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DELIVERABLE

Final report from the application of Smart Farming (SF) advice in Greece

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Executive Summary

The purpose of the deliverable *Final report from the application of the Smart Farming advice in Greece* is to provide all the information about the application of the fertilization, irrigation and pest/disease management advice in the 16 Use Cases 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 milestones “Initial specialised scientific models ready”, “Interim specialised scientific models ready” and “Final 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 two complete growing seasons for the Use Cases of the first wave (started in January 2020 and ended in December 2021) and one complete growing season for the Use Cases of the second wave (started in January 2021 until December 2021).

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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
EU	European Union
GAIA	GAIA EPICHEIREIN ANONYMI ETAIREIA PSIFIAKON YPIRESION
NP	NEUROPUBLIC AE PLIROFORIKIS & EPIKOINONION
ICM	Intelligent Management Crop
SF	Smart Farming
ORESTIADA	Enosi Agrotikon Synetairismon Orestiadas
VELVENTOS	Agrotikos Synetairismos Epexergasias kai Poliseos Oporokipeftikon Proionton (ASEPOP) Velventou SYN.P.E
AIGINA	Omada Pagagogon Kelyfotou Fistikiou Aiginas
ELASSONA	Agrotikos Synetairismos Fytikis kai Zoikis Paragogis – Enosi Elassonas
LASITHI	Enosi Agrotikon Synetairismon Oropediou Lasithiou
SPEKO-PESKO	Koinopraksia Agrotikon Synetairismon – SPEKO-PESKO
KIATO	Geoponiki Kiatou
STYLIDA	Stylis Olive Producers Cooperative
THESTO	Agricultural Cooperative of Thessalian Tomato Producers
THESGI	Farmers' Cooperative of Thessaly
MIRABELLO	Agricultural Cooperative Partnership Mirabello Union S.A.
COSTEIRA	Viña Costeira SCG
CONFAGRI	Confederação Nacional das Cooperativas Agrícolas e do Crédito Agrícola de Portugal CCRL
MESSINIA	Agrotikos Sineterismos Messinias "Enosi Messinias"
ARTA	Apostolidis AE
FARSALA	Agrotikos Synetairismos "Farsalon Gis"
EUBOEA	Atypi Omada Paragogon Tomatas Dystou
PELLA	NOVAPLAN IKE
KOMOTINI	Thrakika Ekokkistiria
DRAMA	Enosi Agrotikon Synetairismon Dramas
KASTORIA	Radopoulos D. LTD

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 16 Use Cases in Greece (see also deliverables: "Documentation of use case existing agricultural practices and restrains, requirements, needed interventions and KPIs" and "Application of Smart Farming (SF) advice in Greec"). The document also provides a high-level overview of the scientific models operation along with the means utilized for rendering their output.

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 16 Use Cases in Greece.

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

Chapter 6 presents a conclusion and cumulative results.

2. The scientific models

In order to enable the development of services for irrigation, pest/disease management and fertilization for the producers of the 16 Use Cases in Greece, scientific predicting models have been developed and adapted to the microclimate and crop requirements of each region (see also deliverable: “Final Specialised Scientific Models”. 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, 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 micronutrient, 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:

$$^{o}D = [(T_{max} + T_{min}) / 2] - TL.$$

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.

Table 1 summarizes the pest/disease management models adjusted to each Use Case in Greece. In total, 48 scientific models have been adjusted to offer advice on pest and disease management while 2 scientific models could not be adjusted due to different reasons.

More specifically as far as *Lygus Hesperus* is concerned the scientific bibliography is extremely poor and monitoring insect populations is relatively time consuming and demanding as on – site inspection is required in and around the field and is done primarily using abstinence scanning protocols with the use of cloth or fabric. In addition, there are references to tolerable density limits but there are relative modifications depending on the region and the crop. Moreover, the development of a forecasting model requires data on:

- The overwintering of dormant adults in adjacent cultivated areas, which is a key aspect of the winter ecology of Lygus. However little is known about adult rest.
- The end of the dormancy and the movement of populations in cultivated areas from neighboring crops (with special emphasis on alfalfa)
- Prevailing temperatures in the areas of interest, as it significantly affects the egg production of females as well as the mortality levels of all stages of development of the Lygus
- The relationship between population density and infestation of crops of interest
- The relationship between growth temperature and resting end temperature
- Evidence of the enemy's polyphagia, stenophagia or monophagia
- Evidence for the possible existence of an insect predator in the areas of interest

Consequently, the development of a scientific model for Lygus Hesperus without the aforementioned scientific documentations involved a high risk.

Similarly with Lygus Hesperus, the available scientific data on the biology of Eurygaster maura, are extremely limited and monitoring insect populations is particulatly time consuming and dematnind as it can be don twith visual abstraction scanning protocols. Eurygaster maura demographic data are available from Mohaghegh (2007 in Sun Pests and their control in the near east. RH. Miller and JG Morse (eds). The data refer to the calculation of life tables in stable laboratory conditions and do not include growth data at different temperatures that could be used to develop Degree-days' (°D) models. There is also a reference to tolerable density limits in the gray literature which are not supported by experimental data. These limits are based on the counting of wintering adults in adjacent cultivated areas and on corresponding measurements of adults, eggs and other developmental stages in cereal crops. The density of measurements is given as the number of persons per unit area of land (eg square meter) and the intervention thresholds specify specific intervention densities. Moreover, the development of a forecasting model requires data on:

- The overwintering of dormant adults in adjacent cultivated areas.
- The end of the dormancy and the movement of populations in cultivated areas from neighboring crops
- Prevailing temperatures in the areas where phenological data are available
- The relationship between population density and infestation of crops of interest
- The relationship between growth temperature and resting end temperature
- Evidence of the enemy's polyphagia, stenophagia or monophagia

Consequently, the development of a scientific model for Eurygaster maura without the aforementioned scientific documentations involved a high risk.

