D4.1 - Decision Support, Benchmarking and Performance Indicator Monitoring Tools

Dissemination Level: Public
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1 Executive Summary

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, Benchmarking, Earth Observation, etc., in order 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.

To enable the achievement of the aforementioned objectives, and to promote the targeted technological, business, adoption and socio-economic impacts, DEMETER will design and develop a targeted decision support system that will enable the delivery of tailored advisory services to the agricultural sector. This DSS will combine the data analytics from WP2 with AI-based expert system, machine learning and benchmarking techniques to provide precision decision support to the users. This deliverable describes the AI-based analytic functions, Benchmarking techniques and performance monitoring tools that serve as core building blocks of the DEMETER DSS for addressing the needs of the pilots. While delivering the AI building block services, a full-service lifecycle approach will be carried out to cover each step of the DSS development. For Benchmarking, the pilots have provided a minimum set of data needed to calculate the benchmarking indicators. The Benchmark tools will provide feedback to the pilots and farmers based on these indicators. A reporting tool will also be provided which will indicate how to improve the data collection activities to obtain a more specific benchmark report. These benchmark tools will implement a set of flexible rules to define the optimal list of farms with similar condition according with size, environmental, and economic conditions, type of farming activities. The selected farms will be used to provide to a specific benchmark value of the indicators.

This deliverable has been recalled by the EC, through the formal Review Report issued on July 16th, to be reworked and resubmitted by September 20th. As such, the previous version of this deliverable was submitted on May 31st, while this version (v2.0) is submitted on 17th 08 2020. The comments received to this document are as follows:

#	Review Comment	Response / Section where the comment is being addressed
1	Solid document & work in several respects.	Many thanks for the compliment.
2	SOCS: is the SOCS only a "The collaboration space is implemented as a public/private discussion forum to support the engagement, interaction and collaboration scenarios through the DEMETER platform." as stated in D4.1?	This definition came from the DOA. SOCS is not defined nor introduced in this document; that formal definition fell under the realm of D4.2. However, in the sections covering WP4 as a whole the description of SOCS has been updated to that used in D4.2.
3	The Requirements Diagrams do not show the outputs, so it is difficult to understand what is the actual services rendered to the users.	The document has been completely restructured in attempt to make the requirements gathering process a bit clearer. All of the input from the pilots and other sources have now been placed in Annexes and description of the process and analysis added to the main text. With specific respect to output requirements, the DSS components are to be shipped as containerised services and do not have direct end-user interfaces. The data which comprises their output was considered in the requirements in terms of the simplest of the possible user interfaces i.e. the Visualisation which is part of task T4.3, which is defined in D4.2 so this was not covered in any detail here. However, this process is still on-going post D4.2, so while D4.2 does contain more about the outputs, it still does not contain the final definition. Further input will be provided in upcoming deliverables D4.3 and D4.4.
4	Good identification of functional modules for the DSS.	Many thanks for the compliment.
5	Requirements announced to be found in annex B, embedded with too much other information.	The document has been reshuffled to present the Annexes as input information and main body as including the analysis. Now, requirements are being covered in Annex C and Annex D. Annex C deals with the analysis of the requirements from the DEMETER Pilots, while Annex D covers the requirements for the solution proposed by the DEMETER Pilots. The solution proposed by the pilot, though, does not necessarily represent a single WP4 component.

6	It is unclear, to which extend user needs have been considered in defining the described tools & solutions. This will have a huge influence on later adoption and impact.	The pilots needs have been evaluated and the outcomes of this analysis are reported in Section 7, where requirements from the DEMETER Reference Architecture and their instances for each Pilot Cluster are listed. Further, several common components have been identified for specific purposes that can be potentially be used by several pilots with similar requirements. In this release, Section 7 has been reworked and cleared out, by extracting content to the Annexes, to emphasize the message and the findings.
7	Among others, preliminary results of a first survey are not very encouraging with respect to usefulness and data availability. A broader base for assessing farmers' needs and attitudes is required. Suggested solutions should clearly take those elements into consideration, and show how they accommodate those.	Whilst true, it is necessary to point out that the survey was a preliminary exercise aiming at gauging what the DEMETER farm partners prioritise regarding the benchmarking activity. Indeed, the suggestions are going to be taken into consideration and executed in the upcoming weeks/months. Their results will be documented in the next D4.3.
8	First survey results indicate, that the respective farmers are more interested in some forms of benchmarking, while hesitant with regard to others. This could be a good space for dialogue among different actors and their perspectives: what can we learn from the standard 'textbook' view of benchmarking opportunities? What is the clear business value providers offer in the context of farming? What is most useful and fits the business & personal context of the farmer? -> What are benchmarking solutions proposed after 'negotiating' those and/or other relevant perspectives?	Whilst true, it is necessary to point out that the survey was a preliminary exercise aiming at gauging what the DEMETER farm partners prioritise regarding the benchmarking activity. Indeed, the suggestions are going to be taken into consideration and executed in the upcoming weeks/months. Their results will be documented in the next D4.3.

2 Document History

Version	Author	Description
D4.1_V0.1	Agricolus - ICE	First Draft with TOC
D4.1_V0.2	Agricolus	Updated version, confirmed with contributors and agreed on distribution of work
D4.1_V0.3	All mentioned authors (see table below)	WP2 interval review

D4.1_V0.4	All mentioned authors (see table below)	Updated version, comments and adjustments from partners reviewed by Agricolus and ICE.
D4.1_V0.5	All mentioned authors (see table below)	Updated version, comments and adjustments from partners reviewed by Agricolus and ICE.
D4.1_V0.6	All mentioned authors (see table below)	Updated version, TOC restructured and updated, minor changes in texts
D4.1_V0.7	Agricolus	Version for first internal review (2020-05-18)
D4.1_V0.8	Agricolus	Feedback from reviewers (25-05-2020)
D4.1_V0.9	Agricolus	Reviewed version (26-05-2020)
D4.1_V2.0	Agricolus - ICE	Updated version as per Review Report

3 Acronyms

AI	Artificial Intelligence
AIS	Agricultural Interoperability Space
ANN	Artificial Neural Network
API	Application Programming Interface
BBCH	Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie
CAP	Common Agricultural Policy
CART	Classification and Regression Tree
DEH	DEMETER Enabler HUB
DOY	Day of the Year
DL	Deep Learning
DT	Decision Tree
DSS	Decision Support System
EI	Environmental Indicators
EO	Earth Observations
ET_0	Reference Evapotranspiration
ET_R	Real crop Evapotranspiration
ECU	European Currency Unit
ESU	European Size Unit
FADN	Farm Accountancy Data Network
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FMIS	Farming Management Information Systems
IACS	Integrated Administration and Control System

ICT	Information and Communications Technology
GDD	Growing Degree Day
GHG	Greenhouse Gas
IOT	Internet of Things
IPM	Integrated Pest Management
KPI	Key performance indicators
MFFB	Mel-Frequency Filter Bank
MFCC	Mel-Frequency Cepstral coefficients
ML	Machine Learning
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NUTS	Nomenclature of Territorial Units for Statistics
PCA	Principal Component Analysis
REST	Representational state transfer
RF	Random Forest
RMS	Root Mean Square
RMSE	Root Mean Square Error
RP	Rinkeby Platform
RS	Remote Sensing
SGM	Standard Gross Margin
SC	Specific Costs
SO	Standard Output
SOCS	Stakeholders Open Collaboration Space
SVM	Support Vector Machines
TF	Type of Farming
USDA	United States Department of Agriculture

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5 Introduction

This deliverable summarizes the initial results of various WP4 tasks related to AI-Decision-making, Benchmarking and Performance Indicator Monitoring Tools.

Aims of these tasks were:

- to deliver building blocks of decision-making systems that serve the specific needs of the DEMETER pilots; these building blocks use AI-based expert systems, machine learning and benchmarking techniques to provide tailored advice in specific agro-management environments.
- to integrate the data, services and platform adopted in the pilots to support the creation of a benchmarking system that can be used at farm level to evaluate the productivity and the sustainability of the practices adopted and to test and evaluate the efficacy of the developed digital solution in reducing costs, improve the production and support the long-term sustainability.

The document is structured as follows.

Section 6 describes the requirement gathering processes adopted by WP4 to determine the needs of the pilots with respect to the Decision Support Systems and Benchmarking. As these are two very different subjects, different approaches were taken to obtain the requirements. The DSS approach was to ask the partners associated closely with the pilots to provide the DSS requirements and high-level design ideas for the various solutions. These high-level design details provide an overview of the challenges that are being addressed, while designing the DSS-solutions in DEMETER. The Benchmarking approach involved surveys sent to pilot leaders to develop benchmarking indicators and to assess the data availability. An important outcome of this section is the presentation of the results of the survey on benchmarking requirements of DEMETER pilots. This survey questioned the pilots' representatives about the principal aims of the DEMETER benchmarking system laying the foundations for the identification of indicators for the comparison and the availability of data (agronomic, environmental, and financial) at the farm level.

Section 7 describes the results of the analysis of the various requirements gathering exercises. This provides a clearer view of the different components to be developed and deployed for each pilot and how the DSS will help to enrich the DEMETER Reference Architecture by adding those components to the architecture. At the end of the section, areas of applications have been defined and a set of enablers/component are introduced for each area, in order to design the future works regarding the DSS creation for the pilots.

Section 8 provides a description of some of the areas for artificial intelligence technologies within the various DSS solutions based on aggregated pilot requirements and module-enabler requirements gathered in WP5. For each area, a state of the art DSS solution is suggested. In addition, a brief description of the functions and the input/output structure of the components of the DSS to be integrated in the frame of DEMETER is reported, as well as a list of components for the selected areas to be implemented.

Section 9 describes the implementation of the benchmarking system of DEMETER. First, a state of the art about the scope of agricultural benchmarking is reported, the indicators to be used for the comparison and the type of comparison among farms that can be carried out. As a starting point for benchmarking solutions in DEMETER, descriptions of agronomic, environmental, and economic indicators are available. Finally, the benchmarking adoption in DEMETER has been depicted, as well as the benchmarking system components which will be implemented and demonstrated in the pilots' activities.

The Annexes contain the information received about the pilots. Annex A contains basic information about the pilot taken from the original pilot description and from the contents of D5.1 and early drafts of D5.2. Annex B contains Architecture Diagram supplied by the pilots at the request of WP3. Annex C contains the DSS requirements information supplied by the pilots. Annex D contain the high-level design ideas for the DSS solutions provided by the pilots.

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6 Decision Support and Benchmarking Challenges in DEMETER

6.1 The DEMETER Objectives

DEMETER will design and develop targeted decision support systems that will enable the delivery of tailored advisory services to the agricultural sector. The decision support systems will combine the data analytics services (from WP2) with AI-based expert system, machine learning and benchmarking techniques to provide precision decision support to the users.

In DEMETER, the decision support functionalities are undertaken in 5 key tasks:

- **AI-based Decision-making** uses the data analytics components (from WP2) to deliver building blocks of decision-making systems that serve the specific needs of the DEMETER pilots. These building blocks, delivered as services, use AI-based expert systems, machine learning and benchmarking techniques to provide tailored advice in specific agro-management environments. The AI-based services use the raw and processed data coming from pilot domains; and take into account the requirements and scenarios put forwards by pilots to suggest corrective, predictive and optimisation measures to pilot providers. In this respect, the decision-making services in DEMETER implement proven AI-based decision-making approaches to tackle the needs of challenging pilot scenarios and provide actionable advices.
- **Benchmarking on Performance of Farms, Services, Technologies and Practices** is carried out through the development of a benchmarking system that can be used at farm level to evaluate the productivity and the sustainability of the practices adopted and to test and evaluate the efficacy of the developed digital solution. DEMETER provides a shared benchmarking framework to evaluate the performance of developed Decision Support Systems defining with pilots' coordinators, a list of specific indicators in three areas:
    - Agronomic performance: indicators about crop yield (levels, variability in time and space, coping with climatic and environmental changes) and indicators about the quality of the production.
    - Economic performance: a set of economic indicators about the farm profit and profitability, efficiency (technical and financial).
    - Environmental performance: water and carbon footprint, reduction of water, soil, and air potential pollution.

  The indicators are defined using the Common Data Models (from D2.1) to ensure the interoperability with other DEMETER components. The benchmark framework implements a set of flexible rules to define the optimal list of farms with similar condition according with size, environmental and economic conditions, type of farming activities.

- **Adaptive Visualisations for Dashboards** are developed in DEMETER to address the UX needs of decision support systems in the DEMETER pilots. The dashboard framework allows users to query the data analytics, apply the decision-making services, visualise the outcome of benchmarking techniques or create visualisations based on the workflows of enablers. Using the dashboard framework, users are able to customise the dashboard based on their own needs by means of interlinking multiple visualisations or manipulating service outcomes in different ways. The users will also be able to compare the results of various services e.g. to perform as-is *vs* what-if analysis.
- **Decision Support Enablers and Advisory Support Tools** are developed as open components that accelerate the development of sector or pilot specific decision support systems. The enablers deliver the analysis/analytics of data from across the agro-management value chain in the form of easily plug & play micro-services. The enablers are offered through a web-based repository and come with standard APIs for data management and exchange, based on the DEMETER data models (defined in WP2). The nature of enablers ranges from image

processing to data transformation maps, IoT gateways, system connectors and data analytic microservices. The standardised APIs and reusable nature of the generic enablers will allow the composition of several enablers in modular DSS.

- Finally, the **Stakeholder Open Collaboration Space** will offer a complete collaboration environment, dedicated to all stakeholders (farmers, advisors, and suppliers) where they can collaborate, share best practices, and participate in co-creation processes. The knowledge-driven services, complemented by the collaborative and innovation side of the Platform, will create a virtual environment where providers and consumers of digital technologies are not just matching assets and needs, but they are collaborating together towards joint innovations. Indeed, the SOCS aims to “put farmers fully in control of their needs, of their choices, of their speed of adoption of solutions, of their data” and would like to represent a response to their need to be supported when they have to choose between different solutions.

The current document describes the tasks relating to **AI-based Decision-Making** and **Benchmarking**. Details of the tasks relating to **Adaptive Visualisations for Dashboards, Decision Support Enablers and Advisory Support Tools,** and the **Stakeholder Open Collaboration Space,** will be provided in deliverable D4.2, “Decision Enablers, Advisory Support Tools and DEMETER Stakeholder Open Collaboration Space”.

6.2 Decision Support – Requirement Gathering for DEMETER

The process of requirements gathering for the Decision Support Systems involved several iterations and includes using the results of work performed by other work packages.

The first iteration was provided by WP5 in the form of deliverable D5.1, “Initial Stakeholder Requirements, Pilots Design, Specification and Planning V1.1”. This provided valuable background information about each of the pilots, though the quantity and quality varied from pilot to pilot. A summary of the information gleaned from D5.1 can be found in Annex A. However, there was insufficient detail about the solutions required to be able to extract requirements for Decision Support Systems. Therefore WP4, like other WPs, initiated a WP4-specific requirement gathering exercise.

The first of these requirement gathering exercises to be completed was initiated by WP3. They had created a reference architectural diagram showing how the DEMETER Enablers were positioned relative to external systems and data sources. Each of the pilots was asked to produce a corresponding architectural diagram for their pilot. The enhanced enablers shown on these diagrams were shown as blue ovals and these were expected to be the components that would be needed to be developed by WP2 and WP4. However, the actual diagrams, which can be found in Annex B, were not as clear as expected since some blue ovals could be identified as either WP2 or WP4 components, many were abstract concepts.

Within WP4, there were several separate requirements gathering exercises: Benchmarking will be described in section 6.3, and SOCS will be described in deliverable D4.2. The requirements gathering exercise for Decision support, which covers both **AI-based Decision-making** and **Decision Support Enablers and Advisory Support Tools,** was slightly different in that it was targeted at the pilot leaders as the level of information to be gathered was considered too technical for end users. Many of the pilot leaders are also WP4 partners who also work closely with the end users as part of their role in WP5. The pilots were asked to fill in a table providing some information on the required DSS and to provide a diagram showing a High-Level Design of the DSS indicating the type of inputs to be processed and interfaces. The tables returned by the pilots can be found in Annex C. The High-Level Design diagrams can be found in Annex D. Visualisation mock-ups were also requested to provide an indication of the output expected from the DSS. Note, the Visualisation will be described in D4.2 so no further mention will be made of these mock-ups in this document. Finally, they were asked to include a copy of their WP3 architecture diagrams which, it was hoped, would help tie everything together.

The next stage was to analyse the results. WP2 produced a list containing a small number of WP2 components and a large number of WP4 components. This was based on WP2 interpretation of the blue ovals in the Architecture Diagrams. WP4 interpretation, which still had a large number of WP4 components, also contained some which were not very clear.

WP4 analysis of the responses from the WP4 DSS exercise showed that there was a lot of inconsistencies between the two diagrams and the table. However, the analysis of these results coupled with those from WP2, led to the identification of a number of possible common components. Many of these had been described with different names on the diagrams. This required another round of discussions with the pilots to confirm that the identified components were actually what they wanted.

Finally, the identified components, together with the Benchmarking components, were grouped into similar thematic Areas as defined in section 7.2. This allowed us to set up Area specific working parties. Most Areas covered several pilots and most pilots are involved in several Areas. These areas will enable work to be focused on the specific needs of the pilots whilst maximising the opportunity for reuse of components amongst similar pilots.

6.3 Benchmarking Requirements of DEMETER Pilots

6.3.1 Survey structure

To implement the DEMETER benchmarking system as an interactive process, it is necessary to gather input from farms involved in the pilot activities. Indeed, building a benchmarking system is a participatory process that must be performed with and for the farmers. At the stage of the project in which this work was started, the farms engaged for the pilot activities were not definitely selected, as the scouting process was ongoing to maximize the participation of farm's numbers. The survey described in this section has, therefore, been addressed to pilots' leaders as they have a general idea about the type of farms that are being engaged in by their pilots.

The aim of the DEMETER benchmarking system is to provide farmers and advisors with tools to assess agronomic and economic performance, as well as environmental sustainability, and to compare results to facilitate individual and peer to peer learning in relation to the impact of operational processes.

The survey had the aim to collect feedback from each pilot leader on the proposed DSS requirements and to develop benchmarking indicators, as well as to gather information on data availability at the level of pilot farms.

After the first implementation and release of the benchmarking system tool, farmers will be involved with a participatory approach to tailor and to refine the tools, according to their suggestions and needs. This participatory process is within the aims of WP7.

As a starting point for the benchmarking system development, we focused on how to answer the following questions: “How is a farm doing, versus the average or the best in class?”.

The scope of the survey was to assess, according to the current pilot leaders' knowledge, the type of data that need to be collected from farms engaged in each pilot to be used for the benchmarking tools, as the quality and completeness of the gathered data is of crucial importance for the success of the benchmarking system.

To design the benchmarking tools, the role of the farms engaged in the pilots can be envisaged as reported in the following steps:

- provide the data.
- interpret the output of benchmarking.
- give feedback on the benchmarking.

Data gathering should be as simple as possible for farmers and they should not be asked to enter data that are already available in the system.

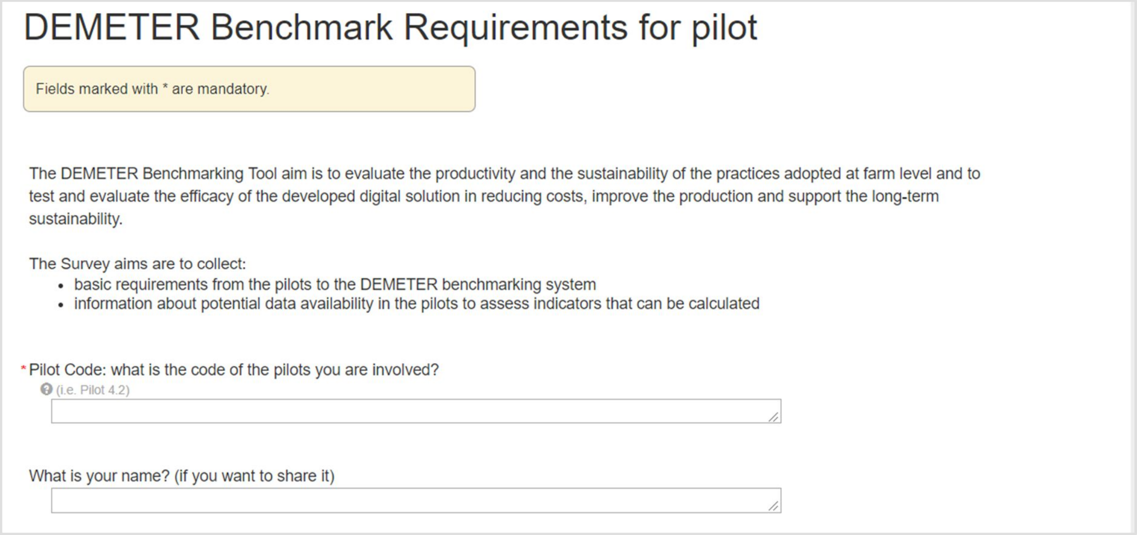
The key function of the benchmarking system is to provide an analysis in understandable format, so that the farmers may select proper indicators based on their interests and build their own dashboard.

The on-line survey (https://ec.europa.eu/eusurvey/runner/d0f5f2c1-411f-b861-51ed-028daa8dfc45) was addressed to pilot leaders to collect feedback and ideas on benchmarking system implementation (e.g., DSS and indicator assessment) and on potentially available data at the pilot farm level.

The survey was structured in the following three main sections: respondent identification, DSS requirements and data availability.

Respondent identification:

The first questions were about pilot leader identification



DEMETER Benchmark Requirements for pilot

Fields marked with * are mandatory.

The DEMETER Benchmarking Tool aim is to evaluate the productivity and the sustainability of the practices adopted at farm level and to test and evaluate the efficacy of the developed digital solution in reducing costs, improve the production and support the long-term sustainability.

The Survey aims are to collect:
- basic requirements from the pilots to the DEMETER benchmarking system
- information about potential data availability in the pilots to assess indicators that can be calculated

* Pilot Code: what is the code of the pilots you are involved?
(i.e. Pilot 4.2)

What is your name? (if you want to share it)

Figure 1. Questions about pilot leader identification

DSS requirements:

The section about DSS requirements was structured in two subsections. While the first subsection (a) had the aim of gathering the perspective of pilots' leaders about the general purpose and the propositions of the benchmarking system, the second sub-section (b) aimed to collect pilot leader point of views about possible indicators to be used in the benchmarking system.

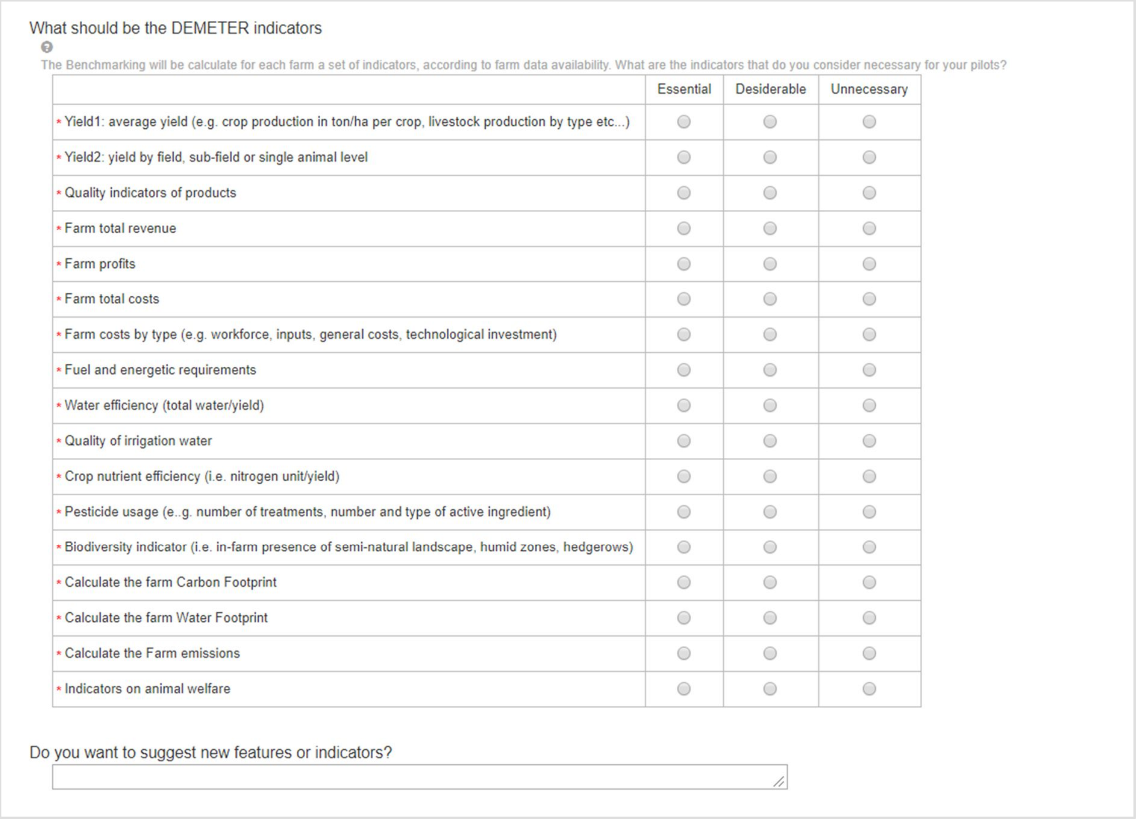
Figure 2 rates the different propositions of what should be addressed by the benchmarking system according to the options ("essential", "desirable" or "unnecessary") given. Figure 3 classifies a given set of indicators to be used for the DEMETER benchmarking system according to the same ratio ("essential", "desirable" or "unnecessary"). Considering the great differences among the 20 pilots of

DEMETER, the set of proposed indicators try to cover all pilot activities and types of benchmarking (environmental, agronomic, and economic).

The Benchmarking system should:

	Essential	Desiderable	Unnecessary
* ...support farmers in choosing a specific technology or a DEMETER solution	○	○	○
* ...allow a farmer to compare his farm performance with neighbours (using a regional average or grouping users belonging to the same organisation)	○	○	○
* ...support farmers in evaluating how the farm is performing respect to the past	○	○	○
* ...support farmers in evaluating how the farm is performing after the adoption of a new technology	○	○	○
* ...calculate KPIs for all DEMETER pilots	○	○	○
* ...assess the sustainability performance of farming practices	○	○	○
* ...evaluate the efficacy of the DSS developed in DEMETER	○	○	○

Figure 2. Identification of what the benchmarking system should address



What should be the DEMETER indicators

The Benchmarking will be calculate for each farm a set of indicators, according to farm data availability. What are the indicators that do you consider necessary for your pilots?

	Essential	Desiderable	Unnecessary
* Yield1: average yield (e.g. crop production in ton/ha per crop, livestock production by type etc...)	○	○	○
* Yield2: yield by field, sub-field or single animal level	○	○	○
* Quality indicators of products	○	○	○
* Farm total revenue	○	○	○
* Farm profits	○	○	○
* Farm total costs	○	○	○
* Farm costs by type (e.g. workforce, inputs, general costs, technological investment)	○	○	○
* Fuel and energetic requirements	○	○	○
* Water efficiency (total water/yield)	○	○	○
* Quality of irrigation water	○	○	○
* Crop nutrient efficiency (i.e. nitrogen unit/yield)	○	○	○
* Pesticide usage (e..g. number of treatments, number and type of active ingredient)	○	○	○
* Biodiversity indicator (i.e. in-farm presence of semi-natural landscape, humid zones, hedgerows)	○	○	○
* Calculate the farm Carbon Footprint	○	○	○
* Calculate the farm Water Footprint	○	○	○
* Calculate the Farm emissions	○	○	○
* Indicators on animal welfare	○	○	○

Do you want to suggest new features or indicators?

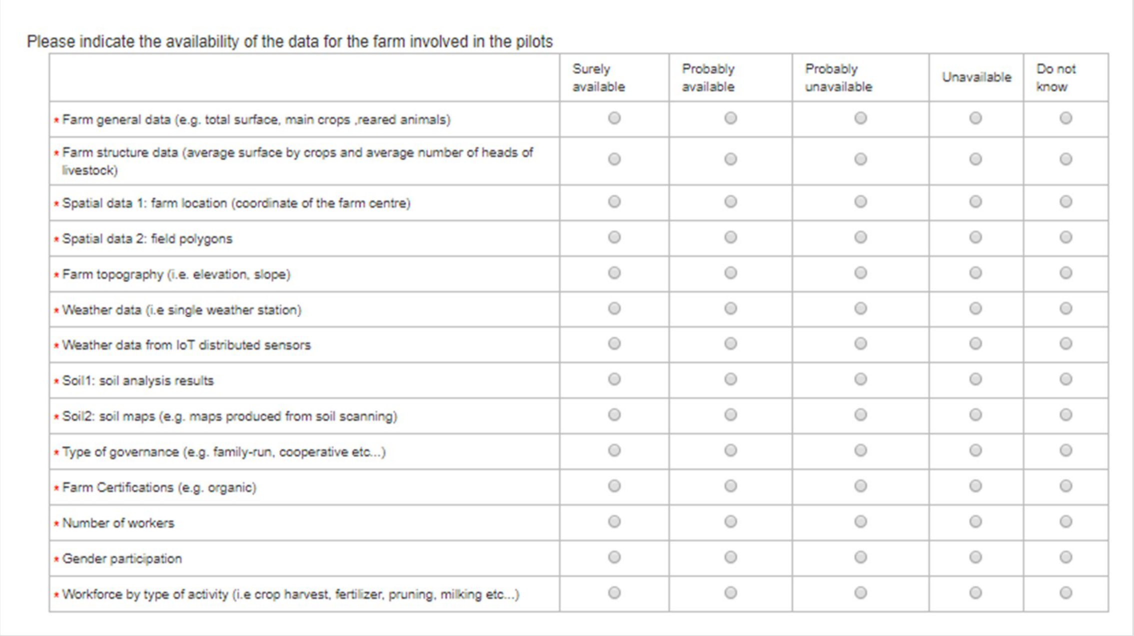
Figure 3. Identification of indicators to be used for the DEMETER benchmarking system

Data Availability:

This section of the survey covered the aspects related to the type of data needed for the benchmarking system and its availability in the different farms engaged for the pilots' activities. This section has been further divided according to the aspects to be evaluated, namely farm general structure, input and output, and economic data.

Pilot leaders were asked to evaluate, according to their knowledge, data availability at the farm level, by selecting one of the options (“surely available”, “probably available”, “probably unavailable”, “do not know”, “unavailable”).

Figure 4 covers the farm general structure where general characteristics of the farm, being these common across the engaged farms, are tackled. These characteristics include spatial and soil data, availability of agrometeorological data, type of governance, number of workers, etc. Figure 5 deal with farm input and output data which are related to the information about production quantity (yield, livestock), amount of input used (water, pesticides, agrochemicals, ...), soil management, sensors, animal nutrition and welfare. Finally, Figure 6 displays farm’s economic data questions about farm revenue, profit, and costs.



Please indicate the availability of the data for the farm involved in the pilots

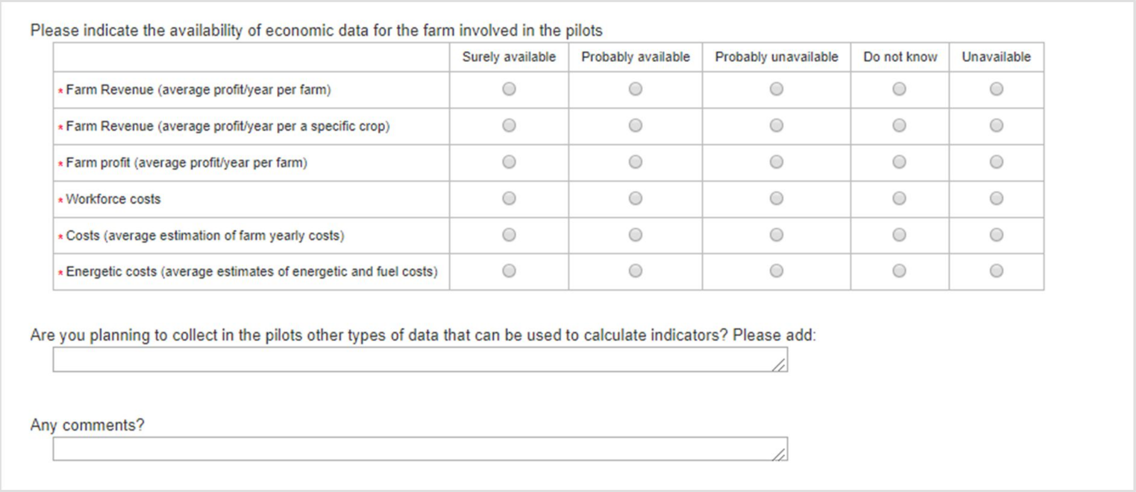
	Surely available	Probably available	Probably unavailable	Unavailable	Do not know
* Farm general data (e.g. total surface, main crops ,reared animals)	○	○	○	○	○
* Farm structure data (average surface by crops and average number of heads of livestock)	○	○	○	○	○
* Spatial data 1: farm location (coordinate of the farm centre)	○	○	○	○	○
* Spatial data 2: field polygons	○	○	○	○	○
* Farm topography (i.e. elevation, slope)	○	○	○	○	○
* Weather data (i.e single weather station)	○	○	○	○	○
* Weather data from IoT distributed sensors	○	○	○	○	○
* Soil1: soil analysis results	○	○	○	○	○
* Soil2: soil maps (e.g. maps produced from soil scanning)	○	○	○	○	○
* Type of governance (e.g. family-run, cooperative etc...)	○	○	○	○	○
* Farm Certifications (e.g. organic)	○	○	○	○	○
* Number of workers	○	○	○	○	○
* Gender participation	○	○	○	○	○
* Workforce by type of activity (i.e crop harvest, fertilizer, pruning, milking etc...)	○	○	○	○	○

Figure 4. Farm general structure

Please indicate the availability of the data for the farm involved in the pilots

	Surely available	Probably available	Probably unavailable	Unavailable	Do not know
* Yield1: average yield for each crop at the farm level	○	○	○	○	○
* Yield2: Yield at field level	○	○	○	○	○
* Yield3. Yield maps	○	○	○	○	○
* Quality data of the production (e.g. sugar content on grape, protein on cereals, fat in milk)	○	○	○	○	○
* Livestock production: (year total production: meat, milk, eggs etc...)	○	○	○	○	○
* Detailed livestock production (e.g. daily milk productions, animal weights etc...)	○	○	○	○	○
* Water general consumption (e.g. average volume/ha per crops)	○	○	○	○	○
* Water logs (e.g. water volume per day and per field)	○	○	○	○	○
* Fertilizer general consumption (e.g.average nitrogen unit/ha per crop)	○	○	○	○	○
* Fertilizer logs (single log with the date, type of fertilizer, amount per field)	○	○	○	○	○
* Pesticides general use (number of treatments per year per crop)	○	○	○	○	○
* Pesticide logs (single spraying events with date, field and product)	○	○	○	○	○
* Soil management (e.g. number of soil tillage activities per year/crop)	○	○	○	○	○
* Soil management logs (list of single tillage activities)	○	○	○	○	○
* Weed control management (frequency, products)	○	○	○	○	○
* GPS logs from the machinery	○	○	○	○	○
* Sensor data from the machinery	○	○	○	○	○
* AnimalNutrition1. the average amount of feedings used yearly	○	○	○	○	○
* AnimalNutrition2: animal rations data (by period and by type)	○	○	○	○	○
* AnimalNutrition3: individual rations obtained by sensor data	○	○	○	○	○
* Animal welfare data (stable structure, farming methods)	○	○	○	○	○
* Animal sensor data (collars, pedometers, thermometers)	○	○	○	○	○

Figure 5. Farm input and output



Please indicate the availability of economic data for the farm involved in the pilots

	Surely available	Probably available	Probably unavailable	Do not know	Unavailable
* Farm Revenue (average profit/year per farm)	○	○	○	○	○
* Farm Revenue (average profit/year per a specific crop)	○	○	○	○	○
* Farm profit (average profit/year per farm)	○	○	○	○	○
* Workforce costs	○	○	○	○	○
* Costs (average estimation of farm yearly costs)	○	○	○	○	○
* Energetic costs (average estimates of energetic and fuel costs)	○	○	○	○	○

Are you planning to collect in the pilots other types of data that can be used to calculate indicators? Please add:

Any comments?

Figure 6. Economic data

The survey was opened on-line on February 18th and closed on March 16th, when the last pilot leader filled it online.

The following statistical overview is based on the 23 replies to the survey. We collected answers from all pilot leaders (twenty pilots). Two pilot leaders, being responsible for more than one pilot, gave one answer each, which was considered as one for each pilot they are responsible for. For each of pilot 1.4, 2.2, 4.3 and 5.1, we got two answers.

6.3.2 Survey results

The majority of respondents to the question of what “the benchmarking system should accomplish”, highlighted that the suggestions proposed were “essential” (38%) and “desirable” (48%), while the total proposed solutions were considered “unnecessary” for only the 14% of the total answers (Figure 7). To weight the answers, we created an index by assigning a score to each answer, as follows:

$$Index = \frac{[number\ of\ \text{essential} + (number\ of\ \text{desirable}) * 0.6]}{number\ of\ total\ answers}$$

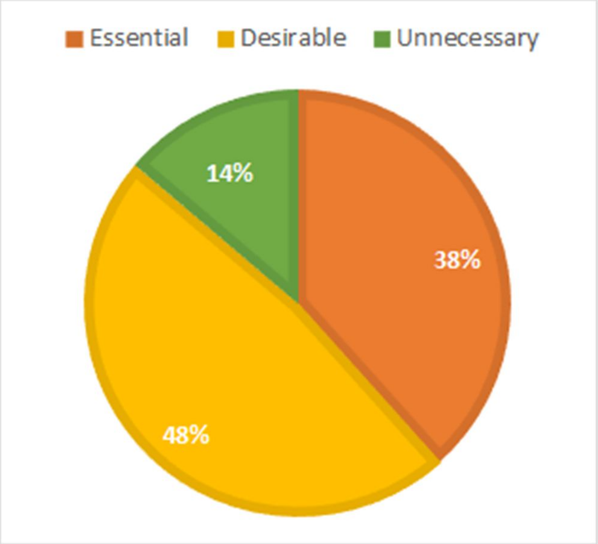


Figure 7. Distribution of the answers for what the benchmarking system should address

For the majority of the respondents, the DEMETER benchmarking system should support farmers in evaluating the performance after the adoption of new technology (76%) and in comparison with past performance (70%). More than with peers (or with average or with the best in class), farmers considered self-comparison of their farms to be important.

Figure 8 shows the total score of the index on what the benchmarking system should address and distribution of the answers within the clusters. After analysing the distribution of the answers within the five clusters, homogeneity can be observed, for the first two questions. For cluster 3, “evaluate the efficacy of the DSS developed in DEMETER” was considered more important (“essential”).

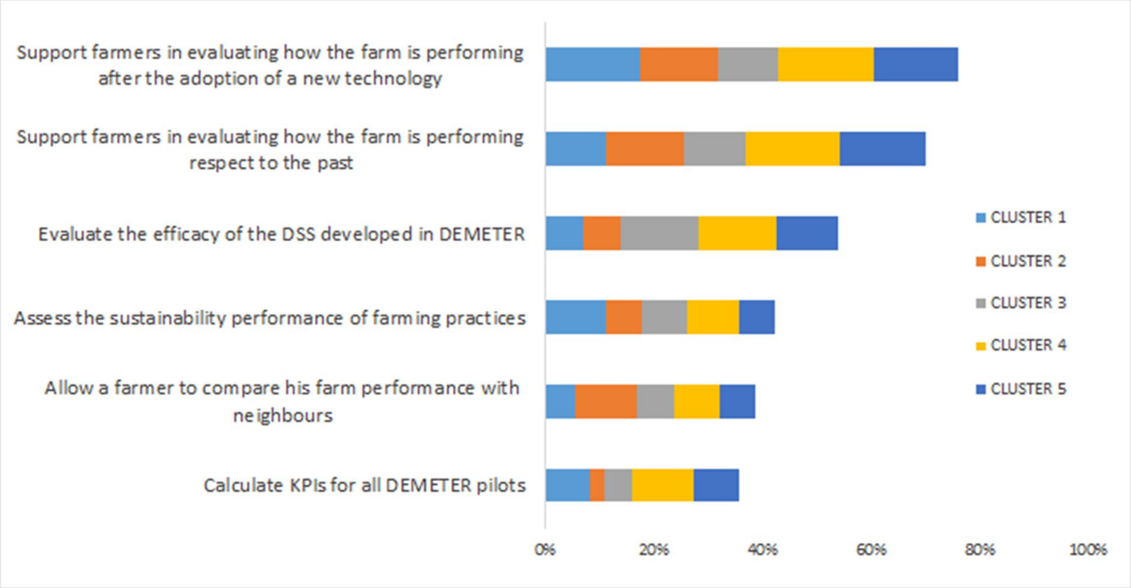


Figure 8. Total score of the index on what the benchmarking system should address

6.3.3 Results on requested indicators

The second section of the survey aimed to identify indicators to be used in the DEMETER benchmarking system.

Figure 9 shows the distribution of the answers for the proposed indicators for the DEMETER benchmarking system. All indicators were considered “essential” for 26% of the total answers and “desirable” for 37%; so, the proposed indicators were important for 63% of the total answers. All the proposed indicators were judged “unnecessary” for 37% of the total answers. The 20 pilots within DEMETER divided in five clusters are pretty heterogeneous, in terms of characteristics of the farms, activities and objectives. Therefore, the proposed indicators covered as much as possible all the pilot needs. Given the large heterogeneity, however, reaching 100% of pilot needs was impossible.

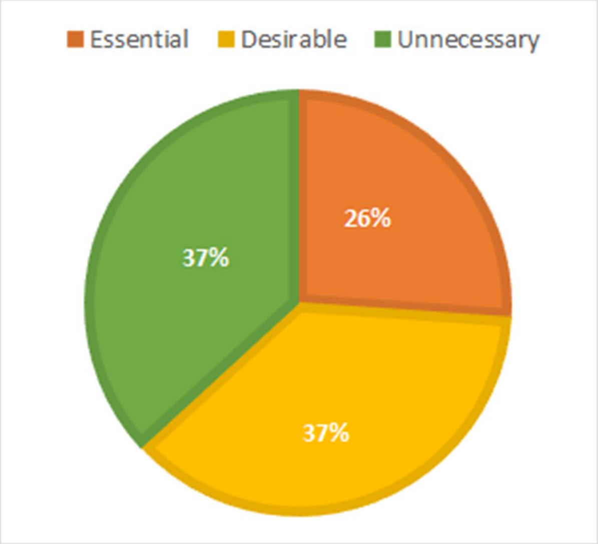


Figure 9. Distribution of the answers

Figure 10 displays the total score of the index on the suggested DEMETER indicators and distribution of the answers within the clusters. The indicator with the highest score, was yield1 (average yield, e.g., crop production in ton/ha per crop, livestock production by type, etc.) with homogeneous distribution within clusters, while the second scored (water efficiency - yield/total water) obtained less interest form cluster 2, due to the fact that cluster 2 is about agricultural machinery. Similarly behaved the third scored, which is related to the assessment of water footprint, linked somehow to the water efficiency index. The indicators on pesticide usage, on farm total costs and on farm profit, achieved a good score and a homogeneous distribution of interest within the five clusters.

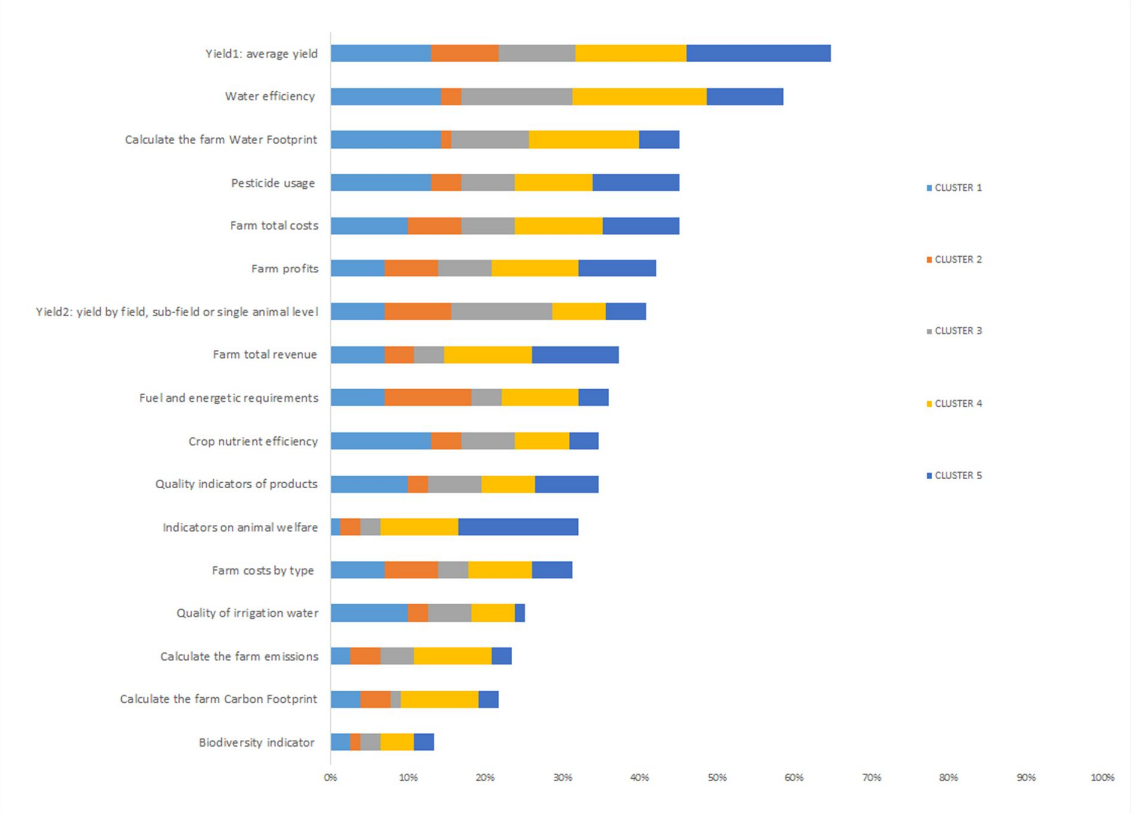


Figure 10. Total score of the index on the suggested DEMETER indicators

This question also included an open space to suggest new features or indicators, where we collected only one answer: "percent / number of identified farms to optimised costs, revenues or income; number of benchmarking analysis" for the pilot 2.4.

