sensors capable of recording the status at different depths levels. The measurements are integrated into the models that calculate - on a forecast basis - when the water reservoir will reach a minimum. This information is processed by qualified advisors who are responsible for creating the respective agricultural advice.

2.2. Fertilization management

In order to adapt the crop fertilization models to the requirements of each one of the Use Cases, both in Portugal but also in Greece and in Spain, a series of processes are conducted in order to document the status quo and record the specific conditions in each of them. Analysis of the various related attributes like location, pH value from which alkalinity of the soil is determined, along with percentage of macronutrients like Nitrogen (N) and micronutrients, is required for the development of fertilization models. Location is used along with the use of other information like, weather and temperature, type of soil, nutrient value of the soil in that region, amount of rainfall in the region, and soil composition. All these attributes of data are analyzed. The resulting outcomes are integrated into the models, which should be able to produce a proper recommendation about required fertilizer ratio based on atmospheric and soil parameters of the land that are harmonised and consistent with the status of each area as well as the requirements of each variety.

2.3. Pest/disease hazard estimation

Among the most critical factors involved in defining potential risk infestations from pest enemies is temperature, while for diseases is the combination of temperature and leaf wetness of the plant. It is well known that temperature controls the growth acceleration of many species. Plants and insects require a specific amount of heat to develop from one point in their lifecycle to another. It has been proved that the amount of temperature that is needed to complete the development of an organism is specific and countable. This measure of accumulated heat is known as physiological time. Theoretically, the physiological time consists of a common measure of organisms' growth. Although temperatures and days to maturity may vary, the organism's physiological time (a combination of time and temperature) remains relatively constant. The physiological time is expressed in units called Degree-days (°D). Degree-days (°D) is a measurement unit that combines temperature and time. At the lowest temperature, the time to maturity required the most days. At the highest temperature, the time to maturity required the least days. In other words, temperature and time work together with such that the time for the development of the organism's life cycle, or any stage or portion of the life cycle, decreases as the temperature increases (Knight, 2007).

For many species, the temperature limits (upper and lower temperatures) affecting their growth have already been defined by carefully controlled laboratory and field experiments. The lower growth limit for an organism is the temperature where below that limit, the growth development ceases. Likewise, the upper limit of growth is the temperature where over that limit, the growth rate starts to decrease or even stop altogether. These limits are defined as temperature thresholds. The lower developmental threshold (TL) for a species is the minimum temperature at which development can begin. The upper developmental threshold (TU) is the temperature at which the rate of development ceases to increase and begins to decrease. Each insect species has its particular development rate.

One degree-day is accumulated when the temperature is one degree above the TL for a 24-hour period. There are several methods used to calculate °D in the field:

- The simplest calculations are the "linear" methods. These types of calculations are based on the assumption that the rate of development is linear with temperature. Field temperatures follow a cyclical pattern, each 24-hour period having a minimum temperature (Tmin).
- The "averaging" method used to estimate °D first takes the average of the day's high and low temperatures, then subtracts from that figure the lower developmental threshold temperature for the specific pest or organism. The equation is:

$$^{o}D = [(Tmax + Tmin) / 2] - TL.$$

In order to track the development of pests and diseases a starting date is crucial. This starting date is termed as the *biofix*. *Biofix* points are usually based on planting dates, first trap catch or first occurrence of the pest. Once the biofix point is established, then tracking and accumulating degree-days can begin.

The gaiasense system provides the appropriate technical infrastructure (atmospheric sensors) capable of recording the necessary data, that is, temperature and relative humidity at hour intervals that are used along with other data sources to develop the disease prediction models. The agro-climatic measurements are fed to each model that has been calibrated according to the local cultivation conditions estimating the risk of an infestation appearance by combining all the inputs, like temperature, leaf wetness, and phenological stage.

