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DELIVERABLE

Final Specialised Scientific Models

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Executive Summary

The purpose of the deliverable Final Specialized Scientific Models is to provide all the information about the development of the crop and climate specific scientific models that were used to produce the SF advice on Irrigation, Fertilisation and Pest Management/Hazard Warnings for all 18 demonstration sites defined in actions B4 (11 in Greece), B5 (1 in Spain), B6 (1 in Portugal) and B8 (5 in Greece). 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 cultivating periods, which started in January 2020 and ended in December 2021.

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Definitions, Acronyms and Abbreviations

Acronym	Title
AB	Advisory Board
ALs	Action Leaders
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
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

1. Introduction

1.1. Project Summary

The main objective of the LIFE Gaiasense 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 Gaiasense 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 development of the crop and climate specific scientific models that were used to produce the SF advice on Irrigation, Fertilisation and Pest Management/Hazard Warnings for all 18 demonstration sites defined in actions B4 (11 in Greece), B5 (1 in Spain), B6 (1 in Portugal) and B8 (5 in Greece).

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 methodology applied for the development of the crop and climate specific scientific models that were used to produce the SF advice on Irrigation, Fertilisation and Pest Management

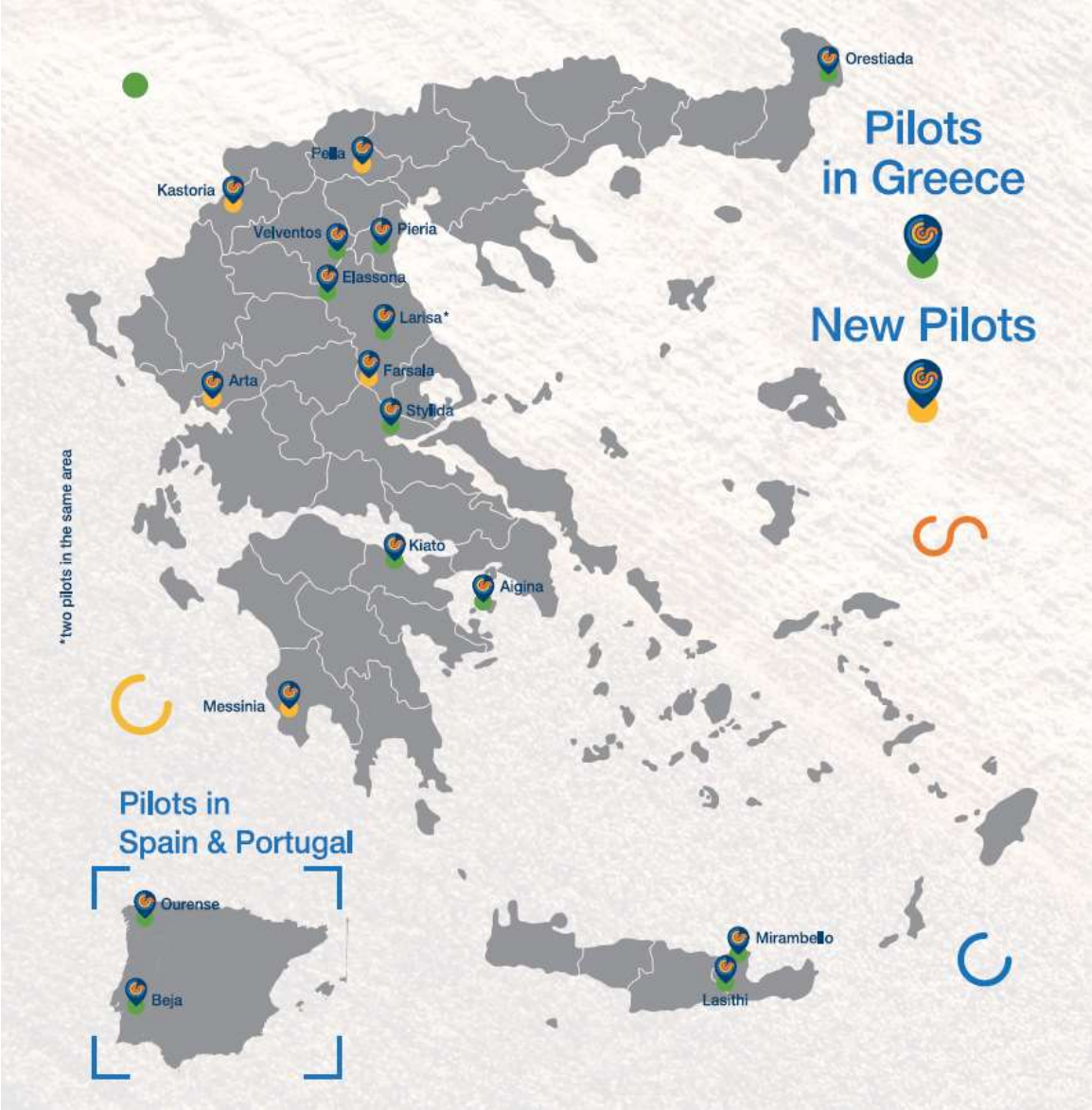
Chapter 3 describes in details the final specialised scientific models.

2. Methodology applied for the development and/or adaptation of the scientific models

In order to enable the development of services for irrigation, pest/disease management and fertilization for the producers of the 18 demonstration sites defined in actions B4 (11 in Greece), B5 (1 in Spain), B6 (1 in Portugal) and B8 (5 in Greece) scientific predicting models have been developed and adapted to the microclimate and crop requirements of each region. Data were driven 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.

The spatial distribution of the Use Cases is shown in Figure 1

Figure 1: Spatial distribution of the Use Cases participating in the LIFE GAIA Sense project



2.1. Irrigation Scientific Models

2.1.1. Introduction

Smart irrigation is a method of calculating the water needs of the crop, using technological and scientific tools, in order to provide to the farmer consulting advices regarding the optimum time and quantity of irrigation required for his cultivation. The main goal of smart irrigation is to save water for the benefit of both the producer and the environment something that is achieved by developing algorithmic models specific to each region and crop.

The theoretical basis of the method is based on the assumption that the optimal amount of irrigation dose is the one that allows the wetting of most of the root system of plants while preventing the movement of water at levels below the zone of the root system of plants.

The application of the irrigation methodology described above, while it may be relatively easier in annual crops with limited root system, presents significant difficulties in perennial crops which are characterized by larger size and degree of non-uniform root system. Achieving complete wetting of the root system of plants can be monitored and ensured with the installation of special sensors that record soil moisture at clearly defined and default depths along the root system of plants. The correct choice of the depth of placement of the senses presupposes the accurate estimation of the spatial distribution of the active rhizome of the plants which is defined as that part of the total root system through which the absorption of soil water and nutrients takes place. The determination of the active rhizosphere can be done by analyzing the rate of change of soil moisture at different depths as a function of time. The zone of the active rhizome, which is characterized by a rapid decrease of soil moisture, corresponds to the soil zone with the most intense colonization and therefore the highest activity and presence of a root system.

In order to find the active root system of the plants, a continuous recording of the soil moisture was carried out at different, pre-selected depths with the installation of an integrated measuring system which was accompanied by a fully equipped and energy-independent measuring recorder. The standard deviation of the average values of soil moisture content regardless of cultivation and methodology of taking the measurements, was significantly higher at the most superficial measurement depth. This could be attributed to the fact that the surface layer is characterized by more intense and faster differentiation values of moisture content due to the higher moisture losses through evaporation.

The next step of the experimental design was the study of the correlation of soil moisture values at the level of the active rhizosphere with ecophysiological parameters of the plants, aiming at the determination of critical values which signal the need to start irrigation. From the ecophysiological parameters, the most important descriptive indicators of the water status of the plants are considered the water potential of the leaves (Ψ) and the stomatal conductance (Cs).

The water potential, which describes the energy state of the water in the plant tissue, reaches its maximum value early in the morning (water base potential or maximum water potential - Predawn water potential (Ψpd) when the mouths are closed and the respiratory losses are zero. Then the value of water potential is determined solely by the moisture status of the soil. During the day the value of water potential is constantly decreasing - taking the minimum value at noon (water potential of noon or minimum water potential) - directly affected by both the soil moisture and the rate of respiratory losses In most plant species the value of water potential is lower in plants under water stress compared to fully irrigated regardless of the time of measurement. Exceptions are isohydric plants - such as vines - in which the control of respiratory losses through the operation of the stomatal apparatus results in the minimum value of water potential not differing between water-stressed and fully irrigated plants. In these species, the base water potential (Predawn water potential) is a more accurate and therefore preferred indicator for assessing the water status of plants (Patakas et al.,

2005). On the other hand, given that the first reaction of plants to water stress conditions is manifested by closing the mouths in order to reduce water loss through the process of perspiration, it was deemed appropriate to investigate the change in stomatal conductance during the measurements' period.

2.1.2. Service development and implementation

In order to be able to issue a SF irrigation advice it was important to follow certain procedures, which are described as follows:

Initially, a representative plot of a crop is selected within the desired zone, in which the gaiatron is installed. (For further details, see deliverable B2. Report on the Deployed Networks of Telemetric Stations and Traps).

The gaiatron records meteorological data (eg solar radiation, rainfall, wind speed, etc.) and soil moisture.

