2018 Joint Call
Mid-Term Progress Report
Closing the water cycle gap - Sustainable management of water resources

An integrative information aqueduct to close the gaps between global satellite observation of water cycle and local sustainable management of water resources

(iAqueduct)

An integrative information aqueduct to close the gaps between global satellite observation of water cycle and local sustainable management of water resources （iAqueduct）

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1. Publishable Summary

- Project context and objectives

The past decades have seen rapid advancements in space-based monitoring of essential water cycle variables, providing products related to precipitation, evapotranspiration, and soil moisture, often at tens of kilometer scales. Whilst these data effectively characterize water cycle variability at regional to global scales, they are less suitable for sustainable management of local water resources, which needs detailed information to represent the spatial heterogeneity of soil and vegetation. The following questions are critical to effectively exploit information from remotely sensed and in situ Earth observations (EOs): How to downscale the global water cycle products to the local scale using multiple sources and scales of EO data? How to explore and apply the downscaled information at the management level for a better understanding of soil-water-vegetation-energy processes? How can such fine-scale information be used to improve the management of soil and water resources? An integrative information flow (i.e., iAqueduct theoretical framework) will be developed to close the gaps between satellite water cycle products and local information necessary for sustainable management of water resources. The integrated iAqueduct framework aims to address the above mentioned scientific questions by combining medium-resolution (10 m–1 km) Copernicus satellite data with high-resolution (cm) unmanned aerial system (UAS) data, in situ observations, analytical- and physical-based models, as well as big-data analytics with machine learning algorithms.

- Current results

One of first results is the Random Forest (RF) -based downscaling of Sentinel-1 soil moisture (SM) products at 1km to 15 cm, taking land surface features derived from UAS (e.g., land surface temperature, vegetation Index, and elevation) as predictor variables. The developed machine learning algorithm together with satellite and UAS data have been compiled into a web-based tool for downscaling satellite SM data to very high resolution SM data in the field.

While downscaling satellite water cycle products to a fine spatial resolution is achievable as demonstrated using RF algorithm, the satellite product typically refer to surface information that needs to be transferred to the root zone soil moisture (RZSM). The Soil Moisture Analytical Relationship (SMAR) model and the Cumulative Distribution Function (CDF) depth scaling approach have been applied to derive RZSM.

Because soil spectroscopy contains information about soil minerals, organic compounds, and hydrological properties, this has been used to predict water infiltration rate (WIR), which reveals important upper soil layer information (e.g. crust) for agricultural management in arid and semi-arid area.

A simplistic biophysical model was coupled with an agent-based model to simulate a smallholder farmer system, to study how each farmer's choice of water affect yield and economic gain of the single farmer and the community; and how these previous experiences affect the farmers' choice regarding water management and use.

- - Expected results & impacts

iAqueduct will enable the understanding of the space-time variability of EO data (e.g., regarding soil physical characteristics, soil moisture, and evapotranspiration fluxes) from the in situ/plot scale, to field and regional, and to global scales. An end-to-end system will be developed to translate scientific data and knowledge into tailored water productivity information, establish a science–policy–business–society interface to allow for continuous dialogues and interactions across different scales and levels, influencing stakeholders towards desirable behaviors for sustainable water management.

- Project Website & iAqueduct toolbox

iAqueduct website: https://www.costharmonious.eu/iaqueduct-conceptual-framework/

iAqueduct toolbox: http://iaqueduct.itc.utwente.nl/iaqueduct/

2. Work Performed and the Results achieved during the reporting period

a. Scientific and technological progress

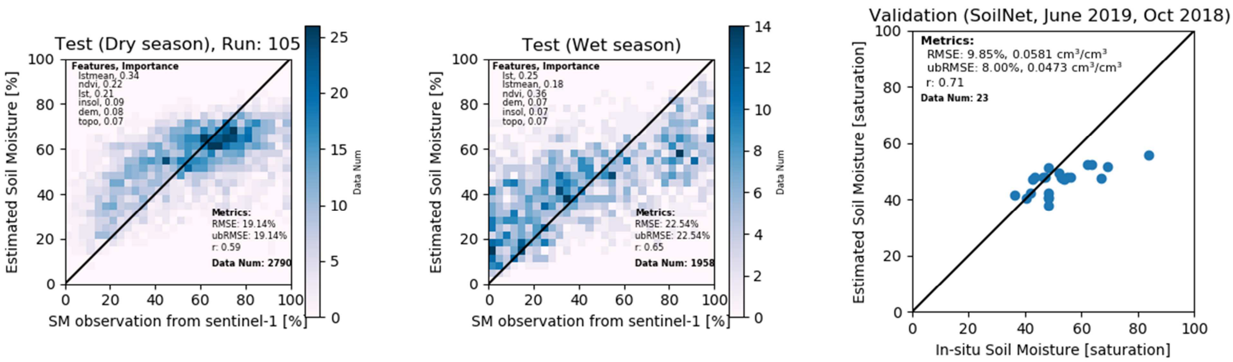
WP1 Downscaling of Satellite Water Cycle Products

The main objective of WP1 is monitoring the spatial variability of soil moisture in the top surface and in root-zone layer and developing methods and procedures for downscaling remotely sensed data. To reach this goal, in the first year of the project the dataset available from the field networks of the different pilot field sites has been assembled and organised. The database contains time-series of the available field soil moisture measurements and of different relevant hydrological variables useful for the interpretation of soil moisture data (i.e. rainfall, discharge, air temperature, relative humidity, wind speed, net solar radiation).

According with action point 3) Task 1.1 ('Generation of high resolution water cycle products of soil moisture, vegetation patterns and vegetation stress at sub-meter spatial scale and daily interval'), intense field campaigns have been conducted during the 2018, 2019 and 2020 years to collect visible (VIS), multispectral (MS) and thermal (TIR) images with UAS platforms in the Alento river catchment pilot site (southern Italy). For each survey, high resolutions VIS-C orthorectified maps, TIR maps (during the day and at night) and the MS map have been generated. The VIS, TIR and MS data have a spatial resolution of approximately 0.04, 0.05m and 0.15m respectively. Furthermore, hyperspectral images with UAS platform have been collected to relate soil spectral information with soil basic properties and hydraulic properties collected by WP2. All these data, after a preliminary validation with outcomes of field measurements and outputs from other models, will be used to downscale satellite products.

In addition, according with point 4) of Task 1.1 ('Characterization of the spatio-temporal distribution of soil moisture and evapotranspiration processes will be conducted after validations of the high resolution imagery from UAS with outcomes of field measurements and outputs from other models'), a simplification of thermal inertia approach, the apparent thermal inertia (ATI), has been applied to map soil water content over unshaded and unvegetated areas in the same catchment. Such data were compared with ground soil sampling carried out with the thermo-gravimetric and time domain reflectometry (TDR). The results obtained show a satisfactory relation between in situ observations and the estimated SM values with coefficient between ATI and soil water content measured over unshaded bare soil around 0.7 for the gravimetric and the TDR methods (Paruta et al., 2020). At the same time, high resolution NDVI maps have been generated from multispectral images. These maps, replicated for different crop growing seasons, can allow to estimate a possible relationship with evapotranspiration at field scale. All these information are essential for linking satellite to point measurements of soil moisture and evapotranspiration supporting the development of downscaling procedures.

The spatial downscaling methods scheduled in action points 1), 2) and 5) of Task 1.1 ('Downscaling of the remote sensing data up to the field scale from hectometer to plot scale using a Bayesian approach') are based on the relationship between soil moisture and various environmental variables. Thus, the proper description on the controlling factors for the spatial variability of soil moisture have been investigated using a rule-based machine learning approach, random forest (RF). Land surface temperature, NDVI, DEM, albedo, slope, insolation, porosity and topographic index are the employed environmental variables. For this purpose, different products from NASA MODIS (land surface temperature, albedo and NDVI), LANDSAT 8 (land surface temperature, NDVI) and Copernicus Sentinel 1C satellite data (soil moisture), operated by the European Space Agency (ESA), were collected at different spatial scale (from 1km to 100m). Additional data products collected are: 1) soil porosity (from Soil grids – 1km) and DTM at high resolution (5m) and low resolution (1km). This study have allowed to understand the importance of each variable in the downscaling process of soil moisture.



(a) dry season test results (b) wet season test results (c) validation results

Figure 1. Test and validation results of SM downscaling using random forest regression, which is trained using features: land surface temperature, NDVI, solar radiance, DEM, topographic index. (a) test of model over dry season, together with features importance; (b) test results over wet season; (c) validation using SoilNet in-situ soil moisture data.

With regard to the task 1.2 ('Derive profile soil water content from surface soil moisture information'), a study has been performed over the Tibetan Plateau pilot site. A depth scaling has been performed based on the blended SSM product, using Cumulative Distribution Function (CDF) matching approach and simulation with Soil Moisture Analytical Relationship (SMAR) model, to estimate the RZSM. The final product is a set of long-term (~10 yr) consistent SSM and RZSM products (Zhuang et al. 2020). The inter-comparison with other existing SSM and RZSM products have demonstrated the credibility of the data blending procedure used in this study and the reliability of the CDF matching method and SMAR model in deriving the RZSM.

According with the framework and chronology of activities, a draft of the first Deliverable D1.1. called 'Satellite/UAS data' has been produced. This deliverable provides a description of field, UAS and Satellite data available and collected during the first year of the project for the selected field sites. Such data are referred to different hydrological variables and are useful for downscaling soil moisture data based on remotely sensed data. This draft needs to be integrated with the contribution of the other partners and will be continuously updated as soon as new data become available also for the different pilot field sites within the project.

WP2 Retrieval of Soil Hydraulic and Thermal Properties

WP2 will apply pedotransfer functions to derive local field specific SHP/STP properties for the modelling of soil water and heat dynamics at field-scale precision. It will bridge soil spectral information that can be obtained at a high resolution by satellites and UAS and the needed soil properties that are traditionally obtained at limited locations by in situ sample collections.

<u>Task 2.1 Collection of field scale data</u>

For the collection of field scale data we listed soil properties required by the models that will be used in WP3. The simulations needs information on water content at saturation, field capacity and wilting point, plant available water content, saturated hydraulic conductivity and parameters of the Mualem-van Genuchten model to describe water retention and hydraulic conductivity in the full suction range.

