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WP4

D4.1 Value Proposition Specification

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Table of contents

Abbreviations

AI Artificial Intelligence	Artificial Intelligence
ANBI	National Association of Italian Consortium
API	Application Programming Interface
CIM	Common Information Model of SWAMP approach
CPS	Cyber-Physical System
ESC	Electronic System Component
FAO	Food and Agriculture Organisation
FC	Flight Controller
GE	FIWARE Generic Enabler
HTTP	Hyper Text transfer Protocol
ICT	Information and Communication Technologies
IoT	Internet of Things
JS	JavaScript
JSON	JavaScript Object Notation
LOD	Linked Open Data
NGSI	FIWARE message protocol
OMA	Open Mobile Alliance
REST	Representational State Transfer
SEPA	SPARQL Event Processing Architecture
SSN	Semantic Sensor Network
TRL	Technology Readiness Level
VRI	Variable Rate Irrigation
W3C	World Wide Web Consortium

Executive Summary

This deliverable - D4.1 Value Proposition Specification - results from Task 4.1 Value Proposition of Applications. The objective of this document is to describe the intended value proposition of SWAMP platform, to describe what are the systems built on top of it, and to define what the applications to be developed will deliver to end users (i.e., farmers and water distribution operators). The use of drones is described. The business potential is analysed by developing two initial business model canvases.

The aim is to give a holistic view of the project by answering the following questions: What is the SWAMP platform and systems? What are the elements that create the precision irrigation systems in different pilots? What kind of water distribution solutions are needed in the pilots? What is the value of the results for system developers who build on top of the platform, and for final system users using the developed irrigation and water distribution solutions?

1. Introduction

The water is an essential resource for every life on the earth. Sustainable and efficient use of water is a necessity for all of us. Agriculture is the biggest single user of fresh water. SWAMP project aims at developing and piloting solutions for saving the water and energy used in agriculture (mainly farming) and in distributing the water for agriculture.

The idea of precision irrigation is simple. The system must provide the right amount of water, into the right place, at the right time. The problems are related to the definition of "right" and infeasible costs and constraints. The right amount of water depends on the needs of the crop and water content of the soil. The optimum is also affected by other soil properties such as nutrition, soil type and soil structure. The right place of irrigation depends on the location and size of the plant root system. It also may depend on current state of the plant life cycle and environmental conditions. The right timing should consider the plants' water need as well as environmental conditions such as temperature, humidity, solar radiation, windiness, and the like, to minimise the loss of water, and the forecasting of natural availability of water. All these issues should be handled with minimum loss of water and with a minimum amount of energy spent on irrigation, and by also optimising the crop yield and quality.

The aim in a water distribution system is to deliver the irrigation water with appropriate quality to the farmer with minimal losses and minimal energy and cost. The water distribution system is typically a shared system with multiple users. Therefore, it must balance between different farmers' requests and optimisation of water distribution cost. Sometimes the statuses of water reservoirs need to be considered and maintained as part of the process.

The objective of this document is to consider the value proposition of SWAMP platform and systems, based on experiences made during the project's first months and the ideas developed during the specification and the first implementation phases of the pilots. The idea is not to present the final value proposition, but to consider the possibilities of value proposition and to improve the planning of both the platform and systems.

The structure of the document follows. Chapter 2 presents the main ideas of SWAMP approach and the irrigation and water distribution systems. Chapter 3 outlines the main expected benefits of SWAMP to farmers, water distribution organisations, society and environment. Chapter 4 considers the expected path of SWAMP results to actual commercial use. Chapters 5 to 7 outline the value proposition ideas of SWAMP platform for system developers, drone system for irrigation system developers, and irrigation systems to farmers and, eventually, water management system to water distribution organisations that the project aims to achieve. Chapter 8 details two initial business model canvases, one for SWAMP precision irrigation systems and one for SWAMP water distribution systems. The final chapter summarises our findings.

2. SWAMP approach

The SWAMP approach is described in Project Plan and deliverable D1.1. Initial SWAMP architecture. The core idea is to create a platform (SWAMP platform) that allows the collection of data from various sources and storage of the data. For precision irrigation purposes, the platform provides analysis services for the water need of the crop, services for planning the irrigation, execution of irrigation, and interaction with farmers through Internet. For the water distribution purposes, the platform creates a link between farmers' water need, the status of water distribution system, and water distribution capabilities. The main elements are illustrated in Figure 1.

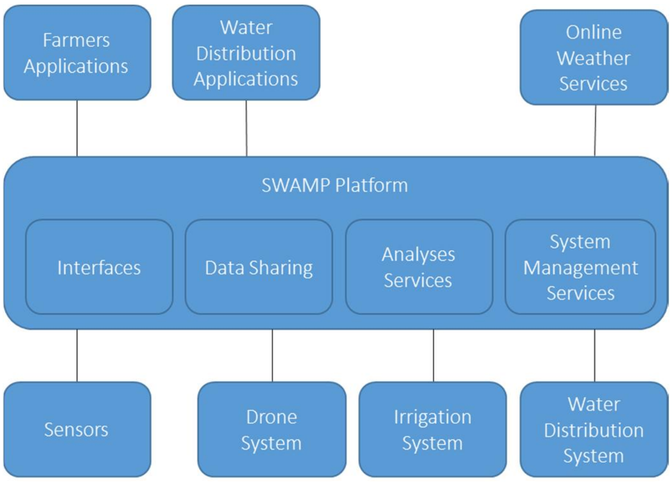

FIGURE 1. SWAMP PLATFORM, APPLICATIONS AND CONNECTED SYSTEMS.

The SWAMP platform offers the basic capabilities needed in final system, but the system installing and deployment actually defines how the final system will look like. The platform part consists of:

- Communication interfaces and solutions for developing communication infrastructure
- Databases and supporting functions of data sharing. Data presentation and sharing are based on a common information model (CIM) of SWAMP. Common model is an extension of subsets of standardized ontology models of IOT (e.g., W3C SSN) and farming (e.g., FAO AGROVOC).
- Basic analytic services for water need estimation and water distribution system analyses.
- Basic services for management such as installation and setup support, interaction with irrigation systems and interaction with water distribution system.