In the specific plot:

- Soil analysis is performed according to a specific protocol (for further details, see deliverable B4 Application of a SF advice)
- Data are registered in the ICM regarding
  - the characteristic of the agricultural holding eg irrigation system, age, variety, planting distances etc.
  - all cultivating practices eg irrigations, fertilization, phenological stages, etc.

An analytical study took place in the framework of the A.1 Action Documentation of Use Case Existing Agricultural Practices and Restraints, Requirements, Needed Interventions and KPIs where climatic zones were identified and presented cumulatively as follows:

Table 1. Identified climatic zones of the 18 Use Cases for the development of the irrigation scientific models

Country		Acronym	Crop	Climatic zones	Region
Greece	First Wave	ORESTIADA	cotton	5	Eastern Macedonia and Thrace
		VELVENTOS	table peach	4	Western Macedonia
		AIGINA	pistachio	2	Attica
		ELASSONA	walnut	3	Thessaly
		LASITHI	potato	3	Crete
		SPEKO-PESKO	kiwi	5	Central Macedonia
		KIATO	table tomato	3	Peloponnese
		STYLIDA	table olive	3	Central Greece
		THESTO	industrial tomato	5	Thessaly
		THESGI	cotton	3	Thessaly
		MIRABELLO	olive	4	Crete
	Second Wave	FARSALA	cotton	4	Thessaly
		ARTA	kiwi	5	Epirus
		PELLA	peach	4	Macedonia
		EUBOEA / KASTORIA	tomato	4	EUBOEA / KASTORIA
		MESSINIA	olive	2	Peloponnese
Spain		COSTEIRA	grape	2	Galicia
Portugal		CONFAGRI	olive	2	Alentejo

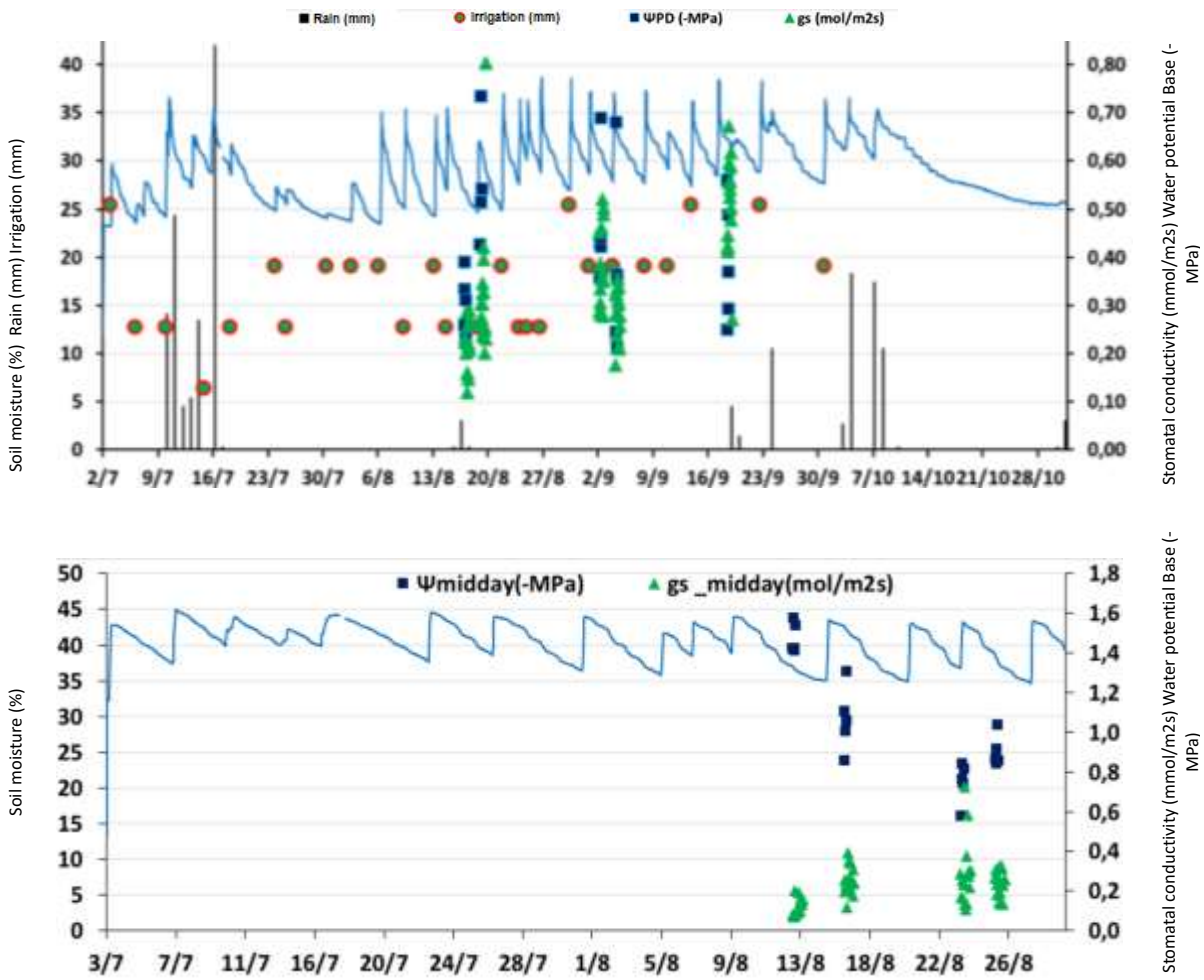
In the framework of the aforementioned study the following irrigation practices, Irrigation needs and challenges were identified for the 18 Use Cases and presented cumulatively as follows:

Table 2 Characteristics and challenges of the irrigation systems of the 18 Use Cases

Country		Acronym	Crop	Irrigation practices	Irrigation needs and challenges	Water Source
Greece	First Wave	ORESTIADA	cotton	Sprinkler irrigation system	There is need for high amounts of water during the cultivation period.	Public Regulator Service for Irrigation Water Supply
		VELVENTOS	table peach	Sprinkler irrigation system with electric pumps	Old irrigation network which faces sometimes technical problems	Public Regulator Service for Irrigation Water Supply Velventos (Polyfytos Lake)
		AIGINA	pistachio	Sprinkler irrigation system	Limited availability of water, water of high salinity	Drilled well
		ELASSONA	walnut	Sprinkler irrigation system	More targeted irrigation	Public water supply network
		LASITHI	potato	Sprinkler irrigation system	Great need for water both for irrigation and pest prevention in order to control the population.	Drilled well
		SPEKO-PESKO	kiwi	Sprinkler irrigation system	More targeted irrigation	Public water supply network and drilled well
		KIATO	table tomato	Surface drip irrigation system	Water availability	Drilled well
		STYLIDA	table olive	Microsprinklers	Many problems with fungal diseases are caused by the irrigation practices (sprinklers)	Drilled well
		THESTO	industrial tomato	Surface drip irrigation system	More targeted irrigation	Drilled well

		THESGI	cotton	Surface drip irrigation system	Crop type of high water demand	Canal/channel irrigation and drilled well
		MIRABELLO	olive	Drip irrigation system	Water availability	Drilled well
	Second Wave	FARSALA	cotton	Surface drip irrigation system, pivot	Crop type of high water demand	Public water supply network and drilled well
		ARTA	kiwi	Drip irrigation system	More targeted irrigation	Drilled well
		PELLA	peach	Microsprinklers, surface drip irrigation, flooding, subsurface drip irrigation	Crop type of high water demand	Public water supply network and drilled well
		EUBOEA / KASTORIA	tomato	Surface drip irrigation	Water availability	Drilled well
		MESSINIA	olive	Drip irrigation system	Water availability and quality	Drilled well
Spain		COSTEIRA	grape	Drip irrigation hoses	High need for irrigation in Spring and Summer because of the soil type.	Water regulating tank fed by 5 wells
Portugal		CONFAGRI	olive	Local drip irrigation	Reduce irrigation costs	Public Regulator Service for Irrigation Water Supply (Alqueva Dam)

- Water analysis is performed according to a specific protocol in order to verify the quality of the irrigating water
- Measurements of ecophysiological parameters of plants are performed by agronomists according to a specific protocol with the use of specialized instruments. Specifically, the stomatal conductance and water potential are measured, which are important indicators of the water status of the plant.



Indicative example of measurements performed early in the morning and at noon regarding ecophysiological parameters and soil moisture

After the completion of the first irrigation period all the aforementioned data were forwarded to the scientific expert who was responsible to process them and deliver an Irrigation model per irrigation class. In cases that it was not possible to deliver a model according to the aforementioned method, either due to adverse weather conditions during the cultivating season, (which affected the measurements of ecophysiological parameters) or due to problems that arose during the measurement process itself, a different methodology and irrigation model was delivered. In these cases the model was based upon the water balance between rain - evapotranspiration - irrigation, based on the guidelines for irrigation schemes proposed by the Food and Agriculture Organization (FAO)

Should be noted that the Scientific Expert was responsible for delivering the Scientific models for each climatic zone. The integration of the models' variables and their combination with data derived from the gaiatron and ICM in order to obtain the irrigation advice per plot (irrigation algorithm) and in order to issue a SF advice was performed by the Data Science department of Neuropublic.

