Interreg Greece-Italy IR2MA European Regional Development Fund

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WP3

Deliverable 3.1.4

DSS adaption and extension

(9)

DSS operation evaluation

Interreg V- A Greece-Italy Programme 2014 2020

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IR2MA
Large Scale Irrigation Management Tools for Sustainable Water Management in Rural Areas and Protection of Receiving Aquatic Ecosystems

Subsidy Contract No: I1/2.3/27

Project co-funded by European Union, European Regional Development Funds (E.R.D.F.) and by National Funds of Greece and Italy

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Partners

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Associated partners

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Notes

Deliverable 3.1.4 DSS adaption and extension

DSS operation evaluation

Involved partners:

PB1 University of Ioannina

Authoring team:

Tsirogiannis Ioannis

Place and time: Arta, 2020

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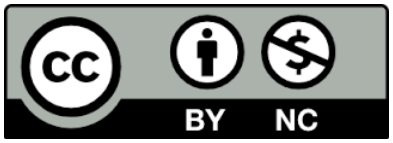

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Introduction

One of the main crop treatments is the management of soil moisture. The most typical questions that arise for the management of any kind of irrigation method and system are when it is best to irrigate? and how much water should be provided? for soil moisture to be maintained within the limits of readily available water. Failure to meet these goal leads to low water use efficiency as less or excessive water could be applied and of course, in case of over irrigation this is accompanied by energy waste.

The relevant decisions are still based mainly on the grower's experience or the generic recommendations of the agronomists. But how can we control effectively something that we do not measure? a question that is more significant when dealing with crops that have high water needs and when the irrigation frequency is high as well.

In the framework that:

- a climate change period is evolving which has direct impact on the availability of water resources and the need for irrigation of crops,
- in Greece 70-80% of the water resources is used for agriculture while the actual efficiency of irrigation systems is often lower than 50%,
- Greece has adopted the Directive 60/2000 EU, in the framework of which legislation is developed regarding the use, costing and billing of irrigation water,
- the efficient operation of Land Reclamation Organisations (OEB)[1] depends significantly on water and energy savings,
- the modern quality systems that certify the compliance of cropping systems with good agricultural practices demand the documentation of the proper use of water -among other natural resources -, while certifications regarding low water footprint provide adding value to the final product,

the efficient irrigation is a priority and a significant factor for the achievement of sustainable agricultural systems.

At the plain of Arta, a participatory system for irrigation recommendations has been developed in the framework of cross-boundary cooperation programme Greece-Italy 2007-2013 IRMA. The term participatory derives from the system's layered concept in the framework of which a team of end-users, agronomists, and irrigation experts contribute to a bi-directional flow of information in order to continuously improve the operation of the system.

The present study regards the evaluation of the DSS when used for the case of kiwifruit orchards at the plain of Arta. The first orchards of kiwifruit (Actinidia deliciosa) were planted at the plain of Arta (Region of Epirus / NW Greece) during the early 1980's. In our days, this crop covers about 1.200 ha, most of which regards the variety 'Hayward' (OPEKEPE, 2016). Kiwifruit crop has high irrigation water requirements when cultivated in Mediterranean regions, while it is easily susceptible to water stress (Dichio et al., 2013; Torres-Ruiz et al., 2016).

According to the Greek legislation (GMA, 1989), the limits for irrigation water usage for kiwifruit in the Region of Epirus range between 6320 and 7800 m^3 ha^{-1} for an irrigation period spanning for April to

[1] Organismi Egion Veltioseon / Οργανισμοί Εγγείων Βελτιώσεων (OEB) in Greek

September, without taking into account the efficiency of the irrigation system. The relevant values when irrigation efficiency for micro-sprinklers according to GMA (1989) is taken into account are 7036 and 8624 m^3 ha^{-1}. For a typical kiwifruit orchard in Arta, more than 50 irrigation applications are performed per year to provide more than 7000 m^3 of water per ha. Thus, improved irrigation management matters.

Materials and methods

The DSS

This precision agriculture decision support system (DSS) covers an area of 46.432,5 ha, inside of which 5 existing and one under formation OEB's are operating. This system is available continuously from 2015, proving the sustainability of IRMA project results, and is probably the only actually functionable large scale system of this kind that operates in Greece.

The system was improved in the framework of Interreg Greece-Italy 2014-2020, IR2MA project and is available at https://arta.interregir2ma.eu/ (the system hereafter, Fig. 1).

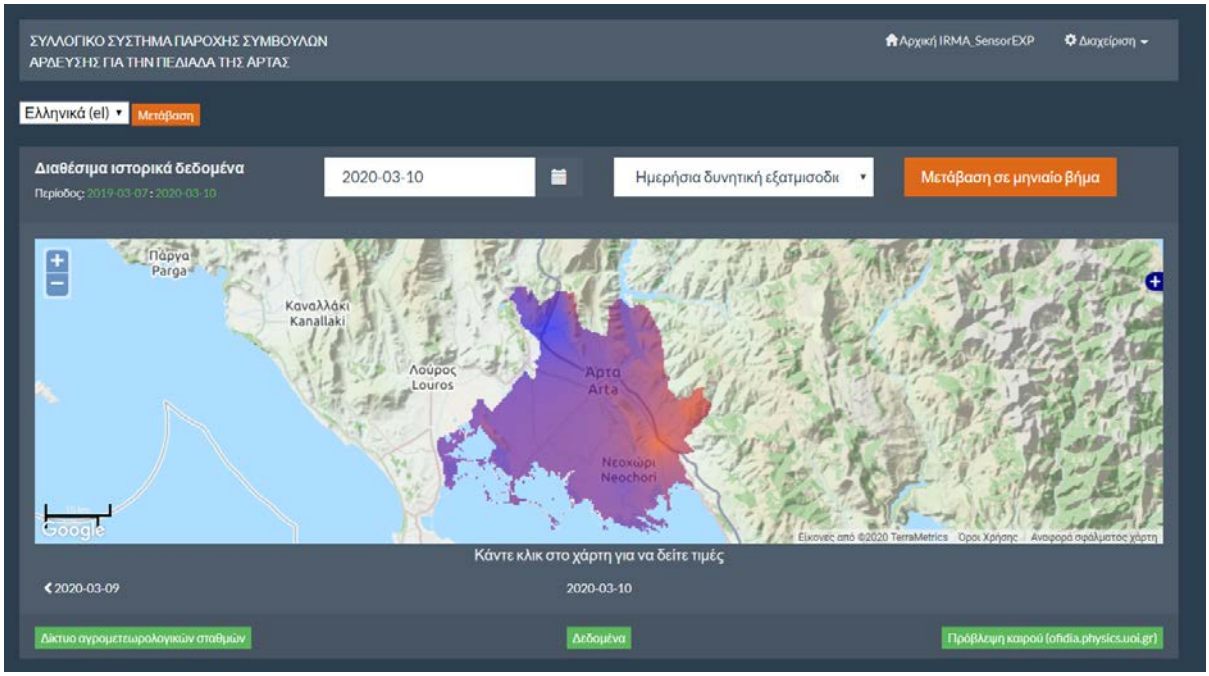


Fig. 1 Typical opening screen of the DSS

The basic characteristics of the DSS are:

- it uses free data from agrometeorological stations that are placed on selected sites around the plain of Arta (https://system.irrigation-management.eu/, (DAEWM, 2015))
- it incorporates weather forecast for three days beyond from free relevant services (https://agromonitoring.com/)
- it incorporates basic soil moisture levels like saturation, field capacity and wilting point
- using data of the agrometerological stations, basic weather parameters like rainfall, air temperature, reference evapotranspiration etc are calculated using spatial interpolation methods, on daily basis for any point within the plain., thus, numerus virtual agrometeorological stations can be installed in this area using the system
- it provides various options for registration of the irrigation events – the most basic of which do not use the installation of any relevant sensor at the field
- it uses FAO's irrigation water balance model (Allen et al., 1998) as a basis for the estimation of soil moisture on daily basis at the site of each virtual agrometeorological station / field, the model takes into account: (a) measurements of weather parameters from agrometeorological

stations in the area; (b) soil, crop and irrigation system parameters; (c) time and volume of the actual irrigation applications and (d) weather data forecasting (Malamos et al., 2016).

- based on the outcomes of the water balance model, it provides recommendations for future irrigation applications and estimation regarding the level of water stress of the crop,
- it is web based, so that anyone with any type of computer device (computer, tablet or smart phone) that runs a web browser (ie. MS Edge, Google Chrome or other) can use the system
- the recommendations are also sent via email to each user and her or his supervisor
- all the data and information regarding fields, virtual agrometeorological station, performed irrigation events etc are available to each user and her or his supervisor.

Pilot fields, period and instrumentation that were used for the evaluation

Evaluation period

The evaluation was carried out for three irrigation periods, 2018, 2019 and 2020 (from 1/4 up to 30/9), in commercial orchards of kiwifruit 'Hayward' (Clone 8) located at the plain of Arta. The results that are presented in this report regard the 2019 and 2020 irrigation periods. This is because the version of the system that was running from the beginning of 2019 irrigation period, incorporated all the improvements that were developed in the framework of IR2MA.

Field instrumentation

For monitoring soil moisture, six dielectric capacitance sensors (type 10HS, METER Group, Inc. USA, Fig. 2) were placed 0.5 m away from micro-sprinklers, at a depth of 15 cm. The generic equation provided by the manufacturer for calculating volumetric water content in mineral soils was used (accuracy ±0.03 m^3 m^{-3}). Data were stored to field dataloggers (type EM50, METER Group, Inc. USA, Fig. 3) Soil moisture was considered uniform through the whole soil depth under consideration. Water usage by the irrigation system was measured using three 25mm volumetric dry dial water meters (accuracy 1L, type DS-TRP, Madalena S.P.A., Italy, Fig. 4) placed on selected lateral pipes of the irrigation system. The analysis was made using MS-Excel. In some cases, IR2MA LB LORA flowmeters where also placed next to dial water meters for evaluation purposes (Fig. 4).

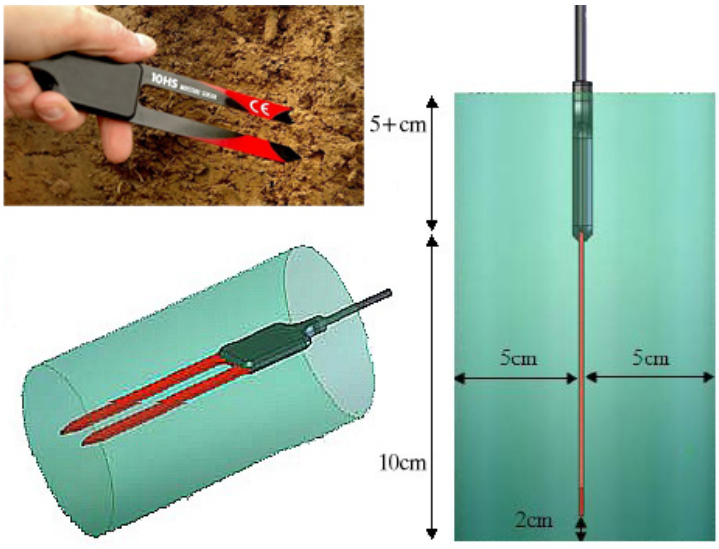


Fig. 2 METER 10HS and its volume of sensitivity (Cobos, 2008)