Sensors are the sources of data. The SWAMP does not specify the sensors or sensor type at all. There can be any type of sensors related to soil, weather, plant, environment, and irrigation system monitoring as long as they can be connected to the platform communication systems.

The drone system is an external system that has several purposes and SWAMP platform has support for some features. The drone can carry a mobile gateway that can read sensor nodes with short-range radios such as RFID and Bluetooth. The gateway can communicate directly to the SWAMP platform. The drone can also act as a sensor platform and execute missions with different imaging devices (i.e. hyperspectral camera) that can be connected to mobile gateway too.

Irrigation system in SWAMP is defined to contain the water distribution network from a farmer's water reservoir to the field. In SWAMP pilots there are sprinkler, drip, and central-pivot irrigation systems enhanced with variable-rate irrigation solutions. A typical system consists of pumps, valves, pipelines, filters, and actual irrigation devices. The SWAMP platform will provide control for automation of operation of irrigation system elements.

Farmer application is the interface for Farmer to use SWAMP precision irrigation system. The application itself can be implemented as a web interface to the system. Main functions are monitoring of status, execution of analyses, and control of irrigation.

Water distribution system is defined in SWAMP as an external distribution system that provides water for farmers such as open canal system in Italian pilot. The objective of water distribution optimisation is to minimise the loss of water in the situations that multiple user's request water and distribution system operation needs to be shared.

Water distribution application is water distribution system operator's interface to SWAMP platform.

The system setup and maintenance will be implemented using web interface to access the deployment and management services defined in deliverable D1.3.

Online weather services provide weather forecast information for the irrigation planning service.

The types of physical elements or objects of the SWAMP approach are shown in Figure 2. Their actual type depends on where and what are deployed at the farms and water distribution systems. Sensor node elements do the sensing and measurement tasks. It also includes the possible local weather station. Actuator nodes are the valves, pumps, and gates. Drones can be used to carry sensors and gateways on top of the field. Communication infrastructure consists of local and mobile gateways. Computational elements are fog and cloud servers (and services inside them). Online weather service (i.e. the interface to cloud service) is needed to access the weather forecast. Browsers provide interaction with end users and system managers. A local power unit is needed for powering devices outside the electrical network (i.e. on the field).

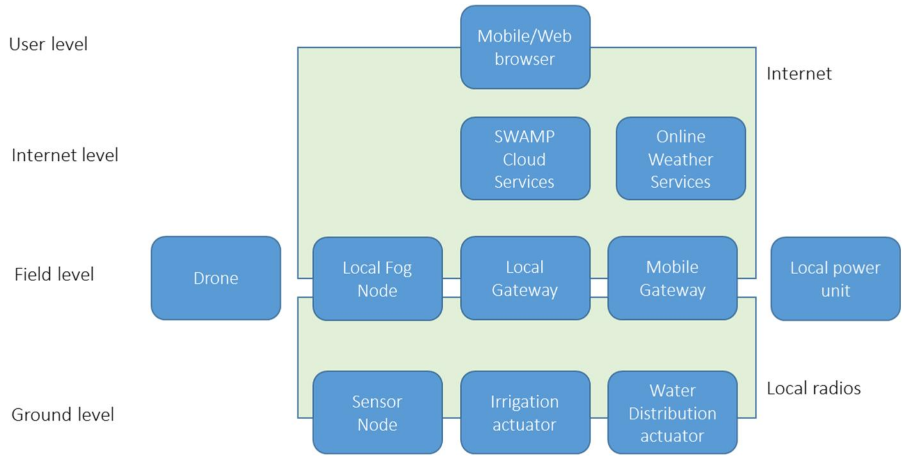

FIGURE 2. IMPLEMENTATION ELEMENTS OF SWAMP SYSTEM

The actual devices (or initial ideas of actual devices) are described in deliverable D5.1 Pilot Specifications. Different pilots have different compositions of devices depending on the irrigation systems, crops, and piloting purposes.

2.1. SWAMP based system for precision irrigation

SWAMP is piloting precision irrigation systems in all four pilots in Spain (Cartagena), Italy (Reggio Emilia), and Brazil (Guaspari and MATOPIBA). The value propositions of pilots are different. Each irrigation system shares the main principles of SWAMP platform but there are also differences in the type of irrigation devices and required irrigation planning, monitoring systems, analysing of water need, crops, and on the aim of applying precision irrigation. The key characteristics of irrigation pilots are described in the following table.

TABLE 1. MAIN FEATURES OF SWAMP PILOTS.

Feature	Cartagena	Emilia Romagna	Guaspari	MATOPIBA
Field and crop	Less than 1 ha. Baby leaf spinach and lettuce	3 pilot farms: Pear, drip irrigation=about 4ha Grapevine, drip irrigation = 3ha Grapevine, sprinkler irrigation= about 10ha	Grapevine, 1,1 ha Drip irrigation	100 ha, soya beans, corn, cotton
Monitoring system	Soil parameters with RFID and BT (+Drone reader) and Lora sensors developed by VTT, commercial Libellium soil sensors. 4G.	Multispectral camera carried by drone, soil sensors with LoRa communication.	Soil probes developed by EMBRAPA, equipped with LoRaWAN communication features	Soil probes developed by EMBRAPA, equipped with LoRaWAN communication features
Water need analysis	Water potential based soil moisture	Multispectral image based analysis and crop-based water need estimation.	Water potential based soil moisture	Water potential based soil moisture
Weather status	Libellium weather station and online weather service (tbd.)	Meteorological analysis ERG5 grid of Emilia-Romagna, developed by Arpae-SIMC. Cell 01015 - S. Michele (coordinates: 44.7675, 10.7097775)	Farmer/SWAMP local weather station and online weather service (INMET – Brazilian National Institute of Meteorology)	Farmer/SWAMP local weather station and online weather service (INMET – Brazilian National Institute of Meteorology)
Irrigation system target	Sprinkler and drip irrigation (semi-automated, automated)	Sprinkler irrigation and drip irrigation	Drip irrigation	Variable central pivot irrigation
Irrigation plan	Shallow root depth irrigation (0-15cm). Irrigation schedule based on plant status.	Irrigation scheduling according to availability of water in the canals.	Plot based irrigation schedule. Root system depth 20-40 cm.	Management zone based irrigation schedule. Root system depth 20-60 cm.
Pilot's main purpose	Saving water in extreme water scarcity situation	Saving water and providing information to water management consortium.	Improving the quality of crop at vineyard	Saving energy

