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WP5

D5.4 Pilot requirement assessment and recommendations

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Abbreviations

ARD	Acquired knowledge and open Research Datasets
EI	External Intervention
ICT	Information and Communication Technologies
IoT	Internet of Things
KPI	Key Performance Indicator
PI	Performance indicator
SWAMP	Smart Water Management Platform
WP	Work Package

Executive Summary

SWAMP is a Europe-Brazil cooperation project aiming at developing IoT-based methods and approaches for smart water management in the precision irrigation domain. SWAMP aims at testing the developed methodologies in four pilot areas that are characterized by different heterogeneous properties and are representative of different water related challenges for agriculture optimization. The pilots are two in Europe (Italy and Spain) and two in Brazil.

SWAMP aims at improving precision irrigation techniques and water management by increasing the knowledge and monitoring of crop condition, adjusting the irrigation and water distribution practices according to soil and weather conditions as well as in relation to water availability. The partnership's work aims at guaranteeing that SWAMP solutions are flexible enough to adapt to different contexts and to be replicable in different locations and settings; thus, the project brings together a series of challenges inherent to both IoT and agriculture communities.

This document is an output of WP5 (Pilots), whose aims are to specify, design, instantiate, execute, assess, evaluate and analyse the four pilots of the project. This document follows D5.1 (M6) that provides a detailed description of the pilot areas, specifies their specific characteristics as well as objectives and first solutions identified for the achievement of the project targets. This document has three objectives:

1. Following the requirements specification listed in D5.1 this document aims at identifying possible elements of attention that need to be further investigated or monitored during the coming phases.

2. This document provides an assessment and evaluation framework for further phases of the project and the project performance. The assessment and evaluation plan is divided into two phases:

    a. Mid-term assessment at M18 that targets to assess the maturity and state of SWAMP platform and pilots.

    b. Final assessment and evaluation at M36 that aims to the evaluation of the impact and performance of the project against its initial objectives in addition to the assessment of final state of SWAMP platform and pilots.

Considering the relevance and sensitivity of this information, this deliverable is confidential.

1. Introduction

1.1. Objective of pilot requirement assessment and recommendation report

SWAMP project has four pilots specified in D5.1. Pilot in Italy, Reggio Emilia region consists of precision irrigation of various crops and control and management of joint open canal-based water distribution system. Pilot in Cartagena, Spain, focuses on precision irrigation of small plants in very dry area. Pilot in Guaspari, Brazil, aims at improving the crop quality with precision irrigation. Pilot in Manitoba region has goals related to water and energy saving in large-scale agriculture. All pilots will instantiate the SWAMP platform that will be adapted to the field conditions and used irrigation and water distribution systems. The farmers will monitor and control fields, crops, and irrigation systems through SWAMP user applications.

The phases of task 5.4 (evaluation and assessment of pilots) and the purposes of each phase are following:

- At M6, the purpose is to analyse the specification of the pilots and give recommendations to improve them especially from the impact point of view. Furthermore, the initial plans for later phases are created.
- At M18, the purpose is to evaluate the SWAMP approach and the technical quality of the platform components that are existing at that stage.
- At M36, the purpose is to evaluate the impact of the use of SWAMP platforms and the instantiations done in each pilot site.

1.2. Deliverable structure

In relation to deliverable purposes, the remaining part of the document is organized as follows:

- Chapter 2: it summarizes the recommendations that must be considered while evaluating each pilot area (i.e., field surveys and farmers interviews). These represent key aspects to be considered and evaluated during the project to pursue the SWAMP's targets. Considerations and recommendations are organized distinguishing the different research frameworks, namely: ICT platform (2.1), water need estimation (2.2) and water management solutions (2.3.). Finally, section 2.4 reports some general considerations concerning humans' and other users' (i.e., management bodies) role in the overall project.
- Chapter 3: it presents the most relevant assessment and evaluation targets and KPIs that will be monitored during the project. It creates the basis for pilot assessment at M18 (Deliverable D5.5) and at pilot evaluation M36 (Deliverables D5.2 and D5.6).

2. Recommendations for pilot and open issues

This section reports in a synthetic form the recommendations risen during the first phase of the project and emerged during the visits to pilot sites during the partnership's meetings and field trips. The following recommendations have been considered in the identification of the pilot requirements (D5.1). However, this document aims at summarizing some critical points that, despite being known, cannot be totally solved or avoided.

