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DELIVERABLE

Reports on indicator values for environmental and socio-economic impact after each pilot application

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Executive Summary

This report presents Deliverable "C1.2 Reports on indicator values for environmental and socio-economic impact" of the LIFE GAIA Sense project, which has been prepared as part of the monitoring activities of Action C.1. The results of KPIs calculation from the baseline year (2019) and the 1st Smart Farming application year (2020) are also included in the report. The methodology for calculating each indicator and the different indicator types (environmental, social, economic) is described in detail, focusing on the data sources used and the related assumptions and challenges. The results for the indicator values are displayed in tables and diagrams, and in several cases, different indicators are combined in order to provide an integrated impact estimation. The problems encountered in quantifying the indicators, which were primarily due to missing or inaccurate farming practices data, are explained thoroughly and the solutions proposed are presented.

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Definitions, Acronyms and Abbreviations

Acronym	Title
AUTH	ARISTOTELIO PANEPISTIMIO THESSALONIKIS (Aristotle University of Thessaloniki – Special Account of Research Funds)
LHTEE	Laboratory of Heat Transfer and Environmental Engineering
GAIA	GAIA EPICHEIREIN ANONYMI ETAIREIA PSIFIAKON YPIRESION
NP	NEUROPUBLIC AE PLIROFORIKIS & EPIKOINONION
SF	Smart Farming

1. Introduction

Sub-action C1.1 is led by AUTH and focuses on the monitoring of environmental, social and economic indicators throughout the duration of the project, in view of formulating best agricultural practices promoting sustainable agriculture. One of the main objectives of this sub-action was the development and distribution of relevant questionnaires to farmers participating in pilot applications, where also information on agricultural practices would be reported. This information would be then used to calculate the predefined environmental, social and economic indicators, as well as the relevant KPIs.

The development of the questionnaires and their distribution history, as well as the indicators and KPIs to be monitored, have been presented in the Deliverable "C1.1 Questionnaire for farmers participating in pilot applications". In the present Deliverable "C1.2 Reports on indicator values for environmental and socio-economic impact", the actual methodology and stages of data collection, format and analysis and the results on the indicator and KPIs values are discussed, for the baseline (2019) and the first SF application year (2020). Based on this analysis, as well as on combined with data from the ICM and the LCA analysis (that will be performed at a later stage in the project), the actual impact of the SF system on the environment will be quantified and its efficiency as a sustainability promoting tool in the agriculture sector will be holistically assessed.

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 scope of this document is to present the methodology used and the steps followed by AUTH in formatting and analyzing the information provided in the questionnaires targeted to farmers participating in the pilot Smart Farming Advice applications of the LIFE GAIA Sense project. This activity of Action C.1 which is related to the calculation of appropriate indicators for assessing the socio-economic and environmental impact of the project pilot.

1.3. Document Structure

This document is comprised of the following chapters:

Chapter 1. Introduction, which includes the project summary, the document scope and structure

Chapter 2. Methodological steps in indicator calculation

Chapter 3. Environmental indicators

Chapter4. Social indicators

Chapter 5. Economical indicators

Chapter 6.KPIs calculation results

Chapter 7. Conclusions

2. Methodological Steps in Indicator Calculation

2.1. General Methodology

The completed questionnaires from the farmers participating in the SF application of the project were collected from GAIA and shared with AUTH through a designated folder in Google Drive. The received questionnaires were then studied in detail and the containing information was organized in .xls sheets. The sheets included one type of indicator (either environmental, social, or economic) and included the following columns:

- Name/code of farm land
- Indicator name with values for two years 2019 and 2020 (e.g., for environmental indicators the indicators: fertilizer applied quantity (kg/acre/year), fuel consumption (in lt/acre/year), water consumption (in m^3/acre/year), pesticide application (kg/acre/year) as well as other information on agricultural practices used, each in a separate column
- The data in the previously mentioned columns were then used to calculate average values for each crop type and pilot area for the two years and compared using graphs and tables
- The % difference (increase or reduction) in indicator mean values between the two compared cultivating years was also calculated and displayed in graphs and tables
- In particular, for the calculation of the Emissions KPI, a separate .xls file was created, as fertilizer information was first used to calculate the % of N applied, based on which the appropriate emission factors were used to calculate emissions. The calculation of the emissions is analysed in detail in the following section of the methodology

2.2. Number of Questionnaires received and analysed

The outcomes from the statistical analysis of the questionnaire data are directly correlated to the sample size, i.e., the number of the completed questionnaires received, the completeness of the requested information and the accuracy of the reported data. These issues are important elements of the methodology, as they have to be appropriately addressed in advance, in order to deduce valuable and representative results.

The questionnaires used for the calculation of the indicators were the ones for which replies were available for both the baseline and the first SF application year, so that comparative indicator values could be calculated. Detailed quantitative data were requested for environmental indicators (such as fertilisers and pesticides used) and should be completed with accurate information on for example type/substance of the fertilizer/pesticide applied and frequency of application during one cultivating year. Other quantitative data including water and fuel consumption should be reported in the units indicated in the respective questions in the questionnaires, again as a total quantity during one cultivating year. This was raised as a possible source of inaccuracy during the statistical analysis and following comparison with data reported in the ICM. It is assumed, that farmers and agronomists provided more accurate and realistic data in the ICM, as reporting follows shortly after application or agricultural activity, compared to data stated in the questionnaires, as it was noted that different quantities were reported (in some cases showing significant difference of many orders of magnitude) when they were asked to provide year averaged information on the same data, at a later time, after the end of the cultivating year. This is an issue of results representativity when using questionnaire data for statistical analysis in the agriculture sector and is also discussed in the conclusions of the present deliverable.

Taking the above into account, a total of 42 questionnaires, covering 9 crop types and 13 pilot areas were used for the calculation of comparative indicators and KPIs in the present report. Table 1 presents the number of the questionnaires used for each crop type and each pilot area. It should be noted that the selected questionnaires should contain all necessary data, including quantitative data required for the calculation of indicators. In the case of missing data, the quantities in the questionnaires were completed, when available, with data from ICM in order to include them in the analysis.

Table 1. Number of the questionnaires used for each crop type and each pilot areas

Number of questionnaires per Crop Type	Number of questionnaires per Pilot Area
Pistachio: **2**	Aigina (Pistachio): **2**
Peach: **4**	Velventos (Peach): **4**
Walnut: **3**	Elassona (Walnut): **3**
Grape: **2**	Spain (Grape): **2**
Tomato: **8**	Kiato (Tomato): **3**
Potato: **2**	Lasithi (Potato): **2**
Olive: **9**	Mirabello (Olive): **4**
Cotton: **7**	Orestiada (Cotton): **4**
Kiwi: **5**	Pieria (Kiwi): **5**
	Portugal (Olive): **2**
	Stylida (Olive): **3**
	THESGI (Cotton): **3**
	THESTO (Tomato): **5**
SUM: **42**questionnaires	

2.3. Methodology for Calculation of the Emissions KPI

Realistic emission data are a pre-requisite for reliable modelling estimation of the agricultural activities on local air quality and climate. Availability of high temporal and spatial resolution of pollutant emissions in smart farming applications is of particular importance in order to assess the local impact on the atmospheric environment. Atmospheric pollutant emissions are calculated by multiplying the activity rate with an emission factor. In the suggested methodology, emission factors from the EMEP/EEA air pollutant emission inventory guidebook 2019 (EMEP/EEA, 2019) and particularly of the 1A (mobile machinery) and 3D (Crop production and agricultural soils) NFR categories were used for most of the studied pollutants. In particular, for calculation of N_2O emissions resulting from fertilisation of agricultural soil, the IPCC reference emission factor of 1% of kg N fertiliser applied is used. The proposed modelling methodology relies on the calculation of realistic emissions data following a combined Tier 1 and Tier 2 approach for emission calculation. For this purpose, detailed activity data of the specific SF application areas related to agricultural activities were acquired from the questionnaires to farmers as describe above.

A set of environmental indicators specifically targeted the impact on the atmospheric environment and were included to provide quantitative activity data for calculating the related atmospheric pollutant emissions. These indicators particularly included the use of fertilisers and energy use. The related questions required specifically the following information:

1. Use of chemical and organic fertilisers – type (composition) and quantity (annual quantity in kg or per ha) of fertiliser for the specific crop type and the application frequency (e.g., per year or season)
2. Energy use – annual consumption of transport fuel in liters

Based on the on-site activity and soil data acquired from the questionnaires farm-level agricultural operations (for particulate matter), such as ploughing, spraying, harvesting, and storage/handling of agricultural product were represented. The methodology to calculate realistic emissions of atmospheric pollutants and GHGs was structured depending on pollutant type, as follows:

• Tier 1 methodology was applied to calculate emissions of PM10, PM2.5, NO, NMVOC, using the default emission factors (EFs) for NFR Source category 3.D (Crop production and agricultural soils) from Table 3.1 of the EMEP EMEP/EEA air pollutant emission inventory guidebook 2019 (EMEP/EEA, 2019). This source category includes emissions related to the application of N fertilisers (for NO), emissions from cultivated crops (for NMVOC) and fertiliser (kg of fertiliser N) applied and size of the cultivated area (ha) were derived from farmers' questionnaires. The percentage of N of each fertiliser was estimated from the fertiliser commercial name and composition.

• Tier 1 methodology was used for emissions calculation of GHGs (CH4, CO2, N2O) and atmospheric pollutants (NH3, NMVOC, NOx, PM10 and PM2.5), employing the default EFs for NFR Source category 1.A.4.c.ii-Agriculture from Table 3-1 (Tier 1 emission factors for off-road machinery) of the EMEP EMEP/EEA air pollutant emission inventory guidebook 2019 (EMEP/EEA, 2019). This source category includes exhaust emissions related to fuel consumption of off-road vehicles and other machinery used in agriculture. On-site activity data on fuel consumption were derived from farmers' questionnaires.

• Tier 1 methodology was used for calculating N2O emissions from fertiliser application in agricultural soils, according to the default value of 1% of kg-1 fertiliser N applied of IPCC (IPCC, 2006b).

• Tier 2 methodology was applied for the calculation of NH3 emissions resulting from soil fertilisation, taking into account the climate zone of the pilot farm, the soil pH and the amount of N applied to the soil as calculated from the information in the farmers' questionnaires and logbooks. The EFs were selected based on the fertiliser type as recorded by the farmer and applied on each pilot farm, according to Table 3.2 EFs for NH3 emissions from fertilisers (in g NH3 (kg N applied)-1) from the EMEP EMEP/EEA air pollutant emission inventory guidebook 2019 (EMEP/EEA, 2019).

The Tier 1 EFs used to calculate the total emissions are presented in Table 1. Tier 2 EFs for NH3 calculation are related to the fertiliser type applied and can be found in Table 3.2 of the EMEP/EEA air pollutant emission inventory guidebook 2019 (EMEP/EEA, 2019).

Table 2. Emission Factors (EFs) from NFR categories [a, d]

	NFR category			
Pollutants	**Fertiliser application (NFR 3D)**	**Non-road machinery (NFR 1.A.4 cii)**	**Standing crops (NFR 3D) ($kg\cdot ha^{-1}$)**	**Agricultural operations (NFR 3D) ($kg\cdot ha^{-1}$)**
PM10	-	1913 $g\cdot tonnes^{-1}$ fuel	-	1.56
PM2.5	-	1913 $g\cdot tonnes^{-1}$ fuel	-	0.06

NOx	-	34457 g·tonnes^{-1} fuel	-	-
NO	0.04 kg NO_2 kg^{-1} fertiliser N applied	-	-	-
NMVOC	-	3542 g·tonnes^{-1} fuel	0.86	-
NH3	Table 3.2 [c]	8 g·tonnes^{-1} fuel	-	-
N2O	0.01 kg N_2O–N (kg N)$^{-1}$ [b]	136 g·tonnes^{-1} fuel	-	-
CO2	-	3160 kg·tonnes^{-1} fuel	-	-
CH4	-	87 g·tonnes^{-1} fuel	-	-

[a]All emission factors (except the EF of N2O from fertiliser application) are based on EMEP/EEA air pollutant emission inventory guidebook 2019

[b] EF of N2O from fertilizer application is based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories

[c] See Table 3.2 in EMEP/EEA air pollutant emission inventory guidebook 2019

[d] All EFs are Tier 1, except the ones of NH3 from fertiliser application which are Tier 2

At this point, it should be clarified, that the analysis(figures and tables) presented onwards is based only on certain farmers (of each pilot area) from whom questionnaire replies were received (42 in total)and therefore, they may be some differences from the deliverables B4/5/6, in which the cumulative percentages presented were calculated from the totality of the participating (in the LIFE project) farmers of each pilot area.

3. Environmental Indicators

By analysing the questionnaire replies, the following environmental indicators are calculated:

3.1. Farming type

The first information that was imported in the questionnaires regarding the farmer/manager and the farm business was the farming type which was applied in each crop field, while33 out of 42 questionnaires provided the particular data. The results are presented in the following donut chart, as percentage of each farming type applied among the farms. As shown, 39% (20 in numbers) of the farmers used an integrated approach of farming their fields, 61% (13 farmers) a conventional one, while none of them an organic .No changes in farming type were noted between the baseline cultivation (2019) and the 1st smart farming year (2020).

