SIM

Smart Irrigation from Soil Moisture Forecast using Satellite and Hydro Meteo Modelling

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Water JPI
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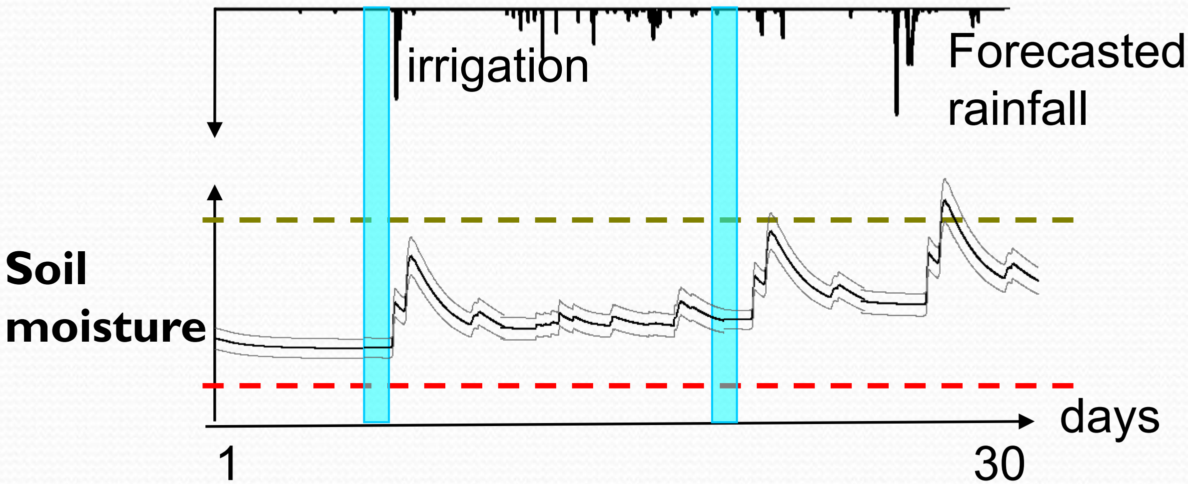
CONSORTIUM DESCRIPTION

ACRONYM	TOPIC	Coordination	Partners
SIM	**3**		
Smart Irrigation from Soil Moisture Forecast using Satellite and Hydro Meteo Modelling		**Smart irrigation, soil moisture forecast, remote sensing, hydro-meteorological forecast**	

PRINCIPAL INVESTIGATOR	INSTITUTION	COUNTRY
Marco Mancini	**Politecnico di Milano**	**Italy**
Massimo Menenti	Delft University of Technology (TUD)	The Netherlands
Li Jia	Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences (RADI-CAS)	China
Romualdo Romero	University of the Balearic Islands (UNI-BAL)	Spain
Josè A. Sobrino	University of Valencia (UVES)	Spain
Stefania Meucci	Modellistica e Monitoraggio Idrologico (MMI)	Italy
Raffaele Salerno	Meteo Operations Italia – Centro Epson Meteo (EPSON)	Italy
Giacomo Branca	Università della Tuscia (UNITU)	Italy

Objectives of the project

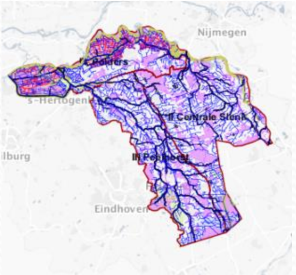
The **objective of the SIM project is to develop and apply a tool for real-time forecast of crop water needs,** to support interventions to reduce water losses in agriculture in case of dry or more severe drought periods and to promote a more sustainable use of the water in agriculture, supporting parsimonious water irrigation management at basin scale moving from the need of a single farmer.



End-users scales and needs:

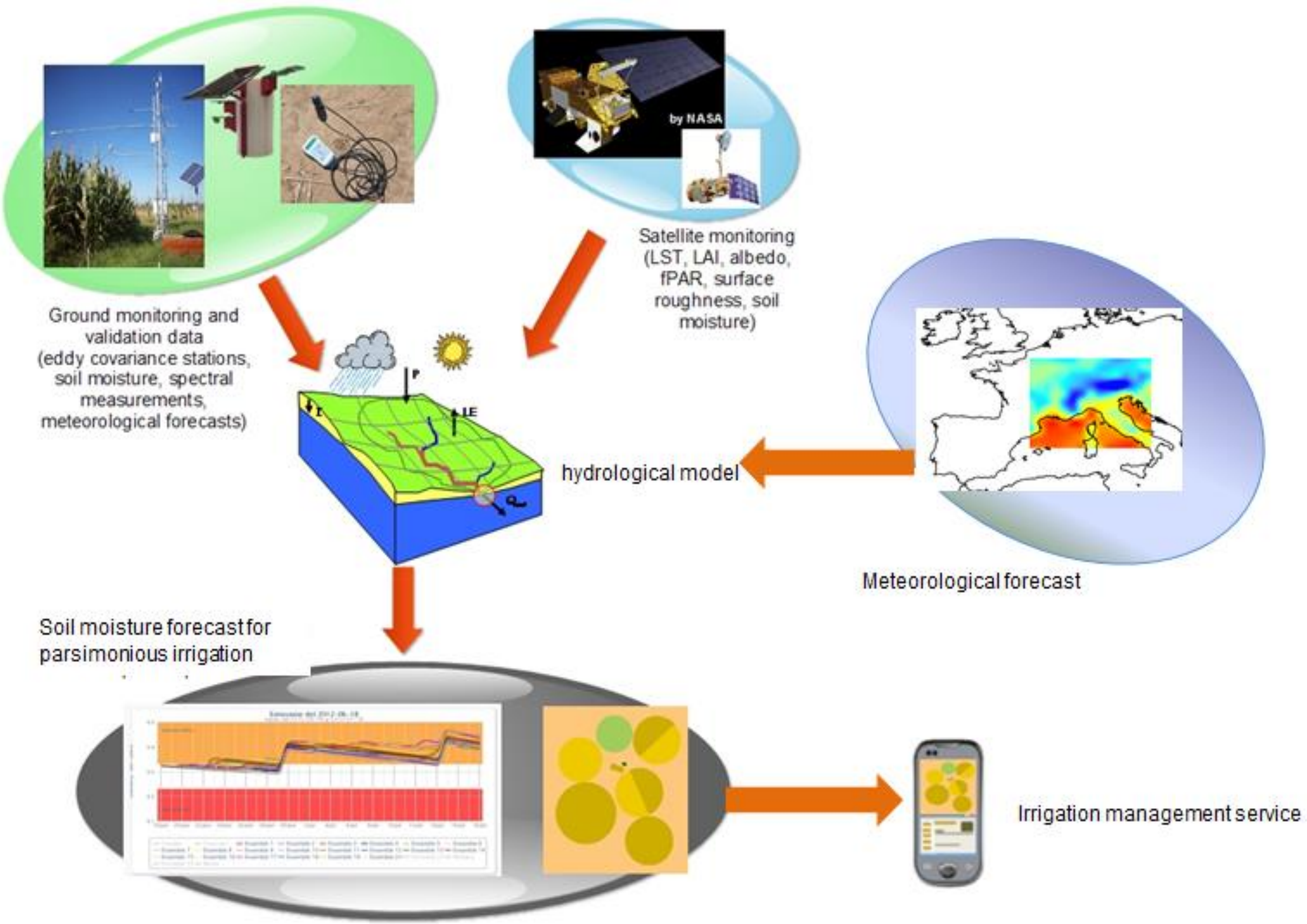
river basin authority

Irrigation consortia



farmers

How objectives will be achieved



SIM

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

<u>Coordinator</u>:
Politecnico di Milano (Italy)
<u>Team</u>:
Delft University (The Netherlands)
University of Valencia (Spain)
University of Baleary (Spain)
Radi-Academy of Science (China)
University of Tuscia (Italy)
Epson meteo (Italy)
MMI srl (Italy)

