SWAMP

SMART WATER MANAGEMENT PLATFORM

Project nº: 777112

WP5

D5.5 Pilot infrastructure assessment and evaluation report

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29 November 2019	Hannu Tanner (VTT)	Some minor comments added and fixes made, otherwise ready for submission.
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Table of contents

Abbreviations

API	Application Programming Interface
FAO 56	Food and Agriculture Organisation Irrigation and Drainage Paper No. 56
GSD	Ground Sample Distance
IoT	Internet of Things
LiPo	Lithium Polymer
LoRa	Long Range [radio interface]
LoRaWAN	Long Range, low-power wide-area network
NDVI	Normalised Differential Vegetation Index
PWM	Pulse Width Modulation
VRI	Variable Rate Irrigation

Executive Summary

This deliverable D5.5 (Pilot infrastructure assessment and evaluation report) from task 5.6 (Pilot assessment and evaluation) evaluates the current pilot deployment plans and implementations, and creates further guidelines and recommendations.

The project has followed the recommendation done at M6 rather accurately. In some cases, the actions will be taken later as the implementations of pilots are not yet in respective phases.

The report shows that the pilot implementations are in different phases and that the SWAMP platform and applications are currently under development, in a stage where most components are ready, with some adjustments and new features yet to be finished.

We have implemented and tested the sensors and data collection in all pilot sites, and SWAMP platform is capable of receiving and visualising data.

The data analysis part (i.e. water need estimation and irrigation planning services) is still under development. The actual services are gradually being integrated into the SWAMP platform.

The irrigation control functionality is different in each pilot. In the Cartagena pilot, the irrigation system components have been designed, and prototypes have been implemented. Full system test has not been done yet. We plan to implement four or five irrigation zones in the last pilot phase. In Reggio Emilia, although not fully operative yet, the water estimation module is at advanced phase, while all sensors (i.e., soil probes, and water level meters), monitoring schemes (i.e., drone) and actuator (I.e. automatic gate) have been installed and tested. In addition, data collected from the sensors are available on-line within the platform. The water management module related to the Italian pilot is currently under development, in agreement with the project timeline. In MATOPIBA, the challenge has been that the central-pivot provider is not committed to the project and will not implement the variable-rate irrigation. A solution is to import a VRI Kit and rush up its adaptation to obtain a single evaluation for the last project months. In Guaspari, the irrigation control is fully automated, and it was planned and implemented by Netafim, the irrigation system supplier. An initial discussion with the company suggests that Netafim still does not have an API for directly accessing the services and configuring the irrigation schedule. In that case, the irrigation plan generated by SWAMP must be configured manually to the Netafim control system, unless they manage to release a cloud-based API in time.

The SWAMP application prototypes are not yet functional, so the farmers and water gatekeepers will test them in the third project year.

The overall assessment of the pilot implementation status is that even with some difficulties, we can complete the pilots and to measure the impact of IoT in precision irrigation. The SWAMP approach has clear advantages to research in the farming domain, and it is expected to bring in new insights in this area. When it comes to practical work, the sensor development, the SWAMP platform design, and the system deployment at pilot sites have taken more effort than initially believed. The FIWARE platform use has been more difficult than believed and especially the data model development has been a complex task, which still needs iterations. In many pilots, there have been technical challenges to bring the system to the required maturity level.

1. Introduction

SWAMP project is a pilot-driven project that aims to develop a software platform and application for precision irrigation and water management for irrigation. The platform integrates IoT-based monitoring and irrigation and water distribution controls with AI-supported analysis of the situation and planning.

The SWAMP platform is based on the requirements of four very different pilots. The target of the project is to build and test the IoT systems, SWAMP platform, and mobile applications in real-life conditions at the farm, and to measure the system's impact to farming and water distribution.

This document is an internal assessment and evaluation of pilot infrastructures based on deliverables D5.1 Pilot specification and deliverable D5.3 Pilot infrastructure implementations. The purpose of the document is to provide a critical and constructive view to SWAMP pilots. The report is based on sections 2 and 3.1 of deliverable D5.4 that describe the recommendations given and M6, and the plan for this M18 assessment.

2. Pilot infrastructure assessment

2.1. Assessment of D5.4 recommendations

The following table describes the actions taken based on the recommendations given for pilots and the project in deliverable D5.4 at M6 of the project.