6.3.4 Results on data availability

In the section of the survey, which aimed to assess the data potentially available at the level of pilot farms, we proposed a set of data considered useful for the calculation of DEMETER benchmarking system indicators. As already explained above, we divided the types of data in three sections: farm general structure, farm input and output, farm economic data.

Although the results have to be considered preliminary due to the fact that the survey was addressed to pilot leaders and not to the final users, at the current stage of the project, a first picture can be drawn to plan the coming activities of the benchmarking system. This draft will be reviewed and completed following the farmer's point of view, within WP7 activity.

For each of the proposed types of data, it was possible to select the response: “surely available” (*sureAvail*, in the formula below), “probably available” (*probAvail*, in the formula below), “probably unavailable” (*probUnavail*), “do not know” (*dontKnow*), “unavailable”.

Also, for this section, the index was calculated, assigning a score to each answer:

$$Index = \frac{sureAvail + probAvail * 0.7 + probUnavail * 0.2 + dontKnow * 0.1}{total\ answers}$$

Regarding data on **farm general structure**, “surely available” was considered for 34% of the answers, “probably available” for 30% of the total answers and “unavailable” for only 10% of the answers (Figure 11).

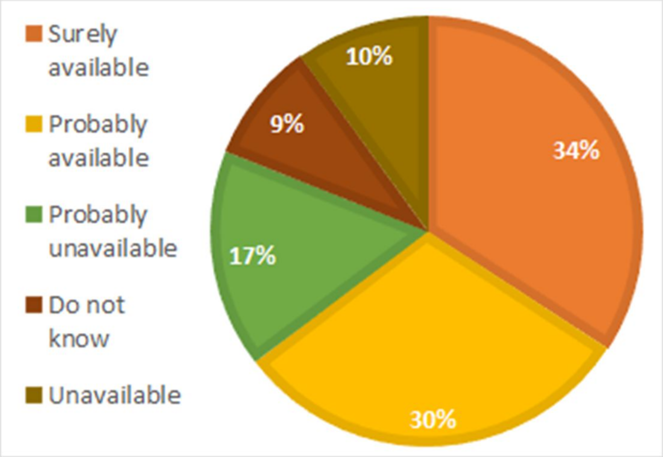


Figure 11. Distribution of the answers for assessing data availability on farm general structure

Figure 12 shows the total score of the index on assessing availability for data on farm general structure and distribution of the answers within the clusters. The highest index (91%) was obtained for farm general data (total surface, main crops, reared animals, …) and data of farm location (geographical coordinates) (87%).

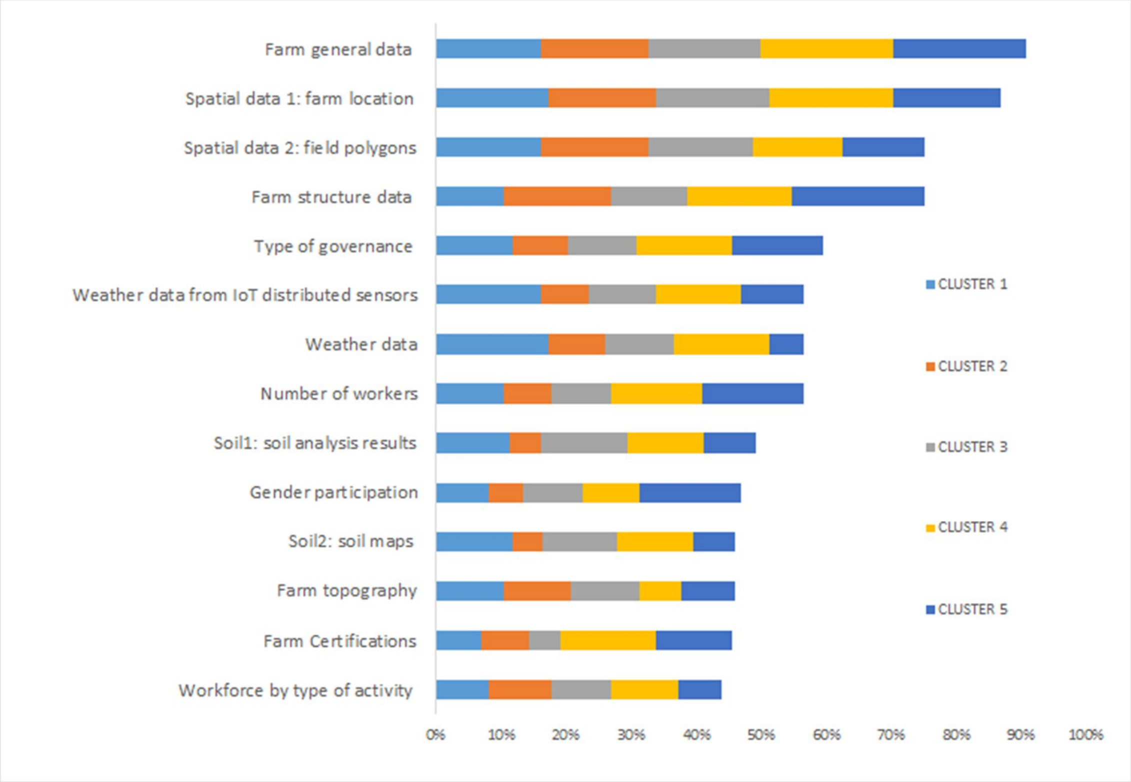


Figure 12. Total score of the index on assessing availability for data on farm general structure

The availability of data on farm input and output, obtained the results shown on Figure 13. Data proposed were considered "surely available" for 21% of the answers and "probably available" for 28% of the total answers, while "unavailable" for 22%.

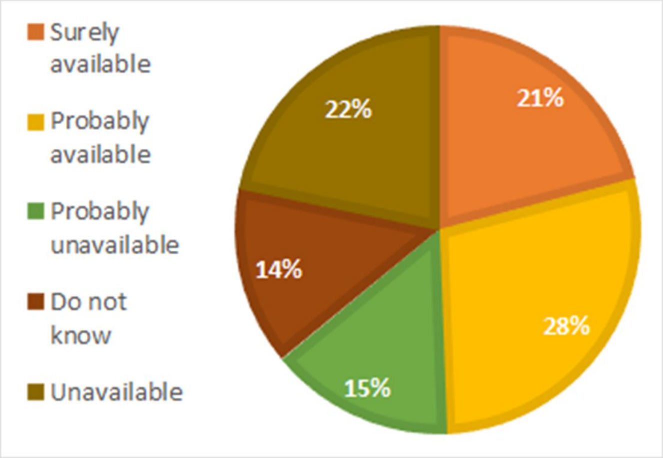


Figure 13. Distribution of the answers for assessing data availability on farm input - output data

Figure 14 displays the total score of the index on assessing availability for data on farm input - output and distribution of the answers within the clusters. Data on yield (as average for each crop) obtained the highest score, 62%, pesticide general use and fertilizer general consumption, obtained 60%.

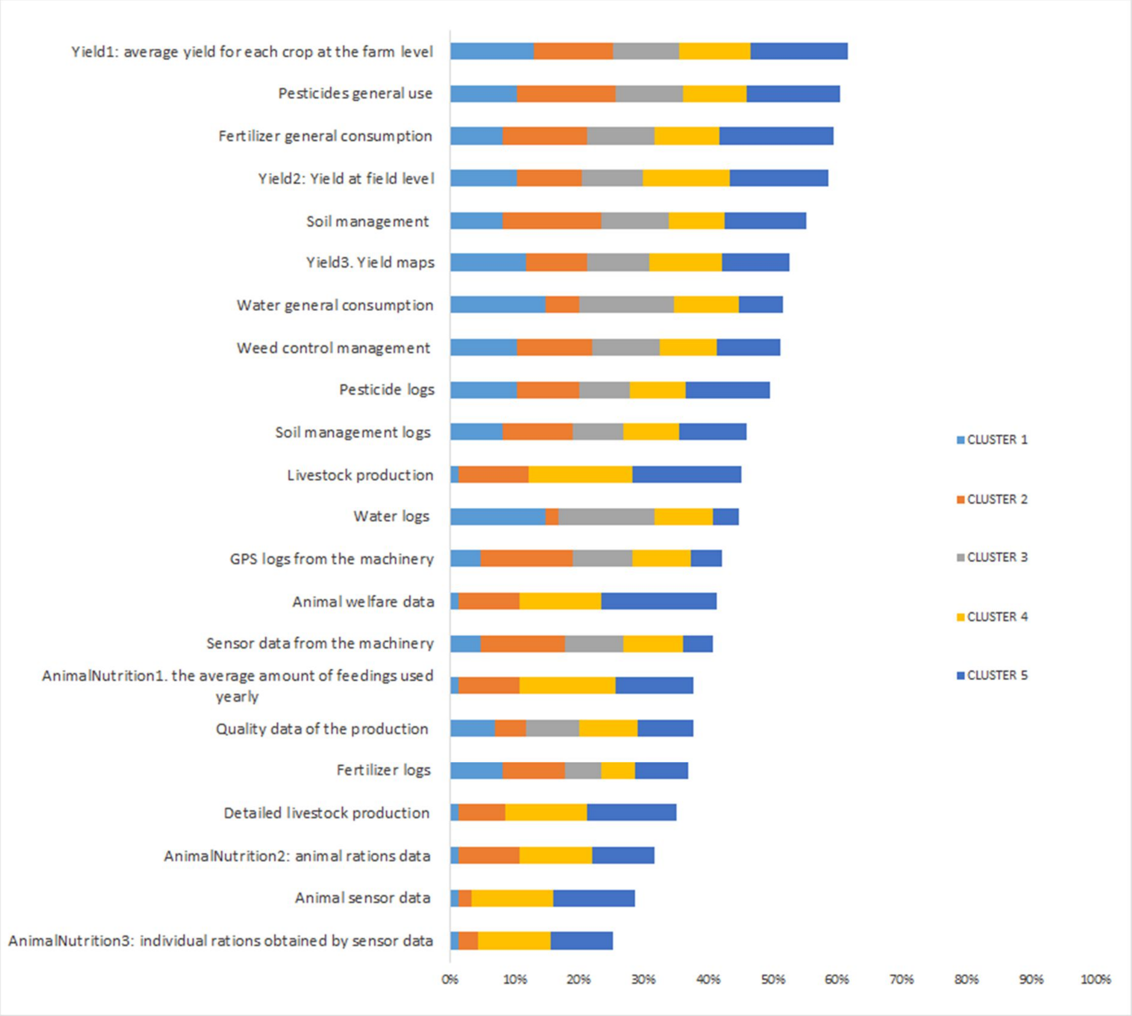


Figure 14. Total score of the index on assessing availability for data on farm input - output

Finally, for the economic data, we tried to assess the availability of some farm economic data. We did not address the willingness of farmers to share these types of data. According to the majority of pilot leaders, the data proposed are “probably available” at the farm level (46% of the answers) or “surely available” (13% of the total answers), while a low percentage (13%) declare that this data will be unavailable (Figure 15).

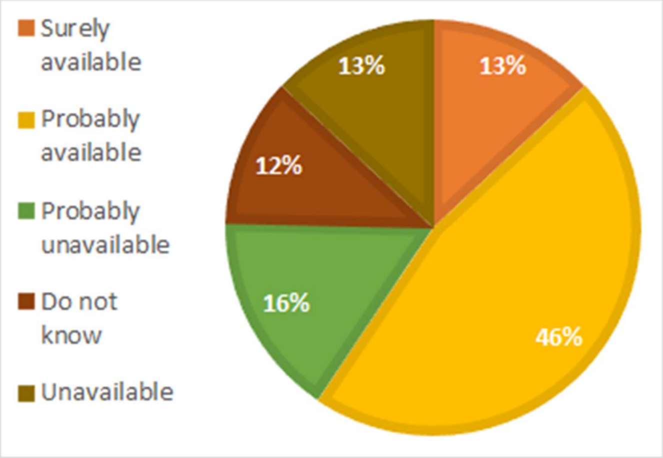


Figure 15. Distribution of the answers for assessing data availability on farm economic data

Figure 16 shows the total score of the index for assessing availability of data on farm economic data and distribution of the answers within the clusters. Data on farm revenue (average profit /year per farm) obtained the highest score, 55%, followed by data on costs (average estimation of farm yearly costs) with 54%.

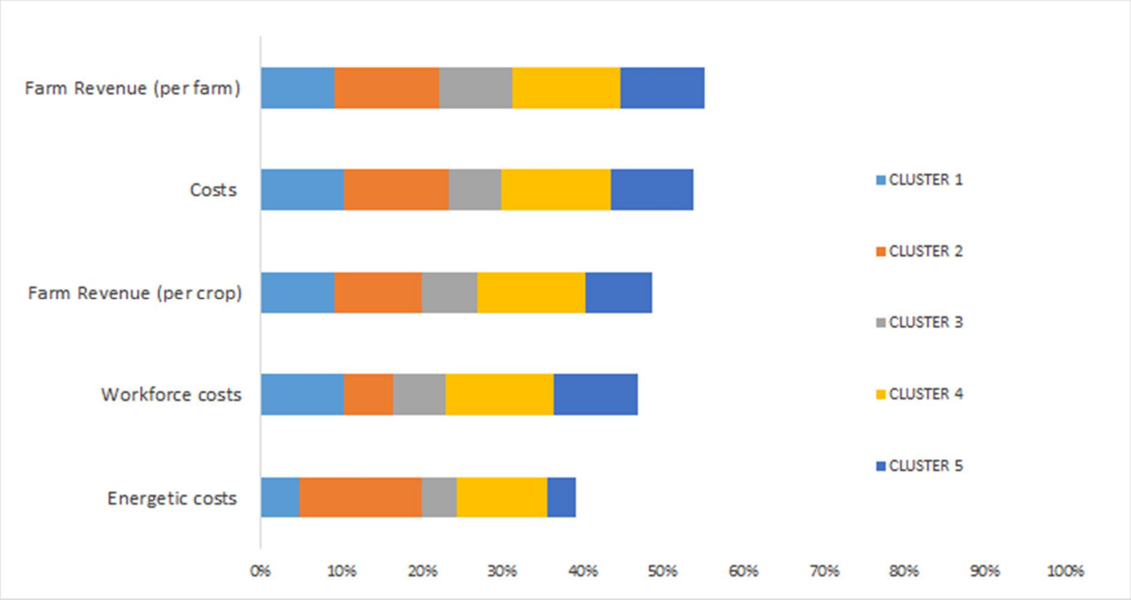


Figure 16. Total score of the index for assessing availability of data on farm economic data

7 Analysis of Results from Requirement Gathering

The results of the various requirement gathering activities were all analysed as the data became available. At this stage, the requirements are still fairly high level giving an idea of the types of components that would be needed to meet the pilots' needs.

The first of results to be received were the reference architecture instances for each of the pilots. Although the pilots had been asked to include a copy of this with the WP4 requirements, the results were analysed as they were being received by WP3. When, subsequently, the WP4 results were received, the combined set of results was compared and analysed. The architectural diagrams received from the pilots can be found in Annex B. The DSS requirement tables and high-level design ideas can be found in Annex C and Annex D respectively.

The following section describes the results of the initial analysis of the architectural diagrams which produced a list of possible components/solutions. This analysis grouped the result according to the WP5-defined Pilot Clusters. Further analysis of this list along with the more specific DSS requirements indicated that trying to organise the WP4 work based on the Pilot Clusters was not a good idea. Section 7.2 describes how the work was organised around a number of thematic "Areas" based on the DSS requirements. Unlike the pilot clusters, this is not a many-to-one relationship between pilots and Areas. Most pilots are associated with more than one Area and all Areas have more than one pilot.

7.1 DEMETER Reference Architecture Instances Summary

Analysis of the Reference Architecture Instances from each of the pilots produced a list of proposed DSS components to be implemented in the project. They have been listed in the tables below, which have been grouped by the Pilot Clusters as identified in section 6 of D5.1, i.e.:

- Pilot Cluster 1. Sector: Arable Crops. Focus: Water & Energy Management
- Pilot Cluster 2. Sector: Arable Crops. Focus: Agricultural Machinery, Precision Farming
- Pilot Cluster 3. Sector: Fruits and Vegetables. Focus: Health and high-quality crops
- Pilot Cluster 4. Sector: Livestock. Focus: Animal Health, High Quality & Optimal Management of Animal Products
- Pilot Cluster 5. Sector: Cross-Sectorial. Focus: Full supply chain, Interoperability, Robotics.

7.1.1 DEMETER Reference Architecture instances Summary for Pilot Cluster 1

Table 1. DEMETER Reference Architecture components proposed by pilots of Cluster 1

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
1.1 & 1.2	• Irrigation Systems Coordinator • Optimized cost & quality irrigation management application • Real time monitoring and water supply control application	• Crop Status Identification • Irrigation Req. Estimation • Fertilisation Req. Estimation • Financial Performance Benchmarking • Water Consumption Monitoring • Fertiliser Consumption Monitoring • Data Storage • Machine Learning & Data Exploitation	• Humidity • Temperature • Soil • Irrigation Control Devices • Weather • Water Consumption • Agriculture sensors and actuators	• LoRa • WIFI • Zigbee • GPRS • 3G • 4G	• Irrigation Systems • Remote Control Systems • MEGA: Irrigation Systems Coordinator • Smart Agriculture	• Weather (weather condition monitoring platform) • Imagery (Copernicus Sentinel 2 platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
1.3	• Smart Irrigation Service for Rice • Smart Irrigation Service for Maize • Fertilization Advisory Service for Rice & Maize	• Crop N uptake estimation • Rice irrigation needs estimation • Maize irrigation needs estimation • Rice N fertilisation needs estimation • Maize N fertilisation needs estimation • Financial performance benchmarking • Water consumption monitoring • Fertiliser application monitoring • Resource utilisation visualization	• SmartPaddy++ EC sensor • UAV imagery (multispectral & thermal) • SmartPaddy++ water height sensor • Tractors • Irrigation and drainage electrical valves • In-field remote weather station	• LoRa • WIFI • Zigbee • GPRS • 3G • 4G	• ELGO water salinity & height monitoring platform • Pix4D Mapper Pro • ELGO UAV thermal imagery analysis platform • ELGO multispectral imagery analysis platform • MESP (Mobile Environmental Sensing Platform) • Tractor VRA platform • IoT Infrastructure Control Platform	• EO (Planet EO platform) • Weather (NOA weather condition monitoring platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
1.4	• DSS Fertilization – Precision Farming / Yield Enhancement • DSS Irrigation – Irrigation Planning • Real time monitoring – Crop Health Status / Weather Alerts	• Crop Status Identification • Maize Irrigation Req. Estimation • GIS / Graphical Dashboard • Maize Fertilisation Req. Estimation • Fertiliser Management • Resource consumption Visualization • Agricultural Works Module	• Air Temperature, Pressure and Humidity Sensors • Wind Speed Sensors • Soil Temperature and Humidity Sensors • Precipitation sensors	• WIFI • 3G • 4G	• GeoScan On Site Meteorological Stations • INOVAGRIA Meteorological Platform • INOVAGRIA Farming Platform • APPR Statistical Data • (Offline data) UAV Pilot, Pest Sensors	• Imagery (Copernicus Sentinel 2 Platform)

7.1.2 DEMETER Reference Architecture instances Summary for Pilot Cluster 2

Table 2. DEMETER Reference Architecture components proposed by pilots of Cluster 2

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
2.1	• Machine Data Monitoring and Documentation	• Fraud detection? (hacked sensors?) (WP4/5?) • Data quality assessment (WP2) • DQ: Check if Data is compliant (WP2/5) • Data fusion with "EDB" (WP2?) • Data storage (WP3?) • Data analysis, NOx estimation (WP4/5) • Diesel consumption monitoring (WP4/5) • Emissions monitoring (WP4/5) • Additional Engine Data monitoring (WP4/5)	• Tractor + sensors • CAN Bus Adapter • dSpace Autobox • Test Computer • 4G Module • Storage Device	• WIFI • CAN BUS SAE J1939 • 3G • 4G	• COGNAC Platform • "Tractor Platform" • "IoT Infrastructure Control Platform"	• Legal Documents (External emission databases) • Machine Data (External testbench databases) • Machine Data (External machine databases)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
2.2	• Job cost calculation and prediction concepts • Automated documentation of arable crop farming processes	• Data Selection • Data Collection • Data quality assessment evaluation • Automated task documentation • Fixed costs calculation • Variable costs calculation • Total job cost calculation	• AutoTrack data (by John Deere / Farmer) • m2Xpert GPS data • Fixed cost data (by Farmer)	• GPRS • 4G	• My JD Operations Center • m2Xpert GPS APIs • COGNAC Platform • IoT Infrastructure Control Platform • Geospatial data Platform	• External agricultural cost databases • External geospatial DB

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
2.3	• Data Brokerage Service and Decision Support System for Farm Management	• Crop Status Identification • Farm work organization • Control of farm processes • Control of machines • Data analysis and data preparation • Financial Performance Benchmarking • Water consumption monitoring • Fertiliser consumption monitoring • Resource consumption visualization • Data storage	• NASA - Landsat • Common Agriculture Policy • INSPIRE • Drones • Copernicus open Access • Grout sensors • Tractor ISO Bus • Weather Meteoblue • Livestock data	• LoRa • WIFI • Zigbee • GPRS • 3G • 4G	• SensLog (Data management, Data analysis, Data publishing, User interface) • HSlayers NG (Data visualisation in 2D and 3D, Data analysis • Open Micka (Metadata management, Metadata Discovery) • Layman (Data management)	• Vector data (LPIS Land Parcel Information System official data of CAP) • Foodie (Foodie data model (Data are guaranteed by government)) • Telemetry (Farm Telemetry Data)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
2.4	• Farm Management System Virtual Farm eDWIN Benchmarking app for farmers • eODR - eDWIN back office Advisor’s tools • Report app / API Scientists and administration	• Economic size models • General benchmarking models • Accountancy benchmarking models • FADN individual report benchmarking	• Meteorological stations • Local sensors (tractor / field / soil)	• LoRa • GPRS • 3G • 4G • CAN	• eDWIN Farm Module • eDWIN Meteo Module • eDWIN DSS Module • eDWIN Alert Module • External Sensors Platform	• EU datasets (Eurostat, CAP, FADN) • Agro exchanges (Market information)

7.1.3 DEMETER Reference Architecture instances Summary for Pilot Cluster 3

Table 3. DEMETER Reference Architecture components proposed by pilots of Cluster 3

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
3.1	• Decision Support System to support olive growers	• Connector with External Weather data sources/sensors • Connector with External FMIS (DNET) • Machine Learning tools for Olive Yield Estimation • Olive Phenology Model Calibration • Agronomic Performance Benchmarking • Environmental Performance Benchmarking	• Smartphones • Weather Sensors • Soil Sensors • Automatic traps	• LoRa • WIFI • 3G • 4G	• Agricolus FMIS • Agricolus Water DSS • Agricolus Nutrient DSS • Agricolus Olive Fruit Fly DSS	• EO (Sentinel2) • Weather (Weather Station)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
3.2	• Decision Support System to support Mediterranean Woody Crops	• Crop Status Identification • Irrigation Estimation • Fertilisation Estimation • Pest & Disease Control • GIS/Graphical Dashboard • Data collection, management, fusion, storage • Machine learning and data exploitation • Connector w/external weather data sources/ sensors	• Machinery Data • Soil Sensors • Weather Stations • Crop Images • Smart Traps • Agriculture sensors and actuators	• LoRa • WIFI • Zigbee • GPRS • 3G • 4G	• Water DSS • Nutrient DSS • Pest & Disease DSS • Smart Agriculture	• Weather (Weather Condition Monitoring Platform) • Imagery (EO Platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
3.3	• DSS for Pest Management • Smart Pest Management App (Control, scheduling, …)	• Crop Status Identification • Farm work organization • Control of pest processes • Citric Fertilisation • Data analysis and data preparation • Financial Performance Benchmarking • Water consumption monitoring • Pesticide level monitoring • Imagery Classification • Labelled Datasets for Training • Insect Recognition	• Common Agriculture Policy • Soil Sensors • Weather Stations • Pest Control Devices • Automatic Traps	• LoRa • WIFI • Zigbee • GPRS • 3G • 4G	• IoT Data Capture & Monitoring Platform • AI Powered Computer Vision Solution • MESP (Mobile Environmental Sensing Platform)	• Weather (NOAA weather condition monitoring platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
3.4	• DSS Variable Rate Application • DSS Crop yield prediction with irrigation scenarios • Data visualizations	• Machine Learning Yield Prediction with EO data • Machine Learning Optimal Irrigation Scheduler • Task Map Generator Variable Rate Applications (EO data) • Potato variety selector	• AVR Machine Data • Soil sensors (optional) • Weather Stations (optional) • Laptop/smartphone WIG application	• LoRa • WIFI • 3G • 4G	• AVR Connect • VITO WatchItGrow (WIG) • IoT Cloud Soil Sensors (optional) • IoT Cloud Weather Stations (optional)	• EO Copernicus (TimeSeries Service openEO) • Weather (National Meteo Service) • Soil Info (Soil Map Service)

7.1.4 DEMETER Reference Architecture instances Summary for Pilot Cluster 4

Table 4. DEMETER Reference Architecture components proposed by pilots of Cluster 4

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
4.1	• Farmers Dashboard - with Climate Accounting/Benchmarking and Milk production prediction ++	• Climate Accounting • Financial Performance Benchmarking • Economic Performance • Cow Growth Function model • Lactation curves algorithms • Milk volume model • Milkman forecast • Supplier order Payment	• Feeding equipment sensors • Cow health sensors • Milk fat sensor + other sensors/sources • Milking robot • Automated data capture	• LoRa • WIFI • Zigbee • GPRS • 3G • 4G	• MIMIRO • Amazon AWS SageMaker • AGRIFLOW • Microsoft MS Azure++	• Weather • EO (Planet EO Platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
4.2	• Milk Processing and Labelling traceability • DSS Animal (livestock) Welfare	• Data Collection & Aggregation • Data Synchronization • Data Mashup • Data Management • Data Enrichment (?) • Data Fusion • Breeding Farm animal metrics (welfare) • Milk quality & composition monitoring • Milk production monitoring • Data Analytics • Traceability Management	• Pedometer (rest of the animal monitoring) • Data Log (animal temperature) • AfiLab (milk quality: fat, protein, lactose) • AfiCollar (rumination, eating habits) • Milko-Box MKII (real-time milk analysis) • MilkoScan FTIR (offline milk analysis)	• WIFI • 3G • 4G	• DataLogger Legacy Server • AfiActII Legacy Server (Pedometer) • AfiFarm 5.3 Legacy Server (AfiLab, AfiCollar) • Milk Box Legacy Server (milk quality) • FTIR Legacy Server (traceability)	• RP (Rinkeby Platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
4.3	• Mobile Application • Data visualization • Bespoke Analog Front End • Data management system (data processing, data analytics, visualization)	• Milk predictive data analytics • PANDA Access Control and Authentication • Cow welfare and Health scoring system • KAFKA producer • Animal illness indicating system	• Pedometer sensors • Accelerometers (Zoetis ear tag) • Lely robot (Automatic milking system) • Body condition (cow) • Disease diagnostic System (hardware) • Conventional milking system performance data	• Azure/ AWS/ MindSphere and Smart Bow tag • LoRa • WIFI • 3G • 4G	• Herd management software • SmartBow platform • SmartBow platform	• SmartBow Cloud Platform (Farm based servers) • Body scoring index (Cow) (Farm based servers)
4.4	• Farmers management application	• Product Passport (place of production, time of slaughter, etc) • Stress recognition • Food travel assessment • Environment condition assessment • Instructions advices for consumption • Power losses • Silo conditions detection	• IoT Data (air speed, CO_2, temp, humidity) • Camera (Audio/Video) • Poultry feeding • Energy meter • Water consumption • GPS Location	• LoRa • WIFI • GPRS • 3G • 4G	• poultryNET • Fleet monitoring platform • SILO monitoring • Farm ERP	

7.1.5 DEMETER Reference Architecture instances Summary for Pilot Cluster 5

Table 5. DEMETER Reference Architecture components proposed by pilots of Cluster 5

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
5.1	• Farmers application	• Product Passport: production place, env. data, time of harvest, disease model, storage, transport condition • Data Analytics • Decision Support • Machinery/sprayer control • Disease recognition • Location assessment	• Tractor • GS1 Digital Link 2D Barcode (QR) • Pheromone trap • Camera • IoT data (Soil moisture, temp, hum, leaf wetness • GPS tracker • Sprayer/robot	• NB-IOT • MQTT • WIFI • GPRS • 3G • 4G	• Product passport platform • Fleet monitoring platform • Network operating system • AgroNET • FEDE Machinery control • Companies ERP	• OriginTrail Decentralized Network /Ethereum • Weather (Weather condition monitoring platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
5.2	• Farmers management application	• Product Passport (place of production, time of slaughter, etc) • Stress recognition • Food travel assessment • Environment condition assessment • Instructions advices for consumption • Power losses • Silo conditions detection	• IoT Data (air speed, CO_2, temp, humidity) • Camera (Audio/Video) • Poultry feeding • Energy meter • Water consumption • GPS Location	• LoRa • WIFI • GPRS • 3G • 4G	• poultryNET • Fleet monitoring platform • SILO monitoring • Farm ERP	
5.3	• Apiary Management System ControlBee • Farm Management System Virtual Farm eDWIN	• Crop Type Identification • Crop Status Identification • Pollination Req. Estimation • Pollination Matching • Spraying Alerts • Territorial Alerts (pest, meteo, etc.) • Yield Benchmarking (per field)	• Hive Sensor • Hive scale • Hive GPS • Farm meteo station	• LoRa • WIFI • Zigbee • GPRS • 3G • 4G	• ControlBee apiary monitoring module • eDWIN farm module • eDWIN pest module • eDWIN alert module • eDWIN meteo module	• EO (Planet EO platform)

Pilot	DEMETER-enabled Applications	Proposed enablers	Data sources	Technologies	Smart Farming Platforms and Systems	Public resources
5.4	• Farmers management application	• Product Passport (place of production, time of slaughter, etc) • Stress recognition • Food travel assessment • Environment condition assessment • Instructions advices for consumption • Data Analytics	• GS1 Digital Link Barcode tags • IoT Data (air speed, CO_2, temp, humidity) • Camera (Audio/Video) • Poultry feeding • GPS tracker	• LoRa • WIFI • GPRS • 3G • 4G	• Product passport platform • Fleet monitoring platform • Network operating system • AgroNET • FEDE Machinery control • Companies ERP	• OriginTrail Decentralized Network /Ethereum • Poultry Consumption market data

7.2 DEMETER Reference Architecture Common Components

DEMETER Reference Architecture from all the pilots, has produced a set of applications and related components related to the Decision Support System. These architecture diagrams, together with a brief summary, are listed in Annex B. The results from the WP4 requirements gathering exercise also provided a list of components. The information received from this exercise can be found in Annex C and Annex D. However, due to inconsistencies in the information supplied, these lists were not the same. The information from both these sources were combined and analysed. Similar requirements were combined to hopefully allow the same component to be used with several pilots. This information was then checked with the pilots again to ensure that the components were acceptable for their use. These components were then grouped into thematic "Areas" as described in the following section to encourage the cooperation on common areas, whilst acknowledging that the breadth of the agricultural activities covered by DEMETER means that there will be no solution that will fit all pilots or all Areas.

7.2.1 DEMETER Decision Support Focus Areas

The requests from the pilots need to be grouped in order to define a set of reusable components that can be integrated in a set of applications and shared across different pilots. Along with pilots and WP5, a set of **Decision Support Focus Areas** was proposed and refined to group together all the components related to the same end users' decision.

The areas have been reviewed also with the other related WPs:

- WP2/WP3: the requests from pilots have been cross-checked with WP2 and WP3 to assess the competences, it has been defined that the general knowledge extraction activities will be performed by WP2 and that the AI-based data analysis with a specific decision target will be done by WP4;
- WP5: the areas have been reviewed with WP5 and all pilots, and it has been ensured that each pilot will belong to at least one main area, and each area will contain more than 1 pilot; the pilot areas and requests have been also verified with Task 5.5 (cross-pilots activities);
- WP7: the result of the pilots mapping activities has been verified with the stakeholder analysis performed by WP7 to share the same areas definition.

We have analysed the agronomic decisions considering the two typologies of farming:

Crop Farming:

- **A - Crop Growth, Status and Yield**: decisions related to the assessment of plant condition, crop stage and harvesting.
- **B - Irrigation Management**: water management and irrigation, estimating the water requirements, define the optimal scheduling of the irrigations.
- **C - Nutrition Management**: decisions related to the fertilisation, and management of crop nutrition issues.
- **D - Machinery and Field Operations**: tillage operations, machinery management, analysis of machine-related data.
- **E - Pest and Disease Management**: decision related the control actions to reduce the impact of pest and disease on the production.

Livestock Farming:

- **F - Animal Yield**: decision related to the feeding, animal husbandry and the analysis and prediction of product quantity and quality.

- **G - Animal Welfare**: decision related to the monitoring and the improvement of animal welfare.

For analysing the general decisions about farm management, two more areas have been created:

- **H - Traceability**: involving the decision related to the marketing decisions and the food traceability along the food chain.
- **I - Benchmarking**: monitoring economic, agronomic, and environmental farming performances, and to support farmers in choosing the right technologies to improve the performance.

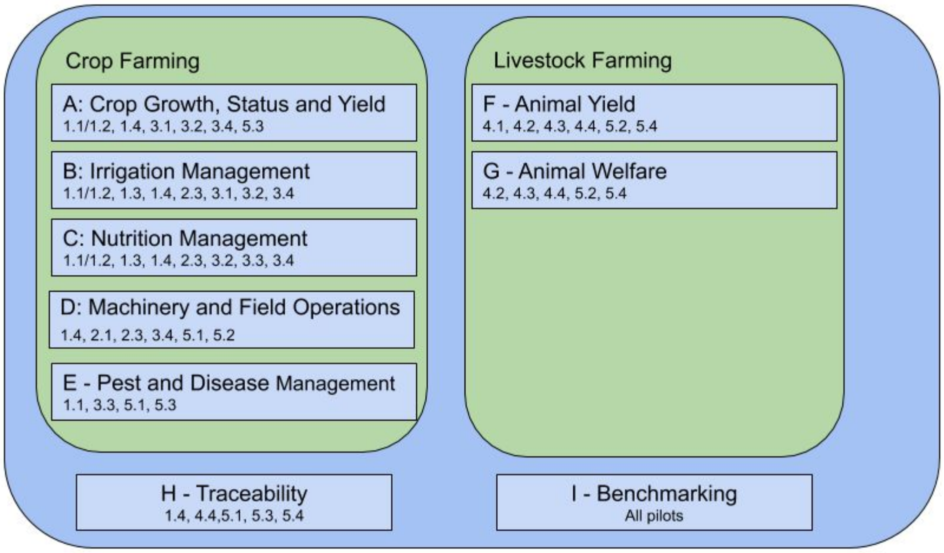


Figure 17. DEMETER Decision Support Focus Areas

7.2.2 Analysis of pilots-related component

After a survey with pilot leaders on the components of each pilot, the pilot components have been associated with the proposed areas.

In DEMETER there will be two activities involving Decision Support System components:

- WP4: AI-related Decision-making and Benchmarking components developed in WP4 to be re-used and integrated in pilots.
- WP5: already existing DSS from partners that needs to be integrated in the DEMETER platform; these components may be:
  - shareable/re-usable: potentially re-usable by other pilots and/or integrated with the WP4 components; the component sharing between pilots will be regulated by Task 5.5; WP4 will collaborate to ensure the correct integration of generic and pilots-specific components.
  - private: the components, at the moment, are related to the application of a specific pilot only.

WP5 is not developing any new component, however both WP5 and WP4 have a number of existing systems that are being “DEMETER-ised” and hence can be used as components. These existing systems were not designed according to DEMETER components so they may not encompass functionality from all the WPs.

The WP5 shareable components can be used in other situations without any changes. The WP5 re-usable components can be used in other situations with a possible provisioning step (e.g., supplying a model). The WP5 private components are related to specific pilots only.

The results of this survey with pilot's leaders are reported in Table 6.

Table 6. Results of the survey with pilot leaders on the development of components for each area

Pilots	A Crop Growth	B Irrigation	C Fertilisation	D Machinery	E Pest & Disease	F Animal Yield	G Animal Welfare	H Traceability	I Benchmark
1.1/1.2	WP5	WP5	WP4		WP4				yes
1.3		WP4	WP4						yes
1.4	WP4	WP4	WP4	WP5 private				WP5 private	yes
2.1				WP5 private					yes
2.2									yes
2.3		WP5	WP5	WP5					yes
2.4									yes
3.1	WP4	WP5	WP5		WP5				yes
3.2	WP4	WP5 private	WP5		WP5				yes
3.3			WP4		wp4				yes
3.4	WP4	WP4		WP5					yes
4.1						WP5			yes
4.2						WP4	WP4		yes
4.3						WP5	WP4		yes
4.4						WP5 private	WP5	WP4	yes
5.1				WP4	WP4			WP5	yes
5.2				WP5 private		WP5	WP5	WP5 private	yes
5.3	WP4				WP4				yes
5.4						WP5 private	WP5	WP4	yes

7.3 Results from Requirements Analysis: WP4 Generic Components

It must be pointed out that many enablers from those reported in the different pilot architectures have been left out. Such components were related to other WPs related and technical issues (e.g., data storage, pre-processing, ML techniques application, weather data, etc.). In this analysis only the decision-related components are considered.

Within a decision area, each pilot request has been associated with a potential general component developed in WP4. We consider the WP4 components as generic DEMETER enablers, dedicated to support the farmers in taking one type of decision and that have a fixed data structure for input and output.

In the next sections the state of the art for Decision Support Systems (8) and Benchmarking (9) will be depicted with a preliminary description of the most requested generic components. Nevertheless, a more detailed image of the requirements of the different pilots to evaluate the necessary operations to be carried out with the data, as well as its format (that will be defined by the Agriculture Information Model to be used in the project) would be required to continue in the creation of enablers that might be applicable to different pilots.

Nevertheless, a more detailed image of the requirements of the different pilots to evaluate the necessary operations to be carried out with the data, as well as their format (that will be defined by the Agriculture Information Model to be used in the project) would be required to continue in the creation of enablers that might be applicable to different pilots.

The Table 7 lists all the general components that could be developed for WP4 including those pre-existing components that are being modified to match the DEMETER architecture as part of WP5 and the private components which only apply to a particular pilot.

As the DSS components and other enablers are run as microservices, they have no direct user interface of their own. They may be driven by other applications and/or the Visualisation Dashboards via a REST interface which can be used to obtain the required results. To get a preliminary view of the output expected by the pilots, they were each asked to supply a mock-up of the Visualisation that that they would expect to see for their pilots. It is assumed, at this stage, that the output to Visualisation will be the same as, or a superset of, output required by applications. As Visualisation will be covered in D4.2 and not in this document and because the actual visualisations are likely to be modified in light of the attempt to common up some components within individual WP4 Component Areas these visualisation mock-ups will not be presented here. These requirements are likely to evolve over time and may not be fixed until the next round of Deliverables, D4.3 and D4.4. Some textual information about output requirement for the Area Components will be provided in D4.2 but the revised visualisation will be defined after D4.2 has been submitted.