2.2. SWAMP based system for water distribution management

2.2.1. Large area water management (Emilia Romagna pilot)

The case of an extensive area water management is represented in the project by the Italian case study, where the Consorzio di Bonifica Emilia Centrale (CBEC) is a reclamation consortium responsible for the irrigation and water drainage in an area larger than 3.000 km^2. The water required for irrigation is withdrawn from the Po-river and then distributed to the farms by an intricate irrigation infrastructure composed of canals, small streams, draining plants, and pump stations.

The pilot district covers in total an area of about 892 ha, 320 ha of which are irrigated during the summer season. The CBEC consortium manages the water deliveries throughout a hydraulic network of almost 14 km that includes both open canals and free-flow pipes, allocating the water to 63 farmers in relation to their requirements. The hydraulic network reaching the farmers in the district is made of canals and pipes connected each other by means of sluice gates that need to be managed by operators of the CBEC. Up to now, the water allocation system is essentially based on the farmer's initiative and acts following a direct interaction with CBEC: farmers contact the CBEC via a call centre or web and communicate irrigation requirements. CBEC processes these requests based on its experience and supply water to farms.

The SWAMP project aims at enhancing the overall system efficiency by acting at farmers and irrigation consortium levels. Concerning the latter, management of the irrigation network, the SWAMP platform will optimize the management of multiple water requests, enabling also the monitoring, automation, and remote control of the major hydraulic infrastructures. The system could allow farmers' intervention in the automation loop. Farmers would be still able to communicate their water requirements (I.e., that could be used for the fine tuning of the system model parameters), but they will also benefit of alerts and advice on the scheduling of water.

2.2.2. Farm level water management

Cartagena pilot:

Cartagena pilot characteristics:

- water from own reservoir
- water distribution infrastructure built from scratch for every growing period
- Infrastructure consists of
    - water intake
    - water level sensors in reservoir
    - pump (with remote control (On/Off) and status indication)
    - water pressure sensor in the main pipeline
    - filtering
    - pipelines
    - valves (with remote control and status indication)
    - water meter (remote reading)
- basic topology is a tree where each branch is separated by a valve

SWAMP contributions to Cartagena system:

- remote monitoring of system status (pump state, valve positions)
- remote reading of amount of water used for irrigation
- remote configuration of topology (adjustment of positions of valves)
- remote control of pump (on/off)

The long-term goal is to automate the remote operations with advanced features of SWAMP platform (i.e. automation of irrigation plan or irrigation recipe execution).

Emilia Romagna pilot:

Emilia Romagna pilot characteristics:

- water is allocated to the field by pipes or canals managed by the CBEC
- water distribution varies from farmers (drip irrigation or above-canopy sprinkler)
- Infrastructure consists of
  - water intake
  - pump (portable by the farmers)
  - water pressure sensor in the main pipeline
  - filtering
  - pipelines
  - valves
  - water meter (remote reading)

SWAMP contributions to Emilia Romagna system:

- remote monitoring of soil properties (water content, temperature and electrical
- conductivity) to refine irrigation/fertigation automation
- remote monitoring of system status (water level into channels, gates opening)
- remote reading of amount of water used for irrigation
- the availability of water is more guaranteed in difficult conditions, and the cost of water at the end is cheaper as losses in distribution network are reduced.

Guaspari pilot:

Guaspari pilot characteristics:

- natural pond as water source
- permanent water distribution infrastructure
- Infrastructure consists of
  - water intake
  - water level sensors in reservoir
  - pumping system (with local computer automated control and status indication)
  - water pressure sensor in the main and secondary pipelines
  - filtering
  - pipelines
  - fertilizer injection (fertigation)
  - valves (with local computer control and status indication)
  - water flow meters (local readings)
- water distributed by shifts (set of plots), one valve per shift

SWAMP contributions to Guaspari system (the aims for whole project):

- remote monitoring of soil properties (water content, temperature and electrical conductivity) to refine irrigation/fertigation automation
- remote monitoring of system status (pump state, valve positions)
- remote reading of amount of water used for irrigation
- refined configuration of shifts (reduced number of plots per shift)
- remote control of pump and valves

The long-term goal is to improve local automation and implement remote control operations with advanced features of SWAMP platform (i.e., refined automation of irrigation/fertigation plan).

MATOPIBA pilot:

MATOPIBA pilot characteristics:

- artificial pond as water source
- permanent water distribution infrastructure (Central pivot)
- Infrastructure consists of
    - water intake
    - pumping system (with connection to the central pivot controller)
    - filtering
    - pipeline
    - fertilizer injection (fertigation)

SWAMP contributions to MATOPIBA system (the aims for whole project):

- remote mapping soil properties (water content, temperature and electrical conductivity) to provide dynamic prescription irrigation/fertigation maps
- implementation of variable rate irrigation (VRI) system (commercial solution)
- remote monitoring of system status (pump state, pivot position, VRI valves status)
- remote reading of amount of water used for irrigation
- estimation of electrical energy usage

The long-term goal is to implement a fully automated remote-controlled variable irrigation system with advanced features of SWAMP platform (i.e. generation and execution of dynamic irrigation prescription maps).

3. Benefits of SWAMP approach

3.1. Benefits for farmers

The SWAMP project will aim to enhance the overall irrigation system efficiency. This will ensure a better estimation of water needs regarding the amount of water, time of delivery, and place of delivery. This will be achieved by the implementation of the IoT infrastructure that enables the integration of ground-based information (e.g., soil moisture, temperature, crops conditions, and the like.) with plant and crop information and weather forecast.