Table 1. Spectral information acquired by spectrometer and UAS platform for the MFC2-Alento Catchment.

Acquired spectral data	State of soil sample				Extension of survey	Equipment used for the survey	Date of survey
	1	2	3	4			
soil reflectance in the 450-1000 and 450-2400 nm range		x	x		20 points, close to the SoilNET probes	ASD Spectrometer with SoilPRO	13 June 2019
soil reflectance in the 450-1000 and 450-2400 nm range	x		x		20 points, close to the SoilNET probes	ASD Spectrometer, Laboratory	3-4 October 2018 13 June 2019
soil reflectance in the 450-950 nm range, 125 channels		x	x		7.5 ha of study site	Cubert UHD-185 hyperspectral snapshot camera on UAS platform with a spatial resolution of 5cm	15 June 2019
soil reflectance in the 450-2400 nm spectral range	x			x	20 points, close to the SoilNET probes	SoilPRO in situ measurement & spectral analysis in laboratory	4 October 2018, 13 June 2019
soil reflectance in the 7.5-13.5 µm range		x	x		7.5 ha of study site	FLIR Tau 336 thermal camera on UAS platform with a spatial resolution of 15cm	3-4 October 2018, 13-14 June 2019
RGB in VIS range		x	x		18 ha of sub-catchment	Fuji X-T20 snapshot camera on UAS platform	13 June 2019

We collected disturbed soil samples and undisturbed soil cores in the MFC2-Alento catchment at 20 locations, corresponding to the positions of the wireless sensor network end-devices (SoilNET) (Romano et al., 2018) (Figure 2). We measured in the laboratory the soil particle-size distribution, oven-dry bulk density, soil organic carbon content, and the hydraulic properties of soil-water retention and hydraulic conductivity at the full suction range. Furthermore, we also acquired visible (VIS), hyperspectral and thermal images with UAS platform and conducted spectral analysis in the laboratory and in the field (Table 1, Fig. 2).

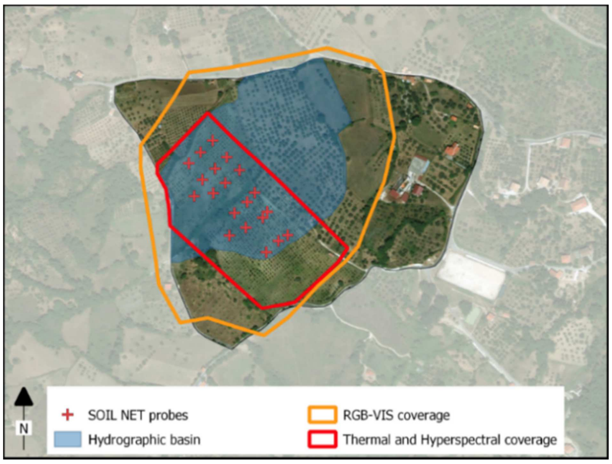


Figure 2. Map of the MFC2-Alento catchment. Red crosses indicate the locations of SoilNet sensors installed at soil depths of 15 cm and 30 cm. The positions of the SoilNet sensors correspond to soil sampling locations. The RGB-VIS coverage area is 18 ha, and the thermal and hyperspectral coverage area is 7.5 ha.

<u>Task 2.2 Soil spectroscopy and hyperspectral remote sensing</u>

VIS-NIR-SWIR spectra contain information about soil minerals, organic compounds, and water. Today, Soil Spectral Libraries (SSLs) are being created worldwide because these datasets have great potential for use as training datasets for machine learning algorithms that can benefit agricultural activity. However, because SSLs are generated under laboratory conditions using disturbed samples it is not clear if they can be used to infer field conditions from remote sensing. Accordingly, we argue that traditional SSLs do not simulate real surface conditions and hence cannot be used to assess soil properties that are strongly dependent on the thin upper soil layer. Water-infiltration rate (WIR) into the soil is strongly related to the upper soil layer condition and it was therefore used to reconcile the existing gap between undisturbed (field) and disturbed (laboratory) soil sampling and reflectance measurements.

A field-based and a lab-based Soil Spectral Library (SSL) with field infiltration rate (WIR) measurements was generated. WIR was measured simultaneously with undisturbed soil spectroscopy using a Mini-Disk-Infiltrometer. The nature of this dataset is varied because it contains different soil types from different countries in the Mediterranean region: Israel, Italy and Greece. This repertory contains 114 samples in which 46 samples are clayey and 59 are sandy. To build this dataset, the following fields were sampled: i) Kibbutz Sde Yoav, Israel (30 samples), ii) Afeka, Tel Aviv, Israel (18 samples), iii) Alento, Italy (21 samples, iv) Central Macedonia, Greece (45 samples from three different fields).

The relation between the field and lab-based dataset was then studied using the WIR because it is strongly dependent of the soil surface condition. A correction factor was generated by calculating the ratio between the laboratory and field spectral observations of all the 114 samples that were collected from Israel, Italy and Greece. Next, the median value of the samples per wavelength was acquired. Then, we smoothed this "spectral ratio" to minimize noise in the corrected samples (Figure 3). This was used as a correction factor for the laboratory spectral data. The 114 samples were randomly divided into two groups: calibration (90% of the samples) and validation (10% of the samples). The same calibration and validation samples were maintained throughout all analyses. Savitzky–Golay first-derivative preprocessing (Savitzky and Golay, 1964) was applied to the spectral data to improve the performance of the models.

After calculating the ratio between the laboratory and field spectral observations, the relationship between the spectra (field and laboratory) and WIR was studied using Partial Least Square Regression (PLSR) model. Three PLSR (Wold et al., 2001) models were calibrated and validated using seven components to predict WIR. The first model was created using the field spectra; the second using the laboratory- data; the third was created using the laboratory-based data after dividing them by the correction factor to evaluate the contribution of field spectral features to the performance of the laboratory-based dataset. The performance of the spectra based WIR predictions (spectrotransfer functions) was described with the root mean square error (RMSE), the coefficient of determination (R2) and performance to deviation (RPD) computed for the calibration (CAL) and validation (VAL) sets.

The result shows that the field-based model presented the best statistical performance in its calibration (R^2_{CAL} = 0.73, $RMSE_{CAL}$ = 0.0004, RPD_{CAL} = 1.91), and in its validation (R^2_{VAL} = 0.82, $RMSE_{VAL}$ = 0.0003, RPD_{VAL} = 2.26). However, the corrected laboratory-based model showed much better results (R^2_{VAL}= 0.66, $RMSE_{VAL}$ = 0.0004, RPD_{VAL} = 1.71; R^2_{VAL} = 0.76, $RMSE_{VAL}$ = 0.0004, RPD_{VAL} = 2) (Figure 6e and 6f) than the laboratory-based non-corrected model (R^2_{VAL} = 0.62, $RMSE_{VAL}$ = 0.0005, RPD_{VAL} = 1.63; R^2_{VAL} = 0.71, $RMSE_{VAL}$ = 0.0004, RPD_{VAL} = 1.83).

These results, show how the spectral gap between laboratory and field spectral observations is manifested in spectral-based predictions. In addition, we found better accuracy for the estimation of WIR by using a simple method to rectify the laboratory-based dataset to better simulate undisturbed spectral observations in the field. Certainly, the correction factor may vary from place to place and it can be relevant to rectify only the used dataset, but still it improved the performance of a dataset composed of different soil types.

Because the field information provided better proxy models than the laboratory measurements, a field-based-model was adapted to the spectral configuration of a hyperspectral sensor onboard a UAV platform to generate a map with the predicted WIR for the top soil layer in the study site of Alento. The results were satisfactorily validated on the ground using field samples. Recently the first paper of this study the "Estimation of WIR of soil using reflectance data from ground and UAV platforms" was submitted to the European Journal of Soil Sciences.

Task 2.3 Basic pedotransfer functions

In Task 2.3 of the iAqueduct project, a basic objective has been to apply and evaluate at selected field sites some pedotransfer functions (PTFs) available in the literature which provide the soil hydraulic characteristics required by models of water flow in soil. We evaluated the performance of parametric applied to the soils of the Upper Alento River Catchment (UARC) (Romano *et al.*, 2018). For this study catchment, a comprehensive dataset of 81 measured soil physical, chemical, and hydraulic properties is available (Table 2). In this report we used sand (%), silt (%), clay (%), and soil organic matter (%) contents, and oven-dry soil bulk density (g cm^{-3}) as input variables for the prediction of soil hydraulic properties (Nasta *et al.*, 2009). We specify that θ_s and K_s were measured and van Genuchten's parameters α and n were fitted on observed data pairs, $\theta(\psi)$ of the WRF (Water Retention Function) based on the use of the suction tables (13 data pairs in the matric pressure head range of $-200 < \psi < 0$ cm) and pressure plate apparatus (3 data pairs at $\psi = -3{,}000$ cm, $\psi = -6{,}000$ cm, $\psi = -12{,}000$ cm).

Table 2. Mean (μ), Standard Deviation (SD), maximum (max) and minimum (min) values of soil textural classes, soil bulk density (ρb), organic matter (OM), saturated water content (θs), water retention parameters (α and n) and saturated hydraulic conductivity (Ks) for the 81 soil samples in UARC.

	μ	SD	min	max
Clay (%)	37.89	15.37	5.08	61.99
Silt (%)	35.35	5.70	21.85	50.79
Sand (%)	26.75	15.74	5.13	67.55
ρ_b (g cm^{-3})	1.30	0.13	1.05	1.61
OM (%)	1.84	0.96	0.32	4.78
θ_s (cm^3 cm^{-3})	0.48	0.048	0.369	0.576
$\log_{10}\alpha$ (cm^{-1})	-0.98	0.43	-1.89	0.067
n (-)	1.13	0.094	1.04	1.60
$\log_{10}K_s$ (cm d^{-1})	-1.25	1.40	-4.42	1.01

The measurement of WRF and K_s is expensive, tedious, time-consuming by resulting rather unrealistic for large-scale soil hydraulic characterization. To circumvent the limitations and burdens associated with both direct and indirect methods, pedotransfer functions (PTFs) have been proposed to estimate soil hydraulic properties by using readily-available or easily-measurable information on soil physical-chemical properties, such as the soil particle-size distribution (PSD), oven-dry soil bulk density, and soil organic carbon content (Van Looy et al., 2017). However, the accuracy of a PTF is constrained by local calibration (which again requires a myriad of measurements).

