# 2016 Joint Call
# Final Progress Report
## Sustainable management of water resources in agriculture, forestry and freshwater aquaculture sectors

### Optimizing water use in agriculture to preserve soil and water resources (WATER4EVER)

This document must be filled in by the project coordinator with the help of its project partners and must be sent to the WaterWorks2015 Follow-up Secretariat by **31/03/2021** (for Consortium WATEREVER)**.**

The WaterWorks2015 Follow-Up Secretariat will ensure distribution to the concerned national funding agencies. The project coordinator is responsible for sending a copy of the report to its partners.

**Optimizing water use in agriculture to preserve soil and water resources (WATER4EVER)**

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Project Website: http://water4ever.eu/
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Duration of project:
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Period covered by this report: 01/07/2017 to 31/12/2020

Title of the Final Technical Report: Optimizing water use in agriculture to preserve soil and water resources (WATER4EVER). Final Technical Report
Authors of the Final Technical Report: WATER4EVER Consortium

**Please ensure that you do enclose the Final Technical Report as an Appendix to this report. If this report cannot be made available publicly in reason to IPR considerations, please provide also a version of the Final Technical Report for dissemination (Public Report).**

1. Publishable Summary

*Maximum 1 page*

Agriculture is by far the largest consumer of water, with about 70% of the diverted water being used in irrigation. Agriculture is also considered as a key source of diffuse pollution with inefficient practices resulting in high water and nutrient (particularly N and P) surpluses that are transferred to water bodies through diffuse processes (runoff and leaching), promoting eutrophication with associated biodiversity loss. WATER4EVER aims to demonstrate the connectivity between agricultural practices carried out at the plot scale and the resulting environmental effects that are usually first perceived further downstream. For that, the project combines the most performant monitoring strategies at the plot scale to provide detailed information of water flow and nutrient transport, integrating then this information at the catchment scale to close the gap between diffuse loads and water quality degradation.

The specific objectives are: (i) to develop an automatic irrigation and fertilization Decision Support System (DSS) based on online data and forecast models; (ii) to develop new strategies for continuous monitoring of crop development based on optical sensors installed on fixed and mobile ground, drone and satellite platforms; (iii) to improve process-based models for the dynamics of water and its implication on nutrient budgets, crop development, and soil erosion; (iv) to connect plot and catchment scale models to quantify the effect of local agriculture practices on downstream water availability and quality; and (v) to disseminate and transfer knowledge and technology by means of public information adapted to different stakeholders.

WATER4EVER was implemented in multiple case studies in Portugal, Spain, Italy, and Turkey. The partners' early work was the collection of field datasets for the calibration/validation of some of the innovative tools and approaches developed in the project. These included: (i) a modular smart camera for crop monitoring, which was integrated with other modular and open-source IoT based technologies to upgrade conventional machinery with variable rate technologies to reach higher levels of precision for crop monitoring; (ii) an improved irrigation scheduling tool for process-based modelling; (iii) a water prediction model for regulated deficit irrigation scheduling based on the Gaussian regression using the day of the year and the daily maximum temperature as inputs; (iv) the IrrigaSys DSS for irrigation water management at the plot scale based on online, open source tools; (v) soil moisture maps (1 km resolution) produced using the DISPATCH (DISaggregation based on a Physical And Theoretical scale CHange) algorithm for the downscaling of soil moisture products (40 km resolution) from MODIS remote sensing data; (vi) soil moisture maps (100 m resolution) retrieved from Sentinel-1 SAR data; and (vii) vegetation products (LAI and NDVI) (30m resolution) derived from Landsat/Sentinel-2 sensors for crop monitoring. Project results further included: (i) validated protocols for sustainable irrigation water management; (ii) guidelines on the best practices for integrating EO data in model-based irrigation and fertilization optimization strategies; and (iii) guidelines on the best practices related to soil and water management for each case study.

WATER4EVER results can contribute directly to the implementation of the Nitrates Directive and of the Water Framework Directive. The Project is particularly dedicated to raising awareness on the causes of diffuse pollution and respective impacts on the availability and quality of downstream water bodies; on reducing costs of production factors by improving irrigation water and fertilizers efficiency; and on demonstrating the capabilities of emerging technologies (smart cameras, satellite data, process-based models) for improving irrigation water and fertilization management.

WATER4EVER is led by Instituto Superior Técnico (Portugal) and includes Deimos Engenharia SA (Portugal), Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência (Portugal), isardSAT (Spain), Universidad Politécnica de Cartagena (Spain), Institute for Agricultural and Earthmoving Machines of the National Research Council of Italy (Italy), and the Abant Izzet Baysal University (Turkey) in the consortium. More information on WATER4EVER is available at http://water4ever.eu/.

2. Work Performed and the Results achieved within the Project

*Maximum 10 pages*

### *a. Scientific and technological progress*

WATER4EVER is strongly dedicated to the development of technologies aimed at monitoring crop needs for improving irrigation water and fertilization use efficiency at the field plot scale. The project further includes a multi-scale approach for establishing the link between local scale agricultural practices and downstream water quality degradation problems, which assessment can only be made at a scale larger than the field plot.

The project was initiated with the kick-off meeting in October 2017, where partners decided to set the number of cases studies to a total of 10 agricultural fields, following the feedback provided by the project's Advisory Board with support of available data. These included the "Lezírias" field in Portugal; "Foradada", "Agramunt", and "Ametllers" in Catalonia, Spain; "Beníajan", "La Hornera", and "Don Fernando" in the Múrcia region, Spain; "Tenuta Cannona" and "Vezzolano" in northern Italy; and "Ardahan" in eastern Turkey. Later, two additional agricultural fields, "Benavente" and "Aveleda", both located in Portugal, in which the available data fitted the purposes of the project, were also added as case studies to the project. The respective catchments where most of these agricultural fields were located were also selected as study sites, namely "Lezíria do Tejo" in Portugal, the Segre basin in Spain; and the Orba basin, in Italy.

WATER4EVER aimed to find tailor-made solutions for local management problems. Hence, the approaches and tools pursued in the project to tackle with those issues varied between case studies. In Portugal and Spain, the solutions addressed water scarcity issues and the development of full and/or regulated deficit irrigation strategies for improving irrigation water use and fruit quality of field and woody crops. In Italy, the focus was on strategies for minimizing runoff and soil erosion of non-irrigated hillslope vineyards. In Turkey, the goal was the assessment of soil organic carbon and nutrient patches as indicators of human-induced disturbances in terrestrial and aquatic ecosystems.

The WP2 "In situ measurement technologies" was coordinated by INESCTEC, with UPCT involvement. The aim of this WP was to (i) research and develop a cost-effective visual monitoring (optical tools) system for plant diagnose/monitoring and precise spraying/irrigation/fertilization; (ii) acquire sensor data in the field considering different protocols for accurate models extraction; and (iii) build control models for the self-regulation of different deficit irrigation treatments according to established irrigation instructions.

The WP2 included 3 tasks and produced 4 deliverables describing results.

Task 2.1 "visual monitoring system development" included the development of a modular prototype of a modular smart camera for crop monitoring. This prototype integrated the modular and open-source IoT based technologies AgIoT (http://agiot.inesctec.pt/), which are open source IoT solutions that are interoperable with ISOBUS and FIWARE standards and portable solutions for different contexts application. In the WATER4EVER context, these meant updating agricultural machinery and tools to acquired crop (canopy, water stress,..) information during their normal operation; updating agricultural machinery and tools with variable rate technologies for higher levels of precision during fertilization and spraying treatments; using conventional agricultural machinery and implements to operate under prescription maps (ISO-XML files) obtained from FMIS and DSS apps and so on. D2.1.1. "Prototype of modular smart camera for crop monitoring" presented a technical description of the prototype (delivered on Month 27). D2.1.2. "Firmware with real time NDVI based processing capabilities" described the embedded algorithms for crop monitoring (Month 27). This prototype had 3 configuration hardware and were tested in "Aveleda", "Vezzolano", and "Beníajan" fields, with D2.1.2. also presenting some of the main results obtained in those fields.