Table 1. The scientific models adjusted to the pest/disease management of the 16 Use Cases

		Use Case	Crop	Diseases	Pests
Greece	First wave	ORESTIADA	cotton	Alternaria alternata	Pectinophora gossypiella
					Helicoverpa armigera
					Lygus hesperus
					Eurygaster maura

		VELVENTOS	table peach	Wilsonomycetes carpophilus	Grapholita molesta
				Taphrina deformans	
				Monilinia fructicola	
				Sphaerotheca pannosa	
		AIGINA	pistachio	Septoria sp.	
				Botryosphaeria dothidea	
		ELASSONA	walnut	Gnomonia leptostyla	Cydia pomonella
		LASITHI	potato	Alternaria alternata	Leptinotarsa decemlineata
				Peronospora infestans	Phthorimaea operculela
		SPEKO-PESKO	kiwi	Stemphylium botrysum	Pseudaulacapsis pentagona
				Pseudomonas syringae	Metcalfa pruinosa
				Alternaria alternata	
		KIATO	table tomato	Alternaria solani	
				Pseudomonas syringae	
				Botrytis cinerea	
				Phytophthora infenstans	
		STYLIDA	table olive	Pseudomonas syringae	Bactrocera oleae
				Colletotrichum gloesporioides	Prays oleae
				Spilocaea oleagina	
		THESTO	industrial tomato	Phytophthora infestans	Helicoverpa armigera
				Leveillula taurica	
				Botrytis cinerea	
				Alternaria solani	
		THESGI	cotton	Alternaria alternata	Helicoverpa armigera
					Pectinophora gossypiella
					Bemisia tabaci
					Lygus hesperus

		MIRABELLO	olive	Pseudomonas syringae	Bactrocera oleae
				Spilocaea oleagina	Prays oleae
				Colletotrichum gloesporioides	
	2nd wave	FARSALA	cotton	Alternaria alternata	Pectinophora gossypiella
					Helicoverpa armigera
		ARTA	kiwi	--	--
		PELLA	Peach	Wilsonomycetes carpophilus	Grapholita molesta
				Taphrina deformans	Anarsia lineatella
				Monilinia fructicola, Monilinia laxa	
		EUBOEA / KASTORIA	table tomato	Phytophthora infestans	Helicoverpa armigera
				Leveillula taurica	
				Botrytis cinerea	
				Alternaria solani	
		MESSINIA	olive	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 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.

The 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). 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 for each Use Case, 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 in each Use Case. Generally, the following requirements are needed to adjust the scientific models to each pest or disease observed to each Use Case:

- 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

In each Use Case, 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

In each Use Case, 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 Velvento, for the Powdery mildew on the peach crop. The area with the red area reflects the high risk and the grey area demonstrates the low risk of appearance of the specific fungal disease.

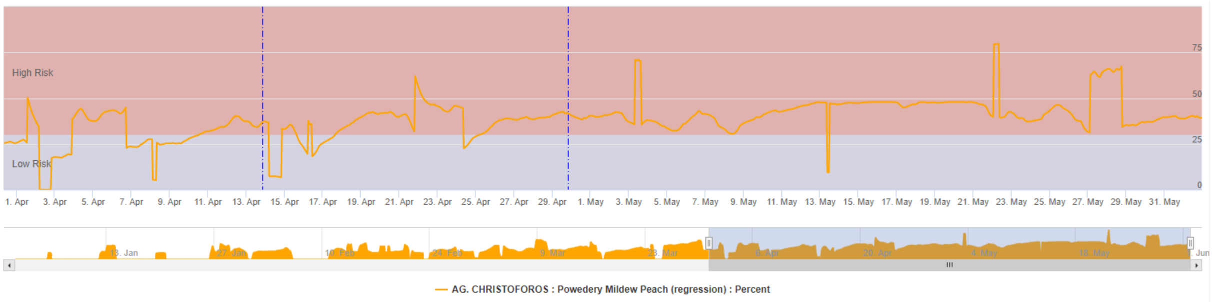


Figure 3. The scientific model adjusted for the Use Case of Velventos, for the peach crop, for the period of April 1st to May 31st.

5. The SF application in the 16 Use Cases in Greece

During the first cultivation period of the project (from Spring to Autumn 2019) farmers and agronomists/farming advisors from the first wave of Use Cases, were contributing a lot to Action B4 and particularly sub-action B4.2, 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. Similar information was gathered for Use Cases that participated in the second wave of the project (cultivating period 2020). This information was shared with NP and the scientific experts for developing and adapting the models but also for creating the baseline – reference costs for each Use Case (see also deliverable A1 LIFE_GAIA_Sense_Documentation of Use Cases v.1.3).

After the completion of the first cultivating period for each Wave 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 presented

1. An individual analysis for each Use Case based on quantities (actual values) used for Irrigation, fertilization and Pest / disease management, including also quantitative information on how many actions performed by the farmers were based on SF advices or based on their usual practices. A discussion on measures taken to address such issues and how they have or not affected project impact for each case is also included.
2. An individual analysis for each Use Case based on reference, treatment and optimal treatment costs of Irrigation, fertilization and Pest / disease management

NOTES

1st Note : Cooperation with farmers

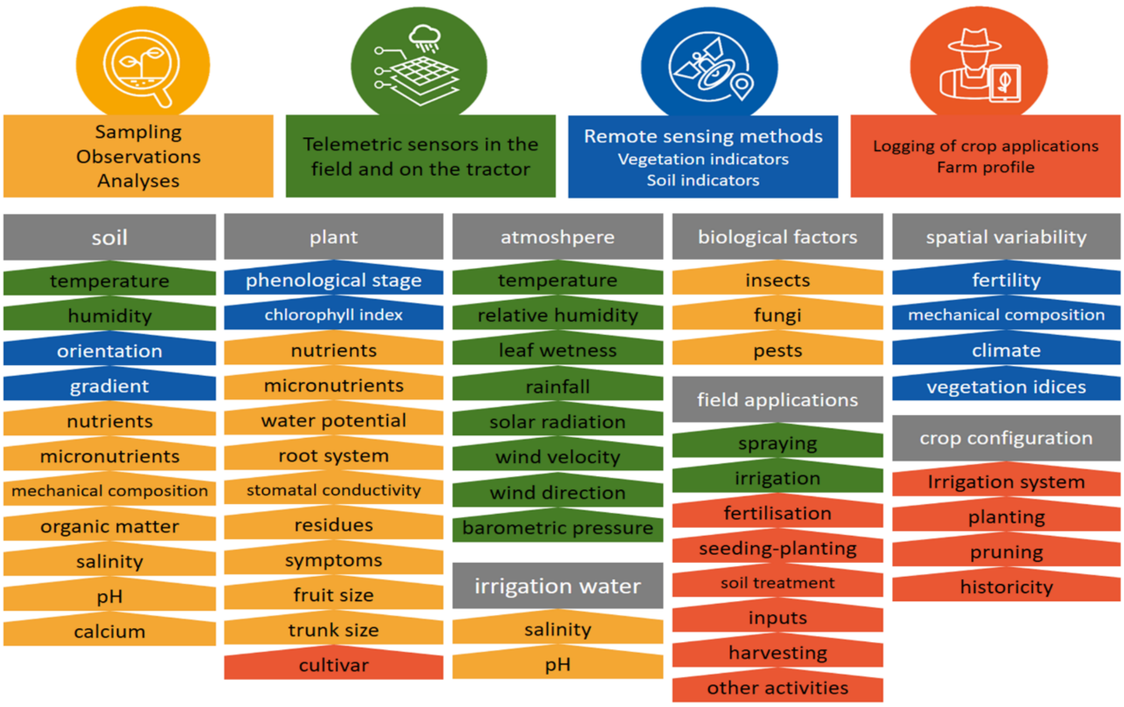
Before moving to the analytic presentation of the aforementioned data, it is important to mention and clarify the following as far as the way that an automated SF advice is issued the gaiasense system and what needs to be done after that:

As already mentioned gaiasense is a four (4) dimensional system where all dimensions interact with each other and are dependent to one another for the good operation of it.