In this report we estimate the five unknown soil hydraulic parameters (α, n, ϑ_r, ϑ_s and K_s) by selecting 11 popular PTFs (Van Looy et al., 2017) that are based on easily-reproducible empirical regression relationships and easy to apply. To measure the predictive capability of the tested PTFs we selected three statistical performance indicators: the Root Mean Square Error (RMSE) of prediction, the coefficient of determination (R^2), and integral mean deviation (IMD) (Table 3.)

Table 3. Performance of PTFs predicting soil water content at saturation (θs) and at 30 prescribed pressure head values. RMSE: root mean square error; R2: coefficient of determination; IMD: integral mean deviation.

PTF	Reference	RMSE θ_s	RMSE WRF	R^2 WRF	IMD WRF
SAX86	Saxton et al. (1986)	0.124	0.078	0.752	0.398
C&S92	Campbell and Shiozawa (1992)	0.047	0.204	0.522	-
R&B85	Rawls and Brakensiek (1985)	0.047	0.079	0.786	0.277
O&C80	Oosterveld and Chang (1980)	0.244	0.126	0.606	0.420
WOS99	Wosten et al. (1999)	0.046	0.070	0.761	-0.027
VER89	Vereecken et al. (1989)	0.023	0.088	0.718	0.169
euptfv2	Szabó et al. (2020)	0.022	0.065	0.728	-0.002
WEY09	Weynants al. (2009)	0.023	0.070	0.769	-0.015
ROSETTA	Schaap et al. (2001)	0.028	0.103	0.679	0.083
T&H98	Tomasella and Hodnett (1998)	0.100	0.077	0.769	-
RAW82	Rawls et al. (1982)	0.068	0.089	0.683	-

Based on the above results, we suggest that the determination of the soil hydraulic properties in the UARC study area should follow the following approaches: 1) parameters to describe WRF and HCF (hydraulic conductivity function) with euptfv2, 2) ϑ_s with euptfv2, 3) ϑ_{FC} calculated from WRF parameters with WEY09+Assouline and Or, 4) K_s with VER89 + Guarracino (2007).

<u>Task 2.4 Advanced pedotransfer functions</u>

Along the results achieved in the prediction of WIR (Task 2.2), we derived spectrotransfer functions on the LUCAS SSL for the estimation of soil basic and hydraulic properties. We predicted sand, silt, clay, organic carbon and calcium carbonate content, pH and the most frequently used soil hydraulic properties, namely water content at saturation, field capacity, wilting point, saturated hydraulic conductivity and parameters of the Mualem-van Genuchten model for the description of the water retention and hydraulic conductivity in the entire suction range.

In order to generate the spectral based models, we selected all the samples which are within a Euclidean distance of 1 degree from the central coordinate of the Alento study site (40°21'54.0"N 15°11'02.4"E). Next the data was randomly split into calibration (80%) and validation (20%) sets to generate spectral based models in two scenarios:

a) Laboratory spectral resolution: the laboratory spectral resolution contains several bands, so for this analysis we applied PLSR using 10 components to predict the soil properties. Before generating the models, the spectral data, was transformed to the apparent absorbance, and then the Savitsky-Golay 1st derivative (Savitzky and Golay, 1964) was calculated.

b) Sentinel 2 spectral resolution: The spectral data was spectrally resampled to the spectral configuration of Sentinel-2. Because the spectral resolution of Sentinel-2 is limited, we used the random forest algorithm to predict the soil properties. Before generating the models, the spectral data, was also converted to the apparent absorbance, and then the Savitsky-Golay 1st derivative was calculated.

In all the cases, those samples that presented predicted values over the maximum or lower than the minimum measured values that were used for the calibration, were equalized to the maximum or minimum measured value respectively.

In both cases of laboratory and Sentinel-2 spectral resolution, all the spectral based models presented excellent performance in their validation stage, with an R2 between 0.69 and 0.92. We will adapt the spectral based models to the hyperspectral information acquired by UAV.

We started to derive spectrotransfer functions for the prediction of clay content of the soil. The i) European SSL (Toth et al., 2013), ii) SSL of Israel (Ogen et al., 2019), iii) SSL of Africa (ICRAF-ISRIC) (World Agroforestry Centre, 2010) and iv) Mediterranean SSL (Geocradle) (Tsakiridis et al., 2018) were used as training datasets. As validation datasets, we used 20 samples that have been randomly selected from three different local SSLs – these samples were not part of any calibration dataset – and the following SSLs as external datasets: i) SSL of Brazil, ii) SSL of the Czech Republic and iii) SSL of Israel (Ogen et al., 2019). The ongoing analyses focus on the way to improve the performance of the prediction models.

WP3. Linking Soil Properties, Soil Moisture, and Evapotranspiration

WP3 of the iAqueduct project deals with the "Retrieval of field/grid specific scaling functions between soil moisture and evapotranspiration". This work package mainly involves the research units at Univ. of Naples Federico II, Univ. Twente, and Univ. Politecnica de Valencia, and is led by Univ. of Naples Federico II. Overall, WP3's activities are expected to advance hydrological modeling by demonstrating the benefits in closing water cycle gaps from the global to local scale in WP5. Upstream activities that mainly feed WP3 are those being underway in WP2, whereas WP3's outcomes are directed toward WP4.

During the reporting period, soil moisture datasets have been retrieved in one sub-catchment of the Upper Alento River Catchment (UARC). This experimental test site of the project, called MFC2 and with a drainage area of about 8 hectares, is a typical agro-forestry environment with the coexistence of olive and cherry trees and horticultural crops (Nasta et al., 2020). The monitoring infrastructure consists of: a) a SoilNet wireless sensor network comprising twenty end-devices connected to sensors positioned at the soil depths of 0.15 m and 0.30 m, b) a stationary cosmic-ray neutron probe (CRNP) positioned at about the center of the sensor network, and c) a weather station monitoring air temperature, air relative humidity, wind speed and direction, global and net solar radiation and rainfall at hour time resolution. At each SoilNet position, GS3 capacitance sensors (that measure soil moisture, soil temperature, and apparent electrical conductivity values) and MPS-6 sensors (that measure soil matric pressure potential values) are installed at two soil depths (15 cm and 30 cm). In accordance with the objectives of this WP3, the stationary devices enable soil moisture to be obtained at two different spatial scales, namely the scale of a soil profile (provided by the SoilNet capacitance sensors) and the field scale (provided by CRNP, with a radial footprint of about 20 hectares).

In addition, eleven sporadic and sparse field campaigns were carried out to measure near-surface soil moisture using a portable Time Domain Reflectometry (TDR) device connected to a 15-cm-long handcrafted three-rod probe. These surficial soil moisture datasets were measured at the same positions of the twenty SoilNet units and, together with the previously described monitoring systems, were particularly useful for the validation of the data retrieved during the three UAS flight campaigns carried out in MFC2 (on 13-14 June 2019; 24 Oct. 2019; 16 July 2020). Note that the periods are being selected also to account for the typical Mediterranean seasonality. The UAS sensors provided maps of the near-surface soil moisture using different retrieval algorithms based on collocated ground measurements. The thermal inertia model builds upon the dependence of the thermal diffusion on soil moisture. The soil thermal inertia is quantified by processing the visible and near-infrared (vis-NIR) and thermal infrared (TIR) images, acquired at two different times of a day (Paruta et al., 2020). The random forest regression model is used to downscale gridded soil moisture from 1.0 km to 15.0 cm by applying UAS-based information on land surface temperature, vegetation index, and elevation. The temperature–vegetation trapezoidal model is also used to map soil moisture over vegetated pixels. This trapezoidal model depicts the soil moisture dependence of the surface energy balance. Comparisons among the three algorithms help define a preliminary standard procedure for retrieving soil moisture with UAS.

Tackling the scaling problem, which is the core objective of WP3, is definitely not a simple task. While considering differences in both space and time scale gives important and useful information, two main issues also come into play that makes it a difficult problem to handle: a) the spatial variability exhibited by the soil properties can enhance the uncertainties when moving through scales, b) the water flow in the soil-vegetation-atmosphere system is a highly nonlinear process. The identification of scaling relationships can be corrupted somehow by these problems. Therefore, intensive field campaigns were carried out in MFC2 to collect undisturbed soil cores and disturbed samples over a square spatial lattice 25-m by 25-m, which are then used to determine in the laboratory the soil physical-chemical (particle-size distribution, texture, soil organic matter, pH, CaCO3, and oven-dry bulk density) and hydraulic properties (soil water retention and unsaturated hydraulic conductivity functions). These soil characteristics provide the key input parameters for the hydrological models and will be also employed in some tasks of WP2. Up to now, a total of 63 both disturbed and undisturbed soil samples were collected over the regular grid (the entire dataset will be available by the end of December 2020).

Laboratory and in-situ spectral measurements of undisturbed soil surface were carried out in the SoilNet-unit positions to build a Soil Spectral Libraries (SSL) for the MFC2 test site (Francos et al., 2020, under review). The laboratory spectral measurements were carried out using the ASD Contact Probe® Assembly (Analytical Spectral Devices Inc., 2012). To get optimal spectral measurements of the undisturbed soils, the ASD spectrometer was connected to the SoilPRO assembly (Ben-Dor et al., 2017). The collected undisturbed soil cores were stored in a sealed plastic bag and brought to the laboratory to carry out the spectral measurements. Although the soil cores were collected when the area was relatively dry, they were air-dried at room temperature for at least three days. Then, the soil samples were sieved to pass a 2-mm sieve.

WP4 Developing Plant- and Plot-Level Ecohydrological Models Using Remote Sensing Information

The state of the art of models describing soil-vegetation atmosphere systems was reviewed and summarized as part of the consortium paper now published (Su et al 2020). There, the characterization of vegetation activity and its coupling with the soil moisture dynamics was identified as a key aspect to correctly and effectively model the soil-plant-atmosphere continuum, but also an area where data availability and model and parameter uncertainty are particularly relevant.