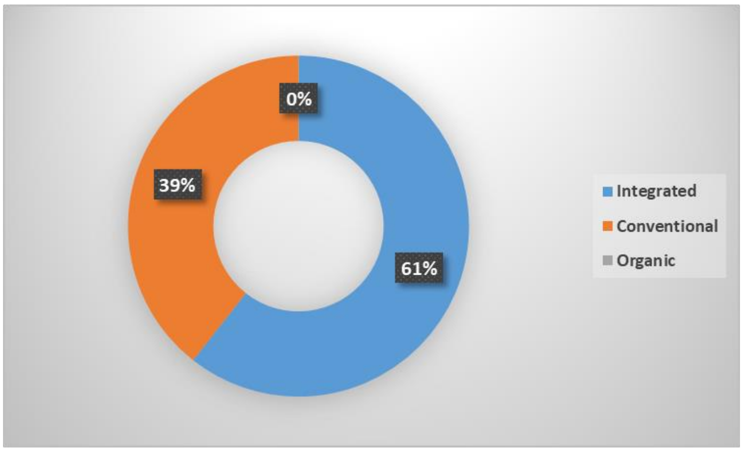

Figure 1. Percentage of each farming type applied among the farms

3.2. Fertlisers applied

For calculating the particular indicator of fertilisers applied,42 questionnaires were used, in which quantitative fertilisers data (in kg/acre/year) were reported for the two years studied. Those quantitative data were cross-checked, and replaced when necessary, with ICM data for QA/QC reasons, as in some cases there were uncertainties noticed regarding the replies of farmers, e.g., in terms of units reported(ICM data are considered as a more realistic source compared to questionnaire replies, as they are recorded from farmers in real time or shortly after application, while questionnaire data are reported as an average at the end of the cultivating year).The results are shown as absolute values of the amount of fertilisers applied for the years 2019 and 2020, averaged for each crop type (Table 3, Figure 2) and for each pilot area (Table 4, Figure 4). In the last column of the tables, relative and percentage differences are calculated for comparison. The actual increases and reductions are also graphically displayed in Figure 3&5.

Table 3. Fertilisers applied averaged per crop type for the baseline (2019) and first SF cultivation year (2020) with percentage relative differences

	Fertilisers applied (kg/acre)		
Crop type	**2019**	**2020**	**% Relative change**
Pistachio	16.2	28.6	+76.54

Peach	135	143	+5.93
Walnut	57.17	16.65	-70.88
Grape	80.13	65.81	-17.87
Tomato	160.91	85.91	-46.61
Potato	229	-	-
Olive	34.84	35.83	+2.82
Cotton	51.38	40.29	-21.59
Kiwi	218.94	186.57	-14.79

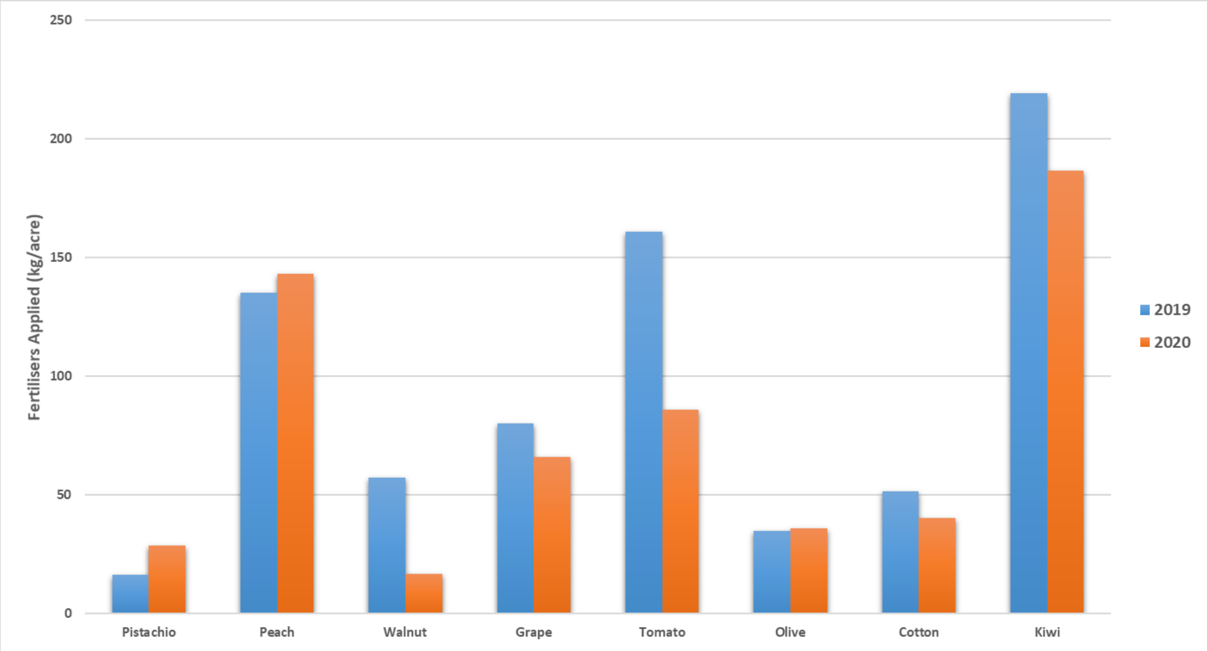

Figure 2. Fertilisers applied averaged per crop type for 2019 and 2020

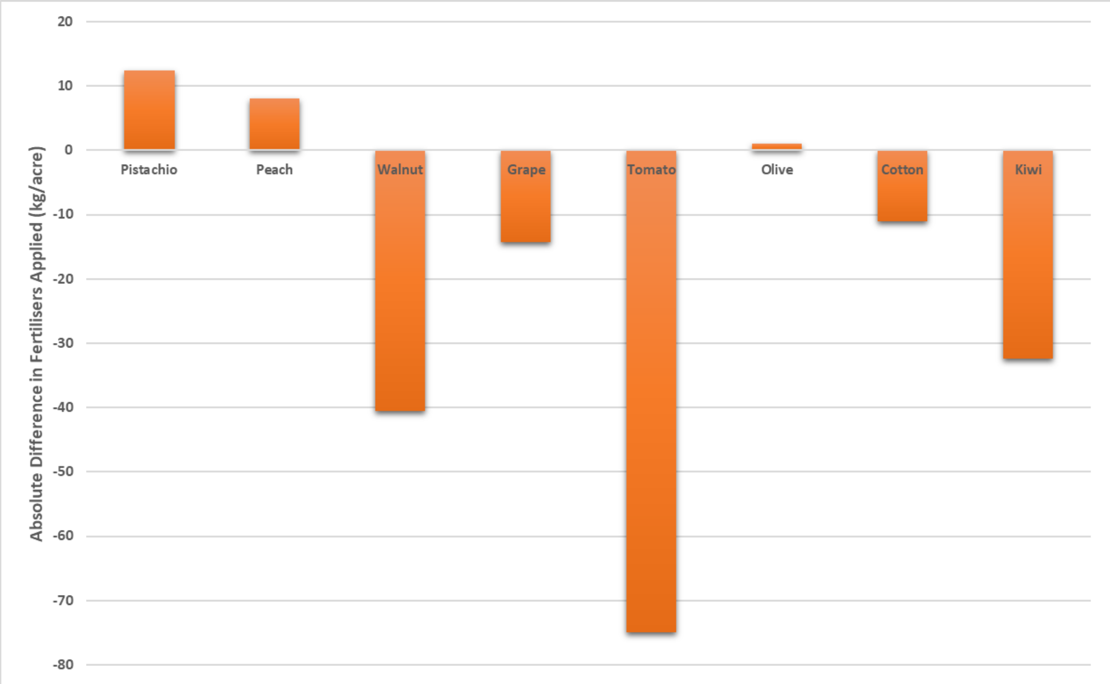

Figure 3. Absolute difference in fertilisers applied between 2019-2020 averaged per crop type

Table 4. Fertilisers applied averaged per pilot area for the baseline (2019) and first SF cultivation year (2020) with percentage relative differences

	Fertilisers applied (kg/acre)		
Pilot area	**2019**	**2020**	**% Relative change**
Aigina (Pistachio)	16.2	28.6	+76.54
Velventos (Peach)	135	143	+5.93
Elassona (Walnut)	57.17	16.65	-70.88
Spain (Grape)	80.13	65.81	-17.87
Kiato (Tomato)	167.83	39.71	-76.34
Lasithi (Potato)	229	-	-
Mirabello (Olive)	41.5	41.65	+0.36
Orestiada (Cotton)	66	55.23	-16.33
Pieria (Kiwi)	218.94	186.57	-14.79
Portugal (Olive)	22.89	19.53	-14.7
Stylida (Olive)	40.14	46.31	+15.36
THESGI (Cotton)	36.77	25.36	-31.04
THESTO (Tomato)	153.99	132.1	-14.22

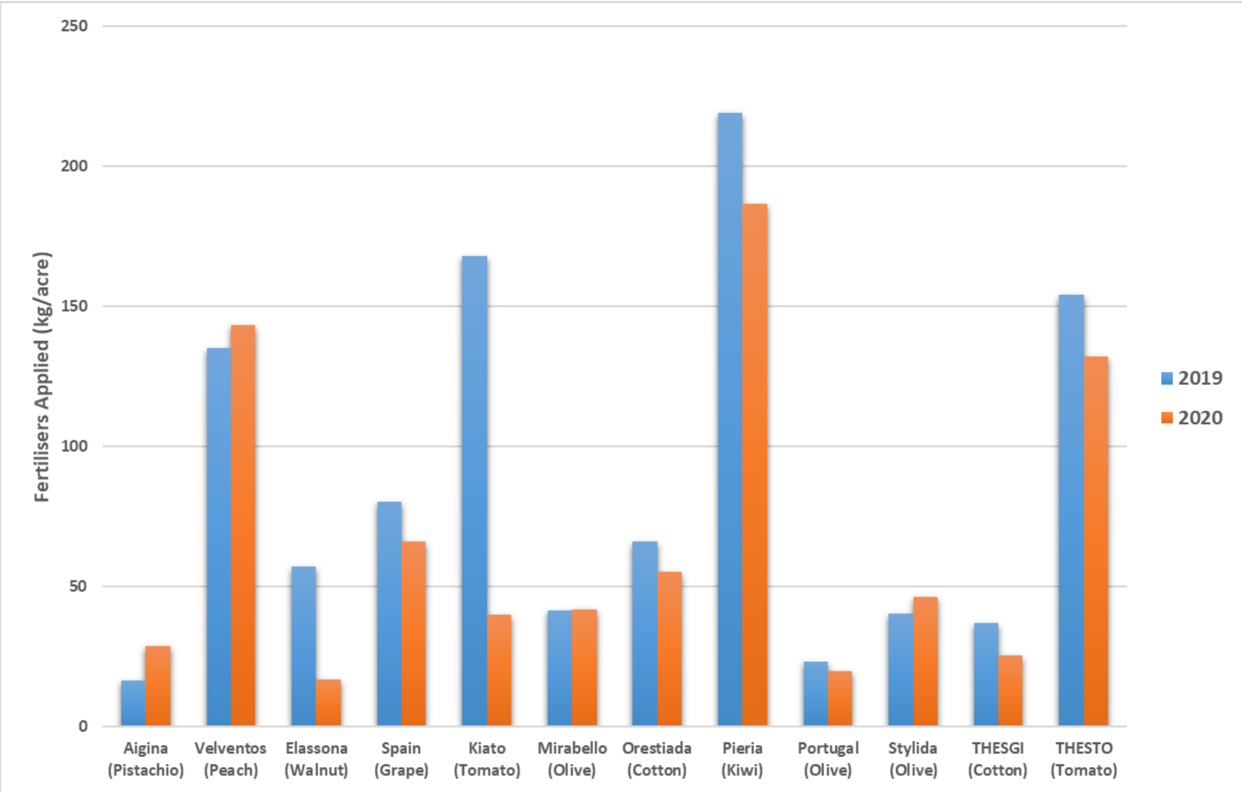

Figure 4. Fertilisers applied averaged per pilot area for 2019 and 2020

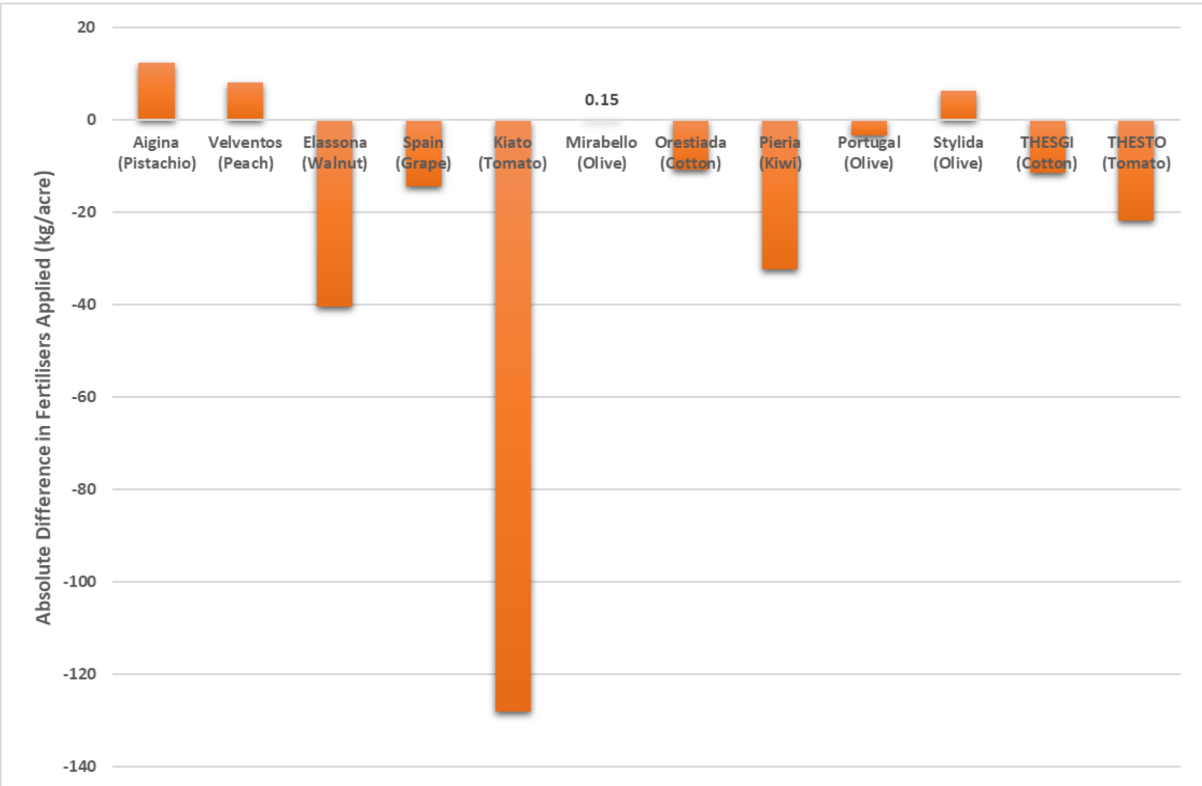

Figure 5. Absolute difference in fertilisers applied between 2019-2020 averaged per pilot area

In general, there were considerable decreases in the amount of fertilisers applied for most of the crop types, except pistachio, peach and olive, which showed increases. Increases are possible to occur and can be attributed to various of reasons. One of them is the different needs in fertilising that emerge in each cultivation year.It is important to be noted that fertilising is an agricultural activity which depends on many factors, e.g., soil nitrogen status, soil and weather conditions, etc. (NRCS/USDA, 2014). Another reason is the quality of cooperation with the farmers, who in some cases do not follow the practical advice of the agronomists in charge.Also, the following observations are being made:

- Relatively (%), between 2019-2020, the largest decreases were noticed for walnut and tomato crops (in descending order).
- In absolute numbers, tomato, walnut and kiwi crops had the largest decreases (in descending order).