Depending on the farmers' goals, different benefits can be obtained from the SWAMP platform. For SWAMP, pilots have slightly different goals and expected benefits:

- Intercrop pilot: Intercrop deals with water scarcity so that saving water is essential for business continuity
- Emilia Romagna pilot: The focus is saving water and energy at farm scale, but also providing information for water distribution of the larger area having more than 5000 farms that consume the water from the same source.
- MATOPIBA pilot: in that region that cost of energy represents a high percentage of the total cost so that decreasing irrigation will decrease the expenses.
- Guaspari pilot: as a winery focused on premium wines, improving quality by precision irrigation is the key goal

Generic benefits for the farmers using SWAMP platform and irrigation system are expected to be following:

- More accurate information related to soil and crop conditions delivered via a web interface.
- Normally, the farmer's decisions tend to be guided by the experience gained on the field so, at times, they do not respond readily to the dramatic climatic variability due to climate change. As a result, in those cases the irrigation regime adopted by the farmer is no longer consistent with the current climate conditions, thus the irrigation advice provided by the SWAMP platform can be a support to address this issue.
- Support for irrigation. At first phase, the system gives instructions for the farmer and how and when irrigation should be done. At the second phase, the system can perform the irrigation automatically (or remotely controlled).
- Adjusting the irrigation guideline to irrigation system, soil properties related to water flow and soil moisture, plant growth stage, weather and environmental conditions, weather forecasts, and water need of the crop will:
    - improve yield through a more optimal growth of plants
    - save water by optimizing the amount water needed by crop
    - save energy be recusing the amount of pumping water
    - decrease unwanted environmental effects by limiting the water flows to outside from filed as water is consumed by crop

3.2. Benefits for water distribution organisations

In case of vast water distribution network managed by central authorities that serves many farms, such as CBEC, the management of the irrigation network will benefit of the optimization of multiple water requests ensured by the technological platform. The SWAMP platform will estimate, and process, water needs of different farms based on field sensors, drone surveys and weather forecasts, adjusting the operational management of the canals network. The scheduling for water allocation will be optimized considering the multiple requirements from farms served by the same irrigation infrastructure, as well as the real condition of the water distribution network monitored in real time (gates status and canal filling). The SWAMP platform will also enable the monitoring, automation and remote control of the principal hydraulic infrastructures, through which the CBEC manages the water distribution within the irrigation district. The renovation of the hydraulic infrastructures (through sensors and automatic devices) together with the implementation of the IoT platform and data analytics scheme will enable a consistent enhancement on the water distribution management that will persist even after the project life.

The infrastructure innovation ensured by the project will certainly improve the degree of knowledge of the irrigation district, for example enabling an accurate monitoring of water allocated to the district or expanding the network management possibilities (e.g., remote control of major gates).

In particular, the benefits for water distribution organizations expected from the project can be considered distinguishing the operational and the water/cost saving point of view.

From the operational point of view:

- Direct interaction with farmers through the SWAMP application
- Efficient management of farmer's requirements through the SWAMP application
- Possibility to record and manage all the data concerning operations in the field (e.g., opening and closing gates for post-processing evaluations, water levels in the canals)
- Real-time and remote control of all water requirements from a given irrigation district by the CBEC operators
- Lower manual operations carried out by operators due to remote control solutions (the level of automation reached in the district will depend on the number and spatial coverage of the automatic actuators).

SWAMP contributions to Emilia Romagna system:

- Efficient water network management based on an appropriate planning of the irrigation scheduling
- Reduction of water wastage and water losses due to infiltration.
- Reduction of energy costs for water pumping.

4. SWAMP platform's value proposition for system

A fundamental idea in SWAMP is to facilitate the replication of water management systems built on top of its platform with minimum redesign and redevelopment. Different layers of the architecture have components that are more generic and thus less difficult to be ported to other pilots, whereas others are more application-specific and thus require new development efforts whenever a new pilot is conceived. The same underlying SWAMP platform can be customized to different pilots considering different countries, climate, soil, and crops.

4.1. SWAMP System Developers

SWAMP identifies two different categories of system developers that may benefit from the SWAMP platform (SWAMP Deliverable D6.6 [1]). When it comes to the value of the SWAMP platforms for developers, both categories should be considered, and their differences should be correctly put into the right perspective.

<u>Developers of IoT Systems</u>: The key contribution of the SWAMP project is the platform for smart water management, particularly for precision irrigation in agriculture. The same underlying SWAMP platform can be customized to different pilots considering different countries, climate, soil, and crops. The SWAMP architecture may be implemented in a range of deployment configurations involving the use of smart algorithms and analytics in the cloud, fog-based smart decisions located on the farm premises and possibly mobile fog nodes acting in the field (e.g., in drones or in the central pivot irrigation mechanisms). Given that the TRL level of the SWAMP platform at the end of the project will lie between 6 and 7, it becomes clear that further advancement is needed for it to be ready for the market. Therefore, there will be plenty of room for developers of IoT systems to exploit the SWAMP platform.

<u>Developers of IoT Platforms</u>: The widespread availability of IoT-based applications requires adequate platforms for both development and operation phases. The former for releasing developers from the need of mastering different technologies outside their core business and that do not add value to the process. The latter for freeing organizations from the need of deploying and testing customized platforms for supporting the operation of IoT-based applications. There are some IoT platforms available today, both open source and proprietary. Remarkably, FIWARE has been attracting general attention for being a worldwide open source solution fostered and funded by the European Commission under Horizon 2020 program. It is comprised of a series of software components called Generic Enablers (GE) that perform functions needed in a different variety of IOT-based applications for smart societies, focusing in cities, farming, industry, healthcare and sustainability. As the SWAMP platform is based on FIWARE IOT Platform, the availability of the SWAMP Platform itself will result in a new exploitation opportunity for the FIWARE community. Another IoT-enabled platform integrated into the SWAMP platform by its members is SEPA, a SPARQL Event Processing Architecture able to deal with linked data [2].