Table 7. Proposed General Components

Area	General component	Pilot	Responsible	Pilot-defined component
A - Crop Growth, Status and Yield	A.1 Plant yield estimation	1.1	WP5	Estimate crop yield using satellite Sentinel2 data
		1.4	WP4	Evaluation of the current status of the crop from the different data sources available
		3.1	WP4	Estimate olive yield from remote sensing data
		3.2	WP4	Estimate crop yield using remote data and ground data
		3.4	WP4	Predict the expected yield under a selection of future meteo scenarios
		5.3	WP4	Compare the crop yields per field to similar field with similar crop types
	A.2 Plant phenology estimation	3.1	WP4	Predict olive phenology phases from weather data using ML
		5.3	WP4	Estimate crop maturity per field
	A.3 Plant stress detection	1.1	WP5	Detect the plant stress
		3.2	WP5	Detect crop status (water stress, water irrigations, fertilization) for woody crops
	A.4 detect crop type	5.3	WP4	Pollination matching
		5.3	WP4	Identify crop type per field based on satellite imagery
	A.5 estimate beehive	5.3	WP4	Estimate the number of bees/hives required to pollinate each field
B - Irrigation Management	B.1 Water balance model	1.1	WP5	MML tools for irrigation needs estimation.
		1.1	WP5	Detect crop water needs; calculate evapotranspiration
		1.3	WP4	Estimate the water requirements for corn
		1.3	WP4	Estimate the water requirements for rice
		1.4	WP4	Identify water needs for crops from different data sources available
		2.3	WP5	Estimate the water requirements and consumption
		3.1	WP5	Olive DSS for irrigation

Area	General component	Pilot	Responsible	Pilot-defined component
		3.2	WP5 private	Plant water requirements and soil availability
		3.2	WP5 private	Estimation of soil water availability
		3.4	WP4	Predict yield with specific irrigation scenarios
	B.2 Data fusion for irrigation	1.1	WP5	Actions on field actuators for optimal irrigation. Water consumption monitoring
		1.3	WP5	Monitorization of the water resources used
C - Fertilisation Management	C.1 Nitrogen balance model	1.1	WP4	Nutrient balance for fertilisation
		1.3	WP4	Estimate the nitrogen requirements using soil, weather, and crop data
		1.4	WP4	Identify fertilizer need for crops from different data sources available
		2.3	WP5	Estimate the nutrient consumption
		3.1	WP5	Olive DSS for fertilization
		3.2	WP5 private	Estimation online fertilizers consumptions
		3.2	WP5	Plant nutrient requirements and soil availability
		3.2	WP5	Estimation of soil availability and online fertilizers consumptions
		3.3	WP4	Monitorization of the fertilization processes followed in citric crops
	C.2 Nutrient monitor	1.1	WP4	Monitorization of the fertilisation needs
		1.3	WP5	Monitorization of the fertiliser consumption
		1.4	WP5 private	Fertilizer data management component
D - Machinery and Field Operations	D.1 Emission	2.1	WP5 private	Estimate the NOx based on different (engine) data
		2.1	WP5 private	Using on-board sensors for monitoring engine data (e.g. emissions) as well as data of the exhaust gas after treatment will help to monitor that machines follow the regulations

Area	General component	Pilot	Responsible	Pilot-defined component
		2.1	WP5 private	Using on-board sensors for monitoring engine data (e.g. Diesel consumption) as well as data of the exhaust gas after treatment will help to monitor that machines follow the regulations.
		2.1	WP5 private	Extend the pilot specific data by using external data bases regarding NOx values or emission data to enrich the analysis possibilities
	D.2 Field operation	1.4	WP5 private	Farm process management component
		2.3	WP5	Control of farm processes
		2.3	WP5	Control of machines
		2.3	WP5	Farm work organization
		5.2	WP5 private	Farm work organization
	D.3 Variable rate	3.4	WP5	Convert NDVI or FAPAR map to a map that can be used to control amount of fertilizer or water
		5.2	WP5 private	Control of machines
		5.1	WP4	Instructions for spraying for the sprayer based on the collected data
E - Pest & Disease Management	E.1 Computer vision-based counting module	3.3	WP4	Classification of the images about insect according to their content
		3.3	WP4	Recognition of insects from imagery data
		5.3	WP4	Detect and analyse the amount of varroa mites present in each hive
	E.2 Pest prediction	3.1	WP5	DSS for olive fruit fly pest management
		5.1	WP4	Decision support for orchard & grapevine
	E.3 Pesticide monitoring	1.1	WP4	Control of the pesticide processes
		3.3	WP4	Control of the different processes related to the pest management
		5.3	WP4	Analyse apiary locations and cross reference with intended spraying operations

Area	General component	Pilot	Responsible	Pilot-defined component
F - Animal Yield	F.1 Estimate milk production	5.2	WP5 private	DSS for animal production and quality
		4.1	WP5 private	Based on observed and predicted milk production, fertility and health, animal economical value is predicted
		4.1	WP5 private	Based on observed and predicted milk production, feed requirement is calculated to optimize herd forage production. Observed feed intake and milk production are used to calculate feed efficiency and the cost of feed into milk
		4.1	WP5	Analyse and predict milk yield based on animal individual lactation curves. Aggregated to herd level.
		4.1	WP5	Analyse and predict milk fat content
		4.2	WP4	Analyse and predict, lactation days, milking days
		4.2	WP4	Analyse and predict milk nutritional values
		4.3	WP5	Analyse cattle performance within the automated milking system
		5.2	WP5 private	Optimize cattle production
	F2. Poultry feeding	4.4	WP5 private	Silo conditions detection for poultry feeding data
		5.4/ 4.4	WP5 private	Silo conditions detection for poultry feeding data
G - Animal Welfare	G.1 Estimate animal welfare condition	4.2	WP4	Predictive analytics to drive decisions in livestock production, health, and welfare comparison for the accuracy of the classifiers created
		4.2	WP4	DSS should also be able to display recommended actions to correct and improve animal welfare measures and consequently milk quality
		4.3	WP4	From Ear Tag behaviour characteristics to be monitored may include cow grazing time, rumination time, activity, and movement

Area	General component	Pilot	Responsible	Pilot-defined component
		5.2	WP5 private	Optimize cattle animal welfare
	G.2 Poultry stress recognition	5.4/ 4.4	WP5 private	Detect poultry stress
		5.4/ 4.4	WP5	Evaluate the potential stress on chicken due to power loss
		5.4/ 4.4	WP5	Environment condition assessment for poultry
		5.4/ 4.4	WP4	Advices for farmers
H - Traceability[1]	H.1 Traceability	5.4/ 4.4	WP5	Composed data about the product from the various input data collections
	H.2 Product preference	5.2	WP5 private	Machine learning tools for product preferences
	H.3 Transport Condition	5.4/4 .4	WP5	Assessment of transport condition of food
I - Benchmarking tool[2]	I.1 Generic benchmarking	1.1	WP4	Benchmarking solution
		1.3	WP4	Benchmarking solution
		1.4	WP4	Generic Benchmarking requirements
		2.4	WP4	First level farm comparison
		3.3	WP4	Monitorization of the pesticide resources consumed for pest control
	I.2 Neighbour benchmarking	2.4	WP4	Second level farm comparison

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[1] The traceability section is dealing mainly with data management rather than with Decision Support Tools. At the moment, there are no direct requests to WP4 for DSS enablers in this area

[2] In the benchmarking table, we are listing the explicit requests from pilots to the Benchmarking Tool, however the Benchmarking tool will be open to all the pilots

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Area	General component	Pilot	Responsible	Pilot-defined component
		3.1	WP4	Compare the olive orchard yield and costs with similar farms, assess the DSS benefits
		4.1	WP4	Compare milk production, i.e., milk yield and milk chemical composition to identify areas of improvement
		4.2	WP4	Allow farmers to compare milk production in time; and to benchmark technologies
	I.3 Technical benchmarking	1.4	WP5 private	Farm resources management component
		2.2	WP5 private	John Deere will define a concept of how to calculate different cost data related to fixed costs.
		2.2	WP5 private	Estimate job cost calculation using maps overlay
		2.2	WP5 private	John Deere will define a concept of how to calculate different cost data related to variable costs.
		1.3	WP4	Financial status estimation focused on fertilisation and watering resources
		2.1	WP4	Compare the results of our NOx estimation (and maybe also the real measured value) with existing (regulation) thresholds and use this as benchmarking
		2.3	WP5	Farm data brokerage establishes a trust-based and compliant data market for agricultural enterprise data
		2.4	WP4	DSS to support economic decision in farmers
		3.2	WP5	Financial status estimation focused on fertilisation and watering resources and pest and diseases treatments costs
		3.3	WP4	Benchmarking solution
		4.1	WP4	Feed is the highest running cost in modern milk production. Feed efficiency is a critical factor and shows a high variation between farms
		4.1	WP4	Compare and identify changes and variation to improve financial return

8 Decision Support Tools

8.1 Decision Support Systems in the Digital Agriculture Domain

Decision support systems (DSS) are information systems that support business or organizations in decision-making activities. They serve the managerial and operational levels of an organization in making decisions in complex and potentially rapidly changing environments. Typically, DSS are aimed at less well-structured problems which require flexible and adaptable decision-making processes, supported by simulation models, data analytics and/or knowledge representation and reasoning techniques which are usually presented in a user-friendly non-technical way [2].

Recent advances in the field of Artificial Intelligence, especially around machine and deep learning led to an increasing adoption of those techniques for decision support systems. These AI-integrated decision support systems are increasingly used in various fields ranging from finance to healthcare, marketing and cybersecurity [3]. Also, the agricultural domain broadly employed machine- and deep learning techniques for various use cases, such as, e.g., crop yield prediction or disease detection. Two comprehensive reviews about the usage of machine learning and deep learning techniques in the agriculture domain were provided by Liakos et al. [4] and Kamilaris & Prenafeta, [5], respectively.

A survey by Rose et al. [6] unveils that, in 2015, 49% of farmers in the UK used some kind of decision support tool to inform decisions and in the group of 782 survey participants a staggering number of 395 different tools were identified to be in use. Even though the UK survey results might not be perfectly transferable to other European countries, it still clearly illustrates the heterogeneity of DSS tools in the agricultural domain and the need for a homogenization of the tool landscape. On the other hand, the survey shows that roughly every second farmer uses decision support tools for their daily work, which underlines the significance and importance of DSS and the reliance on data-driven support in the farm management process. It is self-evident that the high reliance of farmers on DSS, demands for an adoption of state-of-the-art machine- and deep learning approaches to ensure that the best-possible decision support is provided.

The project 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. Solutions for Decision Support based on data science, Machine Learning and Artificial Intelligence are the focus of the present section.

8.2 State of the Art Artificial Intelligence Tools for Decision Support

Over the past decade, machine learning techniques have been deployed across precision agriculture to provide more accurate solutions, mainly because of the capability to handle highly complex and non-linear agricultural problems. While agronomic or parametric models will play a role in the interpretation of data, big data transforms agriculture from model to data-driven (non-parametric). Learning from these massive data collections is likely to identify significant opportunities. The evolution of agricultural system models in precision agriculture is ongoing, making attempts to map inter- and intra-field variability, identify underperforming areas, and develop effective decision support systems. Parametric methods proved to be successful in extracting variables designed for local conditions, but they have limited applicability in a broader operational setting.

The high complexity and non-linearity of problems faced in agriculture required methods able to approximate complex mappings by integrating data coming from different sources and exploiting the information contained in the obtained reference samples. These methodologies are represented by machine learning techniques. Artificial neural networks (ANN), support vector machines, decision trees, and random forests are common machine learning techniques, frequently applied for agricultural management purposes [7].

Surveys refer to ANNs as a powerful tool for crop yield estimation, as the relationship between variables is not known and is complex, but they require a large amount of data to train. Due to lack of data, the alternative solutions which are simpler to train, were most popular in recent years, including support vector machines (SVMs), decision trees (DTs) and random forests (RFs). Support vector machines (SVMs), unlike other kernel methods, have good intrinsic generalization ability and are relatively robust to noise in the training data.

Decision Trees (DT) have been used more frequently in classification applications, but target variables can also take continuous values (e.g., regression trees that predict yield responses from soil variables). The term Classification And Regression Tree (CART) is an umbrella term used to refer to both of the above cases, classification and regression.

Deep Learning (DL) is a quite promising technique that extends classical ANN by adding more complexity ("depth") into the model. Deep learning has become an important technique in computer vision, speech recognition and natural language processing, and time series analysis. Nevertheless, such complex neural networks with a huge number of features and fully connected dense layers are prone to overfitting. Deep learning requires large datasets to work well and appropriate infrastructure.

Looking at DEMETER DSS, the different ML algorithms developed and/or proposed by WP2 as well as WP4 activities will be injected into the different DSS components by using an approach similar to the diagram below, which may evolve once the project enters into the development phases:

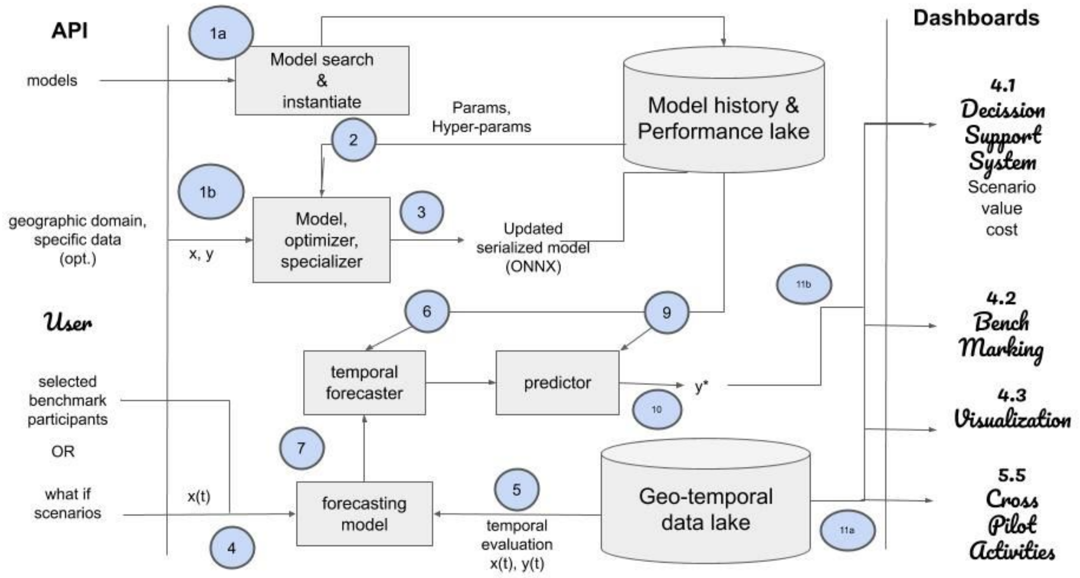

Figure 18. Diagram of the system including two main interfaces

An Application Programming Interface (API) is represented on the left of the diagram, while the set of Decision Support, Benchmarking and Visualization user-facing tools (as well as any cross-pilot activities to be carried out in 5.5) are consumed through Dashboards represented on the right.

A typical interaction scenario is played out in the diagram above by following in order the actions and steps indicated by a circled ordinal index. In particular:

I. A user accesses a trained model repository search engine interface (1a) and potentially provides novel data specific to a geographic domain of interest (1b). The search engine accesses a Model History and Performance database, and returns a selected set of trained models together with their current performance (2) to a Model optimizer/specializer that uses the new data to update the model before returning it to the Model DB (3).

II. The updated /specialized models obtained from the Model DB (6) can be used for prediction in the sense of regression (9) or in the sense of forecasting of temporal series (7) or both (8) based on what-if scenarios or benchmark participants (4), evaluating their performance versus data from a Geo-temporal Data Lake (5). The obtained predicted data can be fed back to the Geo-Temporal data lake or be forwarded for user consumption via the Dashboards on the right-hand side of the diagram (10, 11a, 11b).

The system described above is very adaptable and will be used in at least two DEMETER solutions. Other solution may require more specific components and others will be using pre-existing DSS components which are being DEMETER-ised. There will, therefore, be several DEMETER DSS systems with varying degrees of re-usability.

In the following sections we analyse the state of the art of the Decision Support Systems in agricultural domain for each of the Decision Support Areas identified in the section 7.2.

8.2.1 Growth & Yield Detection/prediction for Crops

Yield estimation is one of the most important topics in precision agriculture. Accurate and timely forecast of yield is required for marketing, storage, and transportation decisions. Yield is affected by a variety of input conditions, including temperature, availability of water and nutrients.

Yield prediction with parametric models are based on crop mechanistic modelling. They describe crop growth in interaction with their environment as dynamical systems. But the calibration process of the dynamic system comes up with much difficulty, because it turns out to be a multi-dimensional non-convex optimization problem.

In contrast, data-driven or non-parametric models have the ability to model very complex systems, but they require a large amount of training data. Complicated models with many features compared to the training examples, are likely to overfit. The application of ML methods combined with sensing technologies, conducted on small areas with small samples of data, leads to a low ability to generalize the learned parameters to areas with different characteristics. The availability of large datasets from diverse sources is necessary to achieve better generalization.

Recent publications on the use of deep learning networks for agriculture focused on classification, e.g. deduce crop type from remote sensing data. Publications on yield prediction mostly had access to a limited set of data or made predictions not intra-field, not per field but on larger aggregated scales. The study from Chen & Cournède [8] used 720 records of corn yield at county scale provided by the United States Department of Agriculture (USDA) and the associated climatic data. The study of Durgun [9] explores the trade-off between the different spatial resolutions provided by ROBA-V products *versus* the temporal frequency and, additionally, explores the use of thermal time to improve statistical yield estimations. The ground data are winter wheat yields at the field level for 39 fields across Northern France during one growing season 2014–2015. This lack of data hinders the use of neural networks or deep learning techniques to model the complex interactions that influence crop yields.

Soil is highly heterogeneous, with complex mechanisms that are difficult to understand and interpret. For instance, the amount of water in a given place is affected by several geo-environmental factors. Machine learning techniques, when representative models are used, can provide a low cost and reliable solution for the accurate estimation of soil conditions, since they are well-adapted for modelling complex behaviours including several factors of importance. In this way, the time-consuming conventional soil measurements can be avoided.

Spatial variability is of crucial importance to understand the interaction of important variables that affect crop variability. One serious limitation of using the aforementioned models is that they assume homogeneity; fields are not usually homogeneous, leading to false assumptions in yield simulations. Soil conditions can vary within the field, as such the knowledge of spatial variability of soil components helps understanding variabilities in production. Accurate estimations of soil properties are needed to optimize soil management, make nutrient planning, and take land-use decisions.

Soil moisture is an important parameter in irrigation scheduling and application. Knowledge of root zone volumetric water content can support decisions for more efficient irrigation management by enabling estimation of required water application rates at appropriate temporal and spatial scales. Hassan-Esfahani et al. [10] proposed a data mining approach that combines known field conditions with remote sensing observations to provide probabilistic estimates of root zone soil moisture at three different depths in the root zone soil profile. This line of thought may also be applied in the DEMETER project when combining data inputs from several pilots.

The availability of Sentinel data (both Sentinel-1 SAR data and Sentinel-2 imagery) already provides us with better remote sensing data at a finer spatial resolution, while temporal resolution is still adequate. The rise of IoT provides us with more detailed information on intra-field level on weather data, soil characteristics and machine operations. These new developments require the use of deep learning techniques to maximally exploit the available data in order to model crop yield.

In DEMETER, we aim to make maximum use of the datasets available to construct ML models that can combine data sources to derive other data that might not available for certain fields, and as such feed ML models for the prediction of crop yield. By linking remote sensing data (SAR, optical, LST - Land Surface Temperature) with IoT data (local meteo stations, soil moisture sensors, machine information including detailed yields), new ML models can be constructed to predict crop yield (before the end of the growing season).

The following models may be considered:

- Estimation of soil moisture (at different depths)
  - Input data: remote sensing LST
  - Training data ground truth: IoT soil moisture sensors
  - Auxiliary data: soil type, crop type
- Estimation of evapotranspiration
  - Dependent on temperature, solar radiation, wind, humidity, and crop growth stage
  - Input data: remote sensing crop growth curves, local weather data
  - Training data ground truth: IoT soil moisture sensors
  - Auxiliary data: soil type, crop type
- Estimate growing stage (NDVI - Normalized Difference Vegetation Index, FAPAR - Fraction of Absorbed Photosynthetically Active Radiation) by remote sensing data
  - fusion of Sentinel-1 with Sentinel-2 to deal with missing data because of clouds
  - Output: daily NDVI or FAPAR series
- Yield prediction
  - Input: soil moisture time series, evapotranspiration data per Sentinel pixel (10m x 10m), crop growth time series, predicted weather
  - Output: predicted yield per Sentinel pixel
  - Training data (ground truth): detailed yield data (AVR harvester: yield per second of harvesting), so intra-field yield data

The crop growth curve is an indicator of growing conditions, any deviation marks the deficiency of some parameter. However, for irrigation advice, early are necessary so irrigation can start before the water stress is visible in the crop growth curve (from remote sensing data).

8.2.2 Irrigation & Fertilization Optimization

The increasing shortage of water resources, due to the impact of climate changes, forces the agricultural system to the application of innovative technologies to increase irrigation crop water efficiency through more sapient water management. Technology-based solutions are required to finely determine crop water needs and to schedule irrigation, with the aim of achieving sustainable production targets, by supplying the precise amount of water required by the crop.

To properly assess the irrigation requirements of crops, several sources of information (plant, soil, atmosphere) need to be harmonized and the output should be delivered through user-friendly tools. The integration, analysis and sharing of data and information from various source, namely forecasting models, in-field sensors, remotely sensed indices, are all crucial to implement online platform and decision support systems to guide farmers and advisors towards more sustainable use of resources.

The modelling approach and the implementation of techniques integrated in decision support system tools for irrigation have demonstrated the potential of saving water, as reported in reviews on precision irrigation (i.e. [11] and [12]).

Models to estimate crop water requirements are based on the assessment of the balance between input (rain and irrigation) and output (water losses by plant-soil system), working at a daily time step. The most used modelling approach is the one proposed by FAO Irrigation and Drainage papers 56 [13], in which crop losses are evaluated at field level with an algorithm that simulates the reference crop evapotranspiration ET_0 and the real crop evapotranspiration ET_R (ET_R is obtained multiplying ET_0 by a specific crop coefficient function of the phenological stage of the crop). Meteorological variables required by the model are daily minimum and maximum temperature and rainfall. These variables need to be provided at the field level by one or more agrometeorological stations or IoT sensors. Water balance model outputs are crop water status and irrigation requirements at a daily time step and temporal patterns of soil moisture level.

To consider other parameters involved in the precise assessment of the crop water status, local micro-climatic factors can be implemented in the calculation of irrigation requirements, for adjusting the water balance model. For example, the use of real-time information from soil parameters (soil moisture sensors) allows for adapting the water balance mode to specific local variation and delivering accurate irrigation advice.

In addition to crop water balance model, crop-based indicators of water status at the field level can be derived from remotely sensed data. Integrating satellite data with water balance models may bring new tools in DSS for the optimization of irrigation. As an example, Sentinel-2 and multispectral instruments can be useful for developing spatial-vegetation indices and data in order to manage irrigation scheduling based on near real-time crop water needs [14]. An index of plant moisture commonly used is the Normalized Difference Moisture Index (NDMI) or Normalized Difference Water Index (NDWI), which is related to the canopy moisture and usually correlated with NDVI, being influenced by both vegetation vigour and water stress. As a consequence, low levels of NDMI indicate water stress and/or low canopy coverage of the field.

The use of fertilizers must be optimized, to meet the requirements of the crop to maintain the target production but at the same time to avoid any unnecessary expense for the farmer and harmful effects on the environment. Nitrogen management is one of the most critical components of farming, interest has greatly increased in improving its use in crops to reach high nitrogen use efficiency, adequate yield and environmental sustainability. The optimization of fertilization is therefore linked to obtaining adequate knowledge of the actual crop uptake across different areas of fields.

The precise estimation of crop nutrient needs may be achieved by nutrient balance models requiring as input crop traits and agrometeorological data (temperature and rainfall). As crop water balance model, nutrient balance models run on targeted phenological stage, providing crop nutrient requirements, and proposing fertilization scheduling over the crop cycle.

Remotely sensed data can be use along with nutrient balance model and data analysis tools to more accurately estimate the crop nitrogen status and in-field difference, thus obtaining nitrogen map to realize variable rate nitrogen application. Among the remotely sensed indices, the (NDVI) is the most used because it is easy to calculate and interpret. The NDVI has been widely tested to assess wheat N-nutritional status and yield, with promising results. Various simplified approaches based on NDVI have been developed through user-friendly web interfaces (e.g., CropSAT, OneSoil).

The most innovative approaches to assess crop nutrients requirements and the fertilization scheduling in precision agriculture, use a combination of various technologies such as modelling, geographic information system, remotely sensed indices, global navigation satellite system, variable rate technology and yield mapping.

In conclusion a complete approach for irrigation and fertilization optimization through DSS is the integration of several technologies, which allow the farmer to evaluate all the important information needed to take decisions:

- a FMIS to track farm data, irrigation, and fertilization logs.
- remote sensing tools to evaluate the field homogeneity and how to adapt the irrigation and fertilization scheme to field variability.
- in-field IoT sensors to monitor soil moisture, agrometeorological parameters and to evaluate the current status of the crop.
- models estimating the crop irrigation requirements and crop nitrogen needs using as input crop and soil traits, and agrometeorological trend.
- data analysis tools to process and integrate information coming from the different sources (remote sensing, field sensors, model) through data fusion and ML techniques.
- DSS for farmers and advisors with user-friendly graphical interface and dashboard with specific advice for each decision.

One example on the use of ML in smart irrigation decision support system is the one proposed by Navarro-Hellin et al. [15] which is composed of three components: a collection device to collect data on soil water content, soil water potential and soil temperature; a weather station to record temperature, rainfall, wind speed, global radiation, relative humidity; and a decision-making tool. The decision-making process adopts two machine learning models to remove unnecessary variables when soil measurements and meteorological data are redundant and to minimize estimated errors under a given threshold.

Goldstein et al. [16] developed a model to capture the unstructured decision process of an agronomist about crop irrigation needs and scheduling. The model is based on the application of machine learning on a dataset comprising sensor-based soil moisture data, meteorological data, and irrigation plans defined by the agronomist in the past to learn his irrigation decision-making process.

ML techniques can combine various parameters and perform complex non-linear modelling of crop yield dependence on nutrients to have optimal agro-chemicals input targeted in terms of time and place [7]. For instance, ML may be applied for the estimation of nitrogen status, to process enormous amounts of remotely sensed data from different platforms, due to its capability process a large number of inputs and handle non-linear tasks [17]. This study asserts that more targeted application of the sensor platforms and ML techniques, the fusion of different sensor modalities and expert knowledge, and the development of hybrid systems combining different ML and signal processing techniques will provide comprehensive solutions for better crop and environment state estimation and decision-making.

8.2.3 Pest & Disease Detection/Prediction

Insects of economic significance and plant pathogenic fungi represent the most important threats for crop production. Their management is a highly challenging problem and may cause dramatic yield losses if not handled timely. Thus, there is a need of extension warning programs and the use of interdisciplinary technologies for sustainable control strategies. Sustainable pest management implies the optimization and the reduction of pesticide use, indeed the use of agrochemicals for pest and disease control without any rules, has caused resistance, negative impacts on natural enemies, and safety problems for the environment and the food supply chain. Farmers need to protect their crops in a cost-effective way, with high ecological, environmental, and socially-aware solutions; requiring decision support for rational management.

Pest population modelling in integrated pest management (IPM) allows the determining of an optimal control strategy for a given situation. The use of models allows forecasting and identifying warning situations, as well as advice on timing of starting in-field monitoring activity to observe symptoms and presence of pests and disease and to evaluate the need of control actions. Many available forecasting models are based on the assumption that insects and plant pathogenic fungi are poikilothermic and heterothermic organisms whose development and growth vary considerably in relation to ambient temperature [18]. For insect pests, the relationship between environmental temperature and phenology has been used for building models to simulate insect development. For plant disease, biotic factors such as wet conditions, relative humidity, wind speed, and host suitability have a great influence. Model approaches have been translated into practical forecasting tools and related DSS for IPM which represent decision-based procedures, involving the integration of several parameters for optimizing the control of pests and disease in an ecologically and economically sound approach. Decision-based procedures in IPM are also based on field monitoring and scheduled management actions based on the availability of integrated, high-quality information. Pest models support the decision-making because they offer means to predict the exact time of pest phenological development, mostly based on climatic data. In the last years, new hardware technology has permitted the automatic registration of climatic data, the use of hyperspectral imaging in detecting fruits infestation and infection, and the development of automatic monitoring (electronic traps and infield camera). For example, electronic traps can significantly reduce cost for monitoring, and if they operate an automatic recognition of the pest, the time-consuming identification activity is improved. Indeed, quick access to time sensitive information is a key issue for pest and disease management. Dynamic web and user-friendly interfaces can serve as decision support systems providing the user with real-time pest and disease warnings and recommendations for management actions, based on practical decision tools such as monitoring, forecasting models, and economic injury levels. The interaction with end-users is of crucial importance, through smartphones and tablets, in order to allow the upload and the customisation of information to run models in the field. DSS for pest and disease management and predictions, helping farmers to evaluate all the important information needed to take decisions, may be composed by the following sections:

- a FMIS to collect farm data, pesticide logs.
- in-field IoT sensors to monitor agrometeorological parameters and to assess the presence of pest and disease (e.g. electronic traps, cameras).
- models estimating pest and disease risk and development.
- data analysis tools to process and integrate information coming data from the different sources.
- DSS for farmers and advisors with user-friendly graphical interface and dashboard for decisions.

ML and other decision-making approaches may play an important role in IPM. In the review of Damos [18] examples are reported on how AI may provide services to the direction of decision-making rather than to simple decision support, when there is too much data for a human to comprehend at one time. ML models have demonstrated their ability in predicting complex relationships between pest/disease and their meteorological drivers [19]. Kalamatianos et al. [20] applied machine learning technique to predict the olive fruit fly trap measurements, given input knowledge of previous trap measurements and the temperature in a degree day model.

ML techniques are also applied to recognition of insect pests from images taken by electronic traps and cameras [21]. To apply ML to pest recognition, large amounts of images are needed to train the models.

8.2.4 Field Operation and Machinery Analytics

Mechanization has had a dramatic effect on lowering production costs, efficiency levels, energy use, labour requirements, and product quality in agriculture all over the world. As tractor sizes have increased, the sizes of other machinery have also increased to keep pace. These increases have contributed to higher machinery investment per farm and more efficient use of labour and have made it possible for an individual operator to farm many acres. The quality of work performed by farm machinery has also risen dramatically. Field losses during harvesting have been greatly reduced. Improved seed and fertilizer placement have made it possible to reduce the amount of tillage performed.

Thus, farm management systems are evolving towards real-time programs based on artificial intelligence, providing valuable recommendations and information to help farmers make decisions and take effective action. The data generated on modern farms is provided by a large variety of sensors. These sensors provide a better understanding of the operational environment (crop dynamics, soil, and weather conditions) and of the operation itself (machinery data). This leads to more accurate and faster decision-making. Sensitive yield monitors, more accurate sprayers and applicators, and the use of satellite positioning technology have spawned a new set of practices known as precision agriculture.

Allocation of machinery expenses is combining information on machinery use, such as the number of hours of use or land area covered, with engineering data, such as fuel consumption per hour of use or hectares covered. This will likely lead to more accurate results. ML techniques will help reducing the global costs by automatically documenting the operation tasks (i.e., ploughing, irrigation, fertilizing etc.), analysing the best combination of treatments for specific crops or fields (for example by using the yield-map data and the operation data).

During agricultural operations, tractor engines consume large amounts of fuel and emit combustion gases. Although environmental pollution from exhaust gas emissions is not directly perceptible through the price of final products, it has a negative impact on human health (the air we breathe is contaminated, products are grown in contaminated soil or irrigated with contaminated water) [22]. Using machinery (such as tractor) sensor data during different farm operations, ML technique can identify abnormal emission rates or abnormal fuel consumption and give active feedback to the farmer (we can think of advice such as need to check the machine or to change its way of driving). Many algorithms are available to detect outliers (aka anomalies and spikes): these are values that “lie outside” the other values.

Based on generic (in the meaning of no new or extra sensor needed) sensor devices, ML techniques can be used to analyse in real-time not-yet-fully-explored additional or alternative data from the machine CAN-Bus: it will allow the monitoring, documenting, and use of the analysis results for further action (DSS for farmers).

8.2.5 Animal Yield

The ability to utilize the digital solutions will be crucial in order to preserve and strengthen the competitiveness of future agriculture.

Due to the rapid technological development, digital data is gaining momentum from various sensors that are integrated into the technical solution and thus involve a wide range of equipment and data suppliers. It can be from sensors in the milking robot, which provides information on production, milk chemical composition, fertility, and animal health. New and more frequent data creates new opportunities, but also challenges for the farmer. There are four prerequisites that must be in place to develop and innovate the digital solutions of the future.

The first is a platform that can efficiently store huge data volumes. It must have a structure that ensures efficient data transactions and gives those who enter data a high security in relation to anonymization and encryption, so that they cannot be abused.

The second prerequisite is automated data capture, so the farmer saves time in data collection. This will be done through the use of sensors connected to animals and the milking robot. In this area, often called IoT, the development is fast and accelerating, a development where the various sensors are connected in so-called digital ecosystems. This means that data from a single sensor has limited value, but the value increases exponentially when data from many sensors are linked together in a network [23]. Collecting and utilizing real-time data is the basis for developing decision support tools, for making the right decisions in order to achieve optimal, efficient and sustainable production.

The new data collection solutions will form the basis for the third premise, namely new methods for data analysis and data model development. We will go from today's simple documentation solutions, based on traditional statistics, to advanced digital advisors with the ability to look ahead, solutions that can look around the corner and predict consequences based on recognizable patterns. These methods are called machine learning (ML), artificial intelligence (AI) and blockchain, which bind information together and are used to develop forecasting models and suggestions for good decisions. Innovation in this area provides the opportunity to develop a traceable value chain that will give the food industry a unique opportunity to describe the various processes in production and give the consumers a greater security and insight into food production. For the farmer, it will give a better understanding of the production and an improved possibility to optimize the production. Thus, efficient forecasting models will be crucial for improvement and make future dairy milk production more efficient. At the same time, it is important to be aware that the production data first creates value for the farmer when they are inserted into a system. A single fat percentage for a cow in a herd has a limited value, while several analyses over time and for all the cows in the herd can give clear indications of how the feeding is in the herd.

The fourth prerequisite, perhaps the most important, is digital maturity. It is the farmer's ability and interest to use the new technology and the digital solutions. Studies shows that the high-tech dairy farmer with a milking robot is very digital and has been able to see the opportunities and use them. At the same time, we must not be blinded by technology and digital solutions. Good livestock and agronomy knowledge will always be important, but in the future, we must become skilled at seeing the potential of the interaction between biology and technology. Use of AI will be an important tool to strengthen these interactions.

In this future picture, there are several important issues. How should we utilize the new technology and digital solutions to strengthen the competitiveness, efficiency, and sustainability of modern dairy production? How should we drive innovation in technology and data? It is important to think about what best serves agriculture and not least what benefits each farmer. Today, there are several solutions that handle the farmer's data, but they are not sufficiently built on the farmer's needs. This will also affect those who are building the future digital solutions. New analytical tools, technology and data will challenge our way of development and business models [24]. Thus, a good AI strategy is needed for this work since data means nothing if it can’t be understood, which is why we are looking to turn data into information, information to knowledge, knowledge to understanding and understanding to insight [24].

Artificial intelligence (AI) encompasses a variety of solutions for analysing and processing data. The methods associated with AI have the potential to influence future business models and solutions. In our project we want to evaluate different steps in this process. This work includes assessments of partnership strategy for: 1) Access to data, 2) Technical solutions, 3) Competence in analytics and 4) Operationalization.

In the present project DSS for animal production will focus on milk and beef forecasting. The following points will be highlighted:

- Concept solutions for milk and meat forecast decision solutions.
- Data integration from milking robot for highly frequent production and activity data.
- Use of ML to develop lactation curves on individual cows and at herd level. The hypothesis is that ML will create more robust or precise lactation curves, which are the basic for improved milk forecasting models.
- Use of ML to develop a culling model, which predicts the economic value of each animal in the herd. The hypothesis is that that will be the driving force for the herd culling strategy.
- Frontend solutions for farmers including simulation possibilities for milk and meat forecasting strategies and decisions.
- Use milk and meat forecasting models to predict feed requirements and optimisation.
- Provide data for greenhouse gas emissions.

8.2.6 Animal Welfare

Moving livestock production from experience based to precision farming by using sensors technologies able to measure relevant parameters helping in decision-making process made a revolutionary improvement in the whole production process and the state of the art still revolves around this approach. Precision livestock farming is aimed to provide animal welfare, increase productivity, and reduce negative environmental impact. Improvement of animal welfare became able by using sensors for monitoring animal weight, temperature, blood pressure, digestion, respiration rate, monitoring reproduction cycles, food and water intake ([25] to [31]), thus supporting decision-making.

Using experts’ algorithms for analysis of gathered data the predictions are available helping in decision-making. This allows automation in everyday activities affecting not just in labour saving but in improving animal health and wellbeing. Automated precision feeding harmonized with animal needs and combined with feeding behaviour ([32] and [33]) provides not just optimization in cost and improvement in animal production, but also influence on decreasing of feed waste and provides valuable information to feed suppliers. This all has a potential to provide improvement through the whole supply chain, from livestock producers, feed suppliers, animal retailers, slaughter companies to the consumers.

8.2.7 Traceability

Traceability has become one of the most important topics in the food supply chain, receiving worldwide attention as consumers get increasingly interested in understanding and accessing all the details about the products they purchase. At the same time, the consumers expect producers to have in place effective practices to ensure such detailed descriptions can get to them and are accessible for consulting. Traceability is also paramount to food safety, and there are a few reasons for this. The first one is the need to trace chemicals, such as pesticides and fertilizers for crops, drugs for farm animals and food additives in general, which could be harmful to human health or degrade the overall quality of the final product or its raw elements [34]; another reason concerning food safety is related to the recall of those products deemed unsuited, dangerous or toxic for the consumers: with a good traceability method in place, such issues would be handled with much more precision and celerity, because it’s a lot easier to trace where each and every item went when each step of the production and distribution has been safely recorded and stored according to an impossible-to-tamper-with manner and place. This last requirement brings forth one more detail for traceability to function properly, that is the integrity of the data being recorded and the possibility to make sure it remains that way, thus guaranteeing an overall transparency of the processes. The fact that any kind of information stored in such a way can be retrieved and consulted without the risk of accessing manipulated data is also helping in meeting with high standards all the strict compliance regulations from both government agencies and retail customers which, in turn, protect the brand image on the market and the quality of its products [35].

Applications of technological innovations in IoT and in a wide variety of sectors such as healthcare, finance government sector, smart cities and, most importantly, smart farming, are gradually developing great interest in distributed ledger systems and, in particular, blockchain technology to implement the traceability requirements which are now becoming paramount if one is to secure consumers' fidelity, trust and well-being.

Born as a mean to provide security and trust in cryptocurrency transactions in the absence of a central authority, Blockchain is an emerging technology which is being discovered useful outside of its original scope and, lately, especially in the agricultural sector, since it definitely has the capability of meeting the above requirements for a correct and useful traceability system. Thanks to its architecture, the blockchain provides cryptography, traceability, and immutability of the data it stores. It is made up of blocks containing verified transactions/data and nodes, which are the participants in the network, storing one copy of the whole blockchain each, so that there is no central authority, with the only existing version of the database to which everyone must submit. Once the data has been approved and entered the blockchain, it is virtually impossible to tamper with it; every transaction (which can be custom designed according to the need of the traceability scenario) has a timestamp associated with it and needs to be confirmed by more than fifty percent of the nodes in the chain. Besides the timestamp, every block also includes a hash of the previous block, such that if an attacker changes the data inside a past block, the hash of this block would change with it; since the changed hash is never referenced by another block, it would not be accepted by the rest of the network, and it would effectively create a fork of the blockchain. The rule with forks is that the longest chain is always the leading one, so in order to have the modified block accepted by the network, the attacker would need to grow their chain faster than the rest of the network combined to pass the longest chain [36]. These reasons make blockchain a good choice in terms of data traceability; moreover, blockchain was also shown able to be integrated on resource-constrained IoT devices, highlighting its capabilities of being a flexible and innovative technology in a smart farming setup [37].

Members' participation in a blockchain network divides it in two different categories: permissioned and permission-less. A permission-less blockchain is the technology underlying cryptocurrency systems such as Bitcoin, where everyone must be free to join. A permissioned blockchain can be useful, instead, in all other sectors where participation to the blockchain needs prior approval. This last version is the most useful in terms of smart farming and traceability in the food supply chain, since the only members of the network are those taking part to the production chain itself and producing valuable data to be stored. Moreover, permissioned blockchains can have varying degrees of decentralization and anonymity of data, according to the needs of the particular transaction they must handle.

The blockchain technology can be further extended with smart contract functionality. Smart contracts are agreements between parties through code that will be executed once the required conditions are met. This shows the strength of blockchain autonomy which eliminates the need of a third party or a central government to check on the validity of the transaction, the contract being issued, and the conditions being met.

8.3 Decision Support Components in DEMETER

This section describes the functions and the input/output structure of the components of one of the Decision Support System to be integrated in the frame of the DEMETER project.

The following subsections describe the DSS solutions that may be required by each of the Area component identified to data without going into any implementation detail.

8.3.1 Component A.1 Plant Yield Estimation

DSS AREA: A-Crop Growth, Status and Yield

What: Data-driven Machine learning algorithms fed with crop type and crop variety, RS Input (e.g. Fapar or NDVI time-series data enhanced with Sentinel-1 SAR data), meteorological data and future weather predictions (up to the end of the growing season), historical RS time-series and historical yield-map or field yield data, to be used as a yield prediction during the season. The RS time series can be viewed as a proxy for the environmental factors and its effect on the crop (soil moisture, nutrient availability, temperature, ...). Historical time series data provide a view on what crop growth curve we may expect, while any deviation from the optimal curve will signal potential problems for crop growth (e.g. water stress).

Input: Multi-temporal remote sensing data, and, to build the model, historical yield maps of yield estimation at field level; Remote Sensing input from time-series of biophysical parameters (NDVI, FAPAR) can either have a spatially coarse but temporally dense time series, e.g. Proba-V at 300m resolution and daily frequency, or a spatially finer but temporally sparser time series, e.g. Sentinel-1 at 10m spatial resolution and 5-daily interval for central Europe. In order to use Remote Sensing time series as input to machine learning algorithms for yield prediction, the time series of biophysical parameters should contain enough information to reconstruct the growth curve faithfully up to the point of prediction. While the crop growth curve from RS data provides an indication of crop growth throughout the growing season up to the moment of prediction, the prediction of future crop yield will need input on predicted weather scenarios, as well as an estimation of the current water balance of the soil.

Output: Yield estimation as an average per hectare (ton/ha). Yield estimation may be on field level, or on finer level (e.g. sentinel-2 pixel of 10 x 10 m^2), depending on the level of detail of the inputs used.

Pilots involved: 1.4, 3.1, 3.2, 3.4, 5.3

8.3.2 Component A.2 Plant Phenology Estimation

DSS AREA: A-Crop Growth, Status and Yield

What: A component that estimates the date of a phenology stage of a crop.

Input: Phenological observations, containing for each observation the date (day of the year) and the phenological phase (according to BBCH scale) and daily minimum and maximum temperature for growing degree day calculation, starting from the first day of the year. Machine learning models have been already trained with olive tree phenological observations and daily temperature data. The number of phenological observations should be high enough for ML testing purposes.

In general terms, ambient temperature is the main factor in plant development. Ambient temperature is transformed into GDD and the date is transformed into day-of-year (DOY). DOY is the number of days elapsed since the first day of the current year. The calculation of DOY from a date is straightforward. On the other hand, GDD are a measure of heat accumulation defined as the number of temperature degrees above a base temperature, the base temperature being the temperature below which plant growth is zero.

Output: An estimation of the date at which the main phenological phases occur.

Pilots involved: 3.1, 5.3

8.3.3 Component B.1 Water Balance Model

DSS AREA: B-Irrigation Management

This component describes a crop water balance model that estimates crop soil moisture and the irrigation requirements of crops. AGRICOLUS (pilot 3.1 DSS to support olive growers) and DNET have already developed a crop-soil water balance model. This component is therefore a data model which can be adopted by other pilots dealing with irrigation management.

What: A component that estimates crop-soil moisture and crop daily irrigation needs during the season.

Input: Farm data (geographic coordinates), crop traits, date of sowing or transplanting for annual crop, soil texture, type of irrigation system, daily agrometeorological data (minimum and maximum temperature, rainfall) since the first day of the current year.

Output: Crop water status and irrigation requirements at a daily time step, temporal patterns of soil moisture level. Additional data outputs given by the model are: crop phenological phase, daily ET_0, water stress coefficient.

Pilots involved: 1.3, 1.4, 2,3, 3.1, 3.4

8.3.4 Component B.2 Data Fusion for Irrigation

DSS AREA: B-Irrigation Management

A promising approach in crop water management is the integration of several technologies, providing all the important information needed to support farmers in daily decision-making on irrigation management, combining data to evaluate the current status of the crop and assess the irrigation needs.

What: A component that combines data from different sources (water balance model), IoT sensors and remotely sensed data to estimate current soil moisture and plant water status.

Input: Data for calculating the water balance model (as described in component B1), data from in-field soil moisture sensors, indices calculated with remotely sensed data.

Output: Irrigation advice based on crop water status and irrigation requirements at a daily time step, temporal patterns of soil moisture level and crop water status.

Pilots involved: 1.3, 1.4, 3.1, 3.4

8.3.5 Component C.1 Nitrogen Balance Model

DSS AREA: C-Fertilization Management

This component describes a crop nitrogen balance model that estimates crop nitrogen requirements and provides the scheduling of fertilization. AGRICOLUS (pilot 3.1 DSS to support olive growers) has developed a nitrogen balance model which is integrated in platform along with remotely sensed indices. This component is therefore a data model which can be used by other pilots dealing with fertilization management.

What: A component that estimates crop nitrogen needs and the crop fertilization scheduling during the season to optimize nitrogen fertilization, avoiding nitrogen excess.

Input: Farm data (geographic coordinates), crop traits, expected yield, date of sowing or transplanting for annual crop, plant density and pruning system for tree crops, soil texture, agrometeorological data (minimum and maximum temperature, rainfall), remotely sensed indices (e.g. NDVI)

Output: Cop nitrogen status, fertilization requirements and scheduling during phenological development with different results in each section of the field, nitrogen prescription maps.

Pilots involved: 1.1 & 1.2, 1.3, 1.4, 3.1, 3.3

8.3.6 Component E.1 Computer vision-based counting module

DSS AREA: E-Pest and Disease Management

What: A component that counts the number of appearances of a given element on an image.

Input: A set of images containing the elements to be identified properly labelled to be used as a training set and a set of unlabelled images to count the elements from the training set. The number of labelled images for training purposes should be high enough for ML application.

Output: An estimation of the number of elements to be counted.

Pilots involved: 1.1 & 1.2, 3.3, 5.1

8.3.7 Component E.2 Estimate temperature-related pest events

DSS AREA: E-Pest and Disease Management

The structure of the present component, currently under active development and validation, will be similar to the one described for the component in A.3 Plant Phenology estimation, on which it is being modelled. Essentially, the problem of predicting the temporal location of pest peaks is parallel in broad methodological terms to the one with phenology: we have an observed date with a maximum peak of presence of the pest (or initial presence of the pest) and we try to use it to build a model based on day degree to estimate the peak or the initial flight. In this sense, the data structure is similar to the one for phenology, but it is used with a different target.

What: A component that estimates the date and the extension of a pest event.

Input: Pest observations, containing for each observation the date (day of the year) and the pest catches in traps (according to a quantitative ordinal scale at least), and daily minimum and maximum temperature for growing degree day calculation, starting from the first day of the year. In general terms, ambient temperature is one of the important factors in the development of pest events. For this purpose, ambient temperature and date are among the raw data available. As for A.3 Plant Phenology Estimation, ambient temperature is transformed into GDD and the date is transformed into day-of-year (DOY).

Output: An estimation of the date at which the main pest phases occur.

Pilots involved: 3.1, 3.3

8.3.8 Component F.1 Estimate Milk Production

DSS AREA: F-Animal Yield

What: Milk yield forecasting using data from milking robots in 620 dairy farms. The dairy farms will provide basic cow data (age, lactation no., days in milk, breed) and milk production (milking frequency, milk yield). Data are integrated in Mimiro's platform, which is built on AWS technology, architecture, and analytic platform (Lakeformation, Sagemaker). The robot data are generating 182 million data rows per year, which will be used in the development of the milk forecasting DSS. In the machine learning approach, we will evaluate several algorithms. One alternative is to use random forest algorithms, where use of decision tree is the basic building block. In the project we will also evaluate other algorithms which have been used in development of forecasting models. In the pilot we will test the following alternatives, which are available on the AWS Sagemaker. The AWS Forecast predictor uses an algorithm to train a model, then uses the model to make a forecast using an input dataset group. The following algorithms will be evaluated:

- Autoregressive Integrated Moving Average (ARIMA)
- DeepAR+ Algorithm
- Exponential Smoothing (ETS) Algorithm
- Non-Parametric Time Series (NPTS) Algorithm
- Prophet Algorithm.

In addition, we will use the K-Means clustering algorithm to develop models for herd culling strategy.