WATERWORKS 2014 COFUNDED CALL

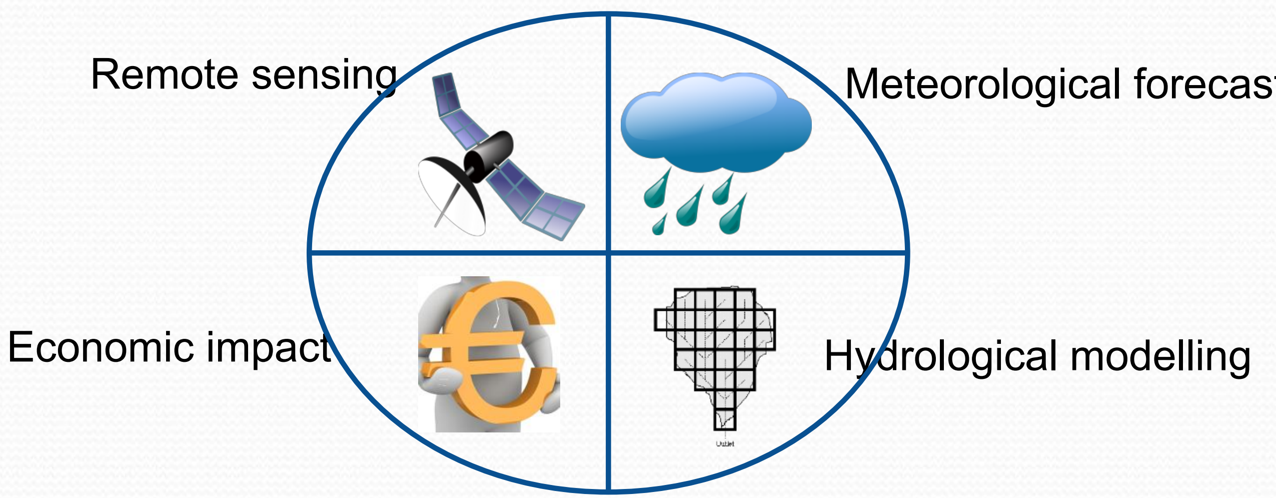
State-of-art and the originality and innovative aspects of the project

Many studies available in literature on **optimizing irrigation management**, few studies focused on the coupling of meteorological forecast and hydrological modeling (*Gowing and Ejieji*, 2001; *Jensen and Thysen*, 2003)

Irriframe
IL PORTALE DELL'IRRIGAZIONE

A number of applications for irrigation management is now available based **on remote sensing data** (*D'Urso*, 2001), used to retrieve soil moisture, evapotranspiration,and also vegetation and surface parameters (LAI, albedo, fractional cover, etc..). Example of use of EO data in real time: The Satellite Irrigation Management Support (SIMS) (NASA's data) (*Forrest et al*., 2012)