2.1. IoT platform and data collection infrastructures

The IoT platform and data collection infrastructures represent crucial nodes of the SWAMP platform. Most of the services offered by the SWAMP platform will be driven by real time (or near-real time) data gathered from sensors on the ground, sensors on the distribution canals (if present), drones' sensors, weather stations and online services (e.g., weather forecast). All these data sources are highly heterogeneous: the SWAMP platform should be able to collect all these data and make them available in an interoperable format. Network coverage and power consumption (e.g., for battery powered devices) are two critical points that should be considered for the system deploying. The same applies to automatic actuators (if present). The SWAMP platform is required to store all the collected data to be analysed and visualized. In fact, the tuning of the algorithms for precision irrigation and water distribution is based on the process of the collected data. The risk of losing stored data should be considered and backup techniques should be implemented. Additional data could also be entered by users (e.g., gatekeeper in the Italian pilot). In this case the design of the user interface is another relevant point to be addressed.

Concrete recommendations	
1.	Finalise the common data model and guarantee the data interoperability using semantic models.
2.	When not served by solar panel, battery capacity limitations should be considered by developing ways of analysing and motoring battery statuses.
3.	Data backup capabilities need to be added to IoT platform.

2.2. Water need estimation: modelling and sensors

In order to have a precise and reliable estimation of the irrigation requirements, several parameters must be taken into account: perhaps soil moisture, crop biophysical requirements, and weather information are needed to assess the water demand in both timing and location (see also D3.2). Given the complexity of the exchanges that take place within the soil-plant-atmosphere system, water balance models can be used to analyse the problem. Thus, this modelling approach will be used within the SWAMP pilots to evaluate the use of water in different situations, places and crops, and it will involve some specific challenges.

The first one is about the “replicability” of the model. Since SWAMP intends to create a flexible platform usable in various scenarios of industries involved in precision irrigation, models for water requirements estimation will be different, considering mathematical and decision aspects. Differences are very common and well known. The “replicability” should be based on a kind of wrapper approach, i.e. a flexible wrapper model capable of applying conventional models (tuning their parameters with smart algorithms) or proposing a totally different model (based on a data science work). In fact, the four pilots present different features, so testing and validating the same model in more than one of them could be a way to verify this aspect.

Furthermore, the smart approach pursued by SWAMP involves the use of sensors in each pilot to measure various parameters, notably soil moisture and crop features. Such data give information on the water status respectively of the soil and of the crop, but their inclusion in a water balance model represents a non-trivial task that will be carefully studied. Maybe they could be used for the model’s calibration phase. A proper use of adopted sensors is of a paramount importance for the reliability of the water need estimation, thus sensors prescriptions and calibration procedures have to be carefully defined.

In addition to that, it must be noticed that the comparison between the irrigation requirements obtained during the different seasons monitored over the project period, and between those and the historical ones, can get complicated because every season is somehow independent. Thus, for the requirements analysis the characteristics of each season must be taken into account. In addition, it is highly recommended, for the overall project duration, to collect data regarding current irrigation procedures (e.g., water delivered to the crops, discharge withdrawn from reservoirs, energy consumptions, etc.) and weather conditions. This information will be useful to investigate the benefit of the SWAMP platform by simulating its application to past irrigation seasons.

Another important challenge is the reconciliation between farmers' perception (or recommendations provided by agricultural technicians/agronomists) about water requirements and those prescriptions provided by the SWAMP model, especially when they conflict in terms of need for irrigation (yes or no) or amount of water. In some way, the smart model should consider "perceptions or technical recommendations" provided by experts. This kind of solution could improve the acceptability for irrigation prescriptions provided by SWAMP platform. Moreover, it is important to emphasize that the final decision for irrigation is in charge of farmers.

Concrete recommendations	
4.	SWAMP platform should guarantee the possibility to deal with different irrigation management configurations and procedures. Modularity and complementarity of the different approaches developed for water need estimation (e.g., considering soil probes, drone data, etc.) are recommended.
5.	Ensuring a continuous monitoring of irrigation-related data during the overall project.
6.	Sensor calibration and sensor installation issues need to be clear. Sensor calibration and installation processes should always be added to platform user guidelines.
7.	The SWAMP platform has to provide means for a farmer to use his knowledge together with automated recommendations. This must be taken into account in system requirements

2.3. Water management solutions: modelling and sensors

The optimization of the water distribution system relies on several factors that regard the hydraulic infrastructure of the water distribution network (e.g., open canal, pressurized pipes, etc.), the availability of sensors and actuators (e.g., automatic water gate, water level sensors, flow meters, etc.), the definition of optimization modelling, as well as the weather condition and the water availability in the district.

Pilot requirements in this context are adequate to manage these factors and have been identified to measure the achievements of the project. However, the following are some conditions and situations that, although not very likely, might get the development of planned activities more difficult:

- Possible variation of the main water distribution system that brings water to the district. Although of a significant impact for the project, this risk appears remote.
- Water shortage constraining a proper crop-oriented irrigation planning. In this case the lack of water might alter the water irrigation planning defined within the platform.
- The high cost of automated water gate constrains the number of actuators that can be installed. This limits the flexibility of the system and the possibility to operate on near real-time on the water

distribution system. This will require the presence of an operator acting on the network in relation to the platform indication. Although this condition does not represent the optimum, the achievement of pilot requirements does not necessarily require the automation of all sluices, which were out of the scope of the project.