Fig. 3 METER EM50 datalogger installed at kiwifruit orchard

Fig. 4 IR2MA LB LORA and mechanical flowmeters

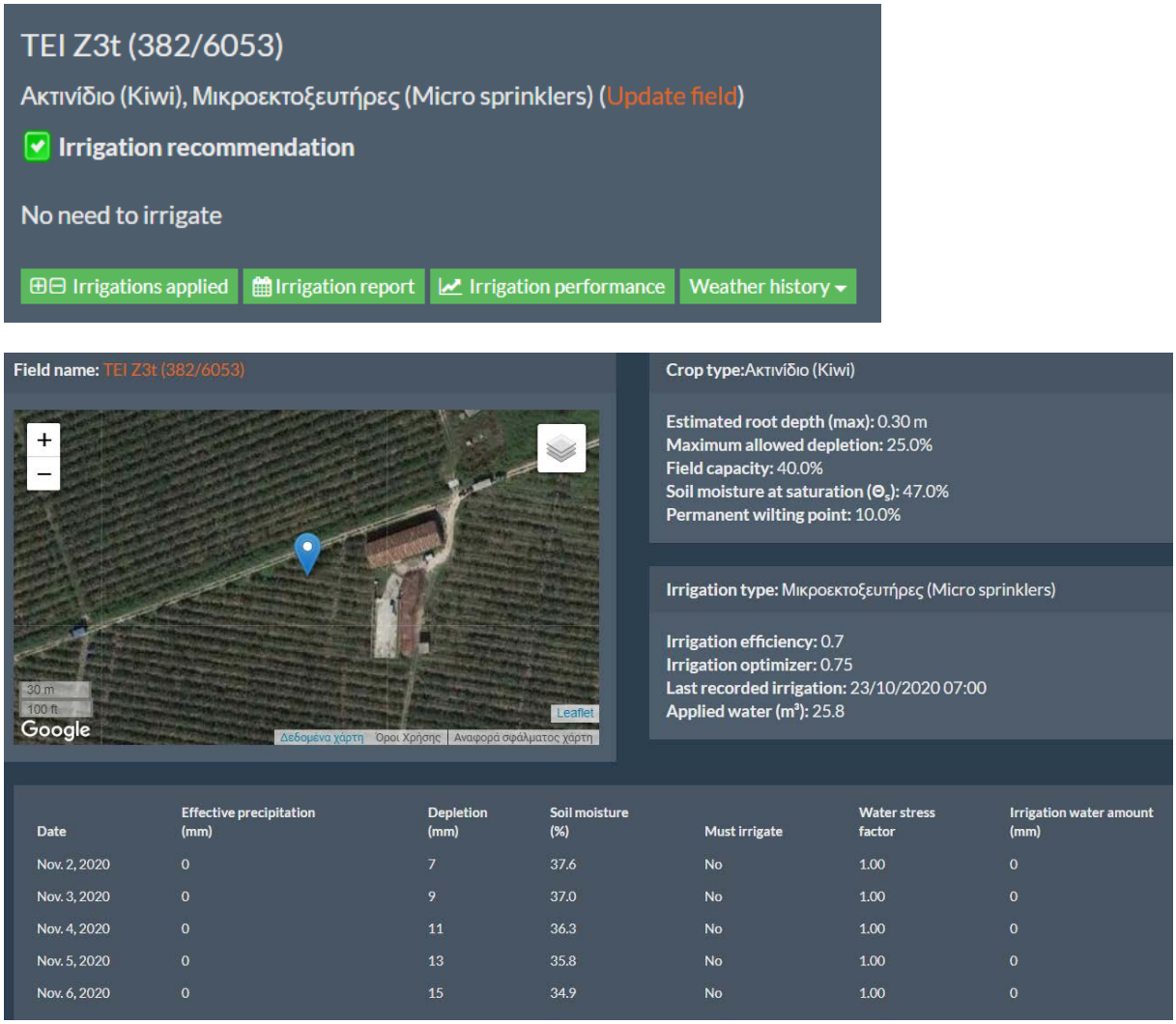
Irrigation recommendations

Irrigation is recommended by the system when soil moisture is estimated to have reached the lower level of the readily available soil water (FC-(FC-PWP)xAD where FC is the field capacity, PWP is the permanent wilting point and AD is the allowable depletion).

Irrigation optimizer (IRT) is a parameter of the system which is used to tune the volume of water that it is recommended to be applied, IRT=1 means that the goal of an irrigation recommendation is to refill soil moisture up to the field capacity, while IRT=0,5 means that the goal of an irrigation recommendation is to refill soil moisture up to half the way between the running value of soil moisture to the field capacity. The lower the value of IRT the more frequent with less amount of water, the irrigation recommendations will be. Lower IRT could be a better choice in cases that we have numerus rain events during the irrigation period or during part of it, because as soil moisture remains lower than the level of FC it has more space to store rain water.

Users are not obliged to follow the recommendations provided by the system, but they registered all the applied irrigation events.

Fig. 5 Add irrigation utility of the system



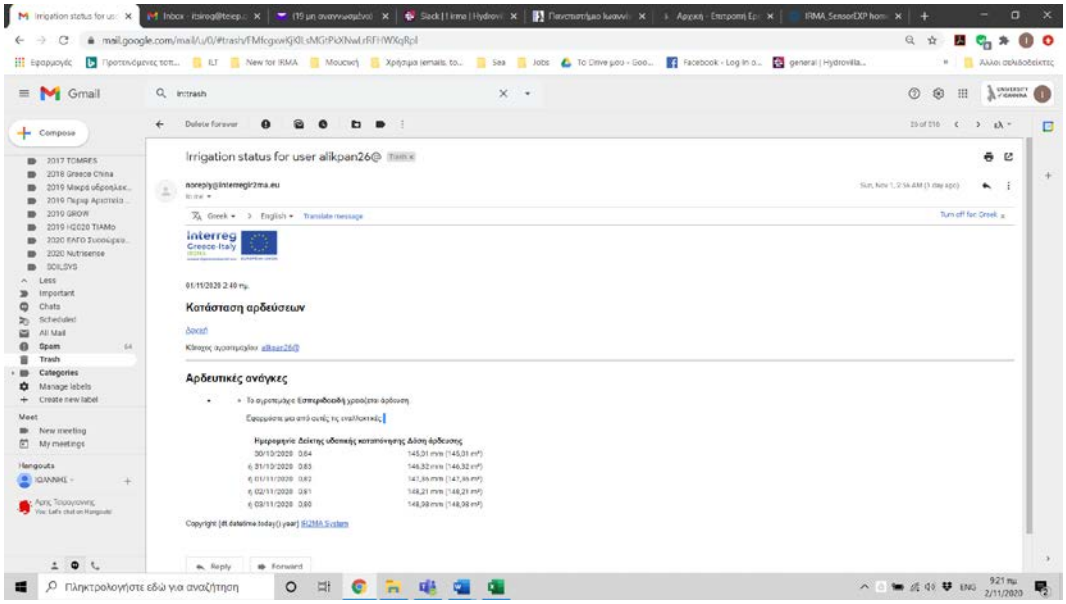


Fig. 6 Brief (up) and analytical (down) irrigation reports and email containing recommendations by the system

Fields and DSS parameterisation

During the 2019 irrigation period, three kiwifruit orchards and during 2020 (KL19 – Agria Paraskevi, TM19 – Kolomodia and EX19 - Neochori), one kiwifruit orchard (KC20 – Plisioi) were used for the evaluation of the system.

All these orchards use the variety 'Hayward' (Clone 8) of kiwifruit, which is the dominant one in the plain of Arta. Fig. 7 presents the length of growth stages and the relevant generic values of Kc values for kiwifruit according to Allen et al. (1998).

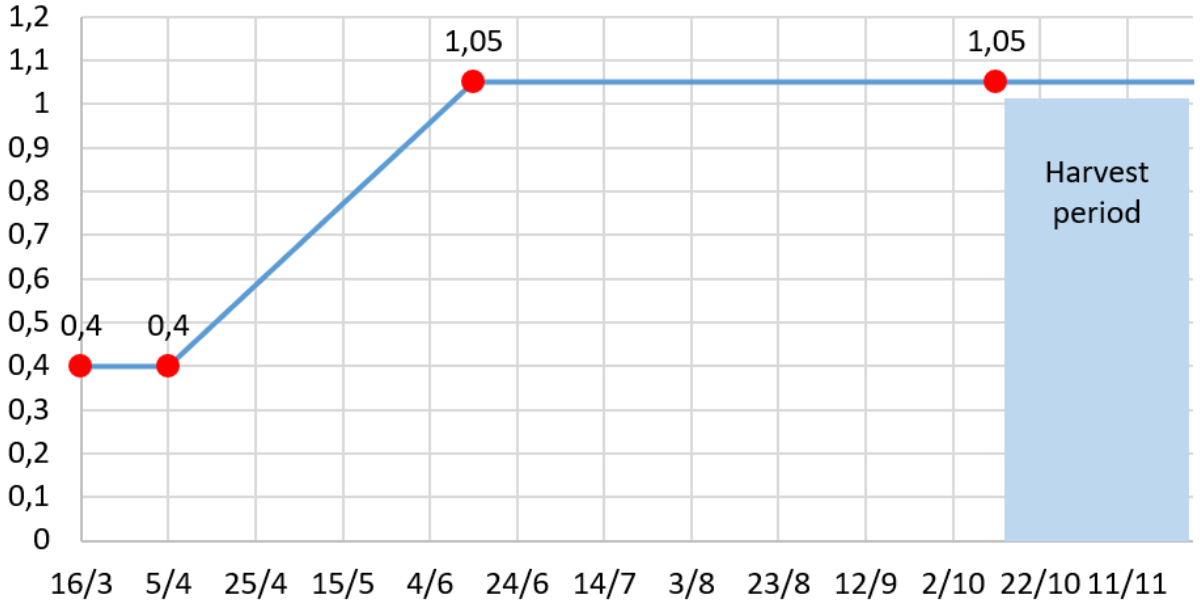


Fig. 7 Kc values for kiwifruit according to Allen et al. (1998)

The orchards, except of their pilot use for system evaluation, were also used as demonstration sites for the system.

Pilot kiwifruit orchard TM19 – Kolomodia

This field is at the area of Kolomodia village (Fig. 8, Fig. 9) at a height of 15 m above sea level. The soil is of silty clay type. The kiwifruit variety is 'Hayward' (Clone 8). The vines were planted in 2001, they were spaced 4.5 x 4.5 m (distance between vines on the row x distance between rows) and trained to a pergola type structure of 1.8 m height (Fig. 10).

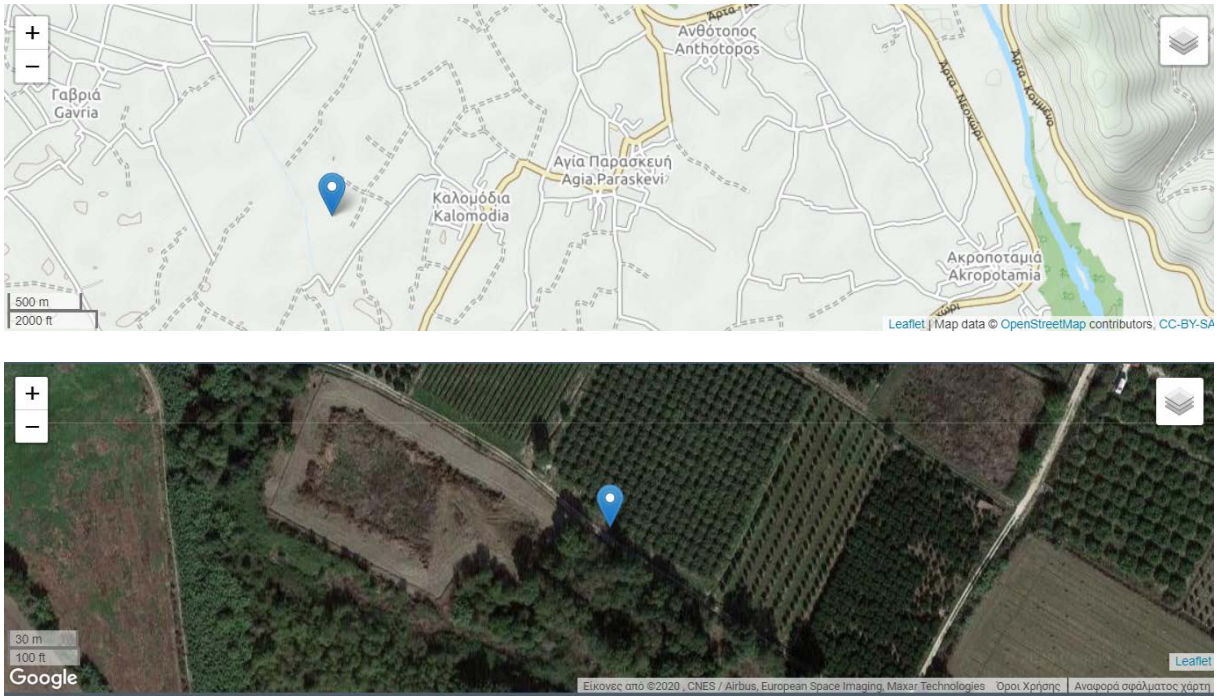


Fig. 8 Satellite view of the pilot kiwifruit orchard TM19 – Kolomodia

Fig. 9 General view of the pilot kiwifruit orchard TM19 – Kolomodia

Irrigation was performed using one micro-sprinkler of 120 Lh^{-1} per plant (Fig. 10). The actual mean flow of each micro-sprinkler was found during an audit to be equal to 78,13 Lh^{-1}. The water is provided by a private drilling in the field.

The grower was very experienced in kiwifruit cultivation (he cultivated kiwifruit professionally for about 10 years). He had access to the system and received recommendations, but he could follow his

own decisions regarding irrigation applications. All the irrigation applications that have been performed were manually registered to the system.

Several sets of parameters for modelling the field at the system were used through the evaluation period. The parameters of the pilot kiwifruit orchard TM19 – Kolomodia at the system that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, are presented in Table 1.

