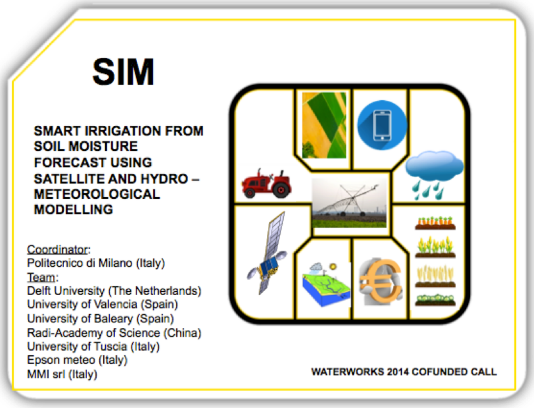
Water Challenges for a Changing World
Joint Programming Initiative

WaterWorks2014 Cofunded Call
Final Progress Report

Research and Innovation for Developing Technological Solutions and Services for Water Systems



SIM

SMART IRRIGATION FROM SOIL MOISTURE FORECAST USING SATELLITE AND HYDRO –METEOROLOGICAL MODELLING

PROJECT TITLE AND ACRONYM

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Title of the Final Technical Report: SIM - SMART IRRIGATION FROM SOIL MOISTURE FORECAST USING SATELLITE AND HYDRO –METEOROLOGICAL MODELLING

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1. Publishable Summary

The Smart Irrigation Modelling (SIM) project, deals with careful and parsimonious use of agricultural water presenting an operational web tool for real-time monitor and forecast irrigation water requirements supporting different level of water users from basin authorities to single farmer. The work is counfunded by EU H2020 Water JPI Waterworks Programme. SIM impacts on careful and parsimonious use of agricultural water as also indicated in the Common Agricultural Policy-CAP and the Water Framework Directive-WFD. The attention to this issue is becoming crucial in Europe also in regions traditionally rich in water as well in emerging countries due to the effect of climatic change and increase of human pressure on water resorources. These consist of an increase of water consumptions among different users and the conteporary increase of nubers of periods characterised by high temperature and rainfall reduction or also more severe drought periods.
The main project result is an operative web-gis system (www.sim.polimi.it), the SIM system, that provides in real-time the monitor and the forecasted of soil moisture behavior at high spatial and temporal resolutions (from 10 m to 250 m, from 1 hour to daily) with forecast horizons from few up to thirty days. This supports irrigation strategy (SIM strategy) allowing to increase the water

efficiency (ton/mc) and water productivity (€/mc) saving important percentage of water, but also of fertilizer and energy, compared to today's irrigation practices.
The SIM strategy irrigation decision criteria in order to plan whether or not to irrigate is based on keeping the monitored and forecasted soil moisture between
a water stress threshold below of which the crop begins to suffer for lack of water and a percolation beginning threshold (field capacity) above wich the percolation phenomena in the soil start to be significant . This criterion determines the correct timing and ammount of irrigation (reducing the number of irrigations), allowing to reduce the passages over the field capacity threshold reducing the percolation flux with a saving of irrigation volume, without impact on the evapotranspiration that remains almost the same.
SIM combines the most recent results of scientific research to compute soil moisture at high spatial and temporal resolution: as the remote sensing data analysis, the soil water balance models, the meteorological forecasts and the economics analysis. System outputs are also organized in performance indicators (water, environment and economic) supporting irrigation strategies of any level of users: farmers who keep soil moisture in an optimum interval, irrigation consortia which manage the water allocation; water authorities which manage reservoirs. This is obtained due to an integrated design based on pixel wise approach, that allows to maintain the same modelling spatial resolution for single cultivated field as well as for the entire region covered by the irrigation consortium or water authority.
The dashboards are available for the five case studies in Northern and Southern Italy, the Netherlands, China and Spain, which have different climates, water availability, crop types and irrigation systems.
The project structure is subdivided in eight WP and for each of them milestones and deliverables are provided according to the project proposal scheme.
The expected innovative tool will have impact both on the scientific community, as well as on operative farms and water authorities. These results will be guarantee from the work team, that represents a good compromise between research institutes and small enterprises which can implement advance research tools into an operative industrial product.

2. Work Performed and Results achieved within the Project

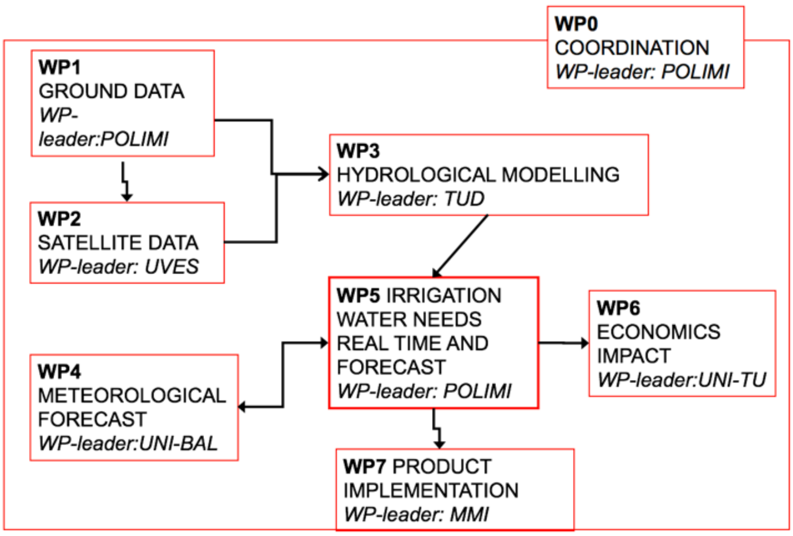
a. Scientific and technological progress

The SIM project reached all its objectives providing deliverables and achieving milestones as planned in the proposal. The results are reported in a more extended way in the attached Appendices.
The main project result is the **operative web-gis system** (www.sim.polimi.it), the SIM system, that provides real-time and forecasted soil moisture behavior at high spatial and temporal resolutions (from 10 m to 250 m, from 1 hour to daily) with forecast horizons from few up to thirty days. **The SIM strategy irrigation decision criteria** in order to plan whether or not to irrigate is based on the comparison between the simulated monitored and forecasted soil moisture and a water stress threshold below of which the crop begins to suffer for lack of water allowing reducing the percolation flux with a saving of irrigation volume, while evapotranspiration remains almost the same. The system allows to quantify the present and future amount and timing of irrigation water required by plants for their optimal yield and economic profitability considering at once the meteorological forcing, the crop stage and the soil characteristics.
This is obtained due to an integrated design based on distributed water balance modelling approach, that allows to maintain the same modelling spatial resolution for single cultivated field as well as for the entire region covered by the irrigation consortium or water authority. The operative web systems (www.sim.polimi.it/dashboard) are available for the five case studies in

Northern and Southern Italy, the Netherlands, China and Spain, which have different climates, water availability, crop types and irrigation systems.

This system combines in the same tool the multidisciplinary expertises of any partner as: the remote sensing data analysis, the soil water balance models, the meteorological forecasts and the economics analysis. This synergic multi-disciplinary approach is showing also interesting research aspects in the field of: agricultural economy and sustainable systems; satellite data and hydrological modelling their integration; meteorological forecasts and hydrological modelling coupling.

The project methodology was tuned since the beginning of the project focusing it to the development of the operative dashboard (WP7) starting from the consolidated experience of each partner which covers the complementary multi-disciplinary fields considered by the system. The methodology consists in setting up the dashboard components as independent numerical tools able to communicate among each other according to a designed flow chart that allow the entire system works (Following Figure). The numerical tools are obtained as project WP outputs, that represent for their specific field (hydrology, irrigation system, remote sensing, meteorological forecast, agricultural economy, informatics of big data), the updated status of the knowledge.