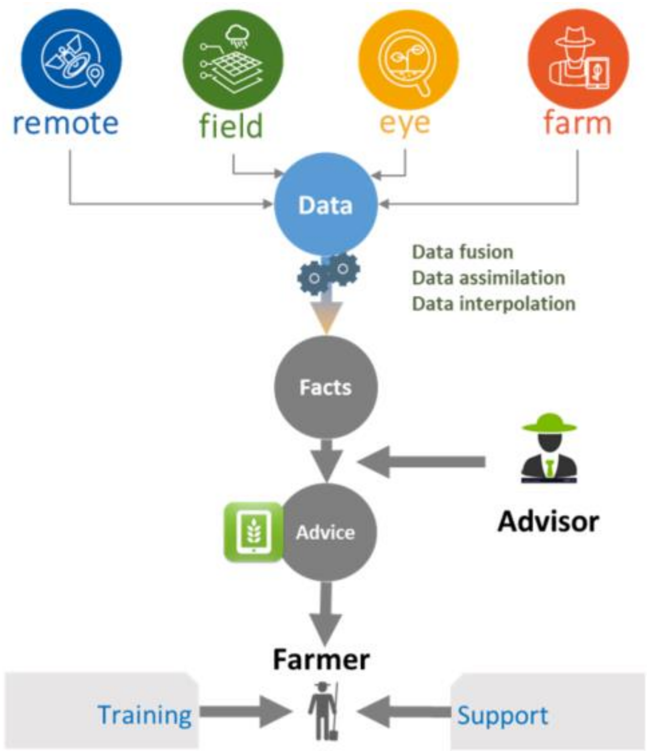
Gaiasense remote	**The dimension of seeing crops from above**
gaiasense remote collects, processes and exploits information for every part of the parcel. The information is acquired from sources such as satellites, aircraft and other aerial vehicles that are equipped with state-of-the-art image capturing systems. The gaiasense remote dimension is utilized to allow gaiasense and its users have a detailed and up-to-date picture of the plant's vitality and the status of the soil. The status of the plants and soil is represented in the form of indices which value change in space and time, such as vegetation / health plant indices (NDVI), indices of the soil's water status (NDWI), etc. These indices can be used along with information from the gaiasense field dimension, referring to atmospheric and soil and other records in the gaiasense farm and gaiasense eye dimensions that are related to the cultivation activities of the producer and observations that are acquired through the field respectively.	
Gaiasense field	**The dimension of monitoring the crop's growing environment**
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. The gaiasense field information is combined with the information gathered from other 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.	
gaiasense eye	**The dimension of observing and analyzing the cultivation closely**
gaiasense eye allows information to be recorded by advisors, agricultural consultants and producers in the field. The information is related to the state of cultivation, through field observations and sampling.	

With gaiasense eye, the producer or agricultural advisor makes several observations during their field visit. Such information includes observing symptoms of infection or infestation, recording of sprays and irrigations, counting insects in insect traps, etc., but also data that come from analysis such as soil and leaf sampling. The data that comes into the system from the gaiasense eye complements those coming from the other dimensions with vital information about the plant, soil, water and air that are not technically feasible to measure by telemetric stations or remote sensing.	
gaiasense farm	**The dimension of recording and evaluating any significant action that takes place within the field**
In order for the user to make the most of the benefits gaiasense can give to the crop of a particular field, the farmer who cultivates the field but also the advisor should become part of the exploitation of the gaiasense farm. gaiasense offers the information system (see chapter 4 about the ICM platform) to record all information that is related to the daily cultivation work of the producer such as fertilization application, plant protection, time and duration of irrigation. This is the full and detailed picture of the exploitation, which contributes significantly to the decision-making process. gaiasense farm completes the other gaiasense information collection dimensions in order to fully capture everything that happens within the parcel. This is also the key for the smart farming to work properly and lead to the best possible decision-making on all farming issues.	

As it can be easily understood this is a great amount of data that can be depicted as follows:



The data that are collected through the four dimensional system are of different importance and therefore they are analyzed and processed with the valuable experience and help of gaiasense **advisors** (scientists and agronomists) who are able to better understand the special needs and conditions of each plot.



So, during a cultivating year, all four (4) dimensions have to continuously work properly for the continuous data feed into the gaiasense system and into ICM platform so as to have **automated agricultural SF advices issued by the system** which need to be **interpreted and handled/characterized** by the advisor.

However given the fact that both farmer and advisor are key actors of the gaiasense system, the establishment of a high level of **timely and direct communication** and **collaboration** among each other is crucial for the best implementation of the SF system.

A short example will make things even more clear: Whenever an action at the field takes place eg a spraying against a specific enemy, the farmer needs to directly inform the advisor so as to proceed to the necessary data entry into the system. If the farmer does not do that **on time** for whatever reason (eg forgot about it, did not think it was important to do it on the same day, was at the fields and did not have access to phone/internet, was reluctant to modernization and found it as an extra daily burden on his activities etc) or the advisor does not do the data entry in time for whatever reason (eg he did not have access to internet when the farmer called him, he was too busy with other agronomic obligations, he was on his annual/illness leave etc) and at the same time the rest of the dimensions show that there are such conditions for an infestation, then there is a chance an automated agricultural SF advice is issued, as an "alert for action", and this alert has to be handled by the advisor.

At this point there are different options for the advisor and/or the farmer:

Advice approval : The advisor, judges that there are such conditions for an infestation, and an action has to be put into practice (eg spraying) so he proceeds to the approval of the SF advice and notifies the farmer for the steps to follow.

Advice Rejection : The advisor, judges that there are no such conditions for an infestation yet or just in the same morning the prefecture proceeded to a selective spraying in the area and the situation has to be reexamined soon, consequently, so there is no need for immediate action. In such case he rejects the SF advice and if need be he adds into the system the reason of Advice Rejection for future reference.

In case of advice approval, the advisor has five (5) days to update the system regarding the execution or not of it by the farmer. If this period passes and no action is performed, or no data entry is done, the system will automatically consider it as a Not Follow Advice and will directly archive it as not executed.

So, an advice is considered as executed, if the producer proceeds to eg crop protection management and the ICM platform is updated. In such case, the Farm Record-keeping/Crop protection tab is automatically updated and no further action is needed. In case an advice is rejected or not executed then the Farm Record-keeping is not automatically updated.

At this point, note also, that the advisor has three (3) days to approve or reject an advice after the initial “alert”. If a day passes by without any action taken, and the conditions are the same, then the advice will reappear in the system the following days, up until the conditions change or the advice is handled by the advisor.