Task 2.2. "setup of experimental plot and data acquisition" served as framework to deploy a series of FDR probes and LVDT sensors for monitoring soil and plant water status, and for establishing improved irrigation schedules of woody crops based on sensor data, model predictions, and weather forecasts. D2.2.1. "Datasets of acquired data by the sensors in the field" described the data collected by those sensors in the cases studies set in the Múrcia region (Month 36). D2.2.2. "Validated protocols for sustainable

irrigation" presented the irrigation protocols for different woody crops grown in southern Spain depending on water availability and quality (Month 36).
Lastly, Task 2.3 "Data analysis and models extraction" included the software developments for irrigation automation based on the analysis of soil, crop, and weather conditions as well as the validated irrigation protocols from the previous task. D2.3.1 "Measuring protocol and a DSS to support optimal crop irrigation" described the model algorithm that was developed with the objective of optimizing the irrigation water in table grapes crops under Mediterranean Semi-Arid Conditions and its integration in a software platform based in the Cloud Computing paradigm (Month 36).
The WP3 "Remote sensing" was coordinated by Deimos and isardSAT, with all partners involved. The WP3 was dedicated to the development, customization, and production of satellite-based products for the different case studies. These were medium to high resolution maps of (i) land use/land cover (LULC) for a better characterization of the land cover information at the catchment scale; (ii) crop vegetation monitoring based on vegetation indices (NDVI) and biophysical parameters (LAI); and soil moisture to better characterize evapotranspiration modelled processes at both plot and catchment scales.
The WP3 included 6 tasks and produced 7 deliverables with results.
Task 3.1 "EO data requirements & procurement plan" aimed at assessing EO products requirements to be developed for the different case studies, including spatial and temporal resolutions of soil moisture, NDVI and LAI maps, and the adoption of LULC classes. For each case study, the spatial resolution of the soil moisture products was set at 1km and 100m, while NDVI and LAI maps were set at a 30 m. The same reference period (2012-2018) was considered for all products. The LULC classes were made to correspond to those required by the MOHID-Land model used in WP4. Task 3.1 further included the data procurement plan for EO products already developed, required satellite planned acquisitions for each defined imagery stream and monitoring period, and validation data for the LULC and soil moisture products. Two deliverables were produced within this task at Month 3, corresponding to D3.1.1 "EO Product specification document v1" which described the EO product requirements mentioned above, and D3.1.2. "Data procurement plan" which explained data needs, formats, sources, and validation procedures for each EO product. The M3.1 "EO products readiness review" was also accomplished by Month 3.
Task 3.2 "1st cycle production and delivery of the LULC and NDVI/LAI products" delivered the LULC and NDVI/LAI products for each case study. The LULC maps were generated from Sentinel-2 and Landsat 8 satellite data using machine learning algorithms, with the CORINE Land Cover data being used then as the ground truth dataset for the training/validation stage. The NDVI/LAI products were computed from satellite bands. A total of 88 NDVI/LAI images were produced for "Lezírias" (Portugal), 158 for Segre (Catalonia, Spain), 150 for Múrcia (Spain), 94 for Orba (Italy), and 110 for Ardahan (Turkey). D3.2.1 "LULC and NDVI/LAI products v1" was delivered at Month 18. The M3.2 "EO products evaluation review" was accomplished at the same time.
Task 3.3 "1st cycle production and delivery of the soil moisture products" produced 1km soil moisture maps for all case studies using the DISPATCH (DISaggregation based on a Physical And Theoretical scale CHange) algorithm for the downscaling of the 40 km SMOS (Soil Moisture and Ocean Salinity) soil moisture data using land surface temperature (LST) and vegetation index (NDVI) data. The algorithm estimated the soil moisture variability at a 1 km resolution within a low (40 km) resolution SMOS pixel by relying on a self-calibrated evaporation model. The soil evaporative efficiency (SEE) term was first derived from LST and vegetation cover data. By taking into account the instantaneous spatial link between SEE and SM, the algorithm then distributed the high-resolution soil moisture around the low resolution observed mean values. The M3.3 "EO products evaluation review" was accomplished at month 18. D3.3.1 "Soil moisture products v1" was accomplished at Month 18, delivering a total of 2386 maps for Lezírias (Portugal), 2403 maps for Segre (Catalonia, Spain), 2386 maps for Segura (Múrcia, Spain), 2401 maps for Orba (Italy), and 2403 maps for Ardahan (Turkey). D3.3.2 "soil moisture products evaluation report" was also delivered at Month 20, presenting the validation results for the 1 km soil moisture products. These included the comparison between soil moisture data derived from satellite products and field sensors installed in the case studies, with respective goodness-of-fit indicators. D3.3.3 "Soil moisture product specification document v2" was also finalized at Month 20.
Task 3.4. "2nd cycle production and delivery of the LULC and NDVI/LAI products" updated the products delivered in Task 3.2. D3.4.1 "LULC and NDVI/LAI products v2" was delivered at Month 35. D3.4.2 "LULC and NDVI/LAI evaluation report v2" evaluated the vegetation products produced in the project (Month

35), updating or including also information from pending deliverables D3.2.2 "LULC and NDVI/LAI products evaluation report" and D3.2.3 "EO product specification document v2".
Task 3.5 "2nd cycle production and delivery of the soil moisture products" delivered 100 m resolution soil moisture maps retrieved from Sentinel-1 SAR data for the "Lezírias", "Foradada", "Agramunt", and "Ametllers" case studies. D3.5.1 "Soil moisture products v2" was accomplished at Month 31. D3.5.2 "soil moisture products evaluation report" was also delivered at the same date.
Lastly, Task 3.6 "best practices report" defined improved guidelines for the integration of EO data into hydrological models based on the results from WP4. D3.6.1 "Best practices report on the EO integration in model-based irrigation and fertilization optimization strategies" was accomplished at month 42, constituting one of the main products of WATER4EVER.
The WP4 "Modelling" was coordinated by IST-ID and AIBU, with all partners involved. The main objective of this WP was to model soil water dynamics and nutrient transport in the different case studies. Plot scale modelling included the simulation of vadose zone hydrology, accounting also for leaching to the saturated zone and crop activity (growth and decay, water and nutrient uptake). Catchment scale modelling focused on the extrapolation of plot results to the catchment scale while also considering leaching, runoff, groundwater dynamics, and nutrient consumption due to vegetation uptake and microbiological activity.
The WP4 included 4 tasks and produced 5 deliverables with results.
Task 4.1 "Catchment modelling - implementation" described the implementation, calibration, and validation of the MOHID-Land model in all case studies and scales. D4.1.1 "Model calibration and validation" was produced at Month 20, presenting the simulating of soil water dynamics and crop development in the different case studies using the MOHID-Land model, as well as the respective goodness-of-fit indicators obtained by comparing model simulations with measured values.
Task 4.2 "Catchment model exploitation" reviewed the previous work based on the inputs from WP3. D4.2.1. "Model performance. Applications using the MOHID-Land model" (updated last at Month 42) gathered the results from applications using the MOHID-Land model. At the field plot scale, the model was used to simulate soil water dynamics and crop development in the "Lezírias", "Benavente", "Foradada", "Agramunt", and "Tenuta Cannona" case studies, providing also improved irrigation schedules for improving irrigation water use efficiency in the different fields. At the catchment scale, the MOHID-land model was implemented in the "Lezíria do Tejo", Segre, and Orba basins. D4.2.1 further presented the comparison between soil moisture outputs from the MOHID-Land model and those from remote sensing products, which helped defining the guidelines issued in D3.6.1. D4.2.2. "Model performance. The SOC-$N_{Anatolia}$ Model" (updated last at Month 42) presented a description of the SOC-$N_{Anatolia}$ Model used in the Ardahan case study and respective results.
Task 4.3 "plot model developments" described the main improvements in MOHID-Land for pursuing the WATER4EVER objectives. These included the upgrade of the irrigation scheduling tool for consideration of the spatial variability of irrigation and crop needs at the field and catchment scales, and the dynamics of crop coefficients for running the model in operational mode. D4.3.1 "model developments" described the respective developments in the MOHID-Land code (last update at M42).
Lastly, Task 4.4 "Plot and catchment model integration" aimed to develop an interface between plot and catchment applications, with processes analysed in detail at the plot scale, with the interface changing then information to access the impacts of agricultural practices at a larger scale. This procedure was implemented in MOHID for ocean modelling, but not in the MOHID-Land version used for terrestrial systems modelling. D4.4.1 "Upscaling farm plot scale into catchment scale" presents the upscaling framework to be included in the MOHID-Land model (Month 42).
The WP5 "Case Studies" was coordinated by IMAMOTER with all partners involved, and focused on the setup and management of the study sites for: (i) field testing and implementation of the innovative monitoring tools and models developed in other WPs; (ii) improvement of the monitoring techniques and upgrade of existing datasets; (iii) comparison of different hydrological and soil conditions for assessment of the capacity of the developed tools; (iv) data providing for calibrating and validating the process-based models simulating water and nutrient dynamics at the plot and catchment scales; and (v) performing the demonstrations necessary to grant the involvement of stakeholders. WP5 activities were carried out in collaboration with other WPs, particularly: WP2 for implementation and testing of new sensors; WP3 for collection and calibration of remote sensing products; and WP4 for implementation and calibration of the hydrological modelling results at the plot and catchment scales.

