D5.4

Final Stakeholder Requirements, Pilots Design, and Specification

Dissemination level: public
Submission date: 30. November 2021

Contents

Executive Summary 5
Acronyms 6
List of Authors 7
List of Figures 7
List of Tables 8
1 Introduction 9
2 Stakeholder Requirements Analysis 11
2.1 Methodology for the Identification of Non-Technical Requirements 13
2.1.1 Clarification of the Stakeholder Analysis 14
2.1.2 Identification of the Vision for DEMETER Digital Spaces 15
2.1.3 User needs and requirements analysis 15
2.1.4 Stakeholder experience mapping 17
2.2 Stakeholder needs and requirements analysis on an overarching, non-technical level 18
2.2.1 Use-case interviews 18
2.2.2 User Interviews for the SOCS Co-Creation Application 21
2.2.3 Elicitation of non-technical user requirements 22
3 Stakeholder requirements on DEMETER Pilot Clusters level 25
3.1 Stakeholder requirements for Pilot Cluster 1 – Arable Crops....................25
3.2 Stakeholder requirements for Pilot Cluster 2 – Precision farming 28
3.3 Stakeholder requirements for Pilot Cluster 3 – Fruits and Vegetables 29
3.4 Stakeholder requirements for Pilot Cluster 4 – Livestock....................32
3.5 Stakeholder requirements for Pilot Cluster 5 – Full supply chain, Interoperability, Robotics 34
4 DEMETER Pilots design and specifications 36
4.1 Pilot 1.1 & 1.2 - Water and Energy Savings in Irrigated Crops....................36
4.1.1 Use-case-specific requirements....................37

This document is issued within the frame and for the purpose of the DEMETER project. This project has received funding from the European Union's Horizon2020 research and innovation programme under Grant Agreement No. 857202. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the European Commission.

4.1.2 Envisioned Scenario 38
4.1.3 Expected Benefits...38
4.1.4 The pilots approach...38
4.1.5 Usage of DEMETER components...39
4.2 Pilot 1.3 - Smart Irrigation Service in Rice & Maize Cultivation 42
4.2.1 Use case specific requirements...42
4.2.2 Envisioned Scenario 43
4.2.3 Expected Benefits...43
4.2.4 The pilots approach...43
4.2.5 Usage of DEMETER components...45
4.3 Pilot 1.4 - IoT Corn Management & Decision Support Platform..49
4.3.1 Use case specific requirements...49
4.3.2 Envisioned Scenario 50
4.3.3 Expected Benefits...51
4.3.4 The pilots approach...51
4.3.5 Usage of DEMETER components...53
4.4 Pilot 2.1 - In-Service Condition Monitoring of Agricultural Machinery 53
4.4.1 Use case specific requirements...53
4.4.2 Envisioned Scenario 54
4.4.3 Expected Benefits...54
4.4.4 The pilots approach...54
4.4.1 Usage of DEMETER components...56
4.5 Pilot 2.2 - Automated Documentation of Arable Crop Farming Processes 56
4.5.1 Use case specific requirements...56
4.5.2 Envisioned Scenario 56
4.5.3 Expected Benefits...57
4.5.4 The pilots approach...57
4.5.5 Usage of DEMETER components...59
4.6 Pilot 2.3 - Data Brokerage Service and Decision Support System for Farm Management 59
4.6.1 Use case specific requirements...59
4.6.2 Envisioned Scenario 60
4.6.3 Expected Benefits...61
4.6.4 The pilots approach...61
4.6.5 Usage of DEMETER components...61
4.7 Pilot 2.4 - Benchmarking at Farm Level Decision Support System 61
4.7.1 Use case specific requirements...61
4.7.2 Envisioned Scenario 62

