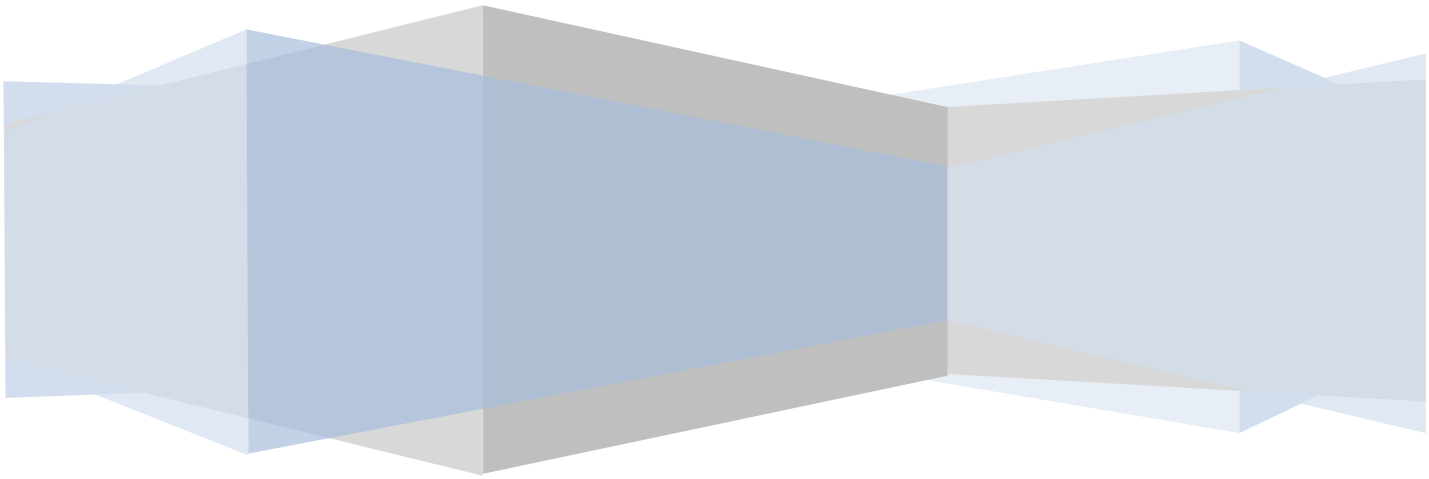
WaterWorks2015 Cofunded Call
Final Progress Report

Sustainable management of water resources in agriculture, forestry and freshwater aquaculture sectors

Operationalizing the increase of water use efficiency and resilience in irrigation (OPERA)

This document must be filled in by the project coordinator with the help of the project partners and must be sent to the WaterWorks2015 Follow-up Secretariat by June 2020 (for Consortium OPERA).

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 the partners.



OPERA
Operationalizing the increase of water use efficiency and resilience in irrigation

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Project Website:
http://www.waterjpi.eu/index.php?option=com_content&view=article&id=559:opera&catid=156:joint-calls
http://opendata.waterjpi.eu/dataset/opera-operationalizing-the-increase-of-water-use-efficiency-and-resilience-in-irrigation

Project code: WaterWorks2015 - OPERA

Duration of project: 30 months + 3 months extension
Start date: April 2017
End date: September/December 2019

Period covered by this report: April 2017 – September/December 2019

Title of the Final Technical Report: Operationalizing the increase of water use efficiency and resilience in irrigation

Authors of the Final Technical Report: Marius Heinen, Claire Jacobs, Francisco José Blanco-Velázquez, André Chanzy, Wieslawa Kasperska-Wołowicz, Filiberto Altobelli, Maria Anaya-Romero, Anna Dalla Marta, Willem de Clercq, Marlene De Witt, Antonio Díaz Espejo, Ewa Kanecka-Geszke

Contents

1 Publishable Summary

Smarter precision technologies for irrigation are needed to strengthen farmers' adaptation to climate change. Within OPERA we distinguished two main lines of research: i) identifying ways on how farmers and irrigation organizations can react more flexible with their crop selection and production to market opportunities under climate variability; and ii) providing operational ICT technologies that allow soil water status identification and upscaling of crop water demands at field and territorial scale.

The first line focussed on stakeholder analysis to identify current bottlenecks and needs for improvement. A general approach on addressing user needs with stakeholders from the different countries was developed. In general, the needs and demands by farmers and other stakeholders varied between the different countries. This implies that different actions are needed for the different regions in Europe and South-Africa. To increase competitiveness, some farmers prefer to increase the size of their farms while others prefer improving marketing strategies or require more training for their staff. More similar results were obtained in the barriers identification for water efficiency and adopting alternative crops. Farmers from each country involved identified the cost of sensor and the high investment cost as the main barriers. In addition, administrative barriers were identified (time to obtaining water intake permit and lack of agility). The uncertainty of predicting market demands and adaptive infrastructure costs were identified as the main limitations to adopting alternative crops. The second major issue addressed was a socio-economic analysis regarding the development of irrigation advisory services, based upon the stakeholder needs. Based on econometric models and the replies from the stakeholders on questions, it was shown that farmers are actually willing to pay for an irrigation support system that results in an economic advantage over their current situation. However, this willingness expressed in terms of Euros per hectare differed between the countries. The results suggest that the policy makers, rather than following conventional command-and-control method of irrigation management, will have to take into account the preferences and associated willingness-to-pay values of the farmers in a meaningful way while formulating irrigation policies.

The second line focussed on the development and field testing of ICT methods for irrigation. In total six methods were studied, involving different combinations of the use of soil-crop simulation models, remote sensing, in-situ soil and plant sensors, and weather forecast. The innovations introduced in the OPERA project mainly concern methods for estimation of crop water needs for optimal irrigation and a good distribution of water resources in shortage conditions. The assessment of water quantities is generally made to cover crop water needs in optimal conditions. The issue of deficit irrigation was addressed in one location (olive orchard irrigation). OPERA has been able to benefit from a technological breakthrough offered by the SENTINEL satellite earth observation mission, which makes it possible to develop new applications based in particular on the high temporal frequency (potentially every 5 days). In addition, the exhaustive spatial coverage and the free access to images offer guarantees for the development of operational services. Most of the methods are based on the dynamics of leaf cover. The use of soil-crop modelling is the second innovation level. Modelling makes it possible to synthesize climate, agricultural practices and soil, and thus to take into account the role of soil, which plays a buffer role against climate variability through its water storage capacity. In addition, because soil-crop models are climate-driven, they are well-suited to integrate weather forecasts. Weather forecasts can be used in irrigation scheduling (in temperate climates) and even ensemble weather forecasts can be used to determine uncertainties about the predicted root zone water content. However, the effect is dependent on the quality of the forecasts, and currently we estimate that forecasts up to five days ahead can be used. The combination of information technologies (mathematical modelling, in-situ soil or plant sensors, ensemble weather forecasts and remote sensing) in OPERA created the possibility to get more precise estimation of water demands and improve efficiency of irrigation water use in a field and larger scale.

2 Work Performed and Results achieved within the Project

(*Maximum* 12 *pages*)

a. Scientific and technological progress

Please describe the work performed, the results obtained during the course of the project and the conformity of work progress with the initial schedule. You can use the Executive Summary from your Final Technical Report here. All deliverables MUST be included as Annexes to this Report.

- *Did the project achieve its main objectives, milestones and deliverables? Please also describe the ways in which they were reached.*
- *How did the project progress in comparison to the original description and milestones? If not/only partly, please describe the reasons for the possible deviations.*
- *How did the project promote a multidisciplinary approach during its lifetime?*

- ***What was the most important result of the project? Please describe why.***

'Operationalizing the increase of water use efficiency and resilience in irrigation' (OPERA) is a project carried out under the ERA-NET Cofund WaterWorks2015 Call. The consortium consisted of the following eight partners: 1) Wageningen Environmental Research (WENR), The Netherlands; 2) Stellenbosch University (SU), South Africa; 3) Evenor Tech (Evenor), Spain; 4) Instituto de Recursos Naturales y Agrobiologia de Sevilla (IRNAS – CSIC), Spain; 5) French National Institute for Agricultural Research (INRA – EMMAH), France; 6) University of Florence (UNIFI – DISPAA), Italy; 7) Council for Agricultural Research and Economics – Research Centre for Policies and Bioeconomy (CREA-PB), Italy; and 8) Institute of Technology and Life Sciences (ITP), Poland.

Smarter, precision technologies for irrigation are needed to strengthen farmers' adaptation to climate change. Within OPERA we distinguished two main lines of research: i) identifying ways on how farmers and irrigation organizations can react more flexible with their crop selection and production to market available opportunities and the predicted climate variability; and ii) providing operational ICT technologies that allow soil water identification and upscaling of crop water demands at field and territorial scale.