The WP5 included 4 tasks and produced 9 deliverables describing its results.
Task 5.1 "Setup of experimental plots" considered: (i) the coordination of all partners involved in the case studies; (ii) the selection of sensors and applicable innovative monitoring technologies; (iii) the designs for the implementation of the study cases; iv) the check and integration of field equipment and instrumentation; and (v) the activities necessary for the involvement of communities and relevant organizations (i.e. water agencies and consortia). This task produced Deliverable D5.1.1 "Experimental plots design plan" at Month 8, giving a complete description of all case studies. Milestone M5.1 "Case studies coordination meeting" was reached during the Kick-off meeting (Lisbon, 10/10/2017).
Task 5.2 "Monitoring activities for implementation of innovative monitoring tools" aimed to perform monitoring activities and collect data at the plot scale (climate data, soil and plant water status, crop growth and yields, and yield quality parameters) for (i) calibration/validation of the modelling tools in WP4, and (ii) implementation/validation of innovative products developed in WP2 and WP3. Deliverable 5.2.1 "Datasets of acquired data by field sensors" listed the available datasets acquired by field sensors for each case study (last update on M40), while D5.2.2 "Protocol of tools application" (M15) summarized the use of the datasets by tools developed in other WP (produced on M16). M5.2 "Start of monitoring activities" was accomplished at project kick-off since most experimental sites were already active at the beginning of the project. Monitoring activities in most fields continued until the end of 2020.
Task 5.3. "Data collection for models calibration" provided data for calibrating/validating the modelling task in WP4, namely for simulating soil water dynamics and nutrient transport at the plot and catchment scales, and for validating the soil moisture products produced in WP3. The data were made available to all partners in a cloud server set up by the Project coordinator. The partners directly involved in the case studies were then responsible for the maintenance and update of their own datasets. Thus, D5.3.1 "Input data for model calibration" (last update on M10), and D5.3.2. "Dataset for model validation" (last update on M40) described the available data for each case study as well as the paths in the cloud server for retrieving it. M5.3 "Update of innovative monitoring techniques" and M5.4 "Mid-term continuous data acquisition" were reached halfway the project timeline.
Finally, activities in Task 5.4. "Data management and providing" focused on the development of some of the main product of the WATER4EVER project: the implementation of forecast models into an automatic irrigation and fertilization Decision Support System (DSS) and development of a user-friendly application; and the guidelines on the best practices related to soil and water management for each case study. Four deliverables were produced in this task. D5.4.1 "Protocol for data management" provided a description of the protocol followed to manage the data collected from case studies, enlisting the data sources for each monitored parameter and the protocol followed to collect/extract data (Month 5). D5.4.1 further described the cloud service employed (Microsoft® OneDrive) by the project coordinator for data sharing amongst partners. D5.4.2 "Architecture of Wireless Sensor Network" reviewed the state-of-the-art related to new trends and developments in the field of wireless sensor networks (WSN), illustrating then the architecture of WSN for the experiments being run in the Project (Month 7). D5.4.3. "Software for irrigation and fertilization automation" described the IrrigaSys as a decision support system for supporting irrigation water management using online, open access tools (last update on Month 29). The description included its structure and needs for implementing and running it at the plot scale, and was tested in the "Lezírias", "Benavente", "Foradada", "Agramunt", and "Ametllers" fields. Lastly, D5.4.4. "Best practices related to soil and water management" compiled the solutions on the best management practices adopted in WATER4EVER for protection soil and water resources in the project case studies (last update on Month 42).
The WP6 "Dissemination" was coordinated by IST-ID and UPCT with all partners involved. The webpage was online on April 2018 with IST-ID and UPCT being set as administrators. 5 newsletters were prepared during the project lifetime: December 2017, June 2018, December 2018, June 2019, and December 2019. Templates were prepared by UPCT while contents were provided by IST-ID with contributions from all partners. The Project results were also presented in several conferences and workshops, but unfortunately the main results of WATER4EVER could not be presented yet to the scientific community due to the pandemic situation related with the SARS-COV-2 outbreak. For this reason, the final workshop was held online and made available to everyone interested in the WATER4EVER project results at https://youtu.be/KsabMe9Q-FI. Thirteen scientific papers were published (or are under revision) in Peer

Reviewed International Journals, and two more were published as book chapters. Three doctoral students and four master student also pursuing their studies within the project framework.

## b. List of students supported by or affiliated with this consortium

| Name | Gender | Host organisation | Country | Field of study | Degree achieved (PhD, MSc, MA, etc.) | Dissertation/ Thesis title | Task in project |
|---|---|---|---|---|---|---|---|
| Lucian Simionesei | Male | IST-ID | Portugal | Irrigation water management | | Modeling water and nutrient fate in different agro-ecosystems for improving land management practices | Modelling |
| Ana Ramos Oliveira | Female | IST-ID | Portugal | Watershed management | | A modelling approach for improving water governance at the regional scale | Modelling |
| Rodrigo Gomes Borges | Male | INESC TEC | Portugal | Remote Sensing modeling | MSc | Noninvasive Techniques for Vine Perception | WP2 water percept |
| Antoni Granés González | Male | isardSAT | Spain | Watershed management | Màster en Geoinformació Universitat Autònoma de Barcelona | Water budget estimation in the Algerri Balaguer irrigation district 13/07/2018 | WP4 Modelling |
| Qi Gao | Female | isardSAT | Spain | Remote Sensing modeling | PhD in Tecnologies de la Informació i la seva Aplicació en Gestió, Arquitectura i Geofísica, Universitat Ramon Llull | Estimation of water resources on continental surfaces by multi-sensor microwave remote sensing | WP3 Remote Sensing |

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| | | | | | | 30/07/2019 | |
| Kadir Yıldız | Male | AIBU | Turkey | Watershed management and modelling | MSc | A process-based model of spatio-temporal dynamics of carbon and nitogen in the case of Ardahan watershed | Modelling |
| Eslem Çınar | Female | AIBU | Turkey | Water quality and estimation of stream metabolism | MSc | Estimation and quantification of surface water metabolism dynamics on monthly basis: a case study of Ardahan | Quantification of water quality |

### c. List of staff supported by or affiliated with this consortium

| Name | Gender | Host organisation | Country | Field of study | Task in project |
|---|---|---|---|---|---|
| Marcella Biddoccu | Female | CNR-IMAMOTER (now CNR-STEMS) | Italy | Sustainable agriculture | Coordination of WP5 (Case studies in Italy, Portugal, Spain and Turkey), of the aspects related to water management and erosion of the soil in agriculture; experimental activities in the Italian case study; dissemination of project results |

### d. Mobility of staff and students supported by or affiliated with this consortium

| Name | Gender | Host organisation | Site of visit | Purpose of visit | Duration of visit | Output of visit |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Marcella Biddoccu (IMAMOTER, Italy) | Female | IST-ID | Lisbon, Portugal | MOHID-Land Training School | 5 days | MOHID-Land setup for implementation in Italian study case |

## e. *Collaboration, coordination and mobility*

The WATER4EVER partners contributed directly or indirectly to the progress of all WP.