4.7.3 Expected Benefits....63
4.7.4 The pilots approach....63
4.7.5 Usage of DEMETER components....64
4.8 Pilot 3.1 - Decision Support System to Support Olive Growers....69
4.8.1 Use case specific requirements....69
4.8.2 Envisioned Scenario....71
4.8.3 Expected Benefits....72
4.8.4 The pilots approach....72
4.8.5 Usage of DEMETER components....72
4.9 Pilot 3.2 - Precision Farming for Mediterranean Woody Crops....72
4.9.1 Use case specific requirements....73
4.9.2 Envisioned Scenario....73
4.9.3 Expected Benefits....74
4.9.4 The pilots approach....75
4.9.5 Usage of DEMETER components....75
4.10 Pilot 3.3 - Pest Management Control on Fruit Fly....76
4.10.1 Envisioned Scenario....76
4.10.2 Expected Benefits....77
4.10.3 The pilots approach....78
4.10.4 Usage of DEMETER components....78
4.11 Pilot 3.4 - Open Platform for Improved Crop Monitoring in Potato Farms....79
4.11.1 Use case specific requirements....79
4.11.2 Envisioned Scenario....80
4.11.3 Expected Benefits....80
4.11.4 The pilots approach....81
4.11.5 Usage of DEMETER components....81
4.12 Pilot 4.1 - Dairy Farmers Dashboard for the Entire Milk and Meat Production Value Chain 82
4.12.1 Use case specific requirements....83
4.12.2 Envisioned Scenario....84
4.12.3 Expected Benefits....84
4.12.4 The pilots approach....84
4.12.5 Usage of DEMETER components....85
4.13 Pilot 4.2 - Consumer Awareness: Milk Quality and Animal Welfare Tracking....85
4.13.1 Use case specific requirements....86
4.13.2 Envisioned Scenario....87
4.13.3 Expected Benefits....88
4.13.1 Stakeholders....88

4.13.2 The pilots approach....88
4.13.3 Usage of DEMETER components....89
4.14 Pilot 4.3 - Proactive Milk Quality Control....91
4.14.1 Use case specific requirements....92
4.14.2 Envisioned scenario....92
4.14.3 Expected Benefits....92
4.14.4 The pilots approach....93
4.14.5 Usage of DEMETER components....93
4.15 Pilot 4.4 - Optimal Chicken Farm Management....95
4.15.1 Use case specific requirements....95
4.15.2 Envisioned Scenario....96
4.15.3 Expected Benefits....96
4.15.4 The pilot approach....97
4.15.5 Usage of DEMETER components....97
4.16 Pilot 5.1 Disease prediction and supply chain transparency for Orchards/vineyards....98
4.16.1 Use case specific requirements....99
4.16.2 Envisioned Scenario....100
4.16.3 Expected Benefits....100
4.16.4 The pilots approach....100
4.16.5 Usage of DEMETER components....100
4.17 Pilot 5.2 - Farm of Things in Extensive Cattle Holdings....101
4.17.1 Use case specific requirements....101
4.17.2 Envisioned Scenario....101
4.17.3 Expected Benefits....102
4.17.4 The pilots approach....102
4.17.5 Usage of DEMETER components....103
4.18 Pilot 5.3 - Pollination optimisation in apiculture....104
4.18.1 Use case specific requirements....104
4.18.2 Envisioned Scenario....105
4.18.3 Expected Benefits....106
4.18.4 The pilots approach....106
4.18.5 Usage of DEMETER components....107
4.19 Pilot 5.4 - Transparent supply chain in poultry industry....107
4.19.1 Use case specific requirements....108
4.19.2 Envisioned Scenario....108
4.19.3 Expected Benefits....108
4.19.4 The pilot approach....108

4.19.5 Usage of DEMETER components....108
5 Conclusion....109

Executive Summary

To achieve a long-lasting and sustainable impact, all DEMETER project activities are closely tied to real world agricultural use cases in the 20 DEMETER pilots across 18 European Countries. The pilots are grouped into 5 thematic clusters. This deliverable is the final version of a series of three iterations and provides the final collection of relevant information to describe the stakeholder requirements and listed in Annex B as well as with respect of the meanwhile developed DEMETER components in Annex E. This deliverable has evolved with strong contribution of the cluster and pilot leads as well as in exchange with the other DEMETER work-packages.