Error! Reference source not found. summarizes the pest/disease management models adjusted to the U se Case of CONFAGRI

Table 1. The scientific model to be adjusted to the pest/disease management of the Use Cases of CONFAGRI

Use Case	Crop	Diseases	Pests
CONFAGRI	olive	Spilocaea oleagina	Prays oleae
		Colletotrichum gloesporioides	Bactrocera Oleae

3. Data collection

In order to produce an accurate and useful SF advice for pest and disease estimation, irrigation and fertilization management data are collected to calibrate the scientific models to the context and needs of each Use Case. All data concerning applications on the field, were documented with the aid of specific forms. These were developed by GAIA and translated in English in order to be used in Spain and Portugal. The platform which was used by farmers and agronomists was the "Intelligent Management Crop – (ICM)" which has been developed by NP and is one of the existing services that were configured and used within the LIFE GAIA Sense project. Even with some difficulties in using the ICM, CONFAGRI made available all the data collected.

The "Intelligent Management Crop – (ICM)" is a multifunctional platform that can properly manage a group of producers or a single farm. 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.).

The aforementioned data are also combined with valuable information which are collected uninterruptedly by the gaiatron telemetric stations, installed at selected points of selected parcels in order to be representative for each crop of a whole area. The density of the gaiatron atmo atmospheric measurement stations' network is such that at least one station corresponds to each type of crop in each microclimate zone, no matter how small that zone is. Accordingly, the density of the gaiatron soil measurement stations' network is such that for each soil area and for each crop there is a station (you can see further details in B2 deliverable: LIFE_GAIA_Sense_Report_networks_of_telemetris_stations_and_traps_v.1). The data that the gaiatron stations collect refer to the atmospheric, soil and biological parameters, such as air and soil temperature, air and soil humidity, soil salinity, leaf wetness, rainfall, solar radiation and so on.

All the above are combined with the information gathered from other gaiasense system dimensions and utilized to accurately calculate the needs of a plant for water, to identify the appropriate time for irrigation, to continually assess the risk of infection by pests and diseases, the monitoring of plants' vitality, their rational fertilization and the timely qualitative and quantitative prediction of production.

3.1. Historic – reference data

The first action is to select the pilot fields and to collect historical – referential information related to the cultivar adjusted at the region, the cultivation conditions and standard practices, and also the weather conditions existed at the potential pilot fields. Moreover, information concerning regular infestations from pest and diseases, the adjacent cultivations that could have hosted potential pathogens and pest enemies, etc., complete the pilot fields' historic information. The information was collected using questionnaires completed by the administrative entity of each pilot site. For more details, see the deliverable "Documentation of use case existing agricultural practices and restrains, requirements, needed interventions and KPIs".

3.2. Irrigation model inputs

For the initial development of the irrigation model the following data are being collected during one cultivation period, when possible:

- Environmental conditions: Solar radiation, precipitation, relative humidity, wind speed, temperature, and soil moisture. Based on these it is feasible to calculate the amount of plant's moisture loss due to the "evapotranspiration" phenomenon.

- Aquatic state of the plant: Leaf water potential and stomatal conductance that are recorded with the use of sophisticated equipment.

- Other parcel details: Irrigation system, planting distances, crop variety, mechanical soil composition, etc.

- Recordings of irrigation: Time and quantity of irrigation water utilized.

After the initial development of the irrigation model only the following parameters are required as input:

- Amount of irrigation water provided to the parcel.

- Amount of precipitation at the parcel.

- Water loss due to evaporation.

- The output of the model is based on the calculated balance among the water inputs and losses and reflects the aquatic condition of the plants. This equilibrium is utilized by the experts in order to recommend the time and the dose of irrigation.

3.3. Fertilization model inputs

For the initial development of the fertilization model the following parameters were utilised:

- Soil parameters: soil type, acidity, organic matter and nutrients
- Crop parameters: variety, plant age, cultivation site.

The correlation of these parameters is based on the application of mathematical models on recordings derived from field experiments. The aim is to assess the optimal nutrient requirements for each crop and to extract metrics and thresholds that will allow the final calibration of the algorithm.