	Recommendation from D5.4	Action done in the period M12-M24
1	Finalise the common data model and guarantee the data interoperability using semantic models.	Semantic data modelling is used. Data models are created and documented in D2.7 and D2.1. The SWAMP platform has entity templates as part of the distribution package. During the pilot and platform development, we have noted that some fine-tuning is needed in some entities, especially related to irrigation system interfacing. Also, the need for new entities has become clear. Update of data model must be done at the end of the project.
2	When not served by solar panel, battery capacity limitations should be considered by developing ways of analysing and motoring battery statuses.	Current implementation monitors the battery capacity at an hourly rate. Battery level data can be visualized since June 6, 2019. Wireless sensor nodes (LoRa Nodes) were designed (hardware, firmware and policies) for low-power operation. After five months of non-stop operation, the battery level of a soil moisture sensor is still above 90% (with commercial batteries). Knowledge about battery behaviour along the seasons, while the weather conditions change, is gathered by the platform and will help in planning battery replacement policies.
3	Data backup capabilities need to be added to the IoT platform.	The need for archiving data has been noted, but the platform does not have this capability yet. The ability to save and reload, for example, farm data are important and they are planned.
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, and drone data) are recommended.	The SWAMP platform is based on FIWARE, and it is by default modular, so that it efficiently separates data form operations, and defines clear interfaces to operations. The platform has two different context brokers, and it supports in the pilots two different water need estimators, and three different irrigation systems.

5	Ensuring continuous monitoring of irrigation-related data during the overall project.	This recommendation has been accomplished for the Italian pilot during past irrigation seasons. All information regarding weather conditions, irrigation requirements within the study area, irrigations executed, scheduling and relative operations within the irrigation district (operations on the canals and gates) have been recorded and are available for the project purposes. The project has had stable flow of data from Guaspari pilot since April 2019. In other pilots, systematically recorded continuous data was not available, but have collected data sets from farming periods.
6	Sensor calibration and sensor installation issues need to be clear. Sensor calibration and installation processes should always be added to platform user guidelines.	We have developed guidelines of soil moisture sensor calibration, and the Italian pilot has developed tool support for calibration.
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.	Farmer application includes the possibility to override the SWAMP recommendations and to modify the irrigation plans.
8	Water management solutions must consider specific pilot infrastructure and requirements. Modularity and complementarity of the different approaches are recommended to face the potential evolution of water management infrastructures.	Tools under development for the optimization of the water management do consider the potential evolution of the infrastructures (canals, gates location). Modularity and flexibility of the methodologies are considered in order to ensure the possibility to adapt the optimization module with a modest effort in case of infrastructure variations.
9	The status of available irrigation water must be added to irrigation planning.	Availability of water is included in irrigation planning function as a constraint.
10	The risks identified in Chapter 2.3 (especially the possible malfunctions and missing data) need to be added as project risks.	Risks have been added with appropriate countermeasures.
11	Ensuring continuous monitoring of irrigation scheduling and operations performed on the canal network during the irrigation seasons.	Irrigation monitoring (i.e. scheduling, operations, and flows) has been continuous during the past season. Data are available for the comparison with the digital twin.

12	End-users role in requirement specification should be enforced by explicitly defining the way how to interact with farmers.	During application development, the pilot farmers and stakeholders have been involved. The idea has been to create easy to use and self-explaining user interfaces.
13	The idea of SWAMP interest group must be realised. The project must put attention in communication with farming communities.	The plan for SIG creation was done and distributed to partners. However, the progress in getting companies to participate has not been satisfactory.