WP1 was led by IST-ID and refers to project management and coordination. IST-ID was responsible for creating the project website, for scheduling and planning the bi-annual coordination and technical meetings, for creating the cloud file sharing service used for exchanging information between partners, for producing the newsletters with project novelties, and for controlling the progress of the project milestones and deliverables. IST-ID was further responsible for coordinating the writing of the mid-term and final progress reports as well as the final technical report. Each partner was then responsible for a specific WP, with the project coordinator supporting them when needed.

WP5 is considered the starting point of WATER4EVER, involving the field activities in the case studies. This WP was coordinated by IMAMOTER, with partners being directly responsible for the case studies in their geographical locations. As such, IST-ID was responsible for "Lezírias" in Portugal; isardSAT for "Foradada", "Agramunt", "Ametllers" and "Algerri Balaguer" in Catalonia, Spain; UPCT for "Beniaján", "La Hornera", and "Don Fernando" in Múrcia, Spain; IMAMOTER for "Tenuta Cannona" and "Vezzolano" in Italy; and AIBU for "Ardahan" in Turkey. The Portuguese and Catalonia sites differed from the others since field management was directly performed by the WATER4EVER Advisory Members Companhia das Lezírias and Aigües del Segarra Garrigues, respectively. IST-ID and isardSAT had only a mere secondary role on the decision-making of those sites. In all other case studies, field activities were directly managed by partners. WP5 produced substantial information on soils and crop monitoring using a wide variety of field sensors that were voluntarily made available to all partners by the case studies leaders, and which were fundamental to carry out the other WPs. Thus, WP5 contributed with field data to WP2 for testing of new sensors; WP3 for calibration and validation of remote sensing data products; and WP4 for implementation, calibration, and validation of the hydrological model at the plot and catchment scales. As such, all partners were in close contact with each other since the beginning of the project to better understand the available information and needs of others. IMAMOTER has had here a fundamental role in trying to speed up the process of data collection and its interpretation. IMAMOTER also led the production of one of the main deliverables of the project, namely the guidelines on the best practices related to soil and water management for each case study.

WP2 was coordinated by INESC TEC, who developed the prototype of the modular smart camera for crop monitoring. This prototype consisted of a modular hardware called AGIOT based on RaspberryPi and Onion Omega processing units to acquire optical based images and enable the ISOBUS communication. This prototype was tested in case studies in Portugal, Spain, and Italy. These tests involved the close cooperation of INESC TEC, UPCT, and IMAMOTER for the logistics involved. Within task WP2, UPCT also developed and tested field sensors and monitoring techniques for the accurate computation of irrigation needs. A series of validated regulated deficit irrigation protocols were established for table grapes, nectarines, and flat peaches based on data from the experimental sites run by UPCT, which considered the availability and quality of irrigation water.

WP3 was coordinated by DEIMOS and isardSAT. DEIMOS produced the LAI/NDVI and LULC products for each case study with a resolution of 30 m, validating them then using the CORINE Land Cover map as ground-truth. isardSAT delivered the 1 km and 100 m soil moisture maps for all case studies, validating them afterwards using data provided by the case studies leaders: DEIMOS, isardSAT, and ISD-ID cooperated then on the delivery of another main output from WATER4EVER project, namely the guidelines on the best practices for integrating EO data in model-based irrigation and fertilization optimization strategies. These guidelines integrated the main findings on the integration of remote sensing products in hydrological modeling performed at WP4.

WP4 was coordinated by IST-ID and AIBU and involved the hydrological modeling of soil physical and chemical processes in the different case studies. IST-ID implemented, calibrated, and validated the MOHID-Land model for the case studies in Portugal and Spain. IMAMOTER run the MOHID-Land simulations for the Italian case study. IST-ID then cooperated with isardSAT for the comparison of model outputs of soil moisture with the correspondent soil moisture products development from remote sensing for the case studies of Portugal, Spain, and Italy. AIBU developed the SOC-NAnatolia Model for simulating the dynamics of soil organic carbon and nitrogen in the Turkish case study.

A training session was first held in Lisbon on October 1-4, 2018 for introducing the MOHID-Land model to the case studies leaders, namely the model's fundamentals, data needs, and implementation, calibration, and

validation procedures. This training section was attended by IMAMOTER and AIBU. A second training section was given by IST in Rio de Janeiro, Brazil, on January 15-18, 2019, which helped disseminating some of the WATER4EVER tools. A third training section was also held in Istanbul on May 2019, for the partners running MOHID-Land model simulations in their case studies. AIBU researchers also spent a week at IST-ID on April 2019 to gain a deeper knowledge on the MOHID-Land model.
WP6 was coordinated by UPCT, with all partners contributing to the dissemination of WATER4EVER objectives and results whenever possible. Particular attention was given to the Advisory Board members, with whom contacts were more regular.
Links with other EU projects:
The WATER4EVER consortium organized a joint session with WATER JPI projects AGRINUPES, REWATER, and AQUAVAL on November 2019, with the purpose of evaluating possible synergies and collaborations between these projects and team consortiums. The WATET4EVER project was further invited by the AGRINUPES project for presenting its results in a joint section help on December 2020, involving also the participation of WATER JPI projects REWATER, OPERA, and POTENTIAL. The team further established links with the following projects REC (H2020-MSCA-RISE-2014), ACCWA (H2020-MSCA-RISE-2018), SMELLS (ESA InnovatorsIII), and SOIL4EVER (FCT).

### f. *Infrastructures*

No infrastructures were used in the project.

### g. *Impact and knowledge output*

The project developed a series of innovative tools, which constituted the main knowledge outputs of WATER4EVER. There were:
(i) a modular smart camera for crop monitoring, which was integrated with other modular and open-source IoT based technologies to upgrade conventional machinery with variable rate technologies to reach higher levels of precision for crop monitoring.
(ii) an improved irrigation scheduling tool that considered the spatial variability of soil properties and crop state variables on process-based modelling of soil water fluxes and crop development.
(iii) a water prediction model for regulated deficit irrigation scheduling based on the Gaussian regression using minimum inputs (day of the year and the daily maximum temperature).
(iv) the IrrigaSys DSS for irrigation water management at the plot scale based on online, open source tools.
(v) soil moisture maps at 1 km and 100 m resolution for watershed and field scale management, respectively.
The project further established a series of protocols and guidelines based on the results obtained. These included:
(i) validated protocols for sustainable irrigation water management
(ii) guidelines on the best practices for integrating EO data in model-based irrigation and fertilization optimization strategies.
(iii) guidelines on the best practices related to soil and water management for each case study.
The impact of the WATER4EVER was expected to increase in the last third of the project timeframe as the innovative tools and management guidelines were being concluded. However, dissemination of these results was seriously affected by the on-going restrictions related to the pandemic crises of SARS-COV-2, with most scientific events being canceled or postponed in 2020 as the project was terminating.

### h. *Which 2016 Joint Call theme/themes were addressed by the project? How did the project cover the main aims & objectives of the Call?*

The main topic addressed by WATER4EVER is Challenge 1), Subtopic 1.a, through innovative water systems to implement precision irrigation. The project also addresses Challenge 2), because through precision irrigation it aims to minimise soil and nutrient losses to surface water and ground water, and through its

catchment scale modelling it addresses the thematic of nitrogen and phosphorus loads from agriculture into rivers.

During the last years, the scientific community has shown a special interest in the development of deficit irrigation strategies, particularly for permanent woody crops, based on significant reductions of the seasonal evapotranspiration (ET) without affecting production or quality. WATER4EVER has thus focused on regulated deficit irrigation (RDI) practices to reduce water supply to crops during non-critical periods while maximizing water productivity. The success of these practices greatly depends on a continuous and precise control of the plant and soil water status to adjust water supplies to crop phenological periods. New methods of estimating crop water requirements by diagnosing plant water status have been proposed in recent years, including the use of stems water potential at midday (SWP) and maximum daily trunk shrinkage (MDS). SWP has proven to be a robust and sensitive indicator, but its use has the disadvantage of being a discontinuous measurement. MDS is an excellent indicator of water stress, with continuous information provided by the LVDT sensors placed in the trunk of the tree.