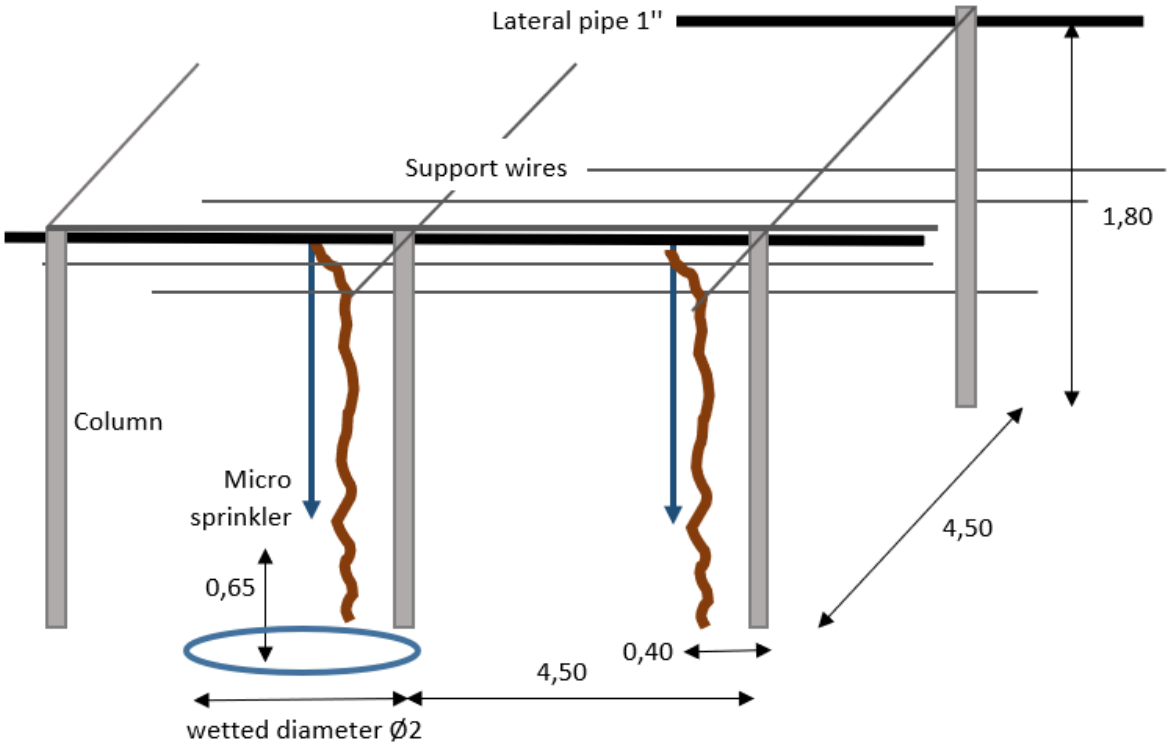


Fig. 10 Planting distances, support structure and irrigation system (dimensions in m) for the pilot kiwifruit orchard TM19 – Kolomodia

Table 1 Field parameters for the pilot kiwifruit orchard TM19 – Kolomodia

Parameter category / name (unit)	Values	Default values proposed by the system and Comments
Basic parameters		
Coordinates (decimal degrees)	20.96903, 39.09663	Longitude and latitude in WGS84
Irrigated area (m^2)	4000	Total area (ha): 0,8
Crop type	Kiwi	-
Custom parameters		
Irrigation type	Micro-sprinklers	-
Irrigation management		
Irrigation efficiency (%)	50	Default value for selected irrigation type: 80%
Irrigation optimizer (IRT) (% of RAW)	25	Default value: 50%
Crop		
(Maximum) allowed depletion (% of available water: FC-PWP)	15	Default value for selected crop type: 35% (Allen et al., 1998)
Estimated root depth (max) (m)	0,4	Default value for selected crop type: 1.3 (Allen et al., 1998)
Estimated root depth (min) (m)	0,3	Default value for selected crop type: 0.7 (Allen et al., 1998)
Kc	The default values were used	Default value for selected crop type (stage length in days and Kc at end of stage), starting from March 16th: 20 and 0.4, 70 and 1.05, 120 and 1.05, 60 and 1.05 (Allen et al., 1998)
Soil		
Field capacity (% v/v)	39	Default value for selected location: 39% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Permanent wilting point (% v/v)	10	Default value for selected location: 10% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Soil moisture at saturation (% v/v)	50	Default value for selected location: 50% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)

Pilot kiwifruit orchard KL19 – Agia Paraskevi

This field is at the area of Agia Paraskevi village (Fig. 11, Fig. 12) at a height of 25 m above sea level. The soil is of silty loam type. The kiwifruit variety is 'Hayward' (Clone 8). The vines were planted in 2011, they were spaced 2 x 5 m (distance between vines on the row x distance between rows) and trained to a pergola type structure of 1.85 m height (Fig. 13).

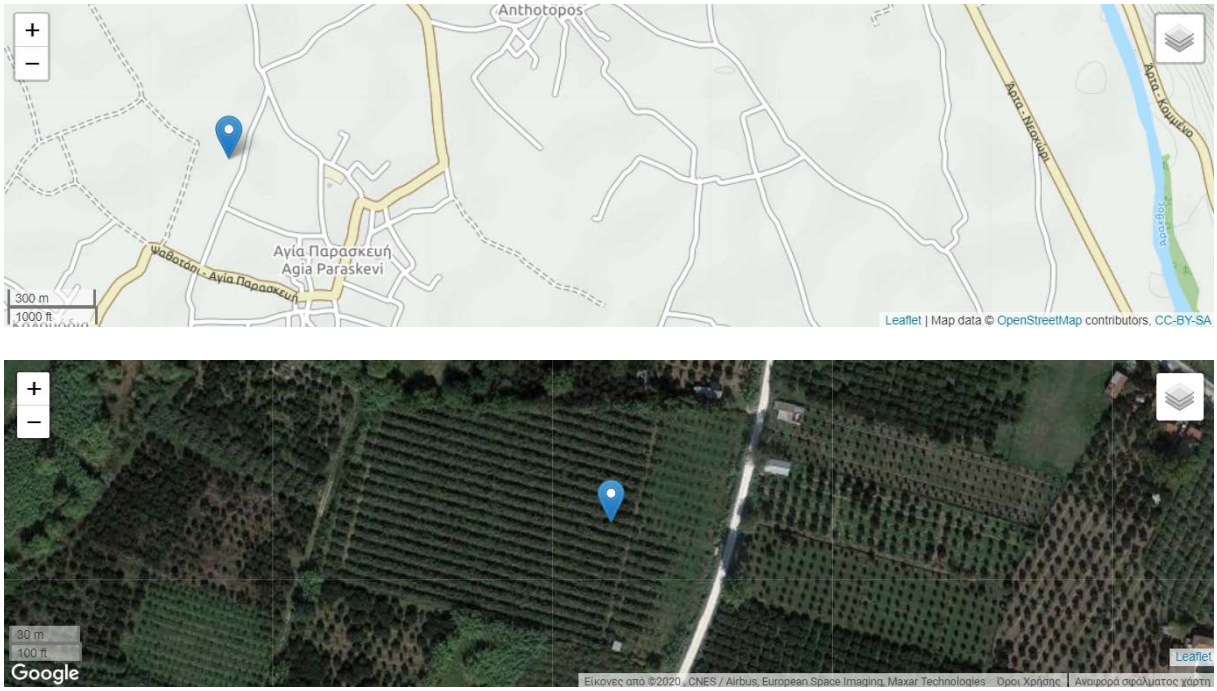


Fig. 11 Satellite view of the pilot kiwifruit orchard KL19 – Agia Paraskevi

Fig. 12 General view of the pilot kiwifruit orchard KL19 – Agia Paraskevi

Irrigation was performed using one micro-sprinkler of 90 Lh^{-1} per plant (Fig. 13). The actual mean flow of each micro-sprinkler was found during an audit to be equal to 69,18 Lh^{-1}. The water is provided by a private drilling in the field.

The grower was very experienced in kiwifruit cultivation (he has a BSc in Agriculture and cultivated kiwifruit professionally for about 10 years). He had access to the system and received recommendations, but he could follow his own decisions regarding irrigation applications. All the irrigation applications that have been performed were manually registered to the system.

Several sets of parameters for modelling the field at the system were used through the evaluation period. The parameters for the pilot kiwifruit orchard KL19 – Agia Paraskevi at the system that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, are presented in Table 2.

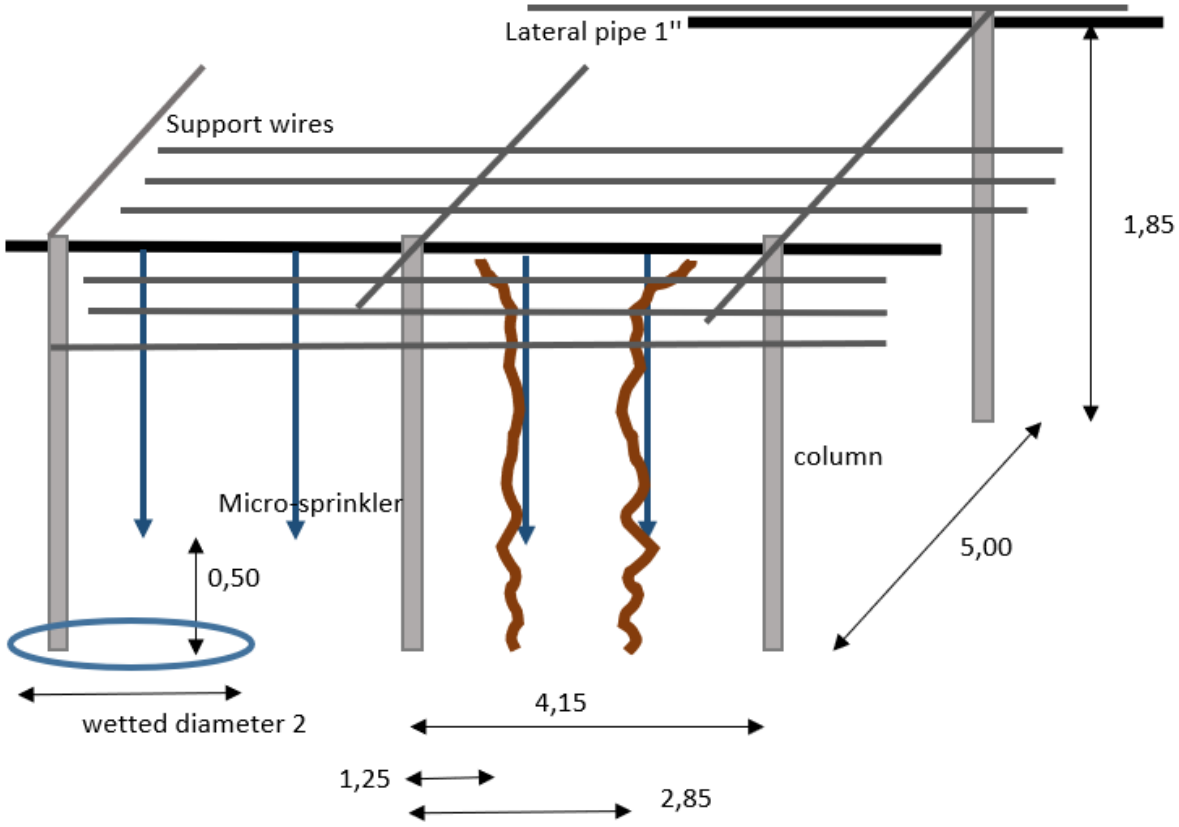


Fig. 13 Planting distances, support structure and irrigation system (dimensions in m) for the pilot kiwifruit orchard KL19 – Agia Paraskevi

Table 2 Field parameters for the pilot kiwifruit orchard KL19 – Agia Paraskevi

Parameter category / name (unit)	Values	Default values proposed by the system and Comments
Basic parameters		
Coordinates (decimal degrees)	20.98692, 39.10257	Longitude and latitude in WGS84
Irrigated area (m^2)	6500	Total area (ha): 1,3
Crop type	Kiwi	-
Custom parameters		
Irrigation type	Micro-sprinklers	-
Irrigation management		
Irrigation efficiency (%)	50	Default value for selected irrigation type: 80%
Irrigation optimizer (IRT) (% of RAW)	75	Default value: 50%
Crop		
(Maximum) allowed depletion (% of available water: FC-PWP)	15	Default value for selected crop type: 35% (Allen et al., 1998)
Estimated root depth (max) (m)	0,30	Default value for selected crop type: 1.3 (Allen et al., 1998)
Estimated root depth (min) (m)	0,30	Default value for selected crop type: 0.7 (Allen et al., 1998)
Kc	The default values were used	Default value for selected crop type (stage length in days and Kc at end of stage), starting from March 16th: 20 and 0.4, 70 and 1.05, 120 and 1.05, 60 and 1.05 (Allen et al., 1998)
Soil		
Field capacity (% v/v)	28	Default value for selected location: 39% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Permanent wilting point (% v/v)	14	Default value for selected location: 10% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Soil moisture at saturation (% v/v)	43	Default value for selected location: 50% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)

Pilot kiwifruit orchard EX19 – Neochori

This field is at the area of Neochori village (Fig. 14, Fig. 15) at a height of 20 m above sea level. The soil is of Silty clay loam / Clay Loam type. The kiwifruit variety is 'Hayward' (Clone 8). The vines were planted in 2009, they were spaced 2 x 5 m (distance between vines on the row x distance between rows) and trained to a pergola type structure of 1.75 m height (Fig. 16).

Irrigation was performed using one micro-sprinkler of 70 Lh^{-1} per plant (Fig. 16). The actual mean flow of each micro-sprinkler was found during an audit to be equal to 65 Lh^{-1}. The water is provided by a private drilling in the field.