2.2. Assessment of pilot infrastructures

Evaluation target at M18	Self-assessment of the status with reference to a possible recommendation in Chapter 3
The readiness of the SWAMP platform resources	
Cloud Servers	SWAMP cloud has been instantiated at UFABC. Virtual machine support exists. Access for all partners exists for instantiation of pilot specific SWAMP runtime systems.
Fog Nodes	Fog computing infrastructures are deployed and used in the Brazilian Pilots. In both cases, simple desktop computers play the role of a fog node. MATOPIBA is based on a heavyweight fog, where communication and data management components are deployed (LoRa Server and FIWARE Orion and related General Enablers) to allow local processing capabilities, which is necessary due to the frequent disconnections from the Internet. In Guaspari, a lightweight fog is deployed (using LoRa Server only). In both cases, the fog nodes are installed in the farm office and use Wi-Fi as local connectivity technology among mist (LoRa Gateway) and fog, as well as existing Internet connections. The existence of fog nodes guarantees that the entire solution - consisting of sensors, solar panels and gateways - is permanently on the farm and transmits data constantly.
The distribution package of SWAMP platform software	Initial versions of distribution packages exist. The initial data model is included in the distribution package. Instances of SWAMP has been created to the cloud. The package will be continuously improved as new features become ready.
The readiness of the SWAMP platform and its components	
IoT communication system	The communication system is part of the IoT Platform that is a component of the SWAMP Platform, reported by deliverable D1.2. IoT communication technologies are ready and extensively tested since the beginning of the project in all four pilots.

Context broker system	The FIWARE Orion Context Broker is an integral part of the IoT component of the SWAMP Platform. Since it is the heart of the IoT Platform, it has been extensively tested and works well.
Time-series storage system	Different time-series databases have been tested, such as InfluxDB and CrateDB. Finally, the FIWARE QuantumLeap Generic Enabler has been defined as the key software component for time series storage, based on CrateDB, which has been extensively tested in the 2nd year of the project.
SEPA solution	Collection and distribution of Linked Data are up and running for several months. Collected data include soil moisture, weather forecasts and canal levels. The CRITERIA-1D crop-based water need estimation model is fed with the collected weather forecasts, and its output is stored back as Linked Data. Real-time and historical data can be visualized online through the SEPA View interface. SEPA security and access control list have been implemented and will be exploited by SEPA based applications.
SEPA-FIWARE interface	The work is on-going, but it has turned out to be more complex than initially understood.
Data models	Initial data models have been developed and documented in D2.1. Data models have been integrated into the current version of the SWAMP distribution package. However, data models are not yet final. Bug fixing and some redesigning will be needed.
Weather forecast interface	The Weather Forecast Interface is implemented and has been running for some time obtaining weather forecast data from AccuWeather for the four pilots.
Soil-based water need estimation	The soil-based Water Need Estimation model, described in deliverable D3.1, is based on a combination of physical models for evapotranspiration (FAO 56) and data-oriented machine learning models. The first implementation is available and is in the process of being integrated as a service to the SWAMP Platform.
Crop based water need estimation	The model CRITERIA-1D, chosen for the SWAMP water balance based approach, is already implemented in the platform. The boundary conditions of the model (water table, soil and crop parameters) for the three farms of the Italian pilot have been gathered and are ready to be configured into the model.
Irrigation planning	Plans are being generated for the Cartagena pilot using the model described in D3.2. Plan feasibility is being evaluated. Evaluation of plan optimality will require more data from pilots and more testing. Nonetheless, improvements in the optimization model are proceeding in parallel to the implementation.
Irrigation control	For Cartagena pilot, the irrigation control will be implemented into the SWAMP platform. The implementation is still missing. In MATOPIBA, the challenge has been that the central-pivot provider is not committed to the project and will not implement the variable-rate

	irrigation. A solution is to import a VRI Kit and rush up its adaptation to obtain a single evaluation for the last project months. In Guaspari, the irrigation control is fully automated, and it was planned and implemented by Netafim, the irrigation system supplier. An initial discussion with the company suggests that Netafim still does not have an API for directly accessing the services and configuring the irrigation schedule. In that case, the irrigation plan generated by SWAMP must be configured manually to the Netafim control system, unless they manage to release a cloud-based API in time.
Drone system	SWAMP drone and mobile gateway exits. Components for SWAMP payload need exists. Autonomous flight planning exists. Several autonomous missions were carried out on three farms of the CBEC (Reggio Emilia) pilot: one pear field and two vineyards. Acquisitions were made with the Red-Edge multispectral camera. The flight experience allowed determining the optimal flight parameters (height, speed, time) to obtain the NDVI measurements with a resolution of up to 10 centimetres. Moreover, the parameters to obtain 3D images have been determined too. Drone system was tested at Cartagena pilot. Autonomous mission flights were done. The drone connects to SWAMP cloud via a mobile gateway. It sends information of its own operations and from camera system or collected data. The drone can also receive commands through the gateway. The functionality of the farmer application that commands the drone is missing.
Multispectral camera data	UBO used the MicaSense RedEdge Multispectral Camera for Precision Agriculture with the following specifications: · 168 grams (with irradiance sensor) · 8 cm/pixel and GSD at 400 ft. · Built-in Wi-Fi, serial Ethernet, and PWM. · Five narrow bands for custom algorithms. · 12-bit sensors · Open APIs for advanced integration. The post-processing of Red-Edge data (image, location and drone attitude) was performed with the Pix4d-Field commercial software, with which both the NDVI with a resolution of up to 10 centimetres and the 3D reconstruction of crops were obtained. A 3D-printed adapter was designed to carry the camera on-board. VTT has implemented a prototype of NDVI camera that can send image data directly from the drone to cloud for processing. The camera has been tested, and data is collected to the cloud, but actual image analysis has not been done yet.