As for each pilot area, the presented tables and figures indicate that there were mostly decreases in the amount of fertilisers applied, while there were also some increases in the pilot areas of Aigina, Velventos and Stylida. Mirabello showed a +0.36 increase, which means that did not show any practical change.More specifically:

- Relatively (%), between 2019-2020, the largest decreases were noticed in Kiato (tomato), Elassona (walnut) and THESGI, Larisa (cotton)pilot areas (in descending order).
- In absolute numbers, Kiato (tomato), Elassona (walnut) and Pieria (Kiwi)managed the largest decreases (in descending order).

3.3. Pesticides applied

For calculating the particular indicator of pesticides (mostly fungicides and insecticides) applied, 42 questionnaires were used, in which quantitative pesticides data (in kg or lt/acre/year) were reported for the two years studied. Those quantitative data were cross-checked, and replaced when necessary, with ICM data for QA/QC reasons, as explained in the previous paragraphs. The results are shown as absolute values of the amount of pesticides applied for the years 2019 and 2020, averaged for each crop type (Table 5, Figure 6) and for each pilot area (Table 6, Figure 8). In the last column of the tables, relative and percentage differences are calculated for comparison. The actual increases and reductions are also graphically displayed in Figure 7 & 9.

Table 5. Pesticides applied averaged per crop type for the baseline (2019) and first SF cultivation year (2020) with percenta gerelative differences

	Pesticides applied (kg/acre)		
Crop type	**2019**	**2020**	**% Relative change**
Pistachio	0.43	0.16	-62.35
Peach	5.7	2.44	-57.25
Walnut	0.83	0.76	-7.63
Grape	3.08	3.69	+19.55
Tomato	0.85	0.62	-27.23
Potato	-	0.69	-

Olive	0.47	0.96	+101.98
Cotton	0.24	0.03	-88.13
Kiwi	0.4	0.23	-42

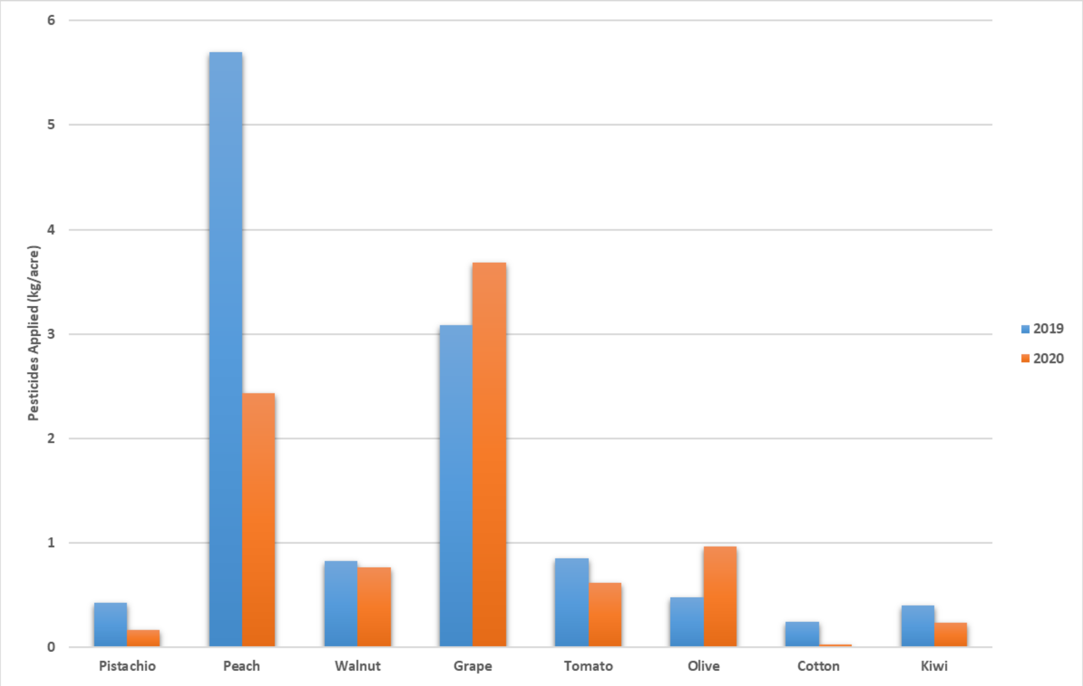

Figure 6. Pesticides applied averaged per crop type for 2019 and 2020

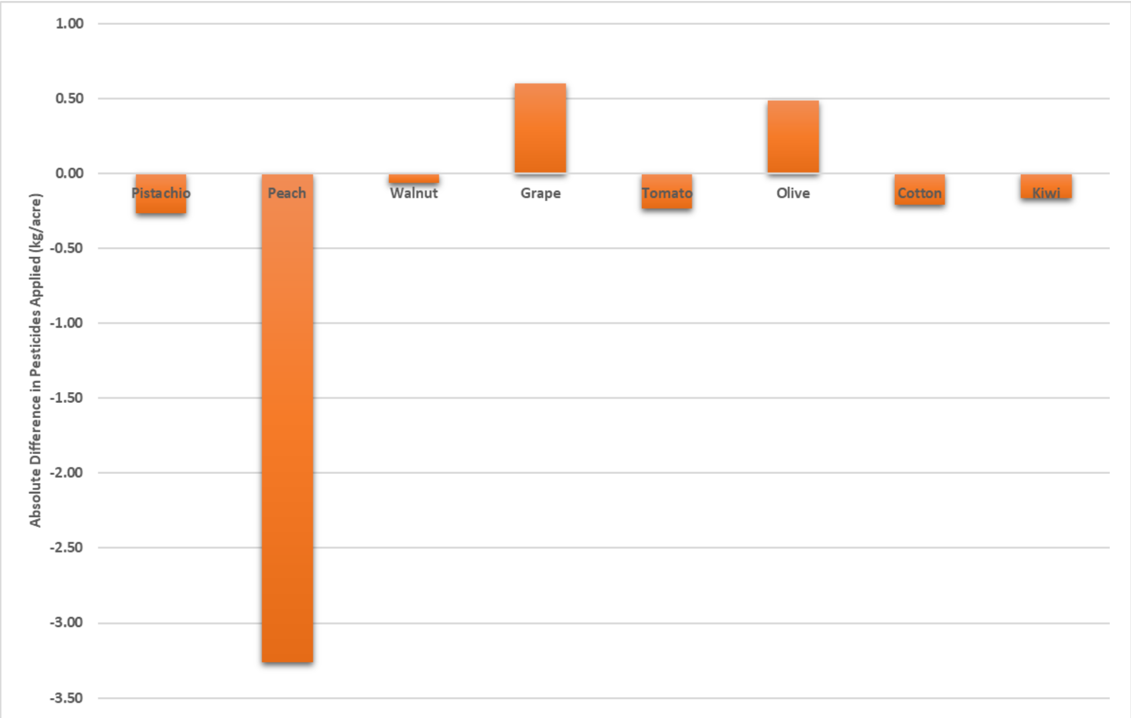

Figure 7. Absolute difference in pesticides applied between 2019-2020 averaged per crop type

Table 6. Pesticides applied averaged per pilot area for the baseline (2019) and first SF cultivation year (2020) with percentage relative differences

	Pesticides applied (kg/acre)		
Pilot area	**2019**	**2020**	**% Relative change**
Aigina (Pistachio)	0.43	0.16	-62.35
Velventos (Peach)	5.7	2.44	-57.25
Elassona (Walnut)	0.83	0.76	-7.63
Spain (Grape)	3.08	3.69	+19.55
Kiato (Tomato)	0.91	0.62	-31.41
Lasithi (Potato)	-	0.69	-
Mirabello (Olive)	0.11	0.36	+222.67
Orestiada (Cotton)	-	0.05	-
Pieria (Kiwi)	0.4	0.23	-42
Portugal (Olive)	0.57	1.22	+113.63
Stylida (Olive)	0.74	1.3	+74.72
THESGI (Cotton)	0.24	0.03	-88.13
THESTO (Tomato)	0.79	0.61	-22.41