WP0 coordination (see ANNEX 0)

An intense coordination activity was carried not only among the project partners but also with the stakeholders of each case study, ensuring their collaboration and interest to the activities for parsimonious water use (as described in the chapters 4 and 5). End-users belong to farmers, irrigation districts and water basin authorities, and have been involved since the early beginning of the project to confirm the specific needs relative to the water use. For example the meeting May 2016 between POLIMI, RADI and the Heihe water basin authority and April 2016 & October 2017 - meeting between POLIMI, RADI, MMI srl and the Capitanata Irrigation Consortium, the Guzzetti farm and the Advisory board.

WP1 ground data (see ANNEX 1)

A large data base consistent with the modelling activity (hydrologic, meteorological and economic) was set up for the different case study for reanalysis data and also for real-time acquisitions allowing the calibration of model parameters as the validation of model outputs variables; and the real-time activities. The acquisition of the data was performed for each case study and was coordinated and pre-organized by a series of meeting among partners project, but also with each national stakeholders. The data were organized and formatted in similar manner for the all case studies (2 Italians, 1 Dutch, 1 Spanish, 1 Chinese) helping in applying the project tools and testing the defined methodology in the different environments.

The data acquired so far are: soil data and their hydrological parametrization, meteorological data series, agronomic data, irrigation type and timing, soil moisture data and evapotranspiration fluxes.

WP2 satellite data, retrieval algorithms and down scaling models (see ANNEX 2)
A data set of satellite images was selected and acquired creating an historical data series and the real-time series for the five case studies. In particular:

- Land Surface Temperature from MODIS, LANDSAT-7 and 8, SENTINEL 3 were acquired and then used as input of different retrieval algorithms.
- reflectance data from LANDSAT-7-8, MODIS and SENTINEL-2 were acquired for vegetation surface parametrization (NDVI, FV, LAI).

The teams involved in this WP2 have used these data also for improve and setting up downscaling models of the satellite data from the coarse spatial and temporal resolution (Δx=1000 m, Δt about 1 day) to the farm field need (Δx 10 m, Δt = 1 hour). These have been validated with ground measurements.

WP3 hydrological modelling (see ANNEX 3)
The FEST-EWB model has been calibrated and validated over all the case studies using the historical ground soil moisture and evapotranspiration data from WP1 and satellite LST at basin scale (WP1 e WP2). FEST-EWB model with its energy-water balance scheme allows to compute continuously in time and distributed in space soil moisture and evapotranspiration (ET) fluxes thanks to a double link with satellite-derived data as input parameters (e.g. LAI) and as variables for model states update as the land surface temperature (LST) (Corbari et al.,2011; Corbari & Mancini, 2014) instead of using dedicated ground measurements. ETMonitor model is forced by meteorological data and several biophysical parameters (LAI, fractional vegetation cover) and surface soil water status (soil moisture) derived from multi-source remote sensing data (from optical to microwave sensors), is applied on the Chinese and Northern Italy case studies.
Then irrigation systems are also analysed: for the Capitanata, where the field irrigation is mainly performed with on demand drip technique, the impact on temporal water distribution is investigated considering the role and the functioning of the distribution aqueduct; for the Barrax test site the impact on field irrigation of water spatial distribution supplied by the very large irrigation pivot is investigated; for the Aa en Maas the role of water table irrigation is analysed respect to the sprinkler irrigation.

WP4: meteorological forecast (see ANNEX 4)
The WP implements the forecast meteorological schemes using multi models approach in their ensemble and deterministic mode for the areas of the case studies. The different meteorological models are: 1) the deterministic MOLOCH at about 1.5 km as spatial grid resolution, 1 hour as temporal resolution with 45 hours as lead time, 2) the deterministic BOLAM at about 11 km as spatial grid resolution, 1 hour as temporal resolution with 72 hours as lead time, 3) The deterministic ECMWF at about 9 km as spatial grid resolution, 6 hours as temporal resolution with 240 hours as lead time, 4) The unperturbed ECMWF (control) run with 50 ensembles at about 18 km as spatial grid resolution, 6 hours as temporal resolution with 240 hours as lead time, 5) The deterministic WRF model at about 3 km as spatial grid resolution, 1 hour as temporal resolution with 96 hours as lead time, 6) the multi-model WRF at about 5 km as spatial grid resolution, 1 hour as temporal resolution with 72 hours as lead time. The models scores are evaluated at irrigation consortium scale and at experimental farms scale. As for the deterministic runs, the skill of the ensemble forecasting system is lower for Chiese than for Capitanata.

WP5 irrigation water needs real time and forecast (see ANNEX 5)
This WP transfers the specific partner experiences into the main project objective, forecast irrigation water need, comparing the simulated soil moisture from the soil water balance models with the soil moisture threshold values of field capacity and crop stress for given soil and crop type. The SIM strategy irrigation decision criteria in order to plan whether or not to irrigate is based on the comparison between the forecasted soil moisture and a water stress threshold below of which the crop begins to suffer for lack of water. This criterion will determine the correct timing of irrigation and the amount of water, allowing to reduce the passages over the field capacity threshold reducing the percolation flux with a saving of irrigation volume. A number of water indicators are computed to summarize the results and to compare the observed irrigations with the SIM strategy at irrigation district scale and at field scale. Then the main aspect related to water saving applying the SIM strategy is the identification of the which water flux is reduced, allowing to save water. In fact, if the water balance fluxes are considered, reducing irrigation allows reducing the drainage flux (which is water losses) and while evapotranspiration remains almost the same.
All the meteorological models (WP4) are coupled with the FEST-EWB (WP3) and used to generate hydro-meteorological forecasts. The cascade forecasting system is currently based on hydrological model initialization from with observed weather data of the previous day till 6 a.m. of the same day of weather model initialization, to set up the initial soil moisture conditions. The model is run with the meteorological model outputs. The hydro-meteorological chain shows a good performance over the Capitanata farms in the growing season of 2016 and 2017 with good agreement with the local observed data. Indeed, performances are more reliable for the lead time day +1 and, in particular, for first days as forecast horizon. As regards the Chiese Consortium River basin, general results are similar to those highlighted for the Capitanata basin with a good agreement.

WP6 economics impacts (see ANNEX 6)
The economic impact of the SIM irrigation strategy is evaluated in terms of farm profitability and productivity based on the local cost of the water and crop production, but also considering the environmental benefit of the SIM parsimonious use of the water. This is done for the two italian irrigation consortia assessing different economic indicators using the European Farm Accountancy Data Network and local farm data. Comparing the observed data with the SIM approach, the implementation of the SIM-project strategy determines water savings (between 23% and 31% of water for the FADN farms), physical water productivity (PWP) increases between 30% and 44% within the FADN dataset, Economic Water Productivity (EWP) increases between 25% and 45% within the FADN dataset (Chiese and Capitanata).

WP7 dashboard implementation (see ANNEX 7)
The complete system is implemented in a web software tool for all the case studies (www.sim.polimi.it/dashboard). (in a real-time operative mode for Chiese irrigation consortium, Capitanata irrigation consortium, barrax case study; in a reanlysis mode for heihe river basin and Aa en Maas case study). The operative web system monitors and forecasts in real time the water content in the soil root layer and compares it with plant stress and soil field capacity water content thresholds, computing the irrigation water needs. The SIM system combines hydrological and meteorological modelling (WP5) together with ground (WP1) and satellite (WP2) data. Real-time simulation data are daily uploaded on the specifically developed web dashboard. These are available in English and in the local language over possible (Italian, Spanish). The results are reported for two different level of users: irrigation consortium/water basin authority and farmers providing different details of information. The results are shown on

Openstreet Map platform and graphs, and stored in a database specifically created for the project.
The dashboard is designed with an integrated approach based on the pixel wise water balance modelling, that allows to maintain the same modelling spatial resolution (about 30 m) for single cultivated field as well as for the entire region covered by the irrigation consortium or water authority.

WP milestones and deliverables
The project activity has reached the scheduled milestones presented in the following Table, that shows the milestone state of achievement. **The deliverables are described in detail for any WP in the attached ANNEXES**.