The first line focussed on stakeholder analysis to identify current bottlenecks and needs for improvement. A general approach on addressing user needs with stakeholders from the different countries was developed. As expected, needs and demands by farmers and other stakeholders varied between the different countries. This implies that there is not a single solution or approach that fulfils each farmers' demands; different actions are needed in the different regions in Europe and South-Africa. To increase competitiveness, some farmers prefer to increase the size of their farms while others prefer improving marketing strategies or need more training for their staff. More similar results were obtained in the barriers identification for water efficiency and adopting alternative crops. Farmers from each country involved identified the cost of sensor and the high investment cost as the main barriers. In addition, administrative barriers were identified (time to obtain water intake permit and lack of agility). The uncertainty of predicting market demands and the infrastructure costs were identified as the main limitations to adopting alternative crops. The second major issue addressed was a socio-economic analysis regarding the development of irrigation advisory services, based upon the stakeholder needs. Based on econometric models and the replies from the stakeholders to questions, it was shown that farmers are actually willing to pay for an irrigation support system that results in an economic advantage over their current situation. However, this willingness expressed in terms of Euros per hectare differed between the countries. The results suggest that the policy makers, rather than following conventional command-and-control method of irrigation management, will have to take into account the preferences and associated willingness-to-pay values of the farmers in a meaningful way while formulating irrigation policies.

The second line focussed on the development and testing of ICT methods for irrigation. In total six methods were studied, involving different combinations of soil-crop simulation models, remote sensing, in-situ soil and plant sensors, and weather forecast (either the average forecast or all ensemble forecasts to predict uncertainty). The innovations introduced in the OPERA project mainly concern the estimation of crop water needs for optimal irrigation and a good distribution of water resources at the scale of a territory (irrigated sector, catchment area) in shortage conditions. The issue of deficit irrigation was addressed in one location (olive orchard irrigation). OPERA has been able to benefit from a technological breakthrough offered by the SENTINEL satellite earth observation mission, which makes it possible to develop new applications based in particular on the high temporal frequency (potentially every 5 days). In addition, the exhaustive spatial coverage and the free access to images offer possibilities for the development of operational services. Most of the methods are based on the dynamics of leaf cover. The use of soil-crop modelling is a second innovation level. Modelling makes it possible to synthesize climate, agricultural practices and soil, and thus to take into account the role of soil, which plays a buffer role against climate variability through its water storage capacity. In addition, because soil-crop models are climate-driven, they are well-suited to integrate weather forecasts. Weather forecasts can be used in irrigation scheduling (in temperate climates) and even ensemble weather forecasts can be used to determine uncertainties about the predicted root zone water content. However, the effect is dependent on the quality of the forecasts, and currently we estimate that forecasts up to five days ahead can be used. The combination of information technologies (mathematical modelling, in-situ soil or plant sensors, ensemble weather forecasts and remote sensing) create the possibility to get more precise estimation of water demands and improve efficiency of irrigation water use in a field and larger scale.

Overall, the OPERA project was performed as scheduled in the project proposal. Some research activities in Italy, however, could not be performed due to lack of funding (see Chapter 12). Anticipated milestones, like collecting groups of stakeholders, getting the field test sites ready for experimentation, stakeholder workshops and interviews, project meetings etc. were all achieved. In total 14 deliverables (mainly project reports, progress reports) were foreseen at the start, which were all published. The reports describe the methods and results obtained in the different work packages. One special deliverable concerns a brief scientific leaflet that summarised the project's results.

The OPERA consortium consisted of researchers with different backgrounds: agronomists, plant physiologists, soil physicists, irrigation engineers, socio-econometrists. Sometimes extra time was needed to understand each other's language and wishes, but in the end OPERA managed to provide a multi-disciplinary view on the subject of 'operationalizing the increase of water use efficiency and resilience in irrigation'.

Because the approach in OPERA was diverse and different methods were tested, there have been several results reported in the different deliverables. The following common results can be mentioned:

- It is not likely that a one-size-fits-all solution exists across Europe (and South Africa) that will solve all farmers/stakeholders problems, since the farmers have different demands and needs.
- Innovation has been achieved by implementing remote sensing data in analysing irrigation demand at the territorial scale as well as by combining them with soil-crop models.
- Farmers are willing to pay for services for irrigation scheduling, such as the use of weather forecasts.

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

In total 11 students contributed to the OPERA project.

#	Name	Major field (degree)	Dissertation/thesis title	Partner, Country
1	T. Rakotonirina	Geomatic (MSc)	Irrigated field mapping using sentinel 1 and Sentinel 2	INRA (Fr)
2	H. Amraoui	Environmental sciences (MSc)	Irrigation practices: spatialization and modelling in the Mediterranean. The Ouveze Bassin (Vaucluse) case	INRA (Fr)
3	Irene Rodríguez Ostos	Climate Change, Carbon and Hydric resources	Climate change impact on agro-climatic sustainability in the olive crops of Mediterranean area. The use of MicroLEIS DSS in OPERA-JPI Water	EVENOR (Sp)
4	Ignacio Fernández Durán	Climate Change, Carbon and Hydric resources	Earth observation techniques for efficient water management in olive groves	EVENOR (Sp)
5	Marta Barril Benjumea	Environmental Sciences (Degree)	Olive farmers' needs and demands in Andalusia	EVENOR (Sp)
6	Raúl Córdoba Verdugo	Environmental Sciences (Degree)	Olive farmers' needs and demands in Andalusia	EVENOR (Sp)
7	Diana Alejandra Morales Santiago	Climate Change, Carbon and Hydric resources	Analysis of agroclimatic indices in OPERA-LPI Water Project	EVENOR (Sp)
8	A. Santini	Economist (MSc)	The role on stakeholder interviews	CREA (It)
9	Adrian Perez-Arcoiza	Biologist (PhD)	Physiological basis for fruit growth and the response to water stress	IRNAS-CSIC (Sp)
10	David Armillota	Agronomist (MSc)	Exploring the advantages and disadvantages of using remote sensing for studying orchard heterogeneity	IRNAS-CSIC (Sp)
11	Simone Pietro	Agronomist (MSc)	Estimation of fruit tree volumes from drones and its application to estimate leaf area distribution in orchards	IRNAS-CSIC (Sp)

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

In total 41 researchers contributed to the OPERA project.

Name (degree)	Partner, Country	Specialization	Role in OPERA
The Netherlands			
Marius Heinen (PhD)	WENR (NL)	Soil physics, agrohydrology, modelling	Project coordinator; method and case study NL
Claire Jacobs (MSc; f)	WENR (NL)	Irrigation, climate smart agriculture, remote sensing	Project coordinator; synthesis; dissemination
Remco Kranendonk (MSc)	WENR (NL)	Governance, biobased economy, communities of practice	Stakeholder interviews + consecutive reporting
Joris Schaap (MSc)	WENR (NL)[1]	Soil classification; field work	Field work
Gerben Bakker (MSc)	WENR (NL)	Field sensors, electronics, head of soil physics laboratory	Testing field sensors and automation of sensor data
Erik van den Elsen (MSc)	WENR (NL)	Field sensors, measurement and control	Advisor usage of field sensors
Jochen Froebrich (PhD)	WENR (NL)	Water, Food and inclusive Growth	Link WSSTP working group
Wonnie Sheikh Abdulla (f)	WENR (NL)	Secretary	Secretary
Poland			
Wieslawa Kasperska-Wolowicz (PhD; f)	ITP (PL)	Agrometeorology, agricultural water management, crop modelling, data quality analysis	Leader WP3; coordinator field work, data analysis, modelling, surveys analysis
Ewa Kanecka-Geszke (PhD; f)	ITP (PL)	Agrometeorology, agricultural water management, agricultural droughts,	Project manager and coordinator for Polish project (second and third year), integration

[1] Private consultant (www.badus.nl); temporarily hired by WENR (NL)

			of WP, stakeholder interviews and surveys analysis, data analysis and modelling
Karolina Smarzynska (PhD; f)	ITP (PL)	Hydrology, modelling	Project manager for Polish project (first year)
Leszek Labedzki (Prof., PhD)	ITP (PL)	Agrometeorology, agricultural water management, irrigation, agricultural droughts	Project initiator; scientific advisor for Polish project, modelling (till July 2019)
Bogdan Bąk (PhD)	ITP (PL)	Meteorology, agricultural drought	Weather forecast analysis, interviews,
Tymoteusz Bolewski (MSc)	ITP (PL)	Agrometeorology, greenhouse gas emissions, agricultural water management	Data analysis, GIS
Jan Meller	ITP (PL)	Technician	Field work, soil-water physical properties analysis help in stakeholder interviews
Grzegorz Bartkowski	ITP (PL)	Technician	Field work, help in stakeholder interviews
France			
André Chanzy (PhD)	INRA-EMMAH (FR)	Soil physics, agronomy, remote sensing	Leader WP2, irrigation detection and management of the French case study
Dominique Courault (PhD; f)	INRA-EMMAH (FR)	Agronomy, remote sensing	Land use mapping
Sameh SAADI (PHD, f)	INRA-EMMAH (FR)	Agronomy, remote sensing	Irrigation detection
Guy Deshaye (MSc)	INRA-EMMAH (FR)	Agronomy, remote sensing	Irrigation detection
Véronique Desfonds (BA; f)	INRA-EMMAH (Fr)	Agronomy	Data management
Fabrice Flamain (BA)	INRA-EMMAH (Fr)	Agronomy	Field and farm survey
Marta Debolini (PHD; f)	INRA-EMMAH (Fr)	Agronomy, geography	Land use and farm survey