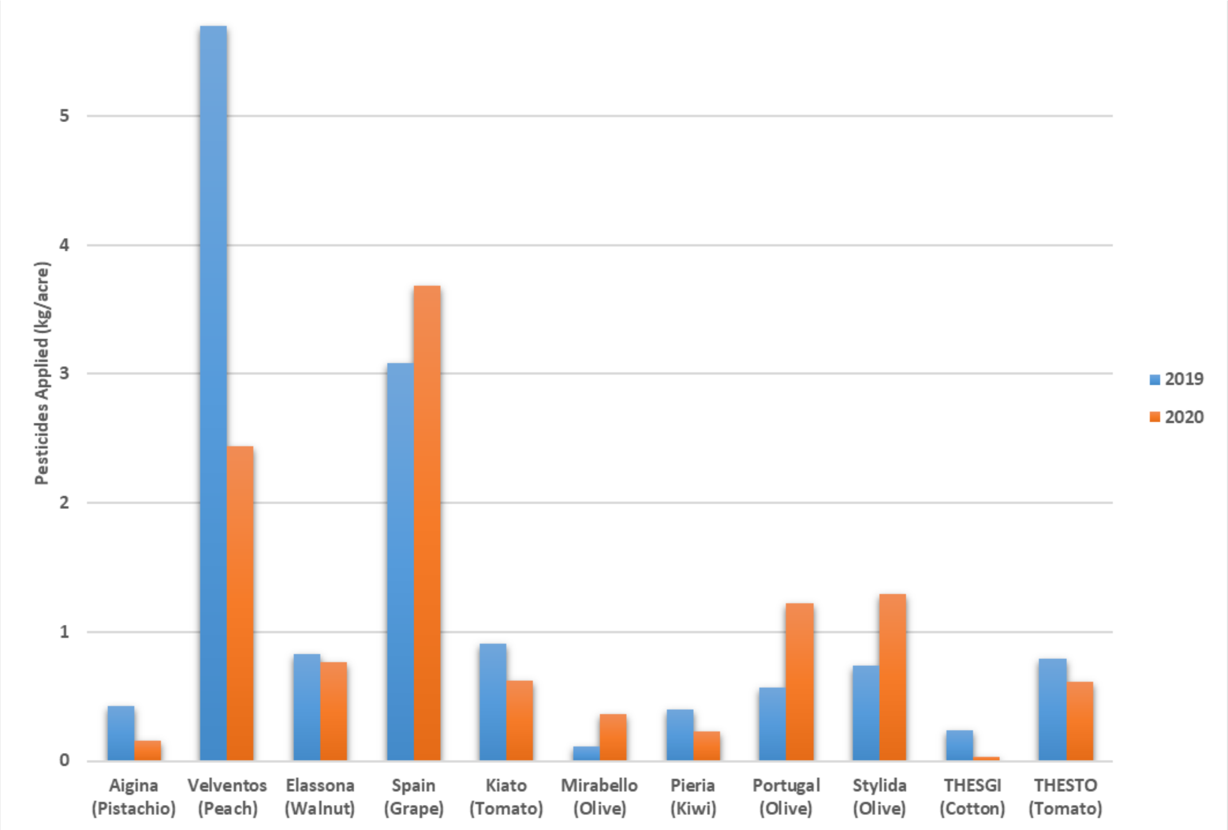

Figure 8. Pesticides applied averaged per pilot area for 2019 and 2020

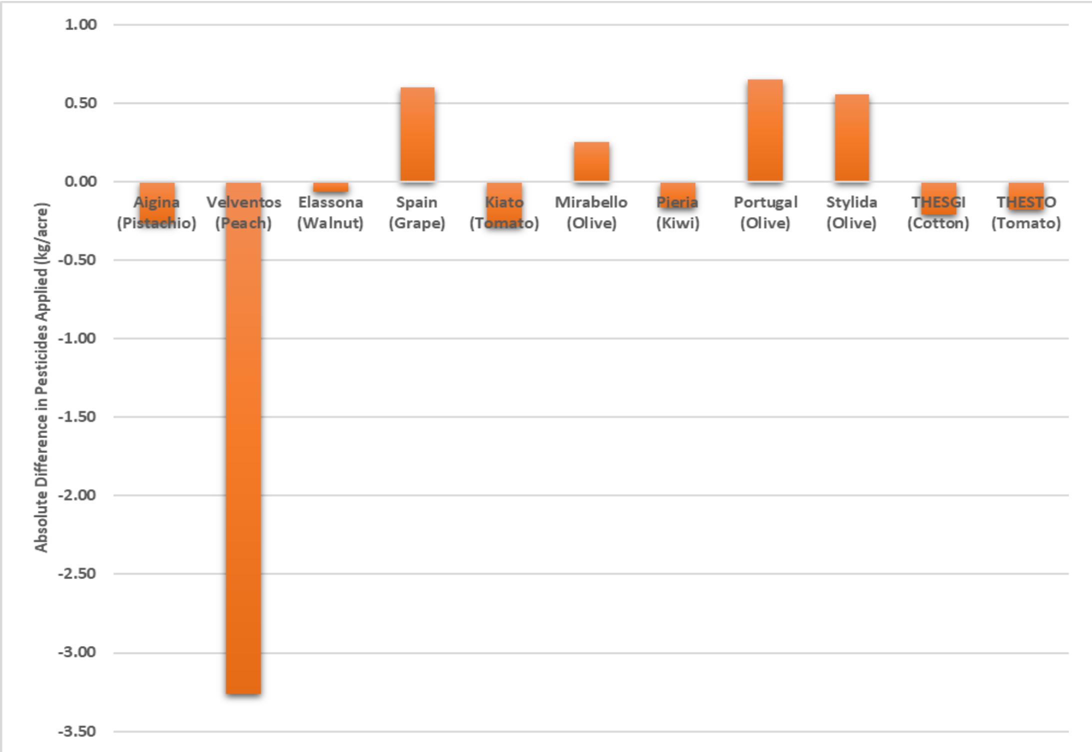

Figure 9. Absolute difference in pesticides applied between 2019-2020 averaged per pilot area

In general, there were considerable decreases in the amount of pesticides applied, except for grape and olive crops. Increases in pesticide use are possible to happen and can be attributed to various of reasons. One of them is the different needs in spraying that emerge in each cultivation year, while another one is the extent to which the instructions of the agronomists were followed. Also, the following observations are being made:

- Relatively (%), between 2019-2020, the largest decreases were noticed for cotton, pistachio and peach (in descending order).
- In absolute numbers, peach had the biggest decrease in pesticide application and in a significantly larger level in comparison to the other crops.

As for each pilot area, the presented tables and figures indicate that there were mostly decreases in the amount of sprayed pesticides, while there were also increases in the pilot areas of Spain (Costeira), Mirabello,Portugal (Confagri)and Stylida. In more detail:

- Relatively (%), between 2019-2020, the largest decreases were noticed in THESGI (cotton), Aigina (pistachio) and Velventos (peach)pilot areas(in descending order), while the largest increase in Mirabello (olive).
- In absolute numbers, Velventos (peach) managed the largest decrease, while the largest increases took place in Portugal(olive), Spain (grape) and Stylida (olive) (in descending order).

3.4. Water consumption

For calculating the particular indicator of water consumption, 42 questionnaires were used, in which quantitative water consumption data in m3/acre/year were reported for the two years studied. Those quantitative data were cross-checked, and replaced when necessary, with ICM data for QA/QC reasons, as explained in the previous paragraphs. The results are shown as absolute values of water consumption for the years 2019 and 2020, averaged for each crop type (Table 7, Figure 10) and for each pilot area (Table 8, Figure 12). In the last column of the table, relative and percentage differences are calculated for comparison. The actual increases and reductions are also graphically displayed in Figure 11 & 13.

Table 7. Water consumption averaged per crop type for the baseline (2019) and first SF cultivation year (2020) with percentage relative differences

	Water consumption (m3/acre)		
Crop Type	**2019**	**2020**	**% Relative Change**
Pistachio	168	199	+18.45
Peach	211.8	177.7	-16.09
Walnut	251.7	191.7	-23.84
Grape	291.5	223.5	-23.33
Tomato	459.9	338.4	-26.42
Potato	437.5	241.9	-44.71
Olive	116.2	114.6	-1.32
Cotton	226.5	165.3	-25.36
Kiwi	772	723.2	-6.31

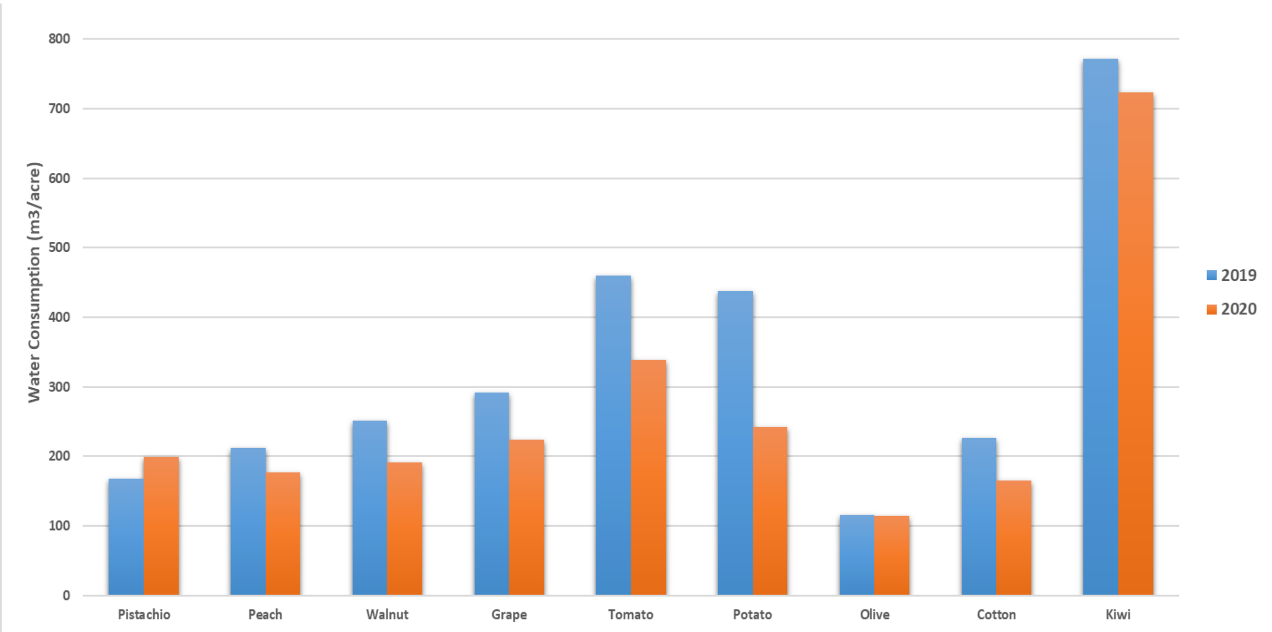

Figure 10. Water consumption averaged per crop type for 2019 and 2020

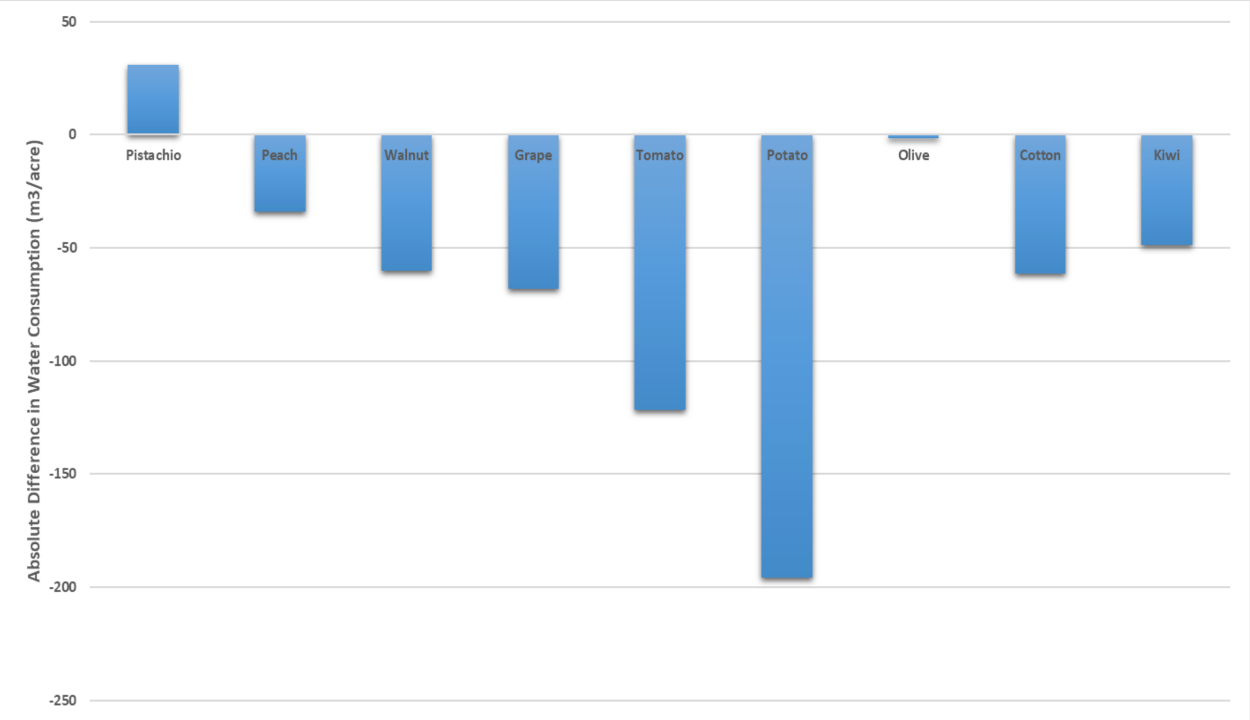

Figure 11. Absolute difference in water consumption between 2019-2020 averaged per crop type

Table 8. Water consumption averaged per pilot area for the baseline (2019) and first SF cultivation year (2020) with percentage relative differences

	Water consumption (m3/acre)		
Pilot Area	**2019**	**2020**	**% Relative Change**
Aigina (Pistachio)	168	199	+18.45
Velventos (Peach)	211.75	177.68	-16.09
Elassona (Walnut)	251.67	191.67	-23.84
Spain (Grape)	291.5	223.48	-23.33
Kiato (Tomato)	336.53	323.75	-3.8
Lasithi (Potato)	437.5	241.88	-44.71
Mirabello (Olive)	93.8	91.5	-2.45
Orestiada (Cotton)	120	90	-25
Pieria (Kiwi)	771.98	723.24	-6.31
Portugal (Olive)	94	75	-20.21
Stylida (Olive)	160.67	177.37	+10.39
THESGI (Cotton)	333	240.65	-27.73
THESTO (Tomato)	583.33	353.05	-39.48