- Possible malfunctions of the actuators controlled by the platform resulting in operation delays, need for the intervention of an operator.
- Delays on sensors and flow meters installation on the water distribution network, with the risk of missing information required for a proper evaluation of the project performance.
- Experienced farmers and/or agricultural technicians/agronomists could provide a different decision regarding the irrigation plan. New decisions can negatively impact on optimization of the water distribution.

In addition to these considerations, it is worth highlighting the peculiarities of the Italian pilot, which challenge the performance assessment and the evaluation of targets achievement. This challenge can be attributed to three main aspects:

- Impossibility to identify two similar pilots for comparison purposes. The irrigation district adopted as pilot represents a unique element, with irrigation canals, pipes and geometries that cannot be identified in another irrigation district. This makes impossible evaluating the performance of the irrigation district by comparing it to a similar one not considered in the project.
- The pilot considers more than 60 farms receiving water through the hydraulic network, while just 3 to 4 of them will be involved within the project for the evaluation of crop water need requirements. This means the coexistence, during the irrigation season, of farms where the water requirements will be estimated based on SWAMP tools and farmers who will continue applying the traditional irrigation scheme (i.e. requests estimated based on their personal experience).
- Intra-annual comparison of the district performance is difficult due to annual variations regarding wheatear conditions, crop types and their dislocations within the district. Thus, each year appears unique in terms of water requirements, water distribution and district efficiency.

In the light of these considerations, the impact of the optimization of the irrigation cannot be inferred by looking at different districts, thus the evaluation of water savage within the district will be performed considering a digital twin of the network. This consists on a hydraulic model of the district that will be developed in order to mimic its hydraulic behavior under the hypothesis of an optimal management practice.

Concrete recommendations	
8.	Water management solutions must consider specific pilot infrastructure and requirements. Modularity and complementarity of the different approaches are recommended to face potential evolution of water management infrastructures.
9.	The status of available irrigation water must be added to irrigation planning.
10.	The risks identified in Chapter 2.3 (especially the possible malfunctions and missing data) need to be added as project risks.
11	Ensuring a continuous monitoring of irrigation scheduling and operations performed on the channel network during the irrigation seasons.

2.4. Farmers role and involvement

Farmers are directly interested in the development of the SWAMP platform: actually, that will not only promote the simplification of the irrigation water requesting process (e.g. Italian pilot) but will also aim to achieve an efficient water management to the benefit of the farmers (e.g. all pilots).

Farmers are the target end-users of the project and therefore any achieved result must be analysed with reference to their degree of satisfaction and understanding of the advantages brought by the project. In addition, trials are carried out at the heart of their personal business, with all the risks and uncertainties that follow.

The way SWAMP was conceived and developed demonstrates the acknowledgment of the key role of farmers in the project. Firstly, in the design of the platform architecture, the corresponding stakeholder was identified in the figure of the "Irrigation Operator", specifying their role and interests in the project and predicting for them a specific graphical interface to be implemented in the Functional View. Moreover, for the drafting of the pilot specifications each working group carried out surveys and meetings with the farms in which the experiments will be carried out to present the project and to discuss the operating methods. Finally, the communication plan explicitly provides for organizing periodic discussions with project stakeholders, including visits to pilot areas and meetings with farmers to receive their feedback on the progress of the project.

These premises suggest that the involvement of farmers will be guaranteed, both in the initial phase and throughout the duration of the project. In this sense, the users' irrigation requests and the way they are currently managed are aspects that SWAMP will have to analyse carefully and take into account.

Concrete recommendations	
12.	End-users role in requirement specification should be enforced by explicitly defining way how to interact with farmers.
13.	The idea of SWAMP interest group must be realised. The project must put attention in communication with farming communities

3. Pilot assessment and evaluation plan

Pilot assessment and evaluation plans represent steps and tools through which the partnership will measure, evaluate and analyse the results and impacts of the project. These surveys will be carried out continuously during the overall project but summarized at the end in two fundamental reports: deliverable D5.5 at month 18 (M18; half of the project duration) and deliverables D5.2 and D5.6 at end of the project (M36).

Data collection plans will be pursued with the aim to monitor three main relevant aspects: Performance and Key Performance Indicators (PIs and KPIs), external interventions (EI), and acquired knowledge and open research datasets (ARD).