Italy			
Anna Dalla Marta (Prof., PhD; f)	UNIFI-DAGRI (IT)	Crop production, crop modelling	Co-leader WP4; project leader field study
Marco Mancini (MSc.)	UNIFI-DAGRI	Agrometeorology, cropping systems	Field work, data processing
Filiberto Altobelli (PhD)	CREA (IT)	Sustainability crop production, irrigation	Leader WP4
Orlando Cimino (PhD)	CREA (IT)	Agricultural Economics	Stakeholder interviews + consecutive reporting
Guido Bonati	CREA (IT)	Agricultural Economics	Stakeholder interviews + consecutive reporting
Francesco Vanni (PhD)	CREA (IT)	Agricultural Economics	Stakeholder interviews + consecutive reporting
Flavio Lupia	CREA (IT)	Geoinformation	Stakeholder interviews + consecutive reporting
Antonella Trisorio (f)	CREA (IT)	Agricultural Economics	Stakeholder interviews + consecutive reporting
Federica Giralico (f)	CREA (IT)	Communication	Stakeholder interviews + consecutive reporting
Spain			
Francisco José Blanco Velasquez (MSc)	EVENOR (ES)	Remote sensing	Leader WP1 (years 2 and 3)
Sara Muñoz Vallés (PhD; f)	EVENOR (ES)	Ecology	Leader WP1 (year 1)
María Anaya Romero (PhD; f)	EVENOR (ES)	Land evaluation, artificial intelligence, modelling under global change scenarios	Co-leader WP1

Antonio Díaz Espejo (PhD)	IRNAS-CSIC (ES)	Plant Physiology, modelling, irrigation	Project leader field study
Virginia Hernandez (f)	IRNAS-CSIC (ES)	Plant Physiology, hydrology, irrigation	Field work, data analysis
José Enrique Fernandez	IRNAS-CSIC (ES)	Agronomy, irrigation	Data analysis, advisor usage of field sensors
Rafael Romero Vicente	IRNAS-CSIC (ES)	Engineering, sensor communication	Field work, sensor installation, satellite data
South Africa			
Willem de Clercq (Prof., PhD)	SU (SA)	Soil science, agricultural water efficiency, hydrological modelling	Project initiator; scientific advisor for South-Africa project
Marlene DeWitt (MSc; f)	SU (SA)	Environmental management, agricultural water efficiency	Stakeholder interviews, data analyses + consecutive reporting

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

In the OPERA proposal no mobility of staff or students was foreseen as this could not fit in the limited budget. Regular skype or webex meetings were held to inform each other on the progress, and all partners were physically present at the kick-off, mid-term and final consortium meetings (see Chapter 4).

e. *Collaboration, coordination, mobility and synergies*

- *Please indicate clearly who performed the work.*
- *Describe how effective and active was the collaboration between partners (incl. in-kind partners).*
- *Were the coordination and organisation of the project effective? Please explain.*
- *Please describe the mobility of the researchers within the Consortium.*
- *How did the project and/or researchers' careers benefit from the mobility within the Consortium?*
- *Please indicate coordination and/or synergies with other projects funded in the WaterWorks2015 Cofunded Call or national or international projects funded by Water JPI or other instruments.*

- *Please indicate clearly who performed the work.*

OPERA consists of eight consortium institutions (partners), for each of which several (principal) investigators performed part of the work. A full list of all personnel involved can be found in Chapter 2, section c. The principal investigators of the following institutions were responsible for leading the mentioned work packages:

WP	Title	WP leader institute
1	Identifying sector needs to increase resource use efficiency	Evenor Tech (ES)
2	Forecasting water availability and critical water demand	INRA-EMMAH (FR)
3	Guidance for optimal irrigation water strategies (case studies)	ITP (PL)
4	Conceptualization of practical service models	CREA (IT)
5	Project management and dissemination	WENR (NL)

Within WP 1-4 actions were defined that were performed by all consortium partners. For example, in WP1+4 standardized questionnaires were developed that were used in workshops or one-to-one interview settings at all participating partners, and all partners worked on methods and case studies that were coordinated by WP2+3.

- *Describe how effective was the collaboration between partners (incl. in-kind partners).*

Because the work flow was structured and coordinated by the different WP leaders, all participating partners worked according to the given instructions. This made analysing the results easy. In that respect, the collaboration between the partners was good. Associated partners were well informed by the local OPERA partners and performed their work accordingly.

- *Were the coordination and organisation of the project effective? Please explain.*

Yes. The project proposal was written in close cooperation between all eight consortium partners and from the start to the end of the project life time the anticipated activities have been performed. There have not been great difficulties in coordinating the work. Part of the practical field work that was foreseen in e.g. Italy could not be performed due to financing problems (see Chapter 12). However this did not hamper the major work flow.

- *Please, describe the mobility of the researchers within the Consortium.*
- *How did the project and/or researchers' careers benefit from the mobility within the Consortium?*

No visit exchanges of researchers have taken place, and these were not foreseen in the project. The main reason for this was budget limitations. All partners, except for South Africa (due to another important internal strategic meeting), were physically present at the kick-off meeting (June 2017, Seville, Spain). All partners, except for Evenor Tech (due to auditing obligations), were present at the mid-term project meeting (September 2018, Bydgoszcz, Poland). All partners were present at the project's final meeting held

in Wageningen, the Netherlands (September, 2019). Exchange of information between the partners was done bi-laterally via e-mail and by frequent skype/WebEx meetings of the WP-leaders and case study representatives (see also Chapter 4 'Consortium Meetings').

- *Please indicate coordination and/or synergies with other projects funded in the 2016 Joint Call or national and international projects funded by other instruments.*

OPERA maintained links with the following projects:

- Copernicus Climate Change Service (C3S) Global agriculture. WENR is leading this contract for ECMWF in which agri-climatic indicators are being developed. Experiences on user uptake and data requirements are shared in OPERA.
- MEDSCOPE project. In the French site, the activities led by INRA are strongly connected to that of the MEDSCOPE project which is funded by ERA4CS program. The goal of this project is to evaluate seasonal forecasts on water need for the irrigation and the water offer from the river networks. Stakeholders are strongly interested by such forecast to have a greater visibility on the forthcoming water stress. The suite of regional model developed in OPERA will be used in MEDSCOPE.
- FATIMA (FArming Tools for external nutrient Input and water Management) (H2020 closed 28/02/2018) - CREA partner.
- National Policy Framework for water governance and integrated water resources management (EU Programme "Sustainable management of water resources in rural areas in Uzbekistan" 2014-2018) – CREA partner.
- WASG (Global framework on water scarcity in agriculture – FAO Initiative) – CREA and UNIFI Italian working group.
- Technological innovations and system of monitoring, forecasting and planning of irrigation and drainage for precise water management on the scale of drainage/irrigation system INOMEL. BIOSTRATEG3/347837/11/NCBR/2017, source of financing: The National Centre for Research and Development (NCBR).
- Estimating WATer efficiency in soil using SATellite images and modelling approach (WATSAT). Financed by BOOSTING INNOVATE DIGITECH VALUE CHAINS FOR AGROFOOD, FORESTRY END ENVIRONMENT (DIVA) – Evenor-Tech partner.
- Physiological basis for the equilibrium between fruit load and leaf area in hedgerow olive orchards. Proyecto de Investigación Fundamental, VI Programa Nacional de Investigación Científica, Ref. AGL2015-71585-R. January 2016 - December 2018.
- Strategies to enhance the synthesis of healthy compounds in olive orchards. Cortijo de Guadiana S.L. Ref. VAPC 20164884. July 2016 - April 2019.

f. Infrastructures

Please describe briefly the infrastructures used in the Project. Has the proposal been based/built on research infrastructures already existing?

All partners were already active in the area of research. In most cases the funding from the OPERA project was used for continuation of or extension of on-going research in which additional OPERA goals could be easily merged. In some cases partners used facilities such as soil labs or experimental field set-ups of existing research sites, completed with additional profile probes.

g. Which WaterWorks2015 Call theme/themes were addressed by the project (listed below for your information)? How did the project cover the main aims & objectives of the Call?

The OPERA project was submitted and granted for funding under the ERA-NET Cofund WaterWorks2015 Call. Within that call OPERA fits under **Challenge 1, sub-topic-1.a**, as it deals with innovative ways for efficient use of water in agriculture, including precision irrigation techniques and making use of models,

sensors and information and communication tools (**I.a.i**). It also takes into account the challenges related to climate change and increasing resilience of agriculture (**1.1.b**), and relates to proper irrigation management, including fertigation (nutrients dissolved in irrigation water) so that water pollution (e.g. nitrate leaching) will be minimized (**2.2.a**).

h. Has the consortium developed or implemented any kind of knowledge hub tool? If yes, which one (i.e. specific working groups, platforms, citizen science initiative)?