Input: basic cow data (age, lactation no., days in milk, breed) information and milk production (milking frequency, milk yield).

Output: milk forecasting DSS.

Pilots involved: 4.1, 4.2

8.3.9 Component G.1 Estimate Animal Welfare Condition

DSS AREA: G-Animal Welfare

What: classification application, where the values we want to predict are a discrete class label such as healthy or sick. In that case, the random forest algorithm will take a majority vote for the predicted class. During training, it is necessary to provide the model any historical data that is relevant to the problem domain and the true value we want the model to learn to predict. The model learns any relationships between the data (known as features in machine learning) and the values we want to predict (called the target). The decision tree forms a structure, calculating the best questions to ask in order to make the most accurate estimates possible. When we ask the decision tree to make a prediction, we must give it the same data it used during training (the features) and it gives us an estimate based on the structure it has learned.

Below there is an example of classification class problem with input data set to predict if the cows are affected by lameness or not.

Input: Date, Pedometer, Cow, Activity 1, Activity 2, Activity 3, Total Daily Lying and ActualLameness.

Output: ActualLameness contains the true value that we want the model to learn and predict.

Pilots involved: 4.2, 4.3, 4.4, 5.4

8.3.10 Component G.2 Stress Recognition: Support Vector Machine for Poultry Stress detection

DSS AREA: G-Animal Welfare

What: Analysis of chicken sounds in intensive livestock production is relatively new research area, thus a small number of scientific papers have been published. In Lee et al. [38], authors proposed a set of features that usually used for speech emotion recognition and voice quality evaluation

We chose this set of features for our baseline system, since our task is very similar to the one in [38]. Additionally, we decided to extend this initial pool of the features with the features used for detection of disease in poultry such as: mel-frequency filter bank (MFFB) outputs and mel-frequency cepstral coefficients (MFCCs). As chicken sound depends on chicken age, environmental conditions, and the stress cause, it can be classified into the following categories:

- normal (sounds in usual chicken activity).
- stressed caused by environment parameters increase (temperature, humidity, light, airflow CO_2).
- stressed caused by fear during maintenance (power loses).
- stressed caused by fear during catching and transferring procedure.
- noised (noise generated by fan or feeding system masks chicken sounds).

Each above-mentioned chicken sound class will be represented by 4 models corresponding to the chicken age expressed in weeks (1, 2, 3 and 4+ weeks). These models can be treated as subclasses. If a classifier could not distinguish these subclasses with the same main class, the confused classes are joined into single.

Additionally, in case of high similarity between two classes corresponding to stressed caused by fear, there is possibility to aggregate them into single class. It is worth to note that there are systems used for sound detection as a symptom of respiratory infection, but it would not be the objective of this phase, since we do not have appropriate labelled audio data.

Input:

Parameter	Sound and camera	Environmental parameters	Power loses
Description	Raw sound for processing	Air temperature, Air humidity, Air Flow, Light Intensity, CO_2.	yes/no

Output: Level of stress; instructions for farmers.

Pilots involved: 4.4, 5.4

9 Benchmarking and Performance Indicators Monitoring Tools

9.1 State of the Art of Benchmarking in the Agricultural Domain

The state of the art of agricultural benchmarking is mainly based on the following document: "EIP-AGRI Focus Group Benchmarking of farm productivity and sustainability performance FINAL REPORT 10 JANUARY 2017" [39], drawn up and published by the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI), focus group on Benchmarking of farm productivity and sustainability performance, with the aim of stimulating innovation and to seek practical solutions to bridge the gap between practice and science.

9.1.1 Definitions

Several benchmarking definitions may be found in literature. We report those considered more appropriate to the aims of the benchmarking system on performance of farms within activities by DEMETER pilots:

I. Benchmarking is an independent efficiency raising process based on the analysis of the existing performance and comparison with other, and an identification of the causes for performance ``gaps'' as the basis for optimum reconfiguration of activities [39];
II. A systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards. The overall aim of benchmarking is to improve the performance of an organisation as measured against its mission and objectives. Benchmarking implies comparison, either internally with previous performance and desired future targets, or externally against similar organisation or organisations performing similar functions [40];
III. Benchmarking is the comparison of one´s performance with the performance of others engaged in a similar activity and learning from the lessons that these comparisons throw up.

Benchmarking was begun in the late 1970s by Xerox Business System. Xerox was losing market share and feeling a lot of pressure from its competitors: Japanese affiliates were selling better quality copiers for less than the manufacturing costs of similar products in the USA. In an attempt to try and "get back into the game", Xerox decided to compare its operations to those of its competitors. After finding quality standards with which to compare itself, Xerox began one of the greatest trends in the business world today [41].

Since that, in the last decades, benchmarking has been increasing popularity as a tool for continuous improvement in several areas.

Benchmarking is the process that allows comparing performance and learning from comparison (against the average or the "best in class"), in order to improve and ameliorate behaviour and working activities. Benchmarking implies sharing information with others, comparing with peers, learning from each other (benchlearning) and identifying actions (benchaction). In the agrifood sector, benchmarking allows farms to better understand their activities, marking target areas for improvement, in order to raise productivity and sustainability performance. Benchmarking represents an ideal way to learn from other farms (farmers), more successful in specific target areas. The main advantage of benchmarking is its effective and efficient approach to bring about improvements, since it involves imitation and adaptation rather than pure research or invention, which would require experimentation and testing.

The application of benchmarking to "agriculture world" may require adjustment and adaptation that we address in the following paragraphs.

As reported in EIP-AGRI final report, the European Union has nearly 11 million farms, most of these are small and semi-subsistence farms that play a number of socio-economic roles, such as maintaining rural welfare and active population in rural areas, contribute to the rural non-farm economy, providing important environmental services (biodiversity, erosion control, attractive landscape), in addition to goods [42]. These farms are hard to reach for advisory services in general and with benchmarking systems in particular. These small farms, generally, are less active in innovation and benchmarking, as they keep limited records and, therefore, their performance is difficult to benchmark with their peers. However, when these small farms are organized in cooperatives, consortia or producer groups, a gradual introduction of benchmarking may become applicable, especially if assisted by advisory services.

9.1.2 Aims of the benchmarking systems

In general, the aim of the implementation of benchmarking tools in the platform is to support farmers in improving productivity and sustainability, both on economic and environmental aspects.

Within DEMETER, the benchmarking system is meant to capture data from different sources, in order to make them available on farm in an integrated way (interoperability), to develop tools for data comparison and to generate clear and self-explanatory advice in decision support, by highlighting relations between the results of comparison between a farm and the other farms utilized for benchmarking.

In addition, the benchmarking system allows farmers to learn new and innovative approaches based on the use of technology developed within DEMETER, improving performance of their farms, and managing issues better, thus providing the basis for training. Benchmarking may act as a vehicle to improve performance, by assisting in setting achievable goals that have already been proven successful by other farms.

Benchmarking systems may benefit from the use of farm management software (produced by ICT companies) in which data management services with benchmark options can be easily introduced.

DEMETER benchmarking tools may act as a process by which farms may look at the “best” (from a technological point of view) and try to imitate styles and processes. In our idea, this will help farms to determine what they could be doing better.

The core steps of benchmarking can be summarized as follows:

- Identify indicators to assess current agronomic, economic, and environmental sustainability of farms.
- Compare farm indicators with others calculated for other farms (or for historical data of the same farm).
- Detect and understand performance gaps.
- Develop and implement an action plan to fill the gap.

9.1.3 Performance indicators and type of benchmark

To implement benchmarking tools, we need to identify KPIs (Key Performance Indicator) to assess economic, environmental, and agronomic performance that we want to compare. The selected indicators require quantitative measure or accurate estimation, the comparison, and a subsequent process of interpretation, allowing to undertake actions.

The KPIs describe the competitive performance achieved, they have to focus on those aspects that are more critical for the current and future success, thus influencing productivity, profitability, sustainability, in the mid-to-long term.

When a measure, a benchmark, is obtained, relative performance can be compared. How can we apply the comparisons? Two main approaches can be followed:

- Internal: compare a farm performance with its historical data (e.g. before the adoption of a technology).
- External:

- Generic approach: compare farm performance with a group or regional/area average (with the same size and type of farming), or individual data of other farms in that area.
- Best in class approach: compare a farm with the average of the best (identifying a percentage of best farms to be used for comparison), or even with the best of the best.

In the DEMETER benchmarking system, we plan to adopt benchmarking comparison following internal and external with generic approaches, building the benchmarking survey filled by pilot leaders.

As benchmarking is based on data sharing, we will need to address privacy and ownership of data. Farmers should remain the owners of data generated on their farms, after introducing benchmarking options.

The system should allow the sharing of farm data to encourage and ensure the operability of benchmarking tools and farmer participation, boosting the dataset and, thereby, improving its accuracy and applicability.

Such types of benchmarking provide information on strengths and weaknesses of farm management, thus identifying key actions that can be adopted to improve the farm performance.

The benchmarking systems will start from a set of homogeneous, comparable farms (e.g., farms belonging to the same pilot), and will bring together data from farms that will have similar changes in their farm system (e.g., adoption of technology, use of field sensors, etc.) at different stages. Indeed, comparisons should be done within a homogeneous group of farms, according to the type of farm and its economic size (i.e., cultivated crop, animal bred, geographical area, farm asset). Homogeneity is difficult to reach, if we consider all the farms engaged in all the pilots, since they differ markedly, even within a cluster, and because of intrinsic straits of farming business.

9.1.4 Data availability

The introduction of new information and communication technology (ICT) in the form of field sensors, remotely sensed data, etc., has made farming processes readably observable. This has resulted in urgent needs of farmers to integrate ICT data from all the sources and to handle flexible dashboards to control interoperability.

Data related to the use of agrochemicals, agricultural inputs and data for livestock management are required to be collected in the relative books and, therefore, farmers should hold useful information about environmental and technical issues. In addition, farmers need to keep receipts of supplies input bought and products sold, keeping track of economic issues as well. However, member states lack standardization protocols for keeping these books.

Farm benchmarking tools have been historically introduced in the areas of economic business and farm productivity. More recently a wide interest has been dedicated in developing sustainability and, more specifically, in environmental and social indicators as benchmarking tools for farmer use.

In the benchmarking system, assessment tools need to be designed to assess a specific level or scale. They may assess the farm-level or the field-level needs, being the target mostly used by farmers. The ownership of data is a difficult concept and will not be addressed in this document. Farmers may want to track and control data they are sharing (e.g., pesticide use for inspection service). To make benchmarking successful, we need to create a system in which farmers feel comfortable in sharing sensible data and from which they may expect useful feedback. In addition, harmonization of data definition is important (e.g., size of a field with or without ditches, when a cow starts counting as a cow, etc.). The real challenge for the benchmarking system is to create trust, interoperability, and data-ownership, and to integrate the data into a useful dashboard for farm management, especially for benchmarking of operational data and for sustainability indicators.

The ongoing development of ICT and data analytics should allow greater sense-making of the data by creating connections between, for example, financial data and farm operations (from different data sources), which will provide farmers with information on most influential management practices. Use of open data: data available within the EU that are made public when privacy laws are not violated. As an example, weather data, soil maps, data on animal movement, the Farm Accountancy Data Network (FADN). This type of data may support benchmarking. Examples derived from other EU projects are available in the use of this kind of data:

BoerenBunder [43] - paying agency RVO made field level data available to the public. Clicking on a field anywhere in the country it is possible to see which crops have been grown since 2009, providing soil and elevation data, and satellite greening index, as indicator of plant growth.

Sostare project - implementation of diagnostic farm-level model for an integrated assessment of sustainability and efficiency from an agronomic, economic, and ecological point of view. Through a web interface of Regione Lombardia web portal, used directly by farmers and advisors, it is possible to compare the performance of the farm to the optimal performance, or to compare the performance of the farm to a reference situation of farmer choice (i.e., the average of the farm typology, the average of all farms). Such benchmarking possibilities provide information on strengths and weaknesses of farm management, in order to identify key actions that can be adopted to improve the farm performance. The tool is structured in such a way that existing data sources, such as the FADN and the Integrated Administration and Control System (IACS) data can be automatically integrated [44].

Data need to be fresh and as reliable as possible. Much of the data and analysis is time sensitive therefore necessary to get information disseminated as quickly as possible.

9.2 Performance Indicators in DEMETER

9.2.1 Agronomic indicator

Yield is a fundamental parameter and the ultimate goal of any agricultural practice since it gives information on productivity per area unit. As an agronomic indicator yield may be defined as following:

- Actual yield: is the level of yield obtained; it reflects the current state of soils and climate, farmer's skills, and technology:
  - real value per field
  - estimated value (e.g. remote sensing).
- Theoretical yield: is the maximum crop yield as determined by biophysical limits to key processes including biomass production and partitioning. It can be estimated with models (so the use is limited by the availability of inputs and parameters and by the model implementation in on-line system).
- Potential yield: is the yield of a current cultivar that may be reached under optimal growing conditions (when water and nutrients are not limited, and without biotic or abiotic stress). The potential yield assumes that growth is determined by factors such as CO_2 concentration, solar radiation, temperature, and genotype. It can be estimated using crop models.

In addition, we have to define the yield gap, as the difference between two levels of yield, the actual and the potential yield. Depending on the purpose of the benchmark different yield gaps may be considered relevant (e.g., actual ~ potential).

The yield benchmarking is of particular interest for farmers and advisors since it may provide indications of the possible improvements that can be obtained in yield or the gap that can be filled if adequate management decisions are undertaken or if a new technology should be applied.

According to FAO report on "yield gap analysis of field crop" [45] four approaches or methods can be identified to benchmark yield and perform an analysis of the yield gap. The methods address the spatial and temporal diversity and the resource available:

- Comparison between actual yield of a farm/field and the best yield that is possible to achieve in comparable environmental conditions (e.g. neighbours with similar soil and topography conditions). This type of comparison is simple to apply and requires minimum inputs, providing a useful benchmark in which yield gaps may be totally allocated to differences in management. The yield used for benchmark may derive from observed and objective measures, yields that have already been obtained.
- Comparison of actual yield is based on the use of simple climatic indices or models of medium - high complexity and does not require any yield information if the models are calibrated. In the use of models, attention has to be paid to the type of weather data. Even if crop modelling allows to estimate the highest possible yield accounting for interactions among weather, soil and management, this type of benchmark requires inputs and parameters which may be not available and the application at specific time scale may be not suitable.
- Comparison of actual yield, expressed as a function of one or few environmental drivers (i.e. seasonal water use, nitrogen uptake, soil properties) in simple models. Actual yield is plotted against an environmental driver, fitting a boundary function the best yield for a given environmental driver, and yield gaps are calculated between actual yields and the boundary function. This type of benchmark partially accounts for different seasonal conditions. Parameters for boundary functions can be estimated with quantile regression. The inclusion of remote sensing-based populations of crop yields may be addressed.
- This type of benchmark is based on the use of a set of approaches combining actual data, remote sensing, GIS, and models. It allows the benchmark at the regional scale or above. Remote sensing applied to yield gap analysis has improved over the last years, but significant constraints remain unsolved including the radiation use efficiency and harvest index, which require a local calibration.

The actual yield may be available at different levels of spatial resolution: first level administrative units (country, region, province), second level administrative units (municipality or sub district level), data reported by farmers or collected through surveys from smaller areas.

Global yield database may be available: e.g. Agro-Maps (FAO) for the first and sometimes second level of administrative units complemented with interpolation methods to achieve full spatial coverage. To implement adequate and satisfactory benchmarks, accurate geospatial distribution of crop yield and their spatio-temporal variability are needed, as well as the distinction between irrigated and rainfed crops where both forms of production exist. Other examples of long-term databases are available at country level for various crop species (FAOSTAT, national database). A good understanding of local conditions is essential to avoid data misinterpretation.

Another issue is that in many countries average yield is not crop specific, that is, they are only reported for aggregate crop categories such as grain, fruit, and vegetables. Yield data estimation may also benefit from data collected through government or industry organization, including growers marketing cooperatives. Within these data may be available input data (fertilizers, irrigation amount, pesticide, etc.) providing the opportunity to quantify impact of management practises on yield and efficiency of water and nutrients.

Yield estimation with remote sensing: this represents indirect measurements via satellite which allow the complementing and crosschecking other sources of data. The frequency at which data can be measured depends on the type of satellite; combinations of different satellites may be used to acquire most of these data with an interval of a few days with different resolutions.

Remote sensing approaches to estimate crop yield can be based on:

- biomass production and partitioning.

- empirical models relating spectral vegetation index and yield.
- integration of remotely sensed data and crop growth models.

We will not go into details of these methods as their complexity to be applied and to be implemented in the DEMETER benchmarking system.

Yield estimation with MODELS: Models to estimate yield may have the form of simple climatic indices or be intermediate models such as AquaCrop, or even more complex such as CERES-type models. More complex models are valuable agronomically because they capture some genetic features of the specific cultivar, and the critical interaction between water and nitrogen. Particular attention needs to be paid to weather data used in modelling yield because significant bias can accrue from inappropriate data sources. Owing to the capacity to capture major interactions among weather, soils and management, crop modelling appeared to be the most reliable way to estimate potential yield for each specific crop within the defined cropping system. However as aforementioned they may require data and information not available, at the pilot level.

9.2.2 Environmental indicators

Environmental indicators (EIs) are commonly defined as numerical values that provide insights into the state of the environment and they are widely used in warning against potential risks and in preventing diseases and death of living organisms. EIs are based on quantitative measurements of environmental conditions and they can be referred to a wide variety of geographic scales, from local to regional or even national scale. Commonly used EIs in various contexts are energy supply, renewable energy, CO_2 emission, air quality, threatened species, forest cover surface, bird/fish biodiversity, organic farming, and many others. In agricultural contexts EIs are often the only tools available to assess the value of some type of production process. Changes in farm structures have been influenced, through the years, by technological innovations, most of which were beneficial for both society and environment. Some innovations, though, were dangerous for the environment, such as the use of certain families of pesticides. Precision farming is then born by the needs to satisfy a growing production demand in an eco-efficient way. These kinds of indicators are particularly relevant in agriculture since farming activities are constitutive part of the ecosystem itself rather than being external to it, unlike most other economic activities. Consequently, the environmental risk indicators are more than just a measure of farming virtue; they are considerations that need to be factored into to the various activities of the production process itself. The agroecological environment is a complex system in which the interactions between the different units are often site-specific and non-linear, with a wide range of biophysical conditions and high level of local or landscape variability. This sometimes makes very difficult the assessment of the environmental impact of the farm.

Environmental indicators will be selected among those which have relevant sustainability aspects and are able to describe environmental concerns for agricultural production processes. Principal aspects taken into account are:

- the use of water for irrigation.
- the use of agrochemicals in pest management.
- the nutrient management.

For the use of water for irrigation we have selected: the irrigation water use efficiency (yield/irrigation water applied kg/mm), no irrigated area in the farm (% surface of the agricultural used area). For the use of agrochemicals in pest and disease management: pesticides usage (number of treatments/ha; number of treatments/crop), pesticide area in the farm (as proportion of farm agricultural used area), the pesticide use trends over time using data in terms of active ingredients. Inputs of nutrients, such as nitrogen and phosphorus, are essential to agricultural production but at the same time they represent a great threat to the environment. Common and easy-to-use indicators of nutrient use efficiency are: i) the measure of the nutrient input/output ratio; ii) the change in nutrient balance across the years. Concerning the first indicator (I/O ratio), outputs can be easily estimated through different algorithms widely used and depending on crop rotation, weather conditions and soil type.

9.2.2.1 Benchmarking on greenhouse gas emission on farm level - Climate for calculation

Agricultural Dataflow SA has started the development of system for automatic dataflow, calculation, and presentation of greenhouse gas emissions on farm level. This system will be introduced into the Farmer's dashboard in pilot 4.1. The system also includes a benchmarking service so the farmer can compare his/her greenhouse gas emissions with other farms. The system and the climate farm calculator are developed so the farmer can identify his/her different types of emissions and with help from his/her climate advisor or other advisors in the agricultural advisory service identify measures to cut the greenhouse gas emissions for each unit produced of milk, meat, grain etc.

The farmer can also share his/hers results with his/her consignee, advisor, bank or collaborators in the web-based Climate farm calculator or can allow businesses and actors integrated to the Dataflow-platform with their ICT-systems to get the results on each farm with an API. The data input for the calculations are also collected via API’s from public databases with soil types, weather data, farm management systems that the farmer uses for livestock or plant production, farm accounts, digital invoices, digital settlements etc. All businesses, actors, data providers are integrated with the Dataflow-platform and both the farmers and other owners of data which are used in the calculations allow using their data through the consent-system on the Dataflow-platform.

The system is based on the HolosNOR-model for greenhouse gas emissions which is a Canadian Holos-model transformed to Norwegian and Nordic (North Europe) conditions. Holos is a whole-farm model that estimates greenhouse gas (GHG) emissions based on information entered for individual farms. The main purpose of Holos is to test possible ways of reducing GHG emissions from farms. Once information is entered into the calculation model, HolosNOR estimates carbon dioxide, nitrous oxide, and methane emissions. The sources of emissions include enteric fermentation and manure management, cropping systems and energy use. Carbon storage and loss from lineal tree plantings and changes in land use and management are also estimated. The result is a greenhouse gas emission estimate for the whole farm and for each production. The Climate farm calculator calculate the emissions for each unit produced. The model can help the user identify ways to reduce farm emissions. Before recommending a feeding strategy for greenhouse gas (GHG) mitigation, it is important to conduct a holistic assessment of all related emissions, including from those arising from feed production, digestion of these feeds, managing the resulting manure, and other on-farm production processes and inputs. Using a whole-systems approach, the HolosNOR model, and experimentally measured data, this study compares the effects of alfalfa silage- versus corn silage-based diets on GHG estimates. Reported GHG reduction factors cannot be simply combined additively because the interwoven effects of management choices cascade through the entire system, sometimes with counter-intuitive outcomes. It is necessary to apply this whole-systems approach before implementing changes in management intended to reduce GHG emissions and improve sustainability.

- Input parameters; see Bonesmo et al. ([46] to [48]).
- Output parameters; see Bonesmo et al. ([46] to [48]).

The Climate farm calculator and the benchmarking on greenhouse gas emissions on the farm will be a service that a farmer can include in his/her farmer dashboard.

9.2.3 Economic Indicators

Benchmarking is the comparison of performance with the performance of others engaged in similar activity and learning from lessons that these comparisons throw up [49]. Different type of benchmarking can be identified according to Franks & Collis [50]:

- Internal, when the performance of the farm business is compared with itself (over time).
- External, when the performance of a farm business is compared to the performance of similar farm enterprises (between peers).

Following some key concepts of farm business analysis:

- Profit: difference between the money that comes into the farm business from the sales of a product and the money that goes out to produce it.
- Technical efficiency: measures the farmer's skill and success in producing the highest possible level of output from a fixed amount of inputs.
- Economic efficiency: measures the financial returns on resources used.

Some common indicators to describe them are:

Group	Indicator
Profit	Farm income (€/unpaid awu*) [51]
Technical Efficiency	Yields per hectare of major food staple and high value crops/livestock [52]
	Production to ha ratio (t/ha)
	Production to unit of input (t/unit)
Economic efficiency	Revenues to costs ratio (€/100 costs) [51]
	Revenues to ha ratio (€/ha)
	Revenues to unit of input (€/unit)

*average working unit

The **Farm Accountancy Data Network** (**FADN**) is a database of microeconomic data managed by the European Commission. Its main purpose is to gather accountancy data from farms for the determination of incomes and business analysis of agricultural holdings, for statistical and political purposes.

FADN relies on annual surveys carried out by the Member States of the European Union. Data are later harmonised. The survey does not cover all the agricultural holdings in the Union but only those which due to their economic dimension could be considered commercial.

Collected data include:

- Physical and structural data, such as location, crop areas, livestock numbers, labour force, etc.
- Economic and financial data, such as the value of production of the different crops, stocks, sales and purchases, production costs, assets, liabilities, production quotas and subsidies, including those connected with the application of CAP measures.

Data are stratified based on 3 criteria:

- farm economic dimension: holdings are classified in economic size classes, the limits of which are expressed in ESU (European size unit), defined as a fixed number of EUR/ECU

(European Currency Unit) of Farm Standard Gross Margin. Over time the number of EUR/ECU per ESU has changed to reflect inflation.

- FADN regions: regions defined by the single nations have been harmonised in the FADN database.
- types of farming (TF): farmers are classified based on the main cultivated crops and reared animals. The classifications are hierarchical (with 3 different levels). The most common TF classification is the TF8 classification, which identifies 8 groups: 1) field crops, 2) horticulture, 3) wine, 4) other permanent crops; 5) milk; 6) other grazing livestock; 7) granivores; 8) mixed.

9.2.3.1 FADN indicators for external benchmarking

FADN indicators can be used to compare the global performances of each farm to the performances of similar farm. To this aim, we can associate each farm to the right class, defined by the farm economic dimension, the FADN region and the type of farming. The economic performances of each farm can be compared with the average value of the class to which it belongs.

A wide range of variables is provided by the FADN database. Some selected indicators can be considered the most interesting in the light of the literature described above. These indicators can be provided to the farm based on the class where it belongs. In this way the farmer can compare his own performances to the average standard situation in his region.

Some of the indicators that can be provided to this aim are:

- Structure indicators: describe the characteristics of unchanging variables of a farm, also quantifying the availability of production factors. They can be used as benchmarking, as in a given FADN region, the companies may compare their structure with other farms. Alternatively, they can be used as criteria to identify the correct set of benchmarking indicators to provide to the farm. Structure indicators include more economic indicators, such as the economic size of the farm, farm main crops (hectares of vineyards, olive yards etc.), and the average yield per hectare of common crops (wheat, barley, corn etc.).
- Production indicators: quantify the production and the economic efficiency of farms. For example, “total output” or “total standard output” quantifies the average monetary value of the farm output at farm-gate price. Based on the structure of an average farm of a region, this data might be disaggregated to understand the standard output of a given crop. Another useful indicator is the “total output/total input” which quantifies the economic efficiency of the farms. Production indicators quantifying the average yield per ha of the main crops are also available. Production indicators can be used as a benchmark for the farmers, who may compare their field or farm performance with the average performance of similar farms.
- Input indicators: they include costs indicators, such as total specific costs per crop, and the costs per single input category, such as fertilizers, crop protection products etc. Costs indicators can be used as a benchmark for the farmers, who may compare their field or farm performance with the average performance of similar farms.

9.2.3.2 FADN indicators for internal benchmarking

Farmers need to compare the variation of their own performances year against year, and also field against field. To this aim, indicators of technical and economic efficiency can be calculated crop by crop or field by field. Crop by crop economic performance indicators support the farmers in the evaluation of yearly performances, also supporting crop planning in arable and horticultural farming. Field by field performance indicators can be used for different purposes, such as comparing different agricultural techniques applied on different fields or comparing the performance of the same field in different years.

Some meaningful indicators that can be used for economic benchmarking are:

- Standard Output (SO): the average monetary value of the agricultural output at farm-gate price of each agricultural product (crop or livestock). The Standard output can be calculated per hectare (or head of livestock) given the farm production and the market price of the product. The SO of the holding is calculated as the sum of the SO of each agricultural product present in the holding multiplied by the relevant number of hectares or heads of livestock of the holding.
- Specific Costs (SC): are the costs of cultivation of each specific crop, namely the costs which would not have been incurred if a defined crop would not have been cultivated. They include fixed and variable costs. The SC can be calculated per hectare (or head of livestock) given farm data such as crop operations, specific input costs, land rental costs etc.
- Standard Gross margin (SGM): describe the crop profit. It is calculated as the value of output minus certain specific costs of each agricultural product (crop or livestock). The SGM can be calculated per hectare (or head of livestock) given farm data. The SGM of the holding is calculated as the sum of the SGM of each agricultural product present in the holding multiplied by the relevant number of hectares or heads of livestock of the holding. Alternatively, to SGM, the ratio SO/SC can be used to describe farm economic efficiency of the crop production.

9.2.3.3 Benchmarking for farm accounts - Financial benchmarking on farm level

Agricultural Dataflow SA is developing a system for benchmarking of farm accounts where the farmer him-/herself can choose which type of farms he/she will compare his financial results with. This system will be included in the farmer’s dashboard in pilot 4.1. The farmer can choose between various selection criteria related to type of productions, geographical location, farm size, economic results, soil type etc.

The system also allows the farmer to share his financial results and the benchmarking with his accountant, advisor, or bank through the Agricultural Dataflow consent system. The financial results are standardized with an own operational farm account standard and can be shared through an API with those persons, businesses and actors which have integrated their ICT-system for accounting, advising, or banking with the Dataflow-platform.

Input: xml-file with farm account data based on Dataflows operational farm account standard based on Norwegian agricultural standard NIBIOs standard for Norwegian farm account plan. The files are delivered from farm accounting systems via an API for each farm after a consent from the farmer.

Output: farm account benchmarking report with financial result and assets for the latest three years with compared with the selected comparison groups results from the latest year. The systems also allow the farmers and accountants to send in period accounts on monthly basis for comparison.

It could be interesting to take a closer look at if the system could be linked to or could get certain financial KPI’s from the FADN-database so the farmer could have an impression of how his/her results are compared to average financial results for farms with the same farm size, production type and perhaps soil type and climate conditions in other countries. This would maybe trigger the curiosity from some farmers to take part in the system.

The benchmarking-system for farm accounts will be a service that the farmer can include in his/her farmer dashboard. The inclusion of this will be demonstrated and tested for the farmer's dashboard in pilot 4.1.

9.3 Benchmarking Components in DEMETER

9.3.1 Benchmarking framework

The benchmarking system will be developed by the implementation of a set of DEMETER compliant components that can be demonstrated in the pilot activities. As a result of the analysis of pilots' requirements, three types of benchmarking were selected to be applied in the specific components:

I. I1 - Generic Farm Comparison: a generic tool usable by all UE farms with a minimum set of requested inputs.
II. I2 - Neighbour Benchmarking: a tool usable by a group of farmers wishing to share anonymously a set of data to create indicators allowing local benchmark.
III. I3 - Technology Benchmarking: a tool helping farmers and stakeholders in evaluating the impact of a technology.

The three components share a common component that is the I0 – Indicators Engine. This component is an API that receives a set of farm-related inputs producing the set of indicators that can be calculated according to the data available in the farm. Each component is both a DEMETER consumer and provider and will be accessible using REST APIs according to the DEMETER requirements for enablers.

The following schema describes the data flows for the benchmarking systems:

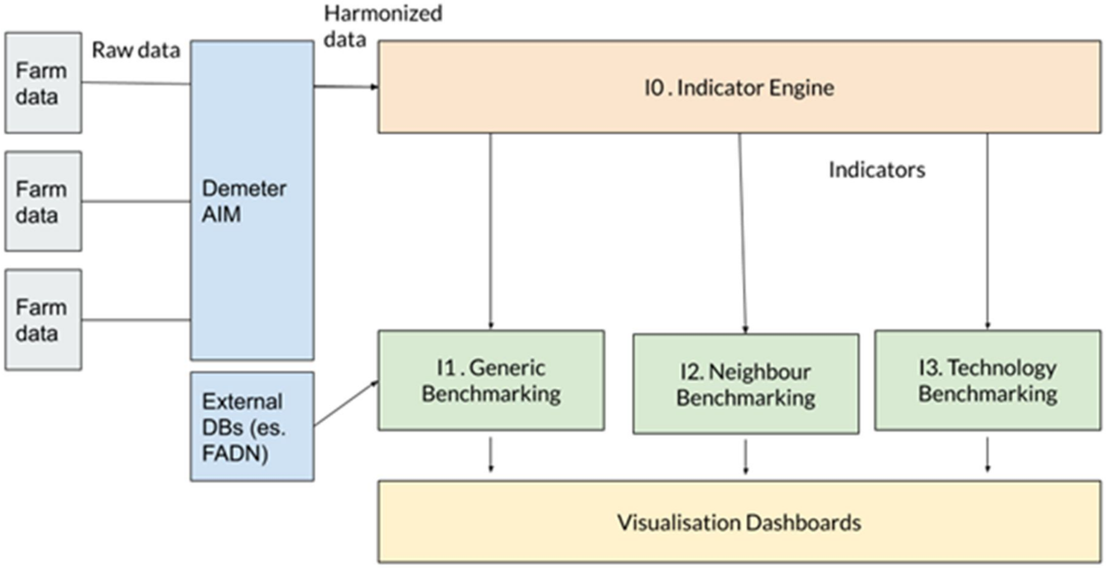

Figure 19. Benchmarking system data flows

The benchmarking tools will use the Agricultural Interoperability Spaces to access the farm data in a standard format. The access to the benchmarking tools and the data exchange among the components will be regulated according to the Data Security and Privacy DEMETER requirements.

When a user accesses the Benchmarking tools, the general interface of the benchmarking system will clearly explain the required data and each farmer will have the control of his own data. It will be possible to define which data to send to the Benchmarking component and if the user agrees that the resulting indicators will be available. The indicator can be used anonymously, to calculate a set of reference values to be used for benchmarking.

A connection has been identified with the H2020 ICT-17 Project DataBench [53] in that it shares two partners with DEMETER: SINTEF and ATOS. An investigation will be conducted to determine if some

DataBench components like the DataBench Toolbox (developed by ATOS), can be re-used in DEMETER to facilitate the development of the DEMETER components.

9.3.2 Benchmarking framework components

9.3.2.1 Component I.0 Indicator Engine for Benchmarking Purpose

The Indicator Engine is a component which allows the identification of indicators to assess the current agronomic, economic, and environmental sustainability with data available at the farm level. The selected indicators will be calculated in order to be used for benchmarking purposes.

The components will have the same features:

- Indicator Management: the core part of the components will be the repository of the indicators available to be calculated in the system. Each indicator will be associated with a general benchmarking area: agronomic, economic, or environmental. For each indicator, the input data required to calculate the indicator will be defined.
- Indicator Calculators: for each indicator, the way to calculate the indicator value will be defined. There will be different types of calculators:
    - Simple Indicators: if the indicators can be calculated with an algebraic formula from the input data, the registration of the formula will allow the calculation of the indicators. That functionality will be integrated in the I0 component.
    - Component/based indicators: if the indicator calculation will be based on a specific algorithm, it will be possible to call a DEMETER component to calculate the result of the indicators; e.g., the water efficiency can be expressed comparing the actual irrigation amount with the water needs estimated by a Decision Support System component (e.g., DSS Component-B.1); the calculator will prepare the input for the external components to get the results;
- Indicator Storage: the benchmarking engine, by design, will never store the input data from the farms. The actual storing of the calculated indicators will be optionally activated according to each user's decision. Any direct reference to the farm will be removed from the indicator value and the indicators will be aggregated to calculate a set of reference values to be used by the other benchmarking components.

A first set of potential indicators has been built based on the result of the questionnaires. In the development of the components we will start from the most requested performance indicators, starting with the yield comparison, then moving on to the water efficiency and farm and field water footprint. These indicators will be developed along with the related DSS Area A (Crop Yield), F (Animal Yield) and B (Irrigation Management).

Input: the inputs may cover all different data covering the farm, as defined by section 6.7.4 "Results on data availability". In any case, we need a spatial and a temporal definition of the input data. For spatial information, the farm can decide to share only the administrative division of the farm centre (NUTS3), if it does not want to share the geographic location.

The data will be grouped in thematic groups: farm general structure and composition, detailed farm spatial information, weather and sensors data, soil data, yield (at different scales of detail), logs of crop practices (irrigation, fertilisation, soil tillage, pest management), data on animal welfare, machinery data, economic data (input, output, profits).

Output: The system will produce a set of indicators. An interface showing the indicators calculated with data available at the farm level will be produced.

The results will be an array of indicator values associated with the indicator code, the area of the indicators, the year/time period related to the indicators and, if available, the reference value to be used in the comparison.

Pilots involved: all the pilots will be involved.

Limitations and challenges: The main issue will be related to data availability and on the errors related to the data harmonisation; we should check the uniformity of the unit of measurement and along with WP2 to get feedback on the quality of input data.

9.3.2.2 Component I.1 Generic Farm Comparison

The component will provide, to each farm, a set of basic economic indicators to be used to get a general benchmark of the farm activities. One of the main limitations for the benchmarking solution is the actual availability of farm data due to the difficulties in collecting them and the lack of trust of the farmers in providing this data.

We have defined the minimal set of data that can be easily available to create the "minimum viable product". The system will be connected to the Farm accountancy data network (FADN) and will be able to provide to each farm an estimated reference of the economic farm performance indicators: expected output, expected input and expected profit, along with an estimation of the input and output division in general areas.

From the farm general structure, a set of general indicators (European regions, dimension, surface by crops, composition of livestock) will be defined. The FADN database will be used to find the closest reference using a search to minimize the Euclidean distance of the farm indicators with the FADN record reference. The economic performances of each farm can be compared with the average value of the class to which it belongs.

Input: A minimum set of mandatory data has been identified. This basic information is the generic location of the farm centre (using coordinates or the related administrative region), the surface of the farm by crop group (e.g., cereals, permanent crops, horticultural crops etc..) and the number of livestock units by species.

If available and shareable by farms, the system may also acquire the basic information from the farms balance sheet (input, output, profit) to calculate the ratio between the expected value and the actual ones, otherwise the user can get the reference value comparing them privately with his own data.

Output: A set of economic indicators derived from FADN or EuroStat that a farm can use to get a reference (e.g., expected output, input and profit) and make the comparison with the same indicators calculated with the farm's own data.

Pilots involved: all the pilots will be involved.

Limitations and challenges: The main issue may be finding the right correspondence between specific farm's data and the FADN database. For specific farms it may be that there is no reference value in the database: e.g., farms that are bigger than usual, producing a crop which is rare in that area or producing high-value products (e.g. top-level wineries) may have no reference value available. The component is a first approximation in supporting farmers with benchmarking value, more advanced farms can access the following components.

9.3.2.3 Component I.2 Neighbour benchmarking

The component allows a group of farms (e.g., cooperatives, consortia, other organizations belonging to a specific area) to share data and compare performance. They select what kind of data they want to share to make performance comparison and which kind of output they wish to obtain.

The first available function is the "group creation", which allows the group coordinator (usually a system integrator) to create a group. The group can be either open (a user with a link to the group can join freely) or closed (only a predetermined set of users can participate). The group creator can also define the list of target indicators that need to be calculated and it will be possible to define the mandatory data needed to participate in the group.

The coordinator can choose the method used to calculate the reference values (e.g., average, median, top 10 percentile). Finally, it will be possible to create a set of profiles within a group to allow heterogeneous farms to compare with farms belonging to the same type (e.g., create sub-group related to specific location, create a group for organic and one for conventional farms etc.).

The second function will allow a user to join the group and to share the data with the other group users. The farm data and indicator results will never be shared, but the value will be used to create the benchmarking target value that will be shared by all the participants. After connecting their own data to the Benchmarking system, the user will be able to access a dashboard showing their own performance with a comparison with the group reference values. The dashboard will also evaluate the variability in time, make a comparison of the actual farm indicators along with the ratio to the reference target in time.

Input: the system requires the data selected by the group coordinator as mandatory; if the farm has insufficient data, it will be received feedback about the missing information.

Output: an interface showing how it is performing each farm, by comparing the selected indicators with the neighbouring indicator average or the "best in class" among neighbours.

Pilots involved: the component will be available to all the pilots, but there is already a set of pilots that are actively working on these benchmarking activities:

- Pilot 2.4 Benchmarking at Farm Level Decision Support System (benchmark productivity and sustainability performance of the farms).
- Pilot 3.1 Decision Support System to support olive growers (share olive yield and farming practices).
- Pilot 4.1 and 4.2 Benchmarking milk production and quality.

Limitations: organising the different types of data from different sources, determining a set of indicators reusable by different cases, how to deal with quantity/quality trade-off (e.g., performing great on yield but with poor product quality) and input use.

9.3.2.4 Component I.3 Technology benchmarking

This component fits the general DEMETER Objective 3: "Establish a benchmarking mechanism for agriculture solutions and business, targeting end-goals in terms of productivity and sustainability performance of farms, services, technologies, and practices based on a set of key performance indicators that are relevant to the farming community".

The farms productivity and sustainability performance has been addressed in the previous components, the current one is focusing on benchmarking services, technologies, and practices with two specific aims:

- provide a reusable component allowing a farmer or a group of farmers to evaluate the performance of a technology from the agronomic, economic, and environmental point of view.
- use the developed component as a DEMETER benchmarking mechanism, using the data collected by the farms participating at the several pilots to support the calculation of the DEMETER project KPIs.

The component has the following functions:

- create a group related to a specific solution or set of solutions, the solution coordinators will create the comparison group associating the group with the user that is testing the technology or the solution, the function is similar at the "group creation" already described in component I.2:
    - the group will contain two sub-groups, the target group, with the cases adopting the technology and a control group with the cases that have not adopted the technology.
    - choose a list of KPIs to compare the adoption of the solution, it will be defined a preliminary set of KPIs that will be combined later.
- Associate each group of the specific solution with the farms or the fields that have adopted that solution: some solutions should be tested at farm level because they involve all the farm activities (e.g., a general digitalisation of the farm), other solutions should be tested on a group of specific fields to make an internal comparison (e.g., testing the solution only on a sub-set of fields); each case should be added to the target or control group.
- Data collection: the system will acquire the required data.

Input: the following types of data will be needed by the component:

- yield - the yield is needed to estimate the economic output of the production and to calculate the solution efficiency (e.g., for water management solutions the water efficiency will be expressed in unit of water per unit of yield); it can be included also crop quality parameters if impacted by the solution (e.g., the increase of fat content in milk due to a precision feeding solution).
- specific data - the system will require the input data if the technology has produced a saving or a change of agronomic input (e.g., monitor water used for irrigation to calculate the reduction of volume after using an irrigation DSS); this type of input may include workforce, machinery, water, fertilizer, pesticides etc.
- prices - to calculate the main economic benchmarking we need to know the price of:
    - output: it can be a reference value for all the cases or defined case by case (the technology may affect the product price).
    - input: cost of each unit of input.
    - cost of the solution: this should include the estimation of the total investment cost connected with the adoption of the technology (licences, machinery, training etc…).

If the Economic data are not available only the agronomic indicators will be calculated.

Output: the output of the component is a report with the value of a set of indicators for the target group (farms that have adopted the technology) and the control group (farms that have not adopted the technology).

The following is a list with some test indicators. A set of indicators are general and will be needed for all the types of adopted solutions, some other indicators will be dedicated to some sectoral solution. (e.g., the irrigation DSS will be evaluated for a set of water-related indicators).

Agronomic indicators		
Indicators	**Description**	**Type**
Yield (t/ha)	yield per hectare	general

N use efficiency (kg/kg)	yield /Nitrogen unit	specific
Water use efficiency (kg/m3)	yield/total water consumption	specific
Treatments (n)	number of treatments	specific
Environmental indicators		
Indicators	**Description**	**Type**
Total water consumption (m3)	total water used for irrigation	specific
Total nitrogen consumption (N units)	total nitrogen used for fertilization	specific
Water footprint (m3)	total water consumed for the production, including the irrigation water and the water needed to produce the input	specific
Economic indicators		
Indicators	**Description**	**Type**
Gross saleable production (GSP)(€/ha)	yield per unit selling price	general
Specific costs (€/ha)	yum of the variable costs per area unit	general
Gross margin (€/ha)	GSP - specific costs	general

For each indicator we will calculate the KPIs of the technology, calculating the difference of the estimated value for target and control group (e.g., the decrease of water and pesticide usage per yield unit and per hectare after the usage of DEMETER enabled DSS).

If the economic indicators are calculated, the system will estimate the return of investment (ROI) of the solution, calculating the differential gross margin of the target cases divided by the total cost of the investment for the enabling technology.

Pilots involved: the solution will be available for all the pilots.

Limitations and challenges: the complete benchmarking of a solution has some related issues that have to be managed:

- it would be better to calculate analytically all the costs at farm or field level; if there are some difficulties for the benchmarking, the user can choose an analytical benchmarking (enter all the field input) or just to consider the inputs that are different among the two cases.
- to achieve a proper comparison, the two fields should be comparable: cultivated with the same crop and variety, similar environmental conditions (elevation, aspect, topography etc.) and agronomic condition (soil type, water availability etc.).
- the data analysis has to deal with the data uncertainty evaluating along with the target KPI the related interval of confidence.
- obtaining proper results probably needs a multi-year analysis to compare the efficacy over different conditions (e.g., the ROI of an innovative irrigation solution is higher in year with low precipitation).

10 Conclusions

This document presents the definition of the core building blocks of the DEMETER Benchmarking and AI-based Decision Support Tools. The pilots' description and Decision Support requirements have been analysed and mapped to define the required commons areas covering the main different types of decision-making subjects in the agri-food domain.

For each area, a set of required common components has been defined and described, mapping each component with a set of pilots. The decision tools have been integrated with the benchmarking components with the aims to support stakeholders in evaluating the productivity and the sustainability of the practices and producing tools to test and evaluate the efficacy of the digital solution in improving the production long-term sustainability.

The complete technical description of the Decision Enablers will be presented in the next D4.2 deliverable "Decision Enablers, Advisory Support Tools and DEMETER Stakeholder Open Collaboration Space – Release 1" due to be released in June 2020.