Table I.Calendar of Project Milestone

WP Number	Milestones	Month	State
WP1	M.1 Case studies consistency control time	6	done
WP2	M.2 implementation of satellite algorithm for hydrological model	12	done
WP3	M.3 Definition of the most appropriate distributed hydrological model for each demonstration area	18	done
WP4	M.4 WRF configuration for operative use	18	done
WP5	M.5 Assessment of hydrological forecast procedure	22	done
WP6	M.6 Assessment of economic crop/farm models for the case study	24	done
WP7	M.7 Assessment of forecasted chain for operative prototype tool	26	done

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

Name	Gender	Consortium Partner	Country	Field of study	Degree achieved (PhD, MSc, MA, etc.)	Dissertation/ Thesis title	Task in project
Erika Ferrari	female	Politecnico di Milano	Italy	hydrology	Ph.D	Assessing basin evapotranspiration from aerodynamic resistance analysis at field scale	WP3
Nicola Paciolla	male	Politecnico di Milano	Italy	Hydrology + remote sensing	MSc (now PhD)	Land surface temperature downscaling techniques and their application for the calibration of a distributed hydrological model in a chinese inland river basin	WP3
Marco Stanganelli	male	Politecnico di Milano	Italy	Hydrology + remote sensing	MSc	Retrieval of parameters and variables of a hydrological water and energy balance model from satellite images Case studies of Barrax and Foggia	WP2 – WP3
Alessandro BRIANZA	male	Politecnico di Milano	Italy	Hydrology	MSc	Calibration and validation of a distributed hydrological model with ground and satellite data: the aa en maas case study	WP3
Davide CANIGGIA	male	Politecnico di Milano	Italy	hydrology	MSc	Calibration and validation of a distributed hydrological model with ground and satellite data: the aa en maas case study	WP3
Drazen Skokovic	male	University of Valencia	Spain	Remote sensing	Ph.D	Calibration and Validation of Thermal Infrared Remote Sensing Sensors and Land/Sea Surface Temperature algorithms over the Iberian Peninsula	WP2
Alejandro Hermoso Verger	male	University of Balearic Islands	Spain	Meteorology	Ph.D	Thesis under development	WP4
Aina Maimó Far	male	University of Balearic Islands	Spain	Meteorology	Ph.D	Thesis under development	WP4

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

Name	Gender	Consortium Partner	Country	Field of study	Task in project
Marco Mancini	Male	Politecnico di Milano	Italy	Hydrology + remote sensing + meteo-hydrological	WP0, WP1, WP3,WP5, WP7
Chiara Corbari	female	Politecnico di Milano	Italy	Hydrology + remote sensing + meteo-hydrological	WP0, WP1, WP3,WP5, WP7
Alesandro Ceppi	Male	Politecnico di Milano	Italy	meteo-hydrological	WP1,WP5
Giovanni Ravazzani	Male	Politecnico di Milano	Italy	Hydrology + meteo-hydrological	WP1,WP3
Imen Ben Charfi	female	Politecnico di Milano	Italy	Hydrology	WP3,WP5
Gabriele Lombardi	Male	Politecnico di Milano	Italy	meteo-hydrological	WP5,WP7
Mouna Feki	female	Politecnico di Milano	Italy	Hydrology	WP3
Luca Cerri	Male	Politecnico di Milano	Italy	ICT software	WP7
Jose A. Sobrino	male	University of Valencia	Spain	Remote sensing	WP2
Juan C. Jimenez	male	University of Valencia	Spain	Remote sensing	WP2
G. Soria	male	University of Valencia	Spain	Remote sensing	WP2
Yves Julien	male	University of Valencia	Spain	Remote sensing	WP2
Romualdo Romero March	male	University of Balearic Islands	Spain	Meteorology	WP4/WP5
Arnau Amengual Pou	male	University of Balearic Islands	Spain	Meteorology	WP4/WP5
Maria del Mar Vich Ramis	male	University of Balearic Islands	Spain	Meteorology	WP4
Jordi Vallespir Lladó	male	University of Balearic Islands	Spain	ICT	WP4
Stefania Meucci	female	MMI srl	Italy	hydraulic	WP3,WP7
Carlo Maiorano	male	MMI srl	Italy	Hydraulic	WP3
Giacomo Branca	male	University of Tuscia	Italy	Agricultural economic	WP6
Ilaria de Benedetti	female	University of Tuscia	Italy	Agricultural economic	WP6
Massimo Menenti	male	Deflt University	The Nethelands	Hydrology + remote sensing	WP2,WP3
Monica Herrero Huerta	female	Deflt University	The Nethelands	Remote sensing	WP2
Seyed Enayat Hosseini Aria	female	Deflt University	The Nethelands	Remote sensing	WP2
Li Jia	female	RADI-CAS	China	Hydrology + remote sensing	WP1, WP3

Chaolei Zheng	male	RADI-CAS	China	Hydrology + remote sensing	WP1, WP3
Guangcheng Hu	female	RADI-CAS	China	Hydrology + remote sensing	WP1, WP3
Raffaele Salerno	male	MOPI srl	Italy	Meteorology	WP4/WP5
Alessandro Perotto	male	MOPI srl	Italy	Meteorology	WP4/WP5
Arjan Peters	male	Aa en Maas water board	The Nethelands	End-users	WP1, WP7
Moorman Joos	male	Aa en Maas water board	The Nethelands	End-users	WP1, WP7
Frank Van der Bolt	male	Aa en Maas water board	The Nethelands	End-users	WP1, WP7
Raffaella Zucaro	female	CREA- economic agriculture	Italy	Agricultural economic	WP6
Massimo Gargano	male	ANBI – Italian association of irrigation consortia	Italy	End-users	WP1, WP7
Francesco Santoro	male	Capitanata irrigation consortium	Italy	End-users	WP1, WP7
Giuseppe de Filippo	male	Capitanata irrigation consortium + farmer	Italy	End-users	WP1, WP7
Luigi Nardella	male	Capitanata irrigation consortium	Italy	End-users	WP1, WP7
Stefano Guzzetti	male	farmer	Italy	End-users	WP1, WP7
Emanuele Bignotti	male	Chiese irrigation consortium	Italy	End-users	WP1, WP7
Luigi Lecchi	male	Chiese irrigation consortium	Italy	End-users	WP1, WP7

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

Name	Gender	Consortium Partner	Site of visit	Purpose of visit	Duration of visit	Output of visit
Marco Stanganelli	male	Politecnico di Milano	Valencia	Remote sensing	February to April 2016	Msc thesis Remote sensing and hydrology interaction
Alessandro BRIANZA	male	Politecnico di Milano	Den Bosh	Hydrology	October to December 2016	Msc thesis hydrological modeling
Davide CANIGGIA	male	Politecnico di Milano	Den Bosh	Hydrology	October to December 2016	Msc thesis hydrological modeling

Nicola Paciolla	male	Politecnico di Milano	Delft	Remote sensing	November to December 2017	Msc thesis Remote sensing and hydrology interaction
Romualdo Romero March	male	University of Balearic Islands	Milan	Meteorology	1 June to 31 August 2018	Meteorological – hydrological model interaction
Arnau Amengual Pou	male	University of Balearic Islands	Milan	Meteorology		Meteorological – hydrological model interaction
Marcelo Silas	male	University of Tuscia	Milan	Agricultural economic	July to December 2017	Agricultural economic
Josè Gomez	male	University of Valencia	Milan	Hydrology	September to December 2017	Remote sensing and hydrology interaction

e. Collaboration, coordination, mobility and synergies

Performed work

The project is a good example of collaboration among several partners, that have already a consolidated experience of common work, but with their own specific competences tied up by the interest in the achievement the main project objective. This may be seen from the list of the authors of each attached annexes. This collaborative approach is witnessed by several meeting and exchange of information among partners which have characterized this first part of the project activities. The activities have been performed according to the project proposal and in the table below the contributions of partners are reported in details.