SIM



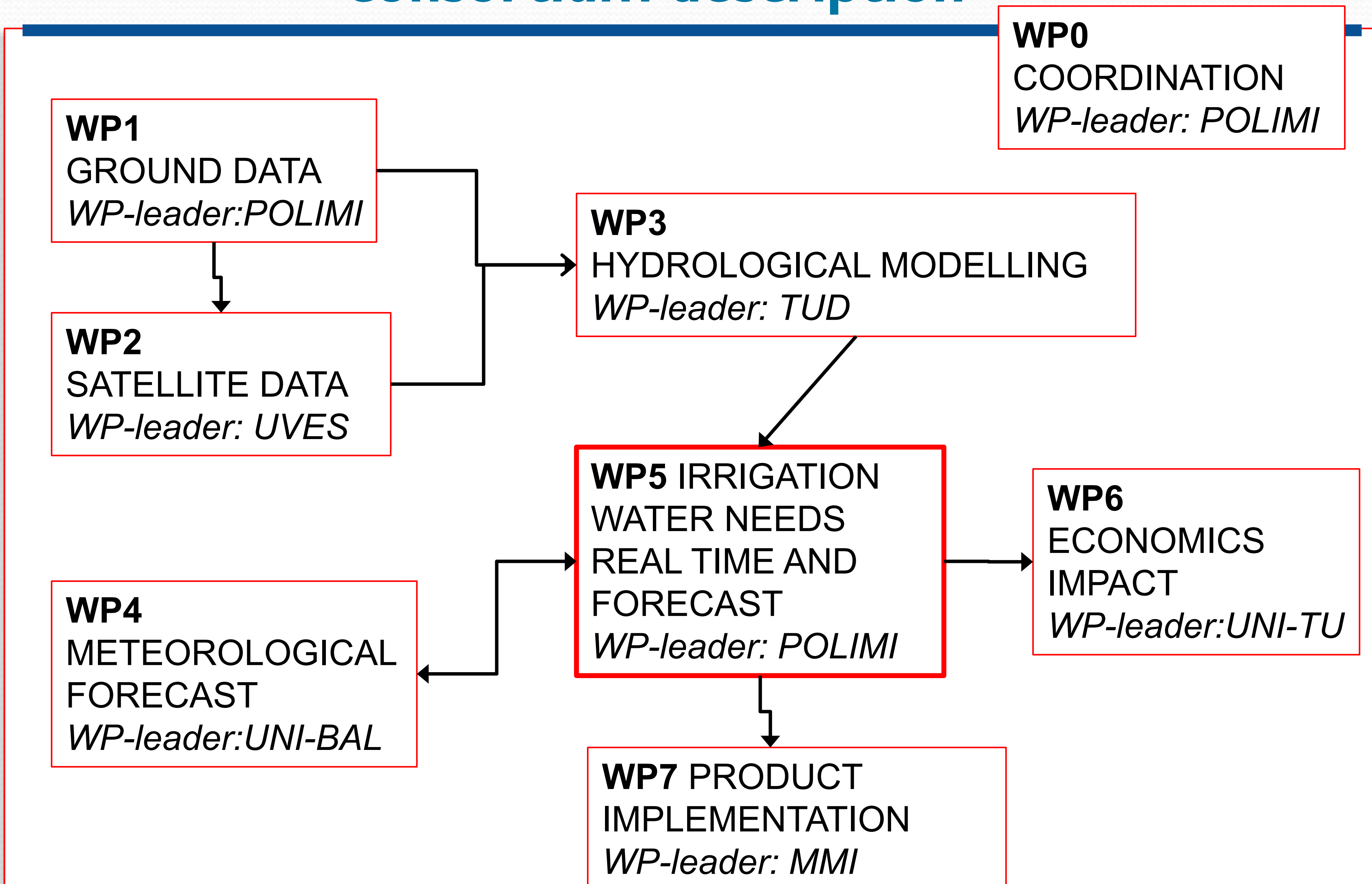
The relation to the scope of the call

The SIM project aims at developing tools for mitigating the impacts and conflicts on water use during water shortage and drought events and responds to the **third subtopic** of the **WaterWorks 2014** call:

3. ***Research and Innovation for Developing Technological Solutions and Services to Mitigate Impacts of Extreme Events (Floods and Droughts) at Catchment Scale.***

- ***Innovative tools for protection from hydroclimatic extreme events, including nature-based solutions, sensor technology, systems for interpreting and communicating data, and monitoring networks;***
- ***Mitigating the harmful impacts of extreme events, implementing the concept of ecosystem services where possible; and***
- ***Developing technological, and/or managerial and/or integrated risk management solutions to urban floods and droughts***.

Work package description/ distribution of tasks/ consortium description



WP0: project coordination

WP Number	WP Title	WP Leader	Duration (months)	Starting Month	End Month
WP0	Coordination	POLIMI	36	1	36

Task.0.1: meetings, internal communication and reports.

- PI will coordinate and control the project activities of the WPs in coordination with the WP-Managers to ensure their execution (meetings in person or voice over ip)
- meetings will be also done to share opinions and results with the scientific experts of the advisory board.
- ***Mid-term progress report and a final report*** with deliverables and milestones
- participation to the three meetings organised by the Water JPI.

Task.0.2: End-user involvement:. End-users, which belong to ***farmers, irrigation districts and water basin authorities***, will be involved:

- in the early beginning of the project to confirm the specific needs relative to the water use,
- during the calibration and validation activities
- At the end of the project end users will be trained for using the implemented tool.

Task.0.3: dissemination:

- project results, published on national and international scientific peer reviewed open access journals and also on specialized agricultural local journals for a direct diffusion to the end users and with presentations in national international and local conferences.
- At the end of the project, a ***public meeting*** will present the project tool and results to a wide assembly of stakeholders and experts
- The SMEs will take care of project tool diffusion into the market, promoting the use of the project tool through the farmers, irrigation consortia and river basin authorities.

WP1: Ground monitoring

WP Number	WP Title	WP Leader	WP Participants	Duration (months)	Starting Month	End Month
WP1	Ground monitoring	POLIMI	UVES, MMI, TUD RADI-CAS, End-Users	35	1	35

The whole acquired dataset will be used as input variables and parameters to the hydrological models, but also for their calibration/validation or state update. ***Two temporal different databases*** will be built including a number of ground data: 1) some ***reanalysis periods from 2010 to 2015*** will be selected for each demonstration area to implement and validate the satellite products and the hydrological models; 2) ***real time data*** for hydrological model input during the service implementation and validation.

Task.1.1: Case studies description

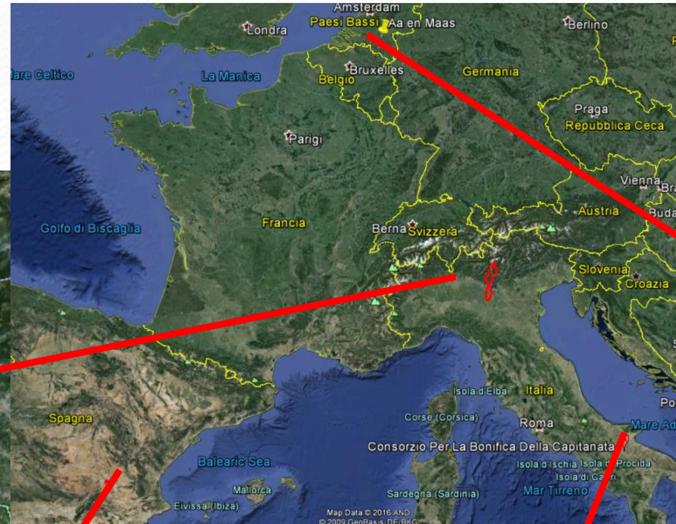
Five case studies between Europe and China are selected considering different climatic characteristic, water availability, type of irrigation practices, water distribution policies, and End-users from farmer to water authorities.

