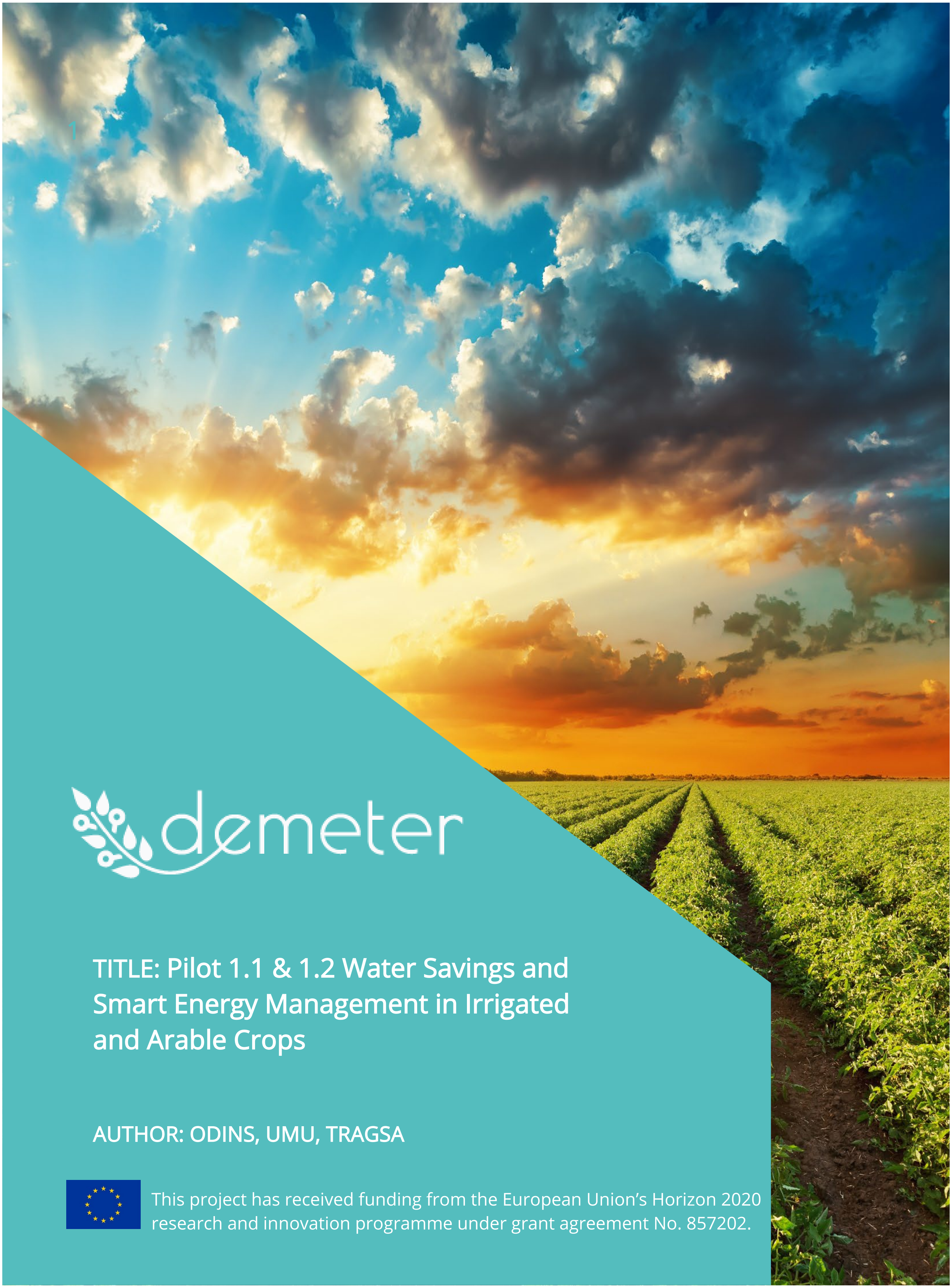

TITLE: Pilot 1.1 & 1.2 Water Savings and Smart Energy Management in Irrigated and Arable Crops

AUTHOR: ODINS, UMU, TRAGSA

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Pilot 1.1 and 1.2 – Water Savings and Smart Energy Management in Irrigated and Arable Crops

1 Introduction

DEMETER aims to lead the Digital Transformation of the European agrifood sector based on the rapid adoption of advanced technologies, such as Internet of Things, Artificial Intelligence, Big Data, Decision Support (DSS), Benchmarking, Earth Observation, etc., to increase performance in multiple aspects of farming operations, as well as to assure the viability and sustainability of the sector in the long term. It aims to put these digital technologies at the service of farmers using a human-in-the-loop approach that constantly focuses on mixing human knowledge and expertise with digital information. DEMETER focuses on interoperability as the main digital enabler, extending the coverage of interoperability across data, platforms, services, applications, and online intelligence, as well as human knowledge, and the implementation of interoperability by connecting farmers and advisors with providers of ICT solutions and machinery.

DEMETER focuses on the deployment of farmer-centric, interoperable smart farming-IoT (Internet of Things) based platforms, to support the digital transformation of Europe's agri-food sector through the rapid adoption of advanced IoT technologies, data science and smart farming, ensuring its long-term viability and sustainability.

Twenty real-world pilot projects, grouped into five pilot clusters, are running within DEMETER to demonstrate and evaluate how agricultural innovations and extended capabilities benefit farmers, technology providers, and society. The topics, scope and size of the pilots are diverse, from saving resources, such as water and energy, to a more environmentally compatible crop management with reduced application of fertilisers and pesticides, to improved animal welfare and the tracing of complete supply chains.