No, the consortium did not develop a specific knowledge hub tool, neither was this mentioned in the project proposal. However, the consortium partners did collect information from stakeholders, including new stakeholders with whom they did not work before. In that sense, the consortium partners have increased their network / platform of stakeholders. In Poland joint interactions have resulted in the establishment of two consortia ("Water for Kujawy" and "Innovative orchards") and elaboration of two joint applications for the projects in the frame of the agricultural European Innovation Partnership (EIP-AGRI), under the Rural Development Program (2014-2020), Action 16 "Cooperation".

i. Do you have any particular suggestion for further R&I development in your field? Please take into account the SRIA of the Water JPI.

The OPERA project has contributed to the SRIA sub-theme 4.1 "Improving the efficiency of water use for a sustainable bio-economy sector". We believe that progress has been made, but that there remain issues that still need to be investigated further before they can be fully integrated in, for example, operational irrigation advisory services. The main subject was to improve water use efficiency, and the results achieved here will be valuable for SRIA subtheme 4.2 "Reducing soil and water pollution", especially when fertigation is practised. The work carried out in OPERA was focused on proof-of-concept; As next step it is now necessary to build systematic evaluation strategies to demonstrate their robustness and improve their credibility with potential users.

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.

Deliverable name	Lead partner	Date delivered	Comments
WP1			
D1.1: Assessment of user requirements of the sector	EVENOR (ES)	July 2018	Completed in time
D1.2: Outcome of the two stakeholder workshops	EVENOR (ES)	November 2019	Completed in time
WP2			
D2.1: Reference framework (Report) defining requirements, implementation condition and evaluation procedure	INRA-EMMAH (FR)	July 2018	Completed in time
D2.2: Portfolio of methods	INRA-EMMAH (FR)	December 2019	Completed in time
WP3			
D3.1: Results of field measurements, weather forecast and simulation models that allow elaborating more precise irrigation scheduling based on actual conditions	ITP (PL)	December 2019	Completed in time
(D3.2: Draft version of practical guidance for optimal irrigation strategies for farmers, farmer associations, local policy makers)			Since we experienced that the final version (D3.3) and the draft version (D3.2) were so much alike we decided not to publish D3.2 separately.
D3.3: Practical guidance for optimal irrigation strategies for farmers, farmer associations, local policy makers	ITP (PL)	December 2019	Completed in time as D3.2/D3.3
WP4			
D4.1: Report on socio-economic assessment	CREA (IT)	November 2019	Completed in time
D4.2: Report on feasible service models for the irrigation sector	CREA (IT)	December 2019	Completed in time
WP5			
D5.1 Inception report	WENR (NL)	August 2017	Completed in time
D5.2 Consortium Agreement signed by all partners	WENR (NL)	April 2017	Completed in time
D5.3 Midterm Progress report	WENR (NL)	July 2018	Completed in time
D5.4a: Final Progress Report D5.4b: Final Technical Report	WENR (NL)	March 2020	Completed in time
D5.5: OPERA scientific booklet	WENR (NL)	December 2019	Completed in time

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

The table below lists all meetings by the OPERA consortium. They include the three major meetings where all partners gathered physically at one location to discuss the set-up, intermediate progress, and finalization of the project. Frequent Skype or Webex meetings were organized between either all partners, all WP leaders, or specific WP leaders to discuss "day-to-day" issues. At the end of the project less frequent project-wide Skype/Webex meetings were organized and communication was bi-lateral through E-mail exchange of ideas and information and specifically of contributions to each other's deliverable reports.

The project coordinator attended the general WaterWorks2015 meetings concerning the kick-off, mid-term and final presentation of the project. We were also invited to present the project OPERA as an example project within the WaterWorks2015 workshop "Water JPI & FACCE-JPI JOINT WORKSHOP: Common Vision and Adapting the Strategies of the Water & FACCE JPIs" held in Paris, September 26, 2019 (attended by A. Chanzy, INRA).

N°	Date dd-mm-yyyy	Location	Attending partners	Purpose/ main issues/main decisions?
1	06-04-2017	Stockholm. Sweden	WENR	2016 Water JPI Joint Call Projects Kick-off meeting (WaterWorks2015)
2	13/14-06-2017	Seville, Spain	All partners	OPERA Project Kick-off meeting including field visit at test site IRNAS-CSIC (Milestone M5.1)
3	11-07-2017	Skype	WP2+WP3+WP5	Skype meeting on case study integration (WP 2, WP 3, WP 5)
4	12-07-2017	Skype	All partners	Skype meeting case study field activities (WP 1, WP 2, WP 3, WP 5)
5	19-07-2017	Skype	WP1+WP4+WP5	Skype meeting on stakeholder involvement (WP 1, WP 4)
6	19-09-2017	Skype	WP1+WP4+WP5	Skype meeting on preparation workshops and surveys (WP 1, WP 4)
7	07-02-2018	WebEx	All partners	Monthly progress meeting
8	28-03-2018	WebEx	All partners	Monthly progress meeting
9	26-04-2018	WebEx	All partners	Monthly progress meeting
10	24-05-2018	WebEx	All partners	Monthly progress meeting
11	11-06-2018	Skype	All partners	Discussion methodologies case studies
12	28-06-2018	WebEx	All partners	Monthly progress meeting
13	05-07-2018	WebEx	WP leaders	Progress meeting
14	06-09-2018	WebEx	WP leaders	Progress meeting
15	18/19-09-2018	Bydgoszcz, Poland	All partners	Mid-term consortium meeting, Bydgoszcz, Poland (second day was field visit)
16	30-10-2018	WebEx	WP leaders	Progress meeting
17	14-01-2019	WebEx	WP1+WP4+WP5	Progress meeting
18	28-03-2019	Madrid, Spain	WENR	Mid-term review meeting of all WaterWorks2015 projects
19	23-04-2019	WebEx	WP2+WP3+WP5	Progress meeting
20	15-05-2019	WebEx	WP leaders	Progress meeting
21	17/18-09-2019	Wageningen, the Netherlands	All partners	Final consortium meeting Wageningen, the Netherlands (second day was field excursion)
22	26-09-2019	Paris, France	INRA	Invited lecture presenting OPERA at the "Water JPI & FACCE-JPI JOINT WORKSHOP: Common Vision and Adapting the Strategies of the Water & FACCE JPIs"
23	September 2020 (?)	???	WENR	Final review meeting of all WaterWorks2015 projects

At the following (inter)national workshops or seminars poster or oral presentations were given regarding the OPERA project (see for more details Chapter 8).

N°	Date	Location	Attending partner	Poster/oral presentation at:
1	May 2017	Huelva, Spain	EVENOR	Poster presented at "Congress on Climate Change"
2	June 2017	Bydgoszcz-Tleń, Poland	ITP	Poster presented at the XXII Plant Irrigation Symposium "Irrigation of plants in the light of sustainable development of rural areas".
3	March, 2018	Wageningen, The Netherlands	WENR	Oral presentation of project at seminar "Weather Information Services for successful local agriculture in Africa"
4	May, 2018	Krakow, Poland	ITP	Oral presentation at the 23rd International Scientific Conference ENVIRO 2018
5	June, 2018	University of Teramo, Italy	CREA	Oral presentation at the congress "Biodiversity 2018. XVII National Congress Biodiversity, Environments and health"
6	June/July, 2018	Minikowo, Poland	ITP	Poster presented at the International Agricultural Trade Fair Agro-Tech Minikowo
7	September, 2018	San Pietro a Marsala, Italy	CREA	Poster presented at the XLVII National Congress of the Italian Society of Agronomy
8	October, 2018	Seville, Spain	IRNAS-CSIC	6th International Conference for the Olive Tree and Olive Products, OLIVEBIOTEQ
9	January, 2019	Bloemfontein, South Africa	SU	Oral presentation at "Soil Science Society of South Africa Conference 2019"
10	June, 2019	Fojutowo, Poland	ITP	Poster presented at XXIII Symposium on Plant Irrigation "Irrigation of plants in the light of sustainable development of rural areas - natural-production and technical-infrastructure aspects"
11	September, 2019	Pisa, Italy	UNIFI	Oral presentation 3rd Workshop Fertilisation and Irrigation, European Vegetable Research Institutes Network (EUVRIN)
12	September, 2019	Seville, Spain	EVENOR	Poster presented at "XXXII Reunion Nacional de Suelos"
13	September, 2019	Pisa, Italy	UNIFI	Oral presentation presented at EUVRIN - 3rd Workshop Fertilization and Irrigation
14	September, 2019	Perugia, Italy	UNIFI	Poster presented at "Società Italiana di Agronomia, XLVIII Convegno Nazionale, Evoluzione e adattamento dei sistemi colturali erbacei"
15	December, 2019	Toruń, Poland	ITP	Oral presentation at Scientific meeting - Polish Geophysical Society, Pomeranian Branch

5 Stakeholder Engagement

On the basis of sentences below (from the Call Announcement), please describe how stakeholders have been involved in the project (e.g. companies, policy-making entities, other) and the types of their engagement (e.g. end-users of data/technology, financial support in complementary activities to the project, consultancy in key issues of the project) in the project.