2.1.3. Description of the SF irrigation models

The SF irrigation model is based on the idea that parcels with similar characteristics (eg cultivation, mechanical composition of the soil, irrigation system, microclimatic conditions etc) have similar irrigation needs. Therefore the model developed on a parcel with specific characteristics can be also used on other parcels of the same area, with have similar characteristics

Also, parcels belonging to the same irrigation class have a common soil factor and a common cultivation factor. The climatic factor can be differentiated depending on the location of the parcel and classifies the parcels into climatic classes.

Therefore, the algorithm of the irrigation model works as follows in order to be able to issue a SF advice:

1. Based on the characteristics and location of each plot, it classifies them in the respective irrigation and climate class in order to use the respective coefficients.

2. Based on its location, it classifies it in a microclimatic zone in order to use the meteorological data of the gaiatron station of the specific zone.

3. Calculates the Maximum Permissible Water Losses until the beginning of water stress defined for the specific irrigation class

   MPWL = 100 * Soil Factor * Cultivation Factor * Climate Factor

4. Calculates on an hourly basis the Water Reservoir of the plot

   WR = MPWL (mm) – Hourly ETo (mm) + Rainfall (mm) + Irrigation*

   **Data regarding the hourly evapotranspiration (ETo) and rainfall derive from the gaiatrons and data regarding irrigation derive from the ICM.*

5. Calculates on an hourly basis the Average Rate of Water Loss due to the evapotranspiration of the last 48 hours

   Average Rate of Water Loss = (Sum of ETos of the last 48 hours) / 48

6. Calculates on an hourly basis how many hours are left until the next irrigation.

   Hours until next irrigation = New Water Reserve / Average Rate of Water Loss

7. Calculates on an hourly basis the exact moment of the Next Irrigation Time

   Next Irrigation Time = Current time+ Hours until next irrigation time

When the result of the last calculation is less than 48 (hours) then there is need to proceed to an irrigation and therefore a SF Irrigation advice appears in the ICM. The advice is initially approved by the agronomist who will then notify the farmer. The role of the agronomist is critical since he will check the advice and if need be he will modify the suggested date and irrigation dose before notifying it to the farmer. Should be noted that in each SF advice should be characterized as executed or rejected in order the calculations restart from the beginning.

As already mentioned in the section **Service development and implementation,** in cases that the aforementioned model was evaluated as not trustworthy an alternative irrigation model was

developed based on the determination of the water balance in the area of the active rhizome of the plant.

Its calculation is a rather complicated process, so the continuous monitoring of inputs and outputs in this area is very important. Examples of inputs and outputs are:

- Inputs: rainfall, irrigation and elevation from groundwater
- Outputs: evapotranspiration, runoff and deep infiltration

Runoff and deep infiltration can be estimated based on local soil and ground factors such as soil properties and slope. Groundwater elevation can also be estimated. However, the values of the last two parameters are being ignored in the calculation of irrigation dosing for most of the crops.

In addition, other factors such as soil type, cultivation, root depth, plant density and irrigation system should be taken into account.

The following decision-making process is applied for the setting of irrigation schedule and is referred as <u>irrigation planning.</u>

- The initial amount of water can be determined by
  - Direct observation (soil moisture sensors)
  - Estimation according to the climatic data of the area
  - Estimation according to the root system information (greater accuracy) – not suitable for cases of significant rainfall.
- The daily values of ETc are then removed until the soil water is reduced to the desired level.
- At this point a quantity of irrigation water, adjusted to the soil profile, the type of crop, the irrigation system and the availability of water, is applied.

For the calibration and grading of the model, the values from the soil moisture sensors should be cross-checked at the different depths, if available. If the irrigation dose is not the desired (according to the measurements) it should be redefined by the amount of water applied or by field observations. For the method to perform properly, the constant monitoring of the water inputs is required. Otherwise, no precise conclusions can be drawn.

<u>For the operation of the model, the following technical terms of irrigation were defined:</u>

Available water is the amount of water stored in the soil volume associated with the active root system or the desired soil depth.

Only a part of the irrigation dose can be absorbed by plants, and this amount is called "available water". The amount of water available within the active root system or the desired soil depth is often called the "soil moisture tank". Only a percentage of the tank is readily available to the root system.

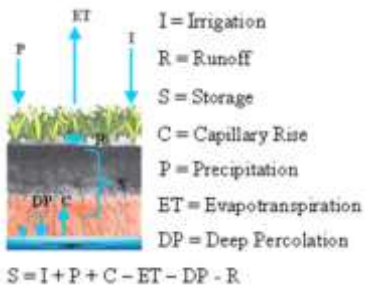


Figure 2 Methodology for the management of irrigation water.

Irrigation class: all plots characterized by the same: cultivation, mechanical composition of the soil, irrigation system, variety (optional), landscaping system (optional).

Irrigation model: The scientific model that concerns an irrigation class of a microclimatic zone. It consists of the 3 following factors

- Soil factor: determined mainly by the mechanical composition of the soil
- Cultivation factor: determined by parameters such as variety and phenological stage
- Climatic factor: determined by the climate of each region

Irrigation algorithm: The process developed in order to issue an SF irrigation advice per plot. The process takes into account the aforementioned factors in combination with data derived from the gaiatrons and from the iCM. Essentially the irrigation model is integrated into the algorithm.

Water potential : is the potential energy of water per unit volume relative to pure water in reference conditions. Water potential quantifies the tendency of water to move from one area to another due to osmosis, gravity, mechanical pressure and matrix effects such as capillary action (which is caused by surface tension).

Stomatal conductance : Usually measured in mmol m-2 s-1, is the measure of the rate of passage of carbon dioxide (CO2) entering, or water vapor exiting through the stomata of a leaf. The rate of stomatal conductance, or its inverse, stomatal resistance, is directly related to the boundary layer resistance of the leaf and the absolute concentration gradient of water vapor from the leaf to the atmosphere.

2.2. Fertilization Models

2.2.1. Introduction

The supply and intake of nutrients are fundamental procedures required for the growth of plants and their metabolism. The term metabolism stands for all the biochemical mechanisms that take place to describe the conversion of inorgan ic nutrients to useful cellular substances. Therefore, nutrients availability is largely associated with the growth of plants and life preservation and continuation. For this reason, it is important to ensure the most suitable nutrition of the plants that constitute human and animal food (crops).

Proper nutrition of crops means that a range of events need to be met. These are directly related to the uptake of the nutrients, their movement within the body of the plants and their accumulation to specific parts, such as stems, leaves and fruits or seeds. To achieve this, specific parameters must be taken into consideration, which depend highly on the nutrient itself, each crop's specific needs and the soil and/ or climatic conditions that prevail. In detail, each nutrient has its own degree of movability in the soil and within the plant, which is partly dependent on the nutrient's chemical properties and, in turn, on the chemical form that the nutrient is available. This determines if the plant can absorb the nutrient and, by extension, the nutrient's distribution and concentration in different parts of the plant.

While all crops may need higher rates of one nutrient than another as a rule of thumb (e.g. more potassium than nitrogen is usually required, micronutrients are needed at substantially lower levels than macronutrients), each crop eventually has its own needs to produce sufficient chlorophyll and synthesize necessary proteins. In other words, each crop requires a balanced diet of nutrients, whereas other parameters, such as the stage of growth of the plant, the season and the soil play important roles. A soil-wise example, high pH values of soil will prevent the uptake of nitrogen in its nitrate form (NO_3^-), whereas low pH values will enhance it. A climate-wise example, it has been observed that some crops will prefer to uptake nitrogen in its ammonium form (NH_4^+) if the prevalent temperatures are considered low.

Consequently, soil fertilisation plans are essential in order to meet the crops' needs and, concurrently, maintain the soil fertility, the environmental health and the economic sustainabilityof the farmers. The construction of the former is achieved with the development and the configuration of soil fertilisation models. To sum up the objective of the latter, the soil fertilisation models need to be able to calculate the optimal rates of nutrients and recommend the optimal chemical forms, while they need to account for the best response of the plants at specific agro-climatic settings.

2.2.2. The role of nutrients and what affects their availability

Nutrients can be divided into two broad categories according to the levels of availability they should respond. Nutrients needed in high amounts fall in the category of macronutrients, while nutrients usually required in trace amounts constitute the category of micronutrients. Nitrogen, phosphorus and potassium are considered macronutrients and compose a basic nutrition plan. Namely, they are traditionally added in the soil-tank to preserve its fertility. Calcium and magnesium have a special role as nutrients due to a multisided character and a range of properties. Manganese, copper, iron, zinc and borium are studied as micronutrients and their addition must be rational and in smaller quantities.

The availability of the nutrients depends on several factors. These factors have been taken into consideration in the development of the soil fertilisation models. Soil pH values are substantial, while soil tanks are considered fertile above a certain baseline. Conflicts among certain nutrients are another

aspect to assess in the models, along with the response of each crop to each nutrient. This is because some crops may absorb the nutrient through specific organs, thus the chemical form and the availability source of the nutrient should benefit the plant. Such factors are explained hereafter.

Nitrogen is an agile nutrient and absorbed primarily as nitrate (NO_3^-) and secondly as ammonium (NH_4^+), but temperatures and soil pH values affect largely the availability of each chemical form. Nitrates contribute into the increase of biomass while ammonium is responsible for the characteristic green color of the leaves (and consequently the production of chlorophyll). Nitrate and ammonium can be respectively more available at low and neutral pH values, while the concentration of the nutrient in the ground can affect how much the plants will absorb.