This white paper describes the pilot Water Savings and Smart Energy Management in Irrigated Crops & Arable Crops, which focuses on increasing the production of irrigated crops while saving water and energy. This pilot will count with inputs from both soil sensors and meteorological stations, as well as satellite images for the prosecution of optimising the irrigation system.

2 Importance of digital agriculture

The cluster 1 focus on an efficient water management system, improving the consumption of water, fertilisation and energy in irrigation arable crops. The aim of the pilot 1.1&1.2 is to improve the automation of the irrigation zones through interoperable remote-control systems and robust management systems adapted to the conditions required by the irrigated agriculture.

Digitalization is crucial for an efficient irrigation management system. The adoption of digital technology will be facilitated using modernised irrigation and remote-control systems characterized by interoperable solutions. In this sense, to get over difficulties in getting managers to adopt digital technology, the pilot can define experiments to prove the benefits for the irrigation management activities.

3 Pilot Overview

Challenge

Most of the national modernized irrigation systems have remote control and irrigation management systems, aimed at obtaining an increase in water management. These remote-control systems are characterized because they are closed solutions that do not share software or hardware elements, which limit their possibilities of modification or extension. Nor have they been designed to be interoperable since the information they send has not been prepared to be consulted by applications other than their own.

In addition, these systems are subject to strong obsolescence (approximately ten years of useful life), so they currently only allow their gradual renewal if it is with identical equipment, with increasingly difficult economic repercussions.

Because there is no interoperability, irrigation components that are dependent (such as pumping stations, irrigation branches and hydrants) do not exchange useful information to optimize exploitation.
All this has an impact on irrigation facilities that are not very efficient in terms of saving water and energy efficiency.

Aim

This pilot aims to optimise irrigation by improving the automation of the irrigation zones and saving water and energy, by means of interoperable and robust systems using real time sensors.

Where pilot is being deployed and who are the partners on this pilot

The pilot is deployed in two specific locations of the Spanish territory thanks to the collaboration with two different irrigation communities:

- Irrigation Community Campo de Cartagena ("Comunidad de Regantes Campo de Cartagena)" in the Murcia Region, where Odin Solutions and the Universidad de Murcia are also involved
- "Left side of Porma River" Irrigation Community ("Comunidad de regantes canal margen izquierda del Porma"), in the Castilla & León Region with the support of TRAGSA.

Solution/Innovation

The pilot uses a proprietary service (Smart Agriculture&MEGA) to register agronomic, sensor, weather, and satellite imagery data in the cloud. It has also developed different DEMETER proprietary enablers, like those to retrieve and expose in AIM the registered data, or the one for Irrigation Management DSS. All these components are integrated by means of DEMETER AIM interoperability, with all the required DEMETER Core Enablers, and also with DEMETER Adaptive Visualization Framework.

Pilot's DEMETER components, once virtualized using Docker technology and tested, are registered by means of the ACS, DEH and BSE/FIE, using available REST APIs and user interfaces. The pilot has integrated its components by means of DEMETER AIM interoperability. Pilot's DEMETER components, once virtualized using Docker technology and tested, were registered by means of the ACS, DEH and BSE/FIE, using available REST APIs and user interfaces. Some of them are integrated with the pilot's proprietary service Smart Agriculture&MEGA to expose, using the AIM data model, registered data in the cloud. Others consume this data and compute their results orchestrated by the DSS component.

The pilot's DSS component is also integrated with DEMETER Adaptive Visualization Framework (Knowage) to show the results to end-users, who are registered in advance in the Demeter identification system (ACS).

<u>Key Benefits</u>

The implementation of standardised and interoperable elements will facilitate the exploitation and maintenance of irrigation systems achieving greater efficiencies in the water and energy savings.

The communities of irrigators who for any reason can make a change in any of the components of their system can make it more easily, since any system that meets the standard can be integrated without major changes. Even irrigation communities that do not have a management irrigation system can bet on this since the risk is lowest because they do not depend solely on a company.