The performance of the DEMETER improved use-cases is measurable by appropriate key performance indicators (KPIs) within an evaluation framework. This framework is defined in Deliverable D5.5 and the KPIs in more detail are in Annex C. The performance monitoring based on the KPIs Framework will be reported in D5.7 by the end of the project. The relation of WP5 to the other DEMETER work packages including their deliverables and tasks is also described in detail in D5.5. The combination of challenges, objectives and evaluation framework serves as major guideline for the development of the pilots and related activities. Whilst the overall objectives and challenges ensure that the overall results of DEMETER will have a sustainable impact on the agricultural communities in Europe, understanding the individual stakeholders and needs in the DEMETER pilots is key to ensuring that these results are of relevance and good use to farmers in real life. The identification of detailed business requirements and external stakeholders are identified and ongoing strategies to reach out to them are developed by WP6 and 7. To fully identify business requirements, an iterative analysis and communication process with the pilots, and eventually with external stakeholders is part of the DEMETER MAA approach. The overall results of the initial collection round were documented in D5.1 followed by the updates in D5.2. These deliverables deemed appropriate input to the technical WP to start their respective work items. The derived baseline for technical concepts and approaches was further refined through additional specific questionnaires. One workshop for all WPs and bi-lateral discussions between individual pilots and the technical WPs had been made as needed. Abstracting the collected input into architectural concerns, concepts and DEMETER components was carried out in the WPs 2, 3 and 4 and is documented in their respective deliverables.

The information collected with this approach has been refined in a second iteration cycle and summarized in this report. Detailed descriptions of each cluster and all pilots provide information about the current situation and challenges, the foreseen goal at the end of the project and how the objectives of DEMETER will be addressed. The maturing understanding of the pilots and their environments is moving the stakeholder identification from looking at involved partners to abstracted stakeholders with generic roles and interest. Instead of the initial diagrams outlining the pilots' partners and their basic relationships and interest, the pilot descriptions now include an initial high-level mapping of the pilots' stakeholders, their roles and their main interests. The identified soft- and hardware components, data sources, standards etc. which provide input to the pilot design, specification and planning process in cooperation with other DEMETER WPs. Preliminary implementation of meanwhile developed DEMETER components are documented here as a general overview for each pilot, while detailed technical testbed planning will be described in the upcoming D5.6.

Acronyms

AI	Artificial Intelligence
API	Application Programming Interface
CoAP	Constrained Application Protocol
COTS	Commercial of the Shelf
DSS	Decision Support System
dt	Deci tonne (100kg)
EO	Earth Observations
FADN	Farm Accountancy Data Network
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FMIS	Farming Management Information Systems
ha	Hectare
HW	Hardware
ICT	Information and Communications Technology
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
IoT	Internet of Things
KPI	Key Performance Indicators
LED	Light Emitting Diode
LFA	Less-Favoured Areas
MAA	Multi Actor Approach
NDMI	Normalized Difference Moisture Index
NGSI / NGSI-LD	Context Information Management Protocols
NPK	Nitrogen, Phosphorus, and Potassium Fertilizer
ML	Machine Learning
KPI	Key Performance Indicators
MQTT	Message Queuing Telemetry Transport Network Protocol
NDVI	Normalized Difference Vegetation Index
NUTS	Nomenclature of Territorial Units for Statistics
UAV	Unmanned Airborne Vehicle (e.g. Drones)
PEMS	Portable Emission Measurement Systems
REST	Representational State Transfer
SOAP	Simple Object Access Protocol
SOCS	Stakeholders Open Collaboration Space
SQuaRE	Software product Quality Requirements and Evaluation
SW	Software
UC#	Use Case
VRA	Variable Rate Application (e.g. of fertiliser or pest treatments)
WFS	Web Feature Service Standard of the Open Geospatial Consortium
WIG	WatchITgrow platform
WMS	Web Mapping Service Standard of the Open Geospatial Consortium
WP	Work Package