- PIs and KPIs represent the metrics by mean of which we will quantify the project achievements, comparing them with expected results;
- External Interventions (EI) indicate all the information reporting the human actions in the crop field;
- Acquired knowledge and open Research Datasets (ARD) represent all information and scientific knowledge that can be opened to general public database sites and shared with the scientific community.

The following sections summarize the most relevant metrics and KPIs that will be monitored during the project. The following indications come from our current knowledge of the pilots and of the technological solutions adopted in the field and implemented in the IoT platform, thus changes and integrations are possible and expected.

3.1. Initial assessment plan at M18

At mid-term, M18, preliminary deployments of subsets of the SWAMP systems at the pilot sites is expected. PIs, EI and ARD will be evaluated in relation to the progress of each pilot and in relation to its specific characteristic and activity planning. The objective of the M18 assessment is to critically evaluate the status of the pilots with respect to the use of SWAMP platform (considering its development degree) and the status of pilot infrastructure implementations (i.e. the sensors, actuator, links to external services, etc.). All the pilots are different, but they rely on instantiations of the same SWAMP platform. Therefore, in the following evaluation plan, we have a section related to maturity and usability of SWAMP platform and its components (deliverables D1.2, D1.3, and D2.1), and separate sections for each pilot with their different implementations (deliverable D5.3).

The mid-term evaluation consists of following targets and their descriptions:

Evaluation target at M18	Evaluation description (evaluation of the existence, quality or readiness of implementations; when suitable it reports the related performance indicators (PI))
Readiness of the SWAMP platform components	
IoT communication system	Testing if we can receive measurement data from pilot fields.
Context broker system	Testing if we can store context information into FIWARE Orion context broker.
Time series storage system	Testing if subscriptions of Quantum Leap work and that we can visualise collected data series using dashboards via web browser and later via mobile applications.
SEPA solution	Existence of dedicated instance with tools installed in the SWAMP

	cloud
Interoperability of SEPA and FIWARE	Testing if SEPA and FIWARE data and services can be used in parallel.
Data models	Evaluating the completeness (as percentage of implemented models) of data model implementation descriptions.
Weather forecast interface	Testing that we can read weather forecast data from Internet forecast providers into FIWARE and SEPA.
Soil-based water need estimation	Evaluating the status of soil-based water need estimation service development. When service is ready, the results will be compared to farmer's opinions. At M18 it is expected to be a specification. At M36 a service of the SWAMP platform.
Crop-based water need estimation	Evaluating the status of crop-based water need estimation service development. When service is ready, the results will be compared to farmer's opinions. At M18, it is expected to be a specification. At M36 a service of the SWAMP platform.
Irrigation planning	Evaluating the status of water allocation and irrigation scheduling services. PI: implementation completeness. At M18, it is expected to be a specification. At M36, a service of the SWAMP platform.
Drone system	Status of the drone prototype with sensors integrated and valid data obtained from the field. Deployment of the drone at three pilot sites. Evaluating the initial data collection from the pilots with the same or equivalent setting. Evaluating the characteristics of drone system such as adequate flight time for data-collection capabilities, capability to carry drone gateway, capability of RFID sensor reading, capability to execute imaging mission with multispectral camera and CONOPS for data collection.
Multispectral camera data support	Evaluating the status of data processing service integration for NDVI and LAI extraction.
Management support system	Evaluation of status of deployment and management service implementations (see details in deliverable D3.1). PI: implementation completeness.
Storing of collected data for further analysis	Status of acquisition, type and quality of historical data available at the pilot. At this stage data should be acquired or the measurement plans should be operative. ARD: datasets of water consumption, irrigation procedures, costs, crop harvest, etc.
Cartagena pilot implementation status	
Soil probes	Status of the probes installed. Is the number of available probes in line with pilot requirements? Are the soil probes producing accurate and reliable information from the soil status? PI: feasibility asked from farmer.
Communication system	Status of field, mobile and Meshlium gateways. Do we receive the data packages to cloud servers? Comparing received messages to