After the development of the model, the agronomists need to collect representative soil samples that will undergo laboratory physico-chemical analysis that will allow the characterization of cultivation's condition. The soil sampling is conducted on specific time periods, also considering the phenological stage of the cultivation, based on a strict methodology and prior the application of any fertilisers. The recordings are imported to the software platform that will proceed with the respective calculation of the potential nutrient deficit. Thus, the agronomic consultant is able to inform the producer of the dose, phase and type of fertilizer that he needs to add to the crop.

3.4. Pest/disease management model inputs

For the initial development of the pest/disease management models, different inputs are required for each prediction model needed, based on the historic – referential data and observations. Generally, the following requirements are needed to adjust the scientific models to each pest or disease observed:

- Data from telemetric stations gaiatron
- Cultivation records (phenological stages, cultivation practices)
- Observations and measurements through sampling of affected plant parts and insect traps by field agronomists

4. The SF advice

As soon as the scientific models are adjusted to the data reflecting each crop and field, then the advice is produced and shared with the advisors/agronomists working in the field for further verification. In practice, the agronomist personalize the directive for each parcel and uses the gaiasense system to advise producers to facilitate the decision making process. The advisors, as the recipients of the final information, should be aware of the applications used by all agronomists. They are called to compose the final picture of the farm with their agronomic perception, and through their cooperation with the rest of the agronomists, in order to assess the provided advice, relating to the whole set of included fields in the smart system of gaiasense.

4.1. Irrigation advice

The data are collected and integrated into the gaiasense system in order to calculate - on a forecast basis - when the water reservoir will reach a minimum. The advice aims to cover the irrigation needs based on multiple parameters, is generated from the system and includes the following information:

- Recommended irrigation dosage (m3/decare/irrigation)
- Recommended irrigation dosage for the whole parcel (m3/decare/irrigation)
- Estimated irrigation duration (minutes)
- Irrigation System flow

This advice can be further processed by qualified advisors balancing also economical drivers and eco-friendliness and include the following information:

- Recommended (by agronomist) irrigation dosage (m3/decare/irrigation)
- Recommended(by agronomist) irrigation dosage for the whole parcel (m3/decare/irrigation)
- Actual time of irrigation (min)
- Estimated irrigation dosage (m3/decare/irrigation)
- Observations

Figure 2 shows the data of the irrigation advice.

Contact detail	
First Name:	....
Last Name:	....
Parcel Data	
Location	....
Cartographic:	....
Parcel ID :	....
Crop:	....
Tel. Number:	....
Irrigation Advice	
Date of irrigation advice:	....
Recommended irrigation dosage (m3/decare/irrigation)	....
Recommended irrigation dosage for the whole parcel (m3)	....
Estimated irrigation duration (minutes)	....
Additional comments / Observations	

Figure 1. Irrigation advice template

4.2. Fertilization advice

The fertilization advice is based on the crop, and refers to the correct nutrients combination and quantities and the appropriate method of application. The advice aims to cover the crop nutritional needs based on soil and foliar analyses while balancing economical drivers and eco-friendliness. Figure 2 shows the template of the fertilization advice.

gaiasense

FERTILIZATION ADVICE

Contact detail	
First Name:	…………….
Last Name:	…………….
Soil Sample Data	
Reference number :	…………….
Depth (cm):	…………….
GPS:	…………….
Parcel Data	
Prefecture:	…………….
Province:	…………….
Parcel Name:	…………….
Cartographic:	…………….
Area (ha):	…………….

Date of fertilization advice:	…………….
Date of soil sampling:	…………….