List of Authors

Organisation	Author
OGC	Nils Hempelmann (editor)
OGC	Martin Klopfer
LESP	Karel Charvat - Junior (pilot 2.3)
LESP	Jaroslav Smejkal (pilot 2.3)
TECNALIA	Belén Martínez (pilot 5.2)
TECNALIA	Sonia Bilbao (pilot 5.2)
TECNALIA	Fernando Jorge (pilot 5.2)
ATOS	Jesús Martínez (pilot 3.3)
ATOS	Sergio Salmerón (pilot 3.3)
ENG	Francesca Cantore (pilot 4.2)
ENG	Antonio Caruso (pilot 4.2)
ODINS	Juan Antonio (pilot 1.1_1.2)
ODINS	Manuel Mora (pilot 1.1_1.2)
TRAGSA	Azucena Sierra
TRAGSA	Carlos Martinez
TRAGSA	Eladio Luis Rego (pilot 1.1_1.2)
Fraunhofer IESE	Christof Schroth (Pilot 2.1, 2.2)
John Deere	Morteza Abdipourchenarestansofla (Pilot 2.2)
John Deere	Andreas Schröder (pilot 2.1)
m2Xpert	Victoria Helmich (Pilot 2.2)
m2Xpert	Hans-Peter Grothaus (Pilot 2.2)
SIMAVI	Alexandra Trif (pilot 1.4)
SIMAVI	Mihai Angheloiu (pilot 1.4)
SIMAVI	Gabriel Nicola (pilot 1.4)
SINTEF	Arne J. Berre (pilot 4.1)
AGRICOLUS	Susanna Marchi, Diego Guidotti (pilot 3.1)
UPM	Ramón Alcarria (pilot 5.2)
UPM	Vicente Hernandez (pilot 5.2)

List of Figures

Figure 1: Location of D5.4 in relation to the DEMETER WPs and their deliverables....10
Figure 2: Timeline of WP5 deliverables. 10
Figure 3 Iterative requirements collection and refinement process....12
Figure 4: Stakeholder identification and analysis process diagram 12
Figure 5: Requirements Analysis Overview 17
Figure 6: Cluster 1 Arable Crops – Experience Map 27
Figure 7: Cluster 2 Precision Farming – Experience Map 29
Figure 8: Cluster 3 (Fruit and Vegetable Production) – Experience Map....31
Figure 9: Cluster 4 Livestock – Experience Map 33
Figure 10: Cluster 5 - Supply Chain – Experience Map 35
Figure 11: Location of Pilot 1.1 and 1.2 37
Figure 12: Used DEMETER components in Pilot 1.1&2 40
Figure 13: Before DEMETER workflow of the agronomic advisory services of Pilot 1.3. 47
Figure 14: After DEMETER workflow of the three applications developed in Pilot 1.3. 48
Figure 15: Location of Pilot 1.4 testing parcels 49

Figure 16: Before & After DEMETER - Component A3 - Plant stress detection 50
Figure 17: Before & After DEMETER - Component C1 -Nitrogen Balance Model 50
Figure 18: NDVI Example 52
Figure 19: Emission measurement system 53
Figure 20: Illustration how the data quality assessment is obtained...54
Figure 21: Pilot 2.1 before and after DEMETER showing the expected impact 55
Figure 22: Data flow of Automated Job Documentation with provided GPS data 58
Figure 23: Situation before and after DEMETER showing the expected impact.....................................59
Figure 24: Diagram showing the relationships between the stakeholders..64
Figure 25: Before and after DEMETER showing the expected impact 65
Figure 26: Connectivity of different compartments..65
Figure 27: Overview – environment for algorithm development and web application front-end for benchmarking 67
Figure 28: Overview of the eDWIN Virtual Farm beta test interfase 68
Figure 29: Deployment testbed of the pilot 69
Figure 30 Farm and field management section...70
Figure 31 Water balance model supporting irrigation scheduling in Agricolus Oliwes, section forecasting models. 70
Figure 32 Nutrients balance model supporting fertilization scheduling in Agricolus Oliwes, section forecasting models. 71
Figure 33: Before and after DEMETER components implementation...71
Figure 34: AgIoT and AgRobotics deployed at pilot 3.2 74
Figure 35: Envisioned deployment of DEMETER components for pilot 3.2 75
Figure 36: Envisioned deployment of DEMETER components for pilot 3.3 77
Figure 37: WatchItGrow web application for visualization of Satellite data and crop growth data.....80
Figure 38: AVR Puma 4.0 potato harvester with GPRS/4G data connection 80
Figure 39 Pilot 4.2 Before DEMETER...90
Figure 40 Pilot 4.2 after DEMETER..91
Figure 41:Before Demeter Pilot 5.3 communication between main actors/stakeholders 104
Figure 42: After Demeter Pilot 5.3 communication between main actors/stakeholders..................106
Figure 43: Screenshot of Mural Board Stakeholder Groups and Interests. 110
Figure 44: Stakeholders using DEMETER platform as provider..110
Figure 45: Stakeholder using DEMETER platform as consumer 111