"Participation of stakeholders (i.e. small and medium enterprises (SMEs), industries, authorities, public administrations, associations, as well as civil society organisations) is encouraged."
"Proposals should build on on-going research activities at EU level and in the participating member states. They should describe opportunities and initiatives for cooperation with these activities."

What has been the added value of the stakeholders' engagement to the project's results?

Has the consortium allowed further exchanges of practices, procedures or technologies among different groups of stakeholders (i.e. researchers, public or private sector, end users)? If yes, how? Please indicate if through dissemination and exploitation plan, business plan or specific meetings at local/international level.

In OPERA, participation of stakeholders played an important role. First, SMEs were actively involved in the project. One of the consortium partners was a SME (Evenor Tech, Spain; WP 1 leader) and in Italy an SME (ARIESPACE) cooperated by providing crop evapotranspiration forecasts.

Secondly, stakeholders were selected to participate in workshops or interviews. Part of the work performed in OPERA was 'to identify sector needs to increase resource use efficiency' (Work Package 1). In WP 1, together with help from WP 4 ('conceptualization of practical service models'), first a communique was developed on how to properly select stakeholders, either to be invited to workshops or to be selected for interviewing ("Guidelines for analysis and selection of stakeholders"). After selection of stakeholders, two sessions of workshops or interviews were performed based on pre-defined questions. The same questions were used in all participating countries, so that an overall analysis could be performed to show if and to what extent stakeholders in the different countries have similar or different wishes and ideas with regard to increasing resource (water) use efficiency. Some of the results of these enquiries were further elaborated in WP 4.

In total, 141 stakeholders from 91 entities (individual farmers, agricultural advisors, irrigation consortia, scientific institutions, representatives of local government and government administration) participated in the workshops or were interviewed. Although this is not the place to provide a complete description of the results (see Deliverables D1.1, D1.2, D4.1) it is noteworthy to mention that a workshop is not always the best way to get all information needed. Instead, face-to-face interviews often resulted in much more detailed information.

Stakeholders have also been involved in the field testing. For example,

- For the French site, the irrigation associations managing the distribution of the surface water were involved in the design of the OPERA methods and their evaluation.
- For Spain, a commercial company is involved that produces premium olive oil, Cortijo de Guadiana, and the applicability of the OPERA method is tested with them. The partner in Spain, IRNAS-CSIC, signed a research contract with the company.
- For Poland, farmers and agricultural producers (SME) were involved, and they are part of the OPERA platform of stakeholders that was established. The individual farm and the producer group farm were chosen for field testing.
- For South Africa, farmers and agricultural consultants have been targeted to gather information.
- For Italy, private representatives were engaged directly as service providers and a representative farmer was identified for field testing on tomato irrigation modelling.

- In the Netherlands, the test case is located on a commercial farm. This farmer and extension researchers from the Dutch Platform on Precision Agriculture (NPPL) were selected for the interviews.

In the case of Poland, the added value of the stakeholders' engagement to the OPERA project's results is to establish further close cooperation with some of them: fruit farmers, agricultural producers, etc., who use irrigation systems and also with the Regional Agriculture Advisory Centre. Joint interactions have resulted in the establishment of two consortia ("Water for Kujawy" and "Innovative orchards") and elaboration of two joint applications for the projects in the frame of the agricultural European Innovation Partnership (EIP-AGRI), under the Rural Development Program (2014-2020), Action 16 "Cooperation".

6 Impact Statement

On the basis of sentences below (from the Call Announcement), please, describe the impacts, scientific and societal from local to global level (e.g. to community, to water management entities, to policy-making, scientific development in the area, contribution to SDGs), resulting from your work. What kind of impact do you anticipate from the project outcomes in five years?

"Cross-cutting issues such as socio-economic and/or capacity developing aspects (contributions to standards and norms) constitute an added value to RDI in this field."

Please describe any other (also unexpected) impacts the project has generated/will probably generate in the future.

Are the main impacts achieved?
Where do the results of the project impact (e.g. industry, end users, policy, etc.)?
Have the partners identified exploitable results?
Has intellectual property protection been considered?

Water scarcity and drought is affecting Europe and climate change will aggravate the occurrence of climatic extremes. With tested methods for improved irrigation scheduling, OPERA contributes to the sustainability of agricultural water management by a better tailoring of water supply to the actual demand.

The innovations introduced in the project concern the estimation of crop water needs for optimal irrigation using new ICT methods. Making use of newly available information, such as weather forecast and sensor (in-situ or remote) information, irrigation can be further fine-tuned to spatial and temporal demands. The main outcomes of the project are:

- A detailed outline on tested combinations of remote sensing, modelling and monitoring for irrigation, based on user interactions and field experiments. This serves as a basis to develop commercial ICT applications with services that are tailored to the user demands as specified during the project. Background information for future business case developments has been included from the various case studies. Establishing innovative service models will help to establish green jobs in the agricultural sector as well as realizing service contracts with local research institutes to provide raw data and simulation results by using latest ICT developments.
- Irrigation guidelines to highlight the added value of the OPERA tools tested and the related impacts on increasing water productivity and water saving,
- Dissemination of OPERA results to the wider scientific community, by peer reviewed papers and presentations at European events and conferences. Transferring research results into operational practice was a key ambition of OPERA. By closely involving farmers, irrigation organizations, universities and other research organizations in the process, results are continuously communicated to practitioners outside the research domain and are likely to be easier adopted.

The short term impact of OPERA is the possibility to pick up the elaborated combinations of ICT products to characterise water needs and to monitor the actual performance. The project delivered insight in ICT solutions that are applicable at European scale (and in South Africa), which can be used as operational methodology for advisory services, for SME service providers, cooperatives and agri-food companies. The innovations introduced in the OPERA project mainly concern the estimation of crop water needs for optimal irrigation and a good distribution of water resources at the scale of a territory (irrigated sector, catchment area) in shortage conditions. Vulnerability to climate change was a key aspect in all case studies. However because of the diversity of contexts in the different study areas, it was impossible to use a 'one size fits all' case-study approach. Not enough resources were available to test one common methodology at the different field test sites given the short life time of the project. Therefore, each case study built (as much as possible) upon already existing research activities and infrastructure at the site. Results from the

stakeholder interactions confirm also that that there seems not to be a single solution or action that fits all wishes of the stakeholders in the different countries involved.

The project contributed to a strong cooperation and sharing of knowledge amongst the EU participants (research, public and SME), and OPERA extended the partnerships between researchers and practitioners from EU member states and Southern Africa. Students have been actively involved in the project in the countries, e.g. from the University of Pablo de Olavide, National Autonomous University of Mexico and the University of Seville in the development of methods and analysis of data for the Spanish case study.

At longer perspective, the mid-term and long-term benefits will result mainly from realizing a better advisory service in the agricultural sector that can lead to a better water demand management, to avoid harvest losses and to a more healthy socio-economic development in the rural farming areas in times of water scarcity and drought.

7 Knowledge Output Transfer

Besides the scientific publications (see Chapter 8) and all project deliverables (See Chapter 3) available as open data (see Chapter 9), the OPERA consortium has identified the following Knowledge Output items as listed in the tables below.

France

Short Title	Flooding pattern detection using Sentinel 2 on agricultural fields.
Knowledge Output Description	R script that analyse Sentinel 2 B11 band (mid infra-red band) and the Sentinel 2 NDVI to detected polygons (agricultural fields) that partly or fully flooded.
Knowledge Type	software/modelling tools
Link to Knowledge Output	Available upon request from Andre Chanzy (andre.chanzy@inra.fr)
Sectors & Subsectors	• Flood Risk Management • Water Scarcity and Droughts • Others ○ Agriculture
End User	o Policy Makers / Decision Makers
IPR	n/a
Policy-Relevance	Can be used to better assess irrigation need in systems using flooding techniques.
Status	Proof of concept done and results are ready to be published.

Spain

Short Title	Deficit irrigation based on the crop physiology
Knowledge Output Description	New algorithm to simulate transpiration and CO2 uptake. Innovative use in agriculture of mechanistic models of stomatal conductance and photosynthesis. Innovative use of remote sensing for tree size determination
Knowledge Type	software/modelling tools
Link to Knowledge Output	Available upon request from Antonio Diaz-Espejo (a.diaz@csic.es)
Sectors & Subsectors	• Irrigation Management • Orchard Management
End User	o Policy Makers / Decision Makers
IPR	n/a
Policy-Relevance	Can be used to better assess irrigation need in semi-arid regions where water is scarce and it is compulsory the implementation of deficit irrigation strategies.
Status	Proof of concept done and results has been already partially published.