Existing Nutritional Status

	Soil type	Mechanical Composition	Clay, %	Silt, %	Sand, %	pH	Conductivity mS/cm	Total $CaCO_3$,%
Measured	-	-	-	-	-	-	-	-
Crop limits	-	-	-	-	-	-	-	-
Characterization	-	-	-	-	-	-	-	-

	Active $CaCO_3$, %	Organic matter, %	$N\text{-}NO_3$ ppm	P, ppm	K, ppm	Mg, ppm
Measured		-	-	-	-	-
Crop limits		-	-	-	-	-
Characterization		-	-	-	-	-

	Ca, ppm	Fe, ppm	Zn, ppm	Mn, ppm	Cu, ppm	B, ppm
Measured	-	-	-	-	-	-
Crop limits	-	-	-	-	-	-
Characterization	-	-	-	-	-	-

Summary of the soil characteristics:	…………….

Fertilizaton Advice

Nutrient	Dosage (units)	Recommended fertilizer		Method of Application	Application period
		kg/ha	type		
N	*e.g. 12*	*e.g. 35*	*e.g. Nitrogen fertilizers*	*e.g. The fertilizer is applied to the parcel in 3 parts:* *1st dosage (20% of the total amount) mid of April* *2nd dosage (40% of the total amount) end of May* *3rd dosage (40% of the total amount) end of June*	*e.g. Mid-end spring*
P					
Fe					
etc.					

Additional comments / Observations	…………….

Figure 2. Fertilization advice template

4.3. Pest/disease management advice

Given the scientific models that have been adjusted to offer advice on pest and disease management, an alert of a pest or disease, informs the farmer on the type of pest or disease and the level of danger, a few days before a specific intervention is needed. Figure 3 presents an example of the scientific model adjusted for the Use Case of CONFAGRI, for the Spilocaea Oleaginea o the olive crop. The area with the red area reflects the high risk and the grey area demonstrates the low risk of appearance of the specific disease.

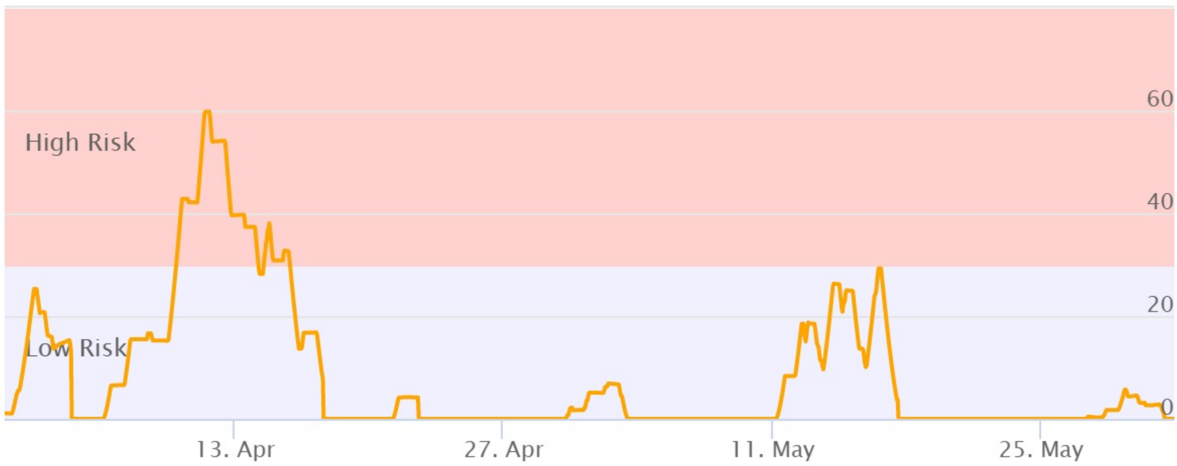

Figure 3. The scientific model adjusted for the Use Case of CONFAGRI , for the olive crop, for the period of April 1st to May 31st.

5. The SF application in the Use Case of CONFAGRI

During the first cultivation period of the project (from Spring to Autumn 2019) farmers and agronomists/farming advisors of the Use Case were contributing a lot to Action B5 and particularly sub-action B5.2, with sharing information about their cultivation practices such as when and how much they irrigated the fields, which product they applied for pest management accompanied with the concentration and the targeted enemy in the framework of the project, when, how much and what type of fertilizers they used etc and the costs of all above. This information was shared with NP and the scientific experts for developing the models but also for creating and updating the **baseline – reference costs** for each Use Case both in Portugal but also in Greece and in Spain (see also deliverable A1 LIFE_GAIA_Sense_Documentation of Use Cases v.1.2).