List of Tables

Table 1: Relevant stakeholder classes 13
Table 2: Information form interviewed farmers and an estimation of the ICT-utilisation level..........19
Table 3 Excerpt of the semi-structured interview moderation guideline 20
Table 4: DEMETER-overarching user requirements 22
Table 5: SOCs Co-Creation Application user requirements...23
Table 6: DEMETER Components for Pilot 1.1&2. 40
Table 7: Overview of the identified stakeholders and interests for Pilot 2.4 63
Table 8: Usage of DEMETER components in Pilot 3.3 78
Table 9: Identified Stakeholder Requirements..86
Table 10: Identified Stakeholder Requirements..96

1 Introduction

This report presents the results of the stakeholder requirements analysis activities that have been carried out in collaboration with DEMETER Pilots. The nature of this final report has changed significantly from its original version, mostly because previous iterations primarily served as input to get the technical work in DEMETER started and aligned with our pilots' real-world requirements. This final version is the cumulative update to describe the stakeholder requirements with information on:

- Improved and detailed descriptions of the pilots, their current challenges, their expectations, and usage of DEMETER components.
- High-level requirements surveys and workshops that identified stakeholders and their roles and interests.
- The collection of available data, data models, data management and sharing principles, communication technologies including protocols and interfaces, interoperability arrangements, the use of standards, and the integration of data produced on farm with externally provided data.
- Outcomes of the Multi Actor Approach (MMA) on Stakeholder requirements on Cluster level.

A detailed mapping of pilots to the resulting WP2, 3 and 4 components is provided in Annex 5 of *D5.3 Testbed Deployment, System Extensions and Applications for Pilot Round 1* with a planned follow up as D5.6 *Testbed Deployment, System Extensions and Applications for Pilot Round 2.*

Workshops between the technical WPs and the pilots were used to ensure that all pilots are aware of mandatory and optional DEMETER enablers, components and services. Doing this at the start of the pilot implementation activities ensured a common picture among the pilots about available building blocks, thus reducing the risk of duplicating efforts on similar requirements. At the same time the exercise triggered first ideas about cross pilot fertilisation and possibilities to transfer approaches to alternative application areas. An example is the development of automated fruit fly detection in Pilot 3.3 for orange groves: whilst adapting the system to other crops, such as olives in Pilot 3.1, seems to be an obvious opportunity, discussions with Pilot 5.3 have started to also consider the application for the identification of varroa mites in beehives. Likewise, the application and integration of pollination services with other arable crop pilots is being discussed.

The Final stakeholder requirements are written alongside with the '*D5.5 Overarching coordination, execution, evaluation, fertilisation and optimisation report for Pilot-Round 1'* as well as the '*D5.6 Testbed Deployment. Systems Extension and Application for Round 2'.* Detailed DEMETER component descriptions are provided by the respective deliverables of the technical Work-Packages and further description of methodology and assessments regarding business and MAA methodology in line with the deliverables of WP 6 and 7 (see Figure 1). This report also presents a revised understanding of the stakeholder roles and how they impact DEMETER, driven by WP7. As the project progresses, the understanding of potentially involved stakeholders, their roles and expectations has significantly matured. In a joint effort, WP5 and WP7 developed a more generalised approach to ensure that dissemination, exploitation and community building activities can better target the stakeholder communities of interest, as part of the DEMETER Multi Actor Approach (MAA) in WP7, as well as through dissemination and exploitation activities in WP6. As the pilots are preparing for the second round of DEMETER implementations, the narrative descriptions of the pilots, which form the core of this report, have been revised to reflect the current state pointing out a general overview of used DEMETER components. Detailed pilot roll out testbed descriptions are documented in D5.6. The relations of the deliverables are shown in Figure 1.