Task 1.2: Real time meteorological data for hydrological models input

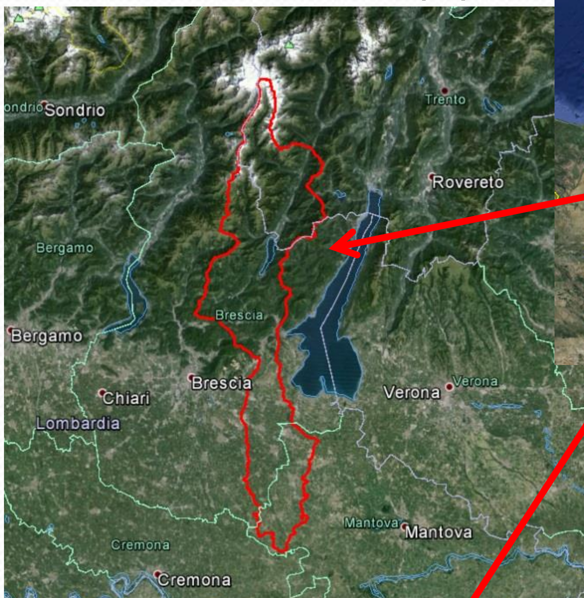
Task 1.3: Soil moisture and evapotranspiration data for the hydrological models validation at farm and basin scale. Different specific fields in the case study areas will be selected for the accurate validation of the project products, looking at evapotranspiration, sensible heat flux, soil moisture, crop water status.

Task 1.4: Radiometric data for satellite data calibration/validation

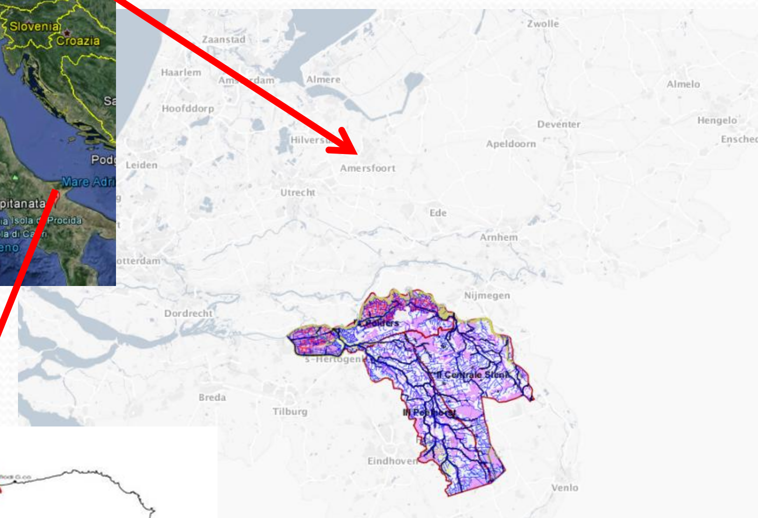
Case studies



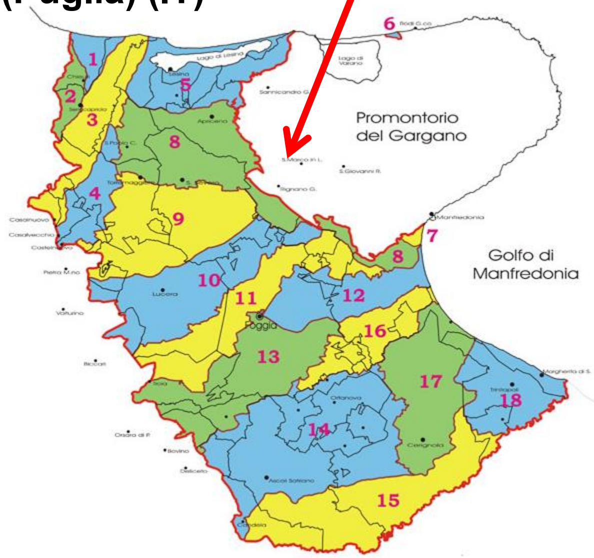
Chiese river basin (IT)