The availability of phosphorus is very much dependent on the medium lower and neutral pH values of the soil. Phosphorus absorption is an active procedure that depends very much on the plants' capability to uptake this nutrient from organic sources or to survive in soils with low phosphorus concentration. It is agile within the plant, unlike within the soil and responsible for supporting with energy the plants' chemical reactions. Its deficiency becomes obvious at the older leaves.

Potassium has a multiplex role and is agile and significant for the function of the cells. Its high availability in the soil can lead to high absorption and is largely reliant on the permeability of the cells' membranes. Potassium cation (K^+) is positively charged; hence, it competes other cations (H^+, Mg^{2+}, Ca^{2+}, Na^+) and their presence in high concentrations will inhibit the plant from absorbing potassium. However, the rate of absorption of Mg^{2+} and Ca^{2+} (magnesium and calcium) are considerably lower than that of K^+ (potassium).

Magnesium is a nutrient that accumulates with the increase of the age of perennial crops, while different annual crops demonstrate different concentrations at different parts. Nitrates tend to act beneficially in the uptake of magnesium unlike potassium, while magnesium competes with manganese. In fact, toxic effects of high concentrations of manganese (Mn^{2+}) can be reversed in the action of magnesium. The latter is rather agile, in contrast to calcium. High temperatures and relative humidity or moisture can slow down its absorbance from the plant. Such a behaviour is observed frequently at the lower parts of the plant, leading to stagnation of the development of the roots, while this can also be enhanced by the presence of ammonium anions (NH_4^+). Certain corps will preferably absorb calcium through the soil, such as the potato, which means that the model needs to incorporate the special behaviour of these corps regarding this nutrient.

Divalent iron (Fe^{2+}) can be uptaken by the plants; however, trivalent iron (Fe^{3+}) is more available in the soils and its reduction to Fe(II) is required. Lower pH values can facilitate this chemical reaction and certain crops can modify the local ambience at the surface of their roots to increase the iron uptake. Other cations can compete with iron and limit its uptake. Iron is not particularly agile within the plant and for this reason, enriching the soil with iron may not always be the best scenario, while specific forms of iron can be easier absorbed by the plants.

Manganese can also be absorbed as a divalent cation (Mn^{2+}) and is not rather agile. The presence of other cations will inhibit its absorbance, along with the higher pH values. While manganese availability is dependent on the soil tank, zinc can be uptaken by a number of pathways. Manganese has the biggest negative impact on zinc's uptake, with calcium and the silicon following. Certain crops may be more resilient to high concentrations of zinc, however this has been observed to relate with a decrease of yield. Zinc is important when it comes to its competition with phosphorus. A proportion of phosphorus concentration by zinc concentration in the leaves bigger than 250 may be interpreted as deficiency of zinc and this can operate as a feedback in the development of soil fertilisation models.

Phosphorus competes with copper too, but nitrogen acts synergistically. Copper is not agile but higher concentrations of nitrogen will lead to higher needs of copper. High concentrations of copper in the plants can displace iron. This leads to the meticulous calculation of the two micronutrients. Finally,

borium is detected with different distributions in different organs of the plants due its hurdle to move. Borium and calcium act synergistically and high presence of the latter should balance with high presence of the former as well.

In outline, each nutrient partakes in the plants' growth, while each nutrient may involve to a degree into the function of another nutrient. Soil fertilisation models take into account the way the nutrients contribute to the development of plants, collaborate or interfere so that the soil fertilisation plans can be balanced for the crops, the environment and the finances of a farm. Macronutrients and micronutrients are essential for the fertilisation plans, but there is a range of other factors that are considered in the models and need to be mentioned and explicated.

2.2.3. Structure, complexity and key factors of soil fertilisation models

The soil fertilisation models have been developed upon a basic structure and are configured for factors ranging from the kind of crop though the cultivation manners applied to the area it grows. The basic structure exhibits a set of variables which require arithmetic values and which accrue via laboratory analyses. This means that a soil composite sample from a field is required and must be submitted to a soil analysis method. Prior to this, the soil sample must be taken following a specific protocol which has also been developed to eliminate errors.

Briefly, the composite sample must be taken from at least 5 points within the same filed following a W or S path and avoiding areas which macroscopically differ (these areas should be sampled separately). The composite is mixed and its mass is reduced to ca. 1 kg and remains in ventilated with no direct sunlight ambience before it is sent to the lab. Due to the analysis for elements like nitrogen which evaporate fast, the protocol suggests that the sample is sent to the laboratory without a delay of more than 2 days. The soil laboratories in collaboration have been tested for accuracy and reproducibility and their methodologies have been approved. Their test reports list the values of the input variables for the soil fertilisation models which depend on lab results. Table 155 summarises all the variables that are required as inputs in the soil fertilisation models.

Table 3. Table of soil algorithm variables

INPUT VARIABLES	
Independent of soil laboratory analyses	Dependent on soil laboratory analyses
• Crop (mandatory) • Cultivation installation (e.g. open-field, greenhouse) • Variety • Cultivation technique(e.g. irrigated, non-irrigated) • Age (for perennial crops) • Destination growth (e.g. industrial)	• Composition (%) in clay, silt and sand • pH • Electric conductivity • Content in organic matter (%) • Content in $CaCO_3$ (%) • Content in nutrients (ppm)

The structure of the soil fertilisation models for each nutrient remains similar in their core as they follow the concept of mass balance. In other words, this means that the deficiency of a nutrient is calculated as equation A shows.

$$Nutrient_{in} - Nutrient_{out} = Deficiency \qquad \textit{Equation A}$$

By $Nutrient_{in}$ or $Nutrient_{out}$, it is the net mass of the nutrient that is calculated entering and exiting the system (soil and plant). A nutrient enters a system through sources such as human addition of fertilisers, crops' biomass etc. and it exits a system mainly through harvesting. If the difference between the two is positive, then the nutrient that entered the system was more than what exited the system and, consequently, the nutrient has accumulated in the soil and it may not be required to be added, depending on the nutrient. Apparently, if the difference is negative, then the nutrient is deficient and its addition is necessary to prepare the soil for the next cultivation. This description is schematically depicted bellow.

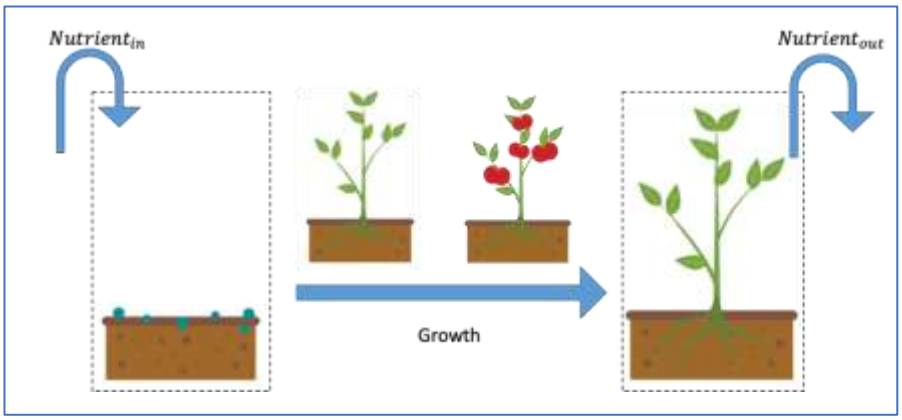


Figure 3

Focusing on nitrogen, the soil fertilisation model involves the nitrogen entering the system from both the organic and inorganic resources, while it differs for each crop and also requires the age and the cultivation features applied, along with soil texture, pH and content of organic matter, of calcium carbonate and of nitrates. Soil parameters are important because they affect the degree of availability of the nutrient. For example, heavier soils (which have a higher content of clay) tend to retain the ions stronger than in lighter soils. The principal structure of the models is reflected on the general equations of figure 4.

$$\left.\begin{aligned} N_{inorg} &= f_1(NO_3^-, silt, clay, sand, org.matter) \\ N_{org} &= f_2(silt, clay, sand, org.matter) \\ C_{avail} &= f_3(silt, clay, sand, pH, CaCO_3) \end{aligned}\right\} \quad N_{in} = f_4(N_{inorg}, N_{org}, C_{avail})$$

$$N_{out} = f_5(crop, age, cult.features)$$

Figure 4

The calculation of the numerical doses of nutrients takes into account the deficiency of other nutrients which may work together or competitively. Nevertheless, the theoretical doses are calculated independently and are based upon the availability coefficient C_{avail} and the deficiency (from Equation

A). The advised doses take into account the theoretical doses and the mass of the nutrient under study that exits the system. Any configuration that may be further needed is attributed to the agro-climatic settings and in these cases a correction coefficient is introduced. Figure 5 suggests the rationale.