The normalized difference vegetation index (NDVI) can also help to diagnose plants water stress, identify nutrition problems, and estimate crop yields. WATER4EVER explored the application of "low-cost" smart cameras for NDVI extraction in fixed crop spots or applied to the agricultural machinery. These smart cameras, with advanced processing algorithms (clustering and classification), can complement continuous data provided by aerial NDVI images and MDS measurements to optimize the output results of crop models used in Decision Support Systems (DSS). Besides, the integration of smart cameras with ISOBUS capability enables precision treatments, which will help reducing fertilizers and pesticides loss. The control of plants' development using low cost sensors installed on fixed or mobile ground platforms and satellite remote sensing (RS) data was one of the main objectives of WATER4EVER, but to get there field measurements had to be carried on first to provide the necessary knowledge about plants' development and activity under RDI conditions.

WATER4EVER is also dedicated to the use of satellite and UAV based RS datasets as input for optimizing agricultural production. The ability to cover large remote areas at different spatial and temporal resolutions, compatible with the characterization of the state and dynamics of several meteorological, vegetation growth, and hydrological variables establishes them as a preferential monitoring data source, especially in regions with limited ground based data. In fact, RS can provide information on different variables such as land surface temperature, precipitation, soil moisture, crop classification, crop phenological period, growth, damage, stress, and yield. In model-based schemes these datasets can be used directly as input, integrated through data assimilation methods, or used as validation/optimization datasets for models' outputs. In this project, two different Earth Observation (EO) based datasets are developed: (i) NDVI/LAI to provide dynamical information on crop growth; and (ii) soil moisture at 100 m and 1 km resolution for monitoring of surface soil moisture status at the field and catchment scales.

Soil conservation and particularly soil erosion is another critical issue addressed in WATER4EVER. Tree crops and vineyards, often situated on steep hill slopes, are particularly subjected to suffer intense runoff and soil erosion, with conventional agricultural practices gradually compromising soil quality, including fertility decrease, nutrient losses, and organic carbon stock reductions. Furthermore, its off-site impacts are relevant, which include water-courses pollution, supply of sediments into rivers and reservoirs, and muddy floods. In WATER4EVER, research has been directed towards developing better soil management practices to enhance soil and water conservation in Mediterranean crops, with particular emphasis on temporary or permanent cover crops.

Lastly, WATER4EVER is dedicated to the development of models to support agricultural water management and integration of field data collected by the wide variety of sensors available today to monitor soil water dynamics and crop development at the plot scale. These models usually describe the vertical movement of water in the vadose zone, root water uptake, and crop development with great detail. Fully distributed models can further integrate the vadose zone, the saturated zone, soil surface runoff, and the river network, and are essential to make the link between plot scale agriculture practices and the catchment scale. Distributed models like the MOHID-Land model (Fig. 1.2.1) compute surface runoff and thus soil erosion and do not have a (artificial) boundary between the vadose zone and the saturated zone. The inclusion of the capacity to simulate a main crop and a cover crop, including its role on water, sediments, organic matter, and nutrient budgets is another advantage of these models to combine RDI and soil conservation. In this case, the agriculture model would get from the catchment model the level of the saturated zone and the catchment

model would get from the plot its contribution for surface runoff, sediment budget, dynamic aquifer recharge, and dissolved salts (including nutrients).

### *i. Is the collaboration between Consortium partners expected to continue after the funding period? If yes, please describe how.*

Collaboration between the consortium partners is expected to continue after the funding period as there are still joint publications awaiting revision or being prepared for submission. Project results also opened new research lines worth exploring with the cooperation of partners. All partners are naturally available for leading or integrating new project proposals that further explore the concepts behind the WATER4EVER project, namely those that address the connectivity between agricultural practices and resulting environmental effects; the role of regulated deficit irrigation practices in maximizing water use efficiency and improving the quality of final products of woody crops; and the development of new variable rate technologies for monitoring crop status.
INESC TEC, DEIMOS, and IMAMOTER (since October, 2020, IMAMOTER has become part of the new Institute of Sciences and Technologies for Sustainable Energy and Mobility, STEMS) are now members of the project SCORPION - Cost effective robots for smart precision spraying (http://scorpion-h2020.eu/).

## 3. Table of Deliverables

Please indicate whether the planned deliverables were completed, delayed or readjusted. Please explain any changes, difficulties encountered and new solutions adopted. Please add/suppress fields, if necessary, in the table below.
*Maximum 3 pages*

| Deliverable name | Lead partner (country) | Date delivered (dd/mm/yyyy) | Comments |
|---|---|---|---|
| **WP1** | | | |
| D1.1.1. Webpage | IST-ID (Portugal) | 28/04/2018 | Completed (http://water4ever.eu/) |
| D1.1.2. International communication strategy and tools | IST-ID (Portugal) | 26/09/2017 | Completed |
| D1.2.1. Minutes of Lisbon meeting | IST-ID (Portugal) | 10/10/2017 | Completed |
| D1.2.2. Minutes of Cartagena meeting | IST-ID (Portugal) | 07/06/2018 | Completed |
| D1.2.3. Minutes of Barcelona meeting | IST-ID (Portugal) | 22/11/2018 | Completed |
| D1.2.4. Minutes of Istanbul meeting | IST-ID (Portugal) | 29/05/2019 | Completed |
| D1.2.5. Minutes of Porto meeting | IST-ID (Portugal) | 15/11/2019 | Completed |
| D1.3.1. Minutes of Advisory Board meeting | IST-ID (Portugal) | 23/11/2018 | Completed |
| **WP2** | | | |

| Deliverable name | Lead partner (country) | Date delivered (dd/mm/yyyy) | Comments |
|---|---|---|---|
| D2.1.1. Prototype of modular smart camera for crop monitoring | INESC TEC (Portugal) | 30/09/2019 | Completed |
| D2.1.2. Firmware with real time NDVI based processing capabilities | INESC TEC (Portugal) | 30/06/2020 | Completed |
| D2.2.1. Dataset of acquired data by the sensors in the field | UPCT (Spain) | 30/06/2020 | Completed |
| D2.2.2. Validated protocols for sustainable irrigation | UPCT (Spain) | 30/06/2020 | Completed |
| D2.3.1. Measuring protocol and a DSS to support optimal crop irrigation | UPCT (Spain) | 30/06/2020 | Completed |
| **WP3** | | | |
| D3.1.1. EO Product specification document v1 | isardSAT (Spain) | 16/12/2017 | Completed |
| D3.1.2. Data procurement plan | isardSAT (Spain) | 16/12/2017 | Completed |
| D3.2.1. LULC and NDVI/LAI product v1 | Deimos (Portugal) | 08/12/2018 | Completed (Dataset) |
| D3.3.1. Soil moisture products v1 | isardSAT (Spain) | 19/02/2019 | Completed (Dataset) |
| D3.3.2. Soil moisture product evaluation report | isardSAT (Spain) | 19/02/2019 | Completed |
| D3.3.3. Soil moisture product specification document v2 | isardSAT (Spain) | 16/02/2019 | Completed |
| D3.4.1. LULC and NDVI/LAI product v2 | Deimos (Portugal) | 08/12/2018 | Completed (Dataset) |
| D3.4.2. LULC and NDVI/LAI evaluation report v2 | Deimos (Portugal) | 20/05/2020 | Completed<br>- Updates D3.2.2 LULC and NDVI/LAI evaluation report v1<br>- Includes D3.2.3. EO Product specification document v1 |
| D3.5.1. Soil moisture products v2 | isardSAT (Spain) | 19/03/2020 | Completed (Dataset) |
| D3.5.2. Soil moisture product evaluation report v2 | isardSAT (Spain) | 19/03/2020 | Completed |
| D3.6.1. Best practices report on the EO integration in model-based irrigation/fertilization optimization strategies | Deimos (Portugal) | 15/12/2020 | Completed |
| **WP4** | | | |
| D4.1.1. Model calibration and validation | IST-ID (Portugal) | 19/02/2019 | Completed |
| D4.2.1. Model performance. Applications using the MOHID-Land model | IST-ID (Portugal) | 14/10/2020 | Completed |
| D4.2.1. Model performance. Applications using the SOC-$N_{Anatolia}$ Model model | AIBU (Turkey) | 16/12/2020 | Completed |
| D4.3.1. Model developments | IST-ID (Portugal) | 14/12/2020 | Completed |