Aa en Maas (NL)

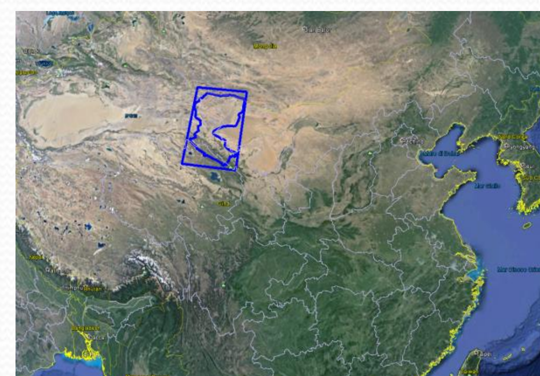


Capitanata consortium + farm (Puglia) (IT)



Barrax (E)

Heihe river basin (CHINA)



WP2: Satellite data for hydrological models

WP Number	WP Title	WP Leader	WP Participants	Duration (months)	Starting Month	End Month
WP2	Satellite data for hydrological models	UVES	RADI-CAS, TUD	35	1	35

Satellite data, collected at different spatial and temporal resolutions, will be ***harmonised*** and analysed for the definition of the ***correct scales*** to compute ***the hydrological-related variables*** and parameters. The temporal resolution and the spatial information of satellite data will allow monitoring over time all the investigated case of studies. Satellite data will be used to retrieve parameters (e.g. LAI, fractional cover, NDVI, albedo) which are used as inputs to the hydrological models; but also as state variables update of the hydrological models (LST, SM). The used satellite data will be Landsat 8 and Sentinel 2-3, MODIS, satellite of Chile and China..

Task.2.1: Time series of Leaf Area Index (LAI), fractional vegetation cover

Task 2.2: Time series of albedo

Task 2.3: Time series of land surface temperature. In order to provide consistent multi sensor temporal series a unique LST algorithm that avoids inconsistencies among different algorithms will be implemented (Jiménez-Muñoz and Sobrino, 2010). Pixel spatial resolution especially for agricultural applications is inversely linked to the temporal resolution so that disaggregation techniques will be applied in order to recover high spatial resolution information from the currently available low spatial resolution data..

Task 2.4: Time series of soil moisture

high resolution soil moisture product by downscaling soil moisture coarse spatial resolution as those from ASCAT, FY-3 and SMOS are based on the relationship between Apparent Thermal Inertia (ATI) and soil moisture (Song and Jia, 2014)

Task 2.5: Real time data

vegetation parameters, albedo, land surface temperature and soil moisture

WP3: Hydrological modelling of water-energy fluxes

WP Number	WP Title	WP Leader	WP Participants	Duration (months)	Starting Month	End Month
WP3	hydrological modelling of water-energy fluxes	TUD	POLIMI, RADI-CAS	18	1	18

Two hydrological models based on different theoretical assumptions will be implemented and validated. The hydrological models here used present a high degree of innovation due to the use of satellite data for parametrization and their validation and control. The models are the a) ***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 EO-data as input parameters (e.g. LAI, fv) and as variables for model states update (LST) and b) ***ETMonitor*** is a hybrid evapotranspiration estimation model that combines theories of energy balance, plant physiology and water balance processes, forced by biophysical parameters and surface soil water status derived from multi-source remote sensing data.

Task 3.1: Implementation of the Hydrological models

Setting parameters and time series

Task 3.2: Calibration and Validation Intercomparison of the two hydrological models

The two models will be ***compared*** for ***each demonstration area*** analysing conceptual scheme, basic hypothesis, input and outputs data. Different issues will be analysed: i) the distinct modelling approaches for soil moisture computation and correlated irrigation water need which are based on satellite microwave (ETmonitor) or thermal infrared data (FEST-EWB); ii) assimilation of remote sensing into hydrological models considering also the spatial and temporal resolution necessary for each case study; iii)model outputs benchmark analysis respect to local measurements and distributed satellite data.

WP4: Meteorological forecast

WP Number	WP Title	WP Leader	WP Participants	Duration (months)	Starting Month	End Month
WP4	Meteorological forecast	UNI-BAL	EPSON	29	6	35

Meteorological forecasts will be produced by running the well known Weather Research and Forecasting model (***WRF***) (Skamarock et al., 2008) at high spatial resolution and with ***forecast horizons from 24 h to 15 days.*** A probabilistic approach based on Local ***Ensemble Prediction System*** will be applied to combine the advantages of global-model ensembles with high-resolution details gained by Numerical Weather Prediction (NWP) models, in order to improve the accuracy of the forecasted variables. WRF model will be run in different configurations using different techniques for providing real-time meteorological variables as input to hydrological models.