As it can be easily understood if there is lack of communication among these two actors, or if there is not timely data entry into the system or objective conditions do not allow to the actors to react (eg travel restrictions due to Covid -19 pandemic, illness etc) then we may notice a number of actions taking place at the field without an Approved SF advice, even in cases where there would be an approval if a timely communication and data entry had taken place. Also, we may notice a number of advices archived into the system as “Not Follow Advice”, or “Not executed” but this does not mean, by no means that these advices were wrong or the producer is not willing to adhere to SF advices.

Having the above in mind, we believe that it would be misleading to generally mention that X number of farmers did follow a SF advice or X number of farmers did not retain their usual practices on a subset of field, because this would be only in individual cases.

However, since a more clear and detailed capture of the cooperation we had with the farmers is required, we have revised the following paragraphs, to include (in addition to the percentages already presented) the number of actions (irrigation/fertilization/pest management) actually carried out based on SF advices and those that took place without a SF advice although this does not directly mean that the producer was not good.

2nd Note : Achieved results and practical difficulties

It is also important to mention that the achieved results of this 2nd 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 further 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 further 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.

5.1. SF application – Analysis based on quantities

In the following paragraphs are depicted data concerning reference, treatment and optimal treatment quantities for Irrigation, fertilization and Pest / disease management

More precisely for IRRIGATION and PEST/DISEASE MANAGEMENT there are for each Use Case:

A **chart** including information about:

(green)	Baseline / reference quantities used (1st cultivating year)
(blue)	Treatment /Actual quantities used (2021)
(yellow)	Optimal treatment - quantities to be used 2021)

and a **table** including information about:

Goal	**Treatment** **(2021)**	**Optimal treatment** **(2021)**
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 quantities are concerned and given the fact that the majority of farmers use compound fertilizers it is not possible to present selectively the quantities optimally proposed by the gaiasense system which include specific nutrients.

Consequently, the fertilization quantities data are presented as follows:

For each Use Case there are :

A **chart** including information about:

(green)	Baseline / reference quantities used (1st cultivating year)
(blue)	Treatment /Actual quantities used (2021)

A **table** including information about:

Goal	**Treatment** (2021)
Reduction targeted goal (%)	Achieved variation based on the actual treatment of the parcels (%)

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

(dark blue)	Baseline / reference quantities used (1st cultivating year)
(blue)	Treatment /Actual quantities used (2021)
(light blue)	Optimal treatment - quantities to be used (2021)

5.2. SF application – Analysis based on costs

In the following paragraphs are depicted data concerning reference, treatment and optimal treatment costs for Irrigation, pest / disease management and fertilization.

More precisely as far as Irrigation and pest / disease management costs, for each Use Case there is:

A **chart** including information about:

(green)	Baseline / reference costs (1st cultivating year)
(blue)	Treatment costs (2021)
(yellow)	Optimal treatment costs (2021)

and a **table** including information about:

Goal	**Treatment (2021)**	**Optimal treatment (2021)**
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:

For each Use Case there is :

A **chart** including information about:

(green)	Baseline / reference costs (1st cultivating year)
(blue)	Treatment costs (2021)

A **table** including information about:

Goal	**Treatment (2021)**

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

6. Conclusion

The achieved results of this 2nd 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 great majority of SF advices. It is strongly believed that aside the aforementioned difficulties, this 2nd year of gaiasense application is completed sufficiently satisfactory.

In the following figures are depicted collectively

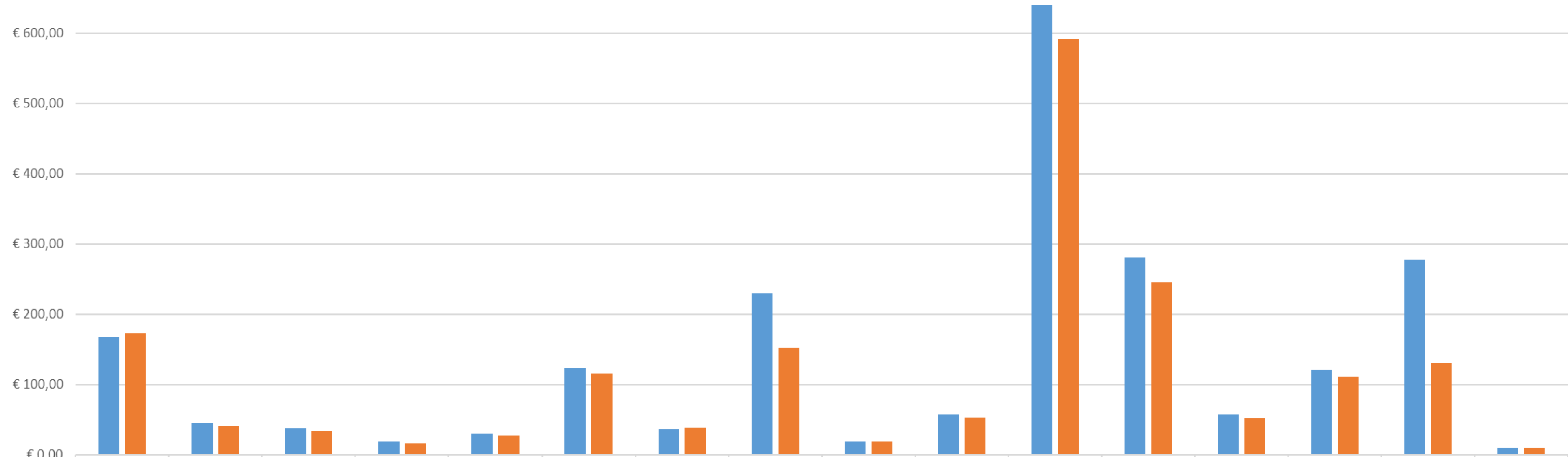
- Variations observed regarding irrigation, fertilization and pest disease management costs
- Statistics of the achieved reductions regarding irrigation, fertilization and pest disease management costs
- Aggregated quantitative information on how many actions performed/ quantities used by the farmers were based on SF advices or based on their usual practices (See Chapter 6)

for the 16 Greek Use Cases

but also

- Variations observed regarding energy consumption
- Statistics of the achieved reductions regarding energy consumption

for the 8 Greek Use Cases.