| Deliverable name | Lead partner (country) | Date delivered (dd/mm/yyyy) | Comments |
|---|---|---|---|
| D4.4.1. Upscaling farm plot scale into catchment scale | IST-ID (Portugal) | 14/12/2020 | Completed |
| **WP5** | | | |
| D5.1.1. Experimental plots design plan | IMAMOTER (Italy) | 28/02/2018 | Completed |
| D5.2.1. Datasets of acquired data by field sensors | IMAMOTER (Italy) | 31/10/2020 | Completed |
| D5.2.2. Protocols of tools applications | INESC TEC (Portugal) | 28/09/2018 | Completed |
| D5.3.1. Input data for model calibration | IMAMOTER (Italy) | 30/04/2018 | Completed |
| D5.3.2. Dataset for model validation | IMAMOTER (Italy) | 31/10/2020 | Completed |
| D5.4.1. Protocol for data management | IMAMOTER (Italy) | 27/12/2017 | Completed |
| D5.4.2. Architecture of wireless sensor network | INESC TEC (Portugal) UPCT (Spain) | 15/01/2018 | Completed |
| D5.4.3. Software for irrigation and fertilization automation and APP | IST-ID (Portugal) | 11/11/2019 | Completed |
| D5.4.4. Best practices related to soil and water management | All | 02/12/2020 | Completed |
| **WP6** | | | |
| D6.1.1. Scientific publications | All | - | See list of publications in section 9 of this report |
| D6.2.1. Participation in Congresses | All | - | See list of presentations in section 9 of this report |
| D6.3.1. Workshops for end-users | All | - | Cancelled due to the SARS-COV-2 pandemic situation |
| D6.4.1. Final Workshop | All | 20/01/2021 | Completed. Session available at https://youtu.be/KsabMe9Q-FI |
| D6.5.1. Project webpage, leaflets, newsletters | All | - | Completed (http://water4ever.eu/) Link to newsletters available in section 9 of this report |

4. Consortium Meetings, conferences, workshops, training courses and other events attended

Please fill in the table below, add/suppress fields as necessary in the table below.

| N° | Date | Location | Attending partners | Purpose |
|---|---|---|---|---|
| **1** | 10/10/2017 | Lisbon, Portugal | All except AIBU | Kick-off meeting. |
| **2** | 11/10/2017 | Oeiras | IST-ID | Presentation |
| **3** | 12/12/2017 | Beja, Portugal | IST-ID | Presentation |
| **4** | 27/04/2018 | Beja, Portugal | IST-ID | Presentation |
| **5** | 04/06/2018 | Santarém, Portugal | IST-ID | Presentation |

| | | | | |
|---|---|---|---|---|
| **6** | 07/06/2018 | Cartagena, Spain | All | Coordination meeting to discuss project milestones and case studies. |
| **7** | 13/09/2018 | Online | All except UPCT | Coordination meeting to discuss project milestones. |
| **8** | 22/11/2018 | Barcelona, Spain | All | Coordination meeting to discuss project milestones and products. |
| **9** | 13/02/2019 | Online | All | Coordination meeting to discuss project status and milestones. |
| **10** | 29/05/2019 | Istanbul, Turkey | All | Coordination meeting to discuss project status and milestones. |
| **11** | 3/09/2019 | Huesca, Spain | IST-ID | Presentation |
| **12** | 04/09/2019 | Online | All | Coordination meeting to discuss project status and milestones. |
| **13** | 15/11/2019 | Porto, Portugal | All except DEIMOS | Coordination meeting to discuss project status and milestones. |
| **14** | 08/04/2020 | Online | All | Presentations at EGU event |
| **15** | 09/10/2020 | Online | All | Preparation for project closure and final workshop event |
| **16** | 06/11/2020 | Online | All | Preparation for project closure and final workshop event |
| **17** | 04/12/2020 | Online | IST-ID | Presentation |
| **18** | 09/12/2020 | Online | All except INESCTEC | Preparation for project closure and final workshop event |
| **19** | 11/01/2021 | Online | All | Preparation for project closure and final workshop event |
| **20** | 20/01/2021 | Online | All | Final workshop |

## 5. Stakeholder Engagement

*Maximum 2 pages*

IST-ID has been in close contact with "Companhia das Lezírias" (CL; https://www.cl.pt/), advisory board member of the WATER4EVER Project. CL is the largest agriculture, cattle and forest farmstead in Portugal, covering the marshlands south of the Tagus River, totalizing about 18,000 ha with the vineyard covering about 185 ha. CL has provided all conditions for implementing the Portuguese case study, including access to the historical field datasets (soil moisture, weather data, and crop water status) used in the project, as well as management practices.

IST-ID has also cooperated with José Núncio, president of the Water Users Association of Vale do Sorraia (Associação de Regantes e Beneficiários do Vale do Sorraia; https://www.arbvs.pt/) and the Portuguese National Federation of Irrigation Managers (Federação Nacional de Regantes; http://www.fenareg.pt/). This resulted in one of the main outcomes of the project: the IrrigaSys decision support system (http://irrigasys.maretec.org/).

IST-ID has also been invited by the Portuguese National Rural Network (RRN; http://www.rederural.gov.pt/), a governing agency from the Portuguese Ministry of Agriculture, for presenting WATER4EVER in several dissemination events related to research and innovation in the agricultural sector. These presentations were held in some of the most important agriculture events in Portugal (Feira Nacional da Agricultura, Ovibeja, Agri Innovation Summit), with the audience being composed mainly of farmers, technicians, and entrepreneurs.

INESC TEC deployed the modular smart camera in the Aveleda S.A. vineyards (https://www.aveleda.com/en), which have shown a real interest in using this solution in their daily operation. Besides, this solution was presented to Portuguese telecommunications companies (NOS, ALTICE), which became interested to be engaged on demonstration pilots for technology evaluation and exploration.

isardSAT was engaged with Aigües del Segarra Garrigues (https://aiguessegarragarrigues.cat/es/), advisory board member of the WATER4EVER project, and responsible for the exploitation of the Segarra Garrigues

irrigation distribution network. This stakeholder provided the necessary field data for the Catalonian cases studies, hosted the project partners during their visit to the Segarra Garrigues irrigation district, and discussed the project results in the final workshop.
IMAMOTER informed stakeholders and farmers, particularly the ones that have already showed their interest in the project, about the on-going activities by means of contacts and distribution of the Newsletters. The Office for water protection (Settore Tutela delle acque, Direzione Ambiente, Governo e Tutela del territorio) of the Regione Piemonte administration was contacted and involved to obtain water quality dataset for the calibration and validation of the model implementation to the Italian study case.

## 6. Impact Statement

WATER4EVER was particularly dedicated to raising awareness on the causes of diffuse pollution and respective impacts on the availability and quality of downstream water bodies. The innovative tools and guidelines developed in the project contributed for reducing costs of production factors by improving irrigation water and fertilizers efficiency at the plot scale. The project further contributed for demonstrating the capabilities of emerging technologies (smart cameras, satellite data, process-based models) for improving irrigation water management.
The prototype of the modular smart camera developed by INESC TEC is here an example. This prototype is used for monitoring the LAI, NDVI, and crop water stress in woody crops. This device can have endless applications in terms of field management. This smart camera developed has a modular IoT solution, that can upgrade old machinery to get crop information and to make precision treatments. This is a relevant tool to allow gathering information regarding crop state, which allows the identification of their real needs and the application of treatments in the right amount and in the right place (tailored-based solutions). This will impact positively the overdosage of nitrogen, improving its use efficiency, and reducing leaching.
The IrrigaSys decision support system developed by IST-ID is another example. This DSS was developed to support irrigation water management at the field plot scale in close collaboration with irrigation managers and farmers. It integrates a series of online, open access tools, which include process-based models, weather forecast models, and dissemination platforms (websites and smartphone applications) to save water, reduce leaching and runoff from agricultural fields, and diffuse pollution.
The project results can have a direct impact on farmers profit by reducing irrigation and fertilization costs, and water agencies by establishing clear links between agricultural activities and eutrophication problems in downstream water bodies, which will surely be helpful in terms of watershed management. Results of WATER4EVER can eventually contribute directly to the implementation of the Nitrates Directive and the Water Framework Directive, and indirectly to the implementation of the Wastewater Treatment Directive.