The planned activities will be constantly monitored during the weekly WP4 conference call. The WP4 will continue the implementation of the enablers and, along with pilots, will keep updated the list of core Decision Support and Benchmarking Components. The details of the implementation and the updated description of the components will be presented in the Deliverable 4.3 "Decision Support, Benchmarking and Performance Indicator Monitoring Tools – Release 2" due to be released M21 (May 2021).

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Annex A Pilot Descriptions

This annex describes the DEMETER pilots, where the decision support services will be applied. This content is a summary of what can be found in D5.1 supplemented by updated information from early version of D5.2 where available.

Note In this and the following Annexes, which each have a subsection for each pilot, the pilots have been grouped in the Pilot Clusters as identified in section 6 of D5.1, i.e.:

- Pilot Cluster 1. Sector: Arable Crops. Focus: Water & Energy Management
- Pilot Cluster 2. Sector: Arable Crops. Focus: Agricultural Machinery, Precision Farming
- Pilot Cluster 3. Sector: Fruits and Vegetables. Focus: Health and high-quality crops
- Pilot Cluster 4. Sector: Livestock. Focus: Animal Health, High Quality & Optimal Management of Animal Products
- Pilot Cluster 5. Sector: Cross-Sectorial. Focus: Full supply chain, Interoperability, Robotics.

A.1. *Pilot Cluster 1. Sector: Arable Crops. Focus: Water & Energy Management*

A.1.1. **Pilot 1.1 & 1.2**

The objective of Pilot 1.1 & 1.2 – Water Savings & Smart Energy Management in Irrigated & Arable Crops - is to increase production of irrigated crops whilst saving water and improving the automation of the irrigation zones through interoperable remote-control systems and robust management systems adapted to the conditions required by the irrigated agriculture. Spain has an area of 3,621,722 hectares for irrigated agriculture, of which 73% is modernized (pressurized irrigation networks) and the remaining, 27% is gravity irrigated. Along with the increase in production and the saving water, another important objective for technical and economic sustainability is to improve energy efficiency in these areas. The achievement of these objectives depends on the automation of the irrigation zones. There must be interoperable remote-control systems and robust management systems that optimize production scenarios and adapt to the conditions required by irrigated agriculture. The adaptation and application of new technologies to achieve these objectives is part of the term "precision agriculture" or "smart agriculture".

A.1.2. **Pilot 1.3**

Pilot 1.3 – Smart Irrigation Service in Rice & Maize Cultivation - aims to improve the management and automation of rice irrigation, along with nitrogen zonal fertilization. The region of Central Macedonia is the main rice producing area in Greece covering more than 20.000 ha. According to the Local Irrigation Authorities (TOEV), every 1 ha of rice field consumes 11200 m3 of irrigated water, delivered mostly from river Axios through a very efficient network of irrigation and drainage cement-made channels of several levels. Besides, rice farmers crop-rotate mainly with maize and also with alfalfa. Crop rotation systems are part of the Good Agricultural Practices, since they offer the only way to efficiently control weeds, diseases, and pests. Furthermore, rice has been listed by the Hellenic Ministry of Agriculture as a high-input cultivation, especially in terms of irrigated water needs. On the other hand, maize (mostly cultivated for silage in the area) also has substantial needs for irrigated water during the cultivation season. As such, the automated irrigation management in order to optimise water quality control (e.g. salinity levels) and quantity is of great importance for the pilot area.

A.1.3. **Pilot 1.4**

Pilot 1.4 – IoT Corn Management & Decision Support Platform - focuses on the Corn Management using IoT Devices to address inefficient fertilizer practices and how the demand for irrigated water contributes to environmental impacts, such as greenhouse gas emissions and poor water quality that drive business risks in corn production. All farmers are using weather data but only some of the farmers are using sensors to correlate aerial measurements (temperature, humidity) with real-time and historical data about soil temperature and humidity, crop types and rotations, type of corn hybrids, wind power and direction. Our decision system should be able to smartly represent this correlated information, offer smart visualisations and trigger real-time or early warning alerts. Implementation of an IoT Corn Decision Support System Platform for farmers will support; Open Field & Cold Greenhouse management; Crop Rotation; Pesticide Rotation; Hybrid selection; Corn residue management; Fertilisation & Sowing modules; Weed management; Tillage systems and IoT Platform Integration. Integration of weather and local sensor data, real-time monitoring, agricultural drone data and satellite imagery will form a compact and robust DSS tailored for efficient corn farm management that will also provide efficient collaboration and information exchange in a short local chain.

A.2. *Pilot Cluster 2. Sector: Arable Crops. Focus: Agricultural Machinery, Precision Farming*

A.2.1. **Pilot 2.1**

This section describes Pilot 2.1 – In-Service Condition Monitoring of Agricultural Machinery - where gaseous pollutant emissions have to be monitored and documented for combustion engines with a separate device. However, neither appropriate sensors nor appropriate real-time analytics are available to fulfil technical and legislative requirements. This pilot aims to address the upcoming objective that NOx has to be monitored and documented from 2026 onwards for combustion engines.

A.2.2. **Pilot 2.2**

Within Pilot 2.2 – Automated Documentation of Arable Crop Farming Processes-, the Documentation is an important process, and in many countries a legal requirement for various farming processes, e.g. plant protection. It is also the mandatory basis for precision farming. But also invoicing and performance metrics are derived from documentation. Therefore, a holistic and accurate documentation is key to smart farming systems. Future decisions are based on this information.

Having this importance in mind, the pilot strives for autonomous documentation by (a) capturing high precision data, (b) merging with data from other Lead Farms/ machines (data sharing), (c) deriving required documentation parameters by applying innovative data analytics, and knowledge management techniques. Autonomous documentation includes but is not limited to: Detection of operation type, detection of start/ end, field boundaries, time tracking (also for invoicing), and progress tracking. Based on the gathered data (also by considering other farms), the pilot will develop a decision support system for live support of agricultural processes and the connected supply chains.

The automated documentation needs to replace manual documentation based on intelligently linked sensor data, from machines and external sensors such as satellite data (e.g. sentinel) or data from weather stations. This information needs to be intelligently linked and interpreted in the respective context such as location, time, activity, or crop. This pilot will therefore focus on the development of a DSS that can integrate; machine data; spatial data; work data; farm inventory data and Cloud Platforms to provide a Data sharing platform that makes use of Data Analysis techniques.

A.2.3. **Pilot 2.3**

In this section, Pilot 2.3 – Data Brokerage Service and Decision Support System for Farm Management-, farm data brokerage aims to establish a trust-based and compliant data market for agricultural enterprise data that sits between the owners and operators of agricultural data Clouds and the farmer. This data market will consist of both a technical platform and advisory services that will ensure easy adoption of data and technology by farmers. The platform will manage integration of data from a variety of existing and emerging Cloud infrastructures and offline sources without loss of detail. Data will be filtered, queried, and processed in order to facilitate information retrieval and exploration. The platform will have transparency functions, e.g. model and check privacy and compliance policies, make dataflows visible, etc, to improve trust of the users.

In addition to integrating data, it is similarly necessary to provide a level of business intelligence that connects data to solving of specific day-to-day farm management tasks through a decision support system either directly at farms/farm managers or their 1st line support: agricultural advisors. Analysis and visualisation applications will facilitate transformation of raw data into decision support for practical decision-making. Advisors and brokers mediate data and services towards the agricultural sector, fostering quicker and easier adoption of data and technologies. There is a current demand this integration and applications among the proposed pilot participants and there is reason to believe that a market for this type of service may be developed rapidly through both geographical and thematically expansion; thus mitigating all five of the issues that speak against a proprietary centralized Cloud infrastructure operated by a small number of private actors.

A.2.4. **Pilot 2.4**

Pilot 2.4 – Benchmarking at Farm Level Decision Support System - will support the benchmarking on the productivity and sustainability performance of the farms, leveraging and extending existing decision support system for farmers (DSS). The goal of this pilot is to extend the Decision Support System (DSS) created by WODR, which currently covers the whole Wielkopolska region (and is foreseen as a base for national system), to support the benchmarking on the productivity and sustainability performance of the farms. The extended system will require to monitor several conditions and parameters affecting such indicators, including soil type, crop type, weather/climate, fertilisation activities, chemicals used, etc. A key challenge for this pilot will be the integration of such disperse and heterogeneous datasets, which will be tackled by adopting and generating Linked Data as a federated layer, complemented with security mechanisms to enable a controlled access to data. This will involve the definition of the underlying semantic models for the representation of data, reusing well-known vocabularies and previous results, including FOODIE ontology for farm data.

A.3. *Pilot Cluster 3. Sector: Fruits and Vegetables. Focus: Health and high-quality crops*

A.3.1. **Pilot 3.1**

Despite the fact DSSs may help farmers in implementing climate smart practices, their use among olive growers is limited due to the lack of user-friendly interfaces and easy-to-interpret outcomes. The aim of Pilot 3.1 – Decision Support System to Support Olive Growers - is to develop a DSS for olive growers, advisers and food processors to address common issues associated with olive tree growing and olive oil production, including integrated pest management, fertilizer use and irrigation needs, as well as adaptation of practice to climate change. The DSS will integrate in-field sensors data, remotely sensed data, a modelling platform and a farm management system, combing territorial information (soil, weather and crop traits) and IoT network, to improve the sustainable production of olive tree orchards. In support of this a pilot a set of sensors, software platform and open data sources will be defined and integrated in a platform to support olive growing and olive oil production; knowledge from farmers, agronomists and IT experts will be integrated into the platform; a DSS will be required for input optimisation and water, nutrient and pest management; and the data will also need to be integrated within all nodes of the supply chain.

A.3.2. **Pilot 3.2**

Farmers need simple, intuitive, and cost-effective technology to help them overcome climate changes, pests and diseases, and become more profitable. Pilot 3.2 – Precision Farming for Mediterranean Woody Crops - aims to enable measurable benefits from intensified data and information flows across small ‘woody crop’ farms. This will be achieved through the integration of IoT (AgIoT), Robotics, Older agricultural machinery, spatial data, work data, cloud platforms and the development of Add-ons for AgIoT (novel cost-effective sensors for crop state), data analytics techniques and a data sharing platform.

A.3.3. **Pilot 3.3 – Pest Management Control on Fruit Fly**

Farmers need cost effective technology to help them to predict the risk and take decisions in the most affected areas by the plague of the Mediterranean fruit fly. The objective of Pilot 3.3 – Pest Management Control on Fruit Fly - is to monitor, control and supervise the Mediterranean fruit fly (*Ceratitis capitata*) using automatic capture traps and remote sensing technologies. This kind of fly is an important plague attacking the citrus groves mainly in Valencia region. Using Unmanned Aerial Vehicle and processing captured images will allow for the prediction of risk and thus support growers in taking decisions in the most affected areas by the plague of the fruit fly.

A.3.4. **Pilot 3.4**

VITO developed a platform, WatchITgrow (www.watchitgrow.be), for potato monitoring in Belgium. In the H2020 Databio project the platform was extended for monitoring other crops in other regions (http://databio.vgt.vito.be). WatchITgrow uses remote sensing data (Sentinel 2, Copernicus program), combined with local meteo and soil data, to inform farmers via a user-friendly web application on the status of their crops and on expected yield. The crop model is based on a detailed physical model that needs to be manually finetuned for every species and variety, using a limited set of ground truth data. This lack of sufficient ground truth data (measured yields, crop variety, exact planting date) hampers the calibration and validation of crop growth models and the provision of specific advice on field management practices. Using detailed data from the AVR machinery in the field through the AVR Connect cloud application (detailed yield information, planting dates), the physical crop model can be replaced by a purely data-driven approach using machine learning techniques. Pilot 3.4 – Open Platform for Improved Crop Monitoring in Potato Farms - expects (i) to gain better insights on the interaction of crop, meteo, soil parameters and field management practices, and their impact on the final yield and (ii) to provide advice to farmers on how to optimize their current field practices in order to increase their yields in a sustainable way. In addition, the farmer can add field specific information such as planting date, variety, field practices (fertilization, irrigation, crop protection...) and crop damages to the WatchITgrow platform.

AVR is a machine construction company for potato planting, harvesting and storing. AVR Connect is the recently started IOT cloud platform acting as a data hub between the machine and other stakeholders in the potato treatment chain. Until now AVR focused mainly on the data collection, storing and treatment. Big data analytics combining this data with other data has not been done yet and should be part of this DEMETER project.

In the frame of the DEMETER project machinery data i.e. data from AVR potato planters and harvesters, will be added to the platform. Using machine learning techniques these data (machine parameters, planting parameters, measured yields) will be combined with crop- and field-specific info such as variety, fertilization, crop protection,..., and with satellite data, weather and soil info i) to gain better insights on the interaction of these parameters and their impact on the final yield as measured at harvest and ii) to provide advice to farmers on how to optimize their current field practices in order to increase their yields in a sustainable way. These are the major Agri-related innovations. This agronomical relevant data and advices will also be sent back to the AVR Connect application and machines to inform the users of the applications and also to propose e.g. optimal settings. Further technical innovations include the automatic detection of parcel boundaries and start/end of the season using machine learning algorithms.

A.4. *Pilot Cluster 4. Sector: Livestock. Focus: Animal Health, High Quality & Optimal Management of Animal Products*

A.4.1. **Pilot 4.1**

The objective of Pilot 4.1 – Dairy Farmers Dashboard for the Entire Milk and Meat Production Value Chain - is to support the interoperability of different platforms including data sharing and data exchange in the value chain from farm production to food processing and payment - including the support for innovative Decision support systems -through a “Dairy Farmers Dashboard – for the full milk and meat production value chain”. The pilot will focus on all milk producing farmers in Norway, with a number of farms in the Trøndelag region selected as the concrete pilot farms.

This pilot focuses on the full dataflow dashboard with animal product accounting, settlement, and payment, including decision support which is based on AI Machine learning from sensor data. The Farmer's Dashboard and Dataflow takes a different approach by identifying and using ontologies for the data and services to be exchanged and accessed – linked into a national platform for reporting for Norway.

A.4.2. **Pilot 4.2**

Pilot 4.2 – Consumer Awareness: Milk Quality and Animal Welfare Tracking - will implement an information flow optimization across different actors of the milk supply chain – from producers to consumers – ensuring the transparency of all stages.

The pilot intends to optimize the flow of information between the actors involved in their short milk supply chain. The scope is to integrate the data collected from the breeding farm to give an overview of the most important animal metrics. These metrics will be used to give insights on the quality of milk and will be accessible by the processing company through a single point of access.

Specifically, the following requirements are envisaged:

- An Animal Welfare DSS aiming at support the most important choices that the breeder has to make in the management of his/her livestock. This DSS aims to provide the breeder with important indicators mainly with respect to animal welfare (i.e. prediction of lameness, mastitis or ketosis) having as input all the data collected in the farm through existing devices and those acquired within the project. The DSS will have as output a pie chart showing a prediction of the percentage of sick and healthy cows for each pathology and will provide recommended actions to the farmer about how to improve highlighted critical situations.
- A Traceability DSS aiming at offer to the processing company a prediction of the milk quality based on data collected by the processing farm. Moreover, the DSS will provide suggestions about what to do to improve critical results.
- A Benchmarking system aiming at provide to the farmer and the processing company with a short report showing a comparison of a set of farm's performance indicators (milk yield by cow, milk total yield, milk quality, cow health, nutrition and company productivity) with a set of target values (i.e. average and optimal indicator values from similar/neighbour companies).

The quality of the milk is closely linked to the welfare of the animal: if the animal eats well, adequate amounts, rests and is healthy, this will increase milk production and milk quality, and lead to increased dairy yields. In addition, the quality milk payment system on “regional basis” (PLQ) encourages the farms to comply with pre-defined quality indicators, defined on a legal basis and focused on the hygiene and welfare of the livestock; with this system the regional health bodies for animal health represent the mediator between the breeding and the processing companies. Based on the quantified measurements of these indicators, the processing industry pays farmers a variable premium based on the quality of the milk.

A.4.3. **Pilot 4.3**

Pilot 4.3 – Proactive Milk Quality Control - aims to use appropriate ICT tools to measure relevant parameters of animal behaviour and physiological status on a continuous, real time basis. This will be achieved through: the review of current animal welfare scoring systems that are available Internationally; the identification of different behaviours and physiological states that can reflect or impact on welfare and health of dairy cows; the establishment of appropriate ICT tools to measure relevant parameters on a continuous, real time basis; the establishment of ‘gold standard’ measurements/ indicators of welfare and health of cows; the creation of a data fusion platform where the data from different sensors will be integrated and a predictive model for various well-being characteristics of the cow will be developed and the creation of a well-being audit for dairy cows that may be used as a reference standard to create management systems that improve animal well-being and that may also be used as a reference standard in the marketing of animal products (milk).

A.4.4. **Pilot 4.4**

At the present time, chicken farms do not currently have solutions for monitoring a variety of parameters and as such have a variety of systems mainly used for the management of individual operations. Pilot 4.4 – Optimal Chicken Farm Management - will deploy and validate open platforms designed for integrated poultry farm management. While doing so, a range of different IoT devices will be connected, live measurements collected and processed on the edge and in the cloud. Using several data analytics and AI based algorithms, advice, and suggestions on how to improve farm operation will be given to the farmers via web, mobile and chatbot clients.

The platform will implement and validate APIs and interfaces based on standards and DEMETER interoperability space to ensure easy interaction and mashing-up of functionalities of various platforms. The pilot will also cover the supply part of the farming business. It will serve as the basis for execution of pilots in the context of Cluster 5, where demand side will be addressed through further integration and interoperation of various systems. To ensure diverse inputs and a potentially wide impact, activities within this pilot will take place across 4 countries.

A.5. ***Pilot Cluster 5. Sector: Cross-Sectorial. Focus: Full supply chain, Interoperability, Robotics***

A.5.1. **Pilot 5.1**

Disease controlling is usually based on experience or data that are not precise enough for each field, resulting in using more pesticides which consequently lead to quality decrease. Additionally, there is a lack of evidence required by consumers willing to have an insight into production process. The goals of Pilot 5.1 – Disease Prediction and Supply Chain Transparency for Orchards/Vineyards - are to evaluate and validate technical aspects of creating a product passport for the fruit and wine products as the basis for creation of a transparent and trusted supply chain. In addition to the technical validation and assessment, pilots will also address the corresponding business models and constellations. Leveraging the interoperability mechanisms provided by DEMETER, the product passport platform will gather relevant information from different farm management platforms about the supply chain activities (production, transport, retail), relying on interoperability interfaces defined by DEMETER. The pilot will investigate the required granularity of data to be collected, its lifespan, as well as technical implications of processing such potentially large amounts of data. A blockchain based protocol (Origin Trail) will be used to ensure trust and transparency between actors in the chain. As consumers are an important element of the supply chain and, having in mind the ever-increasing desire to know more about the food we are eating, food items will be tagged using appropriate tags (printable, combination of normal and functional ink to capture important events) to engage consumers in different settings (shops, restaurants). Consumers will be able to use DEMETER smartphone application to obtain information about the products, about their route from the time of manufacturing to the time of scanning. Information about the context of products scanning (location, time, social profile, etc.) will be shared with supply chain stakeholders who will, based on that, be able to provide additional services to consumers at the time of interaction, extend relationship with the consumers beyond the point of sale as well as to optimize production processes. Validation of the usefulness of the gathered data, the required level of detail expected by consumers, different approaches to presenting traceability information as well as potential monetization models will be done.

A.5.2. **Pilot 5.2 – Farm of Things in Extensive Cattle Holdings**

Pilot 5.2 – Farm of Things in Extensive Cattle Holdings - comprises two use cases in which technological innovations aim, in the first use case, at improving food transparency and user involvement, whereas in the second use case, at improving milk quality in dairies as well as animals' well-being and health.

The food transparency and user involvement use case intends to integrate data brokering solutions in current production systems of dairy products and pastries, with the purpose of tracking ingredients and final products. The company engaged in manufacturing, that is participant in this project, has beaten in 2017 its turnover record in the sale of pastries, after reaching € 28.4 million. These data can be indicative of the number of users interested in the benefits of optimizing production systems.

Regarding the provision of techniques to involve end users in the production of food, two kinds of activities will be included. On the one hand, consumer workshops will be organized in Codan Park (Madrid, Spain), where the process of elaboration and processing of products is explained, and an initial interaction of these groups is provided. On the other hand, CODAN's production platform will be integrated into a retailer platform (Carrefour) in Germany so that, product information and price suggestions can be directly applied to end-users in a German supermarket.

The use case concerning dairies aims at applying innovative solutions to improve outcomes. The demonstrator to be carried out will manage animal wellness and measure crops and soil properties (irrigation, need for fertilising), showing the essential innovations of the project. Grass and soil measurements will be performed also with missions involving autonomous ground vehicles in fields. In the scenario, a cow nutrition system will be deployed and integrated. The optimal feeding of cows requires constant nutrient monitoring because the main food of cows is grass – fresh or silage. A big number of animals in farms require big amount of forage and thus large cultivation areas for growing grass. The new Total Mixed Ration (TMR) feeding method requires a new level of accuracy in nutrient control. In TMR feeding, all fodder ingredients (silage, cereals, supplement feeds, water etc.) are mixed carefully together. To achieve optimal results, the recipe for the mixing requires accurate awareness of nutrient contents, in which the silage has the biggest deviation. An optimal quality of feeding ensures better milk production with better nutritive content, but also contributes to the animal's well-being.

A.5.3. **Pilot 5.3 – Pollination Optimisation in Apiculture**

Enable better communication of farmers and beekeepers to protect bees and to optimise pollination of crops with the aim of improving their yields. Among the many potential responses to pollinator decline, better pesticide control, integrated pest management, and improved pollinator control and management are particularly important activities. Pilot 5.3 – Pollination Optimisation in Apiculture - aims to provide improved yield in crops of farmers and better gains for beekeepers. Studies on the importance of pollinators on crops that are directly consumed by humans show that three out of four crops depend, at least in part, on pollinators. Pollinators are essential for 13 crops, production is highly pollinator dependent for 30, moderately for 27 and slightly for 21 crops. Honeybees, mainly *Apis mellifera*, remain the most economically valuable pollinators of crop monocultures worldwide and yields of some fruit, seed and nut crops decrease by more than 90% without these pollinators (Klein, 2007). Pollination is the highest agriculture contributor to yields worldwide, contributing far beyond any other management practice.

A.5.4. **Pilot 5.4**

Existing systems in poultry farms are mainly used for management of individual operations without a real-time integrated management view. Consequently, there is a lack of services providing relevant information about production to the consumers, i.e. medical treatment, feeding patterns, etc. The goals of Pilot 5.4 – Transparent Supply Chain in Poultry Industry - are to evaluate and validate technical aspects of creating a product passport for the fruit and wine products as the basis for creation of a transparent and trusted supply chain. In addition to the technical validation and assessment, pilots will also address the corresponding business models and constellations. Leveraging the interoperability mechanisms provided by DEMETER, the product passport platform will gather relevant information from different farm management platforms about the supply chain activities (production, transport, retail), relying on interoperability interfaces defined by DEMETER. The pilot will investigate the required granularity of data to be collected, its lifespan, as well as technical implications of processing such potentially large amounts of data. A blockchain based protocol (Origin Trail) will be used to ensure trust and transparency between actors in the chain. As consumers are an important element of the supply chain and, having in mind the ever-increasing desire to know more about the food we are eating, food items will be tagged using appropriate tags (printable, combination of normal and functional ink to capture important events) to engage consumers in different settings (shops, restaurants). Consumers will be able to use DEMETER smartphone application to obtain information about the products, about their route from the time of manufacturing to the time of scanning. Information about the context of products scanning (location, time, social profile, etc.) will be shared with supply chain stakeholders who will, based on that, be able to provide additional services to consumers at the time of interaction, extend relationship with the consumers beyond the point of sale as well as to optimize production processes. Validation of the usefulness of the gathered data, the required level of detail expected by consumers, different approaches to presenting traceability information as well as potential monetization models will be done.

Annex B Pilot Architecture Diagrams from DEMETER Pilots

This section will analyse how the DEMETER Reference Architecture has been instantiated by each pilot of the project in order to depict the DSSs to be implemented in them. This way, we can have a clear view of the different components to be developed in the pilots and how the DSS will help to enrich the DEMETER Reference Architecture by the adding those components to the architecture. In this section, we will introduce the DEMETER Reference Architecture, following with the different DSS architectures (based on the Reference Architecture) of each pilot. At the end, a set of clusters of applications and a set of enablers are introduced in order to design the future works regarding the DSSs creation for the pilots.

B.1. *DEMETER Reference Architecture*

DEMETER project has proposed a Reference Architecture that will be used as the base of different solutions provided in the pilots of this project. Here is to be introduced a brief summary of the description provided in sections 10 and 11 from Deliverable 3.1. This architecture was built upon a set of requirements provided by the different actors involved in the project. This architecture has been described according to ISO/IEC/IEEE 42010 International Standard [1], that provides a conceptual model of architecture description.

The DEMETER Reference Architecture aims at the integration of different components, technologies and systems looking for their use in the creation of personalized solutions for each scenario. To do that, a series of basic concepts have been defined as the main blocks of the methodology proposed:

i) Finally, the **Stakeholder Open Collaboration Space** will offer a complete collaboration environment, dedicated to all stakeholders (farmers, advisors, and suppliers) where they can collaborate, share best practices and participate in co-creation processes. The knowledge-driven services, complemented by the collaborative and innovation side of the Platform, will create a virtual environment where providers and consumers of digital technologies are not just matching assets and needs, but they are collaborating together towards joint innovations. Indeed, the SOCS aims to “put farmers fully in control of their needs, of their choices, of their speed of adoption of solutions, of their data” and would like to represent a response to their need to be supported when they have to choose between different solutions.

ii) The DEMETER Agricultural Interoperability Space (AIS), that gathers all the interoperability mechanisms to be used in the different solutions provided by the platform.

iii) The DEMETER Dashboard that will serve as the main access medium to interact with both the SOCS and the AIS.

iv) The DEMETER Enabler Hub (DEH) where all the available mechanisms, services, components, etc. are listed and described in order to be accessed for the development of new solutions. Additionally, this DEH includes all the required mechanisms to ensure the interoperability of all the different components to be used in the platform so they can properly interconnect with the rest of the components included.

In that DEMETER Enabler Hub, two main roles have been identified:

- DEMETER Providers (those developers or stakeholders that offer DEMETER-enhanced Entities, mechanisms and components published in the DEH).
- DEMETER Consumers (those stakeholders that aim to use those DEMETER-enhanced Entities available in the DEH in order to provide a fitted solution to their requirements).

It has also to be pointed that some DEMETER Enablers that are mandatory for all developments, as they are required in order to guarantee the interoperability with the rest of the DEMETER components. These mandatory DEMETER enablers, called DEMETER Core Enablers, must be available in every DEMETER-enhanced Entity.

Once the main concepts of the DEMETER Reference Architecture have been identified, Figure 20 represents an example of an instantiation of the DEMETER Reference Architecture in a given solution.

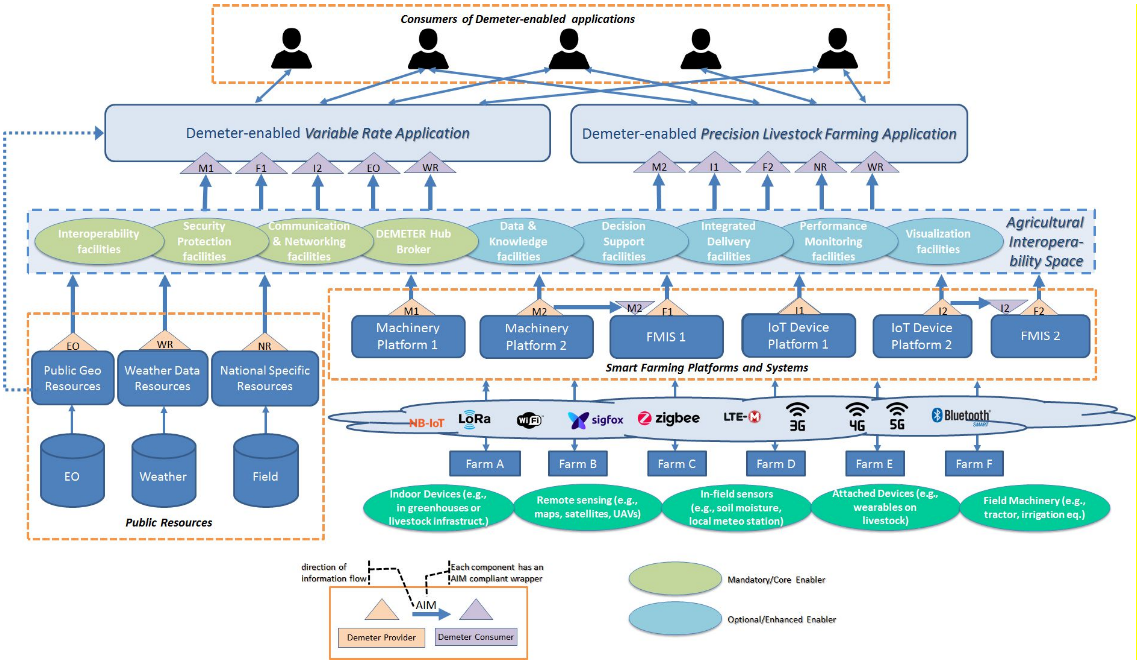


Figure 20. High-level view of DEMETER Reference Architecture instantiation example

As we can see in this example, in the lower part of the diagram, we can see the DEMETER Providers, depicted by an orange triangle, that feed the DEMETER system with data from different sources (In the left side of the diagram we can see public resources that provide data from public data sources such as weather data services, public satellite images, etc., while in the right side of the diagram we can see data sources to be added in this example such as sensors, machinery, etc.). These providers interact with a set of enablers from the AIS (those mandatory DEMETER Core Enablers and the appropriate Enablers corresponding to the Data Providers chosen) generating DEMETER Enhancing Service. These services are used by the resultant applications that consume them (we can see the DEMETER Consumes depicted as blue triangles) in order to provide the final solution to the stakeholders.

Based on the architecture introduced, each DEMETER pilot was requested an instantiation of the architecture adapted to the DSS solutions to be implemented in that pilot. This way, we will be able to identify the different DEMETER-enabled Applications to populate the DEMETER Ecosystem as well as the different enablers that will be used in each one of those applications (or in other applications). In the following sections and diagrams, the different data sources, public resources and Smart Farming Platforms and Systems are depicted, although these elements are more related to the given technologies and devices to be used in each pilot.

B.2. *DEMETER Reference Architecture instances for Pilot Cluster 1*

B.2.1. **Pilot 1.1 & 1.2**

In these pilots, four DEMETER-enabled Applications are proposed, aiming at the coordination and control of irrigation-related systems. Eight different enablers are proposed, focused on irrigation, and fertilisation, as well as the data sources proposed, with soil sensors, irrigation control devices and water consumption sensors (in addition to other general weather sensors and other actuators).

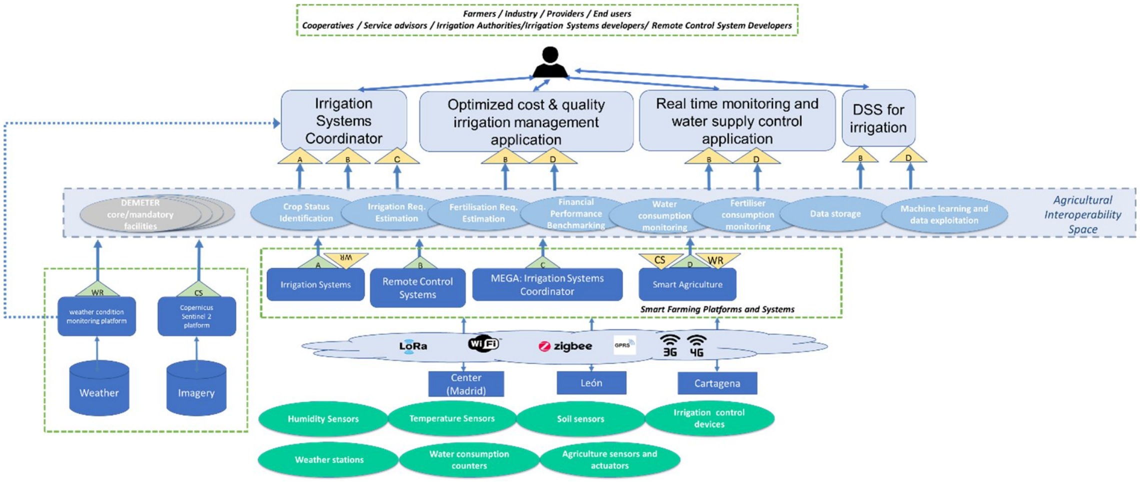


Figure 21. Pilot 1.1 & 1.2 reference architecture

B.2.2. **Pilot 1.3**

Components proposed by the pilot 1.3 architecture instantiation keep some similarities to those proposed in pilot 1.1 & 1.2 as this pilot is also focused on irrigation. In this case, the DEMETER-enabled Applications proposed include a smart irrigation service for each of the two proposed crops as well as a service for advisory applicable for both crops. As in pilots 1.1 & 1.2, enablers proposed are also focused on irrigation and fertilisation.

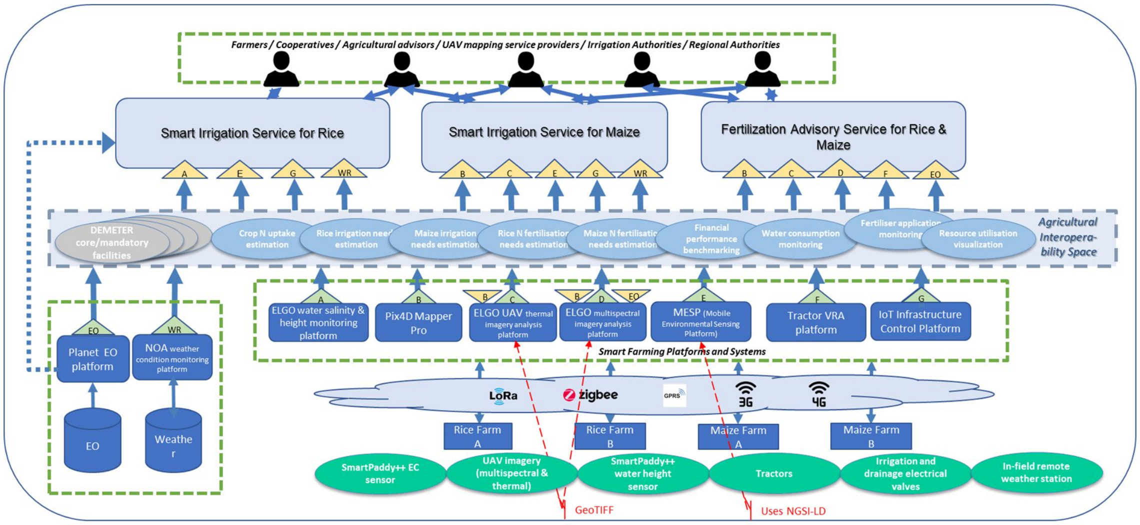


Figure 22. Pilot 1.3 reference architecture

B.2.3. Pilot 1.4

Fertilisation and Irrigation are also the main goals in the DEMETER-enabled Applications proposed by pilot 1.4 (in addition to one to check the crop health status and weather alerts). Also, the enablers proposed are related with both irrigation and fertilisation as well as the data sources (in this case, more focused on weather measurements such as wind or precipitation).

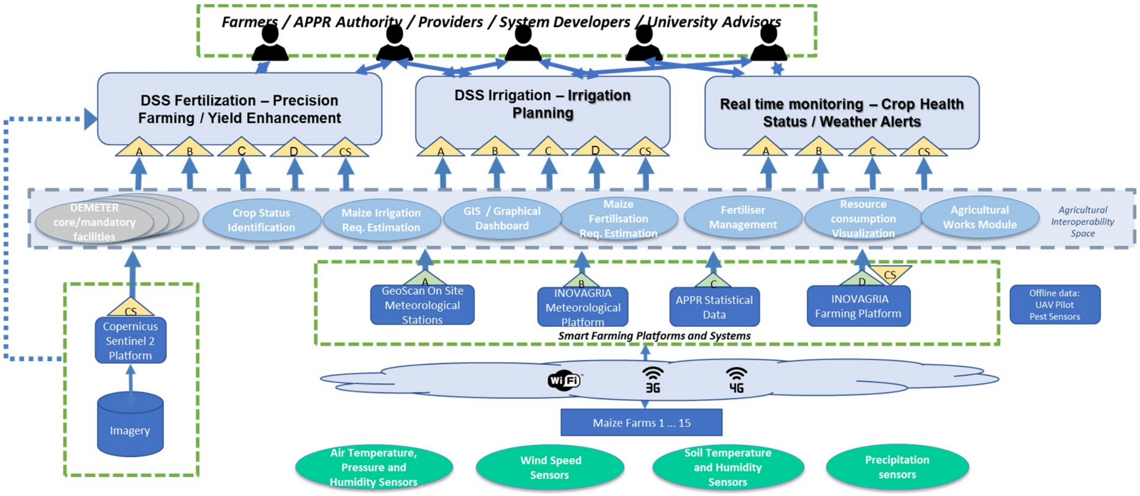


Figure 23. Pilot 1.4 reference architecture

B.3. *DEMETER Reference Architecture instances for Pilot Cluster 2*

B.3.1. Pilot 2.1

This Pilot 2.1 proposes a Machine Data Monitoring and Documentation Application for monitoring agricultural machinery emissions using enablers based on the consumption of that machinery, and emission and chemicals estimations and analyses.

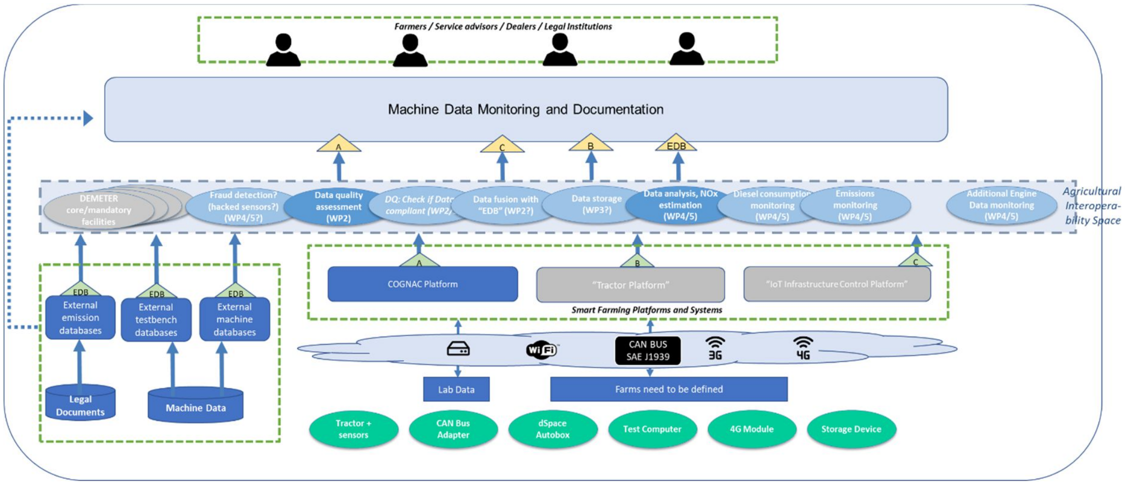


Figure 24. Pilot 2.1 reference architecture

B.3.2. **Pilot 2.2**

For this pilot, two main applications have been proposed: one for job calculation and prediction and another one for documentation. The main enablers proposed are related to the costs calculation and documentation using cost data as input together with GPS and AutoTrack data.

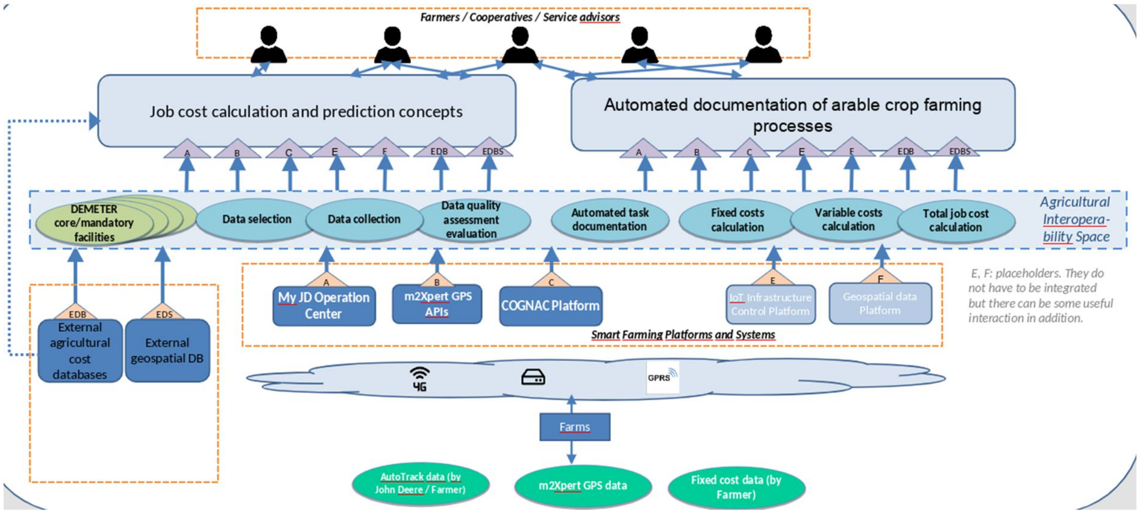


Figure 25. Pilot 2.2 reference architecture

B.3.3. **Pilot 2.3**

Pilot 2.3 proposes a DEMETER-enabled Application for DSS and data brokerage. Due to the wide nature of the data to be handled by that application, a wide variety of enablers have been proposed to be used in this pilot to handle various types of data, including crop status, irrigation and fertilization, or machinery and processes. This variety of data can also be seen in the different data sensors proposed, from satellite images to tractor data going through drones or weather stations data.

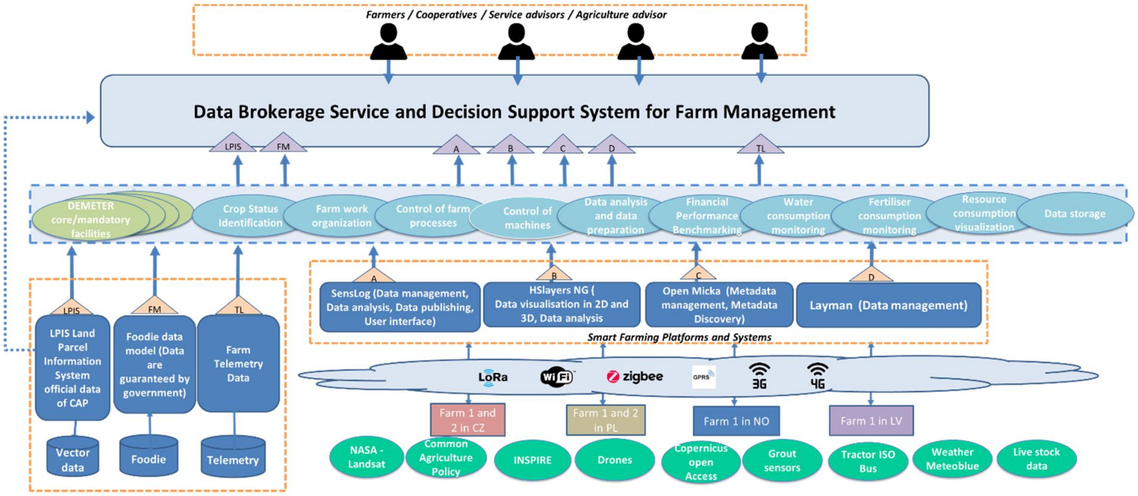


Figure 26. Pilot 2.3 reference architecture

B.3.4. **Pilot 2.4**

Three different DEMETER-enabled Application are introduced in pilot 2.4: A Benchmarking app for farmers, a back office Advisor's tools and a report app all of them focused on the benchmarking-related nature of the pilot. We see how the enablers proposed to the development of these solutions are also related to benchmarking (general benchmarking models, accountancy benchmarking models, FADN individual report benchmarking and economic size models). Regarding the data sources, meteorological stations and local sensors have been proposed to be used (in combination with external data sources capable to provide more benchmarking-focused market information).