	AIGINA	ARTA	ELASSONA	FARSALA	KASTORIA	KIATO	LASITHI	MESSINIA	MIRABELLO	ORESTIADA	PELLA	SPEKO-PESKO	STYLIDA	THESGI	THESTO	VELVENTOS
IRRIGATION REFERENCE_	€ 168,00	€ 45,74	€ 37,93	€ 18,41	€ 29,63	€ 123,54	€ 36,12	€ 229,57	€ 19,25	€ 57,68	€ 640,06	€ 281,26	€ 57,74	€ 121,38	€ 277,19	€ 9,83
IRRIGATION TREATMENT_	€ 173,00	€ 41,14	€ 34,16	€ 15,99	€ 27,52	€ 115,46	€ 39,06	€ 152,06	€ 18,39	€ 52,68	€ 592,08	€ 245,53	€ 51,93	€ 111,15	€ 131,03	€ 9,43

Figure 4. Variation of Irrigation costs for the 16 Greek Use Cases

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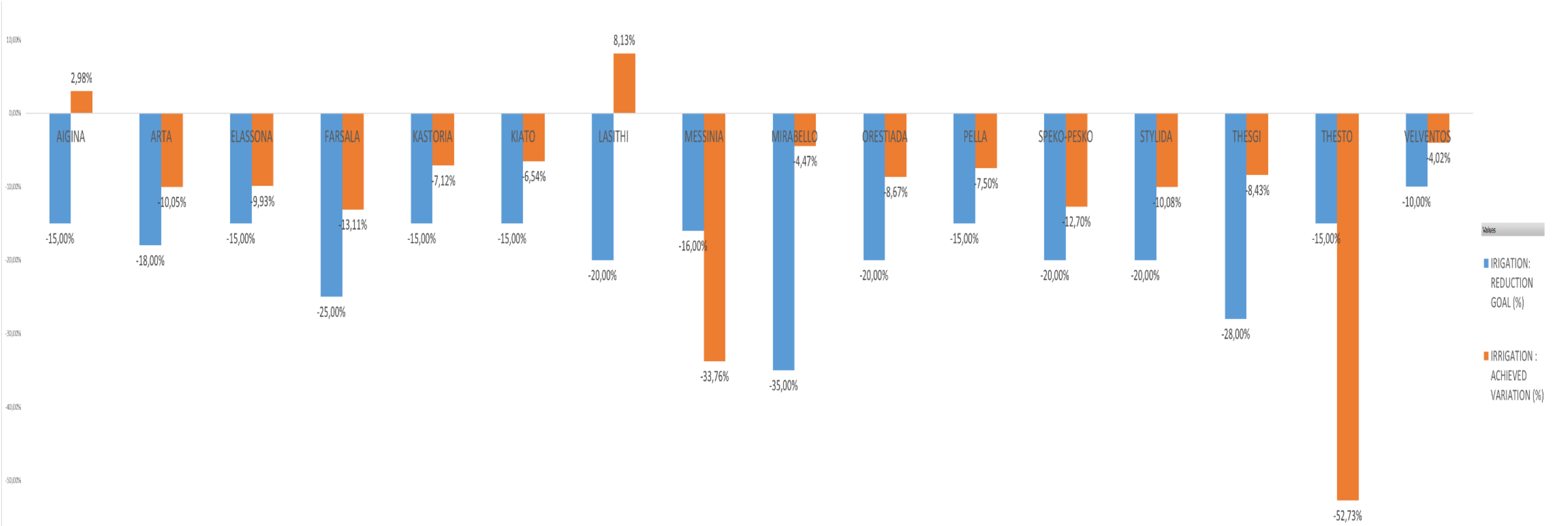
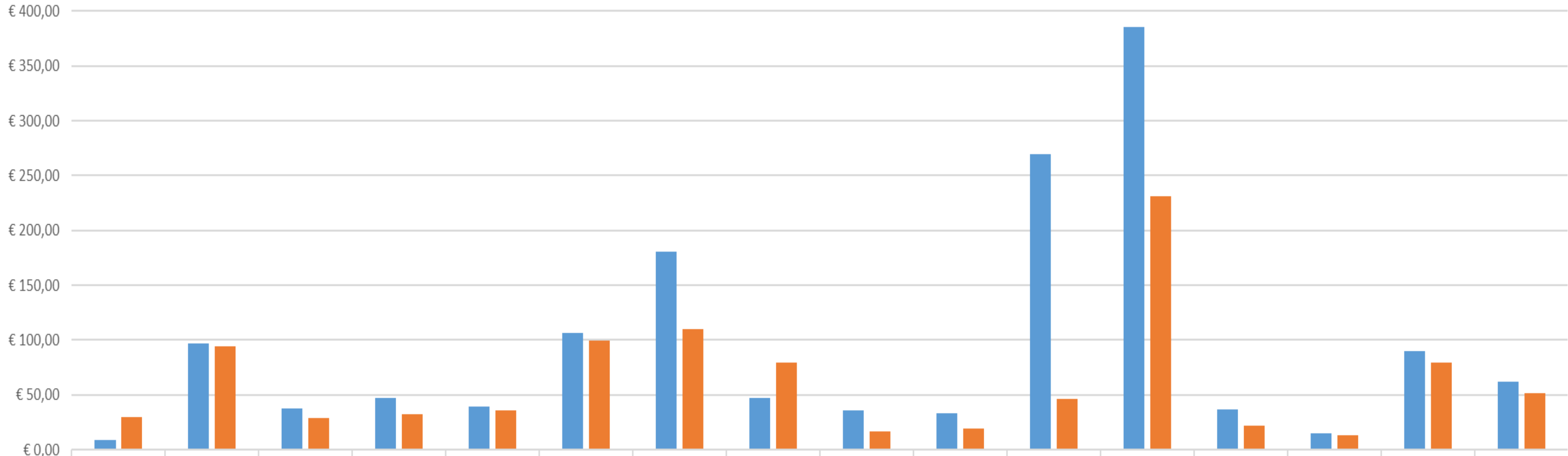


Figure 5. Irrigation reduction goal/achieved (%) for the 16 Greek Use Cases



	AIGINA	ARTA	ELASSONA	FARSALA	KASTORIA	KIATO	LASITHI	MESSINIA	MIRABELLO	ORESTIADA	PELLA	SPEKO-PESKO	STYLIDA	THESGI	THESTO	VELVENTOS
FERTILISATION REFERENCE_	€ 8,48	€ 96,74	€ 37,80	€ 47,20	€ 39,35	€ 106,38	€ 180,82	€ 47,20	€ 35,61	€ 32,96	€ 269,81	€ 385,52	€ 36,33	€ 14,59	€ 90,00	€ 61,72
FERTILISATION TREATMENT_	€ 29,34	€ 93,99	€ 29,05	€ 32,15	€ 35,78	€ 99,13	€ 109,55	€ 79,41	€ 16,51	€ 19,50	€ 46,72	€ 231,00	€ 21,80	€ 12,86	€ 79,33	€ 51,44