## 7. Knowledge Output Transfer

For each of the Knowledge Output arising from the project, please complete the following table.

| | |
|---|---|
| Short Title<br>*Please provide a short and concise title to describe the Knowledge Output* | Smart camera for crop monitoring |
| Knowledge Output Description<br>*Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could* | A modular and open-source IoT based technology to be used during normal operation of conventional agricultural machinery to acquire information on the crop health status (e.g., crop water stress); to update agricultural machinery and tools with variable rate technologies; to use conventional |

| | |
|---|---|
| *exist within one deliverable, and should be separated.*<br>*Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.*<br>*If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).* | machinery and implements to operate under prescription maps obtained from FMIS and DSS apps and so on. |
| Knowledge Type | * prototype |
| Link to Knowledge Output<br>*If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.*<br>*If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.*<br>*If the Knowledge Output is not planned to be publicly available, please state "Not available for public".* | Not available for public |
| Sectors & Subsectors<br>*Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.* | • Others<br>  ○ Agriculture |
| End User<br>*Choose as many options as required*<br>*Per identified End User, please identify possible applications of the Knowledge Output.* | o Industry |
| IPR<br>*Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.*<br>*Please insert "n/a" if no IPR has been applied.* | n/a |
| Policy-Relevance<br>If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why | n/a |
| Status<br>*Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:*<br>*• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?* | More research needed to validate results |

| | |
|---|---|
| • *Is there a corroborating body of evidence, or are contradictory results, available?*<br>• *Does your knowledge progress beyond the current state-of-the-art / evidence base?*<br>• *Is more research or demonstration needed to validate the results?* | |

| | |
|---|---|
| Short Title<br>*Please provide a short and concise title to describe the Knowledge Output* | IrrigaSys Decision Support System |
| Knowledge Output Description<br>*Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated.*<br>*Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.*<br>*If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).* | Decision support system for irrigation water management based on online, open source tools. The DSS includes remote access to local meteorological stations for weather conditions, a meteorological model for weather forecast, the MOHID-Land model for the computation of the soil water balance and irrigation scheduling, and a database for data repository. |
| Knowledge Type | * services/tools |
| Link to Knowledge Output<br>*If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.*<br>*If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.*<br>*If the Knowledge Output is not planned to be publicly available, please state "Not available for public".* | https://doi.org/10.1016/j.compag.2020.105822 |
| Sectors & Subsectors<br>*Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.* | • Others<br>  ○ Agriculture<br>  ○ Stakeholder Involvement |
| End User<br>*Choose as many options as required*<br>*Per identified End User, please identify possible applications of the Knowledge Output.* | o Other |

| | |
|---|---|
| IPR<br>*Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.*<br>*Please insert "n/a" if no IPR has been applied.* | n/a |
| Policy-Relevance<br>If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why | |
| Status<br>*Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:*<br>*• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?*<br>*• Is there a corroborating body of evidence, or are contradictory results, available?*<br>*• Does your knowledge progress beyond the current state-of-the-art / evidence base?*<br>*• Is more research or demonstration needed to validate the results?* | The service provided by IrrigaSys is already being applied in the Vale do Sorraia irrigation district, Portugal, supporting close to 30 farmers and 130 agricultural plots. |

| | |
|---|---|
| Short Title<br>*Please provide a short and concise title to describe the Knowledge Output* | Guidelines on the best management practices for protecting soil and water resources |
| Knowledge Output Description<br>*Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated.*<br>*Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.*<br>*If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).* | Document with the main findings from each case study included in the WATER4EVER project |
| Knowledge Type | * guidelines/standards |
| Link to Knowledge Output<br>*If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.* | https://water4ever.eu/<br>https://youtu.be/KsabMe9Q-FI |

| | |
|---|---|
| *If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.*<br>*If the Knowledge Output is not planned to be publicly available, please state "Not available for public".* | |
| Sectors & Subsectors<br>*Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.* | • Others<br>  ○ Agriculture |
| End User<br>*Choose as many options as required*<br>*Per identified End User, please identify possible applications of the Knowledge Output.* | o Education & Training<br>o Environmental Managers & Monitoring<br>o Policy Makers / Decision Makers<br>o Scientific Community<br>o Civil Society |
| IPR<br>*Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.*<br>*Please insert "n/a" if no IPR has been applied.* | n/a |
| Policy-Relevance<br>If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why | |
| Status<br>*Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:*<br>*• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?*<br>*• Is there a corroborating body of evidence, or are contradictory results, available?*<br>*• Does your knowledge progress beyond the current state-of-the-art / evidence base?*<br>*• Is more research or demonstration needed to validate the results?* | Concluded |

8. Open Data

In relation to Open Data, the funded projects will be requested to submit metadata on all the resources directly generated by the project, as well as additional information on how these data will

be exploited, if and how data will be made accessible for verification and re-use, and how it will be curated and preserved.

Metadata on all project resources are required to be submitted as part of the final reporting. This will be done via the **OpenWaterJPI** Interface, which will be available on the Water JPI website.

9. List of Publications produced by the Project - Open Access

- Please list all oral presentations, posters, and publications in scientific, peer reviewed journals listed in Web of Science derived from this project, separating those in preparation, those in review and those accepted or in press.
- You can provide web sites and/or electronic copies of the key ones.
- Please indicate all the co-authors for each publication.
- Please order publications per date (chronologically) and for each year by alphabetical order
- Please also indicate if it is an open access publication

Metadata on all project publications are required to be submitted as part of the final reporting. This will be done via the **OpenWaterJPI** Interface, which will be available on the Water JPI website. A synthesis is required to be part of the final reporting.

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| International | Peer-reviewed journals | 1. Gao, Q., Zribi, M., Escorihuela, M.J., Baghdadi, N., 2017. Synergetic Use of Sentinel-1 and Sentinel-2 Data for Soil Moisture Mapping at 100 m Resolution, Sensors 17, 1966, https://doi.org/10.3390/s17091966.<br>2. Gao, Q., Zribi, M., Escorihuela, M.J., Baghdadi, N., Segui, P.Q., 2018. Irrigation Mapping Using Sentinel-1 Time Series at Field Scale, Remote Sens. 10(9), 1495, https://doi.org/10.3390/rs10091495.<br>3. Ramos, T. B., Simionesei, L., Oliveira, A. R., Darouich, H., Neves, R., 2018. Assessing the impact of LAI data assimilation on simulations of the soil water balance and maize development using MOHID-Land. Water 10, 1367, https://doi.org/10.3390/w10101367.<br>4. Capello, G., Biddoccu, M., Ferraris, S., Cavallo, 2019. Effects of tractor passes on hydrological and soil erosion processes in tilled and grassed vineyards. Water, 11, 2118, https://doi.org/10.3390/w11102118<br>5. Ramos, T.B., Castanheira, N., Oliveira, A.R., Paz, A.M., Darouich, H., Simionesei, L., Farzamian, M., Gonçalves, M.C., 2020. Soil salinity assessment using vegetation indices derived from Sentinel-2 multispectral data. Application to Lezíria Gande, Portugal. Agric. Water Manage. 241, 106387, https://doi.org/10.1016/j.agwat.2020.106387<br>6. Stefan, V.G., Merlin, O., Escorihuela, M.J., Molero, B., Chihrane, J., Villar, J.M., Er-Raki, S., 2020. Temporal Calibration of an Evaporation-Based Spatial Disaggregation |