Hence, the first step in Task 4.1 was a model intercomparison focusing on stomatal conductance modelling: stomatal functioning represents a key control to water flux from the soil to the atmosphere, but its modelling is still a very active area of research. Models based on the evolutionary principle of optimality are now being considered as very promising approaches to effectively describe plant water fluxes, at scales ranging from the leaf to the ecosystem, and for inclusion in global vegetation models. Yet there is no consensus on the formulation of such models. We thus compared three recently proposed optimization principles and defined which model was most consistent with in situ observations provided by flux towers in 30 sites. The choice of data source was motivated by the need to have homogeneous observations relative to different conditions (e.g., different soil water availabilities) and for a variety of ecosystems, to ensure the transferability of the model. The optimality principles were compared using not only on standard goodness-of-fit metrics, but also on metrics based on information theory - one of the first applications of this approach to ecohydrological model evaluation. The models were thus ranked based on parameter uncertainty after calibration, parsimony, predictive performance, and functional performance (i.e., the extent to which the functional interactions among soil water content, air vapor pressure deficit and evapotranspiration were accurate). This work allowed identifying stomatal conductance models that provide robust realistic results, while at the same time having low parameter requirements and easy transferability across sites (Task 4.1). Given the central role of stomatal conductance in water transport, this was a necessary first step to identify the most promising models towards the development of minimalist soil-plant-atmosphere models for inclusion in the iAqueduct toolbox (Task 4.2). [A manuscript detailing these results is currently under evaluation at New Phytologist (Bassiouni M, Vico G, Insights into predictive and functional performance of stomatal optimization models in a big-leaf framework). This work constitutes part of Deliverable 4.1, comparing different formulations and parameterizations of soil-vegetation models.]

In parallel, we developed a model coupling soil moisture dynamics and plant activities, to determine the total accumulated crop biomass and, employing the harvest index, the final yield; and how the latter is affected by pedoclimatic conditions and local water management (irrigation; and water extracted from on-farm ponds vs. groundwater). Care was exercised to maintain the number of parameters to a minimum, while maintaining realistic results. We embedded this biophysical model into an agent-based model to simulate a smallholder farmer system, to study how each farmer's choice of water source (renewable on farm ponds; less renewable groundwater) affect yield and economic gain of the single farmer and the community; and how these previous experiences affect the farmers' choice regarding water management and use.
A paper detailing these results is now published (Tamburino et al, 2020, Water management for irrigation, crop yield and social attitudes: a socio-agricultural agent-based model to explore a collective action problem, Hydrological Sciences Journal, 65(11), 1815–1829). These results were also taken up by the Swedish radio P4 ("Privata dammar kan rädda framtidens lantbruk", in SverigesRadio P4 Uppland, June 27th, 2020, https://sverigesradio.se/sida/artikel.aspx?programid=114&artikel=7503750). This work was developed as part of Task 4.1 and 4.2, but the explicit inclusion of aspects of water management and decision making under uncertainty is beneficial for the activities planned in WP6, where understanding of decision making under uncertainty will be needed to best tailor the communication of this project results to stakeholders – i.e., those that, in the end, make the strategic decisions around water management. Further, this work is inherently multi-disciplinary in nature, as it combines natural sciences and social sciences in the framework of a minimalist model, to identify the co-evolution of communities and agricultural systems.

At a larger spatial scale, we are now exploring the role of climatic conditions in driving vegetation activity for Europe, exploiting multiple satellite products of vegetation greenness (Normalized Difference Vegetation Index, NDVI, and two types of Enhanced Vegetation Index, EVI). Working at the sub-seasonal time scale, we are identifying the part of the growing season that is most important in controlling vegetation activity, and whether this depends on the ecosystem considered. This effort will allow prioritizing the different aspects of soil-vegetation-atmosphere modelling, towards minimalist, but robust, approaches. And knowledge of the part of the growing season that is most critical for vegetation activities can provide useful information for planning remote sensing field campaigns for further data acquisition. [A manuscript detailing these results is currently under preparation (Wu M et al, Early growing season anomalies determine the large-scale climate-vegetation coupling over Europe).]

WP5 Improving Distributed Catchment-Scale Ecohydrological Models Using Spatial Information

WP5 will demonstrate the benefits in closing water cycle gaps from the global to local scale, in terms of how to effectively handle spatiotemporal data (from in situ, UAS, and satellites), regarding ecohydrological model calibrations and accuracy evaluations of simulated spatial patterns of ecohydrological variables.

In Table 4 the WP5 performed work during the reporting period is summarised. In relation to the original project description and schedule the WP5 will be able to satisfactorily meet the requirements. Deliverable 5.1 "Spatial pattern oriented model calibration" is expected to be delivered at the expected date. Carraixet site is being used in order to accomplish this objective as TETIS is already satisfactorily implemented and results are in progress. Once the spatial calibration methodology is being validated it will be applied at other study test sites in next deliverable.

Table 4. WP5 performed work regarding the reporting period.

Tasks	***Carraixet***	**MFC1**	**Alento**
TETIS*			
1) Topographical, geological, land use, soil hydraulic properties data collection	Done	Done**	In progress
2) Hydrometeorological data collection	Done	Done**	In progress
3) Remote sensing data collection + associated processing: LAI, SSM	Done	In progress	In progress
4) TETIS parameter estimation	Done	In progress	In progress
5) TETIS implementation	Done	In progress	In progress
6) Traditional Q-calibration (mono-objective)	In progress	In progress	In progress
7) Spatial pattern model calibration using RS variables (multi-objective)	In progress	In progress	In progress
8) Model validation and calibration strategies results comparison	In progress	In progress	In progress

* Work related to TETIS was performed by José Gomis and Félix Francés (UPV)
** Work performed by Paolo Nasta and Nunzio Romano (UNINA)

Current WP5 results at UPV involve TETIS inputs parameter estimations together with associated TETIS implementation. Calibration strategies are being run.

WP6 Towards Sustainable Water Management

WP6 is to address stakeholders' requirements, and will develop an integrative information system (an open source iAqueduct toolbox), which will integrate models, soil parameters, forcing and field-scale observation, and gridded water states and fluxes to support the translation of science knowledge into water productivity information for the smart management of water resources. The goal is to develop potentially effective approaches connecting science to the society, thus influencing citizens towards desirable behavior in water management. Currently, the demo about downscaling satellite soil moisture at coarse scale to the downscaled field scale soil moisture data has been achieved (http://iaqueduct.itc.utwente.nl/iaqueduct/). The next step is to make this tool more generic to be applied for any specific field site.

b. Collaboration, coordination and mobility

iAqueduct – Inherent Interlinkages of WPs

iAqueduct includes 6 closely connected work packages (WP) jointly conducted by 7 consortium partners (Figure 8). WP 1 deals with the scaling from global satellite water cycle products to field scale water states which includes both the surface and profile information on water states. Because it has been demonstrated that the soil hydraulic and thermal properties (SHP/STP) play critical role in determining soil water and heat flow and such information is rarely available at detailed scales, WP2 is designed to bridge spectral information that can be obtained at high resolution by satellites and UAS and the needed soil properties that are traditionally obtained at limited locations by in-situ sample collections. Using the information obtained from the two previous WPs, WP3 attempts to retrieve field and grid specific scaling functions between soil moisture and evapotranspiration which is expected to advance hydrological modelling by demonstrating the benefits in closing water cycle gaps from global to local scale in WP5. WP 4 is designed to develop plant- and plot-level ecohydrological models using remote sensing information. And, WP6 is to encapsulate the tools developed in the previous WPs and make them as open source codes so as to easily disseminate the generated knowledge and tools for actual sustainable water management (WP6).

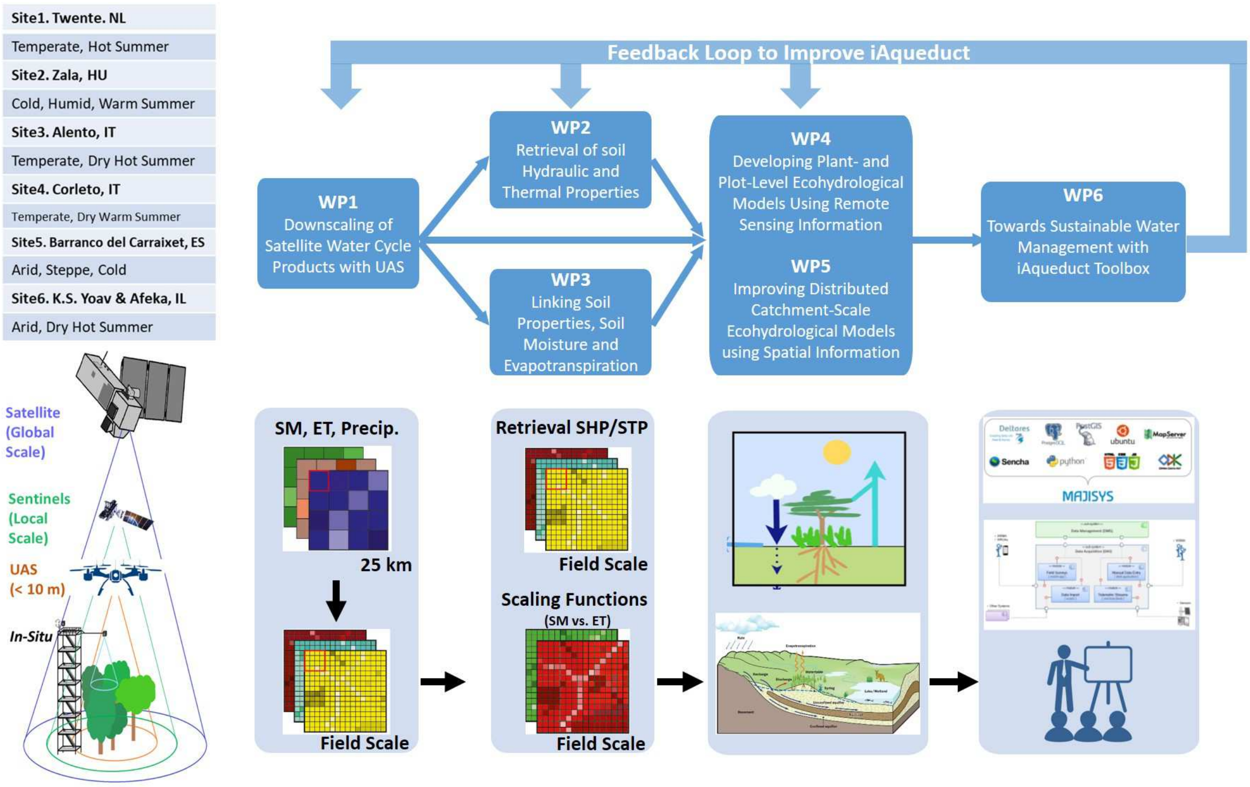


Figure 3 Research framework of iAqueduct: the interconnected work packages (WPs), with the study sites.