WP Number	WP Title	WP Leader	WP Participants
WP0	Coordination	POLIMI	
WP1	Ground monitoring	POLIMI	UVES, MMI, TUD RADI-CAS, End-Users
WP2	Satellite data for hydrological models	UVES	RADI-CAS, TUD
WP3	hydrological modelling of water-energy fluxes	TUD	POLIMI, RADI-CAS
WP4	Meteorological forecast	UNI-BAL	EPSON
WP5	soil moisture and evapotranspiration real time forecast for irrigation water needs	POLIMI	RADI-CAS, TUD
WP6	Economic and environmental analysis	UNITU	
WP7	Product implementation	MMI	EPSON, UNITU, End-Users

Coordination

The POLIMI coordinator has organized the work with several meetings organized among small group of partners with dedicated project objectives, and two group meetings (e.g. Table meetings of this report).

Meetings have been organized by the project coordinator and local project partners with different end-users, which belong to farmers, irrigation districts and water basin authorities. These belong not only to the SIM project case studies but also to other potential end users which might be interested to apply the SIM system.

These meetings have been done in person or voice over IP. Refer to the final report for the list of meetings

Moreover, the coordinator together with partners have identified the members of the advisory board and invited them to review and to advise the project. The advisory board members are chosen combining together the experience of Prof. Eric F. Wood from Princeton University in remote sensing and hydrological processes; the professional experience of Dott. Shelley Mac Millan from World Bank and Prof. Antonio Massarutto from Udine University on agricultural economics at farm and national levels.

Mobility

During the project activities a mobility program has been followed (Table.d) with exchange of researcher and students between consortium partners. This mobility has guaranteed the coordination and exchange of ideas between the different interconnected activities (e.g. the remote sensing data interaction with hydrological modeling, or the meteo-hydrological chain aspects), but also the knowledge transfer with end-users (e.g. Aa en Maas database creation).

Synergies with other projects

The SIM project activities have gain experiences from some interconnected projects: 1) RET-SIF real time soil moisture forecast for smart irrigation (ERANETMED) - 2018-2021(POLIMI, UVEG, MOPI, UNITUS, UCD, CESBIO)Monitoring and forecast of root zone soil moisture; prototype of operative web-dashboard; 2) Managing crOp water Saving with Enterprise Services (MOSES), funded by horizon 2020 (UCD)satellite and hydrological modelling to monitor water requirements and use in irrigated agriculture; 3) DBAR-Water (Asia–Africa–EU) (POLIMI,UCD)Global partnership on water science using satellite data; 4) FLEX Performance Requirements – ESA 2014-2020 (UVEG) Satellite data for vegetation stress monitoring; 5) Multi – source hydrological data products to monitor High Asian River Basins and regional water security (MUSYCADHARB) (Forcing Calibration, validation and data assimilation in basin scale hydrological models using satellite data products 2016-2020 (ESA DRAGON 4 ID 32439_3)

f. Infrastructures

The project has created a new ICT infrastructure with a server for the project database store and for the dashboard management (real-time data acquisition, modelling chain, dashboard running).

Then, several scientific instrumentations have been bought for monitoring soil moisture and evapotranspiration (e.g. eddy covariance instruments as gas analyzer and sonic anemometer, thermohydrometer, radiometer, soil moisture TDR probes).

g. *Which WaterWorks2014 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 SIM project responded to the call theme: 3. Research and Innovation for Developing Technological Solutions and Services to Mitigate Impacts of Extreme Events (Floods and Droughts) at Catchment Scale.

In particular, SIM, thanks to the development of a specific tool supporting a parsimonious use of the irrigation water, has an immediate positive wide impact on the careful and parsimonious use of the water in Europe as well as in China, following the EU CAP agricultural water policies the EU water framework directive. The SIM project tool will impact on the end users community which belongs to farmers, irrigation districts and water basin authorities through the different policy/rules on how

irrigation water is used in several countries respect to the actual and forecasted water request, conditioned by quantitative meteorological forecast. In particular in water limited period the project tool impacts on: farmers who have to maintain soil moisture in an optimum value interval allowing water (energy) saving and reducing plant stress; irrigation consortia who have to manage the water among farmers; water authorities who have to manage at basin scale the water withdraw from reservoirs, groundwater or river stream among farmers or consortia. Respect to this issues, the case studies are identified considering also the different irrigation practices, water availability, climatic conditions, crop types, water distribution policies, that present distinct resilience to drought periods. The case studies span from locations where the water table and the channel drainage network have a considerable role in the water supply, as for the Netherlands case, to locations where drip irrigation is widely use due to the scarcity and the cost of the water as for Southern Italy, Spain and China. The Northern Italy case study experiences another different situation with flood irrigation characterized by a fixed time schedule mainly supplied by a regulated lake
Moreover, the parsimonious use of water has also ecological and social impacts not only as mitigation measures in a drought period. Reducing the amount of water through the SIM system in agricultural fields allows to reduce water withdraws from natural ecosystem, loss of nutrients in the water table, consumption of energy and in addition is an ethic message for itself. Water saving concept is a common good, that need the respect of the whole community, it is an intrinsic message of this project that will have a big positive impact especially on a community that is not grown up with this idea due to the relative abundance of water in Europe.

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)?

The SIM Project developed five web dashbaords (platforms) for each case studies (http://www.sim.polimi.it/dashboards/).
The operative web system monitors and forecasts in real time the water content in the soil root layer and compares it with plant stress and soil field capacity water content thresholds, computing the irrigation water needs. Real-time simulation data are daily uploaded on the specifically developed web dashboard. These are available in English and in the local language over possible (Italian, Spanish) for the differen level of users from farmer to basin water authorities.

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.

WP Number	Deliverables	Month	Date of delivery	Lead partner	Comments
WP0	D.0.1 report of end users needs	06	18/10/2016	ITALY	Completed
	D.0.2 Mid Progress report	18	18/10/2017		
	D.0.3 Final report	36	18/04/2019		
WP1	D.1.1 Report describing crop types and irrigation practices	06	18/10/2016	ITALY	Completed
	D.1.2 Consistent data base of meteorological, hydrological, radiometric data for each case studies from 2010 to 2015 and real-time data	35	18/03/2019		Completed
WP2	D.2 Consistent time series for the period 2010 -2015 and real time for each study area: i) albedo; ii) LST, iii) LAI and fractional cover, iv) SM	35	18/03/2019	SPAIN	Completed
WP3	D.3 estimates of soil moisture, evapotranspiration discharge for the cases studies for both modelling approaches.	18	18/10/2017	NETHERLANDS	
WP4	D.4 Consistent meteorological forecast for each case studies	35	18/03/2019	SPAIN	Completed
WP5	D.5 Maps of forecasted and real time estimates of irrigation water needs, soil moisture, evapotranspiration for each case study.	35	18/03/2019	ITALY	Completed
WP6	D.6 Economic analysis of the project tool on the case studies	36	18/04/2019	ITALY	This has been done for the two italian case studies

WP Number	Deliverables	Month	Date of delivery	Lead partner	Comments
WP7	D.7 Development of operative prototype project tool for each case studies	36	18/04/2019	ITALY	The dashbpoards are available for all the case studies.

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

In the following tables are listed the meetings among partners and with end users involved in the specific case studies. The meetings where set up since when the project approval communication was received (December 2015). This has allowed to better organized the case studies activities and the meeting with local end users before the official project kick-off (April 18 th 2016).