$$N_{def} = g_1(N_{in}, N_{out}) \qquad \textit{Equation A}$$

$$Theor\_Dose_N = g_2(C_{avail}, N_{def})$$

$$Real\_Dose_N = g_3(Theor\_Dose_N, N_{out}, area)$$

Figure 5

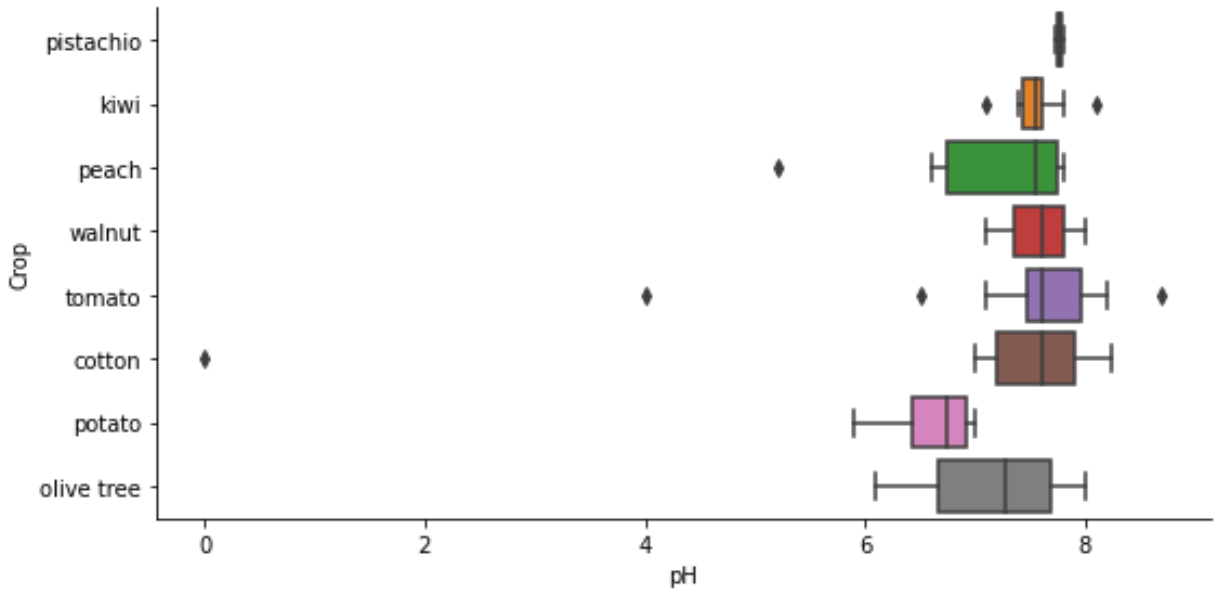
2.2.4. Sensitivity, output and configuration of soil fertilisation models

The input variables determine the output of the soil fertilisation models, but each one of them has a different effect on the output. Studying their sensitivity to the change of each variable separately, it is possible to gain a better idea of the factors that can determine the output and configure accordingly the parameters. At the same time, it is possible to estimate if new factors are needed in the purpose of altering the models and become more responsive to the reality.

Out of the general input variables that accrue from the laboratory analyses, the content of $CaCO_3$ has a very small impact on the nutrients doses. On the contrary, the pH and the soil texture are very defining of the output and, out of the two, it is possible that the pH value may indicate that the soil could need a correction before it gets prepared for a crop. The pH will also determine most of the times the chemical form of the fertiliser, while the doses of the phosphorus fertilisers seem to have a strong dependency on the pH, unlike other nutrients.

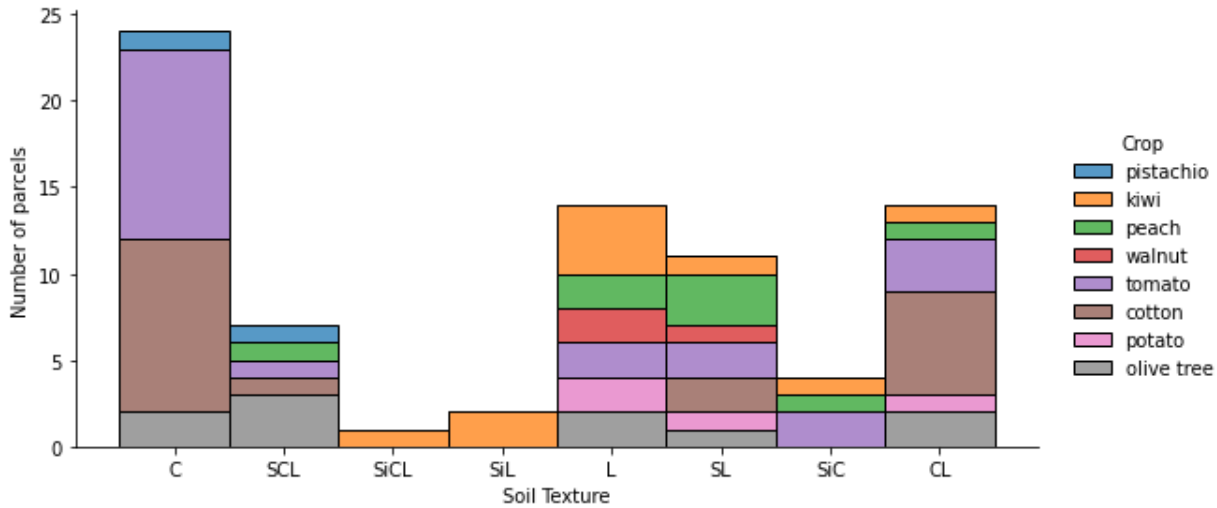
In more detail, low pH values can afford nitrate forms of fertilisers, while alkaline soils require sulfate forms. A configuration that has been set regarding olive trees takes the pH in vast account for the top fertilisation. For pH lower than 5 the chemical form of nitrogen advised is nitrate of lime, so that the correction of the soil with calcium takes place. Calcium ammonium nitrate is intended exclusively for pH between 6 and 7. In other pH values ammonium nitrate is the suggested chemical form.

The pH values of the soil are used to characterise the soil. While a small width from 6.8 to 7.2 is considered as neutral, a wider range, usually from 6 to 7.5 is considered as suitable pH for the soil. Moderately suitable pH values range from 5.5 to 6 and from 7.5 to 8. Marginally suitable pH values are considered between 8 and 8.5, while the rest of the values are attributed as non-suitable. These characterisations are part of the output of the soil fertilisation models and, for this reason, it is important to observe the breadth of values per crop for the study cases of the project (plot 1).



Plot 1

In most cases, the pH values fall under the suitable or moderately suitable characterization, which means that the soil fertilisation models respond without specific instructions or high degree of configuration in this framework. As aforementioned, the rest of the factors have smaller influence. Hence, the scattering of the values is not adequate to demand configurations. However, the soil texture affects stronger the doses. Coarser soils will demand slightly higher doses, since the higher presence of Al^{3+} can hinder nutrients from being available. As a consequence, the variance of the soils is an interesting aspect to explore (plot 2).

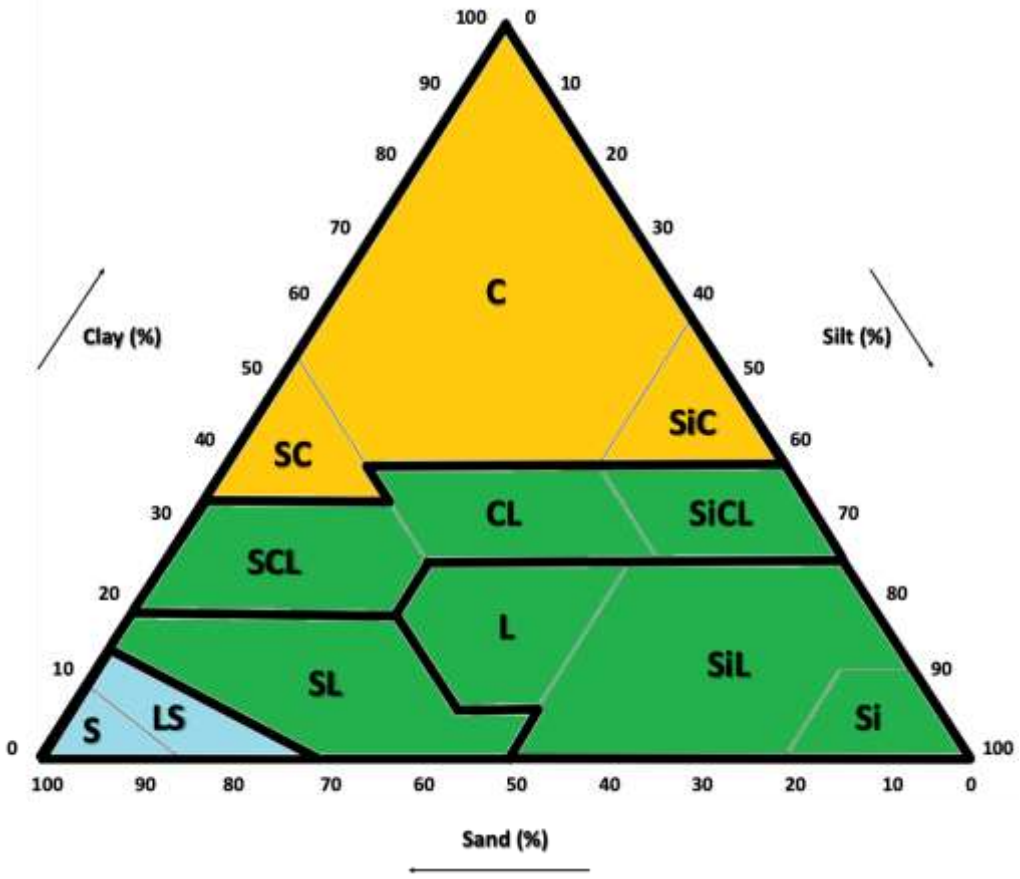


Plot 2

The classes of the soil according to the USDA classification are 12 and plot 2 demonstrates 8 of them. While this classification was taken into consideration, a configuration that was required as necessary classified the soil textures in larger groups. Consequently, most crops would respond well with the classification illustrated in scheme 3. Yellow, green and blue surfaces would encompass coarse, medium and fine soils correspondingly. A 5-categories classification divides the medium class in three:

SL would fall under the medum-fine soils, L, SiL and Si would fall under medium soils and SCL, CL and SiCL would comprise the medium-coarse soils. At this point, it is necessary to indicate that C, Si, L and S stand respectively for clay, silt, loam and sand.