Efficient coordination and organization of iAqueduct

With the inherent, consistent interlinkage between WPs, the iAqueduct project is coordinated and organized effectively, which subsequently increase/encourage the transnational collaboration between partners.

WP1 is led by Salvatore Manfreda (Uni. Naples), who leads research activities on the use of UAS for environmental monitoring and hydrological modelling and is the coordinator of COST Action “Harmonization of UAS techniques for agricultural and natural ecosystems monitoring”. With his UAS expertise and coordination with the COST project, iAqueduct project outcomes can be conveniently scaled up to pan-European level. Uni. Twente, UPV and Uni. Basilicata participated WP1.

WP2 is led by Brigitta Szabó (CAR-HAS), who has expertise in deriving pedotransfer functions and mapping soil hydraulic properties at field, regional and continental scale. TAU, Uni. Naples, Uni. Twente participated this WP2.

WP3 is led by Nunzio Romano (Uni. Naples), who provides the Alento River Hydrological Observatory in Italy that serves as an iAqueduct pilot research site with intensive soil moisture and hydrological observation and modelling, as well as its well-known expertise and laboratory facilities for soil water and hydrological research. Uni. Twente, UPV, and SLU participated WP3.

WP4 is led by Giulia Vico (SLU), who provides to iAqueduct the plant ecophysiological expertise needed to quantify the effects of fluctuations in water availability on vegetation. Uni. Naples, Uni. Twente, and UPV participated this WP4.

WP5 is led by Félix Francés (UPV), with his expertise in distributed ecohydrological modelling. Furthermore, UPV provides the Barranco del Carraixet area and the contact with local stakeholders in Spain. Uni. Twente, Uni. Naples, Uni. Basilicata, CAR-HAS, and TAU participated this WP.

WP6 is led by Bob Su (Uni. Twente), who is a world leader in Earth observation of water cycle, in particular in microwave remote sensing which enjoys a field-weighted citation impact of 3.31 (Scopus 2012-2017, way above the world average of 1.0). Uni. Twente operates the Twente cal/val site for SMAP mission and collaborates with various national (and international) partners for application of Earth observation to water management. Furthermore, Uni. Twente acts as coordinator of the iAqueduct project. Uni. Basilicata, CAR-HAS, TAU, and UPV participated WP6 with their field sites.

The design of the 6 WPs jointly executed by 7 partners at 6 research sites (Figure 10) ensures that iAqueduct will be operated as a whole to achieve the stated research objectives. The northern partners (Uni. Twente and SLU) will gain insightful knowledge from the southern partners (UPV, Uni. Basilicata and Uni. Naples) via field experiments in Italy and Spain, while contributing state-of-the-art knowledge in satellite observation of water cycle, modeling of soil heat and water processes (Uni. Twente) and ecological processes, in particular in scaling between soil moisture and evapotranspiration (SLU). TAU will contribute to the consortium with its renowned expertise in hyperspectral remote sensing and CAR-HAS does so with her expertise in research in pedotransfer functions. Both will gain new knowledge in linking different processes from coarse satellite observation to fine field scale water states and all partners will benefit strongly from the close collaboration with stakeholders at 5 different sites. An additional important aspect of the iAueduct project is to learn the lessons in different climates in coping with extremes.

It is to note that, as research institute in Hungary cannot be funded by Water Works 2017, all the contributions from CAR-HAS are in-kind (WP2 lead) (please also see what have been achieved in WP2 in ‘*section a’*)

Mobility & Coordination with other projects

The seven involved partners in iAqueduct are the core members of working group 3 of the COST Action "Harmonization of UAS techniques for agricultural and natural ecosystems monitoring" (HARMONIOUS Project). As such the partners will continue to benefit from previous expertise in projects related to the research objectives of iAqueduct.

Since 2018, iAqueduct consortium had started to organize the fieldwork over the pilot study site at Alento, Italy, hosted by Prof. Nunzio Romano (Uni. Naples). For the detailed outcome of the fieldwork, please see Table 1 and WP3, which indicate the strong mobility of the researchers within the Consortium.

Furthermore, due to the strong coordination between iAqueduct and HARMONISOU WG3 activities, most of the iAqueduct consortium meetings and fieldwork campaigns are supported by COST ACTION Short Term Science Mission (STSM). Please see 'section 5 Consortium Meetings'.

Particularly, University of Twente and University of Basilicata are currently co-supervising a PhD study, which is assigned for iAqueduct and HARMONISOU WG3 activities.

Furthermore, works at the MFC2 test site were performed as follows (also see WP2 for details):

- Field campaigns for obtaining soil moisture and properties data, together with the related in-situ and laboratory measurements, were carried out by Univ. of Naples Federico II.
- UAS flights were carried out by Univ. of Basilicata and Hungarian Academy of Sciences.
- Spectroscopic measurements were carried out by Tel Aviv Univ. with the help of Univ. of Naples Federico II.
- Univ. Twente carried out measurements for retrieving soil thermal properties.

Paolo Nasta is P.I. of the local research unit at Univ. of Naples Federico II within the project "WATer mixing in the critical ZONe: Observations and predictions under environmental changes – WATZON" (grant number 2017SL7ABC), started on Nov. 2019 and funded by the Italian Ministry of University within the P.R.I.N. program (Progetti di Ricerca di Rilevante Interesse Nazionale – Call 2017), which coordinates with iAqueduct activities.

c. *Impact and knowledge output*

iAqueduct will enable the understanding of the space-time variability of EO data (e.g., regarding soil physical characteristics, soil moisture, and evapotranspiration fluxes) from the in situ/plot scale, to field and regional, and to global scales, for sustainable integrative water management under climate change. An end-to-end system will be developed to translate scientific data and knowledge into tailored water productivity information, establish a science–policy–business–society interface to allow for continuous dialogues and interactions across different scales and levels, influencing stakeholders towards desirable behaviors for sustainable water management.

Achieved main impact

Via the explicit inclusion of water management and decision making under uncertainty, iAqueduct partner (SLU) coupled the biophysical model into an agent-based model to simulate a smallholder farmer system, to study how each farmer's choice of water source (renewable on farm ponds; less renewable groundwater) affect yield and economic gain of the single farmer and the community; and how these previous experiences affect the farmers' choice regarding water management and use. The result of this research has been published in Hydrological Science Journal (see publication nr. 7 in Table 7), which had been also taken up by the Swedish Radio P4 ("Privata dammar kan rädda framtidens lantbruk", in

SverigesRadio P4 Uppland, June 27th, 2020, https://sverigesradio.se/sida/artikel.aspx?programid=114&artikel=7503750).

This work is a vivid example on how to translate scientific knowledge to stakeholders (i.e., those make the strategic decisions around water management), combining natural sciences and social sciences, for their decision making with the understanding of uncertainty.

3. Table of Deliverables

Please indicate whether the planned deliverables are completed, delayed or readjusted. Explain any changes/difficulties encountered and solutions adopted. Please add/delete rows, as necessary in the table below.

Deliverable name	Lead partner (country)	Date of delivery (dd/mm/yyyy)	Changes, difficulties encountered and new solutions adopted
WP1			
D1.1. Satellite/UAS-data	University of Naples Federico II (Italy) [Uni. Naples]; University of Basilicata (Italy) [Uni. Basilicata]	11-06-2020 (original)	There is a slight delay of this deliverable. Nevertheless, this deliverable has been drafted and now awaiting for comments/inputs from all relevant partners. It is expected to be ready in Oct. 2020.
D1.2. Scaling methods from global satellite water cycle products to field scale surface and profile information of water states	University of Naples Federico II (Italy) [Uni. Naples]	11-06-2021 (original)	It is on the track. The scaling method for surface and root zone soil moisture has been developed (and published)
WP2			
D2.1. Soil spectral libraries of distinct soil groups in both laboratory and field and their relationship	TEL AVIV University (Israel) [TAU]	11-06-2020 (original)	This deliverable has been submitted as a journal paper to "European Journal of Soil Science".
D2.2. Maps of soil hydraulic properties for the six experimental sites based on traditional and vis-NIR spectral analysis	Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research (Hungary) [CAR-HAS]	11-06-2021 (original)	It is on the track. Please see 'section a. a. Scientific and technological progress' - WP2.
WP3			
D3.1. Field and grid specific scaling functions between soil moisture and evapotranspiration	University of Naples Federico II (Italy) [Uni. Naples]	11-12-2020 (original)	It is on the track. Please see 'section a. a. Scientific and technological progress' – WP3.
D3.2. STEMMUS simulation results across the selected experimental sites	University of Twente (Netherlands) [Uni. Twente]	11-06-2022 (original)	It is on the track. Please see 'section a. a. Scientific and technological progress' – WP3.
WP4			

Deliverable name	Lead partner (country)	Date of delivery (dd/mm/yyyy)	Changes, difficulties encountered and new solutions adopted
D4.1. Intercomparison of models, soil and vegetation parametrizations and soil parameters	Swedish University of Agricultural Sciences (Sweden) [SLU]	11-12-2020 (original)	It is on the track. This deliverable has been submitted as a journal paper.
D4.2. iAqueduct toolbox.	University of Twente (Netherlands) [Uni. Twente]	11-06-2021 (original)	It is on the track. The downscaling algorithm has been incorporated into this web-based toolbox. Currently, the TETIS model (catchment ecohydrological model), and the soil-water-plant model (STEMMUS-SCOPE) are ongoing to be incorporated to the iAqueduct toolbox as well.
WP5			
D5.1. Spatial-pattern-oriented model calibration	Universitat Politècnica de València (Spain) [UPV]	11-12-2020 (original)	It is on the track. Please see 'section a. a. Scientific and technological progress' – WP5.
D5.2. Multiscale parsimonious distributed ecohydrological model to bridge the scales from plant to plot, subcatchment, and catchment/basin respectively	Universitat Politècnica de València (Spain) [UPV]	11-06-2021 (original)	It is on the track. Please see 'section a. a. Scientific and technological progress' – WP5.
WP6			
D6.1. Scenarios for actual sustainable water management with stakeholders (with the drought events in 2018 as concrete cases).	University of Twente (Netherlands) [Uni. Twente]	11-06-2020 (original)	Due to COVID-19, the contact with stakeholders were limited. Several telecon meetings have been organized with Deltares. With their supports, we will be able to have access to observation data in the field for identifying drought events in 2018 (but also for 2019 and 2020 when possible/available). It is expected the end of 2020, we will be able to deliver this deliverable.