N°	Date	Location	Attending partners	Purpose/ main issues/main decisions?
1	12/01/2016	Delft (NL)	POLIMI, DELFT, RADI, End-user Aa en Maas	First meeting with the End user of the Netherland case study, hydrological modelling activities in the case study
2	06/02/2016 to 07/02/2016	Foggia (IT)	POLIMI, End-user Capitanata irrigation consortium and farmers	First meeting with the End user of the southern Italy case study, hydrological monitoring and modelling activities in the case study
3	19/02/2016	Calcinato (BS) (Italy)	POLIMI, End-User Chiese irrigation consortium	First meeting with the End user of the northern Italy case study
4	16/05/2016 to 21/05/2016	China (Beijing, Heihe case study)	POLIMI, RADI, End-user Heihe water authority	First meeting with the End user of the Chinese case study, hydrological monitoring and modelling activities in the case study
5	**06/06/2016**	**SKYPE**	**All project partners**	**Kickoff meeting**
6	08/06/2016	Calcinato (Italy)	POLIMI, End-User Chiese irrigation consortium	hydrological monitoring and modelling activities in the case study
7	13/06/2016	SKYPE	POLIMI, UNITUS	Economic activities, advisory board definition
8	15/06/2016	SKYPE	POLIMI, MOPI, UNIBAL	Meteorological modelling activities
9	14/07/2016	SKYPE	POLIMI, UVES	Satellite data activities, Spain case study data availability
10	26/07/2016	Den Bosch (NL)	POLIMI, End-user Aa en Maas	hydrological modelling activities in the case study, data availability
11	05/12/2016	Milan (IT)	POLIMI, MMI	Hydraulic modelling for the southern italy case study
12	21/02/2017	Foggia (IT)	POLIMI, End-user Capitanata irrigation consortium and farmers	hydrological monitoring and modelling activities in the case study
13	01/03/2017	Milan (IT)	POLIMI, UNITUS	Economic activities data needs, advisory board definition

N°	Date	Location	Attending partners	Purpose/ main issues/main decisions?
14	27/04/2017	Foggia (IT)	POLIMI, End-user Capitanata irrigation consortium and farmers	SIM invited to be presented to the annual conference of Capitanata irrigation consortium
15	17/05/2017	SKYPE	POLIMI, UVES	Satellite data activities, Spain case study data availability
16	28/05/2017	SKYPE	POLIMI, UNIBAL	Meteorological modelling activities
17	09/06/2017	Foggia (IT)	POLIMI, MMI, End-user Capitanata irrigation consortium and farmers	hydrological monitoring and modelling activities in the case study
18	21/06/2017	Rome (IT)	POLIMI, UNITUS, End-user	Meeting with End-users: CREA (Council for Agricultural Research and Agricultural Economy Analysis) and ANBI (italian nation association of irrigation consortium); meeting for the economic activities
19	03/07/2017	Milan (IT)	POLIMI, MOPI, MMI	Meteorological modelling activities
20	**24-25/10/2017**	**Rome (IT)**	**All project partners, all End-users, advisory board**	**Mid-term meeting and end-users conference**
21	26-27/10/2017	Foggia (IT)	POLIMI, MMI, RADI-CAS, End-user Capitanata irrigation consortium and farmers, advisory board	activities in the case study, visit to the irrigation hydraulic structures and field activities
22	30/10/2017	SKYPE	POLIMI, UNIBAL, MOPI	Meteorological modelling activities
23	11/11/2017	SKYPE	POLIMI, UVES	Interaction satellite data and hydrological modelling
24	15/12/2017	Milan (IT)	POLIMI, UNITUS	meeting for the economic activities
25	9/1/2018	SKYPE	POLIMI, UNITUS	meeting for the economic activities
26	23/1/2018	SKYPE	POLIMI, UVES	Interaction satellite data and hydrological modelling
27	19/2/2018	SKYPE	POLIMI, UVES	Interaction satellite data and hydrological modelling
28	21/2/2018	SKYPE	POLIMI, UNITUS	meeting for the economic activities
29	21/03/2018	Rome (IT)	POLIMI, End-user	Meeting with End-users: CREA (Council for Agricultural Research and Agricultural Economy Analysis) and ANBI (italian nation association of irrigation consortium)
30	2/04/2018	Rome (IT)	POLIMI, End-user	Meeting with End-users: CREA (Council for Agricultural Research and Agricultural Economy Analysis) and ANBI (italian nation association of irrigation consortium)
31	7/9/2018	SKYPE	POLIMI, UNITUS	meeting for the economic activities
32	11/11/2018	SKYPE	POLIMI, UVES	Interaction satellite data and hydrological modelling
33	22/11/2018	SKYPE	POLIMI, UNITUS	meeting for the economic activities
34	03/12/2018	Milan (IT)	POLIMI, MMI	Hydraulic modelling activities
35	3/4/2019	SKYPE	POLIMI, UNITUS	meeting for the economic activities
36	15/4//2019	SKYPE	POLIMI, UVES	Interaction satellite data and hydrological modelling

N°	Date	Location	Attending partners	Purpose/ main issues/main decisions?
37	12/06/2019	Rome (IT)	All project partners, all End-users	Final meeting and end-users conference

5. Stakeholder Engagement

SIM project PI has coordinated with the different partners the active participation to the project of the local end-user, ensuring their collaboration and interest to the activities for parsimonious water use. End-users, which belong to farmers, irrigation districts and water basin authorities, have been involved in the early beginning of the project to confirm the specific needs relative to the water use, during the calibration and validation activities with meetings in person or voice over IP. These needs have been represented for each case study in term of forecast horizon, variables to be displayed, useful water and economic indicators.

This is confirmed by the several meetings between project partners and end-users (Table.4) and by the Deliverable 0.1 which reports the end-users needs for each case study. As the field visit in May 2016 – meeting between POLIMI, RADI and the Heihe water basin authority, or April 2016 & October 2017 - meeting between POLIMI, RADI, MMI srl and the Capitanata Irrigation Consortium, the Guzzetti farm and the Advisory board.

Here in the end-users are reported:
-ANBI: Italian association of Irrigation consortia
-Capitanata irrigation consortium: southern Italy case study
-Guzzetti srl and Futuragri farms: two large farms in the southern Italy case study
-Chiese irrigation consortium: northern Italy case study
-Aa en Maas water basin authority: the Netherlands case study
-Heihe water basin authority: china case study
-Las tiesas farmer: spanish case study

These end-users belong not only to the SIM project case studies but also to other potential end users which might be interested to apply the SIM system. In fact, the project final meeting has been organized at the venue of the Italian Ministry of Agriculture among all partners, ANBI and several representatives of the Italian Irrigation consortia.

Moreover, the industries have been involved in the project not only as end-users but also as project partners. In fact, the presence of the two SMEs is of key importance as it represents a guarantee that there will be market opportunities for the product. Water is a public good and public Institutions are often involved in its management at different levels. However, private agriculture firms rely on water resource for irrigation to make profits; and private Institutions are increasingly called to directly manage water resources. This makes the agriculture water market a complex one due to the presence of different management capacities and conflicting interests. In this frame, parsimonious water use in agriculture implies savings in costs and resources (water, energy, fertilizers), with important implications in terms of market competitiveness, sustainable production and environmental benefits. These aspects are becoming more and more important in this period of climatic changes and increased water scarcity (J. Mv Glade European enviromental Agency 2012). This explains why single farmers, irrigation consortia, and river basin water authorities would be interested to the tool; and represent potential buyers on the open market. It is therefore expected that investments in this product will be characterized by high returns. In WP7 of this project these aspects will be analyzed from the two SMEs.

Moreover, the diffusion of the project tool is done not only on scientific journal, but also on more wide journals and conferences to reach stakeholders and industry.
An article has been published on the Italian Sole24 magazine, while in English on Pan European Networks: Science and Technology http://www.paneuropeannetworks.com/;
La Stampa italian newspaper:" Prevedere il fabbisogno idrico in tempo reale? Adesso si può"
https://www.lastampa.it/tuttogreen/2019/08/06/news/prevedere-il-fabbisogno-idrico-in-tempo-reale-adesso-si-puo-1.37301719

The SIM project has also been presented at the following events:
H2O INTERNATIONAL WATER EXHIBITION Technologies, Treatment Distribution, Sustainability in Bologna (Italy);
"IL CONSORZIO E IL SUO TERRITORIO" (The consortium and its territory) organized by Consorzio per la Bonifica della Capitanata (Capitanata Irrigation Consortium) (Foggia – Italy);
Great Rivers of the World, meeting organized by the Italian Minister of Enviroment, Rome 10 2017.