Task 4.1: Comparison of modelling techniques in WRF

The effect of different spatial resolutions, lead-time forecasts, uncertainties in both initial conditions and mesoscale forcings will be examined on forecasted meteorological variables.

Task 4.2: Analysis of Spatial Scale issue in forecasting lead-time

Task 4.3: Real time forecast of meteorological forcings

WP5: Soil moisture and evapotranspiration real time forecast for irrigation water needs

WP Number	WP Title	WP Leader	WP Participants	Duration (months)	Starting Month	End Month
WP5	soil moisture and evapotranspiration real time forecast for irrigation water needs	POLIMI	RADI-CAS, TUD	16	19	35

The soil moisture forecasting system and the irrigation water need will be implemented based on ***hydrological models*** initialized from ***meteorological model*** output at short or medium range term according to the irrigation rules differently for each case study. ***Satellite*** (WP2) and ***ground data*** (WP1) will be ***assimilated*** in the hydrological models. Soil moisture and evapotranspiration estimates will be provided at ground measurement locations and as digital high resolution maps at farm and basin scale..

Task 5.1 Water need forecast from evapotranspiration or soil moisture estimates

Task 5.2 effect of different techniques of meteorological modelling forecast into hydrological modelling

WP6: Economic and environmental analysis

WP Number	WP Title	WP Leader	WP Participants	Duration (months)	Starting Month	End Month
WP6	Economic and environmental analysis	UNITU		26	9	35

Task 6.1 Assessing current costs and benefits of water use for irrigation.
The task will assess full water supply costs (capital charges, and operation and maintenance costs) at irrigation scheme level for each case studies.

Task 6.2 Estimating optimal water and cost allocation under different policies
This task will apply game theory in irrigation systems (Podimata and Yannopoulos 2014. Crop/farm models developed in task 6.1 will be used to calibrate continuous-time stochastic game models, which will assess the optimal water use when conflicts over water consumption for irrigation take place.

WP7: Product implementation

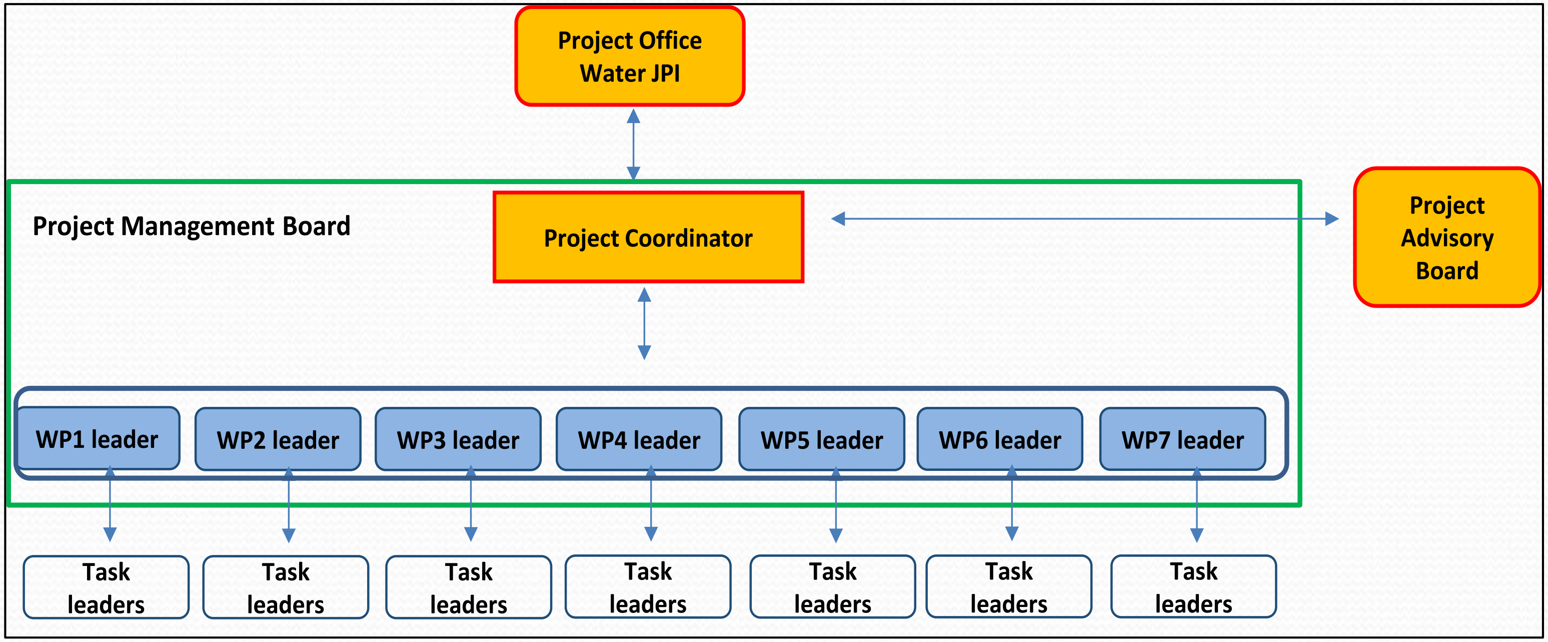
WP Number	WP Title	WP Leader	WP Participants	Duration (months)	Starting Month	End Month
WP7	Product implementation	MMI	EPSON, UNITU,End-Users	18	18	36