Deliverable name	Lead partner (country)	Date of delivery (dd/mm/yyyy)	Changes, difficulties encountered and new solutions adopted
D6.2. Connecting science to society - approaches to influence stakeholders (in particular citizens) towards desirable behaviour	University of Twente (Netherlands); University of Naples Federico II (Italy); Universitat Politècnica de València (Spain)	11-06-2022 (original)	It is on the track. - iAqueduct toolbox is under construction with visible progresses (e.g., webtool for downscaling satellite soil moisture data to field scale; the catchment ecohydrological model and process-based STEMMUS-SCOPE model are to be incorporated in the toolbox.) - iAqueduct partner (SLU) has produced convincing results, in terms of translating scientific knowledge to decision making, while considering the uncertainty. - A coordinated fieldwork, in terms of cross-validating HyperSCOUT, UAV, and in-situ observations/measurements had been conducted over Twente airport region.

4. Budget review

The budget has been used by all iAqueduct partner to hire either post-doc or PhD researchers (Other than CAR-HAS, who provides in-kind contributions).

See Annex I: Budget breakdown for details.

5. Consortium Meetings

N°	Date	Location	Attending partners	Purpose/ main issues/main decisions?
1	10-June-2019 to 11-June-2019	Naples, Italy	iAqueduct consortium	Kick off meeting
2	12-June-2019 to 26-June-2019	Monteforte Cilento, Alento Catchment, Naples,	- Uni. Naples - Uni. Basilicata - Uni. Twente - CAR-HAS (In-kind) - TAU	Fieldwork at Monteforte Cilento, Alento, Naples, Italy

		Italy	- Uni. Palermo (joint activities via COST ACTION HARMONIOU)	
3	06-Nov-2019 to 08-Nov-2019	Coimbra, Portugal	iAqueduct consortium	- WP progress meeting; - iAqueduct concept paper draft meeting; - Coordination/dissemination with COST-ACTION HARMONIOUS project.
4	09-Apr-2020	Online	iAqueduct consortium	Discuss WP2 & WP3 progress, and specify relevant tasks
5	4-May-2020	Online	- Uni. Twente - CAR-HAS (In-kind) - TAU	Discuss details in WP2 and specify task force for different sub-tasks in WP2.
	8-May-2020	Online	Uni. Twente	Design/implementation of iAqueduct web-based toolbox
	12-May-2020	Online	- Uni. Twente - UPV	Discuss WP5 progress and specify relevant tasks for an implementation plan.
	15-May-2020	Online	- Uni. Twente - SLU	WP4 implementation plan.
	15-June-2020	Online	iAqueduct consortium	Discuss WP2 progress and implementation plan.
	06-Jul-20	Online	Uni. Twente	- iAqueduct tasks and deliverables - Setting up of data platform - iAqueduct toolbox/MajiSys
	10-Aug-2020	Online	Uni. Twente	-Discussion on WP1, WP2, WP3 & WP6 subtasks relevant to University of Twente. -Planning for scaling function work
	14-Aug-2020	Online	Uni. Twente Uni. Naples Uni. Basilicata	- Planning for data collection of the Netherlands Demo catchment - LST gaps-filling
	01-Sep-20	Online	- Uni. Twente - UPV	- TETIS implementation - TETIS-iAqueduct ToolBox Meeting - Data input
	16-Sep-20	Online	- Uni. Twente	- iAqueduct progress for each Work Package - iAqueduct toolbox - Progress Report Preparation - LST gap-filling for downscaling

6. Stakeholder/Industry Engagement

Due to the COVID-19, the progress in terms of involving stakeholders in the project has been on hold. Nevertheless, we still managed to be virtually in contacts with our stakeholder (Deltares), in order to get access to data linked to drought monitoring in the Netherlands. Furthermore, there is already a coordinated fieldwork, in terms of cross-validating HyperSCOUT, UAV, and in-situ observations/measurements had been conducted over Twente airport region. Particularly, for Deliverable 6.1, we have started to work on drought monitoring over Twente region, together with stakeholders.

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

- List all presentations, posters, and publications in scientific, peer-reviewed journals derived from this project, separating those in preparation, those in review and those accepted or in press.
- Provide websites and/or electronic copies of the key ones.
- Indicate all the co-authors for each publication.
- Order publications per date (chronologically) and for each year by alphabetical order.

Metadata on all project publications are required to be submitted as part of the final reporting. This will be done via the **Open Data & Open Access platform**, available at: http://opendata.waterjpi.eu/ (also accessible from the bar menu of the Water JPI website).

International	Peer-reviewed journals	1. Su, Z.; Zeng, Y.; Romano, N.; Manfreda, S.; Francés, F.; Ben Dor, E.; Szabó, B.; Vico, G.; Nasta, P.; Zhuang, R.; Francos, N.; Mészáros, J.; Dal Sasso, S.F.; Bassiouni, M.; Zhang, L.; Rwasoka, D.T.; Retsios, B.; Yu, L.; Blatchford, M.L.; Mannaerts, C., (2020), An Integrative Information Aqueduct to Close the Gaps between Satellite Observation of Water Cycle and Local Sustainable Management of Water Resources. Water 2020, 12, 1495, https://doi.org/10.3390/w12051495 2. Zhuang, R.; Zeng, Y.; Manfreda, S.; Su, Z. Quantifying Long-Term Land Surface and Root Zone Soil Moisture over Tibetan Plateau. Remote Sens. 2020, 12, 509, https://doi.org/10.3390/rs12030509 3. Wang, Y., Zeng, Y., Yu, L., Yang, P., Van de Tol, C., Cai, H., and Su, Z., (2020), Integrated Modeling of Photosynthesis and Transfer of Energy, Mass and Momentum in the Soil-Plant-Atmosphere Continuum System, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-85 4. Yu, L., Zeng, Y., and Su, Z.: Understanding the Mass, Momentum and Energy Transfer in the Frozen Soil with Three Levels of Model Complexities, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2020-253 5. Paruta, A., Ciraolo, G., Capodici, F., Manfreda, S., Sasso, S. F. D.,

		Zhuang, R., ... Maltese, A. (2020). A geostatistical approach to map near-surface soil moisture through hyperspatial resolution thermal inertia. IEEE transactions on geoscience and remote sensing, 1-18. https://doi.org/10.1109/TGRS.2020.3019200 6. Yu, L., Zeng, Y., Fatichi, S., and Su, Z.: How vadose zone mass and energy transfer physics affects the ecohydrological dynamics of a Tibetan meadow?, The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-88 7. Tamburino et al, 2020, Water management for irrigation, crop yield and social attitudes: a socio-agricultural agent-based model to explore a collective action problem, Hydrological Sciences Journal, 65(11), 1815–1829 8. Nasta P, Bogena HR, Sica B, Weuthen A, Vereecken H and Romano N (2020) Integrating Invasive and Non-invasive Monitoring Sensors to Detect Field-Scale Soil Hydrological Behavior. Front. Water 2:26. doi: 10.3389/frwa.2020.00026 9. Romano, N. Intertwining Observations and Predictions in Vadose Zone Hydrology: A Review of Selected Studies. Water 2020, 12, 1107. 10. Szabó, B., Weynants, M., and Weber, T. K. D.: Updated European hydraulic pedotransfer functions with communicated uncertainties in the predicted variables (euptfv2), Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-36
	Books or chapters in books	N/A
	Communications (presentations, posters)	1. Francos, N; Ben Dor, E; Romano, N; Nasta, P; Szabó, B; Mészáros, J; Maltese, A; Manfreda, S; Garcia, M; Zeng, Y., (2020), Soil Surface Reflectance as a Tool to Estimate Water Infiltration Rate from UAV Platforms, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-2092, https://doi.org/10.5194/egusphere-egu2020-2092 2. Zhuang, R., Manfreda, S., Zeng, Y., Su, Z., Romano, N., Ben Dor, E., Maltese, A., Capodici, F., Paruta, A., Nasta, P., Francos, N., Ciraolo, G., Szabó, B., Mészáros, J., and Petropoulos, G. P.: (2020) Soil Moisture Retrievals from Unmanned Aerial Systems (UAS), EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-19560, https://doi.org/10.5194/egusphere-egu2020-19560 3. Romano, N., Nasta, P., Su, Z., Zeng, Y., Manfreda, S., Zhuang, R., Toth, B., Mészáros, J., Ben-dor, B., Francos, N., Maltese, A., and Ciraolo, G., (2019), The iAQUEDUCT project activities in a small Mediterranean rural catchment: Preliminary results of field and remote sensing campaigns to parameterize Richards-based hydrological models, AGU 2019, PA13B-1016. 4. Su, Z.; Zeng, Y.; Romano, N.; Manfreda, S.; Francés, F.; Ben Dor, E.; Szabó, B.; Vico, G.; Nasta, P.; Zhuang, R.; Francos, N.; Mészáros, J.; Rwasoka, D.T.; Retsios, B.; Yu, L. (2020), An Integrative Information Aqueduct to Close the Gaps between Satellite Observation of Water Cycle and Local Sustainable Management of Water Resources, EGU 2020, EGU2020-9782 5. Zhao, H., Zeng, Y., Su, B., and Han, X.: Retrieval of basic soil physical properties by assimilating radiometry observations in the community land surface model, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-19116, https://doi.org/10.5194/egusphere-egu2020-19116, 2020