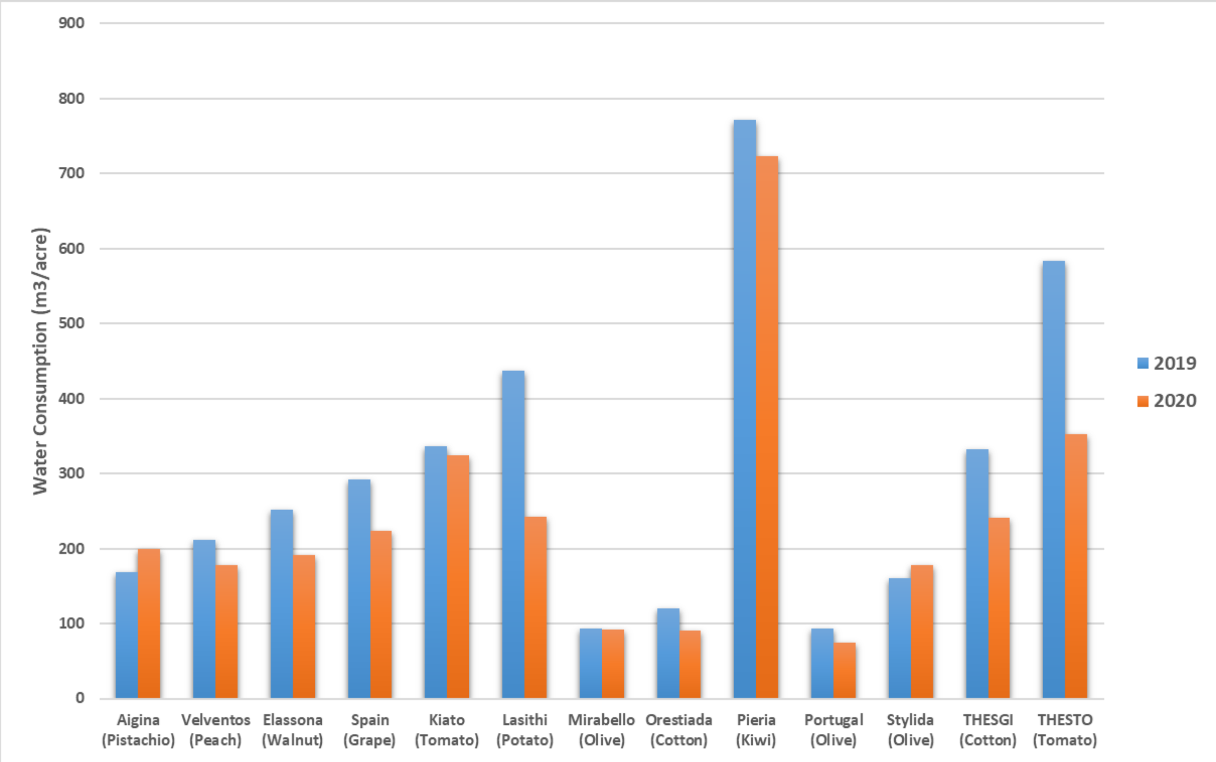

Figure 12. Water consumption averaged per pilot area for 2019 and 2020

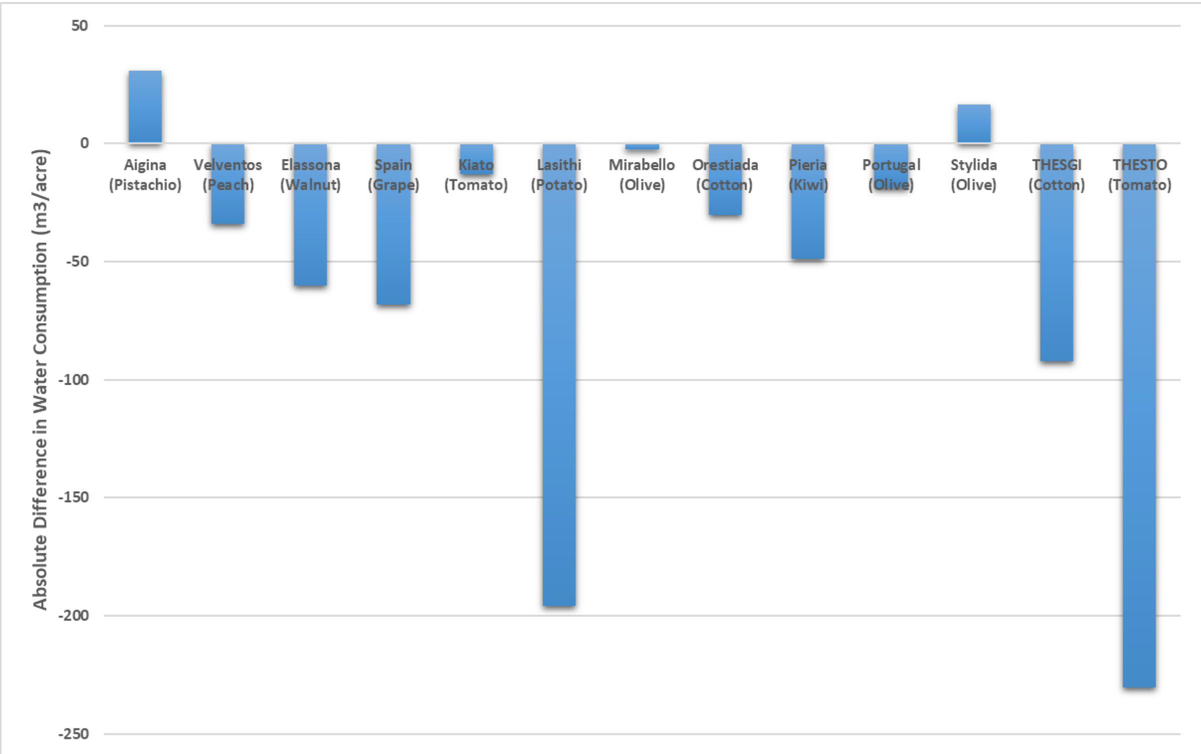

Figure 13. Absolute difference in water consumption between 2019-2020 averaged per pilot area

In general, there were considerable decreases in the amount of water consumed for all crop types, except pistachio, which showed some increase. Increases in water consumption are possible to occur and can be attributed to various of reasons. One of them is the different needs in irrigation that emerge in each cultivation year, while another one is the quality of cooperation between the farmers and the consultants/agronomists. Also, the following observations are being made:

- Relatively (%), between 2019-2020, the most significant decrease was noticed for potato crop.
- In absolute numbers, potato and tomato crops had the largest decreases (in descending order).

As for each pilot area, the presented tables and figures indicate that there were mostly decreases in the amount of water consumption, while there were also increases in the pilot areas of Aigina and Stylida. In more detail:

- Relatively (%), between 2019-2020, the largest decreases where noticed in Lasithi (potato), THESTO (tomato) and THESGI (cotton)pilot areas(in descending order), while the largest increase in Aigina (pistachio).
- In absolute numbers, THESTO (tomato), Lasithi (potato) and THESGI (cotton)managed the largest decreases (in descending order).

3.5. Fuel consumption

For calculating the particular indicator of fuel consumption, 42 questionnaires were used, in which quantitative fuel data (in lt/acre/year) were to be reported for the two years studied. The results are shown as absolute values of the amount of fuel consumed for the years 2019 and 2020, averaged for each crop type (Table 9, Figure 14) and for each pilot area (Table 10, Figure 16). In the last column of the table, relative and percentage differences are calculated for comparison. The actual increases and reductions are also graphically displayed in Figures15 & 17. It is important to note that fuel consumption was the quantity most frequently missing from the questionnaire replies, leading to difficulties in the analysis, as only a limited number of pilot areas were represented.

Table 9. Fuel consumption averaged per crop type for the baseline (2019) and first SF cultivation year (2020) with percentage relative differences

	Fuel consumption (lt/acre)		
Crop Type	**2019**	**2020**	**% Relative Change**
Pistachio	20.4	5.1	-75
Peach	-	-	-
Walnut	26.3	26.3	0
Grape	39.5	36.3	-8.17
Tomato	-	-	-
Potato	-	-	-
Olive	87.3	79.3	-9.23

Cotton	69.8	72.7	+4.24
Kiwi	-	-	-

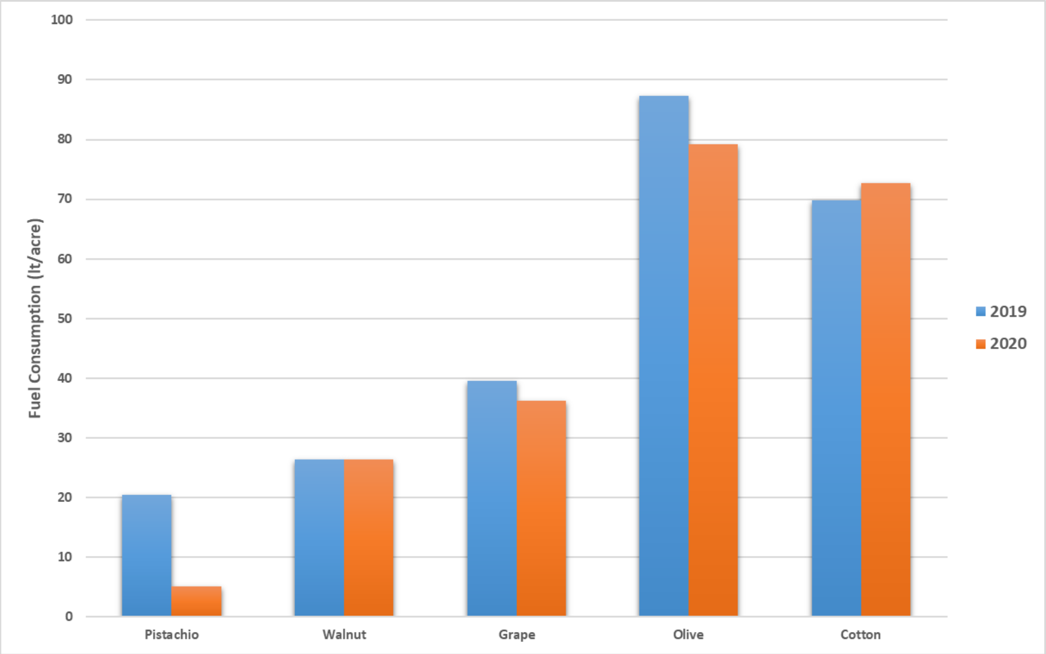

Figure 14. Fuel consumption averaged per crop type for 2019 and 2020

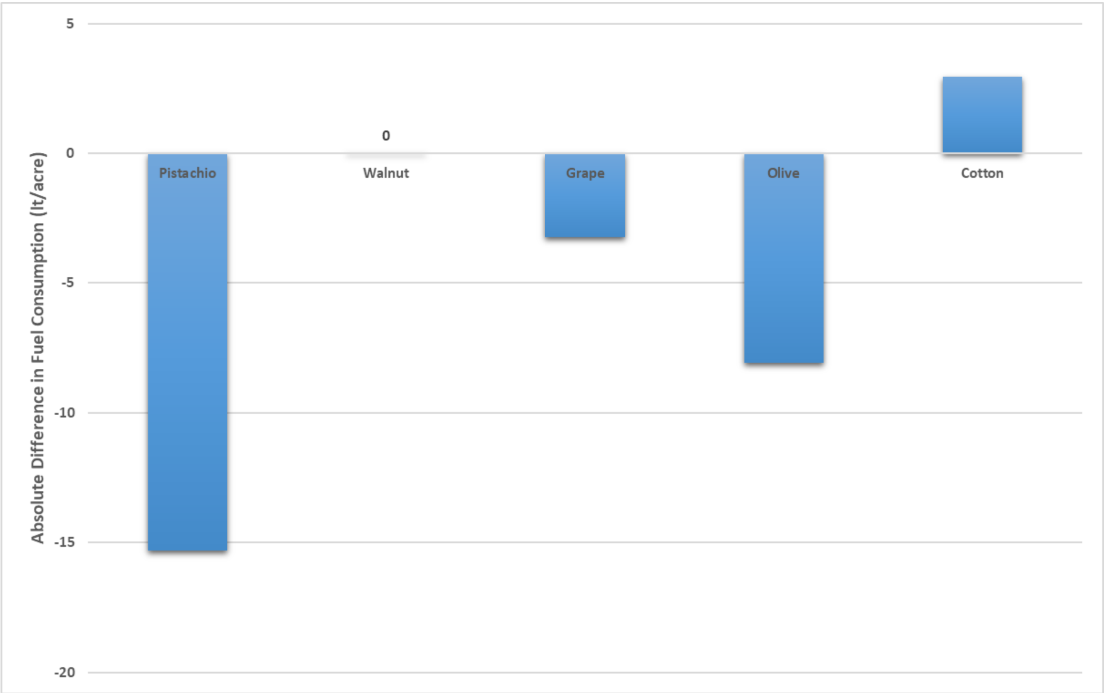

Figure 15. Absolute difference in fuel consumption between 2019-2020 averaged per crop type

Table 10. Fuel consumption averaged per pilot area for the baseline (2019) and first SF cultivation year (2020) with percentage relative differences

	Fuel consumption (lt/acre)		
Pilot Area	**2019**	**2020**	**% Relative Change**
Aigina (Pistachio)	20.41	5.1	-75
Velventos (Peach)	-	-	-
Elassona (Walnut)	26.33	26.33	0
Spain (Grape)	39.49	36.26	-8.17
Kiato (Tomato)	1097.88	-	-
Lasithi (Potato)	-	-	-
Mirabello (Olive)	13.61	10.92	-19.8
Orestiada (Cotton)	-	15.36	-
Pieria (Kiwi)	-	-	-
Portugal (Olive)	192.2	174.47	-9.23
Stylida (Olive)	56.18	52.43	-6.67
THESGI (Cotton)	69.77	72.73	+4.24
THESTO (Tomato)	-	-	-