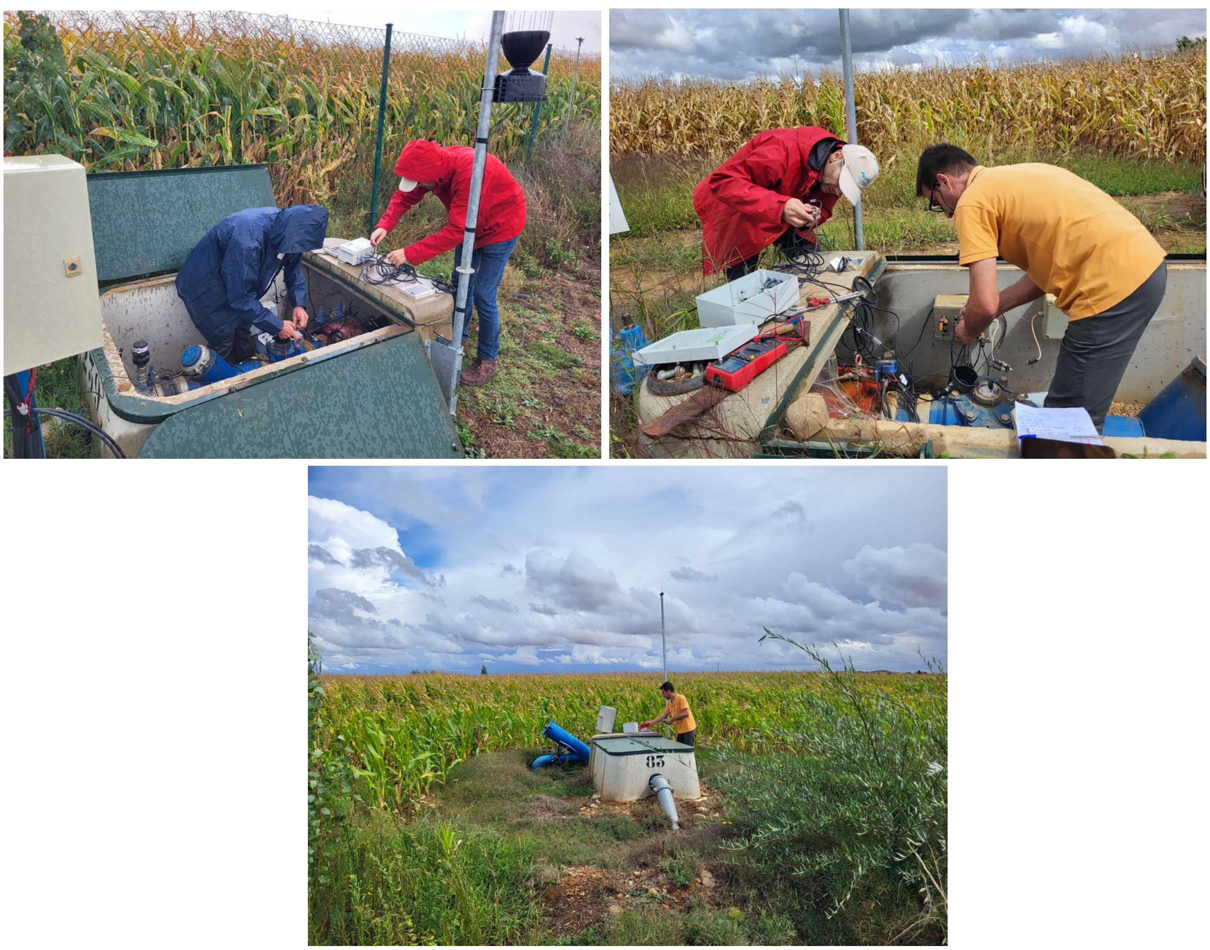


Image 1-3: Pilot in use

4 DEMETER Integration

Key technologies employed

To achieve the objectives of the different pilot's components, they have been developed taking advantage of the technology provided by DEMETER. These components or advanced DEMETER enablers, once virtualized, deployed, and integrated in DEMETER infrastructure by means of the DEMETER Agriculture Information data Model (AIM), ACS, DEH and BSE, will provide a decision support system for the final user.

DEMETER enablers and other technologies

Different components or advanced DEMETER enablers have been developed in DEMETER in work packages 2, 3 and 4 to achieve the objectives of the pilot. There are components in WP2 to achieve interoperability (AIM), to expose data available in the pilot's cloud platform (Smart Agriculture&MEGA) or from external services (i.e., weather services), and to estimate irrigation. We can find components in WP3 related with security (ACS), and to register, remove, or discover other ones (DEH and BSE/FIE). And finally, components in WP4 related with the irrigation, as well as the DSS component that orchestrates the needed components to get the final output for the user.

These components are virtualized using Docker technology. Once tested, they are registered by means of the ACS, DEH, and BSE/FIE using available REST APIs and user interfaces. By means of DEMETER AIM.

All the irrigation information produced by components in WP2 and WP4 is exposed using the DEMETER AIM data model to ensure interoperability, and is managed by the DSS component for irrigation, which result is shown in a dashboard by the DEMETER Adaptive Visualization Framework (Knowage).

Next, we show some figures where it is represented the way this pilot has achieved the interoperability of all its components.