		6. Su, Z., Yu, L., Wang, Y., and Zeng, Y.: Impacts of Enhanced Soil Water and Heat Dynamics on Ecosystem Functioning, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-13774, https://doi.org/10.5194/egusphere-egu2020-13774, 2020
National (separate lists for each nationality)	Peer-reviewed journals	N/A
	Books or chapters in books	N/A
	Communications (presentations, posters)	N/A
Dissemination initiatives	Popular articles	1. https://www.utwente.nl/en/news/2019/1/215381/two-grants-awarded-from-european-call-on-sustainable-water-systems#recowatdig-sustainable-technology-for-thestaged-recovery-of-an-agricultural-water-from-high-moisture-fermentationproducts 2. http://www.waterjpi.eu/joint-calls/joint-call-2018-waterworks-2017/booklet/iaqueduct-1 3. https://www.nwo.nl/en/news-and-events/news/2019/01/eight-dutch-awards-in-joint-programming-initiative-%E2%80%98closing-the-water-cycle-gap%E2%80%99.html 4. https://industrielings.nl/universiteit-twente-pakt-waterschaarste-aan/
	Popularconferences	N/A
	Others	1. https://m.facebook.com/ITC.UTwente/posts/2244620825625535 2. See Annex 1: Twitter-Dissemination

8. Knowledge output transfer

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

Short Title *Please provide a short and concise title to describe the Knowledge Output*	An Integrative Information Aqueduct to Close the Gaps between Satellite Observation of Water Cycle and Local Sustainable Management of Water Resources
Knowledge Output Description *Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated.* *Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.* *If relevant please provide detail of where the*	We managed to publish a paper that presents the mission and science goals of this iAqueduct project. The paper highlights the need to have earth observation data at scales that are appropriate for water and environmental managers. The underlying scientific questions were presented and the proposed strategies to address the questions were also presented and accepted by the scientific community, by virtue of the successful publication of the paper. The paper also presents early results on soil

Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).	moisture downscaling using random forest and unmanned aerial system (drone) data
Knowledge Type	* scientific publication
Link to Knowledge Output *If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.* *If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.* *If the Knowledge Output is not planned to be publicly available, please state "Not available for public".*	doi.org/10.3390/w12051495 https://www.mdpi.com/2073-4441/12/5/1495
Sectors & Subsectors *Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.*	• Basin Management • Flood Risk Management • Water Scarcity and Droughts • Adaptation to Global Change • Others o Other General o Agriculture o Modelling & Prediction
End User *Choose as many options as required* *Per identified End User, please identify possible applications of the Knowledge Output.*	o Scientific Community o Education & Training o Environmental Managers & Monitoring o Policy Makers / Decision Makers
IPR *Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.* *Please insert "n/a" if no IPR has been applied.*	n/a
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why	
Status *Please identify whether the Knowledge Output is*	The paper output has been finalized and published.

finalised, is still being generated or whose status/future is unknown. Consider: *• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?* *• Is there a corroborating body of evidence, or are contradictory results, available?* *• Does your knowledge progress beyond the current state-of-the-art / evidence base?* *• Is more research or demonstration needed to validate the results?*	The task that is now at hand is to implement the workplans and ideas outlined in the published paper.

Short Title *Please provide a short and concise title to describe the Knowledge Output*	iAqueduct toolbox Demonstration Website
Knowledge Output Description *Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated.* *Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.* *If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).*	The iAqueduct open-source toolbox is a critical component of the project. It is important for disseminating and communicating generated knowledge, data, and tools to water managers, companies, and farmers. The toolbox seeks to integrate models, soil parameters, forcing and in-situ data, and gridded water states and fluxes to support the translation of science knowledge into water management and influencing citizen engagement & behaviour change. A demo soil moisture downscaling algorithm has been added to the iAqueduct toolbox page.
Knowledge Type	* software/modelling tools
Link to Knowledge Output *If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.* *If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.* *If the Knowledge Output is not planned to be publicly available, please state "Not available for*	http://iaqueduct.itc.utwente.nl/iaqueduct/

public".	
Sectors & Subsectors *Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.*	• Basin Management • Flood Risk Management • Water Scarcity and Droughts • Others o Other General o Agriculture o Modelling & Prediction 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 o Civil Society o Other
IPR *Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.* *Please insert "n/a" if no IPR has been applied.*	n/a
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why	
Status *Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:* *• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?* *• Is there a corroborating body of evidence, or are contradictory results, available?* *• Does your knowledge progress beyond the current state-of-the-art / evidence base?* *• Is more research or demonstration needed to validate the results?*	The demonstration toolbox website is still under development. More tools and functionalities will be added. Currently, there is a soil moisture downscaling algorithm.

Short Title *Please provide a short and concise title to describe the Knowledge Output*	Integrated Modeling of Photosynthesis and Transfer of Energy, Mass and Momentum in the Soil-Plant-Atmosphere Continuum System
Knowledge Output Description *Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated.* *Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.* *If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).*	We developed a coupled Photosynthesis and Energy, Mass and Momentum transfer model. This coupling is important for understanding and predicting vegetation conditions, water stress, ecohydrological processes and ecosystem functioning in a changing climate. Since the root zone was not well accounted for in both models, we added a dynamic root growth model. The coupled model goes beyond the current state-of-art of vegetation photosynthesis models, which are compromised when it comes to water stressed conditions.
Knowledge Type	Please choose one option – delete the rest: * scientific publication * software/modelling tools
Link to Knowledge Output *If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.* *If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.* *If the Knowledge Output is not planned to be publicly available, please state "Not available for public".*	https://doi.org/10.5194/gmd-2020-85 https://zenodo.org/record/3839092#.X3BdjWgzZPY
Sectors & Subsectors *Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.*	• Basin Management • Flood Risk Management • Water Scarcity and Droughts • Adaptation to Global Change • Others o Other General

	o Agriculture o Modelling & Prediction
End User *Choose as many options as required* *Per identified End User, please identify possible applications of the Knowledge Output.*	o Scientific Community o Education & Training o Environmental Managers & Monitoring o Policy Makers / Decision Makers
IPR *Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.* *Please insert "n/a" if no IPR has been applied.*	n/a
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why	
Status *Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:* *• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?* *• Is there a corroborating body of evidence, or are contradictory results, available?* *• Does your knowledge progress beyond the current state-of-the-art / evidence base?* *• Is more research or demonstration needed to validate the results?*	The coupled model has been developed and can be used by the scientific community. The scientific paper is currently under review. The coupled model sets a new benchmark the modelling in the Soil-Plant-Atmosphere Continuum System. The coupled model would benefit from: • More research into improving the handling of soil boundary conditions under irrigation and including soil moisture in the soil respiration model • More data for validation in different conditions and longer periods of time

Short Title *Please provide a short and concise title to describe the Knowledge Output*	Water management for irrigation, crop yield and social attitudes: a socio-agricultural agent-based model to explore a collective action problem
Knowledge Output Description *Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated.* *Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.* *If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).*	In this paper, we advance socio-hydrology by developing a model for a smallholder farming system under conditions of water scarcity and rainfall unpredictability. The model deals with the investment decision making between developing on farm-ponds vs. further groundwater exploitation under a falling water table. The model identifies the most beneficial water source for economic gain and its stability, and how it can change across communities and under future climate scenarios. Such a model, in iAqueduct, is important for stakeholder engagement and improving water management
Knowledge Type	* scientific publication * software/modelling tools
Link to Knowledge Output *If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.* *If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.* *If the Knowledge Output is not planned to be publicly available, please state "Not available for public".*	doi.org/10.1080/02626667.2020.1769103
Sectors & Subsectors *Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.*	• Basin Management • Water Scarcity and Droughts • Adaptation to Global Change • Others o Other General

	○ Agriculture ○ Modelling & Prediction ○ Socio-Economics ○ Stakeholder Involvement ○ Irrigation
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 o Civil Society
IPR *Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.* *Please insert "n/a" if no IPR has been applied.*	
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why	
Status *Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:* *• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?* *• Is there a corroborating body of evidence, or are contradictory results, available?* *• Does your knowledge progress beyond the current state-of-the-art / evidence base?* *• Is more research or demonstration needed to validate the results?*	We advance the nascent field of socio-hydrology by this model. More demonstration of this model is ideal.