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| | | Method of SMOS Soil Moisture Data. Remote Sensing, 12(10), 1671, https://doi.org/10.3390/rs12101671<br>7. Simionesei, L., Ramos, T.B., Palma, J., Oliveira, A.R., Neves, R., 2020. IrrigaSys: A web-based irrigation decision support system based on open source data and technology. Comp. Elect. Agric. 178, 105822, https://doi.org/10.1016/j.compag.2020.105822<br>8. Yildiz, K., Karakaya, N., Kilic, S., Evrendilek, F., 2020. Interaction effects of the main drivers of global climate change on spatiotemporal dynamics of high altitude ecosystem behaviors: process-based modelling. Environ Monit Assess192: 457. https://doi.org/10.1007/s10661-020-08430-y<br>9. Temnani, A., Conesa, M.R., Ruiz, M., López, J.A., Berríos, P., Pérez-Pastor, A., 2021. Irrigation Protocols in Different Water Availability Scenarios for 'Crimson Seedless' Table Grapes under Mediterranean Semi-Arid Conditions. Water 13(1), 22; https://doi.org/10.3390/w13010022<br>10. Santos, L.C.; dos Santos, F.N.; Morais, R.; Duarte, C. Potential Non-Invasive Technique for Accessing Plant Water Contents Using a Radar System. Agronomy 2021, 11, 279. https://doi.org/10.3390/agronomy11020279<br>11. Silva, D.Q.; Aguiar, A.S.; dos Santos, F.N.; Sousa, A.J.; Rabino, D.; Biddoccu, M.; Bagagiolo, G.; Delmastro, M. Measuring Canopy Geometric Structure Using Optical Sensors Mounted on Terrestrial Vehicles: A Case Study in Vineyards. Agriculture 2021, 11, 208. https://doi.org/10.3390/agriculture11030208<br>12. Bagagiolo, G., Rabino, D., Biddoccu, M., Nigrelli, G., Cat Berro, D., Mercalli, L., Spanna, F., Capello, G., Cavallo, E., 2021. Effects of inter-annual climate variability on grape harvest timing in rainfed hilly vineyards of Piedmont (NW Italy). International Journal of Agrometeorology (under review)<br>13. Stefan, V., Indrio, G., Escorihuela, M.J., Quintana-Seguí, P., Villar, J.M., 2021. Root zone soil moisture retrieval at 1 km resolution from the assimilation of high resolution SMAP surface soil moisture into an exponential filter model, remote sensing (under review). |
| | Books or chapters in books | 1. Mendes, J.M., Filipe, V.M., dos Santos, F.N., Morais dos Santos, R., 2019. A Low-Cost System to Estimate Leaf Area Index Combining Stereo Images and Normalized Difference Vegetation Index. In: Moura Oliveira, P., Novais, P., Reis, L. (eds), Progress in Artificial Intelligence. EPIA 2019. Lecture Notes in Computer Science, vol 11804., Springer, Cham., https://doi.org/10.1007/978-3-030-30241-2_21<br>2. Moura, P., Ribeiro, D., dos Santos, F.N., Gomes, A., Baptista, R., Cunha, M., 2019. Estimation of Vineyard Productivity Map Considering a Cost-Effective LIDAR-Based Sensor. In: Moura Oliveira, P., Novais, P., Reis, L. (eds), Progress in Artificial Intelligence. EPIA 2019. Lecture |

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| National (separate lists for each nationality) | Peer-reviewed journals | |
| | Books or chapters in books | |
| | Communications (presentations, posters) | Portugal:<br>1. Ramos, T.B., 2017. Optimização do uso da água na agricultura para preservar o solo e os recursos hídricos. Jornada Técnica dos Sistemas de Apoio à Decisão na Agricultura de Regadio, 12 December, EDIA, Beja, Portugal |
| Dissemination initiatives | Popularization articles | 1. Bagagiolo, G., Biddoccu, M., Rabino, D., Cavallo, E., 2019. Seguire le curve di livello per ridurre l'erosione. L'Informatore Agrario, vol. 6, p. 46-50, ISSN: 0020-0689<br>2. dos Santos, F.N., Boaventura, J., 2020. A tecnologia a favor da defesa da água, Vida Rural. https://www.vidarural.pt/producao/a-tecnologia-a-favor-da-defesa-da-agua/<br>3. dos Santos, F.N., "O robô que vai tratar das vinhas nas encostas do douro" https://www.dn.pt/sociedade/o-robo-que-vai-tratar-das-vinhas-nas-encostas-do-douro-8683646.html |
| | Popularization conferences | 1. Ramos, T.B., 2018. Optimização do uso da água na agricultura para preservar o solo e os recursos hídricos. Feira Nacional da Agricultura, 4 June, Santarém, Portugal.<br>2. Ramos, T.B., 2018. Optimização do uso da água na agricultura para preservar o solo e os recursos hídricos. Ovibeja, 27 April, Beja, Portugal. |
| | Others | 1. Final workshop of Project WATER4EVER, January 20, 2021, Online event. Session available at https://youtu.be/KsabMe9Q-FI |

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| | | 2. Training school on the MOHID-Land model, October 1-4, 2018, Instituto Superior Técnico, Lisbon, Portugal.<br>3. Training school on the MOHID-Land model, January 15-18, 2019, Rio de Janeiro, Brazil.<br>4. Training school on the MOHID-Land model, May 30, 2019, Istanbul, Turkey.<br>5. Newsletter I (http://water4ever.eu/wp-content/uploads/2018/12/NEWSLETTER-I.pdf)<br>6. Newsletter II (http://water4ever.eu/wp-content/uploads/2018/12/NEWSLETTER-II.pdf)<br>7. Newsletter III (http://water4ever.eu/wp-content/uploads/2018/12/NEWSLETTER-III.pdf)<br>8. Newsletter IV (http://water4ever.eu/wp-content/uploads/2019/07/NEWSLETTER-IV.pdf)<br>9. Newsletter V (http://water4ever.eu/wp-content/uploads/2020/01/NEWSLETTER_V.pdf) |

10. Personnel

List all staff and students supported by or affiliated with this project
Please provide the following details for each staff member/student supported by this project:
____ Please indicate the number of students involved

1. Student Name:
2. Major/Degree field:
3. Degree (Ph.D., M.S., M.A., B.S., B.A., etc):
4. Dissertation/Thesis title:
5. Country:

- Antoni Granés González, "Water Balance in the Algerri Balaguer irrigation district", Màster en Geoinformació, Universitat Autònoma de Barcelona, Spain, held on 13/07/2018.
- Rodrigo Gomes Borges, "Noninvasive Techniques for Vine Perception" Master degree, Faculdade de Engenharia da Universidade do Porto, Portugal, held on 17/08/2018.
- Kadir Yildiz, "A process-based model of spatio-temporal dynamics of carbon and nitogen in the case of Ardahan watershed", Master in Environmental Engineering, AIBU, Turkey, held on January 2020.
- Eslem Çınar, "Estimation and quantification of surface water metabolism dynamics on monthly basis: a case study of Ardahan", Master in Environmental Engineering, AIBU, Turkey, held on May 2019.
- Qi Gao, "Estimation of water resources on continental surfaces by multi-sensor microwave remote sensing", PhD in Hydrology, Université Paul Sabatier – Toulouse III, France, held on 30/07/2019. https://hal.archives-ouvertes.fr/tel-02349622v2/document
- Lucian Simionesei, "Modeling water and nutrient fate in different agro-ecosystems for improving land management practices", PhD in Environmental Engineering, Instituto Superior Técnico, University of Lisbon, expected for 2021.
- Ana Ramos Oliveira, "A modelling approach for improving water governance at the regional scale", PhD in Environmental Engineering, Instituto Superior Técnico, University of Lisbon, expected for 2023.

## 11. Problems Encountered during Project Implementation

Most of the project activities were executed as planned. However, project dissemination was severely affected by the current SARS-COV-2 pandemic crisis, with most scientific events being cancelled in 2020 when the project was terminating. The final workshop was also held online due to that situation. The event was recorded, and the main results are now available to everyone interested in the WATER4EVER project at https://youtu.be/KsabMe9Q-FI.

Notwithstanding the project activities started on 1st July 2017 and regularly advanced, the procedures for the approval of the project, and specifically for the issue of the funding decree, by the Italian Funding Agency (MIUR) were only closed much later. CNR-IMAMOTER has received the approval decree for Water4Ever funding by MIUR after the Mid-term of the project. This situation resulted in problems in the budget and administrative management for recruiting personnel and other expenses for the project. Nevertheless, CNR-IMAMOTER has carried out the project activities with its own resources and personnel, and thus there were some modifications about budget items with respect to that reported in the full proposal

## 12. Continuation strategy

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| Already referred in section 2. |