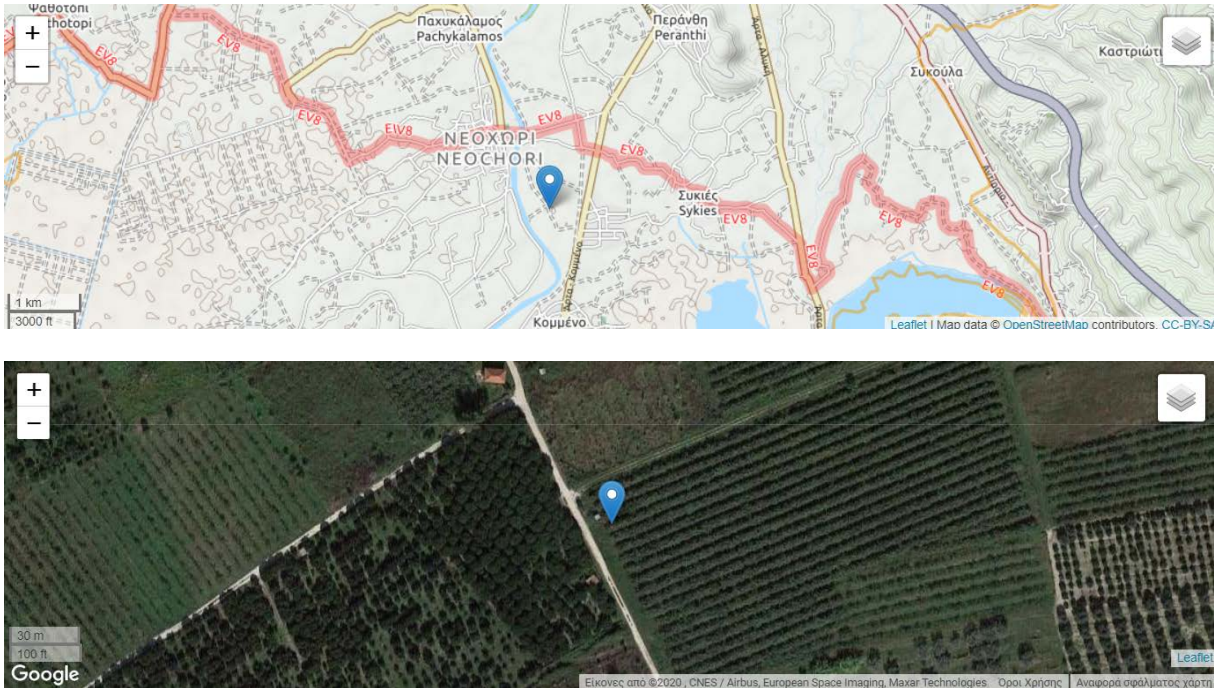


Fig. 14 Map and satellite view of the pilot kiwifruit orchard EX19 – Neochori

The grower was very experienced in kiwifruit cultivation (he has a BSc in Agriculture and cultivated kiwifruit professionally for about 10 years). He had access to the system and received recommendations, but he could follow his own decisions regarding irrigation applications. All the irrigation applications that have been performed were manually registered to the system.

Several sets of parameters for modelling the field at the system were used through the evaluation period. The parameters for the pilot kiwifruit orchard KL19 – Agia Paraskevi at the system that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, are presented in Table 3.

Fig. 15 General view of the pilot kiwifruit orchard EX19 – Neochori taken on 24/5/2019

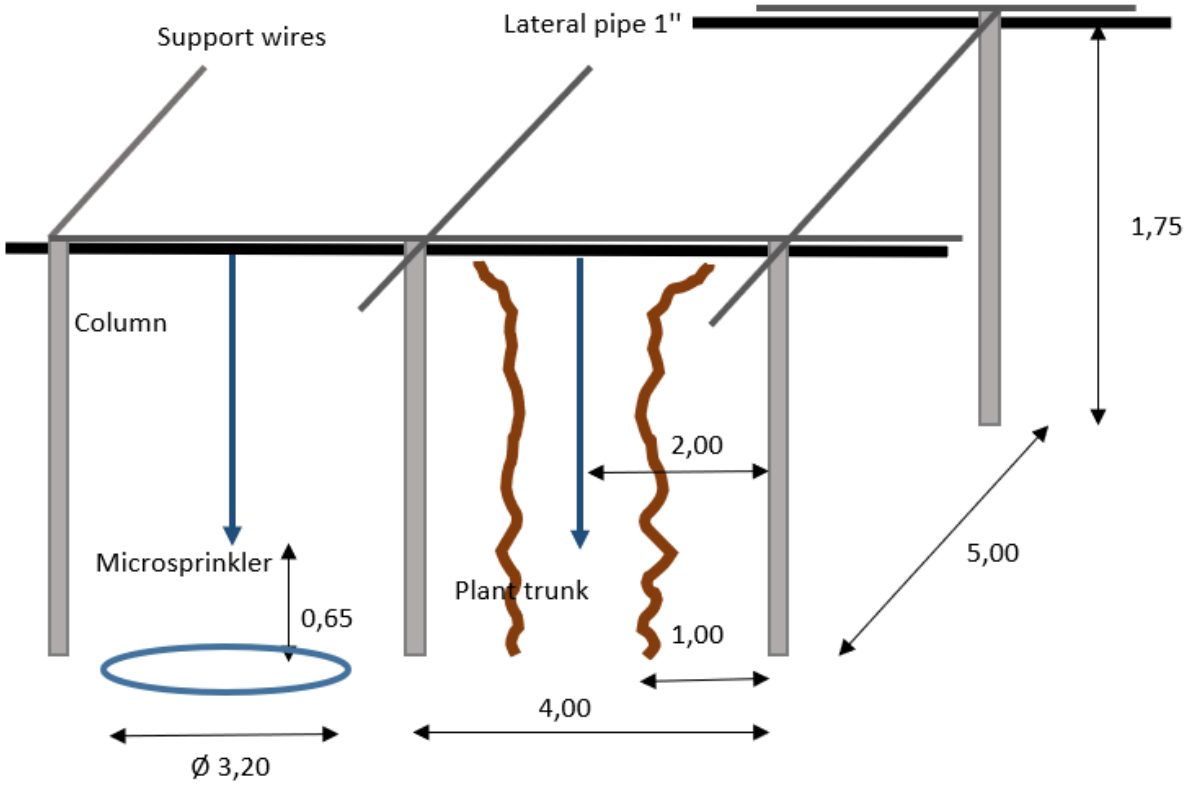


Fig. 16 Planting distances, support structure and irrigation system (dimensions in m) for the pilot kiwifruit orchard EX19 – Neochori

Table 3 Field parameters for the pilot kiwifruit orchard EX19 – Neochori

Parameter category / name (unit)	Values	Default values proposed by the system and Comments
Basic parameters		
Coordinates (decimal degrees)	39.06134, 21.02975	Longitude and latitude in WGS84
Irrigated area (m^2)	15000	Total area (ha): 3
Crop type	Kiwi	-
Custom parameters		
Irrigation type	Micro-sprinklers	-
Irrigation management		
Irrigation efficiency (%)	50	Default value for selected irrigation type: 80%
Irrigation optimizer (IRT) (% of RAW)	100	Default value: 50%
Crop		
(Maximum) allowed depletion (% of available water: FC-PWP)	15	Default value for selected crop type: 35% (Allen et al., 1998)
Estimated root depth (max) (m)	0,20	Default value for selected crop type: 1.3 (Allen et al., 1998)
Estimated root depth (min) (m)	0,10	Default value for selected crop type: 0.7 (Allen et al., 1998)
Kc	The default values were used	Default value for selected crop type (stage length in days and Kc at end of stage), starting from March 16th: 20 and 0.4, 70 and 1.05, 120 and 1.05, 60 and 1.05 (Allen et al., 1998)
Soil		
Field capacity (% v/v)	33	Default value for selected location: 39% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Permanent wilting point (% v/v)	9	Default value for selected location: 10% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Soil moisture at saturation (% v/v)	46	Default value for selected location: 50% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)

Pilot kiwifruit orchard KC20 – Plisioi

This field is at the area of Plisioi village (Fig. 17, Fig. 18) at a height of 10 m above sea level. The soil is of Clay type. The kiwifruit variety is 'Hayward'. The vines were planted in 2015, they were spaced 3 x 5 m (distance between vines on the row x distance between rows) and trained to a pergola type structure of 1.8 m height (Fig. 19).

Irrigation was performed using one micro-sprinkler of 105 Lh^{-1} per plant (Fig. 19). The actual mean flow of each micro-sprinkler was found during an audit to be equal to 90 Lh^{-1}. The water is provided by a private drilling in the field.

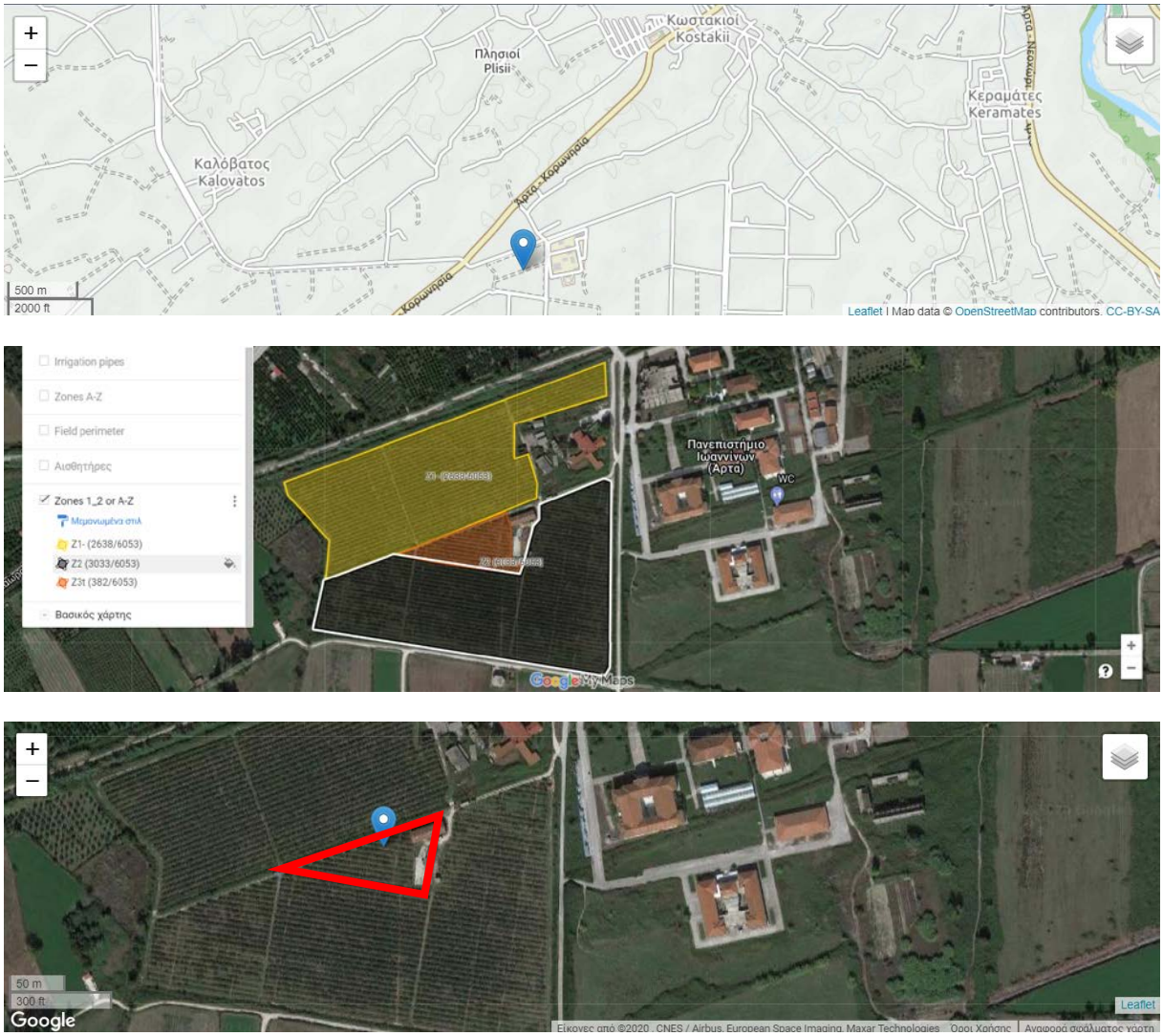


Fig. 17 Map and satellite view of the pilot kiwifruit orchard KC20 – Plisioi (the red triangle bounds the evaluation area of 0,6 ha (Z3t))

Fig. 18 General view of the pilot kiwifruit orchard KC20 – Plisioi taken on 14/7/2020

This 9,5 ha, field is property of a major fruit packaging company of Arta. A specialized to kiwifruit agronomist is in charge for the crop. He had access to the system and received recommendations, but he could follow his own decisions regarding irrigation applications. All the irrigation applications that have been performed were manually registered to the system.

Several sets of parameters for modelling the field at the system were used through the evaluation period. The parameters for the pilot kiwifruit orchard KC20 – Plisioi at the system that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, are presented in Table 4.