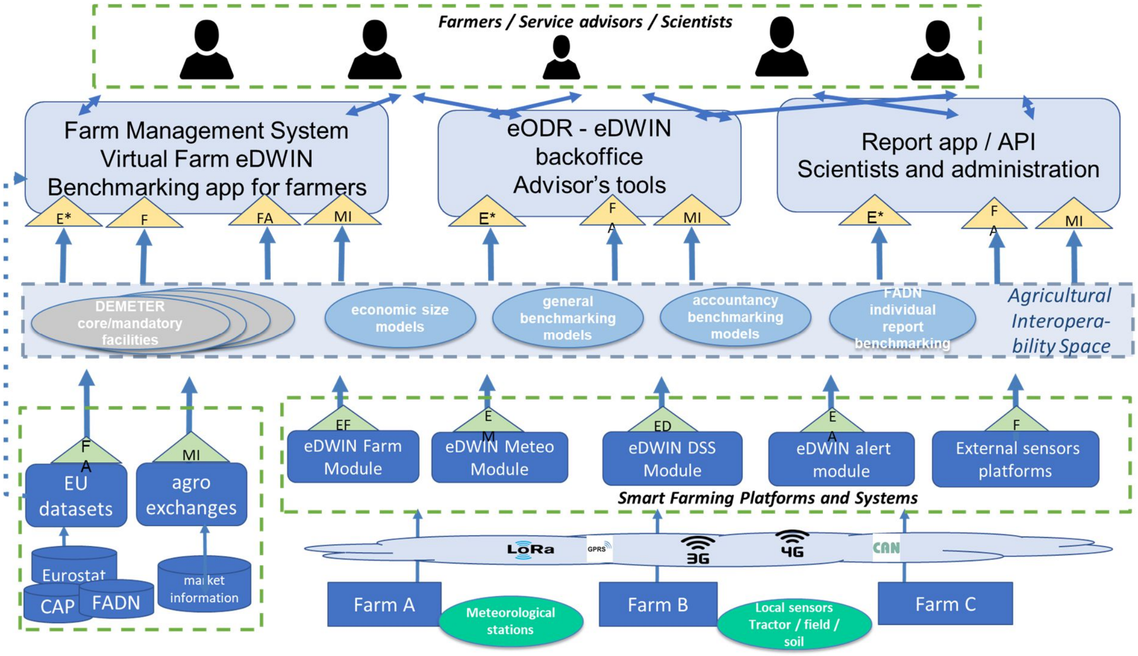


Figure 27. Pilot 2.4 reference architecture

B.4. *DEMETER Reference Architecture instances for Pilot Cluster 3*

B.4.1. **Pilot 3.1**

Pilot 3.1 proposes a DSS to support olive growers based on enablers related to olives (yield estimation, phenology model calibration, agronomic Performance, environmental performance). In order to get data in this pilot, smartphones, weather sensors, soil sensors and automatic traps have been proposed as data sources.

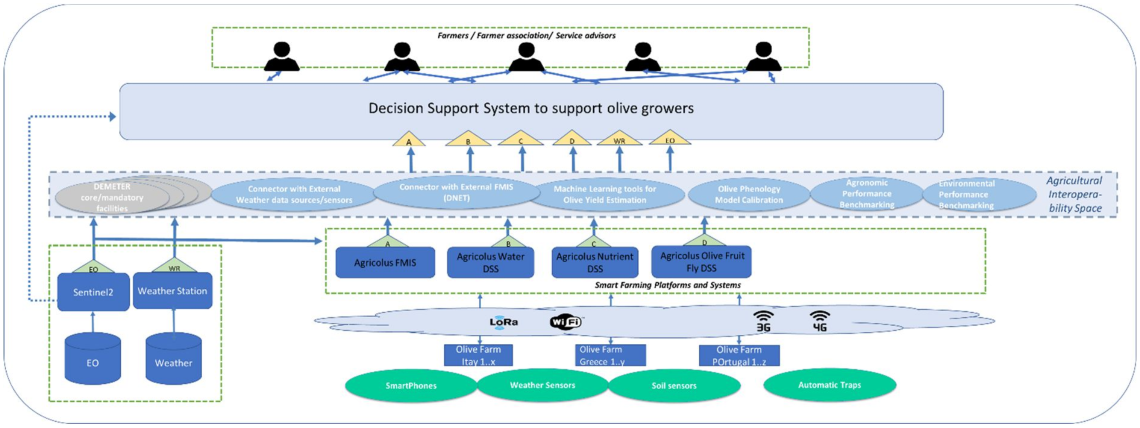


Figure 28. Pilot 3.1 reference architecture

B.4.2. **Pilot 3.2**

Pilot 3.2 main goal is the development of an Application focused on the Support of the Mediterranean woody Crops (like apple trees, olive trees or vineyards). This is expected to be made by using enablers related to crop status identification, irrigation, fertilisation, and pest control (in addition with other technical enablers). Regarding the data sources to be used in this pilot, we can find sensors (agriculture sensors, weather, soil) in combination with machinery data, imagery data and smart traps (for pest control) data.

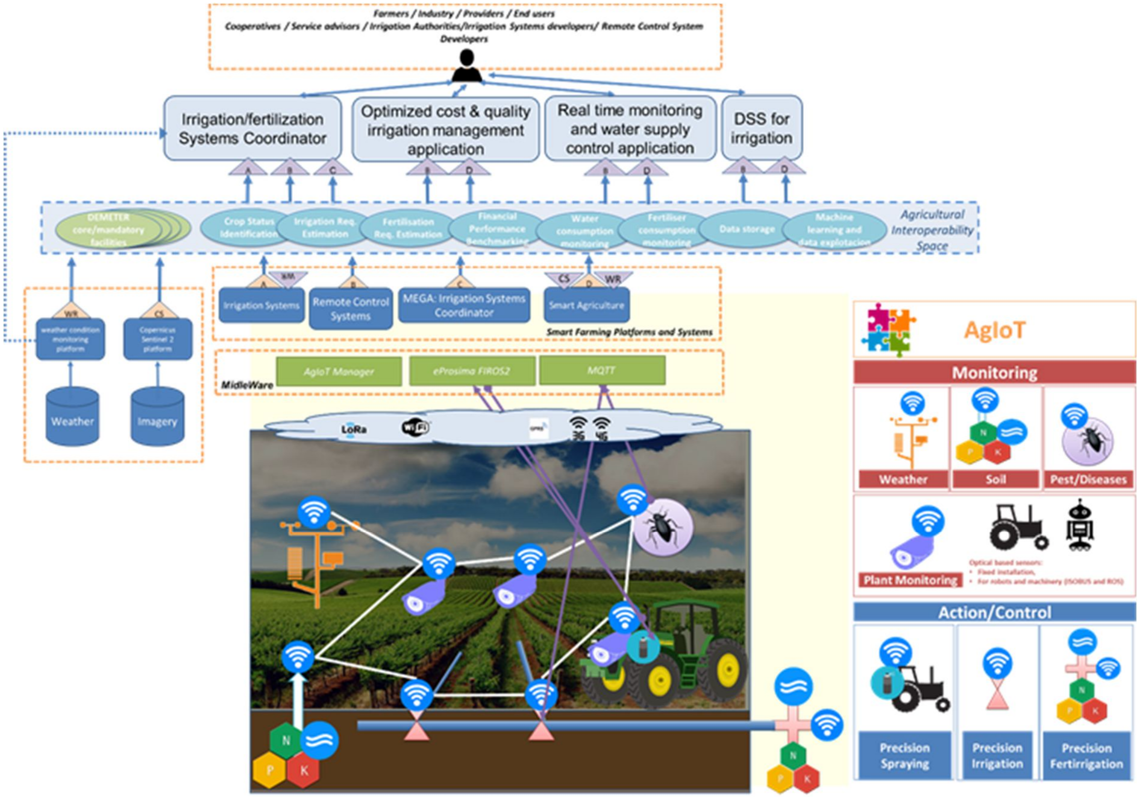
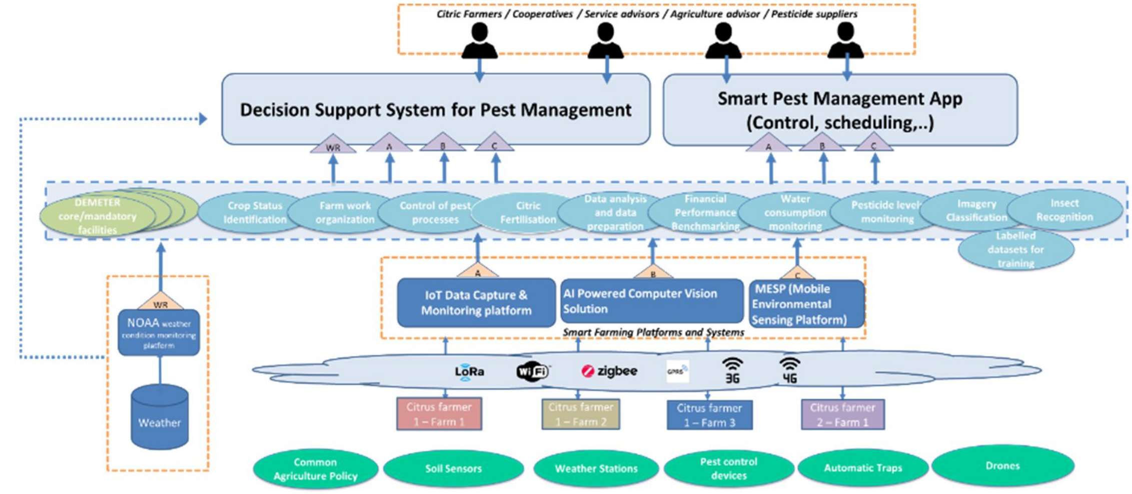


Figure 29. Pilot 3.2 reference architecture

B.4.3. **Pilot 3.3**

Two different DEMETER-enabled Applications have been proposed for Pilot 3.3 focused on fruit fly control: a DSS for pest management and a Smart Pest Management App. In addition to enablers related to fertilisation and irrigation, the main enablers proposed in this pilot deal with image processing in order to count and identify different types of fruit flies (Imagery Classification and Insect recognition). Also, some enablers to address pests have been proposed (Control of pest processes and Pesticide level monitoring). From the data sources point of view, the main novelty (in addition to weather and soil related data sources) of this pilot regarding others is the inclusion of Automatic Traps that will capture fruit flies and take pictures of them.



Possible Additional Capabilities:
- Combine information about Weather and number of flies captured
- Combine information about soil moisture and number of flies captured

Figure 30. Pilot 3.3 reference architecture

B.4.4. **Pilot 3.4**

Pilot 3.4, that aims at the improvement of the potato crop monitoring, proposes three different Applications: a DSS Variable Rate Application, a DSS Crop yield prediction with irrigation scenarios and Data visualizations. Enablers proposed in this pilot make a strong use of machine learning techniques applied to yield prediction with Earth Observation (EO) Data or optimal irrigation scheduling. Other enablers proposed include Task Map Generator Variable Rate Applications (with EO Data) or a potato variety selector. Data coming from AVR machines is proposed as a data sources in addition to soil and weather-related sensors.

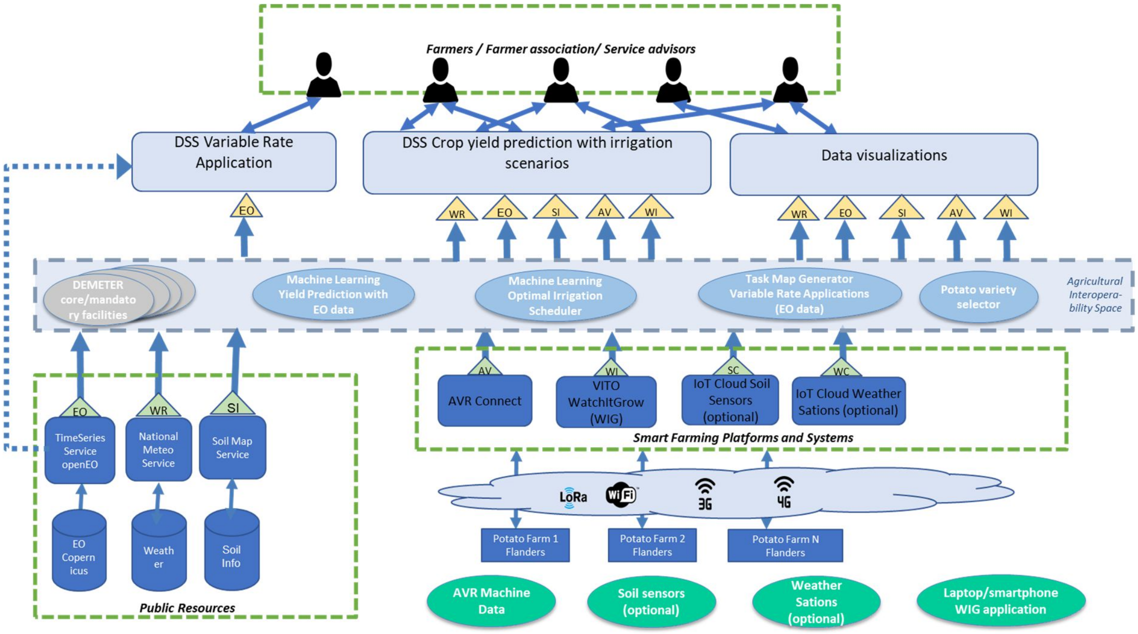


Figure 31. Pilot 3.4 reference architecture

B.5. *DEMETER Reference Architecture instances for Pilot Cluster 4*

B.5.1. **Pilot 4.1**

Pilot 4.1 proposes an application with a dashboard for accounting, benchmarking, and milk production prediction. This dashboard will be generated using a wide variety of enablers: climate (Climate Accounting), economic (Financial Performance Benchmarking, Economic Performance, Supplier Order Payment) and cow/milk related (Cow Growth Function Model, Lactation Curve Algorithms, Milk Volume Model, Milkman Forecast). As we can see in the architecture proposed by the pilot, the main data sources proposed are related to the state of the animal (Feeding Sensors and Cow Health Sensors) and the processing and analysis of the milk (Milk Fat Sensor, Milking Robot Sensors).

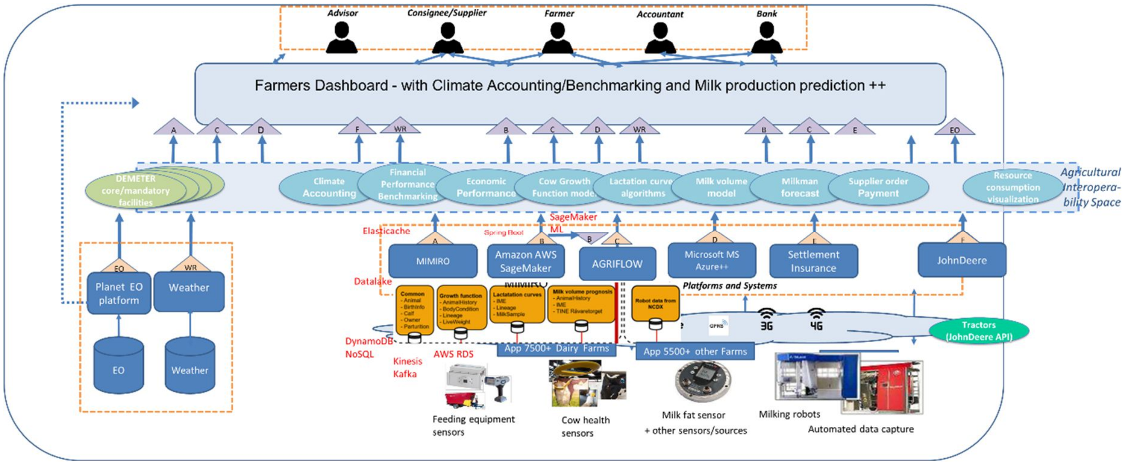


Figure 32. Pilot 4.1 reference architecture

B.5.2. **Pilot 4.2**

Pilot 4.2, centred in both milk quality as well as in animal welfare, proposes two different DEMETER-enabled Applications, each one for one of those goals (Milk Quality Prediction and Labelling Traceability and a DSS for Animal (livestock) Welfare). Several enablers related to data management and processing are proposed, with other more pilot goal-focused, such as Cow Health Prediction, Stress detection, Milk Quality Prediction, Benchmarking, and Traceability Management. In parallel with the two goals that drive this pilot, two kind of data sources are going to be used: animal welfare-related data sources (i.e. pedometer, animal temperature data log, and Aficollar providing animal movement, temperature and eating habits metrics) and milk quality-related data sources (i.e. AfiLab, Milko-box, and MilkoScanFTIR providing milk composition and quality metrics).

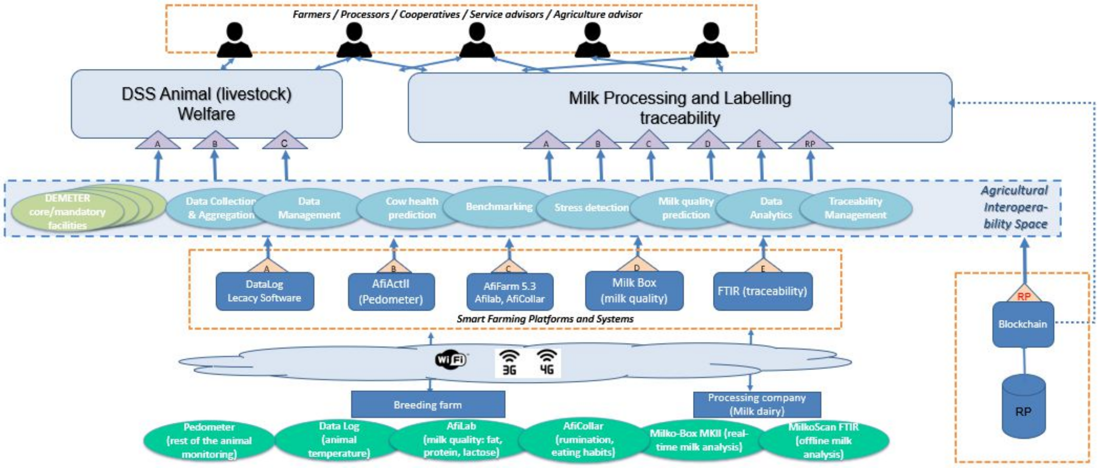


Figure 33. Pilot 4.2 reference architecture

B.5.3. **Pilot 4.3**

Regarding pilot 4.3, four different applications have been proposed, focused on the milk quality control. Enablers proposed for these applications include components focused on the state both of the cow and the milk (i.e. cow welfare and health scoring system and animal illness indicating system). Data sources are also related with the nature of the pilot, proposing the use of pedometer sensors, accelerometers, automatic milking system sensors, cow body condition, disease diagnostic system and conventional milking system performance data.

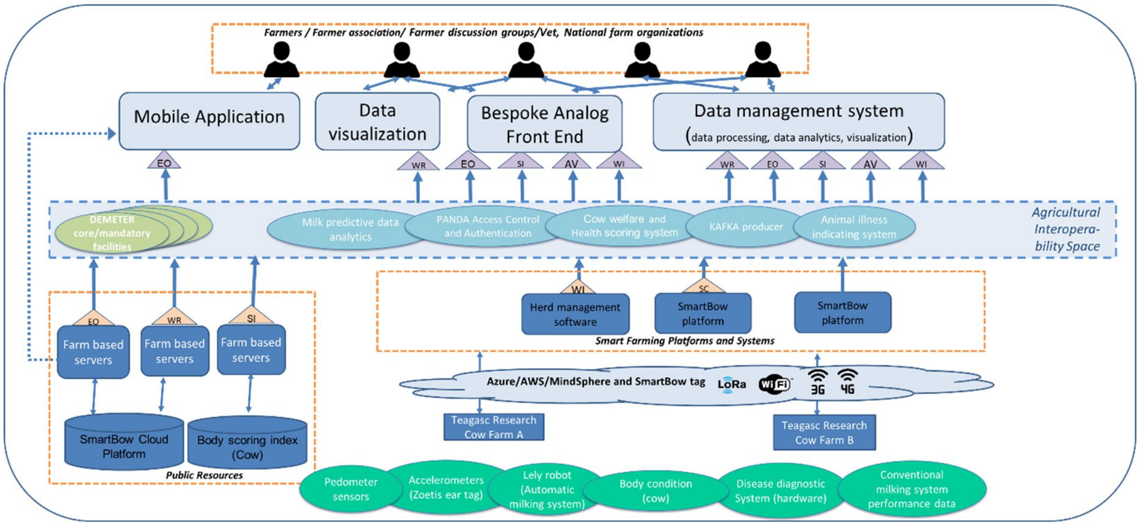


Figure 34. Pilot 4.3 reference architecture

B.5.4. **Pilot 4.4**

Pilot 4.4 aims at optimising chicken farms. To do that, it proposes an application based on the following enablers: Product Passport (related to the processing of the chicken-based product processing), Stress recognition, Food Travel Assessment, Environmental Condition Assessment, Instruction Advices for Consumption, Power Losses and Silo Conditions Detection. Chicken farm-oriented data sources are proposed for their use in this pilot, such as Poultry Feeding or water consumption, and other more generic data sources are also used (such as IoT weather related data, etc.).

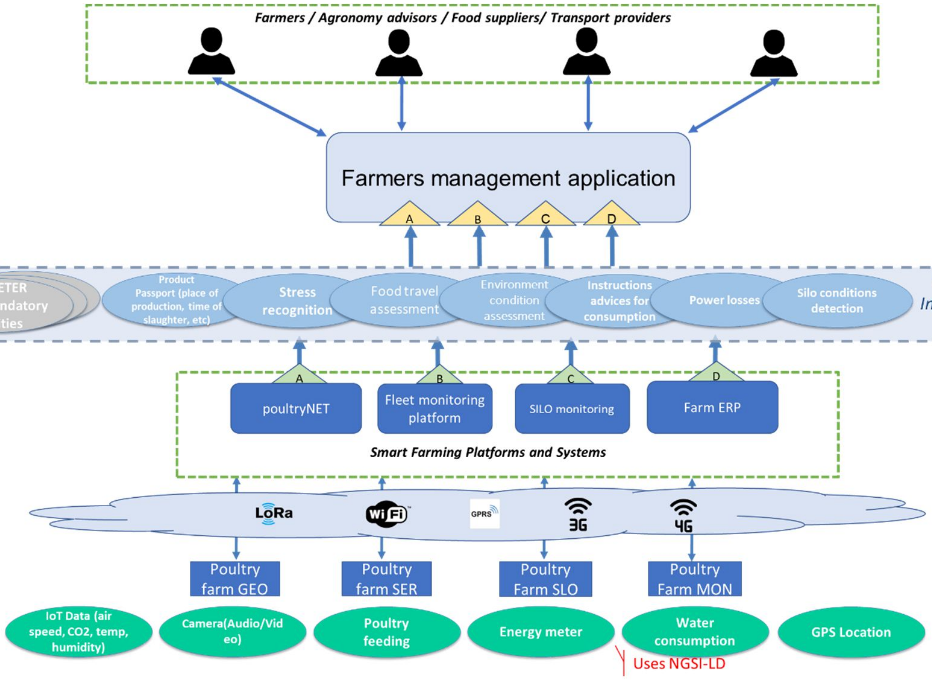


Figure 35. Pilot 4.4 reference architecture

B.6. *DEMETER Reference Architecture instances for Pilot Cluster 5*

B.6.1. **Pilot 5.1**

Pilot 5.1 also proposes a single DEMETER-based Application, aiming at the disease prediction and supply chain transparency for orchards/vineyards. This pilot proposes a set of goal oriented enablers, such as Product passport (following the approach of the enabler proposed in pilot 4.4), Disease recognition and Machinery/sprayer control. Also, some data sources are quite related to the goal of the pilot, such as the Pheromone trap and the Tractor or the Sprayer/robot.

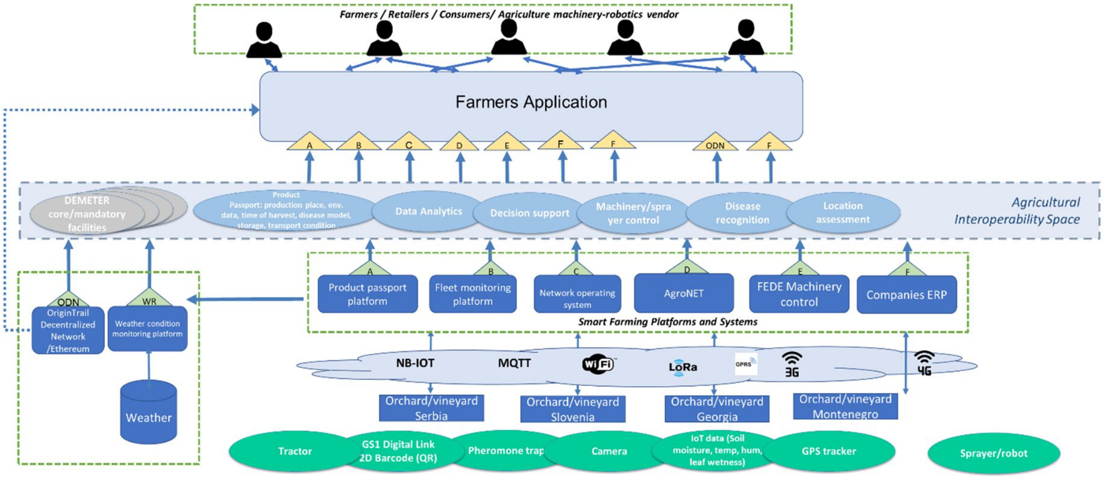


Figure 36. Pilot 5.1 reference architecture

B.6.2. **Pilot 5.2**

Pilot 5.2 proposes a DEMETER-Enabled Application capable to handle cattle holdings data. Most enablers proposed in this pilot are focused in the final product of cattle holdings as well its management (Product Passport, Food Travel Assessment, Instructions Advices for Consumption) with others related with the animal state or other related conditions (Stress Recognition, Environment Condition Assessment) or other enablers (Solo conditions detections, Power Losses). Regarding data sources proposed, several IOT data sensors are proposed (air conditions, temperature, humidity), camera, feeding and water consumption and GPS location.

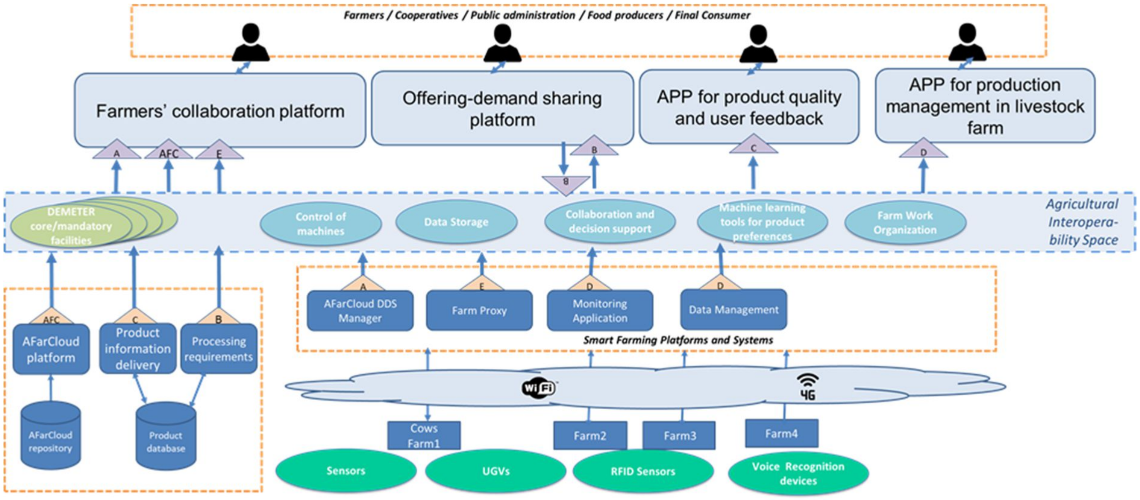


Figure 37. Pilot 5.2 reference architecture

B.6.3. **Pilot 5.3**

Pilot 5.3 is focused on apiculture and pollination, proposing two different DEMETER-enabled Applications: An Apiary Management System ControlBEE and a Farm Management System Virtual Farm eDWIN. A set of pollination-related enablers have been proposed (Pollination Matching, Pollination Req. Estimation or Spraying Alerts) in combination with crop enablers (Crop Type Identification, Crop Status Identification, Yeld Benchmarking or Territorial Alerts). In addition to farm weather station, hive-centred data sources will be used in the pilot (i.e. Hive sensor, Hive scale or Hive GPS).

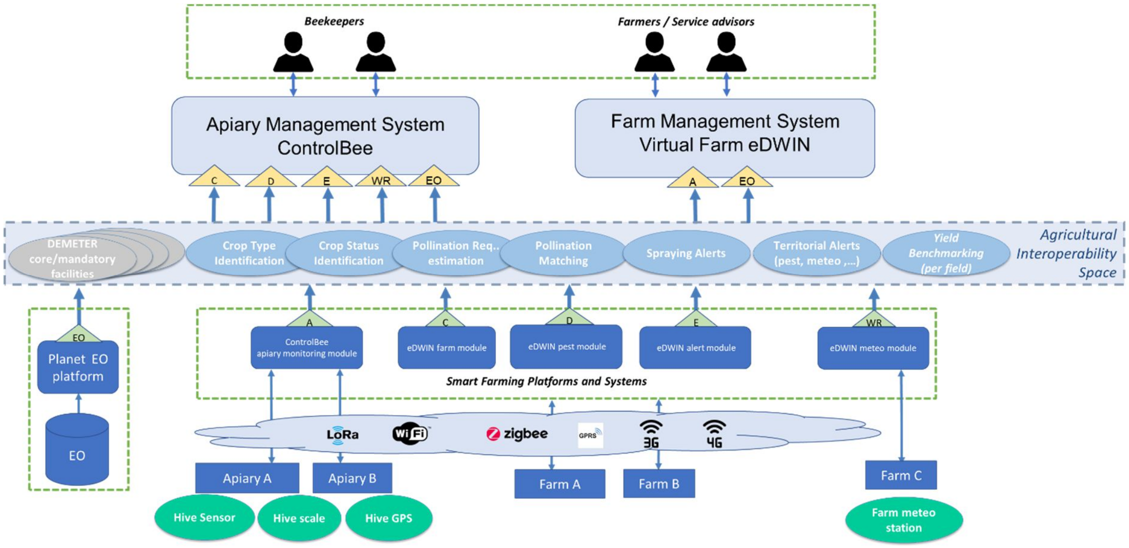


Figure 38. Pilot 5.3 reference architecture

B.6.4. **Pilot 5.4**

Due to the similarities to the pilot 4.4, this pilot also proposes one application focused on poultry industry (as pilot 4.4 was focused on chicken industry). Enablers proposed are similar, including this pilot a Data Analytics enabler. Regarding the data sources, GS1 Digital Link Barcode tags are used in this pilot for tracking in addition to Camera, Poultry feeding data, IoT data and GPS tracker.

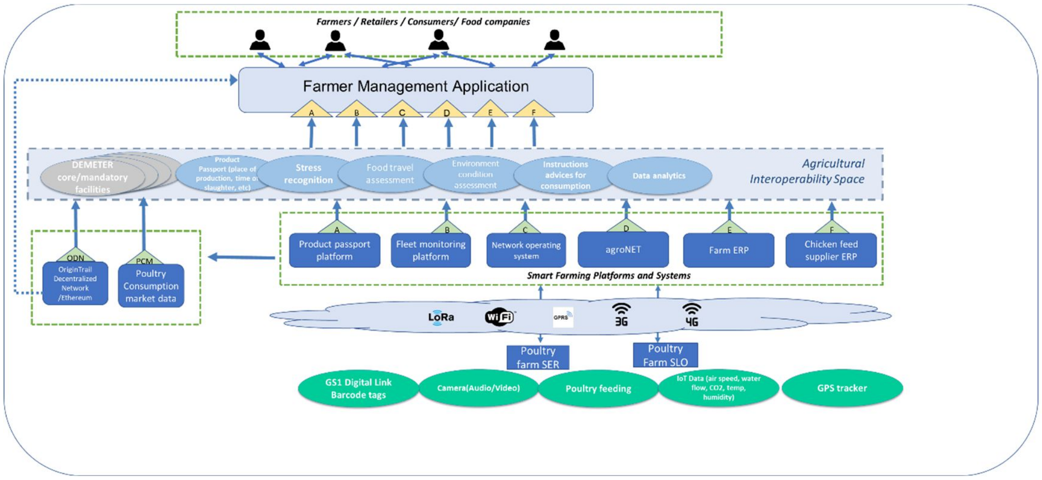


Figure 39. Pilot 5.4 reference architecture

Annex C Decision Support - Requirements from DEMETER Pilots

This annex provides a table per pilot summarising the following data, which has been used for extracting the requirements per pilot and provide the high-level design ideas. The corresponding high-level design diagrams can be found in Annex D.

<table>
<tr><td>Pilot ID</td><td>#</td><td>Version</td><td>#</td><td>Last Update Date</td><td>dd/mm/yyyy</td></tr>
<tr><td>Title</td><td colspan="5">Pilot Title</td></tr>
<tr><td>Description of Proposed Solution</td><td colspan="5">This section should contain a high-level specification of the required solution. It should also indicate which parts of the solution a) already exist, b) under development by a pilot partner, c) to be developed any free WP4 development teams.
e.g. The solution requires the monitoring of independent audio and visual stream together with sensors monitoring temperature, humidity, and feed silo status to determine the reason for elevated stress levels in chicken in a poultry farm. The detection of stress level from audio data already exists. The requirements for other members of WP4 is a machine learning algorithm to correlate the onset of raised stress with event from the other sensors to determine a cause. This can then be used as part of a complex event processing system to alert the user before the event occurs with the aim of preventing it happening. Visualisation be able to display information how particular event are likely to lead to problem. Visualisation should also be able display a warning alert to indicate that a problem is likely.</td></tr>
<tr><td>Relevant Task(s)</td><td colspan="5">The cells below indicate the assessment of each pilot against the activities to be carried out by each WP4 task.
<table>
<tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr>
<tr><td>Relevant</td><td>Yes</td><td>No</td><td>Yes</td><td>Yes</td><td>No</td></tr>
</table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot</td><td colspan="5">List of innovations that can be derived from this pilot, e.g.
• DSS for monitoring and managing the stress levels in chicken</td></tr>
<tr><td>Reference component(s)</td><td colspan="5">List Reference components/modules (or sub-module) in the DEMETER Architecture e.g. WP2, WP3 components. See D2.1 and D3.1 for list items, e.g.
• Data Interoperability
• Data Harmonisation</td></tr>
<tr><td>Reference technology(ies)</td><td colspan="5">List Reference technology for the module or sub-module. These should be illustrated in the accompanying figure e.g. which algorithms or components developed in WP4. E.g.
• CEP for Audio-Video correlation analysis
• Machine Learning for analysing stress level conditions</td></tr>
<tr><td>Involved stakeholders/actors</td><td colspan="5">List stakeholders/actors that are involved in this pilot. E.g.
• Farmers
• Irrigation Communities</td></tr>
<tr><td>Prerequisite(s)</td><td colspan="5">None</td></tr>
<tr><td>Type</td><td colspan="5">Functional (Not relevant)</td></tr>
</table>

Priority Level	Mandatory (Not relevant)
Datasets	List all datasets being used in this solution (also illustrate in accompanying figure). E.g. • Streaming Audio • Streaming Video • Feed Silo and Environmental data from IoT devices
Relevant Partner(s)	List of relevant partners working in this pilot. E.g. • TRAGSA • ICE • Landbrukets
Status	Proposed

C.1. *Decision Support - Requirements from DEMETER Pilot Cluster 1*

C.1.1. **Pilot 1.1 & 1.2**

Pilot ID	1.1 & 1.2	Version	0.3	Last Update Date	02/03/2020
Title	Smart Energy and Water Management in Irrigated & Arable Crops				
Description of Proposed Solution	This pilot proposes a way to harmonize the interaction among the different elements that take part in the irrigation system with the objective of optimizing the management of irrigation water and a reduction of the energy used for that purpose. To do so, on the one hand, we are developing a standard with the support of ISO and a MEGA coordinator, which it is under development by a pilot partner. Additionally, the use of open and standard interfaces such us MQTT at low level, or NGSI (already adopted by FIWARE), and its evolution NGSI-LD (promoted by the ETSI ISG CIM) have been also considered as way to harmonize the communication. Moreover, there are mechanisms for the interconnection of MEGA and NGSI. Regarding the exploitation of the crop production information: • the pilot can already access data from soil IoT sensors (i.e. temperature, moisture, conductivity, etc.), IoT actuators (i.e. water counters and hydrants, etc.), weather stations and weather IoT sensors (i.e. air temperature and humidity, radiation, wind, rain, etc.) and satellite multi-spectral imagery. • the pilot can calculate multiple agro indices related with crop water needs as soil moisture, conductivity and salinity evolution, the number of sun hours and cold hours per day, the thermal integral, and others. • the calculation of other important agro indices as ETO (evapotranspiration), NDVI (*Normalized Difference Vegetation Index*) or NDRE (*Normalized Difference Red Edge*) is being developed. • there are also prediction maps under development. • all agro indices calculated are stored in a repository so they can be easily restored to avoid future repeated calculations.				

<table>
<tr><td></td><td>• using different algorithms and machine learning techniques actually under development, this solution will calculate crop water needs and will offer tailored and automatic control over water actuators for a smart water management.</td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>No</td><td>Yes</td><td>Yes</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot.</td><td>• MEGA Broker coordinator
• Crop maps and Smart Agriculture platform
• NGSI/NGSI-LD interoperability with other systems</td></tr>
<tr><td>Reference component(s)</td><td>• Data Harmonisation.
• Data Fusion
• Data Cleaning</td></tr>
<tr><td>Reference technology(ies)</td><td>• CEP for agro IoT devices integration.
• Algorithms to analyse agronomic IoT data for agro indices.
• Machine learning to analyse satellite imagery for agro indices.
• Machine learning and algorithms to analyse agro indices.</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• Farmers
• Irrigation Communities
• Irrigation systems providers
• Manufacturers
• End users
• Management System Developers
• Control Irrigation System Developers
• CENTER
• TRAGSA
• OdinS
• UMU</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional (Not relevant)</td></tr>
<tr><td>Priority Level</td><td>Mandatory (Not relevant)</td></tr>
<tr><td>Datasets</td><td>• GIS data
• JSON – soil temperature
• JSON – soil salinity
• JSON – soil VIC (volumetric ion content)
• JSON – soil conductivity
• JSON – soil humidity
• JSON – air temperature
• JSON – air humidity
• JSON – wind speed
• JSON – wind direction
• JSON – sun radiation
• JSON – rainwater
• JSON – water counters
• JSON – valves and infield devices
• JSON – relevant agriculture (crop, soil) data</td></tr>
</table>

	• Raw – Imagery from satellite repository (Sentinel 2)
Relevant Partner(s)	• TRAGSA • OdinS • UMU
Status	Proposed

C.1.2. **Pilot 1.3**

<table>
<tr><td>Pilot ID</td><td>1.3</td><td>Version</td><td>0.1</td><td>Last Update Date</td><td>09/03/2020</td></tr>
<tr><td>Title</td><td colspan="5">Smart Irrigation Services in Rice & Maize Cultivation</td></tr>
<tr><td>Description of Proposed Solution</td><td colspan="5">The pilot will provide a service capable of maximising water use efficiency in rice and maize cultivation systems, through the deployment of appropriate sensor systems and science-based decision-making. Thus, both water quality (e.g., salinity levels) and quantity will be optimised. Furthermore, since irrigation is tightly linked to fertilisation, a nitrogen fertilisation advisory service will be setup, leading to optimisation of the spatial distribution of nitrogen application based on the real needs of the field. The real-time salinity sensor, developed within the framework of SmartPaddy (FP7 project), will be slightly improved by adapting the communication system to use a GSM modem and by adding a water height sensor. The SIS sensor will automatically control electric water input valves for irrigation and water outputs valves for drainage. In addition to the automated workflow, the end-users will be able to directly control the sensor by sending messages to overtake actions over the robotic management. In the case of the individual farmers with no automatic Smart Irrigation System will provide only information. Similarly, to rice, maize irrigation will be controlled with an irrigation prediction model to predict time and the amount of water. Moreover, the DEMETER system will deploy a methodology for nitrogen fertilisation management using variable rate application (VRA) technologies, based on spatial information collected by the pilot paddy and maize fields through UAVs or satellite imagery.</td></tr>
<tr><td>Relevant Task(s)</td><td colspan="5"><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>No</td><td>No</td><td>No</td><td>Yes</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot.</td><td colspan="5">• Monitoring and managing rice and maize for irrigation and fertilization support through remotely sensed imagery (aerial and satellite)
• Smart Irrigation Service (SIS) for rice and maize</td></tr>
<tr><td>Reference component(s)</td><td colspan="5">• Data collection, harmonisation & aggregation
• Machine learning for image processing
• Data fusion
• water salinity & height monitoring
• Water consumption monitoring
• Fertiliser application monitoring
• Resource utilisation visualisation
• Financial performance benchmarking</td></tr>
</table>

	- DEMETER data visualisation solution
Reference technology(ies)	- Empirical rice fields' flooding needs estimation - Machine learning (ML) for maize irrigation needs estimation - ML for rice N fertilisation needs estimation - ML for maize N fertilisation needs estimation - ML for crop N uptake estimation - Satellite and UAV multispectral imagery analysis - UAV thermal imagery analysis
Involved stakeholders/actors	- ELGO (Hellenic Agricultural Organization – "DEMETER") - ICCS (Institute of Communication and Computer Systems) - Local Irrigation Authorities (TOEV) - Regional Irrigation Authority (GOEV) - Agronutritional Cooperation Region of Central Macedonia - UAV mapping services providers - Scientific instrumentation trading companies - Agri-consultancy businesses - Agricultural Cooperatives - Groups of Farmers - Individual farmers
Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	- Streaming salinity and water height data (JSON) - Water consumption (JSON) - Variable rate N fertilisation maps (vector files; GeoPackage and/or GeoJSON) - Meteorological data (JSON) - Maize irrigation prescription maps (vector files; GeoPackage and/or GeoJSON)
Relevant Partner(s)	- ELGO - ICCS
Status	Proposed

C.1.3. **Pilot 1.4**

Pilot ID	1.4	Version	0.1	Last Update Date	13/03/2020
Title	IoT Corn Management & Decision Support Platform				
Description of Proposed Solution	The Decision Support System pilot for Corn Management within the DEMETER project proposes to bring modern crop monitoring tools for agricultural Corn crops using combined data from local intelligent sensors, GNSS receptors, GIS tools, satellite, and UAV imagery. The main objective of the pilot is to help the farmers to rationalize production costs through decision support maps and management systems, providing information like crop uniformity, excess water presence, pest impact degree resulted from extreme meteorological phenomenon. Deliverables within the pilot will be composed of fertilization plans, phytosanitary treatment plans, crop diagnosis after				

<table>
<tr><td></td><td>sawing or fertilization processes, plant density (number of plants, leaf volume), weed evaluation and control based on the data collected from the IoT sensors.
Throughout the use of the pilot’s tools used for maize crop monitoring, the farmers will benefit from modern solutions such as: resource optimization of water use, fertilizers and pesticides, crop works decision time improvement, agricultural system durability stability and profit growth gain through larger and higher quality productions.</td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>T4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s) From This Pilot</td><td>Management and monitoring of Corn Crop Farms for fertilization and irrigation support through integration and machine learning using RS Imagery, IoT local sensors, Meteorological Data and Corn Crop Research Data.</td></tr>
<tr><td>Reference component(s)</td><td>• Data collection, harmonisation & aggregation
• Machine learning for image processing
• Data fusion
• Water consumption monitoring
• Fertiliser application monitoring
• Resource utilisation visualisation
• DEMETER data visualisation solution</td></tr>
<tr><td>Reference technology(ies)</td><td>• Machine Learning for fertilisation needs estimation
• Machine Learning for irrigation needs estimation
• Machine Learning for yield prediction
• Satellite and UAV multispectral imagery analysis
• Knowage for data visualisations</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• Technology providers
• Solution providers
• System Developers
• Farmers
• University Advisors
• APPR Authority
• SIVECO
• APPR</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional (Not relevant)</td></tr>
<tr><td>Priority Level</td><td>Mandatory (Not relevant)</td></tr>
<tr><td>Datasets</td><td>• Farm Production data
• Local Air Temperature sensors data
• Local Air Pressure and Humidity sensors data
• Local Wind Speed sensors data
• Local Soil Temperature and Humidity sensors data
• Local Precipitation sensors data
• Local Real time weather service channel data</td></tr>
</table>

	• Farm data: Land use / Irrigated Area / Crop Type, Water availability, slope/drainage, Pesticides, Fertilization, Yield data, Planting date, Harvesting data, Site Inspection Data • APPR Excel Data – historical research data for corn crops • Sentinel 2 data (openEO) • UAV data • Regional Data (NUTS 1-3, Public Soil Maps)
Relevant Partner(s)	• SIVECO • APPR
Status	Proposed

C.2. *Decision Support - Requirements from DEMETER Pilot Cluster 2*

C.2.1. **Pilot 2.1**

Pilot ID	2.1	Version	0.1	Last Update Date	26/02/2020
Title	Fraud detection of machinery sensor, NOx estimation, Engine data and emission monitoring				
Description of Proposed Solution	Challenge: In general, exchanging sensors in the context of pilot 2.1 could be quite effortless. A person can connect a new sensor to the CAN-BUS of a machine and cut-off the original sensor. With this new sensor, the person might provide wrong/manipulated data, which can lead to false results of a monitoring system. Consequently, this would falsify data analysis results, which then might be useless for other stakeholders (such as machine producer or maintenance service providers). The solution should analyse the data and provide support to the user whether a sensor might have been hacked, e.g. by plausibility and consistency checks of the incoming values (with other machine data or maybe public available comparative data). Pilot partners will develop a basic solution for the NOx emission (sensor) data. More analysis/ contributions from other WP4 partners is possible (but limited due to data sharing constraints regarding the data collected by the pilot farms (i.e., except for data sources outside the pilot farms)). Based on different (engine) data (NOx-conversion, exhaust temperatures, from the CAN-Bus) the solution will provide an estimation of the NOx value with additional information on the quality of the result, i.e. providing information on the quality of the data that has been used. This will be developed by the pilot partners. Using on-board sensors for monitoring engine data (e.g. Diesel consumption) as well as data of the exhaust gas after treatment will help to monitor that machines follow the regulations and offers the possibility to use the collected data for further improvements (e.g.				