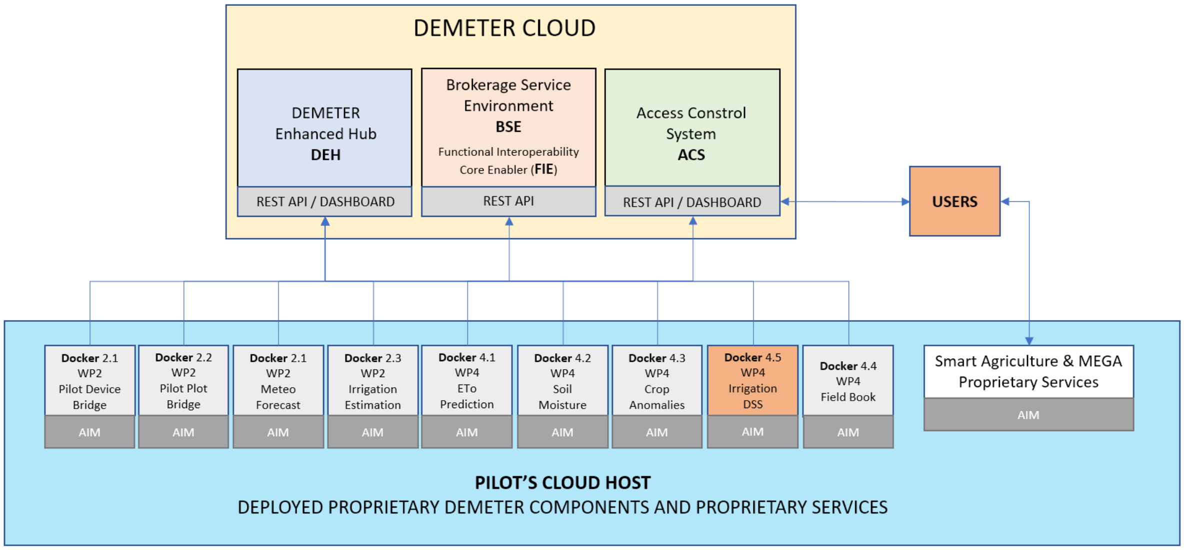
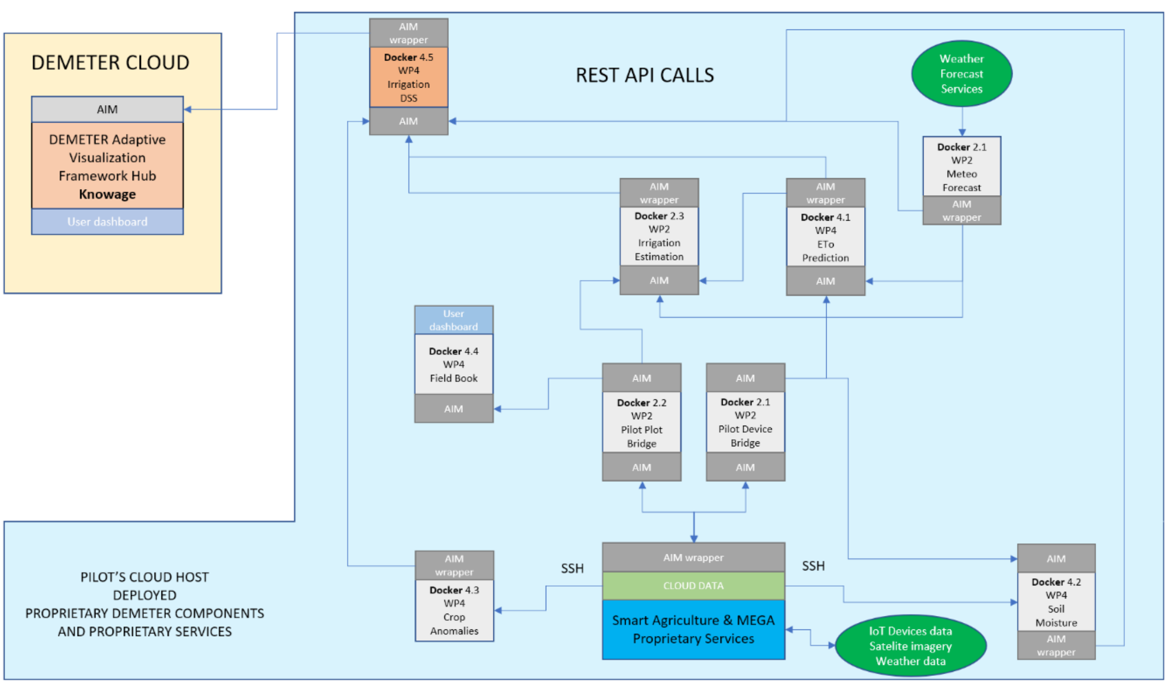


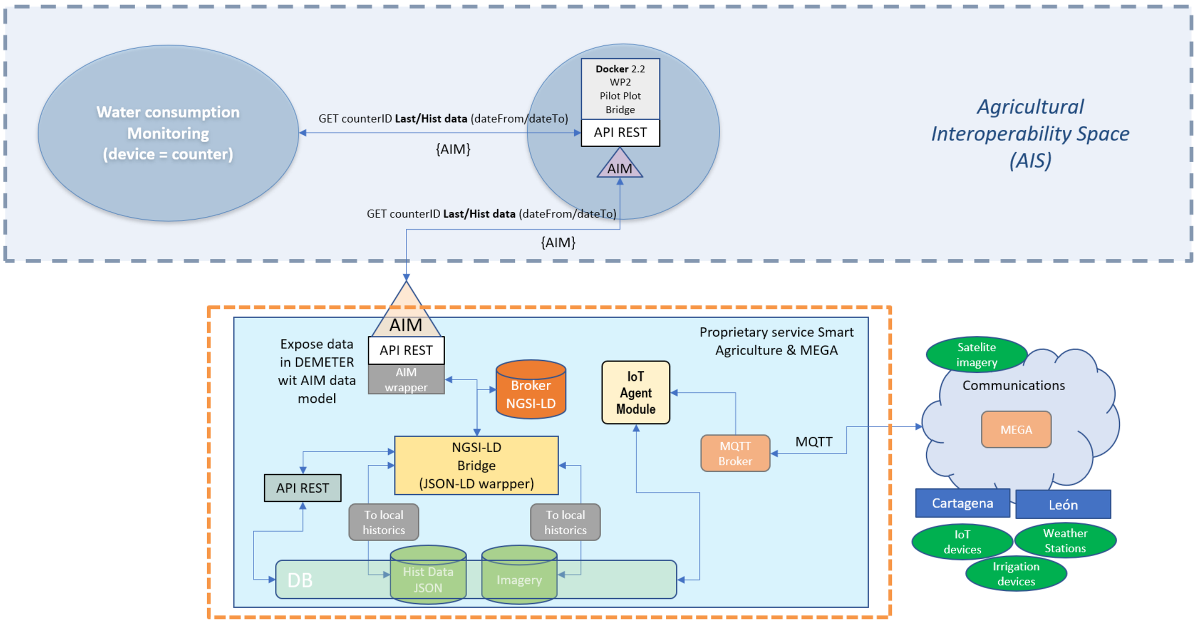
Figure 1: Pilot 1.1&1.2 DEMETER components registration

To achieve the expected functionality of the DSS for Irrigation Management, the pilot's DEMETER components are integrated using DEMETER AIM interoperability. Some of them are integrated with the pilot's proprietary service Smart Agriculture & MEGA to expose, using the AIM data model, registered data in the cloud. Others consume this data and compute their results orchestrated by the DSS component that is the one integrated with DEMETER Adaptive Visualization Framework (Knowage) to show the results to the final user.