Figure 6. Variation of fertilization costs for the 16 Greek Use Cases

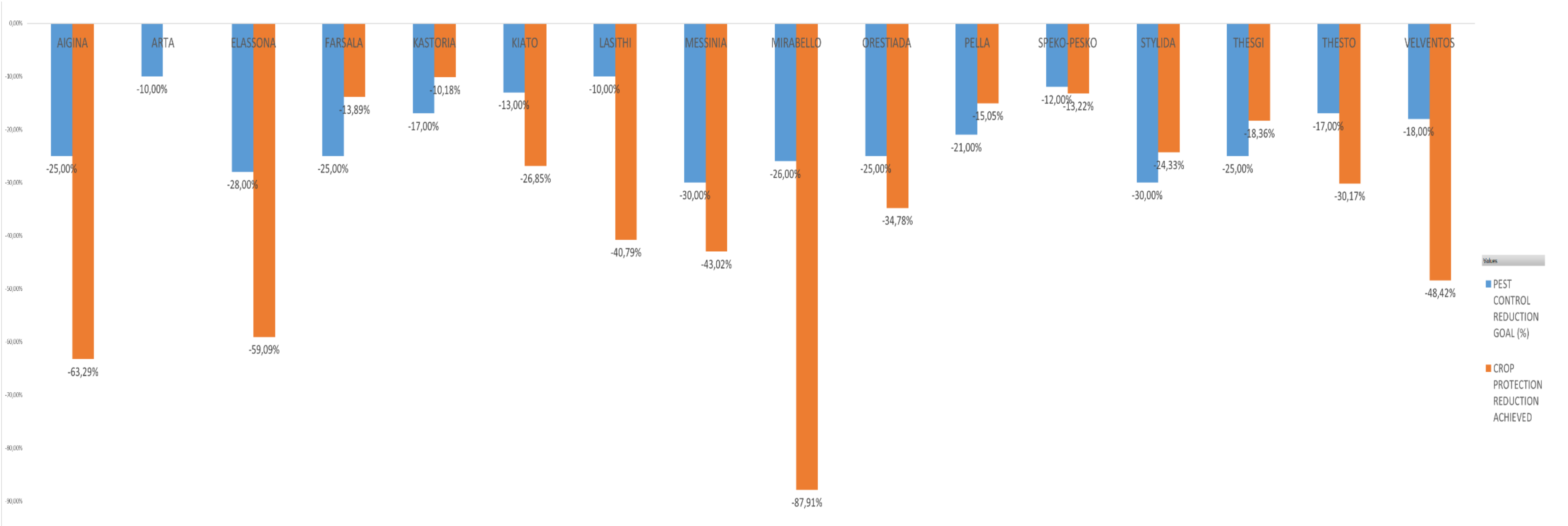
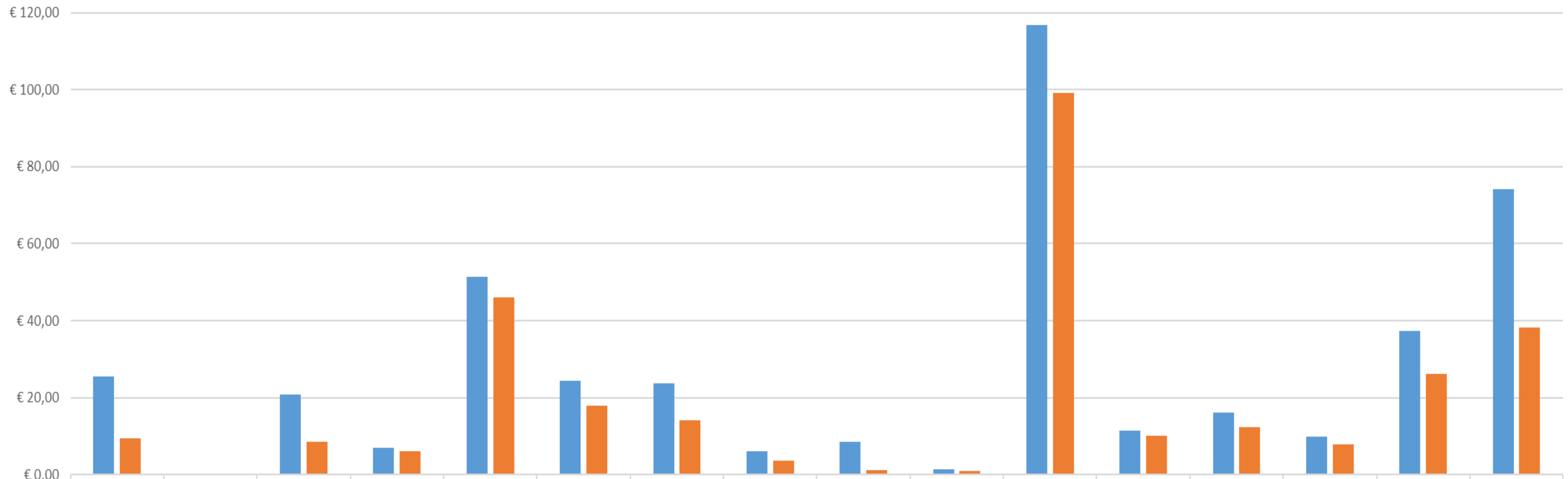


Figure 7. Fertilisation reduction goal/achieved (%) for the 16 Greek Use Cases



	AIGINA	ARTA	ELASSONA	FARSALA	KASTORIA	KIATO	LASITHI	MESSINIA	MIRABELLO	ORESTIADA	PELLA	SPEKO-PESKO	STYLIDA	THESGI	THESTO	VELVENTOS
CROP PROTECTION REFERENCE_	€ 25,50	€ 0,00	€ 20,90	€ 7,03	€ 51,37	€ 24,32	€ 23,66	€ 6,16	€ 8,60	€ 1,38	€ 116,75	€ 11,50	€ 16,15	€ 9,75	€ 37,32	€ 74,14
CROP PROTECTION TREATMENT_	€ 9,36	€ 0,00	€ 8,55	€ 6,05	€ 46,14	€ 17,79	€ 14,01	€ 3,51	€ 1,04	€ 0,90	€ 99,18	€ 9,98	€ 12,22	€ 7,96	€ 26,06	€ 38,24