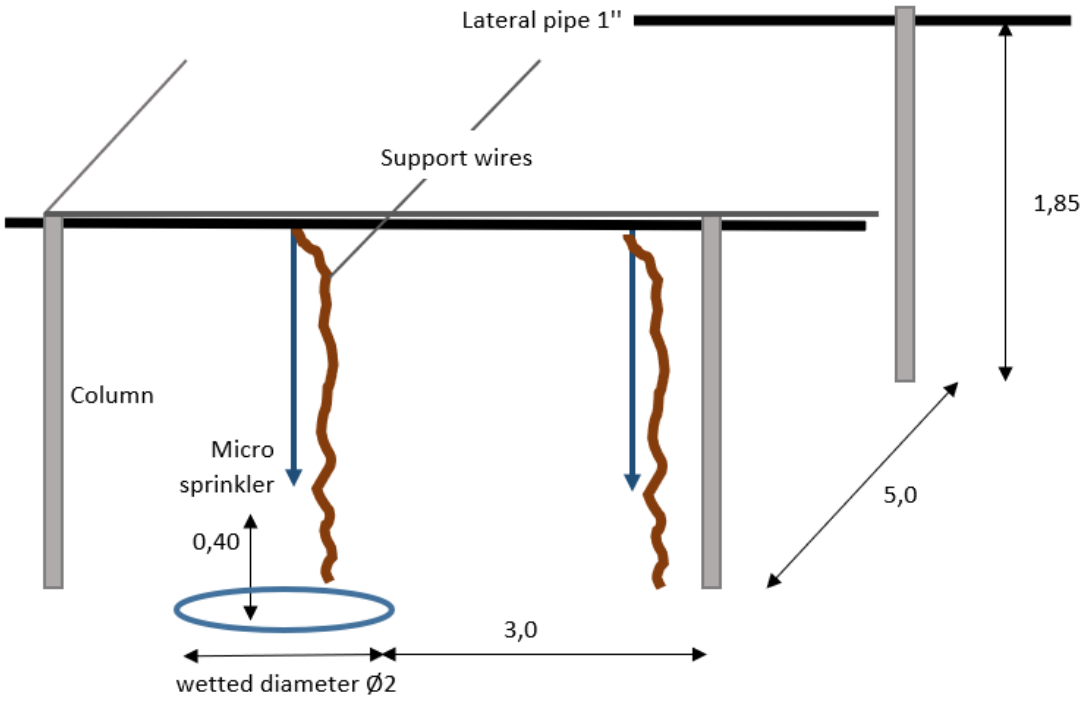


Fig. 19 Planting distances, support structure and irrigation system (dimensions in m) for the pilot kiwifruit orchard KC20 – Plisioi

Table 4 Field parameters for the pilot kiwifruit orchard KC20 – Plisioi

Parameter category / name (unit)	Values	Default values proposed by the system and Comments
Basic parameters		
Coordinates (decimal degrees)	20.94301, 39.11988	Longitude and latitude in WGS84
Irrigated area (m²)	3.000	Total area (ha): 9,5 ha – The evaluation area was one zone (Z) that has a total area of 0,6 ha
Crop type	Kiwi	-
Custom parameters		
Irrigation type	Micro-sprinklers	-
Irrigation management		
Irrigation efficiency (%)	50	Default value for selected irrigation type: 80%
Irrigation optimizer (IRT) (% of RAW)	75	Default value: 50%
Crop		
(Maximum) allowed depletion (% of available water: FC-PWP)	8	Default value for selected crop type: 35% (Allen et al., 1998)
Estimated root depth (max) (m)	0,4	Default value for selected crop type: 1.3 (Allen et al., 1998)
Estimated root depth (min) (m)	0,2	Default value for selected crop type: 0.7 (Allen et al., 1998)
Kc	The default values were used	Default value for selected crop type (stage length in days and Kc at end of stage), starting from March 16th: 20 and 0.4, 70 and 1.05, 120 and 1.05, 60 and 1.05 (Allen et al., 1998)
Soil		
Field capacity (% v/v)	40	Default value for selected location: 39% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Permanent wilting point (% v/v)	10	Default value for selected location: 10% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)
Soil moisture at saturation (% v/v)	47	Default value for selected location: 50% (according to soil analysis results for soil type and Twarakavi et al, 2009 for the volumetric levels)

Results, Discussion and Conclusions

Water usage limits for kiwifruit according to Greek legislation

According to the Greek legislation (GMA, 1989), the limits for irrigation water usage for kiwifruit in the Region of Epirus range between 6320 and 7800 m^3 ha^{-1} for an irrigation period spanning from April to September, without taking into account the efficiency of the irrigation system. The relevant values when the irrigation efficiency for micro-sprinklers according to GMA (1989), is taken into account are 7036 and 8624 m^3 ha^{-1} (or 703,6 to 862,4 mm) (Fig. 20 and Fig. 21).

Υδατικό Διαμέρισμα Ηπείρου 05

ΚΑΤΗΓΟΡΙΑ / ΜΗΝΑΣ	I	II	III	IV	V	VI	VII	VIII
Απρίλιος	33-44	36-48	39-52	42-56	45-60	48-64	51-68	72- 96
Μάιος	63-80	69-87	75-94	80-101	86-109	92-116	98-123	138-174
Ιούνιος	88-107	96-117	104-127	112-136	120-146	128-156	136-166	192-234
Ιούλιος	102-121	111-132	120-143	129-154	139-165	148-176	157-187	222-264
Αύγουστος	96-115	105-126	114-136	122-147	131-157	140-168	149-178	210-252
[illegible]ος	52-69	57-75	62-81	66-87	71-94	76-100	81-106	114-150

ΟΡΙΑ ΓΙΑ ΤΗ ΧΡΗΣΗ ΑΡΔΕΥΤΙΚΟΥ ΝΕΡΟΥ ΑΝΑ ΚΑΤΗΓΟΡΙΑ ΚΑΛΛΙΕΡΓΕΙΩΝ
(σε κυβικά μέτρα νερού ανά στρέμμα, για ολόκληρο το μήνα)

Fig. 20 Limits of irrigation water usage according to GMA (1989): table for the region of Epirus (Hydrological Region No 5), kiwifruit is listed in category VI

For a typical kiwifruit orchard in Arta, the typical irrigation period spans from May to late October, while more than 50 irrigation applications are performed per year to provide more than 7.000 m^3 of water per ha. Thus, improved irrigation management matters (Tsirogiannis et. al., 2017).

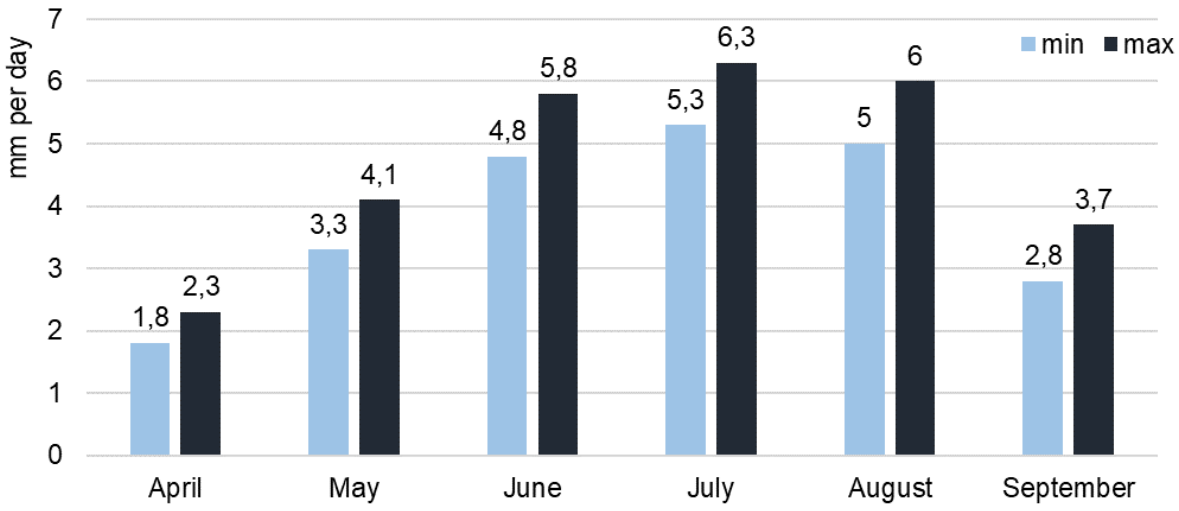


Fig. 21 Limits of irrigation water usage according to GMA (1989) estimated average daily water usage per month

Number of irrigation events, effective rain and water usage of pilot fields

Pilot kiwifruit orchard TM19 – Kolomodia

The set of parameters that is presented in Table 1, which was the one that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, resulted for the system to recommend during the 2019 irrigation period, 104 irrigation events during the irrigation period, while the grower applied 104.

The total effective precipitation (from 15/3/2019, date of initiation of the irrigation period for the DSS up to 25/10/2019, date of the last irrigation event) was 414 mm.

The total recommended by the system irrigation water amount was 1.022 mm, while the total applied irrigation water amount (from 30/3/2019, date of the first irrigation event, up to 25/10/2019, date of the last irrigation event) with reference to the total area was 1.083 mm (percentage difference: 6,0%). The irrigation performance chart and file of the system has registered 2.166 mm but that was referred to the irrigated and not the total area of the field). Fig. 22 presents the soil moisture fluctuation during the irrigation period as registered by soil moisture sensors along with the levels of FC, PWP and RAW, the effective precipitation and the irrigation events for the pilot kiwifruit orchard, while Fig. 23 presents the irrigation performance chart as provided by the system.

For the case that IRT was set equal to 50% (instead of 25%) while all the other parameters remained as presented in Table 1, the system would propose 58 irrigation events during the irrigation period instead of 104 (the grower applied 104 as already mentioned). The respective total recommended by the system irrigation water amount would be 1.046 mm.

The rationale behind the low irrigation efficiency value (50%) is that the mean water flow value per mini-sprinkler that was used, was obtained from a single irrigation audit was used and this does not depict the probable fluctuations of water flow during the irrigation period.

The harvest was made on 2/11/2019 and the yield was 35 tn.

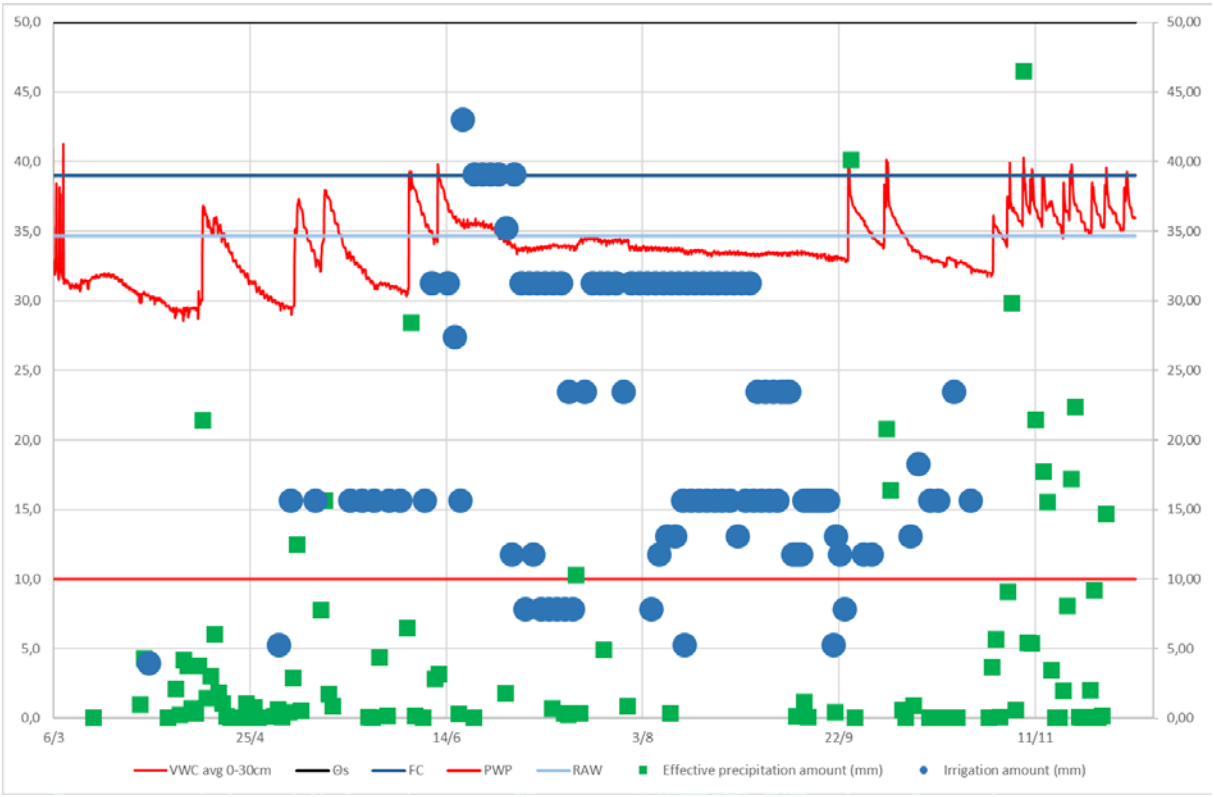


Fig. 22 Soil moisture registered by soil moisture sensors (VWC average for the depth of 0-30 cm), levels of FC, PWP and RAW (15% of available soil water), effective precipitation and irrigation events for the pilot kiwifruit orchard TM19 – Kolomodia