Pilot 1.1&1.2 DEMETER components integration by DEMETER AIM Interoperability

The next figure shows an example of interoperability using DEMETER Reference Architecture view for one of the pilot's DEMETER Enhanced Entities in the AIS.



Pilot 1.1&1.2 R.A. view - Integration example by DEMETER AIM Interoperability

As already mentioned, pilots will use the Adaptive Visualization Framework (Knowage) for the DSS output for the final user, registered in advance in the Demeter identification system (ACS). In the next figure we have an example of this pilot's DSS output based in AIM data provided by the integrated components:

Pilot 1.1&1.2 DSS visualization example using Knowage

The different components as well as their interactions in the frame of the technology provided by DEMETER are described next.

"Data and Knowledge" components (WP2)

- <u>Agricultural Information Model (AIM)</u>
  Used for pilot interoperability. Information exchange between DEMETER components or between components and proprietary services, is performed using the AIM developed within WP2 and based on pilots' specific ontologies (i.e., FIWARE, etc.) and on standards (i.e., JSON-LD format, NGSI-LD, etc.). So, the integration between the different pilot's components take place following a standardised approach, developing the input and output components' schemas ensuring that they are AIM compliant.

- <u>Pilot Device Bridge</u>
  The pilot's platform solution Smart Agriculture allows the integration of multiple IoT devices deployed along the plots, whose data (i.e., soil moisture, soil humidity, air temperature, etc.) registered in the platform cloud infrastructure may be needed to be exposed in DEMETER for other components or solutions to be consumed. This data is valuable, for example, to be shown as time series graphics in the DEMETER DSS or used by DEMETER components in different calculations using mathematical models

or machine learning techniques (i.e., evapotranspiration prediction, soil moisture estimation, etc.). To achieve this in DEMETER, a component has been developed in the frame of WP2 to expose, using the AIM data model and a REST API, the last available data or historical time series from those deployed IoT devices in plots (i.e., soil moisture sensors, counters, weather sensors, etc.) registered in a pilot's platform cloud infrastructure. In this pilot, this component is integrated with the DSS for Irrigation Management WP4 component and with its proprietary solutions (Smart Agriculture&MEGA) using DEMETER interoperability.

- <u>Pilot Plot Bridge</u>
  The pilot's platform solution Smart Agriculture allows the integration of multiple plots with their agronomic information, which data (i.e., about the plot, crop plants, soil, irrigation water, used irrigation system, etc.) registered in the platform cloud infrastructure may be needed to be exposed in DEMETER for other components or solutions to be consumed. This data is valuable, for example, to be shown in the DEMETER DSS or used by DEMETER components in different calculations, for example for the crop irrigation water estimation. To achieve this in DEMETER, a component has been developed in the frame of WP2 to expose, using the AIM data model and a REST API, the agronomic data from those plots registered in a pilot's platform cloud infrastructure.

In this pilot, this component is integrated with the DSS for Irrigation Management WP4 component and with its proprietary solution (Smart Agriculture & MEGA) using DEMETER interoperability.

- <u>Weather Forecast Information</u>
  The understanding of meteorological and climatic variables is essential for agriculture to achieve the maximum production of the crop. Plants and by extension crops depend 100% on environmental conditions to be able to develop properly. All environmental and terrain parameters can become a limiting factor for growth if certain critical limits are exceeded. In agriculture, it is essential to control parameters like air temperature, relative humidity, rainfall, and the sun radiation. Other meteorological factors, such as the wind, can also be needed or even decisive in the case of very high gust values

or associated with storms. Several pilots in DEMETER need meteorological data, not only to work with historical time series but also with weather forecast information, for example to predict the reference evapotranspiration or to improve watering parameters.

So, to improve the functionalities of these pilots, a DEMETER component to expose weather forecast data (i.e., air temperature, relative humidity, wind speed, etc.) from trustworthy external sources (i.e., OpenWeather, Weatherbit, etc.) has been provided. This advanced enhanced enabler, developed in the frame of WP2, exposes hourly weather forecast data for the forthcoming days for a given geolocation using the AIM data model and a REST API. It can also be easily improved by adding more needed weather services in the future.

In this pilot, this component is integrated with the DSS for Irrigation Management WP4 component and with its proprietary solution (Smart Agriculture & MEGA) using DEMETER AIM interoperability.

- Crop Irrigation Water Estimation

  Agriculture, and especially irrigated agriculture, is the sector with by far the largest consumptive water use. In DEMETER, several pilots demand data analysis for crop irrigation requirements estimation for different crop types.