Figure 6



Taking into account the agro-climatic settings, the location may have an impact on the fruits and the rate of maturing. Early and late fruit ripening may affect the nitrogen uptake. However, in most cases correction was not necessary because the Mediterranean climate tends to create more uniform conditions during the summer periods, while the climatic zones influence more other physiologies of the plants rather the nutrients' uptake (table). The destination growth, on the other hand, may alter slightly the nitrogen uptake, but only due to the fact that yield expectations may differ particularly.

2.3. Pest and Diseases Scientific Models

2.3.1. Introduction

Smart farming crop protection management is the application of modern technologies in order to take and implement in time all critical decisions concerning the control of pest and diseases of a crop. This is achieved through scientific algorithmic models and Decision Support Systems (DSS) according to which an Agriculture advice/alert is issued. This procedure aims at reducing the use of plant protection products, while at the same time to protect annual production and environment.

2.3.2. Service development and implementation

In order to develop models for the prediction of the occurrence of the most important pests and diseases for the selected crops (olives, peaches, cotton, pistachio, potatoes, table tomatoes, industrial tomatoes, almonds, kiwi, vine), experimental data that were published in international journals, was collected in order to produce experimental data in the collaborating laboratory of phytopathology of the Agricultural Technologists Department of the Thessaloniki Technical University, which has a long lasting relationship with NP as its scientific advisor in this area and will be a subcontractor in this project.

To that end, an analytical study took place in the framework of the A.1 Action Documentation of Use Case Existing Agricultural Practices and Restraints, Requirements, Needed Interventions and KPIs where the most important diseases and pest/enemies were identified and presented cumulatively as follows:

Table 4. The scientific models adjusted to the crop protection (disease) management of the 18 Use Cases

		Use Case	Crop	Diseases
Greece	First Wave	ORESTIADA	cotton	Alternaria alternata
		VELVENTOS	table peach	Wilsonomycetes carpophilus
				Taphrina deformans
				Monilinia fructicola
				Sphaerotheca pannosa
		AIGINA	pistachio	Septoria sp.
				Botryosphaeria dothidea
		ELASSONA	walnut	Gnomonia leptostyla
		LASITHI	potato	Alternaria alternata
				Peronospora infestans
		SPEKO-PESKO	kiwi	Stemphylium botrysum
				Pseudomonas syringae
				Alternaria alternata
		KIATO	table tomato	Alternaria solani
				Pseudomonas syringae

				Botrytis cinerea
				Phytophthora infenstans
		STYLIDA	table olive	Pseudomonas syringae
				Colletotrichum gloesporioides
				Spilocaea oleagina
		THESTO	industrial tomato	Phytophthora infestans
				Leveillula taurica
				Botrytis cinerea
				Alternaria solani
		THESGI	cotton	Alternaria alternata
		MIRABELLO	olive	Pseudomonas syringae
				Spilocaea oleagina
				Colletotrichum gloesporioides
	Second Wave	FARSALA	cotton	Alternaria alternata
		ARTA	kiwi	--
		PELLA	peach	Wilsonomycetes carpophilus
				Taphrina deformans
				Monilinia fructicola, Monilinia laxa
		EUBOEA / KASTORIA	tomato	Phytophthora infestans
				Leveillula taurica
				Botrytis cinerea
				Alternaria solani
		MESSINIA	olive	Colletotrichum gloesporioides
Spain		COSTEIRA	grape	Erysiphe necator
				Plasmopara viticola
				Botrytis cinerea
				Guignardia bidwellii
Portugal		CONFAGRI	olive	Spilocaea oleagina
				Colletotrichum gloesporioides

Table 5. The scientific models adjusted to the crop protection (pests) management of the 18 Use Cases

		Use Case	Crop	Pests
Greece	First	ORESTIADA	cotton	Pectinophora gossypiella (pink bollworm)
				Helicoverpa armigera

	Second Wave			Lygus hesperus
				Eurygaster maura
		VELVENTOS	table peach	Grapholita molesta
		AIGINA	pistachio	-
		ELASSONA	walnut	Cydia pomonella
		LASITHI	potato	Leptinotarsa decemlineata
				Phthorimaea operculela
		SPEKO-PESKO	kiwi	Pseudaulacapsis pentagona
				Metcalfa pruinosa
		KIATO	table tomato	-
		STYLIDA	table olive	Prays oleae
				Bactrocera oleae
		THESTO	industrial tomato	Helicoverpa armigera
		THESGI	cotton	Helicoverpa armigera
				Pectinophora gossypiella
				Bemisia tabaci
				Lygus hesperus
		MIRABELLO	olive	Bactrocera oleae
				Prays oleae
		FARSALA	cotton	Pectinophora gossypiella
				Helicoverpa armigera
		ARTA	kiwi	-
		PELLA	peach	Grapholita molesta
				Anarsia lineatella
		EUBOEA / KASTORIA	tomato	Helicoverpa armigera
		MESSINIA	olive	Bactrocera oleae
Spain		COSTEIRA	grape	Lobesia botrana
Portugal		CONFAGRI	olive	Bactrocera oleae
				Prays oleae

2.3.3. Description of the SF crop protection models

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 (oD). Degree-days (oD) 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 oD 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 oD 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:

oD = [(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.

3. Final SF models

3.1. Final irrigation models

As a result of aforementioned work presented in Chapter 2.1, complete irrigation models have been developed, for all identified soil climatic zones at each Use Case:

I. SF Irrigation model in ORESTIADA (cotton)

In the framework of the project, three (3) varieties were examined in five (5) soil climatic zones in which gaiatrons and sensors were installed.

Table 6. The climatic zones and varieties cultivated in the Use Case of ORESTIADA

ORESTIADA – cotton		
	SOIL CLIMATIC ZONE	**VARIETY**
1	PETROREMA	St 402
2	A1	Elpida
3	ANADASMOS	Carla
4	LACHANOKIPOS	St 402
5	KALOCHORAFA	St 402

II. SF Irrigation model in VELVENTOS (peach)

In the framework of the project, eight (8) varieties were examined in four (4) soil climatic zones, in which gaiatrons and sensors were installed.

Table 7. The climatic zones and varieties cultivated in the Use Case of VELVENTOS

VELVENTOS – peach		
	SOIL CLIMATIC ZONE	**VARIETY**
1	**BRAVAS**	**Royal summer, Sweet cup**
2	AG. CHRISTOFOROS	June gold, Redhaven, Royal glory
3	PLAKES	Alitop
4	RAGAZIA	Gresano / Kaltezi 2000

III. SF Irrigation model in AIGINA (pistachio)

In the framework of the project, one (1) variety was examined in two (2) soil climatic zones, in which gaiatrons and sensors were installed.

Table 8. The climatic zones and varieties cultivated in the Use Case of AIGINA

AIGINA – pistachio		
	SOIL CLIMATIC ZONE	**VARIETY**
1	AGGELAKIA	aiginis
2	VOVOU	aiginis

IV. SF Irrigation model in ELASSONA (walnut)

In the framework of the project, one (1) variety was examined in three (3) soil climatic zones , in which gaiatrons and sensors were installed.

Table 9. The climatic zones and varieties cultivated in the Use Case of ELASSONA

ELASSONA - walnut		
	SOIL CLIMATIC ZONE	**VARIETY**
1	AMPELIA KOURI	Hartley
2	SYKIES	Hartley
3	PANAGIA	Chandler

V. SF Irrigation model in LASITHI (potato)

In the framework of the project, one (1) variety were examined in three (3) soil climatic zones , in which gaiatrons and sensors were installed.

Table 10. The climatic zones and varieties cultivated in the Use Case of LASITHI

LASITHI – potato					
	SOIL CLIMATIC ZONE		**VARIETY**		
1	PERVOLI		Spunta		
2	AI GIANNIS		Spunta		
3	KAMARAKI		Spunta		
AI GIANNIS	spunta	0,718	0,467	0,893	29,943

VI. SF Irrigation model in PESKO- SPEKO (kiwi)

In the framework of the project, two (2) different varieties were examined in five (5) soil climatic zones, in which gaiatrons and sensors were installed.

Table 11. The climatic zones and varieties cultivated in the Use Case of SPEKO

PESKO- SPEKO - Kiwi		
	SOIL CLIMATIC ZONE	**VARIETY**
1	BOURNAZI	Tsechelidis
2	TOUMPA	Hayward
3	SKANDALIARA	Hayward
4	A' KATIGORIA	Hayward
5	XEROKAMPI	Hayward

VII. SF Irrigation model in KIATO (table tomato)

In the framework of the project, one (1) variety were examined in three (3) soil climatic zones , in which gaiatrons and sensors were installed.