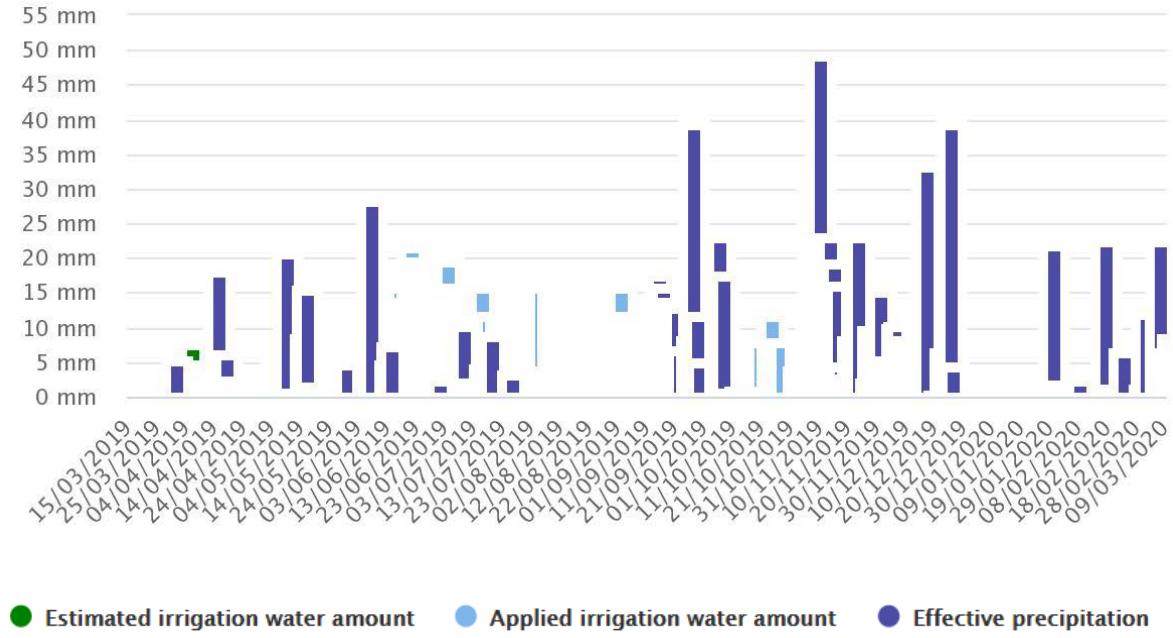


Fig. 23 Irrigation performance (screenshot from the system) for IE=50%, IRT=25% and RAW=15% for the pilot kiwifruit orchard TM19 – Kolomodia

Pilot kiwifruit orchard KL19 – Agia Paraskevi

The set of parameters that is presented in Table 2, which was the one that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, caused the system to recommend during the 2019 irrigation period, 95 irrigation events during the irrigation period, while the grower applied 104.

The total effective precipitation (from 15/3/2019, date of initiation of the irrigation period for the DSS up to 25/10/2019, date of the last irrigation event) was 390 mm.

The total recommended by the system irrigation water amount was 1.112 mm, while the total applied irrigation water amount (from 12/3/2019, date of the first irrigation event up to 25/10/2019, date of the last irrigation event) with reference to the total area was 1.069,50 mm (percentage difference: -4%). The irrigation performance chart and file of the system has registered 2.139 mm but that was referred to the irrigated and not the total area of the field). Fig. 25 presents the soil moisture fluctuation during the irrigation period as registered by soil moisture sensors along with the levels of FC, PWP and RAW, the effective precipitation and the irrigation events for the pilot kiwifruit orchard, while Fig. 26 presents the irrigation performance chart as provided by the system.

For the case that IRT was set equal to 50% (instead of 75%) while all the other parameters remained as presented in Table 2, the system would propose 115 irrigation events during the irrigation period instead of 95 (the grower applied 104 as already mentioned). The respective total recommended by the system irrigation water amount would be 1.098 mm.

The rationale behind the low irrigation efficiency value (50%) is that the mean water flow value per mini-sprinkler that was used, was obtained from a single irrigation audit was used and this does not depict the probable fluctuations of water flow during the irrigation period.

The harvest was made on 26/10/2019 and the yield was 50 tn.

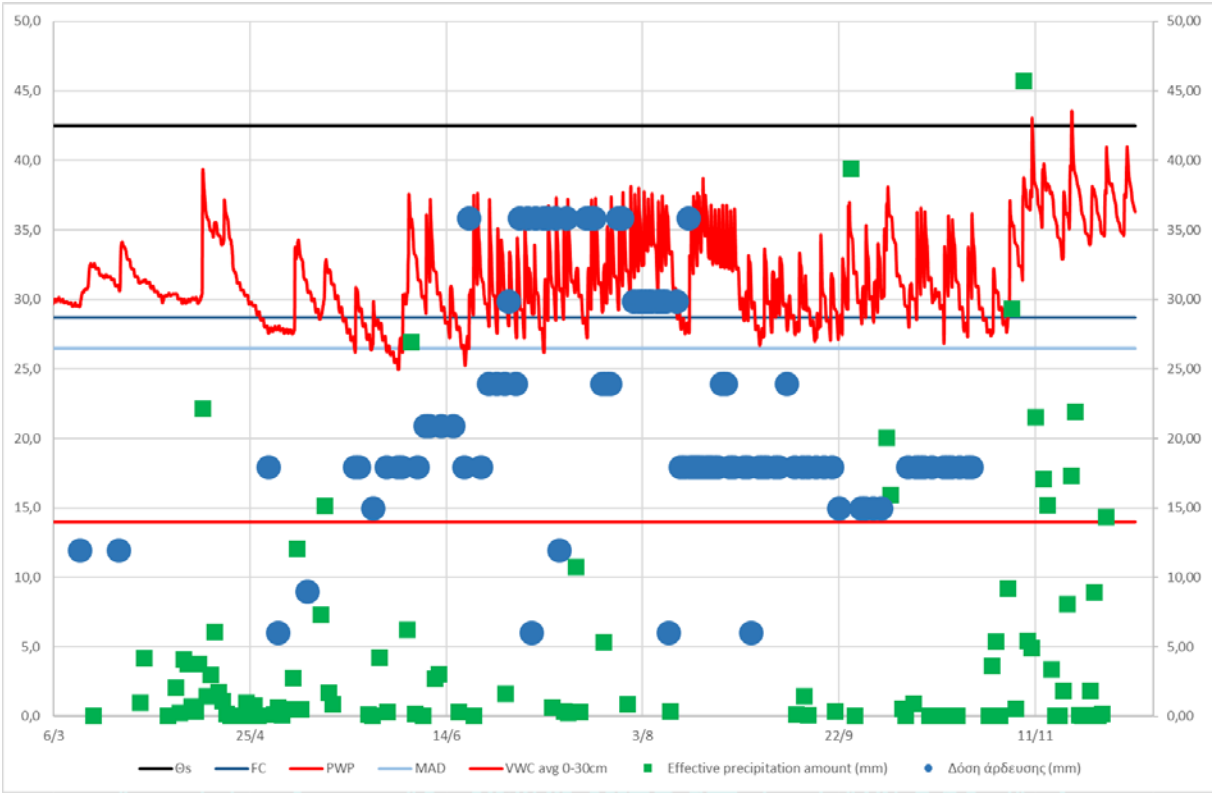


Fig. 24 Soil moisture registered by soil moisture sensors (VWC average for the depth of 0-30 cm), levels of FC, PWP and RAW (15% of available soil water), effective precipitation and irrigation events for the pilot kiwifruit orchard KL19 – Agia Paraskevi

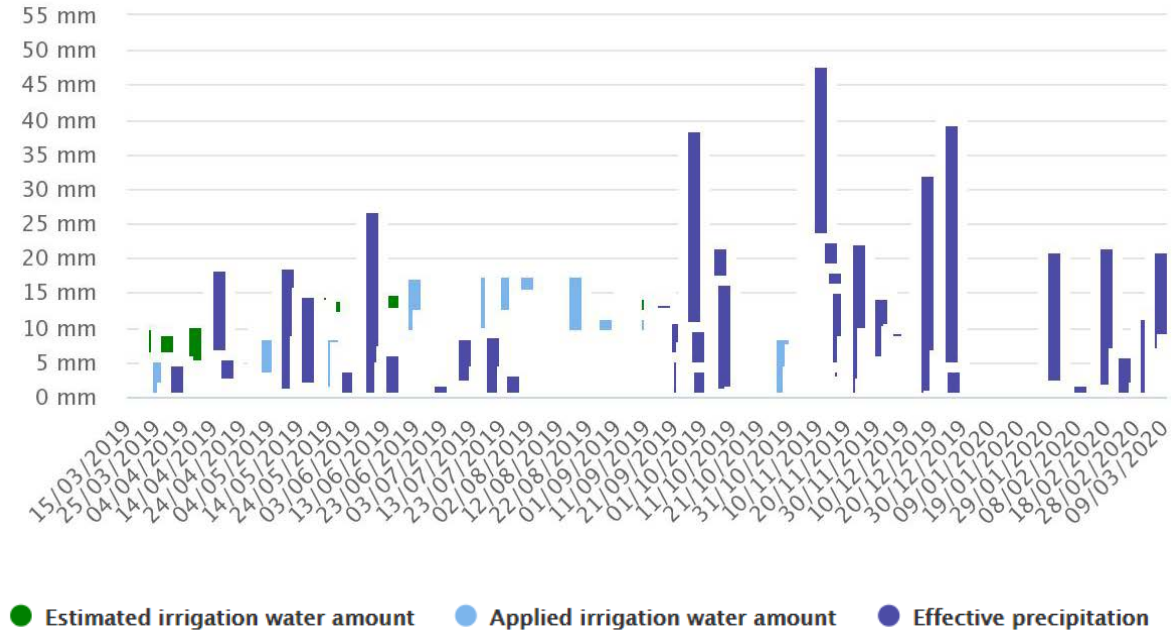


Fig. 25 Irrigation performance (screenshot from the system) for IE=50%, IRT=75% and RAW=15% for the pilot kiwifruit orchard KL19 – Agia Paraskevi

Pilot kiwifruit orchard EX19 – Neochori

The set of parameters that is presented in Table 3, which was the one that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, caused the system to recommend during the 2019 irrigation period, 97 irrigation events during the irrigation period, while the grower applied 103.

The total effective precipitation (from 15/3/2019, date of initiation of the irrigation period for the DSS up to 27/10/2019, date of the last irrigation event) was 289 mm.

The total recommended by the system irrigation water amount was 1.337 mm, while the total applied irrigation water amount (from 14/4/2019, date of the first irrigation event up to 27/10/2019, date of the last irrigation event) with reference to the total area was 1.144,5 mm (percentage difference: -14%). The irrigation performance chart and file of the system has registered 2.289 mm but that was referred to the irrigated and not the total area of the field). Fig. 26 presents the soil moisture fluctuation during the irrigation period as registered by soil moisture sensors along with the levels of FC, PWP and RAW, the effective precipitation and the irrigation events for the pilot kiwifruit orchard, while Fig. 27 presents the irrigation performance chart as provided by the system.

For the case that IRT was set equal to 50% while all the other parameters remained as presented in Table 3, the system would propose 141 irrigation events during the irrigation period instead of 97 (the grower applied 103 as already mentioned). The respective total estimated irrigation water amount would be 1.297 mm.

The rationale behind the low irrigation efficiency value (50%) is that the mean water flow value per mini-sprinkler that was used, was obtained from a single irrigation audit was used and this does not depict the probable fluctuations of water flow during the irrigation period.

The harvest was made on 5/11/2019 and the yield was 123 tn.