  To improve their functionalities in this sense, a component to calculate and expose a crop's irrigation requirement estimation has been developed in DEMETER in the frame of WP2. This advanced enabler uses a mathematical model based on an update of the procedure for calculating the reference evapotranspiration ET_0 and crop evapotranspiration from meteorological data and crop coefficients, which was presented by first time in the publication of the FAO Irrigation and Drainage Series No. 24 «Crop Water Needs" and that is referred to as the "Kc ET_0" approach. In this procedure, the effects of the climate on the water requirements of the crop are reflected in the crop reference evapotranspiration, obtained using the FAO Penman-Monteith method, and the effect of the crop itself incorporated in the crop coefficient (Kc) with other agronomic information from the plot like that about the soil or the irrigation system, just to mention some, and dispensing with the use of sensors deployed in the crops.

  In this pilot, this component is integrated with the DSS for Irrigation Management WP4 component using DEMETER AM interoperability.

"Technology Integration" components (WP3)

- Access Control Enabler (ACS)
  This DEMETER component is used for the pilot user account registration and access grant with the other core and advanced DEMETER enablers, as well as for secure channel communication.

- Brokerage Service Environment (BSE)
  This DEMETER component is used for service registration, discovery and ultimately communication process for pilot DEMETER-enabled resources in a secure and privacy preserving manner.

- Functional Interoperability Core Enabler (FIE)
  This DEMETER component, integrated in the BSE, is used to verify the compatibility in BSE service registration of the pilot's services with the BSE model itself.

- DEMETER Enabler Hub (DEH)
  This DEMETER component is used for pilots' resources registration and discovery into the DEMETER digital space. This pilot's resources, such as the Irrigation Management DSS and its needed components, like the Weather Forecast or the Crop Irrigation Water Estimation, have been registered in the DEH to be discovered by other DEMETER consumers and promoted also for re-usability by other pilots that have the same needs.

- DEH Client Core Enabler
  This component is used for resource consumption metrics monitoring.

"Performance Indicator Monitoring, Benchmarking and Decision Support" components (WP4)

- Reference Evapotranspiration Prediction
  As already mentioned before in the Crop Irrigation Water Estimation WP2 component, it is needed to have the reference evapotranspiration prediction value (ET_0) for the forthcoming days in order to use the crop irrigation water estimation mathematical model based on the "Kc ET_0" approach available as

a WP2 DEMETER component. Also, other pilots with their own solutions for irrigation estimations could need to consider an ET_0 predicted value as accurate as possible.

A component to calculate and expose, using the DEMETER AIM data model, the prediction of the ET_0 value for the forthcoming days in a given geolocation, has been developed in DEMETER in the frame of WP4. This DEMETER advanced enabler uses the FAO Penman-Monteith method with different machine learning techniques (i.e., Neural Network Time Series Forecasts, Naive-Comb, etc.) and using weather forecast and historical data (temperature, humidity, wind speed, and solar radiation) to obtain a better accurate result.

This component, to retrieve the needed data, is integrated with the Pilot Device Bridge and Weather Forecast WP2 components using DEMETER AIM interoperability. In this pilot, this component is also integrated with the DSS for Irrigation Management WP4 component.

- Soil Moisture Estimation

  Surface soil water content has an important role in driving the exchange of latent and sensible heat between the atmosphere and the ground surface through transpiration and evaporation processes, regulating key physiological processes affecting plants growth. Given the high impact of irrigated agriculture on the overall withdrawal rate of freshwater, from the point of view of the water resources themselves and also of the needed energy to obtain it, it is important to help to improve these water resources management for agricultural purposes, and to optimize rain fed crop yield.

  A component to calculate and expose, using the DEMETER AIM data model, the estimation of the soil moisture along the crop soil has been developed in DEMETER in the frame of WP4. This component is based on the recent advances in satellite remote sensing imagery that have led to valuable solutions to estimate soil water content based on microwave or optical/thermal-infrared data. By means of a modification of the Optical Trapezoid Model (OPTRAM) driven by Copernicus Sentinel-2 multispectral imagery and at least one infield soil moisture sensor data, this component generates, using data fusion and machine learning techniques, a 2D image representing the estimated soil moisture along a plot as well as its average value.

This component, to retrieve the needed data, is integrated with the Pilot Device Bridge WP2 component and with the pilot's platform imagery database using DEMETER AIM interoperability. In this pilot, this component is also integrated with the DSS for Irrigation Management WP4 component.

- Crop Water Status Anomalies Detection
  Satellite remote sensing imagery is widely used also to study vegetation status and to monitor crop development. In agriculture they have a big role in various applications such as the extraction of agricultural information, phenotyping, land use monitoring, crop irrigation water monitoring or yield forecasting.
  In the frame of solutions for the detection of plant water status anomalies along a crop, a component has been developed in DEMETER in the frame of WP4 based on the analysis of the multispectral imagery provided by the Copernicus Sentinel-2 satellite and dispensing with the use of sensors deployed in the crops. In this solution, using machine learning techniques, the registered images in the pilot's platform along the time corresponding to the crop over several seasons, are compared with the last image obtained to classify the pixels in several categories, according to the expected behaviour extracted from the history of the same crop or of the adjacent ones.
  This component, to retrieve the needed data, is integrated with the pilot's platform imagery database using DEMETER AIM interoperability.