4.2. Adaptability and Replicability

The SWAMP architecture considers three types of services to ensure its replicability and adaptability to different crops and locations. Entirely replicable services deal with IoT services, virtual entities and storage services, and data analytics and machine learning, respectively. Fully customizable services deal with water data management issues that specialize generic analytic services into specific techniques for different types of irrigation and water distribution. Those services may require being customized whenever a new pilot is designed, developed and deployed. Finally, application specific services require higher development effort since they serve specific farms. The architecture may be implemented in a range of deployment configurations involving the use of smart algorithms and analytics in the cloud, fog-based smart decisions located on the farm premises and possibly mobile fog nodes acting in the field (e.g., drones or in the central pivot irrigation mechanisms).

The design of the SWAMP architecture is influenced by the concept of system commonalities and variability, borrowed from software product lines, which makes it easy to replicate software components in different settings. A commonality is a property shared by all applications of the product line - e.g., collecting sensor data, using drones, sending actuator commands, storing and processing vast amounts of data and using agriculture models and smart algorithms to generate an irrigation prescription map. Variability is when applications differ such as regarding the type and role of sensors, types of crops and soils that require different agriculture expertise, different model parameters and maybe different computational intelligence techniques.

4.3. Interoperability

A software platform for IOT-based smart agriculture applications, such as SWAMP, must face the complexity at multiple levels, involving the whole cycle of information: Genesis, communication, storage, processing, knowledge generation and changing behaviour. A huge amount of raw data comes from different hardware devices (sensors), is transmitted via wireless communication technologies, stored in databases of different kinds (SQL, NoSQL), processed by different distributed processing frameworks (Hadoop, Spark, etc.), transformed into useful information and knowledge by smart algorithms (machine learning, deep learning) and finally is send back to devices (actuators) to automatically change the state and behaviour of the system (the irrigation prescription). All these phases are implemented by different pieces of hardware and software components that must interoperate in order to achieve the final goal.

At the information level, interoperability could be provided by ontologies. This would allow developers to understand the information model and develop their own applications and services. SWAMP will provide a common information model based on a set of standard ontologies that could be extended based on the developer's needs. In the first instance, this set will include the W3C Semantic Sensor Network ontology to model the IoT part and the AGROVOC ontology by FAO as the reference for the agricultural part. From the communication point of view, the use of web API (e.g., HTTP, WebSocket) would facilitate the interaction with the SWAMP platform.

4.4. Data fusion and analysis services

SWAMP will provide soil moisture distribution forecasts and water need estimations based on the data gathered by several sources (e.g., soil model, crop type, NDVI, weather forecasts, real-time soil moisture).

The platform has two approaches for the analysis of soil moisture distribution that is essential in irrigation planning. The methods are soil moisture measurement-based approach and soil type analysis-based approach. First approach is based on the use of frequent soil probe measurements and it is applicable in situations where soil does not keep the water, irrigation is needed frequently, and irrigation can be controlled with bigger accuracy. The second approach is based on the simulation of water flows in the soil. It is applicable in situation where soil can be used as water storage and irrigation is less frequent.

Estimations of crops' water need is supported in the platform with analysis of multispectral images taken by the drone system. The analysis creates a NDVI images and calculates Leaf Area Index. They can be used for understanding the water stress of plants and for adjusting the evapotranspiration forecasts also done by platform.

The developed models can be reused and extended by external data fusion services.

4.5. Extendibility

The extendibility of a system depends on multiple factors, which include the openness, novelty, innovativeness, performance and dependability of the technologies, as well as its level of dissemination and acceptance by the developer community. To encourage extendibility of the SWAMP Platform, we have based it on FIWARE that is a state-of-the-art IOT platform technology.

The FIWARE platform (fiware.org) is attracting general attention for being a worldwide open source solution fostered and funded by the European Commission under Horizon 2020 program. It consists of a series of software components called Generic Enablers (GE) that perform functions needed in a different variety of IOT-based applications for smart societies, focusing in cities, farming, industry, healthcare and sustainability.

GEs can be used to build different applications that exchange information through a REST API following the OMA NGSI standard (openmobilealliance.org/release/NGSI), based on JSON. The central aspect of the FIWARE NGSI Context Management information model is the concept of entities and their attributes.

4.6. Openness

SWAMP actively engages in promoting and supporting collaboration at an international level both intra-project (i.e., among its members) and inter-project (with different partners from different nationalities). Moreover, this challenge of promoting collaboration may be dealt with by firmly relying on open solutions. A real open research ecosystem must be pursued, based on multiple levels of openness, such as a) open source software; b) open data; c) open access; d) open innovation; e) open prototypes; f) open experiences; g) open experiments. Whereas some of these levels of openness are widely known, others are still in development. The key challenge here is how to promote such an open research ecosystem where openness is a pervasive value and stimulates collaboration. Everything should be considered open by design, except for some specific cases such as privacy or intellectual property management [3].

Examples of openness that foster collaboration in SWAMP are listed in the sequence. SWAMP data could be provided as Linked Open Data (LOD). This would allow SWAMP data to be exploited by the LOD community. The SWAMP platform is also open to what concerns the introduction of new data sources or services. Where it applies, sources code of the services can be released as open source through a source sharing platform like GitHub or GitLab. This would be the case for example of the services and apps developed on top of SEPA (SPARQL Event Processing Architecture). SEPA is going to be used for sharing SWAMP data as Dynamic Linked Data (DLD), as well as a reference architecture for the implementation of the Italian pilot and relative services.

4.7. Development possibilities related to platforms

Sophisticated platforms, such as SWAMP, that deal with huge amounts of data coming from sensors generated by IOT-based applications are perfect candidates for business exploitation in different business cases, leveraging from the openness perspective:

- Open Source (code sharing): The platform maybe be freely shared as open source and business can be developed as consultancy services
- Open Platform (platform sharing): In this case, the platform is also offered as a service (Platform as a Service), for organizations who do not want to deal with system operation.
- Open Data (data sharing): data can be provided as a service under a certain fee for consumers with interest in them. In other words, raw data becomes an important asset in the business case, where users connect to the platform and consume data.
- Open Knowledge (knowledge sharing): Build upon the open data business case, in this open knowledge business case the provider can share not only raw data, but also knowledge generated by smart algorithms based on computational intelligence techniques (e.g. machine learning). As far as SWAMP is concerned, this means sharing models and results in the form of irrigation prescription maps.