	planned sending of messages. Operation of both Lora and 4G communication. PI: percentage of missed packets.
Data collection system (SWAMP platform installation)	Status of SWAMP data collection system as end-to-end communication system. Do we have a functional SWAMP IoT platform in operation for the Cartagena pilot?
Powering	Status of power system installations at pilot field. Is the power source reliable? Do we have enough capacity? Comparison of power production to consumption. Estimation of battery duration in case of cloudy periods. Comparison to requirements.
Irrigation system actors	Status of IoT actuators, i.e. valves and pumps. Can we control the valves and pump through SWAMP cloud platform? Reliability is the key target, as farmer has to be able to trust the irrigation control. PI: percentage of correctly executed irrigations measured for resulting soil water content changes and visual monitoring of irrigation system during irrigation (identification of sprinkler operation problems)
Libellium weather station	Status of the Libellium weather station operations. Do we receive in-situ weather data to SWAMP cloud? PI: operation of the data visualisation from SWAMP cloud.
Water meters	Status of the water flow meters. Do we record the water consumption of irrigation events to cloud with specified accuracy? Do we get readings from both pilot field and reference field?
Italian pilot implementation status	
Soil Probes	Status of the probes. Are the number of available probes in line with pilot requirements? Are the soil probes producing accurate and reliable information from the soil status? PI: feasibility asked from farmer.
Communication gateways	Status of gateways. Do we receive the data packages to cloud servers? Comparing received packets to planned sending of packets. PI: percentage of missed packets.
Data collection system	Status of SWAMP data collection system as end-to-end system. Do we have a functional SWAMP IoT platform in operation for the pilot?
Powering	Status of power system installations. Is the power source reliable? Do we have enough capacity? PI: comparison of power production to consumption; estimation of battery duration in case of cloudy periods; comparison to requirements.
Irrigation system actors	Status IoT actuators, i.e. automatic gate. Is the installation phase following the initial plan? Can we control/check the actuator(s) through SWAMP cloud platform? PI: Error rate.
Weather station	Acquisition of weather information from the public weather

	station closer to the case study. Do we receive in-situ weather data to SWAMP cloud? PI: visualisation from SWAMP cloud.
Water meters	Status of the water flow meters. Do we record the water consumption to cloud with specified accuracy? PI: Ratio of recorded irrigation events (by system) to all irrigation events (reported by farmers).
Water level meters	Status of acquisition and installation of water level meters for the monitoring of the irrigation network. ARD: added knowledge of the irrigation system.
MATOPIBA pilot implementation status	
Soil probes	Status of soil probes. Are the soil probes easy to install and maintain? Are the number of available probes in line with pilot requirements? Are the soil probes producing accurate and reliable information from the soil status? PI: feasibility asked from farmer.
Communication gateways	Status of gateways. Do we receive the data packages to fog and to cloud servers? Comparing received packets to planned sending packets. PI: percentage of missed packets.
Data collection system	Status of SWAMP data collection system as end-to-end system. Do we have a functional SWAMP IoT platform in operation for the pilot?
Powering	Status of power system installations. Is the power source reliable? Do we have enough capacity? Is an alternative power source necessary? PIs: comparison of power production to consumption; estimation of battery duration in case of cloudy periods; comparison to requirements.
Irrigation controller API	Status of the API to the VRI (Variable Rate Irrigation) controller, the pivot electronics and the firmware that actuate over valves and pumps to reflect the irrigation prescription maps (IPM) in the field. Can we provide and transfer IPM to the VRI controller through SWAMP fog and cloud platform? API and controller tested in a couple of single events using a grid of graduated cylinders as manual rain gauges. PI: water amount and spatial accuracy.
Weather stations	Status of the local weather stations operation (farmer's and SWAMP). Do we receive in-situ weather data to SWAMP fog and cloud? PI: visualisation from SWAMP cloud.
Water meters	Status of the water flow and water level meters. Do we record the water consumption to fog and cloud with specified accuracy? Do we get separate readings from both VRI and conventional irrigation areas? PI: ratio of irrigation water consumption by area.
Guaspari pilot implementation status	

Soil probes	Status of the soil probes. Are the soil probes easy to install and maintain? Are the number of available probes in line with pilot requirements? Are the soil probes producing accurate and reliable information from the soil status? PI: feasibility asked from farmer.
Communication gateways	Status of gateways. Do we receive the data packages to fog and to cloud servers from both plots at Guaspari? Comparing received packets to planned sending packets. PI: percentage of missed packets.
Data collection system	Status of SWAMP data collection system as end-to-end system. Do we have a functional SWAMP IoT platform in operation for the pilot?
Powering	Status of power system installations. Is the power source reliable? Do we have enough capacity? Is it necessary an alternative power source? PI: comparison of power production to consumption; estimation of battery duration in case of cloudy periods; comparison to requirements.
Irrigation controller API	Status of the API to the existing automated controller, the irrigation system electronics and software that actuates over valves and pumps to reflect the water need for each plot in the field. Can we provide and transfer differentiate water needs by plot to this commercial system through SWAMP fog and cloud platform? API and controller tested in irrigation events. PI: distinct soil moisture by plot.
Weather stations	Status of the local weather stations operation (farmer's and Swamp). Do we receive in-situ weather data to SWAMP fog and cloud? PI: visualisation from SWAMP cloud.
Water meters	Status of the water flow and water level meters. Do we record the water consumption to fog and cloud with specified accuracy? Do we get separate readings from pilot plots and other plots? PI: ratio of irrigation water consumption by plot.
SWAMP applications	
Farmer application	The Farmer Application will provide to the farmer access to the measurement data and analytics services (water need, irrigation planning, etc.). Prototyping of the application user interface and exploration of the platform core services (FIWARE, SEPA) should be finished at M18, with the app UI and requirements specified and validated with farmers.
Water distributor application	Description and the readiness level of water distributor application. At this stage of the project prototyping of the application user interface and exploration of the platform core services (FIWARE, SEPA) should finished. App UI and requirements should be specified and validated with water

	management bodies.
SWAMP platform management applications	Description and the readiness level of SWAMP platform management applications. Services, UI and requirements should be specified.