- DSS for Irrigation Management
  Decision Support Systems (DSS) allow the delivery of tailored advisory services to users, in our pilot case to the agricultural sector, and provide them with the capability to visualize effects of chosen options over a system.
  While classical decision support systems in water management used to rely on a simple model using some sensors' inputs, this DSS component, developed in the frame of WP4, aims to go one step further doing analysis built upon predictive models with the aim to provide better advice for the whole water cycle in a crop. The analytical process will deal with agronomic data (i.e., of irrigation water, soil, crop, etc.), real time data from infield sensors if available, weather services, and satellite imagery. To do so, using DEMETER AIM interoperability, this component will integrate and combine data analytics from the WP2 components with AI-based solutions from the WP4 components described above, to provide a better precision decision support to the final users gathering information about:

- Evapotranspiration predicted value, by the Reference Evapotranspiration Prediction WP4 component.
- Crop irrigation water estimation, by the Crop Irrigation Water Estimation WP2 component.
- Rainwater forecast, by the Weather Forecast WP2 component.
- Average soil moisture estimated value, by the Soil Moisture Estimation WP4 component.
- Average soil moisture with soil probe, by the Pilot Device Bridge WP2 component.
- Soil moisture image visualization, by the Soil Moisture Estimation WP4 component.
- Plant water status anomalies image visualization, by the Crop Water Status Anomalies Detection WP4 component.

Also, this DSS component will get relevant information with historical time series:

- Time series of historical irrigation water.
- Time series of rainwater.
- Time series of estimated average soil moisture.

All the retrieved information will be shown to the user in a dashboard provided by the DEMETER Adaptive Visualization Framework (Knowage).

- <u>Agricultural Field Notebook</u>
  There are several types of field notebooks:
  - The General Agricultural Field notebook.
  - The Organic Farming Field notebook.
  - Other models of agricultural field notebook.
  - The notebook of livestock farms.

The most important and well-known is the General Agricultural Field notebook, usually mandatory for all farmers (in the case of this pilot, in Spain since the Royal Decree 1311/2012 was approved). In this notebook, farmers can record different information like that of all the information about all the phytosanitary products that are used in their crops, so that the Administration can verify that they comply with different regulations (i.e., pest management, etc.). So, although it is mainly a tool for the control of farmers' practices by the Administration, it is also very useful for them, as having everything registered allows them to consult, at any time, the actions that were carried out previously or also to analyse data along different seasons to draw conclusions. In addition, the field notebook is a flexible document that, as long as it collects the mandatory data, can be customized to adapt it to different needs.

So, to improve the functionalities of pilots in clusters related to agronomic tasks and, as the preparation of a field notebook for agricultural operations can be a complex task if you do not have the appropriate tools, it has been developed in the frame of WP4 a DEMETER component that brings this type of notebook for farmers. The information managed in this field notebook component is about*:*

- Identification and agronomic data of the plots.
- Environmental identification data of the plots.
- Registration of phytosanitary products and actions on the plots.
- Registration of use of treated seeds.
- Post-harvest treatment registry.
- Registration of the treatment of storage premises.
- Registration of the means of transportation.
- Traded harvest registration.
- Fertilization recording.

This component, to retrieve some needed agronomic information about the farmers' plots, can be integrated using DEMETER interoperability with the Pilot Plot Bridge component.

- DEMETER Adaptive Visualization Framework (Knowage)
  Round 2 will use the Adaptive Visualization Framework (Knowage) for the DSS output for the final user. The DSS for Irrigation Management is integrated by means of DEMETER AIM interoperability with this component to show in a predefined frontend the information provided to the final user.

AIM Usage

This example shows a three values times series data, with information registered by an air temperature sensor and exposed by the Pilot Device Bridge WP2 component in DEMETER:


```
{
    "@context": [
      "https://w3id.org/demeter/agri-context.jsonld",
        {
          "qudt-unit": "http://qudt.org/vocab/unit/"
        }
    ],
    "@graph": [
      {
        "@id": "urn:demeter:ObservationCollection:idDevAirTemp",
        "@type": "ObservationCollection",
        "description": "Air-temperature",
        "observedProperty": {
          "@id": "http://purl.obolibrary.org/obo/IDOMAL_0000568"
        },
        "madeBySensor": { "@id": "urn:demeter:temperature:1:1"},
        "hasMember": [
          {"@id": "urn:demeter:Observation:idDevAirTemp_1"},
          {"@id": "urn:demeter:Observation:idDevAirTemp_2"},
          {"@id": "urn:demeter:Observation:idDevAirTemp_3"}
        ]
      },
      {
        "@id": "urn:demeter:Observation:idDevAirTemp_1",
        "@type": "Observation",
        "resultTime": "2021-04-10T00:00:00.000Z",
        "hasResult": [
          {
            "@id": "urn:demeter:QuantityValue:idDevAirTemp_1_1",
            "@type": "QuantityValue",
            "numericValue": 37.413,
            "unit": { "@id": "qudt-unit:DEG_C"}
          }
        ]
      },
      {
        "@id": "urn:demeter:Observation:idDevAirTemp_2",
        "@type": "Observation",
        "resultTime": "2021-04-10T00:30:00.000Z",
        "hasResult": [
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            "@id": "urn:demeter:QuantityValue:idDevAirTemp_2_1",
            "@type": "QuantityValue",
            "numericValue": 37.413,
            "unit": { "@id": "qudt-unit:DEG_C"}
          }
        ]
      },
      {
        "@id": "urn:demeter:Observation:idDevAirTemp_3",
        "@type": "Observation",
        "resultTime": "2021-04-10T01:00:00.000Z",
        "hasResult": [
          {
            "@id": "urn:demeter:QuantityValue:idDevAirTemp_3_1",
            "@type": "QuantityValue",
            "numericValue": 37.413,
            "unit": {"@id": "qudt-unit:DEG_C"}
          }
```

```
        ]
      }
    ]
```