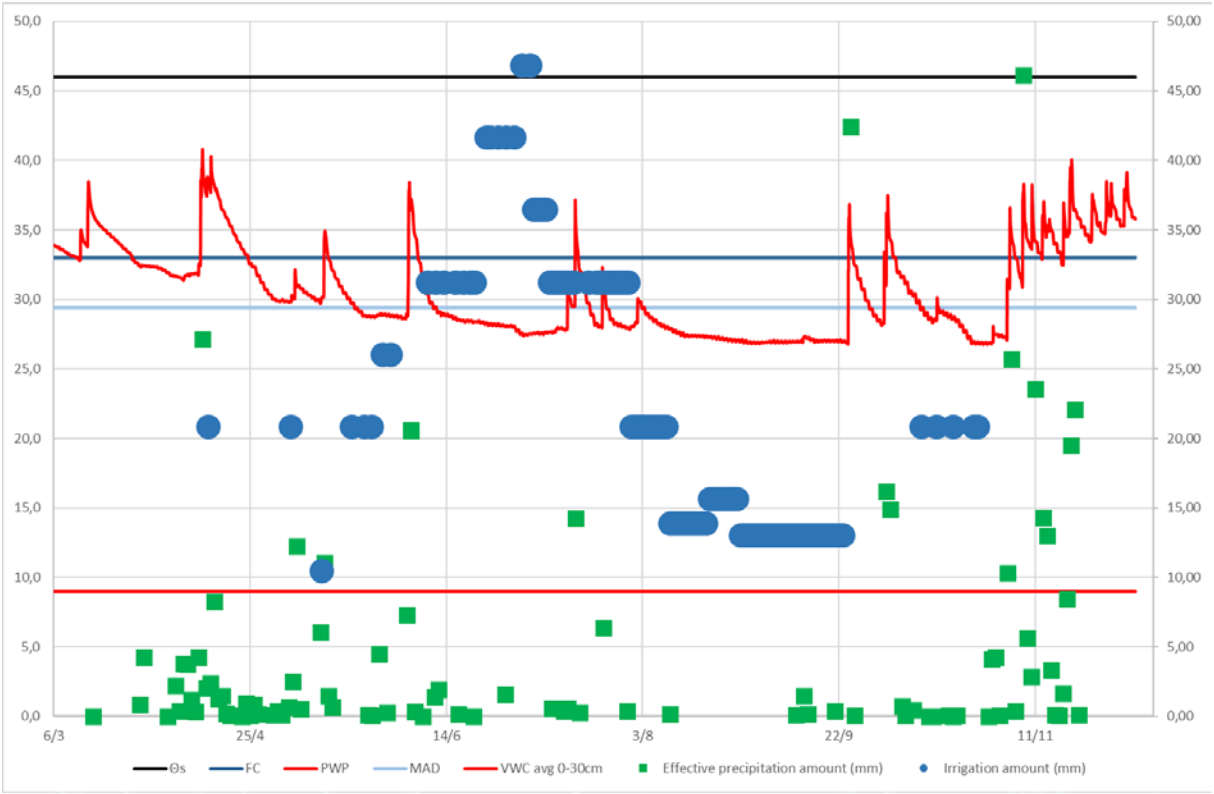


Fig. 26 Soil moisture registered by soil moisture sensors (VWC average for the depth of 0-30 cm), levels of FC, PWP and RAW (15% of available soil water), effective precipitation and irrigation events for the pilot kiwifruit orchard EX19 – Neochori

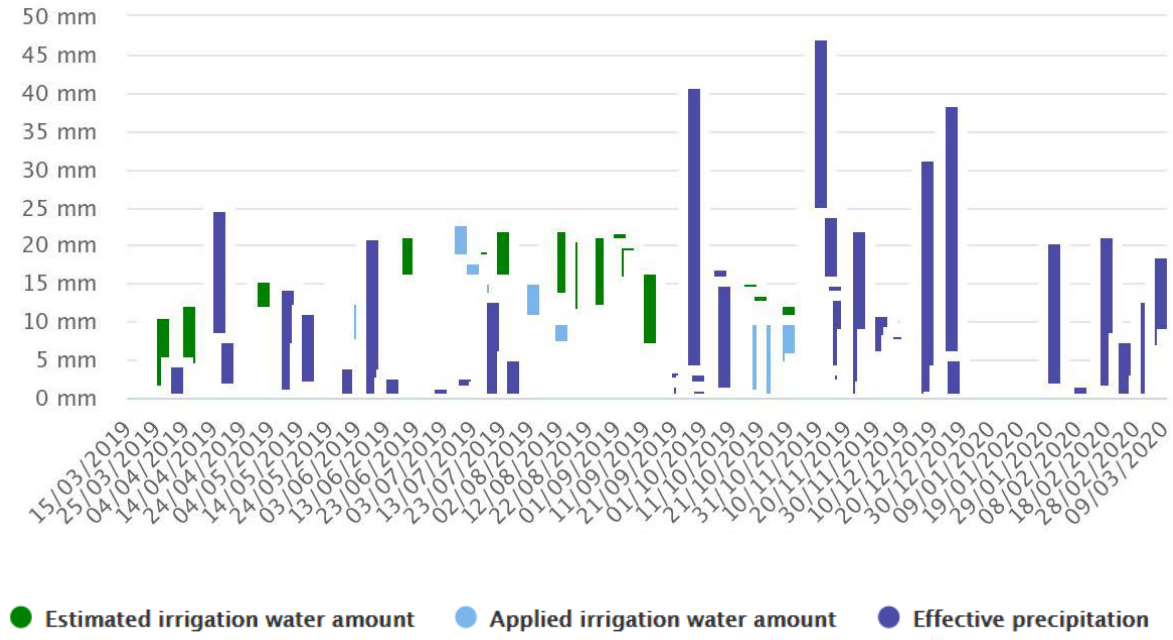


Fig. 27 Irrigation performance (screenshot from the system) for IE=50% IRT=100% and RAW=15% for the pilot kiwifruit orchard EX19 – Neochori

Pilot kiwifruit orchard KC20 – Plisioi

The set of parameters that is presented in Table 4, which was the one that resulted the closed to what was actually applied by the farmer regarding the number of irrigation events, caused the system to recommend during the 2020 irrigation period, 91 irrigation events during the irrigation period, while the grower applied 95.

The total effective precipitation (from 15/3/2019, date of initiation of the irrigation period for the DSS up to 5/11/2020, date of the last irrigation event) was 294 mm.

The total recommended by the system irrigation water amount was 1.200,50 mm, while the total applied irrigation water amount (from 6/5/2020, date of the first irrigation event, up to 5/11/2020, date of the last irrigation event) with reference to the total area was 714 mm (percentage difference: -41%). The irrigation performance chart and file of the system has registered 1.428 mm but that was referred to the irrigated and not the total area of the field). Fig. 28 presents the soil moisture fluctuation during the irrigation period as registered by soil moisture sensors along with the levels of FC, PWP and RAW, the effective precipitation and the irrigation events for the pilot kiwifruit orchard, while Fig. 29 presents the irrigation performance chart as provided by the system.

The rationale behind the low irrigation efficiency value (50%) is that the mean water flow value per mini-sprinkler that was used, was obtained from a single irrigation audit was used and this does not depict the probable fluctuations of water flow during the irrigation period.

The harvest was made on 4/11/2020 and the yield was 4,9 tn for the evaluation area (0,6 ha) while the total yield for the whole field was 107 tn.

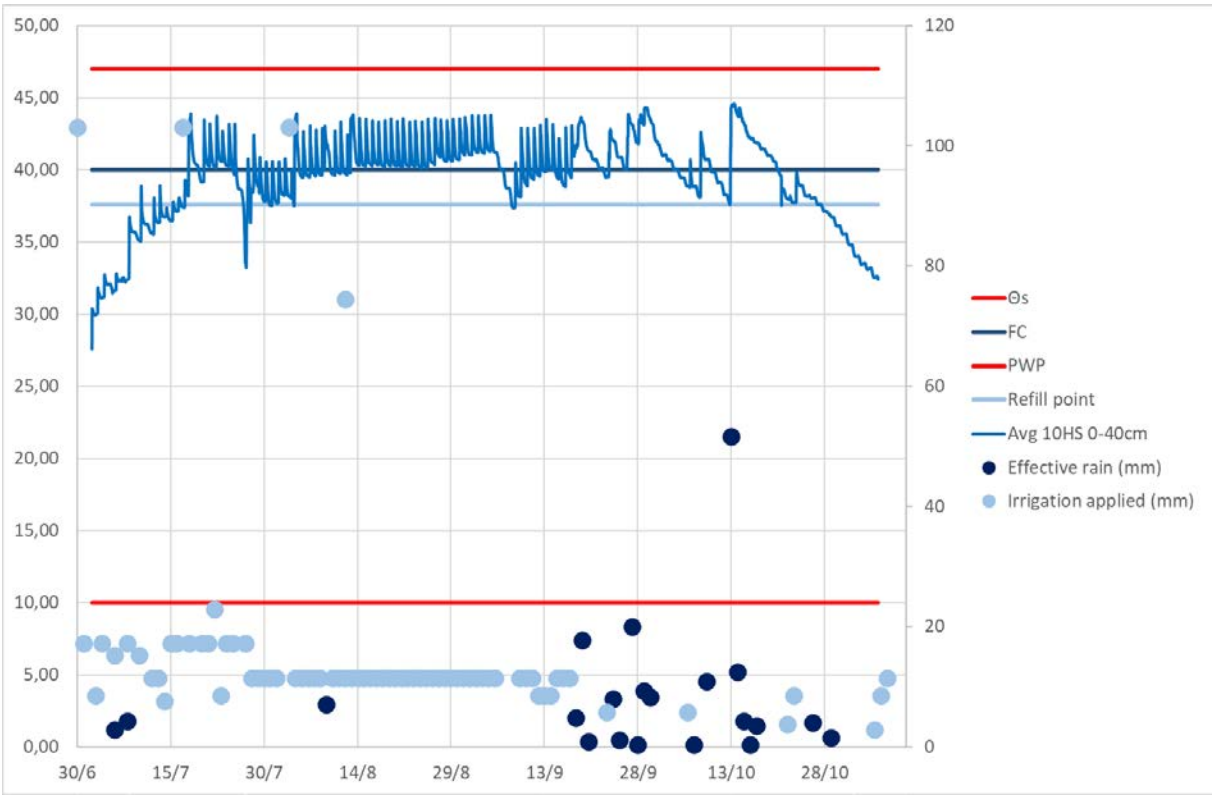


Fig. 28 Soil moisture registered by soil moisture sensors (VWC average for the depth of 0-40 cm), levels of FC, PWP and RAW (8% of available soil water), effective precipitation and irrigation events for the pilot kiwifruit orchard KC20 – Plisioi

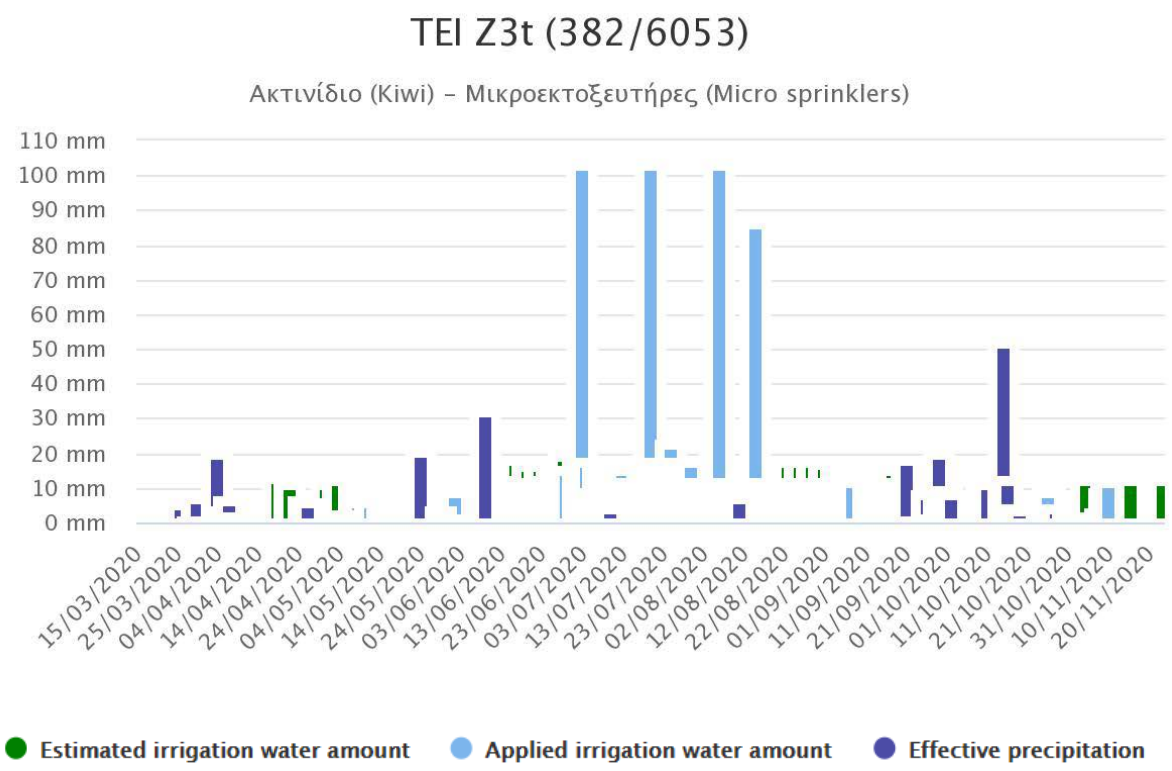


Fig. 29 Irrigation performance (screenshot from the system) for IE=50% IRT=75% and RAW=8% for the pilot kiwifruit orchard KC20 – Plisioi

Summarised results and discussion

Synoptical information regarding pilot fields, DSS parameters and results is presented in Table 5. It has to be noted that 3 of the pilot fields were evaluated during 2019 while one was evaluated during 2020.

Kiwifruit (variety 'Hayward' (Clone 8)) was cultivated in all pilot fields. The density of plants ranged from almost 500 to 1000 plants per hectare while their age at the year of evaluation ranged from 5 to 18 years.

Root depths according to grower estimation as a goal were set to be between 0,1-0,3 m (minimum value) and 0,2-0,4 (maximum value). According to FAO (Allen et. al., 1998) the relevant estimations fro kiwifruit are 0,7 to 1,3 m.

Regarding crop coefficient fluctuation (Kc) the generic periods and values that are provided by FAO (Allen et. al., 1998) were used in all cases (starting from March 16th: 20 and 0.4, 70 and 1.05, 120 and 1.05, 60 and 1.05). This probably does not depict accurately the situation of KC20 – Plisioi pilot field where that plants were very young.

The irrigated area was estimated to be 50% of the total area in all cases.