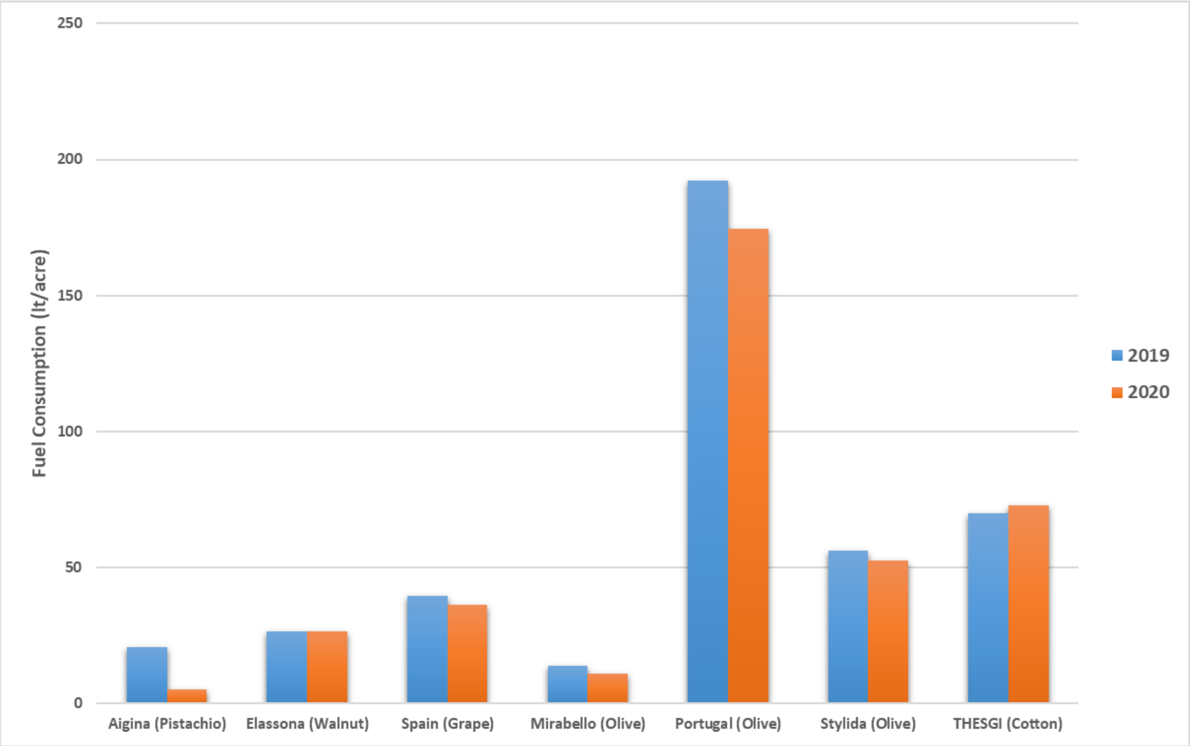

Figure 16. Fuel consumption averaged per pilot area for 2019 and 2020

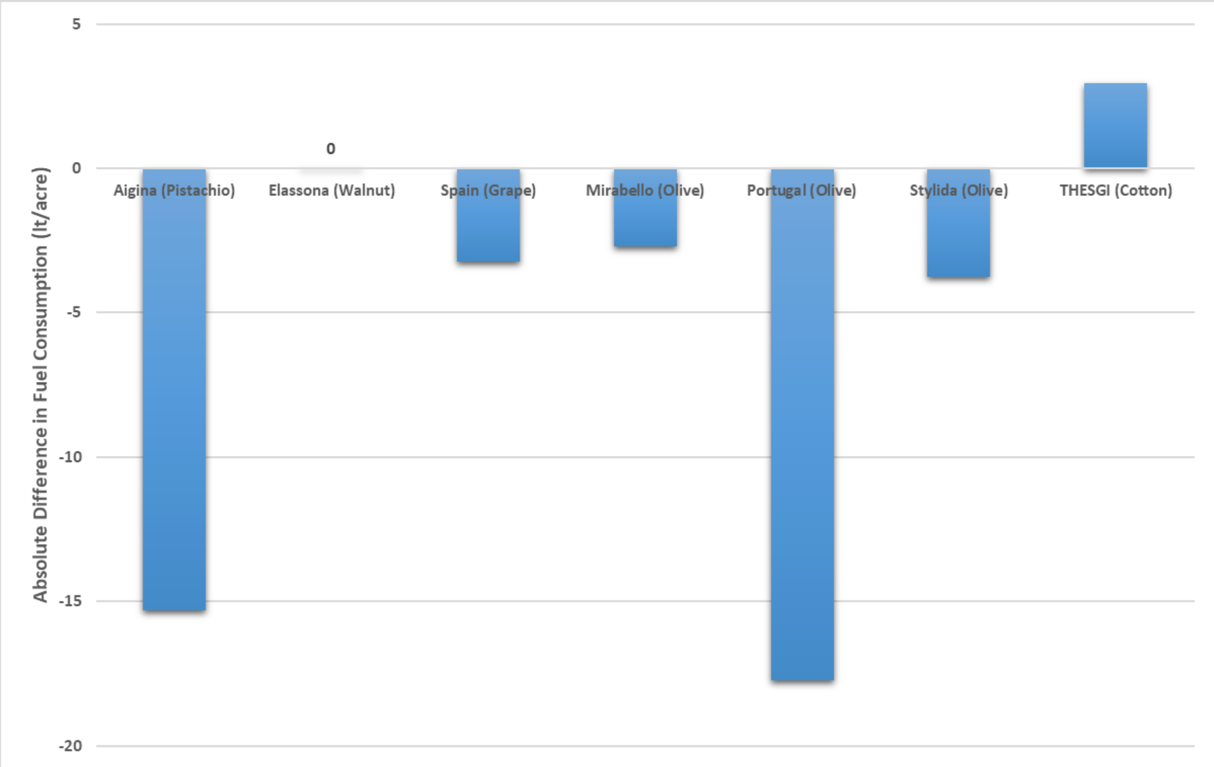

Figure 17. Absolute difference in fuel consumption between 2019-2020 averaged per crop type

In general, there were considerable decreases in the amount of fuel consumed for all crop types. The following observations are being made:

- Relatively (%), between 2019-2020, the most significant decrease in fuel consumption was noticed for pistachio crop and in a significantly larger level in comparison to the other crops.
- In absolute numbers, pistachio and olive crops had the largest decreases (in descending order).

Among the pilot areas, the presented tables and figures indicate that there were mostly decreases in the amount of fuel consumed. In more detail:

- Relatively (%), between 2019-2020, the largest decrease was noticed in Aigina (pistachio)pilot area, in a significantly larger level in comparison to the other pilot areas.
- In absolute numbers, Portugal (Confagri) and Aigina managed the largest decreases (in descending order).

3.6. Waste quantity & management

Difficulties were faced collecting waste data, especially regarding management and quantities of shells, agrochemicals and other kind of waste. As for pruning and plastic residues, more data were available, but still of a small amount. The majority of the farmers could not import the respective data, for it was difficult to quantify, as admitted by some. As a result, the presented information for pruning and plastic residues (for shells, agrochemicals and other kind of waste no analysis could be made) emerge from a small number of farms from each pilot area.

The most common waste management methods for pruning among the farms were incineration and disposal. Burial and composting were also recorded in a few cases. In general, no particular changes in the management method were recorded between the two cultivation years, except Stylida 4, where burial was chosen in 2020, instead of the composting that was carried out in 2019.As for the quantities of pruning, they are presented in Figure 18:

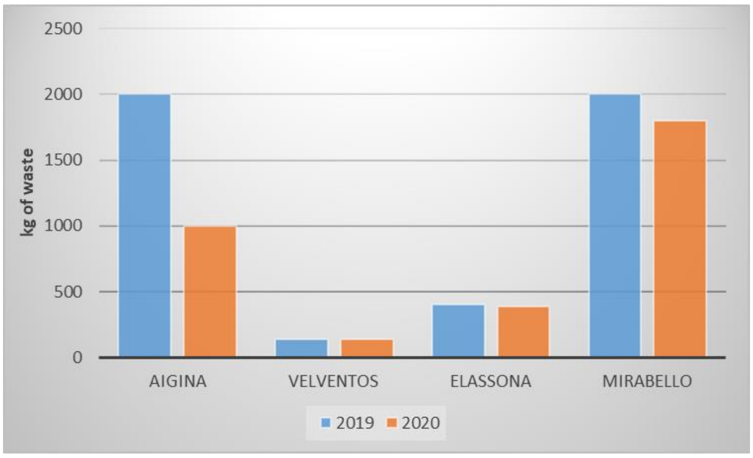

Figure 18. Pruning quantities averaged per pilot area (2019&2020)

As for the five pilot areas for which the respective information could be analysed and presented, the results indicate that there were mostly decreases in the amount of waste. Stylida pilot area is not presented due to the large amount of pruning residues, for it would cover the viewing of the other results in the figure. Let it be noted, that for Stylida, only Stylida 4 provided waste data, for which pruning quantities in 2019 were 60tonnes and decreased in 50tonnes in 2020.

Moreover, the most common waste management method for plastic residues was recycling/reuse, but also disposal was recorded in a few cases. No changes in the management method of plastic were recorded between the two cultivation years. As for the quantities of plastic residues, they are presented in Figure 19:

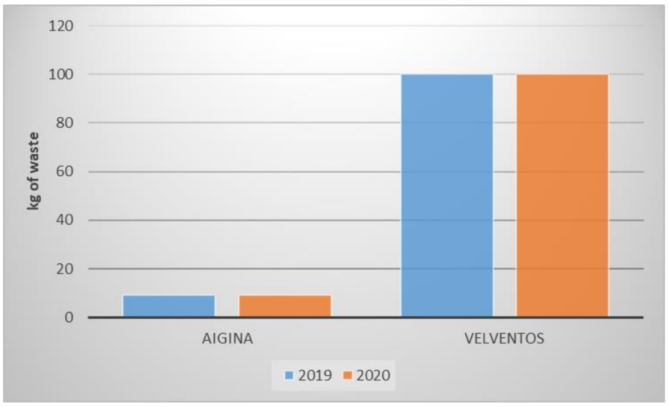

Figure 19. Plastic residues quantities averaged per pilot area (2019 & 2020)

As shown, only for Aigina and Velventos pilot areas analysis could be made, as there was serious lack of data for the rest of the pilot areas. These few results indicate that there were not any changes in the amount of plastic in the respective pilot areas.

3.7. Frequency of agricultural activities

The frequency of specific agricultural activities in a cultivation year was also recorded in the questionnaires. The results presented in Figure 20are averaged from all pilot areas, except Kiato and Pieria, for which the respective data were not imported. Let it be noted, that in the crop of each pilot area, not all activities were performed, as there was no such need. In the figure below, an increase in harvesting, cleaning and drying is noticed, while a slight decrease in the frequency of cultivation performed is also observed.

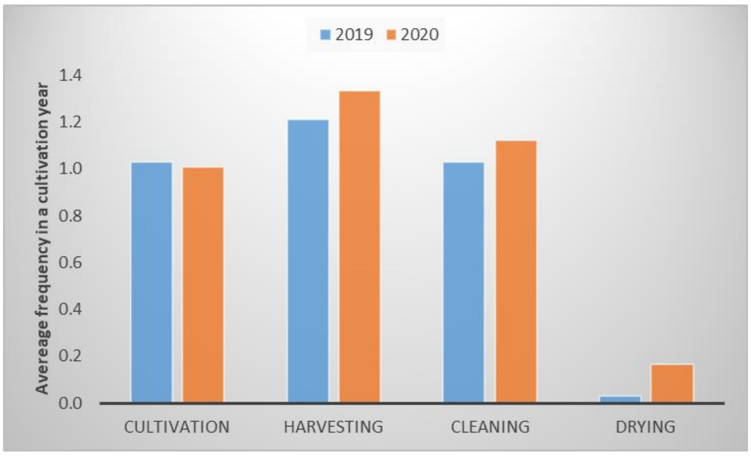

Figure 20. Average (from all pilot areas) frequency of agricultural activities in each cultivation year

4. Social indicators

By analysing the questionnaire replies, the following social indicators are calculated:

4.1. Legal nature of the holder

Regarding the legal nature of each farm, as presented in the following pie chart, 90.4% were of single farmers, while only 9.6%of cooperative.

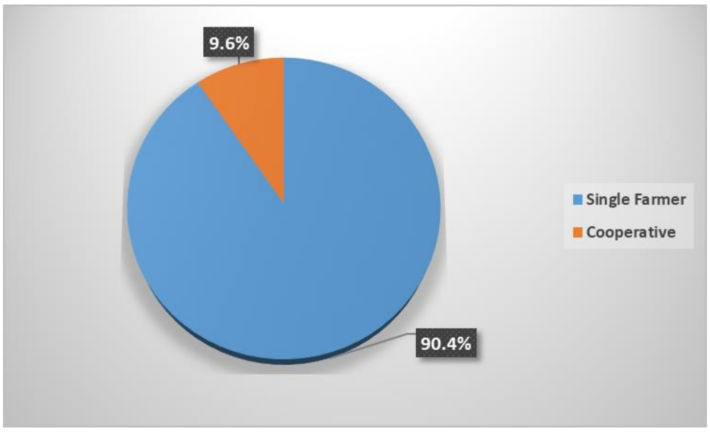

Figure 21. Legal nature of the holder

4.2. Age

The age status of the farm managers was imported in the questionnaires and is presented in Figure 22.16% of them belong to the age group of 25-35, 29% to the group of 35-45, 16% to the 45-55, while the rest of them (39%) exceed the55 years of age.

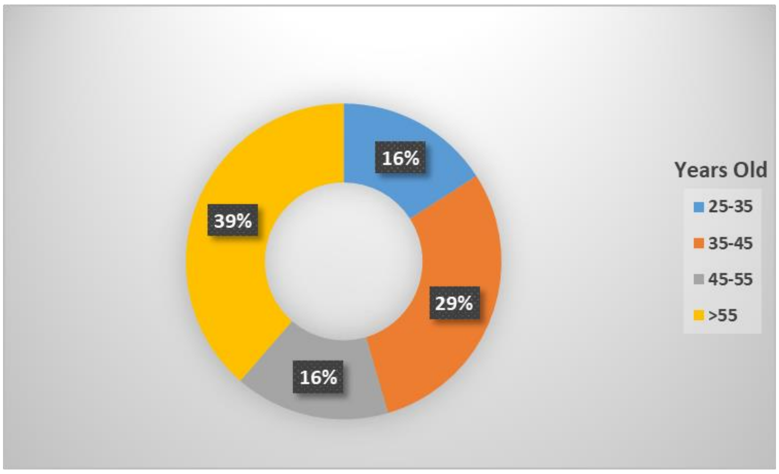

Figure 22. Age status of farm managers

4.3. Education

As for the educational status of the farm managers, among the 42 questionnaire replies, as shown in the donut chart below, 40% of them graduated from high school(17 in numbers) without pursuing higher education, 50% got a B.Sc. degree (21 farmers), while 10% of them (4 in number) obtained a M.Sc. degree.