After the completion of the first year and the development/adaptation of the scientific models in the specific areas and cultivations of interest, we were then able to proceed to the notification of irrigation, fertilization and crop management SF advices to farmers who could henceforth **treat** their parcel accordingly.

However given the fact that a lot of farmers are by nature conservative and are used to treat their parcels in a traditional way that could even be influenced by what their neighboring farmers do in their farm or by mistrust of technology, a couple of deviations were noticed in the actual treatments of their parcels in comparison to what the gaiasense system would **optimally** suggest.

Consequently, in the following paragraphs are depicted data concerning reference, treatment and optimal treatment costs for Irrigation, and Pest / disease management.

For the Use Case CONFAGRI there is :

A **chart** including information about:

Baseline / reference costs

Treatment costs

Optimal treatment costs

and a **table** including information about:

Goal	Treatment	Optimal treatment
Cost reduction targeted goal (%)	Achieved variation based on the actual treatment of the parcels (%)	Possible variation based on optimal treatment of the parcel (%)

As far as fertilization costs are concerned and given the fact that the majority of farmers use compound fertilizers and the price of single nutrients is not available, it would not be accurate to present costs of optimal treatments.

Consequently, the fertilization costs data are presented as follows:

A **chart** including information about:

Baseline / reference costs

Treatment costs

A **table** including information about:

Goal	Treatment
Cost reduction targeted goal (%)	Achieved variation based on the actual treatment of the parcels (%)

Given the fact that the quantity of the irrigated macronutrients but more importantly of Nitrogen (N) is very important, a comparative chart is also included including information about:

Baseline / reference (kg/acre)

Treatment (kg/acre)

Optimal treatment quantity(kg/acre)

NOTE

Before moving to the analytic presentation of the aforementioned data , it is important to mention that the achieved results of this 1st cultivating year that SF advices were applied to participating parcels could be considered as sufficiently satisfactory given the fact that farmers are by nature conservative and they often find it difficult to change the way they traditionally cultivate their farms and adhere to scientific tools. Thankfully, the great majority of the farmers involved were more positive to take advantage of the innovations that IT offers in this very traditional sector and it is believed that the few more skeptical farmers will soon understand the benefits of it and adjust to what gaiasense system can offer to them.

Moreover, we should not neglect to mention the significant difficulties created by Covid -19 to the smooth implementation of the project. In particular, during almost all cultivating year we came across to the following situations:

- Due to travel restrictions, pilot areas that required long-distance traveling could not be easily reached and it was not always possible to collect field data. In order to face this issues, field measurements were organized at a more periodical pace something that created extra difficulties for the adjustment of the scientific SF models to the specific crop type and location
- While no working restriction for the agricultural sector was imposed, since it is a primary sector, however due to the global economic recession that affected the entire country, it was not possible to acquire enough human resources to assist with the required field measurements and monitoring. These measurements were essential for the adjustment of the scientific SF models to the specific crop type and location.

Last but not the least, we should also mention the difficulty of the majority of the farmers to choose a compound fertilizer that would comply to the suggested SF advice and at the same time to be available and at such price that would not affect dramatically his income.

6. Conclusion

The achieved results of this 1st cultivating year that SF advices were applied to participating parcels could be considered as sufficiently satisfactory given the difficulties farmers had to face throughout the year due to the Covid -19 restrictions but also due to their internal tendancy to cultivate their field in a more traditional way. However, both field agronomists and advisors managed through intensive and persistent work and continuous communication with the farmers to persuade them, up to a great extent, to perform the SF advices generated by the gaiasense system. It is strongly believed that aside the aforementioned difficulties, this 1st year of gaiasense application is completed sufficiently satisfactory and similar results are expected for the following 2nd year.