6. Impact Statement

Main impacts achieved

The project activities have followed the schedule presented in the proposal and the project results achieved the proposed impacts. The main impacts are:
1-water saving in agriculture trhought a web-gis support system, based on the SIM strategy irrigation decision criteria in order to plan whether or not to irrigate allowing reducing the percolation flux with a saving of irrigation volume, while evapotranspiration remains almost the same. The system allows to quantify the present and future amount and timing of irrigation water required by plants for their optimal yield and economic profitability
2- the interest in the SIM tool for the careful and parsimonious use of the water by the Capitanata Irrigation consortium and the involved farmers (sothern italy case study) and by the Aa en Maas water authority (the netherlands case study), by the chiese irrigation consortium (norther italy) and the Barrax case study (Spain). This is also of interest of ANBI, the italian association of irrigation consortia.
3-the effort for the diffusion in emerging countries SIM methodology and strategy, following the advise of the advisory board.
4- societal challenges of most of the international organizations dealing with the protection of the planet natural renewable resources and food security
5-The collaboration activities among partners of different countries and for the different case studies is helping to improve not only the knowledge of each partner in their specific branch of science, but also will enlarge partner's specific competence to wider application, strengthening the competitiveness and growth of companies by developing innovations.
6-Collaboration with the presence of SMEs interested in the diffusion, commercialization and improvement of the tool is helping to diffuse it outside the project actors.

Are there any unexpected impacts?

An unexpected impact is related to the SIM tool diffusion which is running into the difficulty of a widespread aceptance, especially among the farmers, due to the peculiar market of the water where low water prices are present. In the next future, nevertheless, this should change in the nex future due to the EU agricultural water policies and the national regulations which are pushing and supporting a more sustainable use of water through water cost based on the effective used volumes and supporting irrigation water saving.
Another difficulty concerns the mechanism of project funding trough different EU member states, that uses different state regulations (coufunded rules, dead lines , etc) that negative impacts on the managemnt of a common project.
This regulation has also penalyzed the present project activity of economic analysis becouse due to a delay in presenting the documentation to Italian Ministry the Tuscia University has losted the entire budegt becoming a partner whithout budget as the Chinese group. The economic analysis where already done thanks to the enthsiasm of Tuscia PI (prof Branca) but of course all the activity has payed this lack of funds.
In addition the Italian partners (those who were funded) have recived the anticipation part of the funds at the end of project (july 2019). This latter episode has exposed the coordinator group of Polimi and the Italian partners, during the whole project duration, not only to run into a finantial exposure, but also in solving all the related difficulties linked to project activities that were done in the absence of financial coverage.

Advisory board comments

The project impacts are also reflected and highlighted by the comments of the SIM adivosry board. This was estabilished at the beginning of the project and is constituted by three experts with different background: Prof. Eric F. Wood from Princeton University senior expert in remote sensing and hydrological processes, Dott. Shelley Mac Millan from World Bank senior expert in irrigation project and investments in emerging and developing countries and Prof. Antonio Massarutto from Udine University expert on agricultural economics at farm and national levels.

The Prof Eric Wood's. The main scientific issues regards the opportunity that the combined use of Distributed hydrological model and surface temperature data from satellite may contribute in controlling the model simulations and downscaling the land surface temperature for monitoring and control soil moisture at the model resolution, that is more suitable for farm agricultural water needs than the satellite data resolution. The FEST-EWB distributed hydrological model may then be used as land surface temperature physical time interpolator between satellite data takes (e.g. increase the 16 days LST LANDSAT resolution) and space interpolator among different contemporary satellite images of the same study area. Monitoring water needs in the farm fields may be also improved experimenting the use of simpler and cheaper sensors (e.g. soil moisture measurements) than the ones already in use and maybe including drones. SIM system is also suitable to provide crop water need seasonal forecast and crop profitability that may be real relevant for the farmers warming up the interest of farmers in the SIM Product. The economic impact of irrigation water part is difficult to assess and is very challenging at once. The water cost is not the main driver in the crop profitability and there is a need to understand also the indirect cost of irrigation on the environment.

For Dott. Shelley Mac Millan the SIM project fits with the World Bank vision. Feeding More People with less water are the two major challenges facing human society. To rise to these challenges, coordinated public and private actions are needed to incentivice water saving measures. Food security versus water security: resolving this apparent controversy problem requires a thorough reconsideration of how water is managed in the agricultural sector. The World Bank is supporting this agenda by: Better water allocation, more productive water use, and improved agricultural return flows. The SIM parsimonious use of water well fit this issues also contributing to reduce conflicts stress among users. The dashboard tool should be easy to use and attractive for developing countries. Water savings alone is not enough to convince people to adopt SIM tool, energy and fertilizer, saving for the same crop productivity may be also considered. It is valuable the effort of the SIM team to demonstrate the economic advantages and eventually additional benefits of using SIM strategy in irrigation use.

According to Prof. Antonio Massarutto, the use of water in a better way has an impact not only on yield productivity, but it can leave free available water for other users at district scale implying new areas that can be irrigated. This suggests different way of calculating the costs and in this sense SIM results will be very interesting in the North of Italy case study, where water is traditionally over abundant than normally, and so there is an high potential of reducing the crop water requirements.

Where do the results of the project impact (e.g. industry, end users, policy, etc.)

The results of the project, as also highlighted before, have an impact at different level, supporting the users in parsimonious irrigation water management from basin authority to single farm. In particular in water limited period: i) farmers to maintain soil moisture in an optimum value interval allowing water saving and reducing plant stress, ii) irrigation consortia to manage the water among farmers; iii) water authorities to *manage at basin scale among farmers or consortia the water withdraw from reservoirs or groundwater or river stream, respect to the actual and forecasted water request and quantitative meteorological forecast. Infact the SIM tool influences the public and private markets due to the peculiar market of the water that refer to a public common resources managed by public, private or mixed companies.*

Have the partners identified exploitable results?

The SIM tool itself is directly an exploitable reuslts. In fact, the dashboard is an operative web-based system which monitors and forecasts water needs in real time, allowing to use less water, fertilizers and energy than in traditional systems, keeping a constant crop yield. The system quantifies the right amount of water at the right time needed for optimal crop production, based on the weather conditions, type of soil and farming practices. Water and economic indicators as water efficiency and water productivuty are compared using the SIM irrigation strategy showing signicant improvements not only in place with flooding irrigation systems like in the Chiese consorzium, but also in place like the Capitanata consortium where the drip irrigation is present.

The main targets of the system are farmers, irrigation consortia and water authorities.

Has intellectual property protection been considered?

This is under evaluation as the preparetion of the documentation for the web-dashboard.

7. Knowledge Output Transfer

Short Title *Please provide a short and concise title to describe the Knowledge Output*	SIM dashboard tool
Knowledge Output Description	The dashboard visualizes project results and manages the different partners' modelling tools providing homogenised output results, emphasizing the local experience in monitoring and modelling such a process and increasing locally the familiarity of the project approach. This control dashboard displays not only present and weekly forecasted irrigation water needs with multiple layers of information at farm and irrigation districts levels in real- time, but also homogenised economic and water management indicators. The tool is in English and local national language of the case study.
Knowledge Type	* software ICT tools
Link to Knowledge Output	http://www.sim.polimi.it/dashboards/
Sectors & Subsectors	• Water Scarcity and Droughts • Adaptation to Global Change • Others o Agriculture o Governance

	o Modelling & Prediction o Socio-Economics o Stakeholder Involvement
End User *Choose as many options as required* *Per identified End User, please identify possible applications of the Knowledge Output.*	o Education & Training o Environmental Managers & Monitoring o Industry o Policy Makers / Decision Makers o Scientific Community
IPR	n/a
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why.	The project deals with careful and parsimonious use of agricultural water presenting an operational web tool for real-time forecast of irrigation water requirements supporting different level of water users from basin authorities to single farmer
Status	The dashboard is the final project result, which is an operative tool running daily automatically in real time. This is available for the case studies and users. Of course, new years of experience will gain new knowledge for further improving the dashboard visualization of results.