Poland

Short Title	**1**. Model CROPIRR **2**. Practical guidance for irrigation strategies (in Polish language) **3**. Polish survey on assessment of the readiness of potential decision support system users to pay for irrigation advisory service - a survey prepared for farmers from the region suffering rainfall deficit in Poland.
Knowledge Output Description	**Ad 1.** The CROPIRR is the method of operational (in real time) predicting crop water demand and irrigation scheduling. The method is intended to aid the operation of irrigation systems using real time information on meteorological conditions and forecast. **Ad 2.** Practical guidance for irrigation strategies (in Polish language) is intended to draw attention to interested parties on crops irrigation needs and to indicate the aspect of effective water use in the context of decreasing water resources and climate change. The guidance is also intended to show the possibility of applying an irrigation control system at farm level and on a larger scale - in the county. **Ad 3.** The survey aimed to: recognize the stakeholders knowledge on irrigation advisory systems (IAS) and using these by farmers in region of high water deficit in agriculture; show what information from such systems stakeholders expect for their business needs; and whether they express a willingness to pay fees for IAS; identify the set of main information of such system which allow to develop innovative tool supporting activities related to irrigation in the region.
Knowledge Type	**Ad 1.** * improved modelling tools, that require IT software **Ad 2.** * guidelines/standards **Ad 3.** * report
Link to Knowledge Output	**Ad 1.** Not available for public **Ad 2, Ad 3.** In the nearest future will be available on the website of the Institute of Technology and Life Sciences and in paper version for all interested.

Sectors & Subsectors	**Ad 1, Ad 2, Ad 3**:
	• Basin Management
	• Water Scarcity and Droughts
	• Others
	  ○ Agriculture
	  ○ Modelling & Prediction
	  ○ Socio-Economics
	  ○ Stakeholder Involvement

End User	**Ad 1, Ad 2, Ad 3**: o Education & Training o Environmental Managers & Monitoring o Policy Makers / Decision Makers o Scientific Community o Civil Society o Other
IPR	**Ad 1, Ad 2, Ad 3**: copyright

Policy-Relevance	The method can be used to better assess operational crop irrigation needs.
Status	The indicated Knowledge Output is needed for more efficient (than before) irrigation water management in agriculture, in regions suffering rainfall water deficits in Poland. Knowledge results on the CROPIRR model are still general. The model requires testing for other field crops what we are planning to do in the next research. The other results are being finalized. Proof of concept has been done and results are ready to be published as a scientific paper.

The Netherlands

Short Title	Model prediction of root zone water content based on ensemble weather forecasts.
Knowledge Output Description	Software was written to automatically run SWAP on a daily basis. First historic weather data were downloaded, second ensemble weather forecasts (51 in total) were downloaded. SWAP status was updated based on historic weather, and then for each member of the weather forecast ensemble SWAP was run for the coming 15 days and the average and band-width of the predicted water content in the root zone was determined. Several graphs were created and send via E-mail to the operator.
Knowledge Type	• software/modelling tools
Link to Knowledge Output	Extended description in deliverables D2.1, D2.2, D3.1 and D3.3. See Table of Deliverables.

Sectors & Subsectors	• Water Scarcity and Droughts
	• Adaptation to Global Change
	• Others
	  ▪ Agriculture
	  ▪ Modelling & Prediction

End User	o Policy Makers / Decision Makers o Other: farmers
IPR	SWAP is freely available at swap.wur.nl Historic KNMI weather data can be obtained from www.knmi.nl ECMWF ensemble weather forecasts are not freely available. Within OPERA these data were bought for scientific research purpose through a contact via KNMI. Therefore, the complete software package cannot be distributed since the weather forecast data are not available.
Policy-Relevance	The method can be used to help farmers in their decision when a certain field needs to be irrigated. When integrated over certain regions it may give insight in water needs for irrigation in that area which may help water boards in regulating their water systems (i.e. taking care of enough water availability for irrigation in that area).
Status	A proof-of-concept has been performed in OPERA and model predictions were partly validated. Results and experience is ready to be published as a scientific paper.

8 List of Publications produced by the Project - Open Access

- In the table below 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. Also, provide a link (DOI) to the publications.
- 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.

INTERNATIONAL

Peer-reviewed journals

2018

Hernandez-Santana, V., Fernandes, R.M.D., Perez-Arcoiza, A., Fernández, J.E., García, J.M., Diaz-Espejo, A., Relationships between fruit growth and oil accumulation with simulated seasonal dynamics of leaf gas exchange in the olive tree. Agricultural and Forest Meteorology, 2018, 256, 458-469. https://doi.org/10.1016/j.agrformet.2018.03.019

Fernandes, R.D.M., Cuevas, M.V., Diaz-Espejo, A., Hernandez-Santana, V. 2018. Effects of water stress on fruit growth and water relations between fruits and leaves in a hedgerow olive orchard. Agricultural Water Management 210: 32-40. https://doi.org/10.1016/j.agwat.2018.07.028

Labędzki, L.; Ostrowski, J. Precipitation Preventing a Deficit of Readily Available Soil Water in Arable Soils in Poland. *Atmosphere* 2018, *9*, 121. www.mdpi.com/journal/atmosphere, doi:10.3390/atmos9040121 (Open Access).

2019

Dalla Marta, A., G.B. Chirico, S.F. Bolognesi, M. Mancini, G. D'Urso, S. Orlandini, C. De Michele and F. Altobelli. 2019. Integrating Sentinel-2 Imagery with AquaCrop for Dynamic Assessment of Tomato Water Requirements in Southern Italy. Agronomy 9, 404; doi:10.3390/agronomy9070404; www.mdpi.com/journal/agronomy (Open Access)

Rodriguez-Dominguez C.M., Hernandez-Santana V., Buckley T.N., Fernández J.E., Diaz-Espejo. 2019. Sensitivity of leaf turgor to air vapour pressure deficit correlates with maximum stomatal conductance. Agricultural and Forest Meteorology, 272-273: 156-165. https://doi.org/10.1016/j.agrformet.2019.04.006 (Open Access)

2020

De Witt, M., De Clercq, W.P., Velazquez, F.J.B., Altobelli, F. & Dalla Marta, A. In Preparation. An in-depth evaluation of personal barriers to technology adoption in irrigated agriculture in South Africa. *In preparation, to be submitted to Agricultural Water Management.*

Books or chapters in books

Diaz-Espejo A, Jose E. Fernández, Jose M. Torres-Ruiz, Celia M. Rodriguez-Dominguez, Alfonso Perez-Martin, Virginia Hernandez-Santana. 2018. The Olive Tree Under Water Stress: Fitting the Pieces of Response Mechanisms in the Crop Performance Puzzle. WATER SCARCITY AND SUSTAINABLE AGRICULTURE IN SEMIARID ENVIRONMENT. Tools, Strategies, and Challenges for Woody Crops. Edited by Iván F. Garcia-Tejero & Hugo Durán-Zuazo. Ed. Academic Press, pp. 589.

Fernández, José E., Diaz-Espejo A, Rafael Romero, Virginia Hernandez-Santana, José M. García, Carmen M. Padilla-Díaz, María V. Cuevas. 2018. Precision Irrigation in Olive (Olea europaea L.) Tree Orchards. WATER SCARCITY AND SUSTAINABLE AGRICULTURE IN SEMIARID ENVIRONMENT. Tools, Strategies, and Challenges for Woody Crops. Edited by Iván F. Garcia-Tejero & Hugo Durán-Zuazo. Ed. Academic Press, pp. 589

Communications (presentations, posters)

2017

Marius Heinen, Claire Jacobs, Jochen Froebrich, Willem De Clercq, André Chanzy, Dominique Courault, Sara Muñoz Vallés, Antonio Díaz Espejo, Anna Dalla Marta, Filiberto Altobelli, Karolina Smarzynska, Wieslawa Kasperska-Wolowicz, Leszek Labedzki. 2017. Operationalizing the increase of water use efficiency and

resilience in irrigation (OPERA). Poster presented at the kick-off Water-JPI WaterWorks2015, 6 April 2017, Stockholm, Sweden.

Sara Muñoz Vallés, Francisco José Blanco-Velázquez, Marius Heinen, Claire Jacobs, Antonio Díaz Espejo, Willem De Clercq, André Chanzy, Dominique Courault, Anna Dalla Marta, Filiberto Altobelli, Karolina Smarzynska, Wieslawa Kasperska-Wolowicz, Leszek Labedzki, María Anaya-Romero. 2017. Operationalizing the increase of water use efficiency and resilience in irrigation: the EU project OPERA. Poster presented at the Congress on Climate Change, 10-12 May 2017, Huelva, Spain.