Management support system	The SWAMP Management System is described in deliverable D1.3 and consists of IoT Management Agents (IoTMA), IoT Manager (IoTMan), IoT Entity Editor (IoTEE) and IoT Sensor Setup (IoTSS). All of them have a first version ready and running, but the development is still work in progress to add new features up to the end of the project. During the deployment of the SWAMP Platform in the pilots, it was understood that an IoT end-to-end data flow requires a management solution to facilitate and streamline the identification and fixing of problems.
SWAMP applications	
Farmer application	An initial version of the application exists. It provides basic monitoring capabilities (e.g., soil moisture and water needs), also allowing visualizing and applying the irrigation plan. Plan customization and monitoring are planned for the updated version in M30.
Gatekeeper application	An initial version of the application exists. API to communicate with the platform is under development.
Water distribution application	Prototype exists. Extensions are being added (e.g. weir opening views, irrigation scheduling views).
Cartagena pilot implementation status	
Soil probes	Three-depth (5, 10, 15cm) soil probes have been implemented, and six units have been deployed in three pilot cycles. Calibration was performed for Cartagena soil at VTT. Probes transmit soil moisture, air temperature, pressure and humidity values to gateway every 5 minutes. The probes are easy to install and use, but there have been reliability problems related to communication.
Communication gateways	We have installed a gateway at the field for sensors and irrigation system, and another one gateway is ready for the pump. Drone gateway has been tested. It needs a performance update, so that multispectral images can be saved fast enough. Gateway reliability was excellent until LoRaWAN version was taken into use. We are currently trying to identify problems.
Data collection system	All components exist. Data from Cartagena pilot side is stored in Quantum Leap in SWAMP Cloud at UFABC Brazil.
Powering	We have 140W solar panel and 100Ah batteries for powering the gateways and irrigation system. The battery was upgraded from 40Ah used in earlier pilot phases to enable the use of weather station. In the first two pilot phases, the battery run out twice due to multiple cloudy days in sequence. The upgrade should fix this.
Irrigation system actuators	One valve that controls the pilot field is installed. One sprinkler valve has been implemented, but not installed. Pump control requires an electrician

	to connect and overpressure valve installation. Irrigation system components have been tested in laboratory conditions.
Weather station	Meshlium gateway has died. We have rerouted the WaspMotes through our field gateway, and we receive the weather station data through this. Already before, the Meshlium turned to be a poor choice as it does not support remote control.
Water meters	Two water meters have installed (pilot and reference fields), and data comes to SWAMP cloud. Accuracy of meters is 10 litres.
Italian pilot implementation status	
Soil moisture sensors	The three farms are equipped following the initial plan. At each field, three calibrated soil moisture sensors (at 15, 40 and 80 cm depth) made by METER have been installed, and the data is collected by means a ZL6 METER datalogger and it is downloaded manually at regular intervals. In vineyard #2, also an analogue Embrapa Soil Probe has been installed at 15 cm depth, and it is connected through a Lora wireless connection. Now, METER sensors are continuously monitored from the METER cloud, whereas Embrapa Soil Probe is controlled by SEPAView platform.
Water table sensors	A Meter CTD-10/HYDROS 21 sensor, calibrated by the supplier, was installed in pear orchard and another one in vineyard #2 at 5 m depth following the initial plan. At the moment, both sensors are not implemented in the SEPAView platform, but they are constantly monitored from METER cloud. Whereas in vineyard #1 CBEC periodically measures the depth of water table with a manual water level meter in standpipes installed at several depths.
Irrigation system actuators	The actuator in the Italian pilot is represented by the automatic gate at the entrance of the irrigation district. Its installation has been carried out following the initial plan: the gate is now in place and operative. Data (e.g., water levels, opening status) sensed at the gate are available in SEPA platform and suitable for hydraulic evaluation and the optimization procedures. However, the automatic gate is not, and is not going to be, directly controlled by Platform. For security reasons operations on the gate will be remotely activated by the gatekeeper based on data and recommendations provided through the SWAMP platform.
Water meters	The operation and the pulse emitter necessary to communicate the data of three flow meters to the platform has been successfully tested. The volume of water withdrawn from the network and used for irrigation by farmers will be available in real-time on the SWAMP platform.
Water level meters	The planned level meters (11 in total) have been installed along the canals network following the original timetable. All of them are settled and working properly: level measurements acquired are accessible to CBEC and available on the SEPA platform every 10 minutes.