Short Title	SIM irrigation methodology
Knowledge Output Description	The SIM irrigation strategy is based on a decision criterion in order to plan whether or not to irrigate. This is based on the comparison between the monitored and forecasted soil moisture with the water stress threshold below of which the crop begins to suffer for lack of water. This criterion determines the correct timing of irrigation (reducing the number of irrigations) and the amount of water, allowing to reduce the passages over the field capacity threshold reducing the percolation flux with a saving of irrigation volume, while evapotranspiration remains almost the same.
Knowledge Type	Please choose one option – delete the rest: * exploitable scientific result * guidelines/standards * services/tools
Link to Knowledge Output	http://www.sim.polimi.it/meetings/final-meeting/

Sectors & Subsectors	• Water Scarcity and Droughts
	• Adaptation to Global Change
	• Others
	  o Agriculture
	  o Governance
	  o Modelling & Prediction
	  o Socio-Economics
	  o Stakeholder Involvement

End User	o Environmental Managers & Monitoring o Industry o Policy Makers / Decision Makers o Scientific Community
IPR	n/a
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why.	The project deals with careful and parsimonious use of agricultural water presenting an operational web tool for real-time forecast of irrigation water requirements supporting different level of water users from basin authorities to single farmer
Status	The irrigation methodology is the final project result, applied in the different case studies. Of course, new years of experience in field testing the methodology will gain new knowledge for further improving the results.

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

Internationa l	Peer-reviewed journals	1. C. Corbari, R. Salerno, A. Ceppi, V. Telesca, M. Mancini, Smart irrigation forecast using satellite LANDSAT data and meteo-hydrological modelling, February 2019, Agricultural Water Management 212:283-294, 2. M.Herrero-Huerta, S.Lag√°ela, S.M.Alfieri, M.Menenti, Generating high-temporal and spatial resolution TIR image data, International Journal of Applied Earth Observation and Geoinformation, 78, 2019, 149-162 3. Mancini M., Corbari C , Ceppi A, Gabriele Lombardi, Giovanni Ravazzani, Imen Ben Charfi, Nicola Paciolla, Erika Ferrari, Luca Cerri, Josè Sobrino, Drazen Skokovic, Li Jia, Chaolei Zheng, Guangcheng Hu, Massimo Menenti, Monica Herrero Huerta, Seyed Enayat Hosseini Aria, Raffaele Salerno, Alessandro Perotto, Romu Romero, Arnau Amengual, Alejandro Hermoso Verger (UNIBAL), Giacomo Branca, Ilaria Benedetti, Raffaella Zucaro,

		The SIM operative web dashboard for parsimonious irrigation, in preparation 4. Corbari C., Skokovic, Sobrino, Nardella, Noviello, Guzzetti S., Corbari L., DeFilippo, P. Riccio, A. Ceppi, Mancini M., Satellite land surface temperature data for the calibration of the soil hydraulic parameters of an energy water balance in the Capitanata irrigation Consortium, in preparation 5. Corbari C., Nardella, Mancini M., SIM Irrigation water needs estimates for the Capitanata irrigation Consortium from remote sensing and energy water balance modelling, in preparation 6. Ceppi, Corbari C., Lombardi, Amengual, Romero, Salerno, Mancini M., effect on soil moisture of meteorological forecast in the Chiese and Capiatanta irrigation Consortia in Italy, in preparation 7. Corbari C., Ravazzani, Bignotti, Mancini M., In series calibration of a distributed energy water balance model using satellite land surface temperature and ground river discharge in the Chiese river basin, in preparation 8. Corbari C., Bignotti, Lecchi, Mancini M., Optimized SIM Irrigation water needs in the Chiese irrigation Consortium from remote sensing and energy water balance modelling , in preparation 9. Corbari, Ben Charfi, Mancini, Precision irrigation and crop yield, indicators, tomatoes and maize in the Chiese and Capitanata irrigation consortia, in preparation 10. Corbari, Ravazzani, Moormann, Van der Bolt, Peters, Mancini, calibration LST and aquifer in Raam district Aa en Maas, in preparation 11. Ben Charfi, Corbari, Skokovic, Sobrino, Mancini, Barrax effect of parsimonious irrigation with an energy water balance model, in preparation 12. Ben Charfi, Corbari, Skokovic, Sobrino, Mancini, Irrigation pivot sprinkler modelling in Barrax, in preparation 13. Ferrari, Corbari, Mancini. Aerodynamic resistance parametrization and its effect on lst? H? , in preparation 14. Paciolla, Corbari, Zheng, Guengfeng, Jia, Menenti, Mancini. Evapotranspiation estimates with LST Heihe, in preparation

		15. Branca, De benetti, Zucaro, Corbari, Mancini, Economic impacts at farm scale of using the SIM irrigation strategy, in preparation
	Books or chapters in books	1. 2. 3.
	Communications (presentations, posters)	1. M. Mancini, C. Corbari , A. Ceppi, G. Ravazzani, M. Menenti , L. Jia 3, R. Romero 4, A. Amengual 4, J. A. Sobrino 5, D. Skokovic 5, S. Meucci 6, R. Salerno 7, G. Branca 8, R. Zucaro 9, smart irrigation from soil moisture forecast using satellite and hydro –meteorological modelling, Proc. Meeting of the Great Rivers of the World, Italian Minister of Enviroment, Rome 10 2017 2. Smart Irrigation From Soil Moisture Forecast Using Satellite And Hydro –Meteorological Modelling, C. Corbari, Politecnico di Milano, Italy M. Mancini, G. Ravazzani, A. Ceppi, R. Salerno, J. A. Sobrino, RECENT ADVANCES IN QUANTITATIVE REMOTE SENSING - RAQRS 2017 18 to 22 September 2017 3. Evapotranspiration estimates from an energy water balance model and satellite Land Surface Temperature over the desertic Heihe river basin, Nicola Paciolla, Chiara Corbari, Chaolei Zheng, Massimo Menenti, Jia Li, and Marco Mancini, European geoscience union, EGU2019 4. A distributional model of simulation water distribution pattern under Center pivot irrigation and its impact on soil moisture, Imen Ben Charfi, Chiara Corbari, and Marco Mancini, European geoscience union, EGU2019 5. SIM: smart irrigation from soil moisture forecast using satellite and hydro –meteorological modelling, Chiara Corbari, alessandro ceppi, giovanni ravazzani, gabriele lombardi, drazen Skokovic, jose sobrino, arnau amengual, romu romero, raffaele salerno, giacomo branca, and marco mancini, European geoscience union, EGU2019 6. SIM: smart irrigation from soil moisture forecast using satellite and hydro –meteorological modelling, Chiara Corbari, alessandro ceppi, giovanni ravazzani, gabriele lombardi, drazen Skokovic, jose sobrino, arnau amengual, romu romero, raffaele salerno, giacomo branca, and marco mancini, Esa living Planet symposium 2019
National (separate lists for each nationality)	Peer-reviewed journals	1. 2. 3.
	Books or chapters in books	1. 2. 3.
	Communications (presentations, posters)	1. Italy – DICA lunch seminar 2. Italy – IDRA - XXXVI Convegno Nazionale di Idraulica e Costruzioni Idrauliche Ancona, 12-14 Settembre 2018, SIM: SMART IRRIGATION FROM SOIL MOISTURE FORECAST USING SATELLITE AND HYDRO –METEOROLOGICAL MODELLING, M. Mancini 1, C. Corbari 1, A.