Marius Heinen, Jochen Froebrich, Claire Jacobs, Willem De Clercq, André Chanzy, Dominique Courault, Sara Muñoz Vallés, Antonio Díaz Espejo, Anna Dalla Marta, Filiberto Altobelli, Karolina Smarzynska, Wieslawa Kasperska-Wolowicz, Leszek Labedzki. 2017. Operationalizing the increase of water use efficiency and resilience in irrigation (OPERA). Poster presented at the XXII Plant Irrigation Symposium "Irrigation of plants in the light of sustainable development of rural areas". 21-23 June 2017, Bydgoszcz-Tleń, Poland.

2018

Labędzki L. Opady krytyczne zapobiegające niedoborom wody łatwo dostępnej w glebach ornych Polski / Precipitation preventing a deficit of readily available soil water in arable soils in Poland. Oral presentation at the 23rd International Scientific Conference ENVIRO 2018. 16-18 May 2018, Krakow, Poland

2019

Baldi Ada, Dalla Marta Anna, Chirico Giovanni Battista, Falanga Bolognesi Salvatore, Mancini Marco, D'Urso Guido, Orlandini Simone, De Michele Carlo, Altobelli Filiberto. 2019. Integrating Sentinel-2 Imagery with AquaCrop for Dynamic Assessment of Tomato Water Requirements in Southern Italy. Presentation 3rd Workshop Fertilisation and Irrigation, European Vegetable Research Institutes Network (EUVRIN), Pisa, 9-11 September 2019.

Andre Chanzy, Marius Heinen, Claire Jacobs, R. Kranendonk, André Chanzy, Dominique Courault, Willem De Clercq, Marlene DeWitt, Francisco José Blanco-Velázquez, Antonio Díaz Espejo, Ewa Kanecka-Geszke, Wieslawa Kasperska, Marco Mancini, Anna Dalla Marta. The Opera project, Water/Facce JPI joint Meeting, Paris 26 September 2019.

De Clercq, W.P. 2019. Conservation farming in irrigated agriculture. Oral presentation at "Soil Science Society of South Africa Conference 2019", University of the Free State, Bloemfontein, South Africa, January 2019.

NATIONAL

Peer-reviewed journals

-

Books or chapters in books

-

Communications (presentations, posters)

2017

Filiberto Altobelli, Marius Heinen, Claire Jacobs, André Chanzy, Dominique Courault, Willem De Clercq, Sara Muñoz Vallés, Antonio Díaz Espejo, Karolina Smarzynska, Wieslawa Kasperska, Leszek Labedzki, Anna Dalla Marta. 2017. Operationalizing the increase of water use efficiency and resilience in irrigation (OPERA). (Sistematizzare l'aumento dell'efficienza dell'uso dell'acqua e la resilienza nell'irrigazione), Poster presented at the Italian Society of Agronomy and Agrometeorology, September 2017, Milan, Italy.

Hernández-Santana, V., Fernández, J.E., Díaz-Espejo, A. Measurement of sap flux density as a tool to automatically estimate gas Exchange and predict fruit growth in olive trees. 10th International Workshop on Sap Flow. Book of Abstracts, pp. 50. Fullerton Arboretum, Fullerton, California, EE.UU. 22-26 May 2017

2018

De Clercq. 2018. Conservation farming in irrigated agriculture. Presentation at Combined Congress of the South African Society of Crop Production, Soil Science Society of South Africa, Southern African Society for Horticultural Sciences and the Southern African Weed Science Society. 15-18.01.2018, Bloemfontein, South Africa.

Claire Jacobs, 2018. Operational agro-climatic data products for the agriculture & food sector. Presentation of project at seminar "Weather Information Services for successful local agriculture in Africa" in Wageningen, The Netherlands, 22 March 2018.

Ewa Kanecka-Geszke (ITP), Wiesława Kasperska-Wołowicz (ITP). „Operacjonalizacja zwiększenia efektywności zużycia wody i elastyczności w nawodnieniach OPERA" (Operationalizing the increase of water use efficiency and resilience in irrigation). Poster presented at the International Agricultural Trade Fair Agro-Tech Minikowo. 30.06-01.07 2018, Minikowo, Poland.

Filiberto Altobelli, Guido D'Urso, Anna Dalla Marta, Francesco Caracciolo, Gianni Cicia, Teresa Del Giudice. 2018. Disponibilità a pagare per i servizi di consulenza per l'irrigazione basati sull'uso integrato dei dati di osservazione della terra e sulle tecnologie di informazione (Willingness to pay for irrigation advisory services based on integration of Earth observation and information technologies). Oral presentation at the congress "Biodiversity 2018. XVII National Congress Biodiversity, Environments and health" University of Teramo 13-15 June 2018.

Filiberto Altobelli, Marius Heinen, Claire Jacobs, R. Kranendonk, André Chanzy, Dominique Courault, Willem De Clercq, Marlene DeWitt, Sara Muñoz Vallés, Antonio Díaz Espejo, Ewa Kanecka-Geszke, Wieslawa Kasperska, Marco Mancini, Anna Dalla Marta. Investigating the roles, institutions and potential markets for operationalizing services to the irrigation sector: OPERA Project. Poster presented at the XLVII National Congress of the Italian Society of Agronomy, San Pietro a Marsala 12-14 September 2018.

Díaz-Espejo, A., Hernández-Santana, V., Fernández, J.E. The future of precision agriculture and the rational application of deficit irrigation. 6th International Conference for the Olive Tree and Olive Products, OLIVEBIOTEQ, Book of Abstracts, pp. 39. Sevilla, España. 15-10 October 2018

2019

Blanco-Velazquez, F.J., I. Rodriguez-Ostos, and M. Anaya-Romero. 2019. Climate change impact on agro-climatic sustainability in the Olive crops of Mediterranean Area. The use of MicroLEIS DSS in OPERA-JPI Water project. Poster presented at "XXXII Reunion Nacional de Suelos", 10-13 Septiembre 2019, Sevilla.

Dalla Marta, A. 2019. Integration of remote sensing and crop modelling for the assessment of tomato water requirements. Oral presentation presented at EUVRIN - 3rd Workshop Fertilization and Irrigation Pisa, 9-11 September 2019.

Dalla Marta, A., G.B. Chirico, S. Falanga Bolognesi, S. Orlandini, G. D'Urso, C. De Michele, M. Mancini, F. Altobelli. 2019. Integration Of Remote Sensing and Crop Modelling for the assessment of tomato water requirements. Poster presented at Società Italiana di Agronomia, XLVIII Convegno Nazionale, Evoluzione e adattamento dei sistemi colturali erbacei, Perugia, 18-20 September 2019.

Kanecka-Geszke E.. 2019. Poster "System wspomagania decyzji nawodnieniowych w świetle projektu OPERA" – in Polish (The decision support system in irrigation in the light of the OPERA project). Poster presented at XXIII Symposium on Plant Irrigation "Irrigation of plants in the light of sustainable development of rural areas - natural-production and technical-infrastructure aspects",11-14 June 2019, Fojutowo, Poland.

Kanecka-Geszke E., Kasperska-Wołowicz W. 2019. "System wspomagania decyzji jako narzędzie efektywnego wykorzystania wody do nawodnień w regionie kujawsko-pomorskim – projekt OPERA" – in Polish (Decision support system as a tool for effective use of water for irrigation in the Kuyavian-Pomeranian region - the OPERA project). Oral presentation at Scientific meeting - Polish Geophysical Society, Pomeranian Branch in Toruń, 20 December 2019, Toruń, Poland.

DISSEMINATION INITIATIVES

Popularization articles

-

Popularization conferences

2017

Leszek Łabędzki. Potrzeby i stan nawodnień na Kujawach (Needs and state of irrigation in Kujawy). Oral presentation at Workshops for stakeholders of the OPERA project. 27 November 2017. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

Karolina Smarzyńska. Cele i oczekiwane rezultaty projektu OPERA (Goals and expected results of the OPERA project). Oral presentation at Workshops for stakeholders of the OPERA project. 27 November 2017. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

2019

Bolewski T. Operacyjne planowanie nawodnień w skali powiatu (upscaling) (Operational irrigation planning at a county scale (upscaling)). Oral presentation at Workshop 2 for stakeholders of the OPERA project. 28 March 2019. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

Kanecka-Geszke E. Cele, założenia i wstępne rezultaty projektu OPERA. Określenie oczekiwań i wymagań użytkowników sektora nawodnień – podsumowanie Warsztatów cz.1. (Objectives, assumptions and preliminary results of the OPERA project. Determining the expectations and requirements of the irrigation sector users - a summary of the Workshops part 1). Oral presentation at Workshop 2 for stakeholders of the OPERA project. 28 March 2019. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

Kanecka-Geszke E. Istniejące systemy wspomagania decyzji gospodarowania wodą na użytkach rolnych (Existing decision support systems for water management on agricultural land). Oral presentation at Workshop 2 for stakeholders of the OPERA project. 28 March 2019. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

Kasperska-Wołowicz W. Poradnik strategii optymalnych nawodnień (Guidance for optimal irrigation strategies). Oral presentation at Workshop 2 for stakeholders of the OPERA project. 28 March 2019. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

Kasperska-Wołowicz W., Kanecka-Geszke E. Wyniki badań polowych na obiektach demonstracyjnych in Poland (Field test results from case studies in Poland). Oral presentation at Workshop 2 for stakeholders of the OPERA project. 28 March 2019. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

Łabędzki L. System sterowania nawodnieniami (Irrigation control system). Oral presentation at Workshop 2 for stakeholders of the OPERA project. 28 March 2019. Kujawsko-Pomorski Agricultural Advisory Centre, Minikowo, Poland

Kanecka-Geszke E., Kasperska-Wołowicz W. Wyniki z projektu OPERA oraz poradnik optymalnych nawodnień (The OPERA project results and guidance for optimal irrigation strategies). Oral presentations for the stakeholders. 18 December 2019. County Agricultural Advisory Team, Radziejów, Poland

Others

Marius Heinen, OPERA. Summary of project on "Kennis-on-Line", https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksprojecten-LNV/Expertisegebieden/kennisonline/Add-Q2-JPI-Waterworks-OPERA-1.htm

On the website of the Institute of Technology and Life Sciences (http://www.itp.edu.pl/index.php?id=opera) and Evenor-Tech (http://www.evenor-tech.com/en/project-opera/), an OPERA project tab was created with information on the progress and Workshops for stakeholders.