Figure 8. Variation of pest / disease costs for the 16 Greek Use Cases

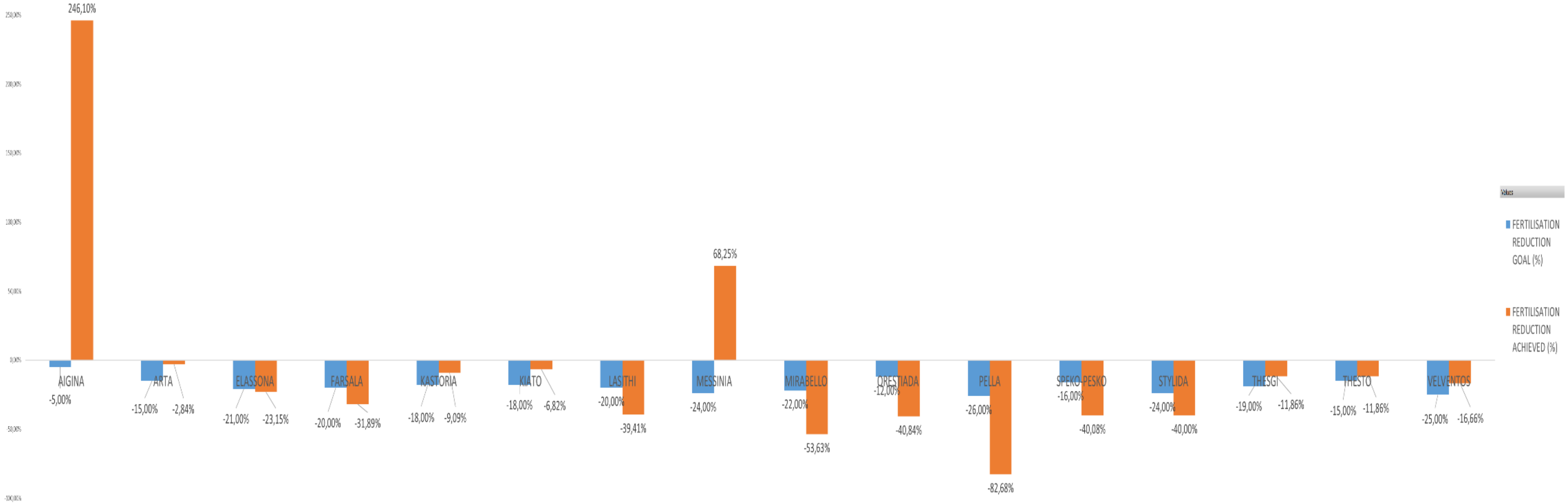
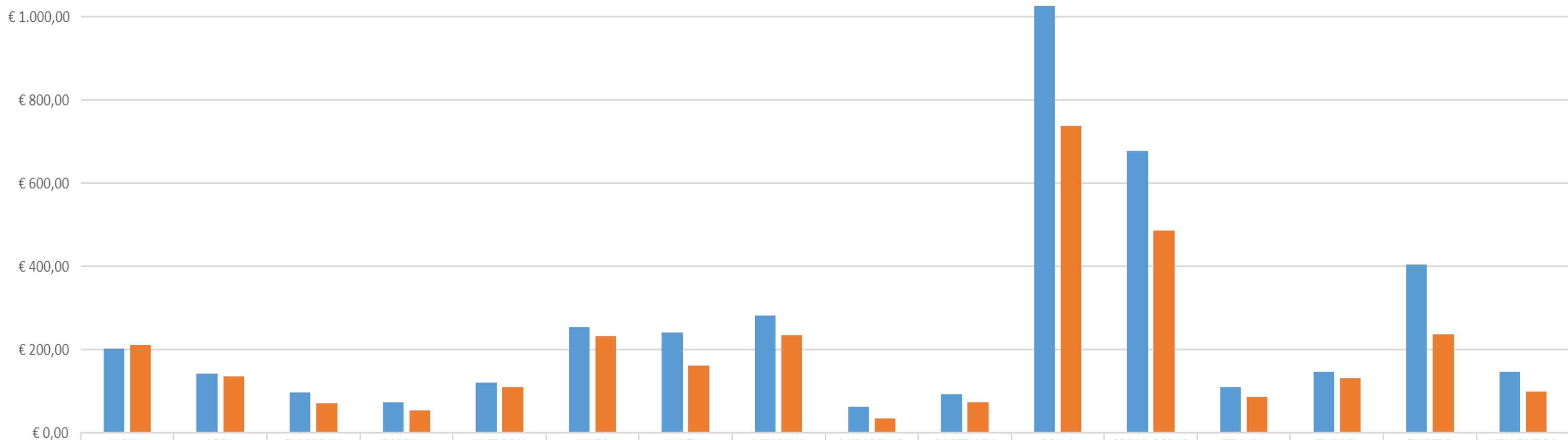


Figure 9. Pest / disease reduction goal/achieved (%) for the 16 Greek Use Cases



	AIGINA	ARTA	ELASSONA	FARSALA	KASTORIA	KIATO	LASITHI	MESSINIA	MIRABELLO	ORESTIADA	PELLA	SPEKO-PESKO	STYLIDA	THESGI	THESTO	VELVENTOS
TOTAL COSTS REFERENCE_	€ 201,98	€ 142,47	€ 96,63	€ 72,64	€ 120,35	€ 254,24	€ 240,60	€ 282,93	€ 63,46	€ 92,02	€ 1.026,63	€ 678,28	€ 110,22	€ 145,72	€ 404,51	€ 145,69
TOTAL COSTS TREATMENT_	€ 211,70	€ 135,13	€ 71,76	€ 54,20	€ 109,43	€ 232,37	€ 162,62	€ 234,98	€ 35,95	€ 73,08	€ 737,98	€ 486,51	€ 85,95	€ 131,97	€ 236,42	€ 99,11

Figure 10. Variation of total costs concerning irrigation/pest disease management, fertilisation for the 16 Greek Use Cases