3.2. Initial plan for final evaluation at M36

Final evaluation of SWAMP achievements will be monitored at M36, the end of project.

Data, indicators and statistics regarding both the use of the IoT platform and the irrigation context will enable the evaluation of the benefits ensured by the technological platform and precise irrigation techniques. At this stage, all the indicators (PIs, KPIs, EI and ARD) adopted for the mid-term monitoring plan will be consolidated and extended at covering the overall project period. These indicators will benefit of a longer testing period and will represent the results over two (or more, in relation to crop and pilot area) irrigation seasons.

At M36, the IoT platform will be completed and it will be tested on all pilots. Thus, in addition to metrics evaluated at the project mid-term (M18), the final evaluation will consider additional impacts. This said, M18 evaluation metrics (see Section 3.1) will be re-evaluated since their status will be different at the end of the project. However, for the sake of brevity, the evaluation plan is not repeated in this section.

Specific evaluation of expected impacts at M36 are following:

Evaluation of expected impact at M36	Evaluation description and KPIs
Reduce water consumption	The evaluation of water saving will be done from the viewpoints of different stakeholders: farmer (water used in the field by farmers) and water manager (water produced and managed). <u>Farmer:</u> Comparison of amount of water used for a given crop adopting the SWAMP platform or following the traditional approach (e.g., m^3/ha/ton of crop per season). The evaluation will be made adopting different approaches in relation to pilot specificity (i.e., digital twin, comparison to a reference field, etc.). KPI: amount of water saved using SWAMP system. *Cartagena pilot:* Evaluation will be performed comparing the irrigation consumption of the pilot with that of a similar spot cultivated in parallel. In both fields, the water consumption will be measured using water meters connected to SWAMP system. *Italian pilot*: The comparison will be made by considering the water need required following the traditional irrigation practice (i.e., based on farmers' experience) for similar crops grown in the same geographic area, but not considered in the pilot. Comparison will be made in terms of amount (cubic meter, m^3) of water used per crop type, per unit of yield (ton) and field extent (ha) [m^3/ha/ton].

	MATOPIBA pilot: Comparison will be made by considering the water need required following the traditional irrigation practice (i.e., based on farmer's experience) in ¾ of pilot area and practicing VRI in ¼ of the remaining area during the same growing season. Comparison will be made in terms of m^3/ha per unit of harvest crop. *Guaspari pilot:* Comparison will be made by considering the water need required following the traditional irrigation practice (i.e., based on farmer's experience) in regular plots and practicing the soil moisture measuring and forecasting method in the pilot plots during the same growing season for the same grape varieties. Comparison will be made in terms of m^3/ha per unit of harvest crop. Water manager: *Italian pilot*: Efficiency of the water allocation system is expressed as the ratio between the overall water volume distributed to the field (i.e., pumped by the farmers for the irrigation) and the volume allocated to the district by CBEC (Consorzio di Bonifica dell'Emilia Centrale), during the irrigation season. This ratio gives an overall estimation of the efficiency of the system that can be compared with previous performances. Data required for this evaluation have been collected by CBEC during past irrigation seasons and are available for statistical comparison. It is worth noting that those past values might be affected by errors since they do not rely on real measurements, but rather on farmers' and gatekeepers' declarations. Data of the irrigation seasons monitored during the project will be collected by means of automatic gate and flow meters installed in the network and at the farmers' fields. Real efficiency will be compared with the one obtained supposing to drive the digital twin of the irrigation district following water need estimation and distribution scheduling retrieved from the SWAMP platform (see also section 2.3).
Reduce energy consumption in the irrigation process	Energy consumption to deliver the water to the field. The evaluation is performed in terms of total amount of energy (e.g., KWh/month; KWh/yield) needed for water withdrawing, pumping, etc., in relation to pilot specificity and stakeholder functions. As performed for the previous impact, the evaluation will be carried out considering both farmer and water manager perspective. KPI: energy saving in irrigation using SWAMP system. *Italian pilot*:

	Farmer: the energy consumption will be evaluated as a function of the "hours of irrigation" (i.e., hours of pumping or hours of tractor required for the irrigation), as a measure of the energy required for the irrigation. Water manager: energy consumption reduction at the district level will be evaluated as a function of the reduction of the water volume distributed within the district. Real volume will be monitored by means of flow meters, whereas the consumption ensured by SWAMP will be estimated through a hydraulic model serving as digital twin of the irrigation network (see also D5.1 and section 2.3 for additional details). *Cartagena pilot:* The energy consumption is directly propositional to amount of water pumped into field. The water flow meters measure both the pilot field and reference area water amounts. They can be compared, and energy saving can be calculated. *MATOPIBA pilot:* The energy consumption is directly propositional to amount of water pumped into field by electrical pumps. The water flow meter (only one per pivot) measures both the conventional ¾ and VRI area. Water amount will be measured, and energy saving can be calculated from measurements for each area. *Guaspari pilot:* The energy consumption is directly propositional to amount of water pumped into field by electrical pumps. The water flow meters (one per group of plots) measure both the conventionally irrigated plots and pilot plots flow. Water amount will be measured, and energy saving can be calculated from measurements for each plot.
Verify the impacts of irrigation strategy in crop quality and harvested quantity.	Evaluation of crop quality and harvest for a given crop (ton/ha for a given crop) in case of adopting, or not, the SWAMP platform. Farmers will measure the amount of crop and analyse the quality of the crop with crop type depended methods (or based on experience). Depending on the pilot the measured values will be compared either to actual data of the same field, or area, or compared to reference field values achieved during the same harvesting period. Reference data for comparison can be represented in terms of data retrieved from similar fields in the surrounding area considered as representative of the pilot or looking at statistical data based on experience and previous observations (i.e., typical average harvest, tonne/ha, in the area of interest). KPIs: crop quality, harvested yield. *Italian pilot:* Ton per hectare [ton/ha] of the considered crop. Comparison

	with similar crops cultivated out of the pilot district. In order to remove possible bias due to farmers' irrigation practices that might affect the harvest, the comparison will also be made referring to historical statistical data on harvest quantity. This data is at disposal of CBEC and can be retrieved from farmers' interviews. *Cartagena pilot:* Farmer will measure the yield of pilot and reference field and estimate the crop quality of both fields. In case of baby-leaf spinach the crop quality evaluation is a standard process and critical for the farmer. Impact of irrigation can be directly compared. Similar evaluations will be performed at MATOPIBA and Guaspari pilots.
Reduce costs of irrigation	The cost of irrigation is mainly a sum of energy, labour, and maintenance costs. Energy consumption depends directly from the amount of water pumped to the field, but its cost depends on the price of energy at given moment as energy price varies depending on the production-consumption situation. For example, the electricity is typically cheaper at the night. Labour costs relate to number of persons needed for the execution of irrigation. Irrigation system maintenance is most difficult to estimate as it depends on the faults and wearing of the system. *Cartagena pilot:* Cartagena pilot will automate the irrigation system that gives more flexibility to irrigation timing. The costs are evaluated using energy price values and irrigation scheduling, recording the amount of work force in both fields, and by monitoring the reliability of developed SWAMP system. We recognise the fact that SWAMP system is not a commercial product level design and if needed, we will use equivalent system data in analysis. *Italian, MATOPIBA and Guaspari pilots:* There will be no evaluation of impacts on the cost of irrigation.
Irrigation and water distribution impacts	
Estimation of the impact of a system when integrated in the preliminary release of the SWAMP framework.	Benefits can be inferred in terms of higher flexibility on the management of the water distribution system, human activities reductions, etc. (ARD). This evaluation, difficult to be performed in a quantitative manner, will be performed referring to feedbacks of users and stakeholders that tested the SWAMP infrastructures and web apps. *Italian pilot*: The optimization of the irrigation scheduling is expected to provide benefits on the management of the irrigation

	scheduling. To infer these benefits, we will refer to a digital twin of the irrigation district based on a hydraulic model. The reader is asked to read D5.1 and section 2.3 for additional details. KPIs: efficiency of the water allocation, water losses due to infiltration, delay of water allocation. *Cartagena, MATOPIBA and Guaspari:* There will be no evaluation of impacts on water distribution or water sources.
Increased knowledge of the current irrigation practices.	The installation of flow meters, environmental and field sensor during the first part of project, as well as the collection of historical data will enable the acquisition of a greater knowledge of the traditional irrigation activities. This knowledge will regard the amount of water usage, amount of water per harvest quantity, energy consumption, manpower required, etc., and represents the element of comparison for the evaluation of the project performances (ARD, KPIs). The impact of increased awareness will be done by interviewing the farmers and other stakeholders. The purpose is to understand how different stakeholders value the awareness. *Cartagena pilot*: In Cartagena pilot, the SWAMP system will have a water meter measuring amount irrigation water both at pilot field and reference field. This increases the awareness of water consumption. *Italian pilot*: Flow meters are going to be installed at the target farms to measure the water withdrawn for irrigation; automatic gate installed at the entrance of the irrigation district enables the monitoring of discharge in time. Monitoring of water level within the irrigation channel will enable a better estimate of losses due to infiltration. *MATOPIBA and Guaspari pilots:* The great expectation at the Brazilian pilots is to better understand water behaviour in soil through the sensor network data (in grid or per management zones). Current irrigation practices can be improved even not making use of Swamp platform itself but the project data comparison for conventional and precision irrigation.
Measurements of human efforts.	This will consider human involvements in activities related to the irrigation and agricultural practices (e.g. manual irrigation, spreading of agrochemicals, early or late harvest) as well as for the management of the water distribution network (e.g., number of field operations on sluice, gates, etc., to ensure water availability) (KPI, EI: improved and easier interaction