<table>
<tr><td></td><td>optimizing machine and simplify maintenance, decreases the need of Portable Emission Measurement Systems (PEMS),…).
This is part of the developments by the pilot partners.
In addition, it might be useful to visualize that information, e.g. to compare the data with existing thresholds. Other WP4 partners could join</td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s) From This Pilot.</td><td>DSS for monitoring and analysing NOx emission of a tractor</td></tr>
<tr><td>Reference component(s)</td><td>• Data Quality Service
• Data Analysis
• (and maybe Data Fusion Service)</td></tr>
<tr><td>Reference technology(ies)</td><td>• Correlation analysis techniques
• Machine Learning for analysing NOx emission conditions</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• Solution providers, Suppliers for machinery, Government entity, Fraunhofer IESE, John Deere</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional</td></tr>
<tr><td>Priority Level</td><td>• Fraud detection of machinery sensor - Desirable
• NOx estimation – Mandatory
• Engine data and emission monitoring - Mandatory</td></tr>
<tr><td>Datasets</td><td>• Machinery data provided by pilot partner (John Deere) together with farmers
• In addition, maybe publicly available machinery data, especially NOx data</td></tr>
<tr><td>Relevant Partner(s)</td><td>• Fraunhofer IESE
• John Deere</td></tr>
<tr><td>Status</td><td>Proposed</td></tr>
<tr><td>Comments/Remarks</td><td>Sharing the mentioned pilot owned dataset might be not possible</td></tr>
</table>

C.2.2. **Pilot 2.2**

<table>
<tr><td>Pilot ID</td><td>2.2</td><td>Version</td><td>0.1</td><td>Last Update Date</td><td>05/03/2020</td></tr>
<tr><td>Title</td><td colspan="5">Automated documentation and job cost calculation</td></tr>
<tr><td>Description of Proposed Solution</td><td colspan="5">In pilot 2.2, the partners will support the automated documentation of arable crop farming processes from different perspectives. m2Xpert focus in pilot 2.2 on automated process recognition of farming processes for semi-automatic (result: documentation proposal) or fully automated documentation (result: documentation without user interaction) in farm management systems. John Deere focus in pilot 2.2 on job cost calculation (later also prediction) for spraying and fertilizing applications. This could enable the farmer to better plan and support</td></tr>
</table>

<table>
<tr><td></td><td>his/her future investments and decisions. Indeed, calculating past job costs could enable the prediction of future job cost. Fraunhofer IESE will develop a method for assessing data quality in the context of agricultural data. In pilot 2.2, this method will be applied and adjusted to the specific needs of this pilot. The output of this work is a report of the data quality, which can then be used by other partners (such as John Deere) to improve or take decisions regarding the data (e.g., its collection, processing or analysis techniques).</td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>T4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>No</td><td>No</td><td>Yes</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot.</td><td>• Data selection, collection
• Data cleaning
• Data visualisation
• Automated task recognition
• Job cost calculation</td></tr>
<tr><td>Reference component(s)</td><td>• GPS-Tracker
• John Deere OP centre</td></tr>
<tr><td>Reference technology(ies)</td><td>• Process prediction algorithms,
• Python</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• Farmers
• Contractors
• System Providers
• John Deere
• m2Xpert
• Fraunhofer IESE</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional (Not relevant)</td></tr>
<tr><td>Priority Level</td><td>Mandatory (Not relevant)</td></tr>
<tr><td>Datasets</td><td>• GPS-Position Data
• Auto track data
• Machinery data and fixed cost Information</td></tr>
<tr><td>Relevant Partner(s)</td><td>• John Deere
• m2Xpert
• Fraunhofer IESE</td></tr>
<tr><td>Status</td><td>Proposed</td></tr>
</table>

C.2.3. **Pilot 2.3**

Pilot ID	2.3	Version	0.1	Last Update Date	29/02/2020
Title	Farm data brokerage system				
Description of Proposed Solution	Farmers are using many technical systems for: • Farm work organization. • Control of farm processes and control of machines. • Data analysis and data preparation.				

<table>
<tr><td></td><td>• And for data storage.
Often, these systems are made by several producers, are using independent communications protocols and based on it – the system of all devices are not able to organize the farm data brokerage. Based on this reality description is necessary to look for solutions that will improve this status.
There is already existing a large number of suppliers for farming-related data. It varies between data from machinery, satellite data, meteorological data, Land parcel information systems, water bodies data, erosion data soil data, etc. This data is offered by different systems, different data models and different API´s. For farmers, it is important to have access to the complete data, but they are not able to provide integration of this data.
Farm data brokerage establishes a trust-based and compliant data market for agricultural enterprise data that sits between the owners and operators of agricultural data Clouds and the farmer. This data market will consist of both a technical platform and advisory services that will ensure easy adoption of data and technology by farmers</td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>YES</td><td>NO</td><td>YES</td><td>NO</td><td>NO</td></tr></table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot.</td><td>• Data selection, collection
• Metadata Discovery and Metadata management
• Data cleaning, management,
• Data analysis
• Data visualization in 2D and 3D
• DSS for Automated task recognition
• DSS for Farm work, effort, and productivity cost calculation
• DSS for Data publishing</td></tr>
<tr><td>Reference component(s)</td><td>• LPIS Land Parcel Information System official data of CAP
• The fixed data model for all country, data can be transferred into FOODIE model
• Farm Telemetry Data
• EO data from Landsat and Sentinel
• Meteorological stations
• Inputs from farm machinery systems.</td></tr>
<tr><td>Reference technology(ies)</td><td>• SensLog
• HSlayers NG
• Open Micka
• Layman</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• farms - in our pilot areas
• Lesprojekt
• WIRELESSINFO
• Avinet
• P.S.N.C.
• Agri machinery and equipment producers</td></tr>
</table>

	• HSRS • Universities • Public administration • Local action groups
Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• Vector data • Streaming data • DataStream • Any geospatial data • Formats: JSON, WMS, WFS, KML, WCS, RDF, GeoJSON, ISO19115, ISO19119/ISO19139,
Relevant Partner(s)	• WIRELESSINFO • P.S.N.C.
Status	Proposed

C.2.4. **Pilot 2.4**

<table>
<tr><td>Pilot ID</td><td>2.4</td><td>Version</td><td>0.2</td><td>Last Update Date</td><td>26/03/2020</td></tr>
<tr><td>Title</td><td colspan="5">Benchmarking at Farm Level Decision Support System</td></tr>
<tr><td>Description of Proposed Solution</td><td colspan="5">Development of a set of services to support the benchmarking on the productivity and sustainability performance of the farms, leveraging and extending existing decision support system for farmers (DSS). The result benchmarking system will enable the use of ICT and IoT technologies in practical management and decision support, with a focus on data integration. This will be done by adopting Linked Data as a federated layer, complemented with security mechanisms, and implementing computational benchmarking models with interfaces that reuse/extend existing decision support and farm management systems (as an added value feature.</td></tr>
<tr><td>Relevant Task(s)</td><td colspan="5"><table><tr><td>Task</td><td>T4.1</td><td>T4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot.</td><td colspan="5">DSS for benchmarking the productivity and sustainability performance of the farms</td></tr>
<tr><td>Reference components</td><td colspan="5">• Common data models
• Semantic Interoperability
• Data collection
• Data management
• Data Integration
• Data model translation</td></tr>
<tr><td>Reference technology(ies)</td><td colspan="5">• Statistical analysis
• Semantic technologies
• Linked data</td></tr>
</table>

Involved stakeholders/actors	• Farmers • Advisory centres • Institutes of agriculture economy • Technology providers
Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• FADN data • Eurostat data • CAP data • Market data • Farm data
Identified by Partner(s)	• WODR • PSNC
Status	Proposed

C.3. *Decision Support - Requirements from DEMETER Pilot Cluster 3*

C.3.1. **Pilot 3.1**

Pilot ID	3.1	Version	0.1	Last Update Date	16/03/2020
Title	Decision Support System to support olive growers				
Description of Proposed Solution	The aim of this pilot is to develop a DSS for olive growers, advisers and agri-food processors to address common issues associated with olive tree growing and olive oil production, including integrated pest management, fertilizer use, and irrigation needs. The DSS will integrate in-field sensors data, remotely sensed data, a modelling platform and a farm management system, combining weather and soil information with crop data, to improve the sustainable production of olive orchards. DEMETER will allow the integration of Agricolus© OLIWES with other solutions and technologies provided by partners. This will promote the use of data coming from different sources (sensors, open source weather data, open spatial data, IoT devices) to deliver integrated data-model solutions to be tested in the pilot. Data analytics and knowledge management systems will be applied to data coming from the use and test of Agricolus© OLIWES in different environmental and farming conditions.				
Relevant Task(s)	Task: T4.1, 4.2, T4.3, T4.4, T4.5 Relevant: Yes, Yes, Yes, No, No				
Actual Innovation(s) From This Pilot.	• Allow the integration of Agricolus© OLIWES with other solutions and technologies provided by partners • improve the existing DSS with ML solutions developed in WP4				
Reference component(s)	• ML for calibrating olive phenology				

Relevant Task(s):

Task	T4.1	4.2	T4.3	T4.4	T4.5
Relevant	Yes	Yes	Yes	No	No

	• ML to improve the existing DSS • Data harmonization • Data fusion • Benchmarking system
Reference technology(ies)	• Agricolus© OLIWES • Machine learning (ML) solutions to parametrize and calibrate the models with new collected data (i.e. SciKit, Keras etc.) • testing Knowage for data visualisations
Involved stakeholders/actors	• Farmers and Farmers' advisors from Italy and Greece • AGRICOLUS
Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• JSON - weather data (Temperature, relative Humidity, precipitation) • JSON: farm data: fields, crop operations, irrigation, and fertilisation data
Relevant Partner(s)	• AGRICOLUS
Status	Proposed

C.3.2. **Pilot 3.2**

Pilot ID	3.2	Version	0.1	Last Update Date	17/03/2020
Title	Precision Farming for Mediterranean Woody Crops				
Description of Proposed Solution	The pilot aims at promoting precision farming practices and providing technology and methods to optimize the precision and intelligence levels of Mediterranean Woody Crops (Apple Trees, Olive Groves, and small Vineyards), considering the small farmers economical constraints. To this end the pilot aims at supporting better knowledge about crop development, pest and diseases and soil state, as well as improved solutions for agricultural practices such as pesticide and fertilization application, by using cost effective IoT solutions and upgrading conventional machinery and technology. This will enable them to make more efficient usage inputs such as water, energy, macronutrients, and pesticides increasing the profits of small farmers and reducing their environmental impact. Reducing the spraying losses (more than 20 %), the irrigation water consumption approximately 10%, and the NPK overdosage in 15%. Another objective of this pilot is to develop and promote novel IoT based technologies (AgIoT) to upgrade conventional machinery with variable rate technologies (relevant for small farmers) to reach higher levels of precision during the fertilization and spraying treatments. The pilot will develop (AgIoT) IoT open source farm structure (interoperable standards) where any standard agricultural sensor and actuator may be connected to acquire agricultural information (soil, weather, water, macro-nutrients, crops, pest and diseases, vegetation dynamics) in				

<table>
<tr><td></td><td>static farm spots or during machinery operations. In this IoT open source farm structure will be integrated two agricultural robots: AgRob V16 to monitor the crop, soil state and water leaks (fruit metabolic state, yield, quality, macronutrients quantification), AgRob V18 to apply autonomously spraying based treatments and novel non-chemical treatments (UV-light). Besides, the pilot will develop a regional cloud management system (FIWARE based) for Mediterranean Woody Crops, fully connected to the IoT technologies deployed on the farms (robots, machinery, actuators, and sensors). This cloud management system will have an open market ecosystem for third party develop Decision Support Apps (to support the daily agricultural decisions and practices). All acquired data (during the project) will be made public to enable the reuse by any third party (agricultural experts and developers).</td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot.</td><td>Integrating different technologies like Internet of Things (IoT) devices, cloud with applications based on data analytics and knowledge management
Work on interoperable standards to ensure that all connected systems can talk to each other
Demonstrate communication exchange of data across different systems and platforms
Sharing data and generating knowledge via capturing and translating more and precise information
Upgrade conventional machinery with variable rate technologies</td></tr>
<tr><td>Reference component(s)</td><td>Data collection, harmonisation & aggregation
Data fusion
DEMETER data visualisation solution
Data analytics techniques</td></tr>
<tr><td>Reference technology(ies)</td><td>AgIoT – Open Source Agricultural IoT solution with interoperability based on MQTT+JSON
AgRob - Agricultural Robots</td></tr>
<tr><td>Involved stakeholders/actors</td><td>Agricultural Cooperatives
Groups of Farmers
Individual farmers
UBIWHERE
INIAV
INESCTEC
FENADEGAS (cooperativa de Amarante)</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional (Not relevant)</td></tr>
<tr><td>Priority Level</td><td>Mandatory (Not relevant)</td></tr>
<tr><td>Datasets</td><td>Low volume dataset
JSON - Air Temperature
JSON - Air Humidity</td></tr>
</table>

	• JSON - Wind • JSON - Rainfall • JSON - Sunlight • JSON - Leaf Wetness • JSON - Soil Ph • JSON - Soil moisture • JSON - Soil temperature • JSON - Air Flow • JSON - Light Intensity High volume datasets • JSON - Photosynthesis data • JSON - GPS/GNSS data • JSON - Machinery Data • JSON - Insect Numbers • JSON - Traps images • JSON - Static Crop images (in several components, RGB and IR) • JSON - 3D point clouds • Raw - Crop reflectance and vegetation indices (e.g. NDVI/EVI/EVA)
Relevant Partner(s)	• UBIWHERE • INIAV • INESCTEC • FENADEGAS (cooperativa de Amarante)
Status	Proposed

C.3.3. **Pilot 3.3**

Pilot ID	3.3	Version	0.1	Last Update Date	27/02/2020
Title	Pest management control on fruit fly				
Description of Proposed Solution	The solution requires the monitoring of different automatic traps working with real time communications and cameras, sensors monitoring temperature and weather conditions to determine the status of fruit fly extension and provide advices about the better actuations. The automatic traps and cameras are under development. The requirement for other members of WP4 is a decision support tool or algorithm to manage the plague and supply the appropriate actuations in order to decrease and improve the effects of the fruit fly: areas where liberate more sterile flies or pesticides solutions. This can be used as part of a system to alert the user before the event occurs with the aim of preventing it happening. User interface will be able to show different warning alerts or messages to indicate to the farmers how the plague acting, and the most affected areas are.				

<table>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s) From This Pilot.</td><td>Decision tool for monitoring and managing the fruit fly pest</td></tr>
<tr><td>Reference component(s)</td><td>• Data analysis, harmonization, and data preparation
• Control of pest processes
• Insect Recognition
• Labelled datasets for training
• Imagery Classification
• Pesticide level monitoring</td></tr>
<tr><td>Reference technology(ies)</td><td>• Machine learning (ML) for image processing and region highlighting (i.e. OpenCV, Keras, Yolo, etc.)
• ML for fly counting from image data
• ML for data fusion
• ML for fly estimation based on other data sources (sensor data, weather forecast, etc.).
• Knowage for data visualisations</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• Farmers cooperatives
• Valencian council
• Moncada Evolutionary
• ICT providers
• Fly releasers
• TRAGSA
• ATOS</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional (Not relevant)</td></tr>
<tr><td>Priority Level</td><td>Mandatory (Not relevant)</td></tr>
<tr><td>Datasets</td><td>• JSON - Temperature
• JSON - Humidity
• JSON - Soil moisture
• JSON - Air Flow
• JSON - Light Intensity
• JSON - Pesticide levels
• JSON - Water Consumption
• JSON - GPS data
• Raw - Image data
• Raw - Labelled dataset (human given fly count)</td></tr>
<tr><td>Relevant Partner(s)</td><td>• TRAGSA
• ATOS</td></tr>
<tr><td>Status</td><td>Proposed</td></tr>
</table>

C.3.4. **Pilot 3.4**

Pilot ID	3.4	Version	0.1	Last Update Date	09/03/2020

<table>
<tr><td>Title</td><td>Open Platform for Improved Crop Monitoring</td></tr>
<tr><td>Description of Proposed Solution</td><td>This Pilot aims at integrating field machinery data with remote sensing, meteo and soil data into the WatchITgrow (WIG) platform. The field data (planting date, planting distance, detailed yield information) is an important source of information for the calibration and validation of the analytical crop models in WIG that use satellite data, meteo data and soil information as inputs to model crop growth. The in-field data could allow the development of a purely data-driven model instead of finetuning physical models. The enhanced crop growth models will be used to give advice to farmers for the optimization of field management practices (optimal harvest date, variable rate haulm killing, variable rate fertilization, irrigation advice).

Using detailed data from the machinery in the field (detailed yield information, planting dates), the physical crop model can be replaced by a purely data-driven approach using machine learning techniques. AVR Connect is the recently started IOT cloud platform from AVR that collects data from the machines (potato planters, potato harvesters) and makes the data available to third parties. In this pilot data from AVR potato planters and harvesters will be coupled to the WatchITgrow platform. These machine data will be combined with crop- and field-specific info such as planting date, crop variety, fertilization activities, crop protection, crop damages ..., and with satellite data, weather and soil info to enhance the crop growth models and give specific advice to farmers on how to optimize field management practices.

Data can be made available for 3rd parties to develop their own yield prediction algorithms and irrigation advice modules.</td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s)
From This Pilot.</td><td>Integration of detailed IoT yield data to create data-driven yield prediction algorithm using machine learning</td></tr>
<tr><td>Reference component(s)</td><td>• Data synchronization
• Data Collection & Aggregation
• Data Management
• Data Fusion
• Data analytics and knowledge extraction
• Data filtering</td></tr>
<tr><td>Reference technology(ies)</td><td>• Machine Learning for data fusion (Sentinel-1 + 2) for dense FAPAR timeseries
• Machine learning for data-driven yield prediction from detailed IoT yield data, combined with meteo and soil type.</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• Potato Farmers in Flanders
• Belgian Potato Farmers Association
• Potato processing industry
• VITO
• AVR</td></tr>
</table>

Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• From AVR IoT devices, available in AVR Cloud: - Planting date - Harvesting data - Yield (detailed, per second) • Sentinel-2 based FAPAR timeseries (openEO) • Data fusion FAPAR timeseries (openEO) • Meteo data (Belgian KMI database) • Belgian soil maps (VITO, Database Underground Flanders)
Relevant Partner(s)	• VITO • AVR
Status	Proposed

C.4. *Decision Support - Requirements from DEMETER Pilot Cluster 4*

C.4.1. **Pilot 4.1**

Pilot ID	4.1	Version	0.1	Last Update Date	16/03/2020
Title	Developing individual herd milk forecasting model by a ML approach				
Description of Proposed Solution	Based on individual cow data from milking robots we will use ML to develop a milk forecasting model. This means using ML to predict individual lactation curves for individual cows and predict economical value of individual cos as a culling strategy				
Relevant Task(s)	Task: T4.1, 4.2, T4.3, T4.4, T4.5 Relevant: Yes, Yes, No, Yes, No				
Actual Innovation(s) From This Pilot.	• Using ML as an efficient tool to develop forecasting models in dairy production • Using ML as a tool for decision-making in dairy herd milk production.				
Reference component(s)	• Data Storage • Data Analytics • Data Tagging • Data Security				
Reference technology(ies)	• Machine learning for analysing milk forecast, culling strategy, feed requirement • Data visualisations				
Involved stakeholders/actors	• Farmers • Milk robot producers • NCDX (Nordic Cattle Data Exchange) • AWS				
Prerequisite(s)	None.				

Relevant Task(s):

Task	T4.1	4.2	T4.3	T4.4	T4.5
Relevant	Yes	Yes	No	Yes	No

Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	Data from NCDX and the nation herd recording system owned and managed by Mimiro
Identified by Partner(s)	• Mimiro
Status	Ongoing. Infrastructure and architecture on AWS decided.

C.4.2. **Pilot 4.2**

Pilot ID	4.2	Version	0.1	Last Update Date	03/03/2020
Title	Consumer Awareness: Milk Quality and Animal Welfare				
Description of Proposed Solution	The solution requires the monitoring of cows' welfare through the analysis of the most important animal metrics built on the basis of data collected through devices at the farmer's premises. After uploading data represented by CSV Files, through an ad hoc interface (REST APIs), DSS will show mainly two kind of charts: • Milking and Nutritional values charts (nutritional values, lactation days, milking days, etc.) • Pathologies charts (lying and lameness risk, ketosis risk, etc.). DSS should also be able to display recommended actions to correct and improve animal welfare measures and consequently milk quality. Users should also be able to set up alerts to receive notifications in case the observed values exceed the default thresholds.				
Relevant Task(s)	Task: T4.1 – Relevant: Yes Task: 4.2 – Relevant: No Task: T4.3 – Relevant: Yes Task: T4.4 – Relevant: No Task: T4.5 – Relevant: No				
Actual Innovation(s) From This Pilot.	DSS for monitoring and managing cow's welfare and milk quality				
Reference component(s)	• Data synchronization • Data Collection & Aggregation • Data Mashup (Harmonisation and Interoperability) • Data Enrichment • Data Management • Data Fusion • Breeding Farm animal metrics • Milk quality & composition monitoring • Milk production monitoring				
Reference technology(ies)	• Digital Enabler for Data Mashup & Data Harmonisation • FIWARE Orion Context Broker Generic Enabler for alerting • FIWARE Perseo CEP Generic Enabler for animal welfare correlation analysis (optional) • KNOWAGE for data visualization				

Relevant Task(s) sub-table:

Task	T4.1	4.2	T4.3	T4.4	T4.5
Relevant	Yes	No	Yes	No	No

Involved stakeholders/actors	- Farmers - Solution providers - Processor consumer - ENG - ROT
Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	- Animal identification, rest and wellbeing, lameness detection (Afiact II - Pedometer) - Rumination, eating, habits and respiration monitoring (AfiCollar) - Animal temperature (DataLog) - Milk quality (AfiLab)
Relevant Partner(s)	- ENG - ROT
Status	Proposed

C.4.3. **Pilot 4.3**

Pilot ID	4.3	Version	0.1	Last Update Date	02/03/2020
Title	Proactive milk quality control				
Description of Proposed Solution	A number of cow behaviour characteristics and physiological states that can reflect or impact on welfare and health of dairy cows will be identified. The behaviour characteristics to be monitored may include cow grazing time, rumination time, activity, and movement. Production characteristics to be monitored may include milk yield and milk conductivity. Behaviour characteristics data will be captured by the use of commercially available SmartBow™ ear tag accelerometers (from Zoetis). Separately sourced commercially available ankle-based pedometer sensors will also be selected. This data capture system will focus on real-time, directly measured information. The performance of the cow (milk yield, composition, and conductivity) can be measured within the automated milking system (at Teagasc Research Farm). Tyndall will develop a disease specific portable diagnostic platform and use it to provide bio-chemical data from stress and disease related biomarkers. Disposable multiplexed sensor cartridges will be developed specifically targeting cytokine markers including serum amyloid A, C-reactive protein and cortisol present initially in saliva and blood, followed by milk. Cow behaviour data, e.g. grazing time and rhythms, rumination time and rhythms, activity, movement, milk production data and the bio-chemical data will also be sent to the cloud. This data will be integrated, and prediction models developed. These models will indicate the accuracy of cow behaviour, milk yield and bio-chemical data in				

	indicating animal illness. Based on the outcome of the model an alert is sent to the farmer/ vet of the animal requiring assistance.
Relevant Task(s)	Task: T4.1, 4.2, T4.3, T4.4, T4.5 Relevant: Yes, No, Yes, No, No
Actual Innovation(s) From This Pilot.	DSS for continuous quality assurance and better welfare standards for cattle.
Reference component(s)	• Knowledge Extraction • Data Fusion
Reference technology(ies)	• PANDA access control and authentication • Kafka cluster architecture • Develop predictive analytics models based on the animal health scoring concepts • Develop a handheld portable disease diagnostic device
Involved stakeholders/actors	• Farmers • Teagasc extension service • Animal welfare informed opinion • Vet • National farm organizations (e.g. Irish Grassland Association) • Farmer discussion groups • TSSG • TEAGASC • ZOETIS • TYNDALL • INTRASOFT
Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• Data collection of cattle behaviours • Wearable sensors and handheld sensor device.
Relevant Partner(s)	• TSSG • TEAGASC • ZOETIS • TYNDALL • INTRASOFT
Status	Proposed

C.4.4. **Pilot 4.4**

Pilot ID	4.4	Version	0.1	Last Update Date	27/02/2020
Title	Stress level monitoring solution for poultry farms				
Description of Proposed Solution	DEMETER needs to provide an integrated management overview of the chicken production system. It must identify and provide algorithms that				

<table>
<tr><td></td><td><p>are able to analyse and process large amounts of data relating to the feeding and stress level monitoring for poultry farms.</p><p>The detection of elevated stress levels currently exists, so it is a requirement for members of WP4 to use a machine learning algorithm to correlate the onset of raised stress with events detected by other sensors, such as video feeds.</p><p>This can then be used as part of a complex event processing system to alert the user before the event occurs. The algorithms should also be able to predict the likelihood of particular events occurring.</p><p>A minimum set of information must be provided, sufficient for the calculation of stress level indicators in a poultry farm and useful to feed the algorithms.</p><p>It must also analyse data relating to the power consumption of a farm, in order to provide Power Issue reports.</p><p>DEMETER will also provide an AI chatbot relating to the animal’s energy consumption.</p></td></tr>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>T4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s) From This Pilot</td><td>DSS for monitoring and managing the stress levels in chicken</td></tr>
<tr><td>Reference component(s)</td><td>Data Collection
Data Filtering</td></tr>
<tr><td>Reference technology(ies)</td><td>CEP for Audio-Video Correlation Analysis
Machine Learning for analysing stress level conditions.
Knowage for data visualisations</td></tr>
<tr><td>Involved stakeholders/actors</td><td>Technology providers
Solution providers
Farmers
Advisors
ICE
DNET</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional (Not relevant)</td></tr>
<tr><td>Priority Level</td><td>Mandatory (Not relevant)</td></tr>
<tr><td>Datasets</td><td>JSON - Silo Fill Level
JSON - Water Level
JSON - Air Flow
JSON - Humidity
JSON - Temperature
JSON - Light Intensity
JSON - GPS data
JSON - Power Consumption
Raw - Raw Audio</td></tr>
</table>

	• Raw - Raw Video
Relevant Partner(s)	• ICE • DNET
Status	Proposed

C.5. *Decision Support - Requirements from DEMETER Pilot Cluster 5*

C.5.1. **Pilot 5.1**

Pilot ID	5.1	Version	0.1	Last Update Date	09/03/2020
Title	Disease prediction and supply chain transparency for Orchards/vineyards				
Description of Proposed Solution	DEMETER needs to provide disease prediction and supply chain transparency for orchards and vineyards. It must uniquely identify products on item level and enable data integrity across the value chain as well as prediction of disease, machinery operations, environmental parameters, and travel of products. The item-level identification will be done using GS1 digital link standard, by tagging bottles with the unique identifiers that will allow monitoring of item in different stages from manufacturing to consumption. The integrity of the data will be based on DLT: using OriginTrail blockchain protocol. Pheromone trap will serve as an indicator of the need for use of chemical substances to supress the level of parasites. Machinery protocols will be used to overview operation of tractors and sprayer control and GPS trackers to monitor the travel of the products. All information is going to be used to compose product passport for each product putting all relevant data at disposal to the stakeholders: production place, environment data, time of harvest, disease model, storage, transport condition, etc.				
Relevant Task(s)	Task: T4.1 / T4.2 / T4.3 / T4.4 / T4.5 Relevant: No / No / No / No / No				
Actual Innovation(s) From This Pilot	Comprehensive multi-agent data fusion and analysis from different actors, sensors and devices used to create the product passport and various data analytics. DSS for disease prediction in vineyards/orchards				
Reference component(s)	• Data Analytics • Knowledge Extraction				
Reference technology(ies)	• SmartGS1 Barcode Digital Link • ADAPT gateway • ISOBUS machinery protocol • OriginTrail DLT protocol • Knowage for data visualisations				
Involved stakeholders/actors	• Technology providers • Retailers • Consumers • Machinery/robot vendor • DNET				

Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• JSON – Product passport • JSON – Environment data • JSON – Disease prediction • JSON – Location data • CSV – Machinery data
Relevant Partner(s)	• DNET
Status	Proposed

C.5.2. **Pilot 5.2**

Pilot ID	5.2	Version	0.1	Last Update Date	20/03/2020
Title	Farm of Things in Extensive Cattle Holdings				
Description of Proposed Solution	DEMETER needs to provide improved means for collecting, transferring and accessing detailed information on the conditions of production of dairy products with the final objectives of optimizing production, product quality and animal welfare, finally increasing end-user involvement and social awareness along the value chain. To this end, the objective of this Pilot is to provide farmers, veterinarians, markets, fairs and abattoirs, downstream dairy companies with tools including smart watch / smart glass GUIs augmented by voice recognition technologies to collect better annotation on production conditions. Those annotations will be tied to specific animals by improved RFID identification technologies and will be transferred to all concerned operators by means of cloud-based technologies granting extensive access to well-identified personnel.				
Relevant Task(s)	Task: T4.1, T4.2, T4.3, T4.4, T4.5 Relevant: No, No, No, No, No				
Actual Innovation(s) From This Pilot	Comprehensive multi-agent analysis from different actors, sensors and devices used to create the product passport and various data analytics. DSS for dairy production in extensive cattle holdings.				
Reference component(s)	• Data Collection				
Reference technology(ies)	• SmartGS1 Barcode Digital Link • Cloud gateway • Knowage for data visualisations				
Involved stakeholders/actors	• Technology providers • Retailers • Consumers • Machinery/robot vendor • TRAGSA				
Prerequisite(s)	None				

Relevant Task(s) nested table:

Task	T4.1	T4.2	T4.3	T4.4	T4.5
Relevant	No	No	No	No	No

Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• JSON – Product passport • JSON – Environment data • JSON – Disease prediction • JSON – Location data • CSV – Machinery data
Identified by Partner(s)	• TRAGSA
Status	Proposed

C.5.3. **Pilot 5.3**

<table>
<tr><td>Pilot ID</td><td>5.3</td><td>Version</td><td>0.1</td><td>Last Update Date</td><td>27/02/2020</td></tr>
<tr><td>Title</td><td colspan="5">Pollination Optimisation</td></tr>
<tr><td>Description of Proposed Solution</td><td colspan="5">DEMETER needs to provide a DSS to that integrates the data from apiary and farm management systems to provide new advisory services to the relevant farmers. It needs to provide both parties with a collaboration service to optimise crop yields and optimise bee pollination.
DEMETER must also provide the apiaries with alerts if any nearby crops are being sprayed and territorial alerts. It must also identify surrounding crops by type and growth status to provide an estimate of the number of Hives or Bees required to pollinate a field. A yield benchmarking system will also be provided.</td></tr>
<tr><td>Relevant Task(s)</td><td colspan="5"><table><tr><td>Task</td><td>T4.1</td><td>4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td></tr></table></td></tr>
<tr><td>Actual Innovation(s) From This Pilot</td><td colspan="5">DSS for optimizing pollination across farms and apiaries through collaboration</td></tr>
<tr><td>Reference component(s)</td><td colspan="5">• Data Collection
• Knowledge Extraction
• Data Analytics
• Connectors to Satellite Imagery</td></tr>
<tr><td>Reference technology(ies)</td><td colspan="5">• Machine Learning to analyse Field Requirements for full pollination (No of Bees/Hives).
• Machine Learning to analyse satellite imagery to detect fields by crop type, and crop maturity.
• Machine Learning to analyse images and detect Varroa mites.
• Knowage for data visualisations</td></tr>
<tr><td>Involved stakeholders/actors</td><td colspan="5">• Technology providers
• Solution providers
• Beekeepers
• Farmers
• Service Advisors
• PSNC
• ICE</td></tr>
</table>

Prerequisite(s)	None
Type	Functional (Not relevant)
Priority Level	Mandatory (Not relevant)
Datasets	• JSON - Hive Temperature • JSON - Hive Weight • JSON - Hive Shock Detection • JSON - Hive Vibration • JSON - Hive Location • Raw (png/jpeg) - Raw Photos • JSON - Satellite Data
Relevant Partner(s)	• PSNC • ICE
Status	Proposed

C.5.4. **Pilot 5.4**

Pilot ID	5.4	Version	0.1	Last Update Date	09/03/2020
Title	Transparent supply chain in poultry industry				
Description of Proposed Solution	DEMETER needs to transparency in supply chain for poultry industry. It must uniquely identify products on item level and enable data integrity across the value chain as well as prediction of disease, assessment of travel and environmental condition to create instruction for consumers. It must identify and provide algorithms that are able to analyse and process large amounts of data relating to the feeding and stress level monitoring for poultry farms. The detection of elevated stress levels currently exists, so it is a requirement for members of WP4 to use a machine learning algorithm to correlate the onset of raised stress with events detected by other sensors, such as video feeds. This can then be used as part of a complex event processing system to alert the user before the event occurs. The algorithms should also be able to predict the likelihood of particular events occurring. A minimum set of information must be provided, sufficient for the calculation of stress level indicators, power losses (factor that influences stress) in a poultry farm and useful to feed the algorithms as well as for creating instructions for consumers. The item-level identification will be done using GS1 digital link standard to identify meat packages with the unique identifiers that will allow monitoring of item in different stages from production to consumption. The integrity of the data will be based on DLT: using OriginTrail blockchain protocol. GPS trackers will be used to monitor the travel of the products and provide input for food travel assessment. Environmental condition will be monitored using IoT devices (air speed, CO_2, temperature, humidity. All information is going to be used to compose product passport for each product putting all relevant data at disposal to the stakeholders: place of production, time of slaughter, environment data, disease model, storage, transport condition, etc.				

<table>
<tr><td>Relevant Task(s)</td><td><table><tr><td>Task</td><td>T4.1</td><td>T4.2</td><td>T4.3</td><td>T4.4</td><td>T4.5</td></tr><tr><td>Relevant</td><td>YES</td><td>No</td><td>Yes</td><td>Yes</td><td>No</td></tr></table></td></tr>
<tr><td>Actual Innovation(s) From This Pilot</td><td>Comprehensive multi-agent data fusion and analysis of the supply chain in poultry industry including DSS for monitoring and managing the stress levels in chicken and algorithms for providing instructions advices for consumption</td></tr>
<tr><td>Reference component(s)</td><td>• Data Collection
• Data Aggregation</td></tr>
<tr><td>Reference technology(ies)</td><td>• SmartGS1 Barcode Digital Link
• OriginTrail DLT protocol
• CEP for Audio-Video Correlation Analysis
• Machine Learning for analysing stress level conditions.
• Knowage for data visualisations</td></tr>
<tr><td>Involved stakeholders/actors</td><td>• Technology providers
• Farmer
• Chicken feed suppliers
• Consumers
• Food companies
• DNET</td></tr>
<tr><td>Prerequisite(s)</td><td>None</td></tr>
<tr><td>Type</td><td>Functional (Not relevant)</td></tr>
<tr><td>Priority Level</td><td>Mandatory (Not relevant)</td></tr>
<tr><td>Datasets</td><td>• JSON – Product passport
• JSON – Environment data
• JSON – Disease prediction
• JSON – Location data
• JSON - Silo Fill Level
• JSON - Water Level
• JSON - Air Flow
• JSON - Humidity
• JSON - Temperature
• JSON - Light Intensity
• JSON - GPS data
• JSON - Power Consumption
• Raw - Raw Audio
• Raw - Raw Video</td></tr>
<tr><td>Identified by Partner(s)</td><td>• DNET</td></tr>
<tr><td>Status</td><td>Proposed</td></tr>
</table>

Annex D Decision Support - Requirements and Solution Design for DEMETER Pilots

This Annex describes the more concrete Decision Support related requirements of the DEMETER pilots (a description of all pilots can be found in Annex A). In addition to the requirements (the summary table for each pilot can be found in Annex C), this section provides high-level design ideas of the decision support functionalities (components, services, systems) to be developed in DEMETER. These high-level design details provide an overview of the challenges (in terms of data types, data formats, algorithms and also existing infrastructure brought in by the pilot partners) that are being addressed while designing the decision support related solutions in the DEMETER project.

D.1. *Decision Support - Requirements and Solution Design for DEMETER Pilot Cluster 1*

D.1.1. **Pilot 1.1 & 1.2**

Pilot 1.1 & 1.2 aims to create a Decision Support System to address the issue of water savings & smart energy management in the irrigated and arable crops. The DSS functionalities created for these pilots will require the development of a standard model of water management applied to irrigation in order to standardise and model the information that is exchanged between the water management and control systems.

To illustrate what is required from the DSS for Pilot 1.1 & 1.2 the diagram below has been designed by the relevant partners. As shown in Figure 40, the applications for this pilot will make use of heterogeneous data coming from IoT Sensors, control systems, satellites and other sources. The available data is already being consumed by existing systems to perform image processing for agro indices, machine learning for the estimation of irrigation needs and pesticide level monitoring. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the analysis of agronomic and weather data, analysis of multispectral crop imagery and other support services. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

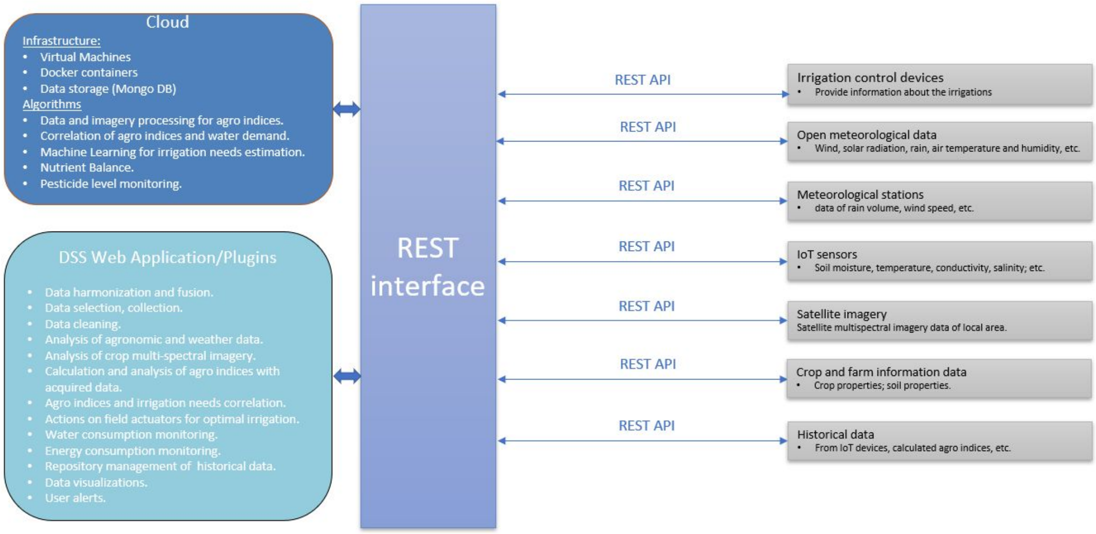


Figure 40. Pilot 1.1 & 1.2 High-Level Design Diagram

D.1.2. **Pilot 1.3**

Pilot 1.3 aim to create a Decision Support System to provide a smart irrigation service in rice and maize cultivation. The DSS created for this pilot will combine a number of different technologies for the holistic management of irrigation water in rice-maize crop rotation system. It is also expected that the system provided will be low maintenance, robust, scalable and at the farm level on a per-field basis.

To illustrate what is required from the DSS for Pilot 1.3 the diagram below has been designed by the relevant partners. As shown in Figure 41, the applications for this pilot will make use of heterogeneous data coming from IoT Sensors, meteorological stations, satellite imagery and other sources. The available data is already being consumed by existing systems to perform the estimation of maize irrigation needs and the estimation of rice and maize fertilisation needs. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the automated control electric valves, the provision of fertilisation prescription needs, water consumption monitoring & alerting and the enhancement of irrigation and fertilisation needs estimation. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

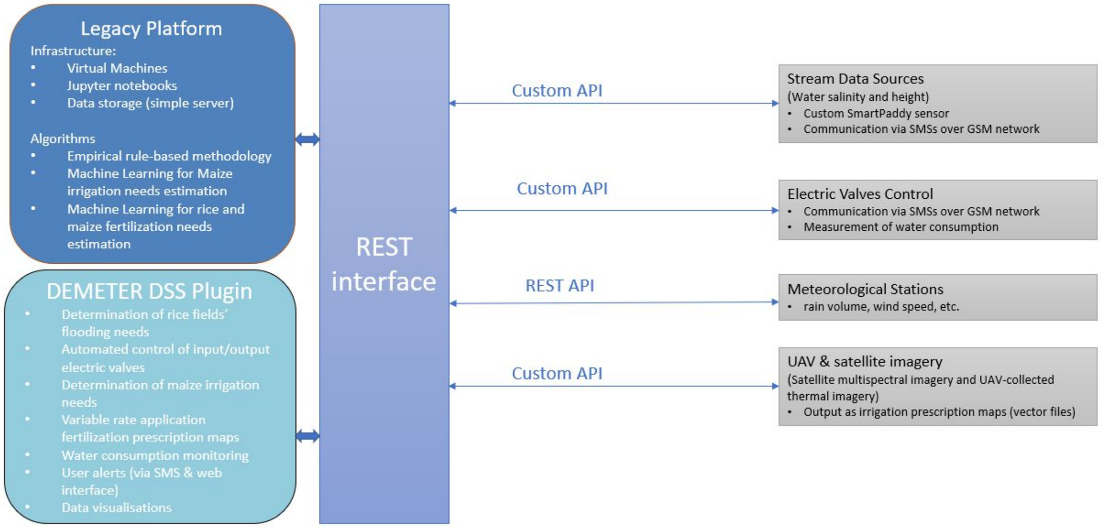


Figure 41. Pilot 1.3 High-Level Design Diagram

D.1.3. **Pilot 1.4**

Pilot 1.4 aims to create a DSS to provide an IoT corn management service. The DSS created for this pilot will be required to collect real-time data from IoT devices and other data sources. The DSS is then required to improve the existing decision support system in use; the Innovagria Management Platform, by extending the number of correlated data types available. This is required in order to enable a more educated automated decision within the existing platform. There is also a requirement from the pilot partners for the DSS to provide; more information to farmers; real-time warnings and forecasts; water, tractor fuel and fertilizer optimisation support while also providing potential users with an increased awareness of its existence.

To illustrate what is required from the DSS for Pilot 1.4 the diagram below has been designed by the relevant partners. As shown in Figure 42, the applications for this pilot will make use of heterogeneous data coming from IoT Sensors, farm management systems, meteorological stations and other sources. The available data is already being consumed by existing systems to perform the estimation of fertilisation and irrigation needs, yield prediction and multispectral imagery analysis. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the enhancement of yield prediction, irrigation planning and the monitoring of crop health and status. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

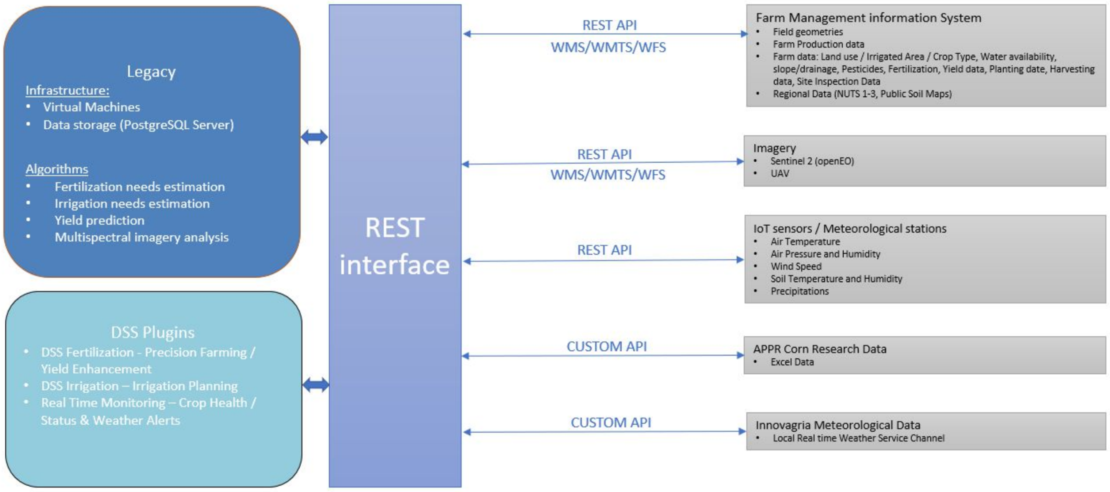


Figure 42. Pilot 1.4 High-Level Design Diagram

D.2. *Decision Support - Requirements and Solution Design for DEMETER Pilot Cluster 2*

D.2.1. **Pilot 2.1**

Pilot 2.1 aims to create a DSS to provide in-service condition monitoring of agricultural machinery. The DSS created for this pilot will be required to analyse real-time emissions data through the use of appropriate algorithms and technologies. The DSS is required to provide its users with the ability to make better informed decisions by providing monitoring, analysis, and documentation of the emissions data.