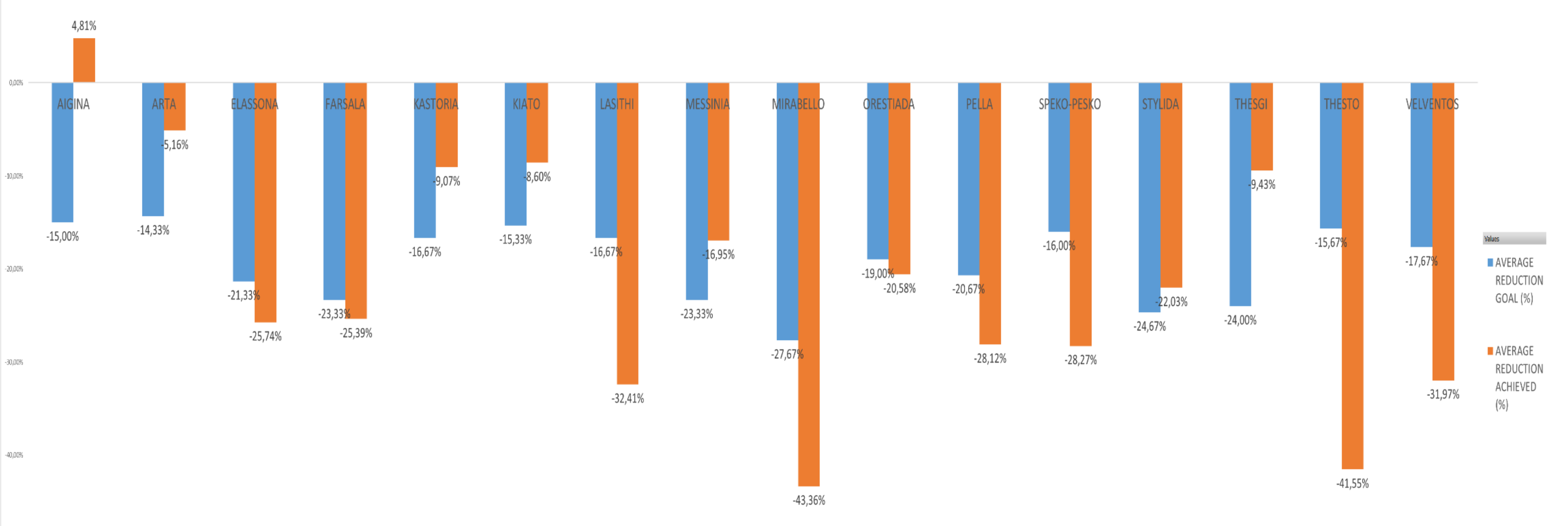
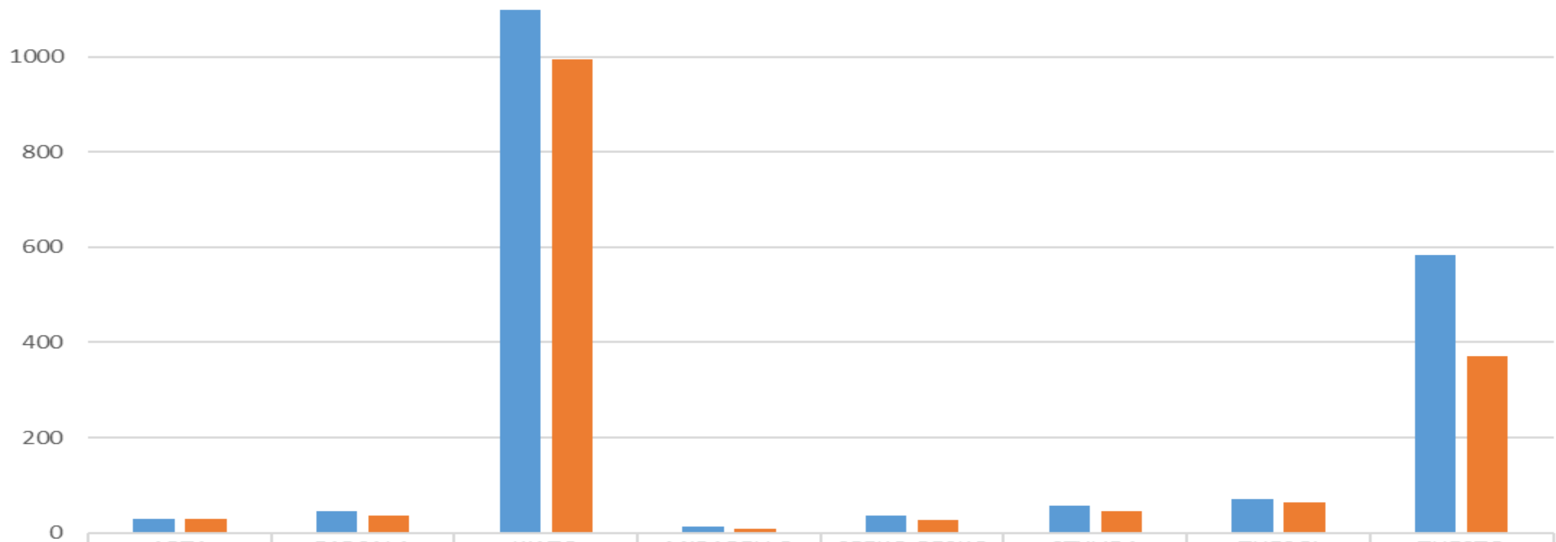


Figure 11. Reduction goals/achieved concerning irrigation/pest disease management, fertilisation for the 16 Greek Use Cases



	ARTA	FARSALA	KIATO	MIRABELLO	SPEKO-PESKO	STYLIDA	THESGI	THESTO
Energy consumption reference (lt/acre)	30	45	1098	14	37	56	70	584
Energy consumption treatment (lt/acre)	28,5	36	995	8,5	28	45	65	370

Figure 12. Energy consumption

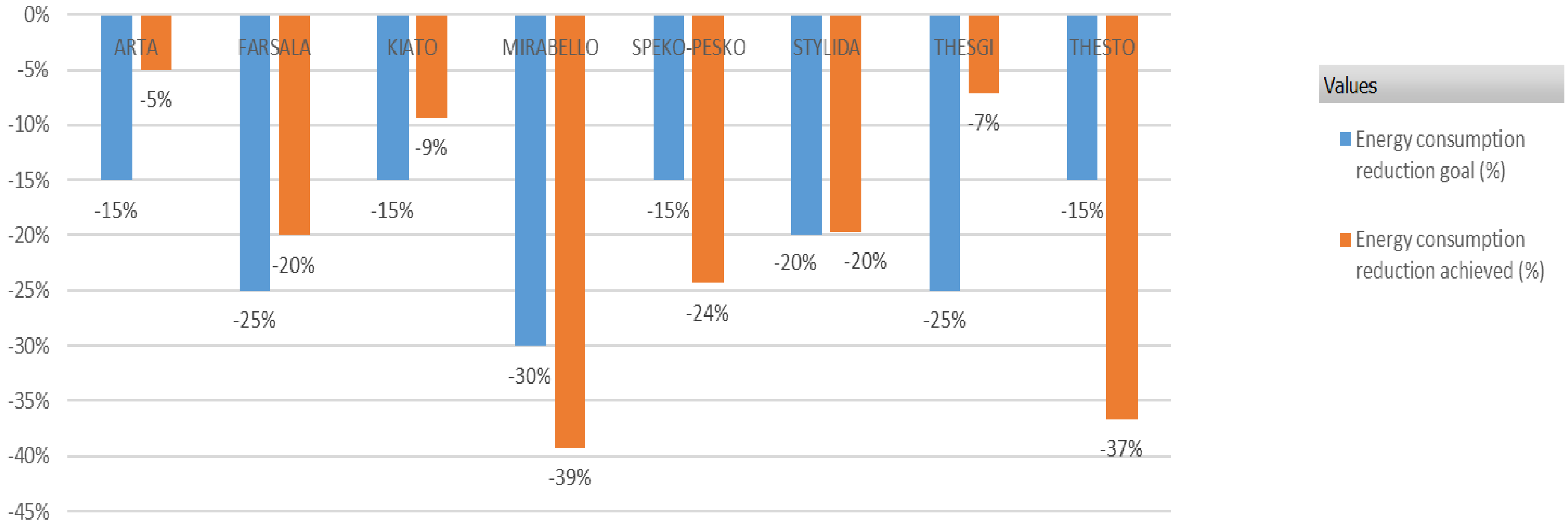


Figure 13. Energy consumption reduction goal/achieved (%)