In the following figures are depicted collectively

- Variations observed regarding total irrigation, fertilization and pest disease management costs
- Statistics of the total achieved reductions regarding irrigation, fertilization and pest disease management costs

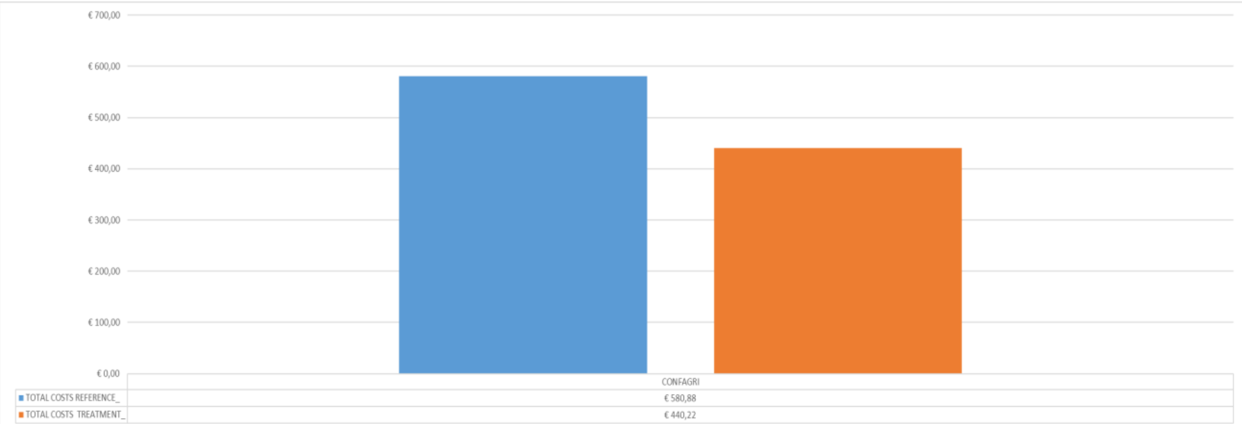

Figure 4. Total costs for CONFAGRI

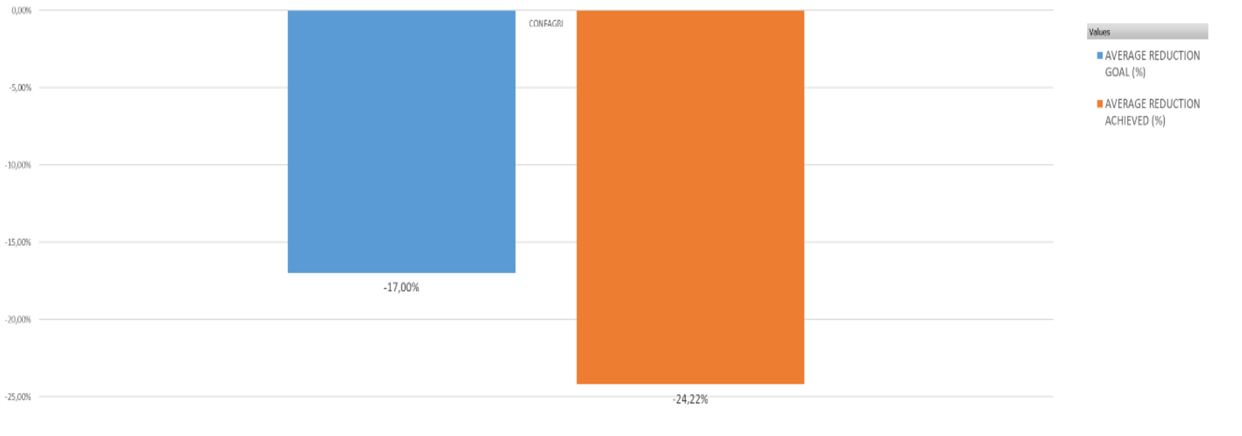

Figure 5. Reduction goals/achieved concerning irrigation/pest disease management, fertilisation for CONFAGRI