MATOPIBA pilot implementation status	
Soil probes	A multi-depth and multi-parameter soil probe to measure moisture, temperature and electrical conductivity is under development. Prototypes for three moisture depths (20, 40, 60cm) and one temperature depth (20cm) have been implemented. Four units have been deployed in the current soybeans cycle. They were set to transmit soil data every 10 minutes and their electronics temperature and battery level every hour. Soil moisture has been transmitted in millivolts. Calibration is in progress by comparison to commercial probes (short term) and by the gravimetric method (long term). The calibration is intended to be applied to the millivolts data set as a post data collecting process. The probe electronics reliability has been the main addressed issue to assure continuous data sending. The probe installation requires special care to assure a good interface between soil and the sensor electrodes to obtain proper moisture data. We are investigating an effect of temperature over soil moisture data, more noticeable at 20 cm depth. The probes power supply solution (1100mAh 3.7V LiPo battery recharged by 1W solar panel) has worked properly.
Mist solution: Communication gateway combined with the Weather Station	On the MATOPIBA pilot, we have installed a single mist solution to collect soil and weather data. It combines the communication gateway and a weather station mounted on a field station structure: 3-meter mast, environmentally sealed housing and solar power system. There were a few communication reliability issues related to the gateway itself. With preventive and corrective maintenance, data has been collected, and the mist has allowed monitoring soil moisture status and weather conditions during important irrigation and precipitation events.
Powering	We have a 65W solar panel and a 50Ah battery for powering the mist solution. Total power consumption is around 5 Watts. This powering system is over-dimensioned for the MATOPIBA climate. We do not expect a long sequence of cloudy days to drain all battery charge. However, the charge controller was replaced once due to malfunctioning. Battery life may also be an issue due to exposition to high temperatures most time.
Irrigation control	The way to control irrigation in MATOPIBA pilot is transferring irrigation prescription maps to the centre pivot VRI controller. There will be no direct interface to valves or any actuators.
Water meter	Not implemented. This is going to be a pulse emitter necessary to communicate the data of a flow meter to the platform. The volume of water withdrawn from the Rio de Pedras river and used for this pilot irrigation shall be available in real-time on the SWAMP platform. There are no data relative to the past irrigation seasons.

Power consumption meter	Not implemented. This is going to be a power emitter necessary to communicate data of power consumption from a single pivot to the platform. There are data form the entire farm pivot system relative to the past irrigation seasons.
Guaspari pilot implementation status	
Soil probes	Same as MATOPIBA pilot. Four probe prototypes with three moisture depths (20, 40, 60cm) and one temperature depth (20cm) have been installed. In opposite to the MATOPIBA soil data observations, there is no noticeable effect of temperature over soil moisture data at any depth.
Mist solution: Communication gateway combined with the Weather Station	Implemented in the same way as MATOPIBA mist, presenting the same issues and providing similar results.
Powering	We have a 65W solar panel and a 50Ah battery for powering the Guaspari mist solution. Total power consumption is around 5 Watts. This powering system is properly dimensioned for the Guaspari expected climate. There were no issues for one year since its installation.
Irrigation control	Not implemented. The way to control irrigation in Guaspari pilot is transferring irrigation recommendations to the existing controlling system. There will be no direct interface to valves or any actuators.
Water meter	Not implemented. This is going to be a pulse emitter necessary to communicate the data of a flow meter to the platform. The volume of water withdrawn from the Guaspari pond and used for this pilot irrigation shall be available in real time on the SWAMP platform. There are data relative to the past irrigation seasons for comparison.