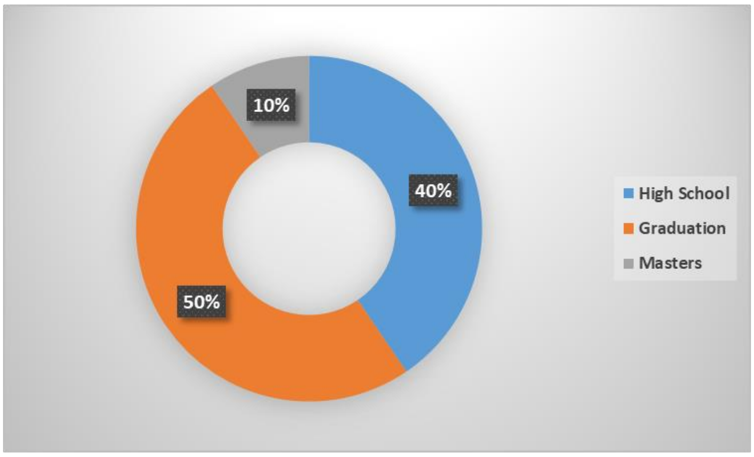

Figure 23. Educational status of farm managers

4.4. Experience in agriculture

Figure 24 shows the years of experience in agriculture of all 42 farm managers, as recorded in the questionnaires. None of them has experience less than 5 years, 19% of them from 5 to 9 years (8 farmers), 33% from 10 to 14 (14 farmers), 12% from 15 to 19 (5 farmers), 24% from 20 to 24 years (10 farmers), while the rest of them (14%) from 25 years of experience and more (5 farmers).

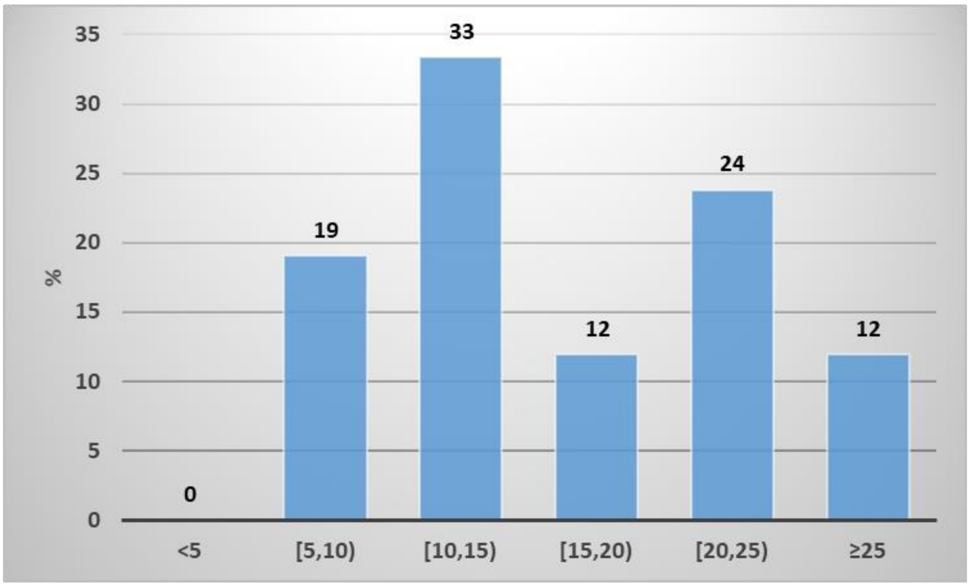

Figure 24. Farm managers' years of experience in agriculture

4.5. Occupation scheme

As for the farm managers' occupation scheme, Figure 25 presents the averaged percentages from the farms of all pilot areas and the following two observations are made:

a) 74% of them are considered to be as full-time farmers(31 farmers), 21% as part-time(9 farmers), while only 5% are retired (2 farmers).
b) The majority of the farms (83%) is family business, while only 17%arenon-family.

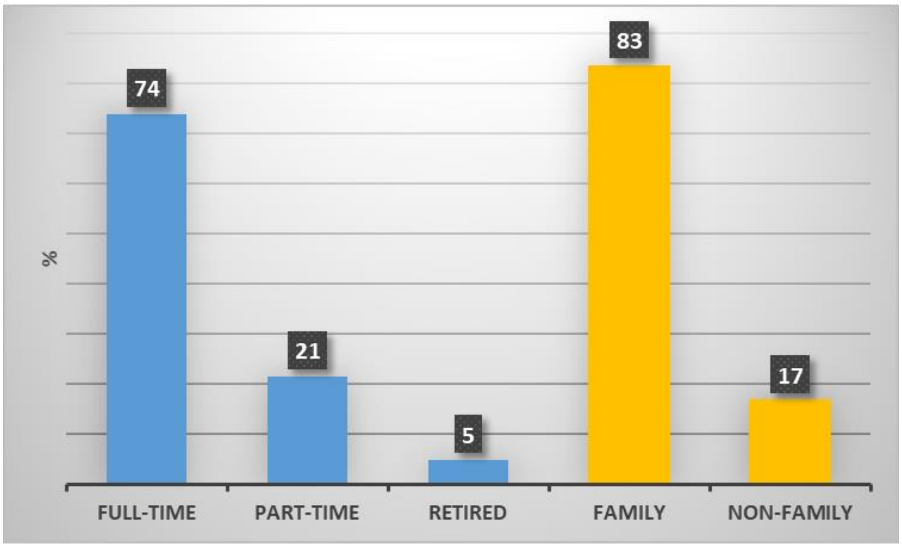

Figure 25. Farm managers' occupation scheme

4.6. Technology index

Another social index that has been under study is the technology index, which expresses the use of technology as an aid to everyday agricultural practices. The way that it has been calculated is presented in the deliverable ''C1.1_Questionnaire for farmers participating in pilot applications". The technology index for both 2019 and 2020 years is shown in Figure 26, averaged for each pilot area.

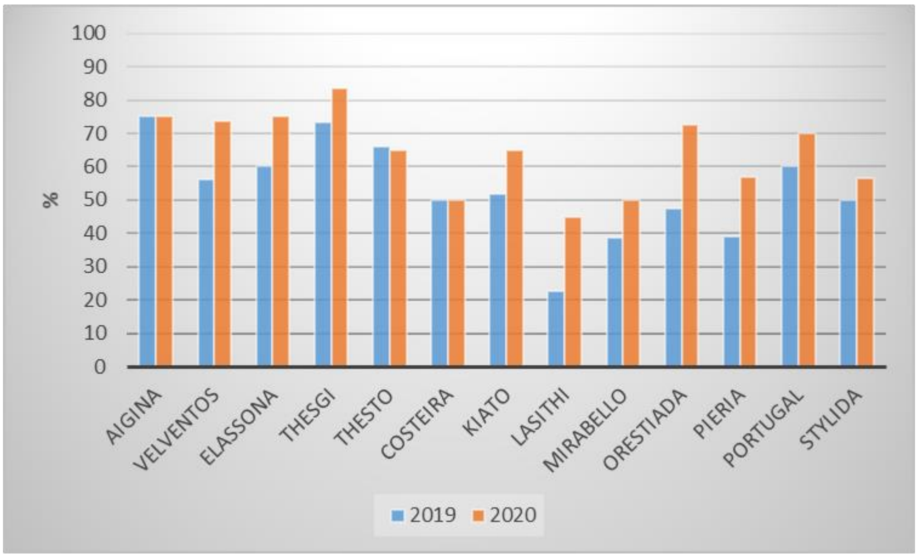

Figure 26. Technology index comparison between the years 2019-2020 for each pilot area

The results show an increase in the index between the two cultivational years almost in every pilot area. This fact can be attributed to the introduction of the technological background of the smart farming system of gaiasense to the farmers' agricultural practices.

Moreover, the correlation of the technology index with other factors, such as the age of the farm managers, as well as their educational status, was set under examination and as observed, the technology use seems to show some correlation with both (not in all pilot areas). As seen in Figure

27, in some pilot areas, in which the mean age of the farmers is high, the technology index is of a low value (e.g., Lasithi, Mirabello and Pieria pilot areas), while the opposite happens with younger farmers (e.g., THESTO, Elassona pilot areas). Finally, Figure 28 shows that in many cases (e.g., Velventos, Elassona, THESGI, THESTO), the higher the educational level of the farmer, the higher the technology index is, while the opposite can also be observed in some pilot areas (e.g., Lasithi, Stylida).

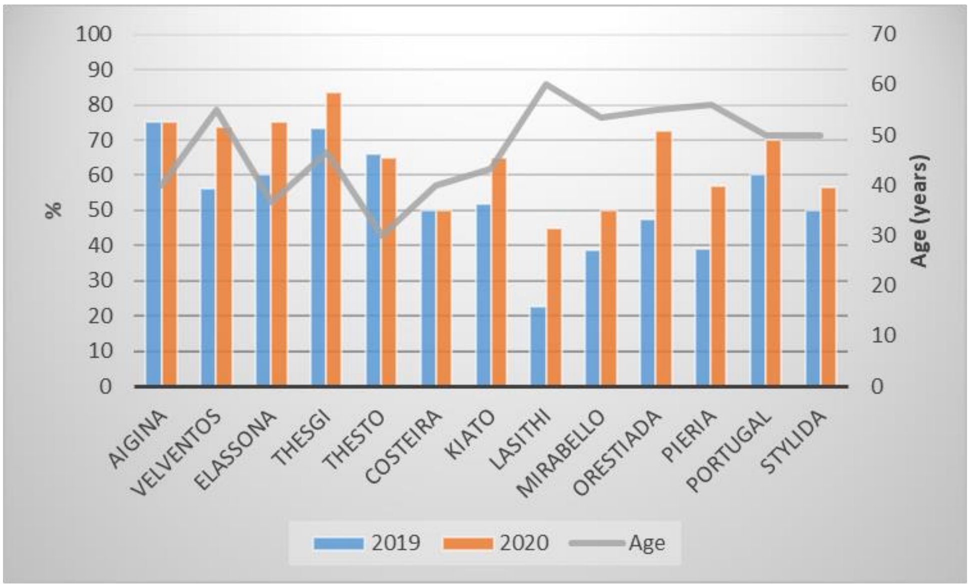

Figure 27. Correlation of technology index and the age of the farm managers

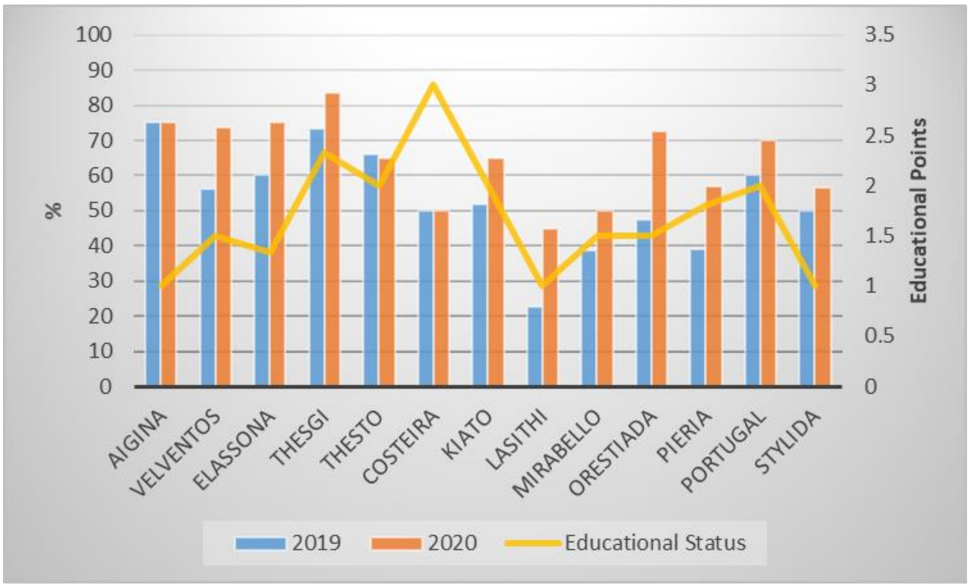

Figure 28. Correlation of technology index and the farm managers' educational status[1]

[1] High school = 1 point, Graduation = 2 points & Masters = 3 points

4.7. Farm labor force

Information about the labor force of the farms were also imported in the questionnaires. The average number (from all pilot areas) of permanently and temporarily employed non-family and family workers during 2019 and 2020, as well as the number of those with technology knowledge, is presented in Figure 29. It is noticed, that in the 1st smart farming year compared to the baseline one:

1. Permanent staff: there was a small increase in the numbers of men and a decrease of women.
2. Temporary staff: there was a small decrease in the numbers of men, while an increase of women.
3. Family staff: there was hardly any change in the numbers of working men(-0.01) and women (+0.01).
4. Technology knowledge: both non-family men and women employees with background knowledge and education on technology happened to increase in numbers. This is to be attributed either in hiring new employees with technology knowledge, or/and enhancing the technological skills of the already existing staff in the context of the smart farming practices.