Pilot1.1_1.2 AIM data model for times series

Next, this is an example with all the needed agronomic data of a plot exposed by the Pilot Plot Bridge wp2 component in DEMETER.


```
{
    "@context": [
        "https://w3id.org/demeter/agri-context.jsonld"
    ],
    "@graph": [
      {
        "@id": "urn:demeter:AgriFarm:5eeb76ccb8f8fe627be2b690",
        "@type": "AgriFarm",
        "name": "Almond trees farm in Cartagena, Spain",
        "hasAgriParcel": [
          {
            "@id": "urn:demeter:AgriParcel:5eeb76ccb8f8fe627be2b690",
            "@type": "AgriParcel",
            "name": "Almond trees",
            "hasGeometry": {
              "@id": "urn: demeter:AgriFarm:geo:1",
              "@type": "Point",
              "asWKT": "POINT(38.59436666 -0.87921111 496)"
            },
            "area": 9000,
            "numberOfPlants": 270,
            "distanceInRow": 5.5,
            "distanceBetweenRows": 6.0,
            "hasAgriCrop": {
              "@id": "urn:demeter:AgriCrop:606dca1389a6c2151cc94311",
              "@type": "AgriCrop",
              "plantDiameter": 0.236,
              "plantType": "woody",
              "cropCoefficient": 0.15,
              "maxWaterConductivity": 4
            },
            "hasAgriSoil": {
              "@id": "urn:demeter:AgriSoil:606dca1389a6c2151cc94311",
              "@type": "AgriSoil",
              "percolatingEficiency": 0.9
            },
            "hasAgriWater": {
              "@id": "urn:demeter:AgriWater:606dca1389a6c2151cc94311",
              "@type": "AgriWater",
              "irrigationType": "drip",
              "waterConductivity": 1,
              "emittersPerPlant": 2,
              "fluidFlowRate": 0.5,
              "sprinklerDistance": 6
            },
            "hasDevice": [
              {"@id": "urn:demeter:temperature:5f85693cf8ve8723e0834710:5f85693df8fe8723e0814700"},
              {"@id": "urn:demeter:humidity:5f85693cf8ve8723e0834710:5f85693cf8fe8223e0814703"},
              {"@id": "urn:demeter:windspeed:5f85693cf8ve8723e0834710:5f85693cf8fe8721e081470c"},
              {"@id": "urn:demeter:sunradiation:5f85693cf8ve8723e0834710:5f85693cf8fe0723e0814709"},
              {"@id": "urn:demeter:precipitation:5f85693cf8ve8723e0834710:5f85193cf8fe8723e0814706"},
              {"@id": "urn:demeter:soilmoisture:5e4dab2015b80f05f0dfad9a: 5e4dad1016b80f05f0dfad93"},
              {"@id": "urn:demeter:watercounter:5e4dab2015b80f05f0dfad9a: 5e4dac1005b80f05f0dfad58"}
            ]
          }
        ]
      }
```

```
   ]
}
```

Table with code 1: Pilot1.1_1.2 AIM data model of plot agronomic data

Next, this is a simplified example for air temperature and air humidity values as exposed in DEMETER by the Weather Forecast WP2 component.


```
{
    "@context": [
      "https://w3id.org/demeter/agri-context.jsonld",
      {  "qudt-unit": "http://qudt.org/vocab/unit/"   }
    ],
    "@graph": [
      {
        "@id": "urn:demeter:ObservationCollection:WeatherBit_temp",
        "@type": "ObservationCollection",
        "description": "Air-temperature",
        "observedProperty": {"@id": "http://purl.obolibrary.org/obo/IDOMAL_0000568"},
        "hasMember": [   {"@id": "urn:demeter:Observation:WeatherBit_temp_1"},
                         {"@id": "urn:demeter:Observation:WeatherBit_temp_2"}
        ]
      },
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}
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Pilot1.1_1.2 AIM data model of weather forecast data

5 Feedback from farmers

<u>**Farmer interactions**</u>

It has been realized different farmer and technical meetings in order to explain and make technology demonstrations to farmers and managers in Cartagena and Leon Irrigation Communities. Also, some Multi Actor Evaluation Surveys have been answered in order to analyse the level of involvement in decision making of the different actors in the pilot.

6 Benefits

KPIs

1. Reduction of energy consumption in pumping water derived from a better monitoring of water consumption (kW h/ha)
2. Reduction of water consumption in crops derived from better follow-up and monitoring of them (m3/ha)
3. Cost savings in crop production due to a reduction in water and energy consumption (€/ha)
4. Investment savings in the renewal of irrigation remote control systems (€/ha)
5. Cost savings in crop production derived from more efficient irrigation management by integrating management systems and remote-control systems from different manufacturers: reduction of operating times, integration of data related to irrigation, better monitoring of breakdowns (€/ha)
6. Cost savings in crop production derived from more efficient irrigation management by integrating management systems and remote-control systems from different manufacturers: reduction of operating times, integration of data related to irrigation, better monitoring of breakdowns (€/ha)

7 Conclusion

Pilot 1.1&1.2 is being very beneficial in terms of improvements of manager's irrigation communities and taking advance of DEMETER enablers as they allow to improve the automation and control of irrigation system guaranteeing interoperability and standardization in the adopted solutions.

Thanks to DEMETER, the pilot will bring a solution that offers a comprehensive and affordable framework to help farmers manage their crops in a more sustainable and ecological way, by means of recommendations and precision irrigation management to improve water use efficiency and energy, using information from the crop by IoT devices, weather stations, and satellite multispectral imagery.

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