3. Recommendations for pilots

3.1. Smart water distribution pilot (Reggio Emilia, Italy)

Flow meters adopted for the accurate measurement of irrigation volumes have been set up and tested. The devices worked properly, but some challenges have been identified based on the different irrigation method. In the case of drip irrigation, the installation is feasible, and the main task will be to connect the data transfer to the platform. This will be the focus of the last year of the project. Two fields are, however, irrigated with mobile sprinkler methods. For this reason, the installation of the flow meter faced some challenges. The flow meter could be installed at the head of the distribution systems of the farm, but the actual irrigation area could be not automatically detected. To overcome this limitation, it has been discussed the possibility to install the flow meter directly at the mobile sprinkler together with a GPS. This will address the issue of having the volume and the precise position of irrigation. The implementation of this solution will be evaluated for monitoring the next irrigation season.

As pointed in deliverable D5.3 "Pilot infrastructure implementations", the weather variables, provided by ARPAE (Regional Agency for the Environmental Protection and Energy of Emilia Romagna Region), belong to the ERG5 grid, which was developed to provide support to agricultural service of Emilia-Romagna. The ERG5 is based on the spatialisation of the weather variables on a regular grid spaced 5x5Km which covers the overall regional area. Given the low resolution of the grid, the provided data is not accurate enough to meet the requirements of the water need estimation model. Therefore, it is recommended for the future to use also weather data provided by CBEC that has weather stations nearby the pilot area. However, the automatic gathering of these data requires further integration steps.

3.2. Smart precision irrigation pilot (Cartagena, Spain)

Cartagena pilot has had two phases, and the third is on-going. The fourth phase will be the final phase, where all features must be in use.

Must do recommendations:

- Water need estimation service is needed as soon as possible. Without water need estimation, we do not even have irrigation recommendations. The farmer can be guided via soil moisture values, which is an improvement to the current state of the art, but it does not equal with planned AI-based estimation.
- Farmer application needs to be deployed at the farm as soon as possible. At least before the end of January.
- Automation of the whole irrigation system needs to be completed. This means mainly the installation of pump gateway. This would allow more flexible irrigation scheduling, e.g. irrigation at night, when evaporation is smaller. This could lead to significant water saving.

If we would have time and resources recommendations:

- Autonomous drone operations. The technical maturity of autonomous flying is such that a totally autonomous drone system might be feasible. We are not far away from the situation where the farmer could take the drone at the field and launch mission from Farmer application.
- Tools for setting up the SWAMP system at the farm. The current system needs IT expertise. Gateways and sensors need an expert for installations.

Lessons learnt:

- Remote pilot operations are a challenge. With the prototype system, fast responses are needed, and remote control does not work in all cases.

- We should have verified the permission to fly at the pilot site. The limitations came as a surprise, and it is really affecting to drone system development, as practical experiences from operations at the farm are not possible.
- The system-level testing should have been started earlier. Simulations and mock-up data might have revealed communication issues. We could have started the development of analyses earlier too.

3.3. Variable-rate irrigation pilot (MATOPIBA, Brazil)

Technical:

- Implementation of LoRaWAN EndNodes for commercial soil moisture sensors (TEROS 12 and TEROS 21), ATMOS Weather Station, Flow meter and power consumption;
- Irrigation prescription maps based on soil moisture probes data at individual management zones;
- Improvement of the dashboard to help to solve sensor issues;

Non-technical:

The MATOPIBA pilot primary commitment is to demonstrate water and energy savings of a variable rate irrigation system based on the centre pivot system. This is far to be accomplished in the remaining project time. MATOPIBA pilot installation schedule is about one year behind all other pilots. Among other reasons, funding to Embrapa came only in August 2018, and we decided to have Lanapre (Embrapa research farm) as a pre-pilot due to the large distance to reach MATOPIBA pilot farm. These would not be a big problem if we had not to deal with an agreement broken by the centre pivot supplier company that would produce the Embrapa soil probes and would develop the variable rate irrigation controller. Right after been notified about the decision of the Fockink Company, we decided to produce our own probes but not the VRI controller.