The irrigation efficiency was set equal to 50%. The rationale behind the low irrigation efficiency value is that the mean water flow value per mini-sprinkler that was used, was obtained from a single

irrigation audit was used and this does not depict the probable fluctuations of water flow during the irrigation period. It also counts for other probable errors regarding registering the irrigation events. So what is proposed is either to perform more than one audits in order to have a more accurate picture of the system flow, or to install a central water meter or smaller water meters on representative pipes in order to measure the actual water flow.

For the irrigation optimizer (IRT) (% of RAW), values between 25 up to 100% were used. So, a value between 50 and 75% could probably be a generic recommendation for kiwifruits. Regarding the (Maximum) allowed depletion (% of available water: FC-PWP) a value of 15% was used for the mature plantations while for the young trees of KC20 – Plisioi pilot field a value of 8% was used. It has to be noted that FAO (Allen et. al., 1998) proposes the value of 35% as maximum.

The set of parameters for the DSS that are presented in Table 5 had as goal to result the same number of irrigation events as the grower would apply. This was made in order not to change all the notion of irrigation for kiwifruit that the grower had already developed, something that would made her/him be more doubtful to accept and apply the recommendations provided by the system. Also because the amount of irrigation water that was presented in the irrigation performance chart and file (csv) of the system in mm, was the result of the sum of the amounts in m3 that were registered by the users for irrigation events, divided by the irrigated area (in m2), in order to be compared to the water needs and the limits of water usage, it was referred to the total irrigated area of the field. To do so it was multiplied by the percentage of the total area that was irrigated.

Table 5 Synoptical information regarding pilot fields, DSS parameters and results

	Default values*	**TM19 – Kolomodia**	**KL19 – Agia Paraskevi**	**EX19 – Neochori**	**KC20 – Plisioi**
Location		Kolomodia, Arta	Agia Paraskevi, Arta	Neochori, Arta	
Gower experience		High	High	High	High
Field coordinates (decimal degrees)		20,96903 39,09663	20,98692 39,10257	21,02975 39,06134	20,94301 39,11988
Heigh of field (m above sea level)		15	25	20	10
Total area (ha)		0,8	1,3	3	0,6
Irrigated (weted) area (ha)	Irrigation system dependent	0,4	0,65	1,5	0,3
Percent irrigated area (%)		50%	50%	50%	50%
Soil texture	Site dependent	Silty clay	Loam	Silty clay loam / Clay Loam	Clay
Crop type	Kiwifruit**	Kiwifruit	Kiwifruit	Kiwifruit	Kiwifruit
Variety		Hayward (Clone 8)	Hayward (Clone 8)	Hayward (Clone 8)	Hayward (Clone 8)
Planting year (y)		2001	2011	2009	2015
Age during evaluation (y)		18	8	10	5
Distance between vines on the row (m)		4,5	2	2	3
Distance between rows (m)		4,5	5	5	5
Crop density (plants / ha)		494	1000	1000	667
Pergola height (m)		1,8	1,85	1,75	1,8
Water source		Private drilling in the field	Private drilling in the field	Private drilling in the field	Private drilling in the field
Irrigation type	Micro-sprinklers**	Micro-sprinklers	Micro-sprinklers	Micro-sprinklers	Micro-sprinklers
Outlets per plant		1	1	0,5	1
Distance of outlets from ground (m)		0,65	0,5	0,65	0,4
Wetted diameter of outlet (m)		2	2	3,2	2
Outlet nominal flow (L h-1)		120	90	70	105
Oultet average actual flow (L h-1)		78,13	69,18	65	90
Number of audits for calculating the oultet average actual flow		1	1	1	1

	Default values*	**TM19 – Kolomodia**	**KL19 – Agia Paraskevi**	**EX19 – Neochori**	**KC20 – Plisioi**
Irrigation efficiency (%)	80%	50%	50%	50%	50%
Irrigation optimizer (IRT) (% of RAW)	50%	25%	75%	100%	75%
(Maximum) allowed depletion (% of available water: FC-PWP)	35%	15%	15%	15%	8%
Estimated root depth (max) (m)	1,3	0,4	0,3	0,2	0,4
Estimated root depth (min) (m)	0,7	0,3	0,3	0,1	0,2
Kc	starting from March 16th: 20 and 0.4, 70 and 1.05, 120 and 1.05, 60 and 1.05	Default values	Default values	Default values	Default values
Field capacity (% v/v)	Site dependent	39%	28%	33%	40%
Permanent wilting point (% v/v)	Site dependent	10%	14%	9%	10%
Soil moisture at saturation (% v/v)	Site dependent	50%	43%	46%	47%
Date of initiation of irrigation period	15/3/2019				
Date of first irrigation event		30/3/2019	12/3/2019	14/4/2019	6/5/2020
Date of last irrigation event		25/10/2019	25/10/2019	27/10/2019	5/11/2020
Effective rain during first and last irrrigation dates (mm)		414	390	289	294
Number of recommended by the DSS irrigation events		104	95	97	91
Number of applied irrigation events		104	104	103	95
Percentage difference regarding irrigation events (%)* **		0%	9%	6%	4%
Recommended irrigation water volume (RI, mm)		1022	1112	1337	1200
Applied irrigation water volume (AI, mm) - as registered in the irrigation performance file of the DSS (m3 of water registered by the user divided by the irrigated area)		2166	2139	2289	1428

	Default values*	TM19 – Kolomodia	KL19 – Agia Paraskevi	EX19 – Neochori	KC20 – Plisioi
Applied irrigation water volume (Airef, mm) - with reference to the total area of the filed		1083	1069,5	1144,5	714
Percentage difference, amount of irrigation water ((Airef-RI)/RI), %)* **		6%	-4%	-14%	-41%
Min limit for irrigation water usage for kiwifruit according to the Greek legislation (GMA, 1989) - for microsprinklers and for irrigation period from April to September (mm)	703,6	703,6	703,6	703,6	703,6
Max limit for irrigation water usage for kiwifruit according to the Greek legislation (GMA, 1989) - for microsprinklers and for irrigation period from April to September (mm)	862,4	862,4	862,4	862,4	862,4
Harvest date		2/11/2019	26/10/2019	5/11/2019	4/11/2020
Yield (tn)		35	50	123	4,90
Yield (tn/ha total)		43,75	38,46	41,00	8,17
Yield (kg/plant)		88,59	38,46	41,00	12,25

* Irrigation efficiency (%) for the selected irrigation type; (Maximum) allowed depletion, Estimated root depth (max) (m), Estimated root depth (min) (m), Kc according to (Allen et al., 1998 for the selected crop type)

** Selected by user

*** Possitive percentage (+) means that more was applied than what was recommended

Conclusions

The system under evaluation is a computer/mobile device based, open and free modular software that provides soil moisture estimations and irrigation recommendations based on the outcomes of a water balance model that followed the principles of FAO's paper 56.

The results of the evaluation for kiwifruit, are very promising regarding the ability of the system's model to reflect the soil moisture at the field and lead to water, energy and labour savings. Improvements regarding the model, the sets of parameters and the registration of irrigation applications are on their way.

The main recommendations are:

1. At the field parameters the total area of the field should be provided along with the percentage of irrigated area. That would be made more straightforward the results that are presented in the irrigation performance chart and file.
2. Crop / variety / age of plants specific sets of growing periods and Kc values would be very valuable. Also, feedback from any field that use the system would be valuable. In this framework the incorporation of remote sensing data to the system, for actual Kc calculation and feedback regarding the water status of the crop would be recommended.
3. Another the recommendation is for multiple irrigation system flow audits to be made or for a flowmeter to be installed at the field and provide information regarding irrigation events.

In every case experimental trials where kiwifruit would be under different irrigation treatments (irrigated according to grower decisions and irrigated according to DSS recommendations using various sets of parameters) would provide more insight regarding the optimum set of parameters and the effect on yield (quality and quantity), plant physiological condition, cost of irrigation / cropping etc.

Synopsis in English language

In Greece –like many Mediterranean countries- irrigation is by far the major water user. In this framework the development of operational tools that support decisions and provide recommendations aiming to improved irrigation management is of great importance. In this report the web-based participatory system for irrigation management (the system hereafter) that operates from 2015 at the plain of Arta (NW Greece) and has been improved in the framework of IR2MA project, is evaluated for the case of kiwifruit, an evolving crop for the area which is characterized by high water requirements. The results of the evaluation for kiwifruit, are very promising regarding the ability of the system's model to reflect the soil moisture at the field and lead to water, energy and labour savings. Improvements regarding the model, the sets of parameters and the registration of irrigation applications are on their way.

Σύνοψη στην ελληνική γλώσσα

Στην Ελλάδα –όπως πολλές μεσογειακές χώρες– η άρδευση είναι ο μεγαλύτερος χρήστης νερού. Έτσι, η ανάπτυξη επιχειρησιακών εργαλείων που υποστηρίζουν αποφάσεις και παρέχουν συστάσεις με στόχο τη βελτίωση της διαχείρισης της άρδευσης είναι εξαιρετικά σημαντική. Σε αυτήν την αναφορά, το διαδικτυακό συμμετοχικό σύστημα διαχείρισης άρδευσης (εφεξής το σύστημα) που λειτουργεί από το 2015 στην πεδιάδα της Άρτας (ΒΔ Ελλάδα) και έχει βελτιωθεί στο πλαίσιο του έργου IR2MA, αξιολογείται για την περίπτωση των ακτινιδίων, εξελισσόμενη καλλιέργεια για την περιοχή που χαρακτηρίζεται από υψηλές απαιτήσεις σε νερό. Τα αποτελέσματα της αξιολόγησης για τα ακτινίδια, είναι πολύ ελπιδοφόρα σχετικά με την ικανότητα του μοντέλου να αντικατοπτρίζει την υγρασία του εδάφους στο χωράφι και να οδηγεί σε εξοικονόμηση νερού, ενέργειας και εργασίας. Βρίσκονται βελτιώσεις σχετικά με το μοντέλο, τα σύνολα παραμέτρων και την καταχώριση των εφαρμογών άρδευσης.

Sinossi in lingua italiana

In Grecia, come molti paesi del Mediterraneo, l'irrigazione è il principale utilizzatore di acqua. Quindi, lo sviluppo di strumenti operativi che supportano le decisioni e forniscono raccomandazioni volte a migliorare la gestione dell'irrigazione è di grande importanza. In questo rapporto viene valutato per il caso del kiwi, un coltura caratterizzata da un elevato fabbisogno idrico. I risultati della valutazione per i kiwi sono molto promettenti per quanto riguarda la capacità del modello del sistema di riflettere l'umidità del suolo sul campo e portare a risparmi di acqua, energia e manodopera. Sono in corso miglioramenti per quanto riguarda il modello, i set di parametri e la registrazione delle applicazioni di irrigazione.

References

Allen, R.G., Pereira, L.S., Raes, D. And Smith, M. 1998. Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. FAO, Rome: http://www.fao.org/docrep/x0490e/x0490e00.htm

Cobos D.R., 2008. 10HS Volume of Sensitivity Decagon Devices, Application Note. Διαθέσιμο στο: http://www.onsetcomp.com/files/15925-B%2010HS%20Volume%20of%20Sensitivity.pdf, Accessed: 10/4/2017

DAEWM (Decentralised Administration of Epirus – West Macedonia), 2015. Agrometeorological network at the plain of Arta: http://system.irrigation-management.eu/

Dichio, B., Montanaro, G., Sofo, A., Xiloyannis, C. (2013). Stem and whole-planthydraulics in olive (Olea europaea) and kiwifruit (Actinidia deliciosa). Trees 27,183–191. https://doi.org/10.1007/s00468-012-0787-3

GMA - Greek Ministry of Agriculture (1989). Determination of minimum and maximum limits of the necessary quantities for the sustainable use of water for irrigation. Govern. Gazette (GG) B' 42 2/6/1989 Ministerial Decision Φ.16/6631 (in Greek)

OPEKEPE - Greek Payment Authority of Common Agricultural Policy (2016). Provision of data regarding arboriculture in Arta / Greece (Codes EFY16: 45.2 / EFY15: Other orchards and POI: 14025, 8194, 45204, 45205 and 45203)

Torres-Ruiz J.M., Perulli G.D., Manfrini L., Zibordi M., Velascoo G.L., Anconelli S., Pierpaoli E., Corelli-Grappadelli L., Morandi B. (2016). Time of irrigation affects vine water relations and the daily patterns ofleaf gas exchanges and vascular flows to kiwifruit (Actinidia deliciosa Chev.). Agr. Wat. Man. 166, 101–110. https://doi.org/10.1016/j.agwat.2015.12.012

Tsirogiannis I., N. Malamos P., P. Barouchas, P. Baltzoi, K. Fotia, G. Tenedios, D. Kateris, D. Giotis, E. Tsoumani, S. Chiras and A. Christophides, 2017. Evaluation of an operational participatory system for irrigation recommendations - Case study for kiwifruit crop in Greece. 28th Conference of the Greek Horticultural Society (Oct 16 - 20, Thessaloniki): 465-468 (in Greek)

Twarakavi, N.K.C., Sakai, M., and Šimůnek, J., 2009. An objective analysis of the dynamic nature of field capacity. Water Resources Research, 45 (10). Available at: http://onlinelibrary.wiley.com/doi/10.1029/2009WR007944/full, accessed: 25/2/2019

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