5. Drone System value proposition for systems

SWAMP drone is a modular, open-source and easy-to-use drone compatible with different types of payload.

Its weight, under 5kg, makes it easy to transport and safe to use. There is no need to have advanced piloting skills or certificates in order to be able to operate a SWAMP drone in most countries and places. And its reduced size and weight make it easy to manoeuvre, being able to operate on reduced spaces. SWAMP drone can also land and take-off from small areas. Which can be very helpful in locations where the ground is very wet or difficult to access.

Its open-source flight controller makes it very easy for developers to integrate with their own technology. SWAMP drone carries a Pixhawk as the FC. Pixhawk is the most popular open-source project for drone flight control. The drone system also carries a Raspberry-PI for the communication gateway, a highly popular module which has become a worldwide standard for open-source embedded development of all types of IoT products.

Thanks to this open-source approach, SWAMP drone can also be controlled using the most popular Ground Control Stations, for example with Taranis or Futaba radio transmitters. And it is also compatible with the main software applications for mission design and control, such as Mission Planner or Q Ground Control, among many others.

The location of the battery in the drone frame, together with the elongated design of the payload mount and the location of such payload, facilitates the usage of different types of cameras and sensors, accepting different weight and size combinations. This is a huge advantage compared to commercial drones currently available. And ensures a proper weight balance during the flight.

SWAMP drone design is minimalistic and modular, which means that it is very fast and affordable to maintain, and any component can be easily replaced if needed. As many components as possible (such as the FC, the rotors, ESCs or propellers) are standard, to make sure that their spare parts and replacements are accessible in most regions of the world and that the drone cost is competitive.

Besides that, SWAMP drone has been designed to optimize flight time, and it has battery technology beyond the state of the art, with the goal to reach flight times beyond 30 minutes. This would be of extremely high value for service providers and end-users, because it multiplies productivity, compared with current alternatives.

5.1. Light-weight infrastructure at the field and water management area

Monitoring infrastructure is a big cost for farmers and water management operators. The communication part is the reason for most of the costs. The value proposition of using drones in this aspect is that it reduces the complexity of needed communication. Sensors can be equipped with very low cost, short range radios reducing their cost and maintenance need. Several gateways that needed in various parts of the farm or water distribution area may also be replaced with mobile gateway carried by the drone.

It must be admitted that with current drone technology and regulations, the economic benefits of using drones as data collectors are not easy to achieve. It is possible if same drones and flying missions can be used for collecting other data as well. Having imaging solutions as sensors create information that is very difficult to get otherwise. The alternative used today is to take multi-spectral images from satellites. They have limitations related to flight routes, accuracy of the images (as they are taken from far away), effects of clouds and other weather conditions, etc. With drones these possible problems can be avoided.

5.2. Automated operations at the field

The main obstacle for using drones in agriculture today especially in precision irrigation domain, is the need to have expert pilot for the drones. At same time, there are several examples of vision and proof of concepts related to autonomous flying. Amazon has published and demonstrated a vision of automatic packet delivery with autonomous drones. Automatic and semi-automatic drones are used in military missions. Demonstrations of synchronous flight operations of drone swarms up to hundreds of drones have been seen.

Totally autonomously operating drone with a possibility to execute different missions with different types of payloads is not yet reality, but it is approaching rapidly. Automatic charging, changing payload with help of robotized environment, AI controlled mission planning taking weather conditions into account are all tasks that could be done already, if enough effort would be put into integration.

6. Farmer Application

6.1. Objectives and Benefits

The objective of the application is to materialize the benefits of the SWAMP platform to the farmer. Through the application, farmers will gain real-time knowledge of their farms' water-related status, including soil moisture, precipitation forecast, and water usage. Past data will also be presented, helping the farmer visualize the evolution of the fields and contributing to his/her decision-making process.

The application will access the platform intelligence and present the water needs and other estimates for the fields. It will also present the irrigation plan computed according to the farmer's objectives, for example, saving water. The farmer will have the final word on the irrigation plan, though. Once satisfied with the plan, the farmer will be able to apply it with a simple push of a button. The application will support automated irrigation through services in the platform. The irrigation process will be monitored and displayed in real-time, along with water consumption statistics.

The application will be developed for mobile platforms, allowing the farmer to monitor and manage the fields in loco or on the go. It will also connect with other important components of the SWAMP platform. This will allow the farmer to send water demands to distribution consortia, as in the Italian pilot, and request drone flights over specific fields.

6.2. Key functionalities

6.2.1. Setup

Application setup takes care of data entry necessary for the platform to deliver value to the user. A Web-based application is the preferred environment for these features, and it facilitates the input of text fields and other static information, although some support is also expected in mobile versions (suitable, for instance, to capture and input location data). Setup features are divided into three major groups:

- Farm properties: where the farmer describes the property, its plots (including, e.g., soil type, geographic and climatic properties, crop types and characteristics), and management zones;
- Irrigation system: here the irrigation areas and corresponding systems (drip, central pivot, etc.) are described to the platform, including actuators (e.g., smart valves and sprinkles, etc.) if it's the case;
- Monitoring system: probes and sensors (soil, weather) are configured here, including geolocation and communication settings.

The setup process is described in more detail in deliverable D1.3 Deployment and Management Services and they will be implemented as services that are accessed via Web Browser.

6.2.2. Monitoring

Monitoring features allow the farmer to have a continuous, up-to-date understanding of his/her property's water and crop status. The data will be presented using maps with layered information (e.g., soil moisture), charts (time series, bar charts, etc.), tables and other appropriate presentation techniques. Monitoring will be preferably accessed from a Web or Mobile-based environment. The following measurements and metrics might be available to the farmer, among others:

- Soil moisture;
- Precipitation;
- Evapotranspiration;
- NDVI and LAI;
- Irrigation history.