Short Title *Please provide a short and concise title to describe the Knowledge Output*	Quantifying Long-Term Land Surface and Root Zone Soil Moisture over Tibetan Plateau
Knowledge Output Description *Please only include generated Knowledge Outputs, not those that are expected. Note: Knowledge Outputs can be non-deliverables, milestones or 'grey knowledge'. Also, multiple Knowledge Outputs could exist within one deliverable, and should be separated.* *Try to give a comprehensive description, making the Knowledge Output fully understandable to a non-expert.* *If relevant please provide detail of where the Knowledge Output differs from its equivalent, e.g. What are the key characteristics of the Knowledge Output? What research is it adding to and what is innovative about the Knowledge Output? (Max 500 characters).*	In this publication we presented methods that are important for, 1) developing surface soil moisture (SSM) products and 2) estimating rootzone soil moisture (RZSM) from SSM. SSM and RZSM data are important for water management, ecosystem services and agriculture. The paper showed how consistent SSM data can be produced by blending model and satellite SSM products. A state-of-the-art constrained blending approach was used to produce SSM. The estimated RZSM showed good correlation with in-situ RZSM data and other products. These methods are useful for iAqueduct.
Knowledge Type	* scientific publication
Link to Knowledge Output *If you can provide a link to the Knowledge Output then please do so, e.g. digital object identifier (DOI), web address, download, research paper.* *If the Knowledge Output is not publicly available currently but will be in the future, please provide details. Also, if it is available but only upon request, please state this.* *If the Knowledge Output is not planned to be publicly available, please state "Not available for public".*	https://www.mdpi.com/2072-4292/12/3/509/htm https://doi.org/10.3390/rs12030509

Sectors & Subsectors
Choose as many options as required from the list. Pick those sectors that you think would benefit from the application of this Knowledge Output.
	• Basin Management
	• Flood Risk Management
	• Water Scarcity and Droughts
	• Adaptation to Global Change
	• Others
	  o Other General
	  o Agriculture
	  o Modelling & Prediction

	o Stakeholder Involvement
End User *Choose as many options as required* *Per identified End User, please identify possible applications of the Knowledge Output.*	o Environmental Managers & Monitoring o Scientific Community o Education & Training o Industry
IPR *Please indicate whether IPR has been applied to this Knowledge Output (applied for a patent, copyright etc), or not.* *Please insert "n/a" if no IPR has been applied.*	n/a
Policy-Relevance If the Knowledge Output is relevant to the WFD or any other related Directives, please list and explain why	
Status *Please identify whether the Knowledge Output is finalised, is still being generated or whose status/future is unknown. Consider:* *• Is your knowledge conclusive enough that it provides sufficient evidence to make an impact on, or be applied by, an End User?* *• Is there a corroborating body of evidence, or are contradictory results, available?* *• Does your knowledge progress beyond the current state-of-the-art / evidence base?* *• Is more research or demonstration needed to validate the results?*	The results are substantive such that a user can apply the methods proposed in the paper. By applying a constrained blending, we made progress beyond the general standard of model-satellite data blending currently in use. More demonstration and validation of this approach in different climates is necessary.

9. Open Data

In relation to Open Data, the funded projects will be requested to submit metadata on all the resources directly generated by the project, as well as additional information on how these data will be exploited, if and how data will be made accessible for verification and re-use, and how it will be curated and preserved. Metadata on all project resources are required to be submitted as part of the final reporting. This will be done via the **Open Data & Open Access platform**, available at: http://opendata.waterjpi.eu/ (also accessible from the bar menu of the Water JPI website).

We had attached a Data Management Plan in Annex II to be aligned with this open data police.

10. Problems Encountered during Project Implementation

There are unexpected disturbance due to the COVID-19 outbreak. The project implementation encountered some delays:

- The contract for hiring post-doc in UPV was only possible to be concluded till April. 2020.
- The WP2/WP3's activities started just at the kick-off meeting during the visit at the test sites and were running smoothly, but in the very short-term the COVID-19 pandemic has definitely led to an unexpected impact since the field campaigns scheduled in spring 2020 at MFC2 were canceled. They have been resumed only in July 2020. Fortunately, processing the previously measured data and writing research reports and papers did not undergo any delays. However, as it is happening in other cases, a 6-month extension of this project should be granted.
- In-person meetings and workshops were not possible since mid-March 2020, hindering both field work and contacts with stakeholders.

11. Suggestions for improvement regarding project implementation?

It was suggested to have an extension of the project implementation for 6 months.

Annex 1: Budget Breakdown

N° of the Partner	Name / Surname of the Principal Investigator	Name of the Institute / Organization / University	Private Company (Yes / No)	Country	Name of the Funding Agency	Funding	Salaries - Personnel Costs (€)				Equipement (€)	Travel & Subsistence (€)	Consumables (€)	Subconstracting (€)	Other Costs (€)	Total Costs	Overheads (%)	Overheads (€)	Total with Overheads (€)
							Permanent Position (already on payroll)	Person Month	Non permanent position	Person Month									
Coordinator	Bob Su	University of Twente	No	NL	NWO	REQUESTED FUNDING			220095	36		14400	0		14600	249095			249095
						OWN FUNDING	63343	6								63343			63343
						TOTAL													312438
Partner 2	Francisco Valles	Universitat Politecnica de Valencia	No	ES	MINECO-AEI	REQUESTED FUNDING			108000	48	14000	8000	1500	9500	6000	147000	0	0	147000
						OWN FUNDING	75880	14								75880	0	0	75880
						TOTAL													222880
Partner 3	Eyal Ben-Dor	Tel Aviv University	No	IL	MoE-IL	REQUESTED FUNDING			75000	18	12000	10000	3500		8000	108500	15%	16275	124775
						OWN FUNDING	140,018	14								140018			140018
						TOTAL													264793
Partner 4	Salvatore Manfreda	Universita degli Studi della Basilicata	No	IT	MIUR	REQUESTED FUNDING			30000	24	8000	5200	725			43925	41.43%	31071	74996
						OWN FUNDING	32142	6								32142			32142
						TOTAL													107138
Partner 5	Nunzio Romano	University of Naples Federico II	No	IT	MIUR	REQUESTED FUNDING			30000	24.00	8000	3928	2001			43929	0.41	31071	75000
						OWN FUNDING	32143	6								32143			32143
						TOTAL													107143
Partner 6	Giulia Vico	Swedish University of Agricultural Sciences	No	SE	FORMAS	REQUESTED FUNDING	13926	2	123518	24		4500			3600	145544	48.18%	66221	211765
						OWN FUNDING	13926	2								13926	48.18%	6710	20636
						TOTAL													232401

Annex 2: Data Management Plan

1	General information	
1.1	Name applicant and project number	Bob Su, iAqueduct
1.2.	Did you ask for support of the datamanagement support office of your institution?	Yes; support from Research Support Coordinator ITC

2	Description dataset	
2.1	Describe the data that will be collected/ generated within the project.	During the iAqueduct project period, the data collection will be carried out with three main categories: 1. The in-situ field campaign. Over the six sites proposed in the iAqueduct project, we will collect soil samples, which will be further processed in the laboratory to determine soil texture, organic matter, bulk density, particle size distribution, soil hydrothermal properties (e.g. soil water retention curve, hydraulic conductivity, thermal conductivity etc.) and other relevant soil parameters. The soil samples will be also collected for the spectral thermal measurements in the lab to determine the dry-less-wet spectra. Furthermore, other than the lab experiment on soil samples, in the field, we will conduct on-site experiments. The SoilPRO® instrument will be used to measure soil reflectance. The KD2 probe will be used to measure the instantaneous thermal properties of the soils. Where possible, the fieldwork on LAI, SAP flow, plant/vegetation-related measurements will be organized and conducted. Meanwhile, the in-situ measurements of soil moisture, soil temperature, soil matric potential, micrometeorological variables, land fluxes will be collected wherever available and possible.

		2. The UAS campaign. After the determination of the scale and timing (e.g. considering the seasonal changes of soil wetness, vegetation states, ET etc.), the UAS flights will be designed and planned for the selected sites of iAqueduct. More specifically, the RGB, thermal and multispectral orthomosaic images will be generated, based on the UAV-collected raw data, following the protocols identified in the COST Action HARMONIOUS project. Wherever needed, additional UAS flights on other relevant environmental sates/variables will be carried out. 3. The satellite data Wherever possible and feasible, the satellite data will be collected for the selected sites of iAqueduct. More specific, the Sentinel 1-2-3 will be the focus.
2.2	Specify the type and format of the data.	The data will be in various formats, including ASCII, tif, NetCDF, xls and other relevant data formats. The in-situ and lab data will be mostly organized and complied in Excel. The UAS data will be in various formats, following the data processing procedures/steps with different softwares (e.g. photoscan, mission planner etc.). The satellite data will be mostly in NetCDF, HDF5, SENTINEL-SAFE, jpeg2000 format, etc.

3	**Data storage**	
	During the research	
3.1	What is the volume of the data and where will the data be stored?	The data volume is expected to be big (>10T). In the iAqueduct, a dedicated server will be developed to store the data, which will be used later on for the to-be developed iAqueduct tool box, based on MajiSYS.
3.2	Is there sufficient storage capacity during the	Yes;

	project?	
	Will the data be backed-up regularly during the project? Who is responsible for this?	Yes; The University of Twente network storage (GDPR compliant and ISO certified) will be used, and access can be determined for the different project partners. The system has a daily backup. ITC has experience with large volume spatial data, no problems are foreseen.
3.3	What are the expected costs? Please specify these and state an amount that is as realistic as possible. How will these costs be covered?	The appropriate ICT facilities needed for data storage and data processing, both during and after the research, are available at the Faculty of Geo-Information Sciences and Earth Observation (ITC), at the University of Twente.

	After the research	

3.4	Specify in which trusted repository the data will be stored after the project.	The faculty ITC uses the DANS-easy repository to store all data underlying their research. DANS Easy is called a trusted repository and this means that it ensures that project data created and used by researchers is “managed, curated, and archived in such a way to preserve the initial investment in collecting them” and that the data “remain useful and meaningful into the future”. The data is stored according the GDPR and the FAIR Principles are used. Storing options: ▪ *Open Access* - The dataset is, without any restriction, made available to all EASY-users, both registered and unregistered ▪ *Open Access for Registered Users* - The dataset is only made available to all registered EASY-users. ▪ *Restricted Access* -The dataset is only made available only after receiving express permission from the Depositor; the researcher and ITC need to give permission ▪ *Other access* is a special category only intended for datasets that are stored at DANS or ITC, but not made available via EASY.
	If the data will not be stored in a trusted repository how will the data be made findable, accessible and reusable?	N.A.
3.5	Will a persistent identifier be used to make the data findable?	Yes Each dataset receives a DOI in DANS Easy
3.6	For how long will the data be archived?	– Minimum 10 years
3.7	What are the expected costs? Please specify these and state an amount that is as realistic as possible. How will the costs be covered?	– All the facilities and software are already available

4	Standards and Metadata	
4.1	How will the data be documented? What metadata standard will be used to make the data accessible and reusable?	For this project, metadata is created for each data file in accordance with the most common disciplinary standard ISO-19115

5	Making data available	
5.1	Are the data available for reuse after the project? If not, please explain why the data are not suitable and/or available for reuse.	Yes, immediately after the project –
5.2	If data are only made available after a certain period then please state the reason for this. If part of the data cannot be made (directly) available then please state the part concerned.	–N.A.
5.3	Are there any conditions for the reuse of the data? If so, are these conditions defined in a consortium agreement?	–N.A.