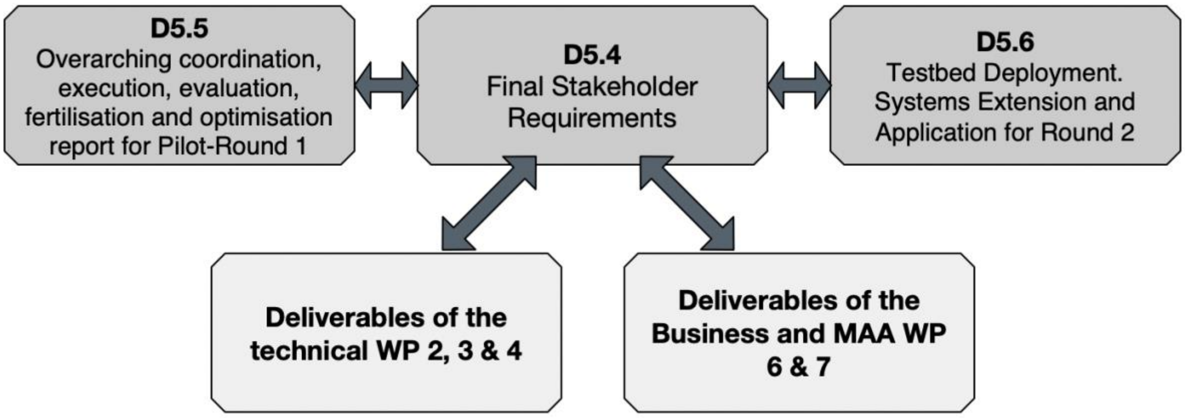


Figure 1: Location of D5.4 in relation to the DEMETER WPs and their deliverables

According to the outcome of the review in May 2021 the timeline of WP, as well as the entire project, is shifted and can be seen Figure 2. Here the additional information in relation to the previous versions D5.1 and D5.2 for this deliverable is also visible.

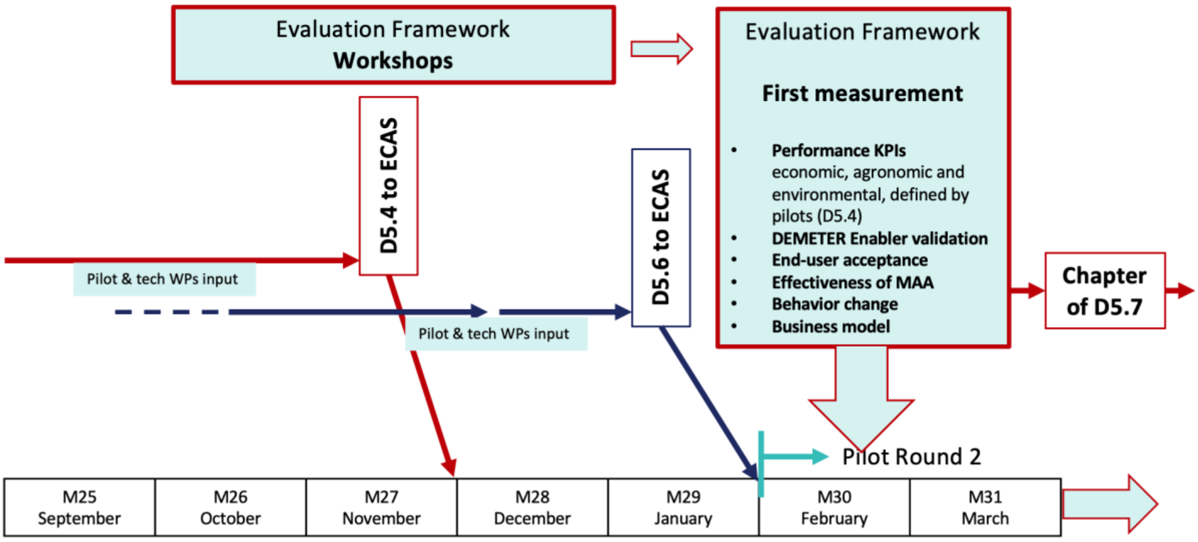


Figure 2: Timeline of WP5 deliverables.