There are VRI capable centre pivot equipment from other suppliers in Brazil, but none installed in MATOPIBA region. Actually, there are just a few installed in the whole country. An imported VRI Kit can be a solution to keep the MATOPIBA pilot at the same farm. On the other hand, all VRI suppliers face a lack of knowledge and feasible technology for obtaining irrigation prescription maps. Therefore, we see this as an opportunity to the SWAMP project to limit its contribution in providing methods and creating feasible tools to produce the irrigation prescription maps during the project left execution time.

We still can purchase the VRI Kit for the MATOPIBA pilot. However, we will need one more soybean crop season (about six more months) to evaluate the water and energy savings. This is possible because the Embrapa and RNP agreement is signed for up to April 2021.

3.4. Precision drop irrigation pilot (Guaspari, Brazil)

Technical:

- Implementation of LoraWan EndNodes for commercial soil moisture sensors (TEROS 12 and TEROS 21), ATMOS Weather Station and Flow meter;
- Water need estimation by management zones;
- Improvement of the dashboard to help to solve sensor issues.

Non-technical:

Pilot Guaspari has been the focus of more extensive studies on precision agriculture, which started by Embrapa at least two years before the SWAMP project began. While this previous work facilitated to convince the producer about the SWAMP activities, the long-term research has weakened somehow the collaboration. It is feared that we will have difficulties in modifying the irrigation control to follow the water need estimation based on soil sensor data as planned. The producer has already decided to limit the research areas to the lower part of the farm. A significant challenge for the SWAMP platform on the Guaspari pilot was exactly the system deployment in two distinct conditions, one at the lower and other at the higher areas of the farm. Even limited to the lower area, we still need to convince the farmer to proceed with the full implementation and effective use of the SWAMP platform.

4. Summary and overall assessment

The document presents the statuses of technical results of SWAMP and statuses of SWAMP pilot implementations after two first years of the three-year project. The project has two distinct areas. First is the development of the sensors, data collection, analyses, controls, and applications that is the SWAMP platform. The second is implementing the SWAMP system to pilot sites and to measure its impacts on water and energy use, and to yield and quality of the crops.

The baseline that was assumed at the beginning of the project has been less mature in almost all technical areas of the SWAMP. Much effort has been spent in developing sensors and actuator nodes, gateways, and intelligence to the system. The learning curve even with FIWARE has been very steep and we have had issues with stability and operation of all versions of it. This has delayed the project and shifted its content from testing of precision irrigation enabled by IoT to the development of the components and systems. The requirement to build an open system that adapts to all pilots and other possible farming uses has been difficult. In practical work, the system deployment at pilot sites has taken more effort than initially believed. Installing prototype-level devices to rural areas has shown its challenges. In many pilots, there have been technical challenges to bring in the system to the required maturity level.

The status of the platform at the end of the second year is:

- The implementation of IoT part of the platform is ready and in operation;
- The analytic services (water need estimators, irrigation planning) are almost finished;
- The visualisation services are available;
- The first prototype of farmer application is being tested, and other applications are under development.

We have collected sensor data from all pilot sites. The whole sensor set that will be used in pilots has been tested at the pilot sites. We have demonstrated to data collection to the SWAMP cloud, but there has been reliability issues in prototypes.

The irrigation control system is under development, but there are still some open issues regarding how it will be implemented, especially in MATOPIBA and Guaspari, where SWAMP will interact with commercial systems. The status in Cartagena is that components have been tested in laboratory conditions. In Reggio Emilia pilot in Italy, the irrigation is manually operated.

The overall assessment of the pilot implementation status is that we can complete the pilots and measure the impact of IoT in precision irrigation. The most critical parts in this process are the platform integration, applications, and reliability of data collection systems. The unpredictability of farming is also a risk, but that cannot be controlled by the project.

5. References

1. SWAMP D5.1 Pilot Specification, SWAMP project v1.3, 2019, 46 pages
2. SWAMP D5.4 Pilot requirement assessment and recommendations v3.0, 2019, 24 pages
3. SWAMP D5.3 Pilot infrastructure implementations v1.0, 2019, 51 pages