Broadcast Countryside Magazine ("Magazyn Wiejski") realized during the Workshops for stakeholders of the OPERA project in Poland. Radio program realized and broadcasting by the regional Radio PiK (Pomerania and Kujawy). During the broadcast, the members and stakeholders of the OPERA project team gave an interview about the goals and assumptions of the OPERA project and issues related to irrigation of crops in the Kujawy region. Broadcasting date: 3 December 2017.

Information materials - Information folder about the OPERA project and Invitation to Workshops for stakeholders of the OPERA project - sent to about 100 potential Stakeholders in Poland (farmers, agricultural advisors, producer groups, water companies and other local decision makers).

In the Netherlands farmers advisors were interviewed who are part of the Dutch Platform on Precision Agriculture (https://www.proeftuinprecisielandbouw.nl/), in which programme amongst others precision irrigation is a research item. Feedback of results obtained in WP1 and WP4 is given back to them.

9 Open Data

All deliverables (see Chapter 3 'Table of Deliverables') are open to the public and can be accessed through the open-data website provided by Water-JPI at http://opendata.waterjpi.eu/dataset/opera-operationalizing-the-increase-of-water-use-efficiency-and-resilience-in-irrigation. Here also a list of scientific publications (see Chapter 8) can be found so that one can see where to retrieve a specific publication. In addition, one can find here the OPERA presentations and posters presented at the WaterWorks2015 kick-off and mid-term meetings.

Not all source data that have been used in the project can be made available through open access. For example, the Dutch partner WENR made use of momentary (daily) weather forecast data that were made available on a paid-for license for research purposes only within the scope of OPERA. Consequently, all input files used by the SWAP-WOFOST modelling for the Dutch test case cannot be made available as these contain weather forecast data. Please contact the primary investigators in case one is interested in specific data.

The following table lists all available documents at the open data website.

Document	Brief explanation
D1.1	Identifying sector needs to increase resource use efficiency. Outcome of first round of workshops.
D1.2	Identifying sector needs to increase resource use efficiency. Outcome of first and second round of workshops.
D2.1	Description of methods.
D2.2	Portfolio of methods.
D3.1	Results of field measurements, weather forecast and simulation models that allow elaborating more precise irrigation scheduling based on actual conditions.
D3.2/D3.3	Practical guidance for optimal irrigation strategies for farmers, farmer associations, local policy makers.
D4.1	Report on socio-economic assessment.
D4.2	Portfolio of business models.
D5.1	Inception report
D5.5	Scientific booklet
ListPublications_V03.docx	List of scientific publication and chapters in books.
OPERA Presentation Kick-off_Stockholm_final.pptx	Oral presentation at WaterWorks2015 kick-off meeting, Stockholm.
Water JPI midterm OPERA March 2019_LowRes.pptx	Oral presentation at WaterWorks2015 mid-term meeting, Madrid.
Water JPI Paris meeting_2019_09_26.pptx	Oral presentation at the Water-JPI / FACCE-JPI joint Meeting, Paris, 26 September 2019.
OPERA Poster 010417.pptx	Poster at WaterWorks2015 kick-off meeting, Stockholm.
OPERA Poster March2019.pptx	Poster at WaterWorks2015 mid-term meeting, Madrid.

10 Continuation strategy

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

The OPERA consortium has been working together successfully. All partners expressed interest in continuation of working together. The main challenge so far is lack of short term available funding opportunities. Moreover, often funding is less than the full costs needed, so that project ideas have to be granted by two or more funding agencies, which makes success less certain. For example, most of the ERA-NET and JPI programs in which the Netherlands is participating is funded by the Dutch Science Organisation, which does not fully fund the Wageningen Research partner. The OPERA project was an exception since the WENR partner was fully funded by The Dutch Ministry of Agriculture. Nevertheless, the consortium remains in close contact and is actively searching for further opportunities to continue research on the OPERA irrigation topics.

11 Innovation Potential

Please describe any results with innovation potential arising from the implantation of the project

The OPERA project identified the most adequate combinations of soil sensors, plant-based sensors, remote sensing, weather forecast and simulation models that allow the better consideration of rainfall, evapotranspiration and soil moisture in irrigation scheduling. Examples are:

- The project revealed the opportunities that remote sensing can have to monitor irrigation activities at the regional scale. In several case studies (France, Spain), remote sensing was successfully used to improve estimation of water requirements for irrigation.
- Further, a method was developed and tested in which the stomatal conductance is the key factor that determines irrigation needs (Spanish test sites). Stomatal conductance is related to photosynthesis and thus with yield and fruit quality.
- In addition, several test cases have shown that weather forecasts can be used in irrigation scheduling (test cases in Italy, Poland and Netherlands). The Italian and Polish case studies used average forecasts for up to 5 days. In the Dutch test case it was investigated how the uncertainty increases in time as the forecast window extends up to 15 days ahead based on the 51 ensemble weather forecasts.
- The South African case evaluated an existing remote sensing product which provided key insights into factors that need to be considered by the European partners in the development of new products to ensure uptake.

A next step is to bring these project advances from remote sensing, soil moisture monitoring, plant responses and forecasting and experiences from users, towards implementation and commercialization in operational advisory services.

12 Administrative & financial aspects / Budget use

Please describe in general terms how the available funding was used for the implementation of the project and identify any administrative/financial aspects that occur during the project lifetime.
For example, did any of the partners find difficulties related to the grant agreement, the availability of funds at national level or other similar issues not specifically related to the technical part of the project?

On December 2, 2016 we received the notification from the WaterWorks2015 secretariat that our proposed project OPERA was recommended for funding. Unfortunately we have experienced that this doesn't guarantee that all supporting funding agencies actually agreed to fulfil their duties. Our two Italian partners (UNIFI-DISPAA and CREA) did not receive funding from the Italian funding organization MIUR during the project lifetime, including the extension to the end of December 2019. It was only through on-going research and goodwill of the Italian researchers involved that they could add to the project. Nevertheless, not all foreseen activities (in Italy) could be performed. For example, one of the consequences was that the planned work on implementation of weather forecasts in Italy could not be performed (usage of weather forecasts in Poland and the Netherlands was not influenced by this). Only at the end of the project's life-time (mid of September, 2019; the day before the project's final meeting) our two Italian partners were informed that they would receive their funding: much too late to overcome the previous-mentioned problems, and early 2020 they haven't received anything yet.

There was also a delay in funding during the first year for the Spanish and South-African partners. This caused a delay in buying equipment (Spain) and in hiring a researcher (SA).

To give us some more time to finish final reporting we were granted (July 1, 2019; by scientific officer WaterWorks2015) an extension of the projects life time by 3 months (official end date was September 2019; new end date was December 2019).

To the best knowledge of the project coordinators, the budget that was asked for by the different partners in the project proposal was used by the project partners for their personnel and material expenses as planned (Exception: Italy, as described above). The project coordinators were not informed by the partners of any further problems (regarding financing and/or national reporting) with their funding agencies.

Appendix I – Technical Report

Together with the final progress report a final technical report (deliverable D5.4b) was sent to the secretary of WaterWorks2015. This technical report summarizes the methods, results, and conclusions from the main deliverables in this project (i.e. D1.1, D1.2, D2.1, D2.2, D3.1, D3.2/D3.3, D4.1 and D4.2). Alternatively, a shorter summary can be read in the scientific booklet, which was published as deliverable D5.5.

Appendix II – Deliverables

All deliverables from the OPERA project have been sent to the secretary of WaterWorks2015 together with the final progress report. Publicly available deliverables can also be accessed at the open-data website provided by Water-JPI at http://opendata.waterjpi.eu/dataset/opera-operationalizing-the-increase-of-water-use-efficiency-and-resilience-in-irrigation