	between the gatekeeper and farmers for the planning and management of the irrigation phases). *Italian Pilot*: The impact of the SWAMP project in terms of human efforts will be evaluated considering the efforts of the gatekeeper during the irrigation season. This will be quantified in terms of number of field operations on sluice and gates dislocated in the district. The comparison will be referred to the number of real operations performed in the pilot by the gatekeeper and those required by applying the SWAMP platform to the digital twin pilot. Also, the benefit of the platform could be evaluated as improvement on farmers and gatekeeper interactions thanks to the use of web applications. *Cartagena pilot:* The aim is to automate the current, manual irrigation process. The main task in manual process is the configuration and operation of the irrigation system. In practice, it means turning valves at field in correct positions and manual controlling of the pump. The KPI is measured comparing the human effort needed in reference field to effort needed in automated field. Average effort per valve is estimated and results are scaled to reflect the situation in the whole farm. *MATOPIBA pilot:* The main foreseeing benefit is the possibility of planning or splitting irrigation events to only happen at night time periods. Labour efforts and costs in case of automated and not automated situations can be compared. *Guaspari pilot:* There is already an automated system for irrigation planning and execution. Human efforts can be measured and compared for manual and automated collection of data for irrigation plan refinements.
Water losses due to infiltration for the water distribution network	Expressed as m^3 of water lost during the irrigation season due to infiltration through the earthen channels. This value will be estimated by monitoring the water level in time along the main channels by means of the water level meters that will be installed in the district. Even in this case, the benefit will be evaluated by referring to the digital twin that will provide water level, and duration of its permanence, along the irrigation channels.

SWAMP technological performance indicators from initial plan (project will monitor these in order to understand how the SWAMP will cover the needs of the domain, and what are the limitations of technology in these applications).	
New types of Virtual Entities	Number of new device types (i.e., sensors, actuators, drones) exposed as IoT-Architecture, integrated to the IoT baseline, and validated in the pilots (KPI, ARD).
New smart water management services	Number of new data analytics and water management optimization services integrated to the IoT baseline and validated in the pilots (KPI, ARD).
Number of end-user applications	Number of precision irrigation and water distribution applications validated in the pilots (KPI).
Reliability of pilot deployments	Monitoring of the uptime of systems during the pilots (KPI).
Generic applicability of these architectures, platforms and standards, identifying missing standards or needs of evolvement.	Comparing SWAMP solutions to technologies and systems used in precision irrigation domain. KPI is the coverage of applicability of SWAMP technologies.
Monitoring of sensor functionality. Achievement of expected performances in terms of sensor communication.	The evaluation will consider the spatial coverage of the signal, the data sampling in time, the battery life, Drones as data mule. Expected performance of data collection system is monitored using collected data value in the platform. The analysis of data collection parameters will be based on comparing the changes to values with data collection timing.
Economic sustainability of the platform.	Estimating the costs for the sensors and technological devices used in the field, considering installation and maintenance costs (KPI: Share of total irrigation system).
Applicability of drone system for precision irrigation.	Evaluation will cover issues related to value of data collected by drone system and adequateness of performance of drone system. Value of data will be assessed by end users and stakeholders of irrigation systems. Performance evaluation focuses maintenance and usage costs and expected life-cycle of drone system. Various business models for using drones as part of system will be compared.

4. Final Remark

This document collects partners' recommendations and open issues that came to light visiting the pilot areas and during the number of project meetings organized since the beginning of the project. The deliverable is considered confidential and brings about the key aspects that deserve attention during the project development and that will be used for the evaluation of SWAMP performances.

Chapter 2 has summarized critical considerations and recommendation that, despite being known, cannot be solved at this stage in the development of the pilots.

Chapter 3 lists the assessment and evaluation targets for mid-term and final evaluation. The aim is to understand the achievements of the project and to find places for improvement.

In doing so, D5.4 represents a tool to guide partners' activities during the upcoming months ensuring the best performance of the project.