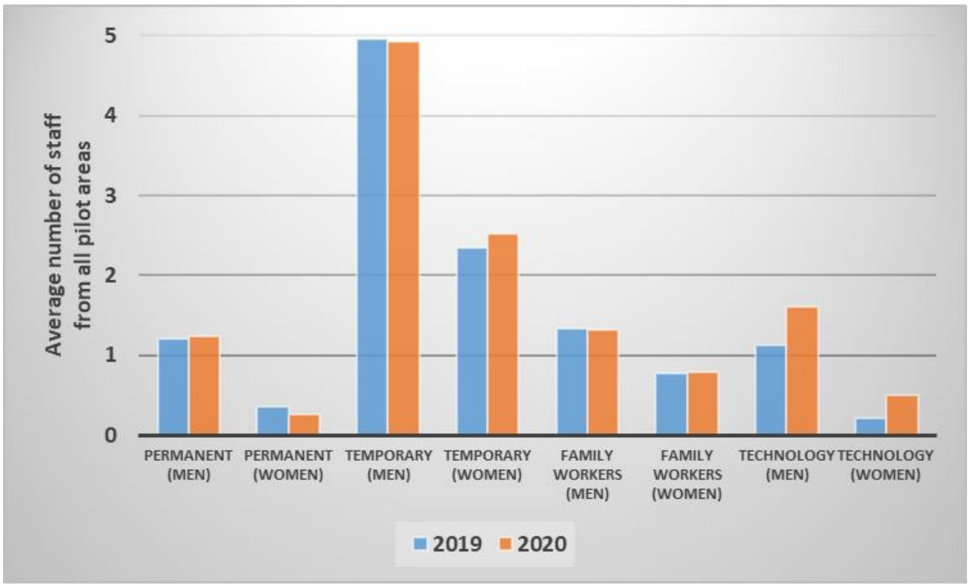

Figure 29. Average number of farm labor force

5. Economical indicators

By analysing the questionnaire replies (42 in total), the following economical indicators are calculated:

5.1. Size of smart farming application area

Firstly, in Figure 30&31 the size of SF application area averaged per pilot area and per crop is presented. The pilot areas with the largest SF application areas are: Confagri/Portugal (Olive crop), THESTO/Larisa (Tomato), Orestiada (Cotton)and THESGI/Larisa (Cotton), in descending order. Making the same comparison per crop type, olive, cotton and tomato are the crops with the largest SF application areas in the context of the LIFE project, in descending order.

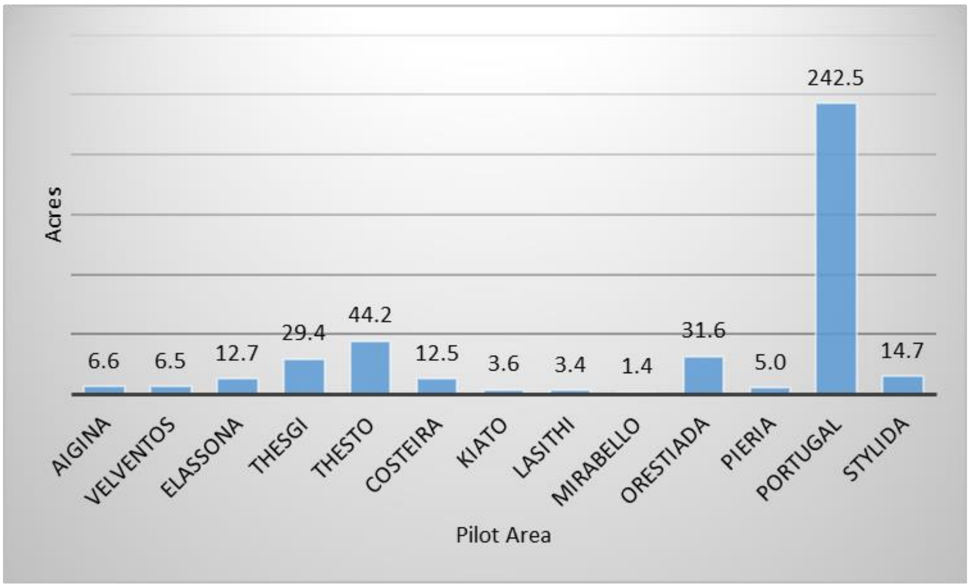

Figure 30. Size of SF application area averaged per pilot area

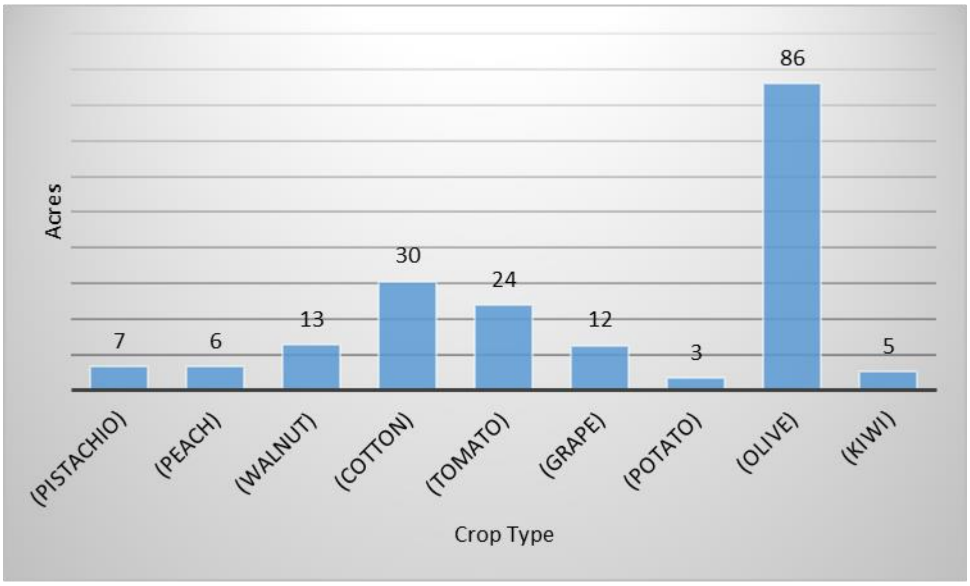

Figure 31. Size of SF application area averaged per crop type

5.2. Annual gross income &production yield

The annual gross income and production yield are economical information which were recorded in the questionnaires and their correlation is of great importance for observations to be made. Data regarding the annual expenses of the agricultural holdings are of respective importance, but unfortunately, only few of the farmers recorded them, so no analysis of them could be made.In Figure 32, the annual gross income is presented in correlation to the annual production yield of the cultivated land in SF application area per pilot area. Income data are not presented for Vina Costeira (Spain) and Confagri (Portugal),for they are sensitive data which refer to cooperatives and not just individual producers.

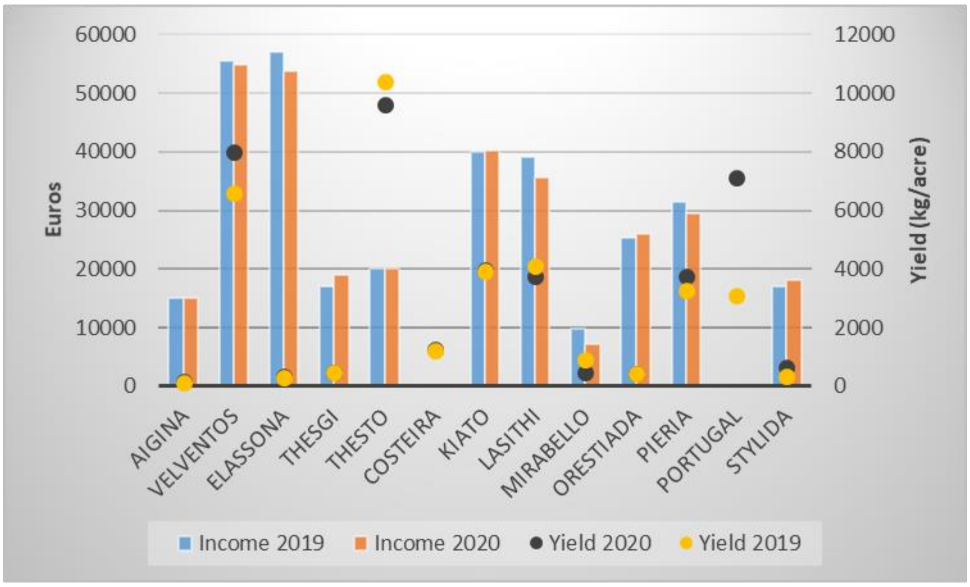

Figure 32. Annual gross income in correlation to cultivation yield per pilot area (2019-2020)

In some cases, the yearly changes in production yield does not necessarily follow the same trend in the gross income, a fact that can be attributed to various socio-economic factors, such as the temporal changes in the price of the product etc. For example, in Aigina pilot area, although there was an increase in the annual yield by almost 15%, there was no respective increase in income. Another example is the case of Velventos, in which there was an increase in yield by 21%, but a decrease in income by 1.4%. Let it be noted, for Stylida and Mirabello, olive crop yield is recorded as olive oil produced and that is why the values of yield seem to be very low.

5.3. Farm machinery

Among the farms of all pilot areas, the vast majority of the farm machinery (tractors, soil working, sowing, planting, fertilising, irrigation & harvesting machinery, technology equipment) was not rented, but private property, both in 2019 and 2020. No particular changes were made between the two cultivation years regarding the number of each machine used, as well as changing their property form (rented to private andthe opposite).

6. KPIs calculation results

By calculating the air emissions from fertilisers application and fuel consumption, averaged for each pilot area, the following KPIS are presented:

Table 11. Emissions & GHGs KPIs averaged from the crop fields of each pilot area

KPIs	PILOT AREAS	AIGINA	VELVENTOS	ELASSONA	SPAIN	KIATO	LASITHI
	Targeted Reduction (%)	Real Change (%)	Real Change (%)	Real Change (%)	Real Change (%)	Real Change (%)	Real Change (%)
PM10	**-10**	-75	-	0	-7.46	-	-
NOx	**-15**	-75	-	0	-7.46	-	-
NMVOC	**-15**	-75	-	0	-7.46	-	-
NH3	**-30**	-50.71	+4.48	-15.8	-42.67	-59.42	-
N2O	**-32**	+17.86	+5.84	-14.18	-15.81	-66.95	-
CO2	**-32**	-75	-	0	-7.46	-	-
CH4	**-32**	-75	-	0	-7.46	-	-

	MIRABELLO	ORESTIADA	PIERIA	PORTUGAL	STYLIDA	THESGI	THESTO
	Real Change (%)	Real Change (%)	Real Change (%)	Real Change (%)	Real Change (%)	Real Change (%)	Real Change (%)
PM10	+15	-	-	-7.08	-6.67	+4.24	-
NOx	+15	-	-	-7.08	-6.67	+4.24	-
NMVOC	+15	-	-	-7.08	-6.67	+4.24	-
NH3	-7.84	+7.59	-45.98	-10.43	+34.74	+30.93	-4.42
N2O	-11.98	-21.64	-30.27	-11.73	+19.05	+29.67	-11.31
CO2	+15	-	-	-7.08	-6.67	+4.24	-
CH4	+15	-	-	-7.08	-6.67	+4.24	-

As observed, for each air pollutant and greenhouse gas and their targeted reductions, the following conclusions are being made:

PM10: As seen in Table 11, the targeted reduction was -10%. 1 pilot area managed to reach and overcome it to a great extent, while another 3pilot areas also accomplished significant (close to the target) reductions. On the contrary, in 2 pilot areas an increase in PM10 emissions occurred due to increases in fuel consumption, while in 1, no changes were calculated.

NOx&NMVOC: The targeted reductions were-15%.1 pilot area managed to reach and overcome the targets remarkably, while another 3 pilot areas also managed notable decreases. Furthermore, in 2 pilot areas increases in PM10 & NMVOC emissions took place due to respective changes in fuel consumption, while in 1, no changes were calculated.

NH3: The targeted reduction was -30%. 6 pilot areas achieved to overcome it significantly, while another 4 pilot areas also accomplished notable reductions, as result of decreased fertiliser use. On the other hand, in 4 pilot areas increases in NH3 emissions occurred, due to increased fertiliser application.

N2O: The targeted reduction was -32%. 1 pilot area achieved to reach and overcome the target, while another 7 pilot areas also accomplished reductions of a great magnitude. Additionally, in 4 pilot areas increases in N2O emissions took place, mostly due to increases in fertiliser application.

CO2 & CH4: The targeted reductions was -32%. 1 pilot area managed to overcome it remarkably, while another 3 pilot areas also accomplished some reductions. On the other hand, in 2 pilot areas small increases in CO2 & CH4 emissions occurred due to increases in fuel consumption, while in 1, no changes took place.

In Table 11, it can be observed that for some pilot areas, KPI emission values related to fuel consumption (i.e., PM10, NOx, NMVOC, CO2, CH4) could not be calculated, as a result of missing fuel consumption data.

As for the KPIs averaged from all pilot areas into a single score for each air emission, the targeted reductions were accomplished only for PM10emissions. NOx, NMVOC and NH3 emissions did not manage to reach the targets, but they also showed significant reductions. Finally, N2O, CO2 and CH4 emissions also showed some decreases, but not close enough to the targeted ones, as seen in Table 12.

Table 12. Emissions & GHGs KPIs averaged from all pilot areas

KPIs	ALL PILOT AREAS	
	Targeted Reduction (%)	**Real Change (%)**
PM10	**-10**	-11
NOx	**-15**	-11
NMVOC	**-15**	-11
NH3	**-30**	-13.29
N2O	**-32**	-9.29
CO2	**-32**	-11
CH4	**-32**	-11

As mentioned in 3.6, difficulties were faced collecting waste data (management and quantities). As a result, no relative KPI could be calculated and presented, in order to make conclusions.

7. Conclusions

The present report presents in detail the results of the statistical analysis of the data provided by farmers in their responses to the targeted questionnaires prepared by AUTH and distributed by GAIA and Neuropublic, within the frame of Action C.1. of the LIFE GAIA Sense project. The results are used to calculate environmental, social and economical indicators and the indicator values are compared with target values set in the initial stages of the project. The analysis is a first step in evaluating the efficiency of the proposed GAIA Sense SF solution in terms of environmental and socioeconomic benefits for farmers, compared to conventional farming practices. At a later stage in the project the results will be also used as part of an integrated assessment of the SF system, using LCA methodology. The statistical analysis provided scientific evidence of the suitability of the SF approach in agricultural management in regard to sustainability targets, as well as specifically of the efficiency of the GAIA Sense SF system in reducing resource consumption and managing environmental impacts of agricultural practices in Greece, Spain and Portugal.

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