		Ceppi 1, G. Ravazzani, M. Menenti 2, L. Jia 3, R. Romero 4, J. A. Sobrino 5, S. Meucci 6, R. Salerno 7, G. Branca 8, R. Zucaro9
Dissemination initiatives	Popularization articles	1. Smart irrigation Monitoring and Forecast (SIM), Science and Technology vol. 25, 12, 2017, pag. 248-249; Pan European Networks, 2017. http://edition.pagesuite-professional.co.uk/html5/reader/production/default.aspx?pubname=&edid=c780812e-ef43-4ea4-bf5a-7c8f0cfe1e7d 2. Irrigation smart e piene (Smart irrigation and floods), Platinum – Sole 24 Ore, Research & Innovation, 66, November 2017 3. la stampa: Prevedere il fabbisogno idrico in tempo reale? Adesso si può https://www.google.it/amp/s/www.lastampa.it/tuttogreen/2019/08/06/news/prevedere-il-fabbisogno-idrico-in-tempo-reale-adesso-si-puo-1.37301719/amp/
	Popularization conferences	1.MAC FRUIT 9-5-2019 RIMINI, Il Progetto Sim Smart Irrigation Modelling al convegno Terza Giornata Nazionale dell'innovazione per l'irrigazione - acqua campus: 2 Il Sistema SIM, al convegno Quantificazione e monitoraggio dei dati sulle risorse idriche per la valutazione delle politiche, CREA –MIPAF , Roma 22_5_2019,
	Project Website	www.sim.polimi.it
	Others	1. 2. 3.

9. Open Data

Maximum 1 page

The mid-term and final reports are uploaded on the OpenWaterJPI Interface; while the presentations by all project partners and some stakeholders at the final SIM meeting are reported in the project website (http://www.sim.polimi.it/meetings/final-meeting/) due to space limitations on the openWaterJPI interface.

10. Continuation strategy

The innovative aspects of the SIM tool set up in the project and the presence of SMEs (partner and sub-contracts) interested in the diffusion, commercialization and improvement of the tool will make possible to maintain the tool operative for some case studies also after the official conclusion of the project.

Moreover, other scientific projects will be persecuted by the different partners in their fields of studies at international and national levels in water savings for agriculture themes (e.g. PRIMA call – 2019 second stage reached, new horizon Europe…). There are already two funded projects which involve some of the partners: 1) RET-SIF real time soil moisture forecast for smart irrigation (ERANETMED call) - 2018-2021(POLIMI, UVEG, MOPI, UNITUS) for monitoring and forecast of root zone soil moisture; prototype of operative web-dashboard, 2) GROW H2020 project 2019 (POLIMI) for low cost soil moisture sensors from citizen science platform.

Operative technical projects will also be implemented directly with own funding of large farms or irrigation consortia through universities spin-off and SMEs.
The idea then is to try to patent the SIM dashboard methodology which can contribute to the possible follow-up of the project also after its ending. In fact, the loyalties earned form this patent will be reinvested to continue the research in the SIM field of water savings and parsimonious managements.
Besides, the system that has been implemented in the SIM project is very flexible and can be reproduced in any agricultural area of the word. This characteristic is due to the project design structure and the type of physically based models implemented, which are pixel wise. Hence, single farms fields can be monitored as well as irrigation districts or water basins. Moreover, the meteorological models and remote sensing data are not limited by geographical or political boundaries. Hence replicability and transferability are intrinsically embedded in the system. This consideration is of major importance to insure to adaptability and replicability of the project worldwide.

11. Innovation Potential

The project originality holds in the synergic combination of meteorological, satellite, agronomic, hydrological and economical tools organised in a pixel wise architecture framework able to compute, to display and to support on-farm irrigation water management and relative economic convenience and to extrapolate its achievements to the entire irrigation district.
Then, proposed approach relies on different and original tools developed by the project partners in the very last few years, which are considered in the scientific community to be at the state of the art. These deal with:
•a web platform for irrigation water management (Ceppi et al., 2014) based on meteorological ensemble predictions at medium-range coupled with local hydrological simulations of water balance (without satellite data) to forecast the soil water content on a single maize field.
•the FEST-EWB model with its energy-water balance scheme allows to compute continuously in time and distributed in space soil moisture and evapotranspiration fluxes thanks to a double link with satellite data as input parameters (e.g. LAI) and as variables for model states update (LST) and its pixel wise calibration (Corbari et al.,2011; Corbari & Mancini, 2014).
•the ETMonitor is a hybrid evapotranspiration estimation model that combines theories of energy balance, plant physiology and water balance processes, forced by a variety of biophysical parameters and surface soil water status which are derived from multi-source remote sensing data (from optical to microwave sensors) (Hu and Jia, 2015, Jia et al., 2014; Cui and Jia, 2014),
• the Economic analysis is in line with the latest EU orientation with respect to water management in agriculture and recently expressed within WFD and the CAP reform.

12. Administrative & financial aspects / Budget use

Politecnico di Milano
Cost description: A general summary of our expenses, in % of total: PERSONNEL own-funding= 50 %, PERSONNEL funded by project = 24,5 %, overhead= 7,5 %, instruments = 4,7 %, sub-contracting = 8,6 %, other costs= 4,7 %.
Difficulties related to founds: A huge delay in the funding from the Italian Ministry led to a remarkably effort to perform the project. In fact, all the activities (results and deliverables) have been achieved. This has been possible due to personal funding and to the University that anticipated part of the

budget. The contract with the Italian Ministry has been signed about one month before the end of the project, 38 months from the start of the project itself!!!

MOPI

Difficulties related to founds: From the administrative point of view no particular difficulties have been occurred during the development of the project both in terms of documentation and preparation. Everything has been clear from the technical point of view and the collaboration has been very effective. From the financial point of view, however, due to the huge delays in the funding (the contract has been signed about one month before the end of the project, then after 38 months from the start of the project itself), the project has been developed with an extraordinary effort in terms of used resources (personnel and structure). In this framework, the use of the internal personnel has been increased, reducing the use of contractual research. Other marginal costs has also been re modulate r.
Cost description: Hence, except for some costs (about a 10%) related to overhead and general expenditure, and about a 12% of costs related to contractual research, the remaining part of the budget has been used to the internal personnel. A positive aspect, however, can be caught for this situation, since this need, on the other hand, has further increased the internal competences and direct expertise.

MMI srl

Cost description: personnel = 21,7 %, overhead= 10,8 %, instruments = 7 %, sub-contracting = 58,2 %, other costs= 2,3 %.
Difficulties related to founds: Similarly to the other Italian partners, the huge delay in the funding from the Italian Ministry led to a remarkable effort to perform the project and reach the proposal objectives that were in any case achieved as scheduled. The delay in the funding and relative difficulties has also implied a modification of the initial budget . The partecipation to the project had a positive impact on the company increasing the company profile and its personnel competence.

Delft University

Cost description: *Labour costs / personnel: postdocs, PhD students; Travel and living costs for project meetings and field work; Sub-contracts: acquisition of in-situ data on two study areas: Hei-He basin in China and Aa&Maas in The Netherlands*
Difficulties related to founds: no difficulties are reported

University of Balearic Islands

Cost description: A general summary of our expenses, in % of total: PERSONNEL Graduate Level (contribution of project to their PhD Thesis) = 40 %, PERSONNEL PostDoc Level = 45 %, COMPUTER EQUIPMENT (PC + disk storage systems) = 10 %, TRAVEL (short stays abroad + project meetings) = 5 %.
Difficulties related to founds: no difficulties with the financial aspects, because despite the transfer of money from the Spanish Ministry is typically delayed several months, the University anticipates part of the budget in order to start the activities of the project.

University of Valencia

Cost description: 102.942,40 (€) have been used for the Staff, 4.435,53 (€) for Travel and subsistence, 7.413,39 (€) for Overheads and other costs. The TOTAL COST is 114.791,30 (€).
Difficulties related to founds: The initial budget of the project was reduced from €150,000 to €115,000, so certain activities could not be carried out (as instrumentation purchase) or have reduced their budget (travel and other expenses). In addition, the money for the project did not arrive until

June 2016, so the staff could not be hired until November (taking into account the bureaucratic delays of the call). In spite of this, the initial objectives of the project have been maintained and satisfactorily fulfilled.

Appendix I: Technical Report

Appendix II: Deliverables