Table 12. The climatic zones and varieties cultivated in the Use Case of KIATO

KIATO – cotton cultivation		
	SOIL CLIMATIC ZONE	**VARIETY**
1	PANAGIA	Troy
2	KLIOZI	Troy
3	FIERI	Troy

VIII. SF Irrigation model in STYLIDA (olives)

The olive tree is considered to be a plant resistant to water stress and a short exposure to mild shortage of irrigation water does not have a particularly negative impact on the quality and quantity of the product produced and consequently on the economic result of the crop.

In the framework of the project, one (1) variety was examined in three (3) soil climatic zones, in which gaiatrons and sensors were installed.

Table 13. The climatic zones and varieties cultivated in the Use Case of STYLIDA

STYLIDA - olives		
	SOIL CLIMATIC ZONE	**VARIETY**
1	KOUVELA - MEG. PERIVOLI	amfisis
2	AGIOS NIKOLAOS	amfisis
3	LEFKA	amfisis

IX. SF Irrigation model in THESTO (industrial tomato)

In the framework of the project, two (2) varieties were examined in five (5) soil climatic zones , in which gaiatrons and sensors were installed.

Table 14. The climatic zones and varieties cultivated in the Use Case of THESTO

THESTO – industrial tomato		
	SOIL CLIMATIC ZONE	**VARIETY**
1	GELADINA	3402
2	MAXALAS	dexter
3	GENIGERI	3402
4	KAPATSAIR	3402
5	KAPSALES	3402

X. SF Irrigation model in THESGI (cotton)

Cotton is a water intensive crop that requires regular irrigations throughout its lifecycle.

In the framework of the project, three (3) varieties were examined in three (3) soil climatic zones , in which gaiatrons and sensors were installed.

Table 15. The climatic zones and varieties cultivated in the Use Case of THESGI

THESGI – cotton

	SOIL CLIMATIC ZONE	VARIETY
1	KAPATSAIR	St 318
2	MAVRACHOMATA	dp 332
3	DELTA	prime 9811

XI. SF Irrigation model in MIRABELLO (olives)

The olive tree is considered to be a plant resistant to water stress and a short exposure to mild shortage of irrigation water does not have a particularly negative impact on the quality and quantity of the product produced and consequently on the economic result of the crop.

In the framework of the project, one (1) variety was examined in four (4) soil climatic zones, in which gaiatrons and sensors were installed.

Table 16. The climatic zones and varieties cultivated in the Use Case of MIRABELLO

MIRABELLO - olives		
	SOIL CLIMATIC ZONE	**VARIETY**
1	PETROMENOUS	koroneiki
2	AMBELLA	koroneiki
3	AG. PARASKEVI	koroneiki
4	KAMPOS	koroneiki

Table 17 Mathematical values of the alternative irrigation algorithm for koroneiki variety in KAMPOS.

Soil climatic zone	*Variety*	*Soil Type*	*Crop coefficient*	*irrigation dose*
KAMPOS	koroneiki	Clay	0.46-0.54	5.0-10.0

XII. SF Irrigation model in FARSALA (cotton)

Cotton is a water intensive crop that requires regular irrigations throughout its lifecycle.

In the framework of the project, one (1) variety was examined in four (4) soil climatic zones, in which gaiatrons and sensors were installed.

Table 18. The climatic zones and varieties cultivated in the Use Case of FARSALA

FARSALA – cotton cultivation		
	SOIL CLIMATIC ZONE	**VARIETY**
1	KAMPADIKA	elpida
2	KLARIA	elpida
3	MAVROGIA (1)	elpida
4	MAVROGIA (2)	elpida

XIII. SF Irrigation model in ARTA (kiwi)

Kiwi is considered to be quite sensitive to lack of water and even a mild lack of irrigation water can have negative effects on the size of the fruit and therefore on the economic result of the crop.

In the framework of the project, two (2) varieties were examined in five (5) soil climatic zones, in which gaiatrons and sensors were installed.

Table 19. The climatic zones and varieties cultivated in the Use Case of ARTA

ARTA - Kiwi cultivation		
	SOIL CLIMATIC ZONE	**VARIETY**
1	VASTAGA	Hayward
2	VAKOUFIA	Hayward
3	DOKIMIA	Tsechelidis
4	SOULIOTIKA TOPALTI	Hayward
5	GOMARES	Hayward

XIV. SF Irrigation model in PELLA (peach)

In the framework of the project, one (1) varietiy was examined in four (4) soil climatic zones], in which gaiatrons and sensors were installed.

Table 20. The climatic zones and varieties cultivated in the Use Case of PELLA

PELLA – peach cultivation		
	SOIL CLIMATIC ZONE	**VARIETY**
1	ARAPTARLA	Andross
2	TSAIRI	Andross
3	ASPRA CHOMATA	Andross
4	MPACHTSEDES	Andross

XV. SF Irrigation model in EUBOEA / KASTORIA (table tomato)

In the framework of the project, two (2) varieties were examined in three (3) soil climatic zones in which gaiatrons and sensors were installed.

Table 21. The climatic zones and varieties cultivated in the Use Case of EUBOEA / KASTORIA

EUBOEA / KASTORIA – table tomato			
	SOIL CLIMATIC ZONE		**VARIETY**
	EUBOEA	**KASTORIA**	
1	LYSSE	POROS	alliance
2	FOUSTA	AMMOS	alliance
3	KAMPOS	KOURITO	belladonna

XVI. SF Irrigation model in MESSINIA (olives)

The olive tree is considered to be a plant resistant to water stress and a short exposure to mild shortage of irrigation water does not have a particularly negative impact on the quality and quantity of the product produced and consequently on the economic result of the crop.

In the framework of the project, one (1) variety was examined in two (2) soil climatic zones in which gaiatrons and sensors were installed.

Table 22. The climatic zones and varieties cultivated in the Use Case of MESSINIA

MESSINIA - olives		
	SOIL CLIMATIC ZONE	**VARIETY**
1	VRYSOULA	koroneiki
2	GKOURI	koroneiki

XVII. SF Irrigation model in COSTEIRA (vine)

In the framework of the project, one (1) variety were examined in two (2) soil climatic zones in which gaiatrons and sensors were installed.:

Table 23. The climatic zones and varieties cultivated in the Use Case of COSTEIRA

COSTEIRA – vine		
	SOIL CLIMATIC ZONE	**VARIETY**
1	SAN CIBRAO	treixadura
2	COIO BRANCO	treixadura

XVIII. SF Irrigation model in CONFAGRI (olives)

The olive tree is considered to be a plant resistant to water stress and a short exposure to mild shortage of irrigation water does not have a particularly negative impact on the quality and quantity of the product produced and consequently on the economic result of the crop.

In the framework of the project, one (1) variety was examined in four (4) soil climatic zones in which gaiatrons and sensors were installed.

Table 24. The climatic zones and varieties cultivated in the Use Case of CONFAGRI

CONFAGRI - olives		
	SOIL CLIMATIC ZONE	**VARIETY**
1	BEJA	arbequina
2	SERPA	arbequina

3.2. Final SF fertilization models

As a result of the aforementioned work presented in Chapter 2.2, complete fertilization models have been adapted for all Use Cases.

3.3. Final SF disease models

As a result of the aforementioned work presented in Chapter 2.3, complete predictive models have been developed, for all targeted pest and diseases at each crop:

I. SF disease model in Orestiada (cotton)

In the framework of the project, one (1) disease was studied in the Use Case of ORESTIADA for the cultivation of cotton

Table 25. Disease studied in the Use Case of ORESTIADA for the cultivation of cotton

ORESTIADA - cotton	
1	Alternaria alternata

II. SF disease models in VELVENTOS (peach)

In the framework of the project, four (4) diseases were studied in the Use Case of VELVENTOS for the cultivation of peach.

Table 26. Diseases studied in the Use Case of VELVENTOS for the cultivation of peach.

VELVENTOS – peach	
1	Wilsonomyces carpophilus
2	Taphrina deformans
3	Monilinia fructicola
4	Sphaerotheca pannosa

III. SF disease models in AIGINA (pistachio)

In the framework of the project, two (2) diseases were studied in the Use Case of AIGINA for the cultivation of pistachio.

Table 27. Diseases studied in the Use Case of AIGINA for the cultivation of pistachio.

AIGINA – pistachio	
1	Septoria sp.
2	Botryosphaeria dothidea

IV. SF disease model in ELASSONA (walnut)

In the framework of the project, one (1) disease was studied in the Use Case of ELASSONA for the cultivation of walnut.

Table 28. Disease studied in the Use Case of ELASSONA for the cultivation of walnut.

ELLASONA – walnut	
1	Gnomonia leptostyla

V. SF disease models in LASITHI (potato)

In the framework of the project, two (2) diseases were studied in the Use Case of LASITHI for the cultivation of potato

Table 29. Diseases studied in the Use Case of LASITHI for the cultivation of potato

LASITHI - potato	
1	Alternaria alternata
2	Peronospora infestans

VI. SF disease models in SPEKO-PESKO (kiwi)

In the framework of the project, three (3) diseases were studied in the Use Case of SPEKO-PESKO for the cultivation of kiwi.

Table 30. Diseases studied in the Use Case of SPEKO-PESKO for the cultivation of kiwi.

SPEKO-PESKO – kiwi	
1	Stemphylium botrysum
2	Pseudomonas syringae
3	Alternaria alternata

VII. SF disease models in KIATO (table tomato)

In the framework of the project, four (4) diseases were studied in the Use Case of KIATO for the cultivation of table tomato.