The project tool will be implemented with the effort of the two private companies and under the guide of UNITU for the economic aspects as prototype. It will be implemented as a web system reachable from the end-user via web also with modern smart devices and independently from the operative system. The product will be operative for any of the case studies. A business plan will be performed considering the peculiarity of the water market.

Task 7.1 Service implementation.
The developed algorithms (WP5) will be applied in order to provide real time and forecasted net crop water needs. Automatic acquisition and elaboration will be also implemented for ground (WP1) and for satellite data (WP2). These data will be used as inputs or state update for the two hydrological models. A web-service will be implemented for each demonstration area using a dashboard approach, so that end-users will directly have access to the product and the data..

Task 7.2 Interaction with the end users
The two SMEs will take care of project tool diffusion into the market, promoting the use of the project tool through the farmers, irrigation consortia and river basin authorities, with the project coordinator (WP0)

Management structure



The ***project coordination*** is performed by Politecnico of Milano, that will be responsible for the correct financial management, the scientific coordination and the respect of each WP deliverable**.** The project coordinator will be in contact with the ***Project Office*** of Water JPI and with an ***Advisory Board***. The ***project management board*** is chaired by the project coordinator and contains the seven WP leaders, and it will be responsible for verifying progress of the project and adopting appropriate actions in case of deviations from the work plan, monitoring and evaluation of performance and responsible for the approval of deliverables and milestones. ***The WP leaders*** are responsible for the coordination of the activities within their WPs and with other WPs, promoting synergy, identifying possible inconsistencies and generally overseeing implementation and monitoring and reporting on the progress. The ***tasks leaders*** are responsible for the execution of their own tasks as described in the proposal according to their specific expertise.

Expected impacts (research-related/ innovation-related/ societal-related)

- The 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.

- Impact on research-related results by ***combined use of state-of-the-art researches*** in the field of hydrology, meteorological modeling, remote sensing, and economic analysis.

- Positive impact on parsimonious use of water for irrigation, that ***implies protection of the planet natural renewable resources*** and ***food security*** (societal-related)

- Immediate, mid and long-term impacts on knowledge of each ***project partners***

Milestones and deliverables

WP Number	Deliverables	Month	Milestones	Month
WP0	D.0.1 report of end users needs	06		
	D.0.2 Mid Progress report	18		
	D.0.3 Final report	36		
WP1	D.1.1 Report describing crop types and irrigation practices	06	M.1 Case studies consistency control time	6
	D.1.2 Consistent data base of meteorological, hydrological, radiometric data for each case studies from 2010 to 2015 and real-time data	35		
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	M.2 implementation of satellite algorithm for hydrological model	12
WP3	D.3 estimates of soil moisture , evapotranspiration discharge for the cases studies for both modelling approaches.	18	M.3 Definition of the most appropriate distributed hydrological model for each demonstration area	18
WP4	D.4 Consistent meteorological forecast for each case studies	35	M.4 WRF configuration for operative use	18
WP5	D.5 Maps of forecasted and real time estimates of irrigation water needs, soil moisture, evapotranspiration for each case study.	35	M.5 Assessment of hydrological forecast procedure	22
WP6	D.6 Economic analysis of the project tool on the case studies	36	M.6 Assessment of economic crop/farm models for the case study	24
WP7	D.7 Development of operative prototype project tool for each case studies	36	M.7 Assessment of forecasted chain for operative prototype tool	26

Thank you for your attention