6.2.3. Analyses

From the data collected in the field, it will be possible to provide the farmer with richer information to facilitate decision making. With estimation and prediction models of the platform, the following metrics will be available to the farmer, both instantaneous and historical:

- Forecast of the fields soil moisture and irrigation need;
- Plant water stress and need (from NDVI, evapotranspiration and soil moisture);
- Water supply needs (amount of water to be request from the distribution network);
- Crop productivity and quality analysis (based on water status).

6.2.4. Irrigation guidelines

From the collected data and analysis, application might provide guidelines for the irrigation of individual plots or management zones. The guidelines will consider precipitation forecast as well as characteristics of the irrigation system. In this case, it will be up to the farmer to decide on using (or adjusting) the guidelines and applying them in the field. For the SWAMP platform to improve its models, it is important that the farmers inform the application on the actual amount of water used.

6.2.5. Automatic irrigation

Once irrigation guidelines are computed, automated irrigation features can be used to leverage the installed infrastructure and make the whole process end-to-end. However, the farmer will retain the ability to fine-tune and even completely override the automated irrigation system with his/her own prescriptions. Among other features, the application should allow the farmer to:

- Enable or disable automatic irrigation (per plot or whole farm);
- Adjust existing or insert new irrigation prescriptions;
- Trigger irrigation immediately (one-click irrigation);
- Schedule irrigation events;
- Visualize irrigation history

6.3. Development roadmap

6.3.1. Environments

Farmer applications will rely on back-end services running on the SWAMP platform. These services will provide the application with monitoring, analytics and prescription data. The applications will be responsible for presenting the data to the users (farmers) and capturing their input and commands. The three main environments the applications are expected to run are:

- Dashboard (via Browser): IoT platforms (such as FIWARE) offer simple mechanisms to present monitoring data using graphs and charts over a web interface. This kind of environment can be used for quick development and prototyping. Final versions (i.e., released to farmers) are not expected to use this type of environment.
- Web (via Browser): dynamic Web applications can be deployed in the SWAMP or 3rd-party Clouds, allowing for global access from virtually all kinds of devices. Web-based applications are suitable for data entry and allow for the visualization of more information in the screen. Web applications, however, require continuous access to the internet, something that must be considered in the case of farms, which very often have unreliable connectivity.
- Mobile (Smartphones, Tablets): given the ubiquity of mobile devices and their practicality, farmers will expect SWAMP applications to be available in this environment. Initially, the responsive (i.e., screen-size aware) web-based applications can be accessed and used from mobile devices, however the experience is not as smooth as with native applications. Native mobile applications should be

implemented for less data-entry intensive features (monitoring, analytics, recommendations and automatic irrigation).

6.3.2. Development phases

The SWAMP project schedule specifies three major milestones for the application development: a prototype (M18), the application(s) deliverable (M24) and an update (M30). These milestones were used as reference for the development process, with the features expected to be covered at each stage, as describe below:

- M18 (D4.2 Prototype): Focus on monitoring functionalities for displaying data from probes in the fields. Target environments will be Dashboard, for UI experimentation, with final UI specification of the mobile application in parallel.
- M24 (D4.2 Deliverable): First version of the mobile application (Farmer App), providing Water Need and Irrigation Planning functionalities to the farmer.
- M30 (D4.2 Update): The last iteration will focus on improving analytics and irrigation recommendation functionalities, as well as implementing automatic irrigation features.

Intermediate deliverable D4.2 Farmer Application at M18 describes the use cases, user interfaces and main functionalities of farmer application to be implemented as mobile application. The functionalities will be based on SWAMP platform services related IoT platform, i.e IoT agents, Orion and QuantumLeap (and their databases Mongo and Crate), and to water need estimation services specified in deliverable D3.1 Water Need Estimation, and irrigation planning services specified in deliverable D3.2 Optimization for water irrigation. The final application will be developed for the Android platform.

7. Water Distributor Application

7.1. Objectives and guidelines

Regarding the water distributor perspective, the application of the SWAMP platform will enable to:

- Simplify the water delivery to multiple farmers served by the same distribution network, especially in the case of water scarcity.
- Enhance the fairness of the water distribution: the water allocation among farmers will be defined on scientific bases (i.e., water needs estimation with sensors, weather forecasts, and the like.) and not exclusively based on farmers requests. This objective is expected to assume higher relevance moving towards future scenarios of water scarcity.
- Reduce water wastage due to no optimized water allocation solutions. The scheduling of the incoming water requirements will be settled minimizing hydraulic network functional costs (such as: water losses due to infiltration and evaporation, water losses due to filling/emptying of canals, number of operations of the gatekeeper) and maximizing the system efficiency (perhaps in terms of number of customers and volume of water supplied to farmers).
- Cost and energy saving due to optimal water usage.

The objective of the project is to test the functionality of the SWAMP platform in the management of the irrigation network when this is shared by multiple farmers and managed by a third, external, authority. The CBEC pilot represents a testbed that is representative of a large agricultural area in Northern Italy (almost the overall Po valley, nearly 46 000 km^2). The positive outcomes expected from the SWAMP project might stimulate the spread of IOT based solutions and of the SWAMP platform in similar contexts.

7.2. Key functionalities

Key functionalities for water distributor application are:

- Setup of farms' features required by the platform for the optimization process. This phase will take advantage of the Web-based application set up for the irrigation purposes (see Chapter 7), collecting additional elements that identify the location of the fields and the characteristics of the river network serving the farmer.
- Real-time and remote monitoring of the river network (i.e., water level measurements within the channels, sluice gates conditions, river discharge distributed through main gates).
- Analysis and irrigation scheduling: the system will provide the water distributor manager with the optimized irrigation scheduling, driving the operator (or actuators) to the required operations for the water delivery.

7.3. Roadmap

The project specifies three major milestones for the development of such application:

- M18 (D4.3 Prototype): setup and Monitoring are expected to be mostly ready at this point.
- M24 (D4.3 Deliverable): at this stage irrigation scheduling functionalities based on water need estimations should be ready.
- M30 (D4.2 Update): the last development will focus on improving analytics and irrigation scheduling functionalities. Final versions of Web-based and Mobile applications are expected to be able to manage eventual actuators available in the district.