Table 31. Diseases studied in the Use Case of KIATO for the cultivation of table tomato

KIATO – table tomato	
1	Alternaria solani
2	Pseudomonas syringae
3	Botrytis cinerea

4	Phytophthora infenstans

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VIII. SF disease models in STYLIDA (olives)

In the framework of the project, three (3) diseases were studied in the Use Case of STYLIDA for the cultivation of olives.

Table 32. Diseases studied in the Use Case of STYLIDA for the cultivation of olives.

STYLIDA – olives	
1	Pseudomonas syringae subsp. savastanoi
2	Colletotrichum gloesporioides
3	Spilocaea oleagina

IX. SF disease models in THESTO (table tomato)

In the framework of the project, four (4) diseases were studied in the Use Case of THESTO for the cultivation of table tomato.

Table 33. Diseases studied in the Use Case of THESTO for the cultivation of table tomato.

THESTO – table tomato	
1	Phytophthora infestans
2	Leveillula taurica
3	Botrytis cinerea
4	Alternaria solani

X. SF disease models in THESGI (cotton)

In the framework of the project, one (1) disease was studied in the Use Case of THESGI for the cultivation of cotton.

Table 34. Disease studied in the Use Case of THESGI for the cultivation of cotton.

THESGI - cotton	
1	Alternaria alternata

XI. SF disease models in MIRABELLO (olives)

In the framework of the project, three(3) diseases were studied in the Use Case of MIRABELLO for the cultivation of olives.

Table 35. Diseases studied in the Use Case of MIRABELLO for the cultivation of olives.

MIRABELLO– olives	
1	Pseudomonas syringae subsp. savastanoi
2	Spilocaea oleagina
3	Colletotrichum gloesporioides

XII. SF disease model in FARSALA (cotton)

In the framework of the project, one (1) disease was studied in the Use Case of FARSALA for the cultivation of cotton.

Table 36. Disease studied in the Use Case of FARSALA for the cultivation of cotton.

FARSALA - cotton	
1	Alternaria alternata

XIII. SF disease models in ARTA (kiwi)

No important diseases were identified for the cultivation of kiwi in the Use Case ARTA.

XIV. SF disease models in PELLA (peach)

In the framework of the project, three (3) diseases were studied in the Use Case of PELLA for the cultivation of peach.

Table 37. Diseases studied in the Use Case of Use Case of PELLA for the cultivation of peach.

PELLA – peach	
1	Wilsonomyces carpophilus
2	Taphrina deformans
3	Monilinia fructicola, Monilinia laxa

XV. SF disease models in KASTORIA (table tomato)

In the framework of the project, four (4) diseases were studied in the Use Case of KASTORIA for the cultivation of table tomato.

Table 38. Diseases studied in the Use Case of KASTORIA for the cultivation of table tomato.

KASTORIA - table tomato	
1	Phytophthora infestans

2	Leveillula taurica
3	Botrytis cinerea
4	Alternaria solani

XVI. SF disease model in MESSINIA (olives)

In the framework of the project, one (1) disease was studied in the Use Case of MESSINIA for the cultivation of olives.

Table 39. Disease studied in the Use Case of MESSINIA for the cultivation of olives.

MESSINIA – olives	
1	Colletotrichum gloesporioides

XVII. SF disease models in COSTEIRA (vine)

In the framework of the project, four (4) diseases were studied in the Use Case of COSTEIRA for the cultivation of vine.

Table 40. Diseases studied in the Use Case of COSTEIRA for the cultivation of vine.

COSTEIRA – vine	
1	Erysiphe necator
2	Plasmopara viticola
3	Botrytis cinerea
4	Guignardia bidwellii

XVIII. SF disease models in CONFAGRI (olives)

In the framework of the project, two (2) diseases were studied in the Use Case of CONFAGRI for the cultivation of olives.

Table 41. Diseases studied in the Use Case of CONFAGRI for the cultivation of olives.

CONFAGRI – olives	
1	Spilocaea oleagina
2	Colletotrichum gloesporioides

3.3.1. Final SF pests models

I. SF pest models in ORESTIADA (cotton)

In the framework of the project, four (4) pests were studied in the Use Case of ORESTIADA for the cultivation of cotton

Table 42. Pests studied in the Use Case of ORESTIADA for the cultivation of cotton

ORESTIADA - cotton	
1	Pectinophora gossypiella (pink bollworm)
2	Helicoverpa armigera
3	Lygus hesperus
4	Eurygaster maura

II. SF pest model in VELVENTOS (peach)

In the framework of the project, one (1) pest was studied in the Use Case of VELVENTOS for the cultivation of peach.

Table 43. Pest studied in the Use Case of VELVENTOS for the cultivation of peach.

VELVENTOS – peach	
1	Grapholita molesta

III. SF pests model in AIGINA

No important pests were identified for the cultivation of pistachio in the Use Case of Aigina.

IV. SF pest model in ELASSONA (walnut)

In the framework of the project, one (1) pest was studied in the Use Case of ELASSONA for the cultivation of walnut.

Table 44. Pest studied in the Use Case of ELASSONA for the cultivation of walnut.

ELLASONA – walnut	
1	Cydia pomonella

V. SF pest models in LASITHI (potato)

In the framework of the project, two (2) pests were studied in the Use Case of LASITHI for the cultivation of potato.

Table 45. Pests studied in the Use Case of LASITHI for the cultivation of potato.

LASITHI - potato	
1	Leptinotarsa decemlineata
2	Phthorimaea operculela

VI. SF pest models in SPEKO-PESKO (kiwi)

In the framework of the project, two (2) pests were studied in the Use Case of SPEKO-PESKO for the cultivation of kiwi.

Table 46. Pests studied in the Use Case of SPEKO-PESKO for the cultivation of kiwi.

SPEKO-PESKO – kiwi	
1	Pseudaulacapsis pentagona
2	Metcalfa pruinosa

VII. SF pest models in KIATO

No important pests were identified for the cultivation of tomato in the Use Case of Kiato.

VIII. SF pest models in STYLIDA (olives)

In the framework of the project, two (2) pests were studied in the Use Case of STYLIDA for the cultivation of olives.

Table 47. Pests studied in the Use Case of STYLIDA for the cultivation of olives.

STYLIDA – olives	
1	Prays oleae
2	Bactrocera oleae

IX. SF pest model in THESTO (table tomato)

In the framework of the project, one (1) pest were studied in the Use Case of THESTO for the cultivation of table tomato.

Table 48. Pest studied in the Use Case of THESTO for the cultivation of table tomato.

THESTO – table tomato	
1	Helicoverpa armigera

X. SF pest models in THESGI (cotton)

In the framework of the project, four (4) pests were studied in the Use Case of THESGI for the cultivation of cotton.

Table 49. Pests studied in the Use Case of THESGI for the cultivation of cotton.

THESGI - cotton	
1	Helicoverpa armigera
2	Pectinophora gossypiella
3	Bemisia tabaci
4	Lygus hesperus

XI. SF pests model in MIRABELLO (olives)

In the framework of the project, two (2) pest was studied in the Use Case of MIRABELLO for the cultivation of olives.

Table 50. Pest studied in the Use Case of MIRABELLO for the cultivation of olives.

MIRABELLO - olives	
1	Bactrocera oleae
2	Prays oleae

XII. SF pests model in FARSALA (cotton)

In the framework of the project, one (1) pest was studied in the Use Case of FARSALA for the cultivation of cotton.

Table 51. Pest studied in the Use Case of FARSALA for the cultivation of cotton.

FARSALA - cotton	
1	Pectinophora gossypiella
2	Helicoverpa armigera

XIII. SF pest models in ARTA

No important pests were identified for the cultivation of kiwi in the Use Case of Kiato

XIV. SF pest models in PELLA (peach)

In the framework of the project, two (2) pests were studied in the Use Case of PELLA for the cultivation of peach.

Table 52. Pests studied in the Use Case of Use Case of PELLA for the cultivation of peach.

PELLA – peach cultivation	
1	Grapholita molesta
2	Anarsia lineatella

XV. Pest model in KASTORIA (table tomato)

In the framework of the project, one (1) pest was studied in the Use Case of KASTORIA for the cultivation of table tomato.

Table 53. Pest studied in the Use Case of KASTORIA for the cultivation of table tomato.

KASTORIA - table tomato	
1	Helicoverpa armigera

XVI. Pest model in MESSINIA (olives)

In the framework of the project, one (1) pest was studied in the Use Case of MESSINIA for the cultivation of olives.

Table 54. Pest studied in the Use Case of MESSINIA for the cultivation of olives.

MESSINIA – olives	
1	Bactrocera oleae

XVII. SF pest model in COSTEIRA (vine)

In the framework of the project, one (1) pest was studied in the Use Case of COSTEIRA for the cultivation of vine.

Table 55. Pest studied in the Use Case of COSTEIRA for the cultivation of vine.

COSTEIRA – vine	
1	Lobesia botrana

XVIII. SF pest models in CONFAGRI (olives)

In the framework of the project, two (2) pests were studied in the Use Case of CONFAGRI for the cultivation of olives.

Table 56. Pests studied in the Use Case of CONFAGRI for the cultivation of olives.

	CONFAGRI – olives
1	Bactrocera oleae
2	Prays oleae