To illustrate what is required from the DSS for Pilot 2.1 the diagram below has been designed by the relevant partners. As shown in Figure 43, the applications for this pilot will make use of heterogeneous data coming from tractor sensors, public open data such as EU regulations and other sources. The available data is already being consumed by existing systems to perform correlation analysis. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the detection of fraudulent machinery sensors, the estimation of NOx emissions and the monitoring of emissions and engine data. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

Contrary to other pilots' architecture diagrams, the one depicted in Figure 43 shows that the interface between the Legacy Platform and the DSS Plugin against the data sources is partially based on REST. The reason behind this "partially" relies on the fact that only parts of the elements of this diagram may have REST interfaces (e.g. maybe an external database that could be used to get some thresholds for emissions). Another possibility to include a REST interface is the Quality Assessment Component from WP2 (currently named in pilot 2.1 as "fraud detection of machinery"-Plug-In), if we can generalize it at a later phase of the project. However, the data itself coming from the sensors and the NOx estimation and monitoring (i.e. the data analysis) will not be accessible by REST APIs.

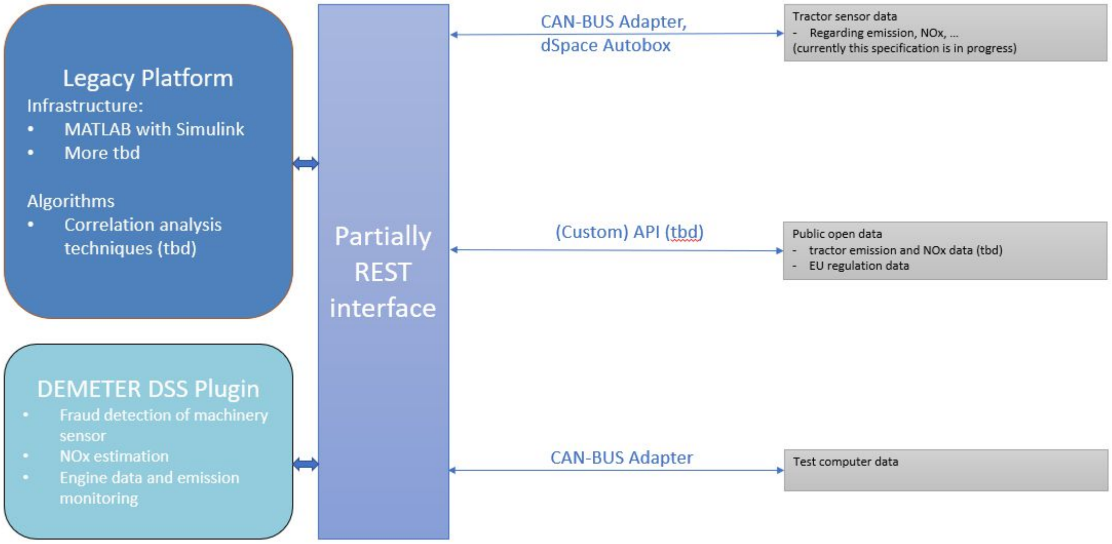


Figure 43. Pilot 2.1 High-Level Design Diagram

D.2.2. **Pilot 2.2**

Pilot 2.2 aims to create a DSS to provide the automated documentation of arable crop farming processes. The DSS created for this pilot will be required to capture high-precision data from a farms agricultural processes while merging this with equivalent data from other farms. The DSS is required to then derive documentation parameters using data analytics and knowledge management techniques.

To illustrate what is required from the DSS for Pilot 2.2 the diagram below has been designed by the relevant partners. As shown in Figure 44, the applications for this pilot will make use of heterogeneous data coming from AutoTrack Systems, GPS tracking devices and financial records. The available data is already being consumed by existing systems to perform map overlays. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning data selection and collection, automated task recognition and cost analysis. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

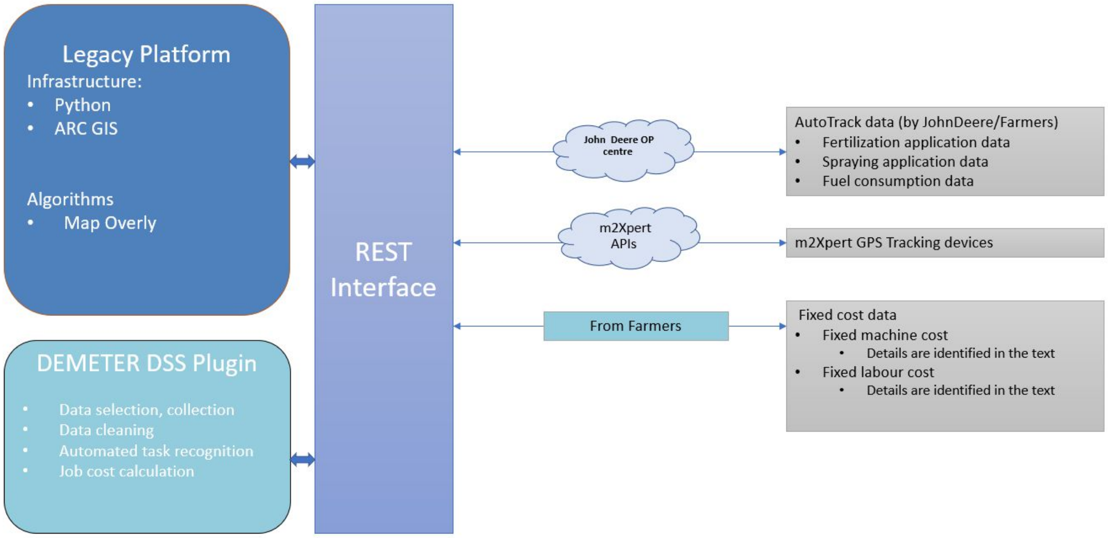


Figure 44. Pilot 2.2 High-Level Design Diagram

D.2.3. **Pilot 2.3**

Pilot 2.3 aims to create a DSS to provide a data brokerage service to farms with existing systems. The DSS will be required to establish a trust based and compliant data market for agricultural enterprise that resides between the farmer and the many systems they may use such as farm and process management and data analysis and storage.

To illustrate what is required from the DSS for Pilot 2.3 the diagram below has been designed by the relevant partners. As shown in Figure 45, the applications for this pilot will make use of heterogeneous data coming from farm telemetry Systems, meteorological stations, IoT sensors and other sources. The available data is already being consumed by existing systems to perform data transformations. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning data selection and collection, metadata discovery & analysis, data & cost analysis and data publishing. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

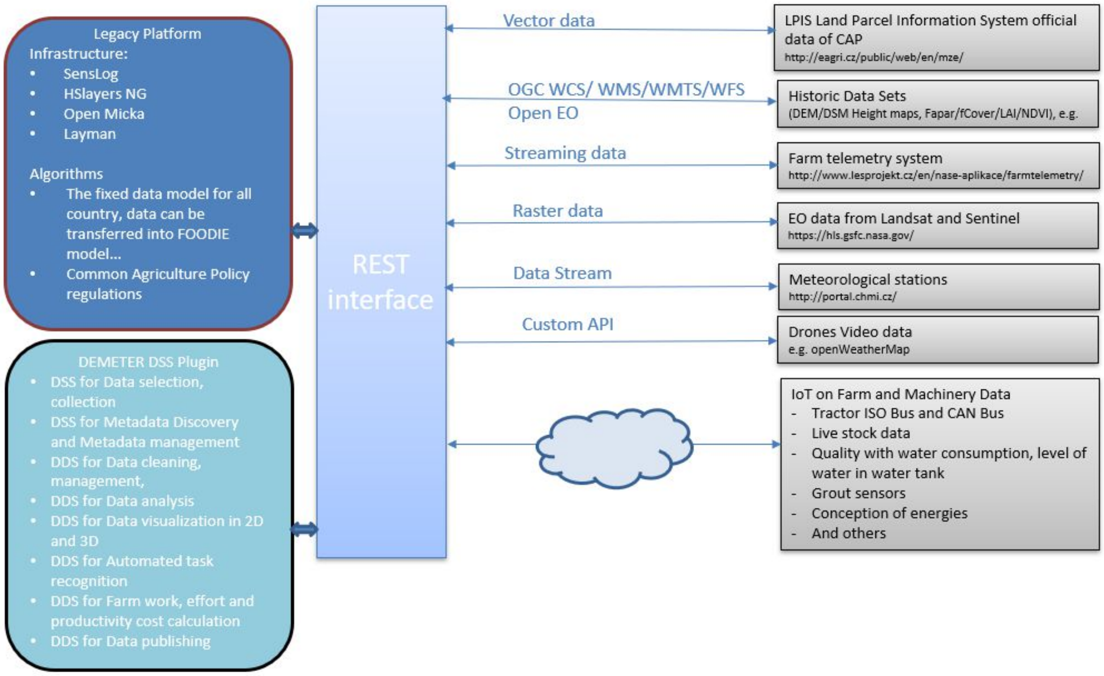


Figure 45. Pilot 2.3 High-Level Design Diagram

D.2.4. **Pilot 2.4**

Pilot 2.4 aims to create a DSS to provide benchmarking at a farm level. The DSS will be required to collect and monitor data from IoT technologies and from within current practical management and decision support systems. The DSS is then required to integrate this into a unified layer where it can maintain access.

To illustrate what is required from the DSS for Pilot 2.4 the diagram below has been designed by the relevant partners. As shown in Figure 46, the applications for this pilot will make use of heterogeneous data coming from farm accountancy data networks, the eDwin platform, Eurostat and other sources. The available data is already being consumed by existing systems to perform alerting. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning data analysis and its visualisation.

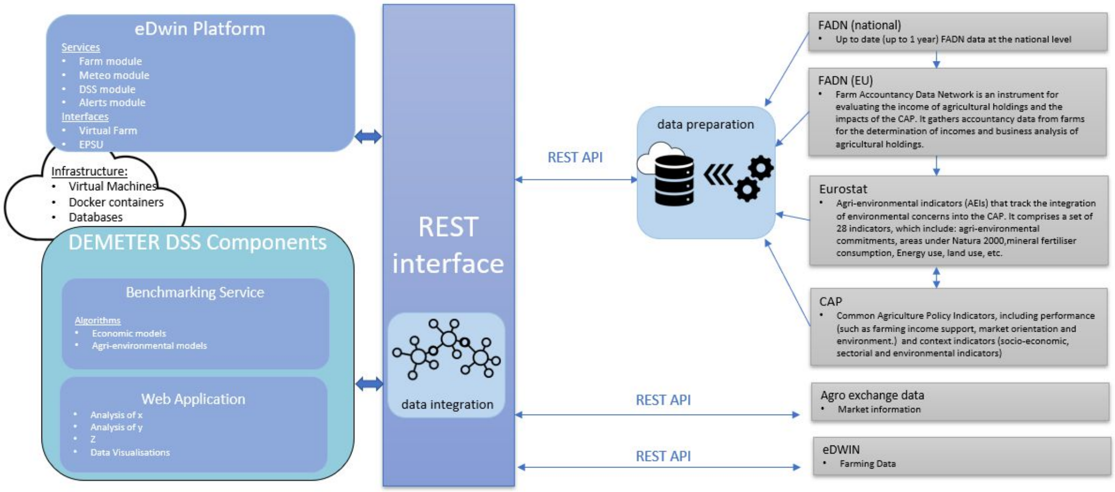


Figure 46. Pilot 2.4 High-Level Design Diagram

D.3. *Decision Support - Requirements and Solution Design for DEMETER Pilot Cluster 3*

D.3.1. **Pilot 3.1**

Pilot 3.1 aims to create a DSS to provide support to olive growers and improve the sustainable production or olive tree orchards. The DSS will be required to collect and integrate territorial data from in-field sensors, remote sensors and the IoT network alongside data coming from existing modelling platforms and farm management systems.

To illustrate what is required from the DSS for Pilot 3.1 the diagram below has been designed by the relevant partners. As shown in Figure 47, the applications for this pilot will make use of heterogeneous data coming from farm management systems, meteorological stations and IoT sensors. The available data is already being consumed by existing systems to perform water and nutrient analysis and pest control. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning data fusion and harmonisation, olive phenology calibration and to also enhance the existing DSS in use. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

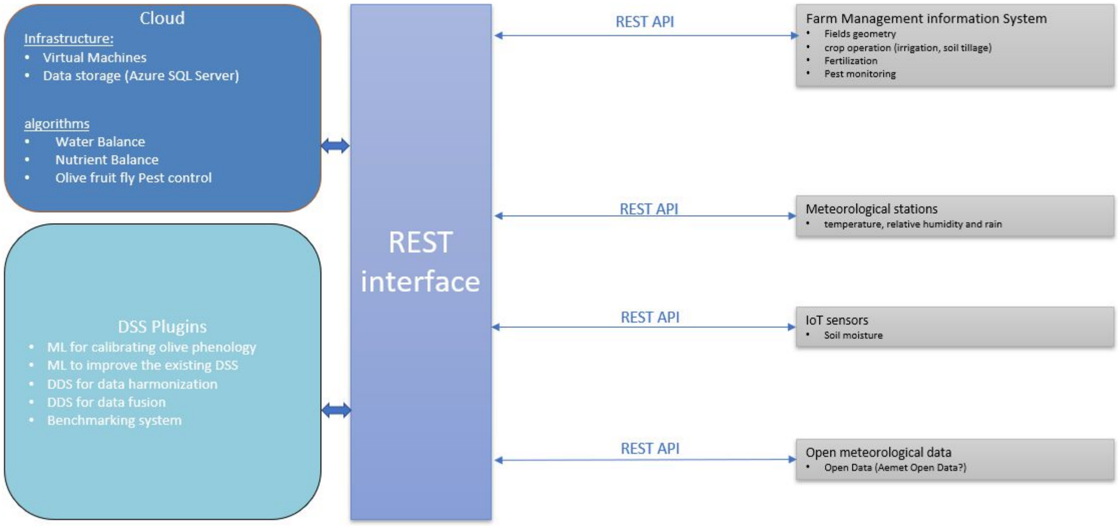


Figure 47. Pilot 3.1 High-Level Design Diagram

D.3.2. **Pilot 3.2**

Pilot 3.2 aims to create a DSS to provide support for the precision farming of Mediterranean woody crops. The DSS will be required to collect and analyse IoT and robotics data to monitor and analyse the agricultural processes used to produce Mediterranean woody crops. The DSS will be required to provide improved solutions for the agricultural practices in use, such as pesticide and fertilisation application. The DSS will also be required to promote the use of IoT based technologies within existing conventional machinery to enable higher levels of precision within the agricultural practices in use.

To illustrate what is required from the DSS for Pilot 3.2 the diagram below has been designed by the relevant partners. As shown in Figure 48, the applications for this pilot will make use of heterogeneous data coming from meteorological stations, IoT sensors and machinery data. The available data is already being consumed by existing systems to perform multispectral imagery analysis, fertilisations and irrigation needs estimation and nutrient balance and yield prediction. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the optimisation of irrigation and fertilisation needs and of growth and yield detection and prediction, the analysis of agronomic and weather data and the analysis of crop multispectral imagery. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

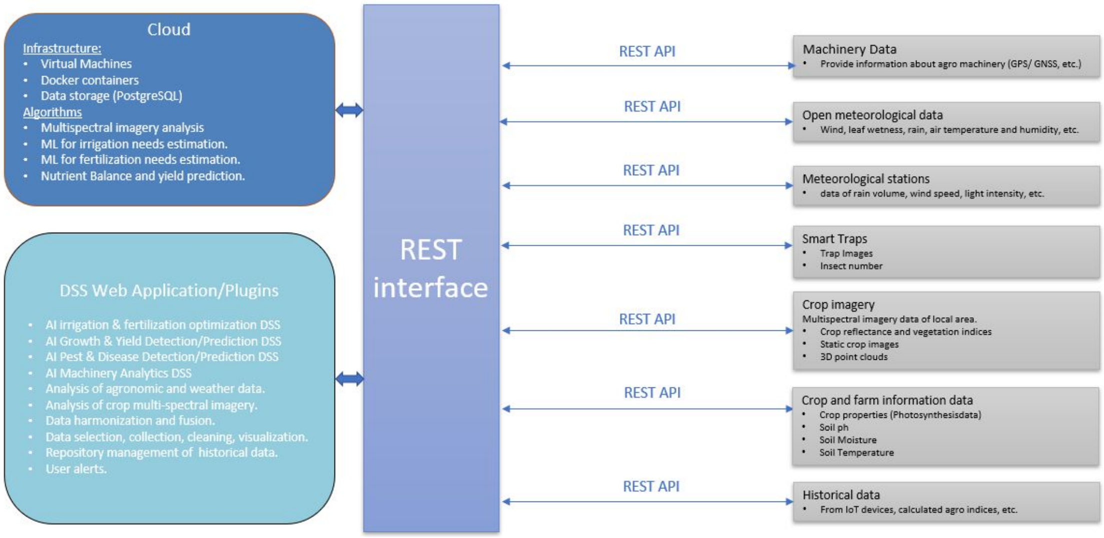


Figure 48. Pilot 3.2 High-Level Design Diagram

D.3.3. **Pilot 3.3**

Pilot 3.3 aims to create a DSS to provide better knowledge and pest management control of the Mediterranean fruit fly. The DSS will be required to collect and analyse real-time data from cameras, sensors and other IoT devices to determine the status of the fruit fly extension while also providing support for appropriate actuations that will improve the pest management situation.

To illustrate what is required from the DSS for Pilot 3.3 the diagram below has been designed by the relevant partners. As shown in Figure 49, the applications for this pilot will make use of heterogeneous data coming from fly control systems, meteorological stations, IoT sensors and other sources. The available data is already being consumed by existing systems to perform insect recognition, pesticide level monitoring, imagery classification and to control pest processes. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the control of citrus growing areas, analysis of tree pesticide levels, the monitoring of environmental variables and also to enhance the image processing and analysis that currently exists. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

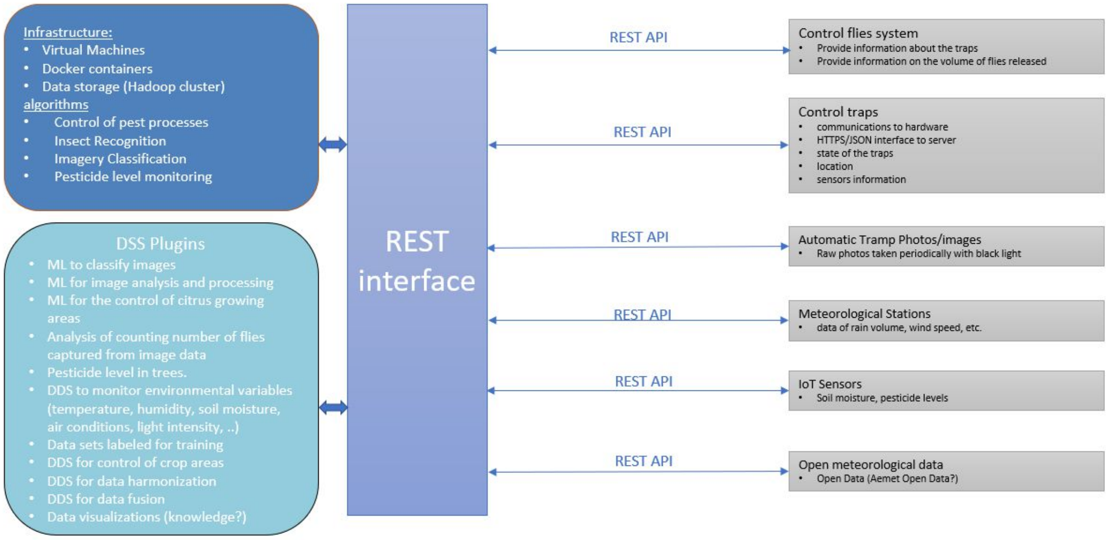


Figure 49. Pilot 3.3 High-Level Design Diagram

D.3.4. **Pilot 3.4**

Pilot 3.4 aims to create a DSS to provide an open platform for improved crop monitoring in potato farms. The DSS will be required to provide a machine learning processing module that is able to receive data from a variety of IoT devices and other data sources. The DSS will then be required to optimise a range of crop models for various crop types through training or finetuning of the optimisation algorithm.

To illustrate what is required from the DSS for Pilot 3.4 the diagram below has been designed by the relevant partners. As shown in Figure 50, the applications for this pilot will make use of heterogeneous data coming from satellite images and timeseries, public meteo data, IoT sensors and other sources. The available data is already being consumed by existing systems to perform potato yield forecasting and field performance analysis. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning task maps for variable rate applications and the enhancement of potato yield forecasting.

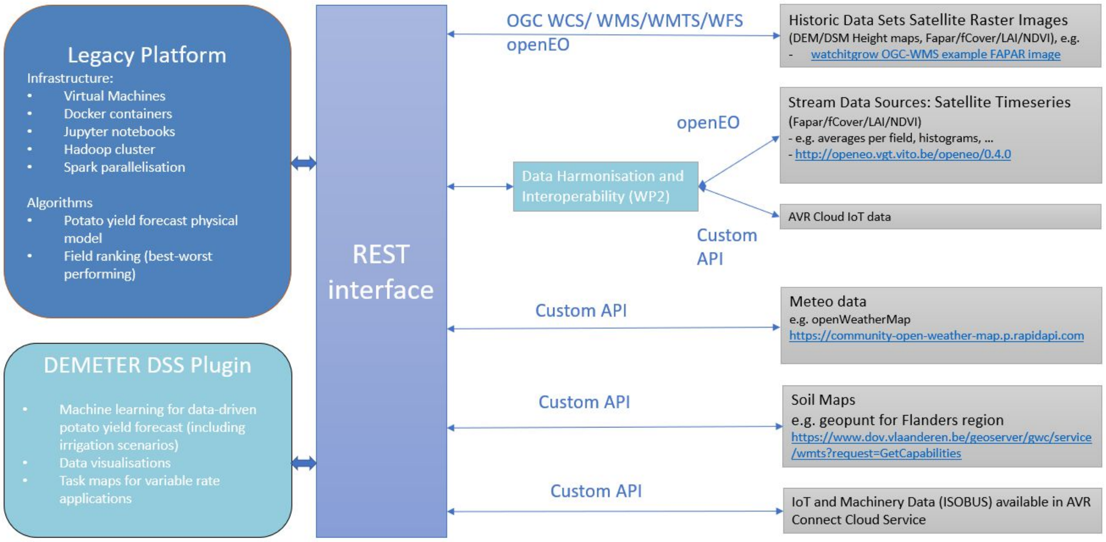


Figure 50. Pilot 3.4 High-Level Design Diagram

D.4. *Decision Support - Requirements and Solution Design for DEMETER Pilot Cluster 4*

D.4.1. **Pilot 4.1**

Pilot 4.1 aims to create a DSS that will provide a dairy farmers dashboard for the entire milk and meat production value chain. The DSS will be required to develop forecasting models at different aggregated levels, from single animals to that at a national level. The DSS is then required to plan and optimise the production of the animals accounting for a variety of parameters, from economic factors to the number and quality of the animal products produced.

To illustrate what is required from the DSS for Pilot 4.1 the diagram below has been designed by the relevant partners. As shown in Figure 51, the applications for this pilot will make use of heterogeneous data coming from Nordic cattle exchange data, historic data sets, IoT sensors and other sources. The available data is already being consumed by existing systems to perform milk forecasting, lactation analysis and cull value analysis. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning feed requirement analysis, the provision of a culling strategy and the enhancement of milk forecasting. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

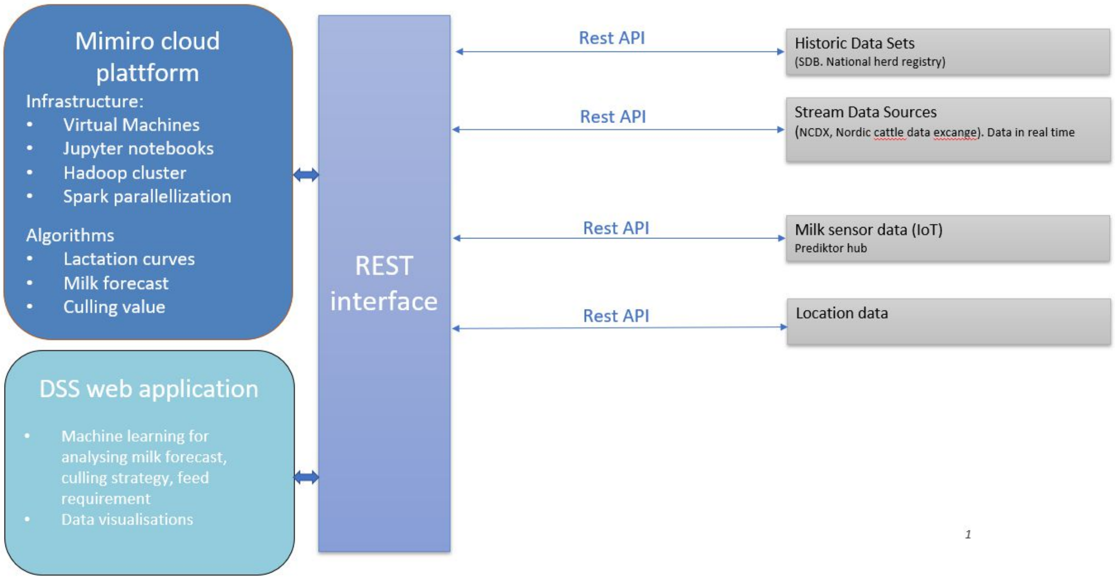


Figure 51. Pilot 4.1 High-Level Design Diagram

D.4.2. **Pilot 4.2**

Pilot 4.2 aims to create a DSS that will provide consumer awareness in terms of milk quality and animal welfare tracking. The DSS will be required to collect, integrate and aggregate data from a variety of sensors, control device and software systems. The DSS will then be required to provide insights into the animals' welfare while offering corrective actions where applicable.

To illustrate what is required from the DSS for Pilot 4.2 the diagram below has been designed by the relevant partners. As shown in Figure 52, the applications for this pilot will make use of heterogeneous data coming from sensors and legacy servers. The available data is already being consumed by existing systems to perform animal movement analysis and the detection of milk quality. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the enhancement of milk analysis through nutrition analysis and pathology analysis. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

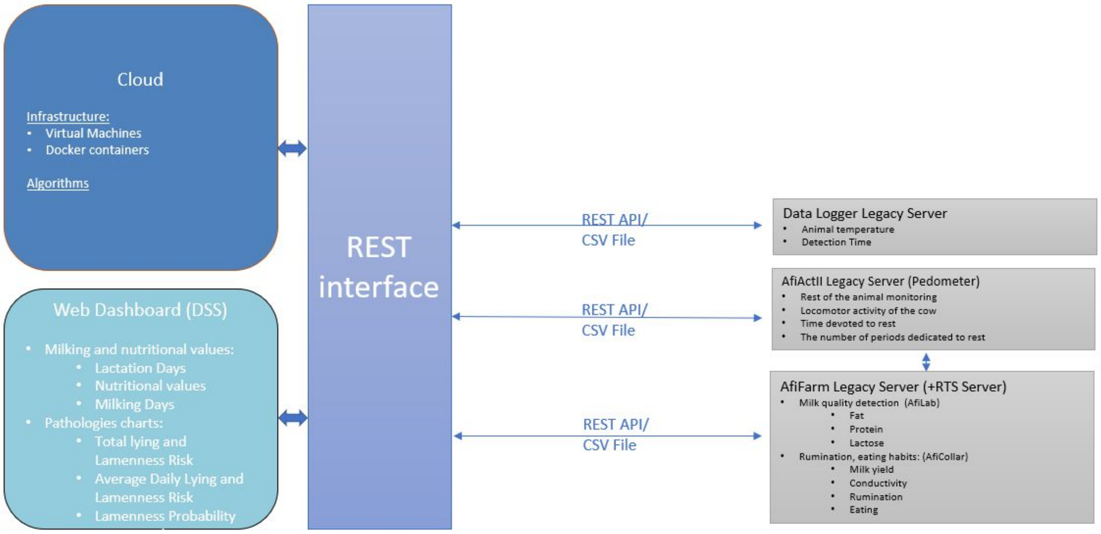


Figure 52. Pilot 4.2 High-Level Design Diagram

D.4.3. **Pilot 4.3**

Pilot 4.3 aims to create a DSS that will provide proactive milk quality control. The DSS will be required to collect and integrate data from sensors and the current systems in use. The DSS will then be required to develop predictive models from which it will analyse parameters of the animal's health and the quality of the milk it produces. It is then expected that the DSS will provide its users with real-time monitoring and alerting.

To illustrate what is required from the DSS for Pilot 4.3 the diagram below has been designed by the relevant partners. As shown in Figure 53, the applications for this pilot will make use of heterogeneous data coming from control systems and IoT sensors. The available data is already being consumed by existing systems to perform an analysis of milk production and animal activity. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the analysis of cow behaviour, milk-yield and bio-chemical data to provide illness alerts, pathological charts and milking & nutritional monitoring. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

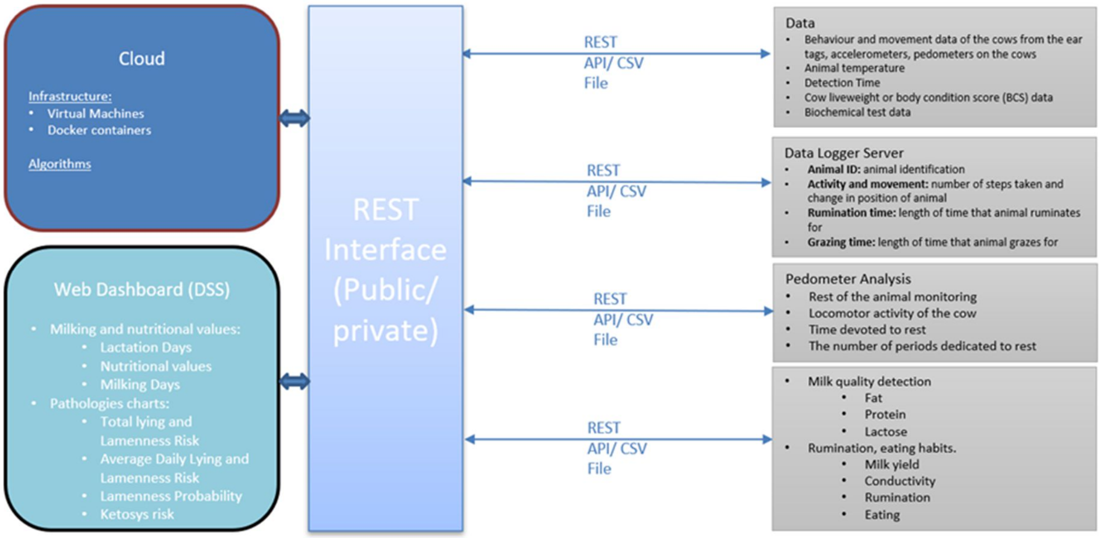


Figure 53. Pilot 4.3 High-Level Design Diagram

D.4.4. **Pilot 4.4**

Pilot 4.4 aims to create a DSS that will optimise the management of chicken farms. The DSS will be required to collect and integrate data from a variety of sensors, IoT devices and existing platforms or systems in use. The DSS will then be required to develop algorithms for the analysis of this data from which it can provide real-time monitoring of parameters that may affect the chicken health or stress level while also providing predictions of these events occurring. The DSS will also be required to provide alerts to its users where applicable and provide a chatbot for energy consumption management.

To illustrate what is required from the DSS for Pilot 4.4 the diagram below has been designed by the relevant partners. As shown in Figure 54, the applications for this pilot will make use of heterogeneous data coming from control systems, IoT sensors, audio/visual devices and other sources. The available data is already being consumed by existing systems to perform an analysis of the animal's environment quality. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning animal health monitoring, disease and growth prediction, feed analysis and the provision of full product passports. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

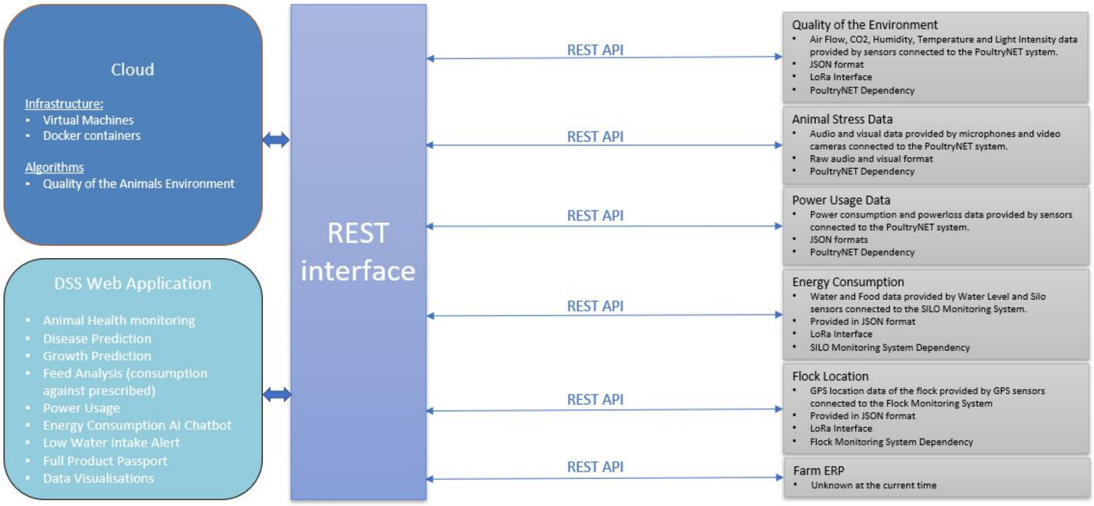


Figure 54. Pilot 4.4 High-Level Design Diagram

D.5. *Decision Support - Requirements and Solution Design for DEMETER Pilot Cluster 5*

D.5.1. **Pilot 5.1**

Pilot 5.1 aims to create a DSS to provide disease prediction and supply chain transparency orchards and vineyards. The DSS will be required to collect and integrate data from a range of sensors, device and existing systems or platforms. It is then expected that the DSS will develop predictive models for disease and provide its users with advice to better manage pests and disease and optimise the production of crops and the pesticides in use.

To illustrate what is required from the DSS for Pilot 5.1 the diagram below has been designed by the relevant partners. As shown in Figure 55, the applications for this pilot will make use of heterogeneous data coming from control systems, IoT and GPS sensors, audio/visual devices and other sources. The available data is already being consumed by existing systems to perform disease prediction. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the enhancement of disease prediction, the monitoring of machinery operations and the provision of full product passports. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

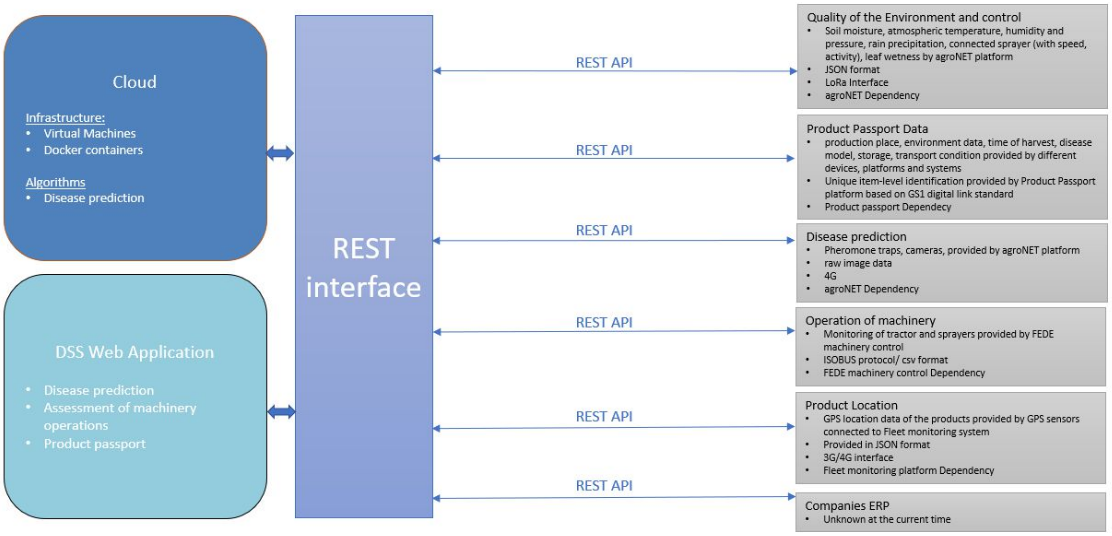


Figure 55. Pilot 5.1 High-Level Design Diagram

D.5.2. **Pilot 5.2**

Pilot 5.2 aims to create a DSS to provide a collaboration space for work management within extensive cattle holdings. The DSS will be required to collect and integrate data from a multitude of heterogeneous data sources and provide a refined and smart view of the available farm data.

To illustrate what is required from the DSS for Pilot 5.2 the diagram below has been designed by the relevant partners. As shown in Figure 56, the applications for this pilot will make use of heterogeneous data coming from control systems, IoT sensors, audio/visual devices and other sources. The available data is already being consumed by existing systems to perform an analysis of the animal's environment quality. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning animal health monitoring, disease and growth prediction, feed analysis and the provision of full product passports. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

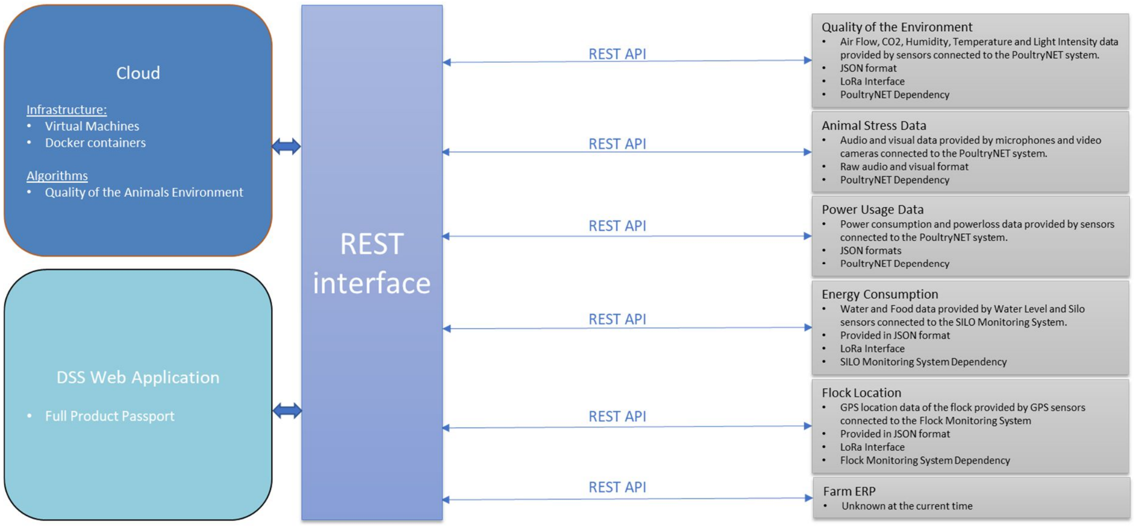


Figure 56. Pilot 5.2 High-Level Design Diagram

D.5.3. **Pilot 5.3**

Pilot 5.3 aims to create a DSS to facilitate pollination optimisation in apiculture. The DSS will be required to connect the DSS created by the regional agriculture advisory centre (WODR), with farm and apiary management systems to manage beekeeping information, including apiaries and farming activities like planned fertilizations (based on the information from farmers), and to provide new advisory services. The DSS will also be required to collect and analyse hive images, then develop machine learning models to detect Varroa mites.

To illustrate what is required from the DSS for Pilot 5.3 the diagram below has been designed by the relevant partners. As shown in Figure 57, the applications for this pilot will make use of heterogeneous data coming from control systems, hive sensors, visual devices and satellite data. The available data is already being consumed by existing systems to perform hive environment analysis. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning the enhancement of hive environment analysis, crop type and growth analysis, Varroa mite detection and the analysis of field pollination requirements. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

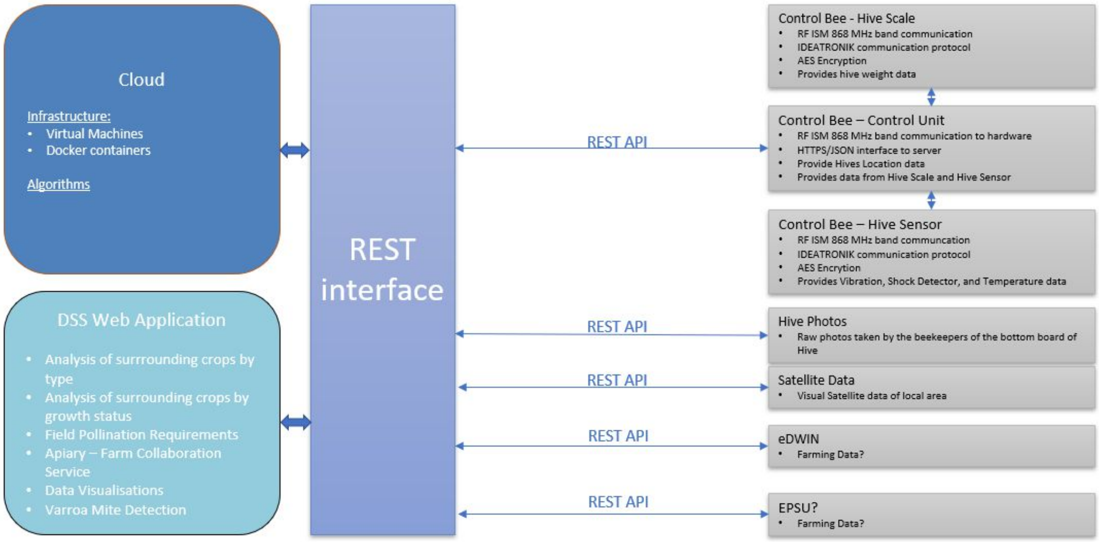


Figure 57. Pilot 5.3 High-Level Design Diagram

D.5.4. **Pilot 5.4**

Pilot 5.4 aims to create a DSS to enable a transparent supply chain within the poultry industry. The DSS will be required to collect data from a range of sensors, devices and existing platforms and systems. The DSS will then be required to identify products on an item level and develop algorithms to analyse animal health and predict disease. It then expected that the DSS will provide full product passports for each animal to enable transparency.

To illustrate what is required from the DSS for Pilot 5.4 the diagram below has been designed by the relevant partners. As shown in Figure 58, the applications for this pilot will make use of heterogeneous data coming from the PoultryNET platform, IoT sensors, audio/visual devices and other sources. The available data is already being consumed by existing systems to perform an analysis of the animal's environment quality. The Decision Support services developed in DEMETER will make use of this data and operate in conjunction with existing services (legacy infrastructure) to provide decision support concerning animal health monitoring, disease and growth prediction, feed analysis & alerting and the provision of full product passports. It should also be noted that the diagram represents a specification for WP4 requirements and does not show components that may be used from WP2 or WP3.

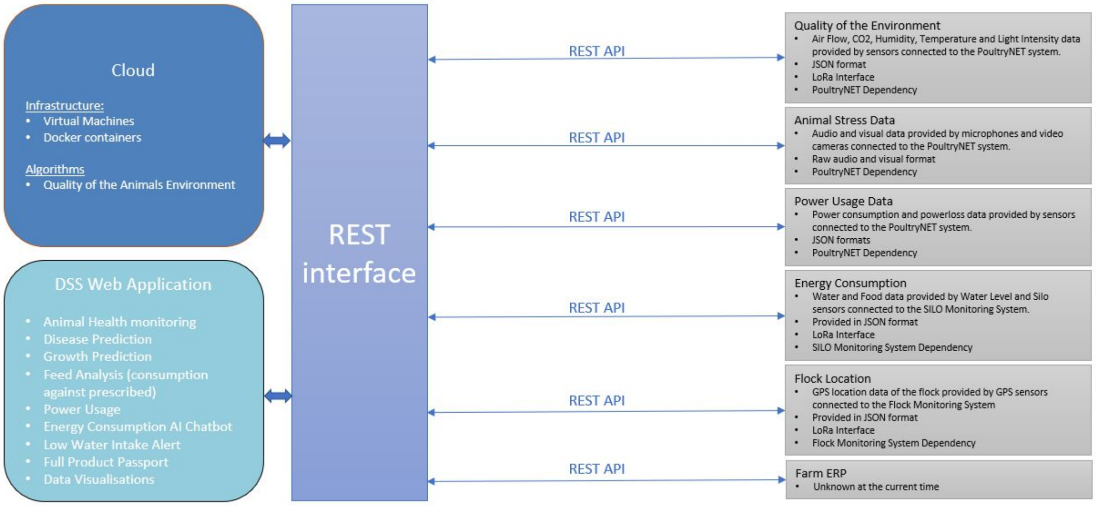


Figure 58. Pilot 5.4 High-Level Design Diagram