Intermediate deliverable D4.3 Water Distributor Application at M18 describes the use cases, user interfaces and main functionalities of water distribution application.

The functionalities will be based on SWAMP platform services related IoT platform, i.e, IoT agents, Orion and QuantumLeap (and their databases Mongo and Crate), and water distribution optimisation services to be specified in deliverable D3.3 Water Distribution Service. However, the data source and backend of this application will be SEPA that interacts with SWAMP platform services.

Final application will be developed using SEPA application development process. It will be a Web Application based on HTML and JS. It will a responsible application that runs on various platforms such PC, Laptop, Apple and Android phones. Final decision on actual JS platform has not yet been done, but it is likely to be Bootstrap.

8. Initial business models

The SWAMP project aims to develop the SWAMP approach at the level that can be tested on real-life pilots. This means technology readiness level 7 (TRL7) at the end of the project. Therefore, we will not have a final product at the end. Some essential elements will be missing, and the planning has been restricted to the needs of SWAMP pilots.

The objective of this chapter is to draft initial business models (using the business model canvas method) both for precision irrigation system and water distribution system based on SWAMP platform. In both cases, the actual deployments or SWAMP platform and approach depend on the environment and purpose of the system. As can be seen from the pilots in the project, the uses and details of implemented systems vary from each other. The business models described below are therefore generic and, in some sense, also simplified. In real business planning, the details of each actual use should be taken thoroughly account.

The value of these business models is that they force the project to think the needs of exploitation and business in the definition of both platform characteristics and system instantiation. The initial business models will highlight what will be needed in the final phases of commercialisation, what are the stakeholders that need to be considered, and what the technical and economical frameworks are where SWAMP must operate.

8.1. Business model canvas for SWAMP precision irrigation system

There are several options on how SWAMP irrigation solution could be brought to the market. This canvas presents generic elements. The SWAMP irrigation system should be brought to the market via a company that has expertise on services for farmers.

Key activities

- Automated or semi-automated irrigation where the amount of water and timing of irrigation depend on measured water need, weather forecasts, and knowledge of the plant and crop growth needs.
- Providing data of crop status and soil conditions to the farmer.

Key resources

- Field sensors, drone sensors, water sensors
- Communication infrastructure (gateways, base stations)
- Internet access
- Data storage and analytics services in SWAMP cloud
- Plant database, agriculture knowledge
- Weather forecast service
- Drone system and payload management
- Irrigation infrastructure remotely controlled (via the Internet)
- Web application
- Web browser
- Irrigation water

Key partners

- Weather forecast service provider
- Plant/crop growth knowledge provider
- Mobile and/or IOT operator
- Web host

Value propositions

- Better yield with less cost

- Higher quality of crop due to managed growth environment
- Saving of water, energy, and environment
- Less work effort needed
- Support to risk management and to react (adapt) to climate change (based on knowledge and data)

Channels

- Basic system should be bought by farmer from expert shop. Installation could be service.
- Advanced analyses could be provided as Internet services
- Farming societies, public organisations could be used as distributors

Customer segments

- SWAMP irrigation solution is basically agnostic to what is irrigated, and how irrigation is implemented.
- Product and service to the mass market, but each deployment has to be tailored to particular farm.
- Farmers, farms

Customer relationships

- This type of system needs expert assistance both in clarifying needs, installation, and maintenance.

Cost structure

- Cost should depend on created value for farmers. The cost structure should have elements on both fixed cost (i.e. infrastructure) and variable cost (i.e. use of analytic services or maintenance).

Revenue stream

- Asset sale or renting combined with subscription or usage fees.

8.2. Business model canvas for SWAMP water distribution system

Key activities:

- Optimal scheduling of irrigation requests
- Operation planning: a temporal sequence of gate opening/closing for operators
- Real-time control of both, network (i.e., water levels and discharges) and infrastructures (i.e., gates) state.
- Direct and easy interaction with final users.

Key resources:

- Field, water level sensors and flow meters
- Weather forecast services
- Web connection
- Web applications
- Pc and Mobiles
- Actuators
- Energy for sensors and IOT solutions
- Water

Key partners:

- Service suppliers: weather forecast agency (e.g., ARPA-E)
- Agency operators
- Farmers

- Technical assistance for IoT solutions
- Web provider

Value propositions:

- Provide farmers with the correct amount of water and at the right time
- Provide farmers with the required information to monitor field condition
- Efficient tool for irrigation management: limited number of field operations, continuous monitoring of the network, efficient and fast communication tool with farmers.

Channels:

- ANBI (National Association of Italian Consortium)
- CBEC website
- IOT and Agri-food conferences (see details in Dissemination plan D6.1)

Customer segments:

- Water agencies managing irrigation network
- Large companies managing their own irrigation network with multiple requirements
- Small or large farms

Customer relationships:

- Project website

Cost structure:

- Actuators
- Pc/mobiles
- Operators
- Sensors

Revenue stream

- Income: annual contribution from farmers, lower costs for energy
- Costs: technological infrastructure maintenance, operators

9. Summary

This document describes the main features of SWAMP platforms and illustrates the possible irrigation and water distribution systems that can be built on top of the platform. The systems are based on the experiences gained so far from the SWAMP pilots in Emilia Romagna, Cartagena, MATOBIPA, and Guaspari.

We have tried to analyse and understand which benefits are achieved from using SWAMP results. Both farmers and water distribution organisations, that are two main groups of users identified in SWAMP, are considered. The value propositions of platform itself and system derived from it are considered. The application and value for end users are discussed. In addition, we have discussed the drone-based additions. Finally, we have created initial business models for both irrigation system and water distribution system.

The value of SWAMP platform comes through the systems and end user's experiences. The key issues in both are the quality of data collection infrastructure, the quality of analysis of water need of plants, and irrigation and/or water distribution planning. The planned saving of water and energy can only be achieved when everything is implemented with high quality.

SWAMP project cannot cover the whole area of agriculture and farming. The pilots do highlight various aspects of them, but we must acknowledge that we only scratch the surface in this aspect.

The analysis in this document also shows that SWAMP results do have significant business potential. It is also clear that there are challenges on how the potential can be realised.

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