Within WP 5 five thematic clusters (see chapter 3) have been addressed by pilot representatives and the resulting information was documented in internal pilot fact sheets, and a file template to ensure a harmonized structure of the pilot description. The pilot descriptions files are maintained as living documents to have a single place where relevant details can be updated or added. Information relevant to public DEMETER deliverables has been sourced from these factsheets. They are the base for identification of the DEMETER technical requirements derived by the technical WPs and technical components accordingly designed:

a. the pilots stated functional requirements,
b. DEMETER platform requirements proposed by partners,
c. the relevant technical assets brought in by partners or available as Commercial off the Shelf (COTS) and the requirements to support them, and
d. a State of the Art and standards analysis.

The requirements were evaluated at Task and WP levels and refined through several surveys, which have been carried out jointly by WPs 2, 3 and 4. The process was based on a common requirements template table (available in D3.2). The full process and survey descriptions and the consolidated results are documented in the following deliverables:

- D2.1& 3 - Common Data Models and Semantic Interoperability Mechanisms - Release 1 & 2
- D2.2 & 4 - DEMETER Data and Knowledge Extraction Tools- Release 1 & 2
- D3.2 - DEMETER Technology Integration Tools - Release 1
- D3.1 & 3 - DEMETER Reference Architecture (Release 1 & 2)
- D4.1/3 - Decision Support, Benchmarking and Performance Indicator Monitoring Tools- Release 1 & 2
- D4.2 & 4 - Decision Enablers, Advisory Support Tools and DEMETER Stakeholder Open Collaboration Space – release 1 & 2

They are the results of a specific translation and abstraction of the real-world stakeholder requirements finally described in this report into architectural concerns, concepts and DEMETER components carried out by the WP 2, 3 and 4. The Decision Support Areas have been defined in WP4 in collaboration with the pilots and are described in detail in the WP4 reports. The technical components being developed by the technical WPs are deployed in the Pilots use cases and their progress, the corresponding challenges as well as the necessities of improvements for the usability.. During the pilot roll out round 1 the core of the DEMETER spaces had been collectively learned and improved. After the stakeholder requirements being finalised and the technical components being initially familiar to the pilots and users, the second round can roll out. A corresponding deployment plan is being elaborated and will be reported in the DEMETER deliverable D5.6 - Testbed, deployment, system extensions and applications for pilot round 2 with the description of the DEMETER Pilot Roll out round 2. D5.6 is the follow up of D5.3 with the corresponding Pilot roll out round 1, the first iteration cycle of identifying the real-world user requirements, supporting their translation into technical requirements in the technical WPs.

This deliverable is organised in three main sections followed by a conclusion:

- Section: Stakeholder requirements Analysis
  Description of methodology as well as focussing on the overarching, non-technical level
- Section: Stakeholder requirements on DEMETER Pilot Cluster Level
  Requirements are described according to the DEMETER thematic clusters.
- DEMETER Pilots design and specifications
  In this section the requirements are described for each individual pilot including the approaches and initials DEMETER component implementations

2 Stakeholder Requirements Analysis

DEMETER is a multi-actor project, which means achieving more demand-driven innovation through the effective and sufficient involvement of various actors throughout the project, from the participation in the planning of work, through the piloting/demonstration phase, to the dissemination of the results. Since WP5 is the major hub for information flow from and to the pilots, the work and deliverables (such as this one) typically address two areas:

- The collection of the pilots' technical needs, validation and testing of proposed DEMETER concepts and components, and the demonstration and evaluation of results.
- The identification of internal and external stakeholders and their business requirements.

Within DEMETER the identification of requirements and assessment of proposed DEMETER solutions follows an iterative approach involving all WPs and the pilots as outlined in Figure 3.

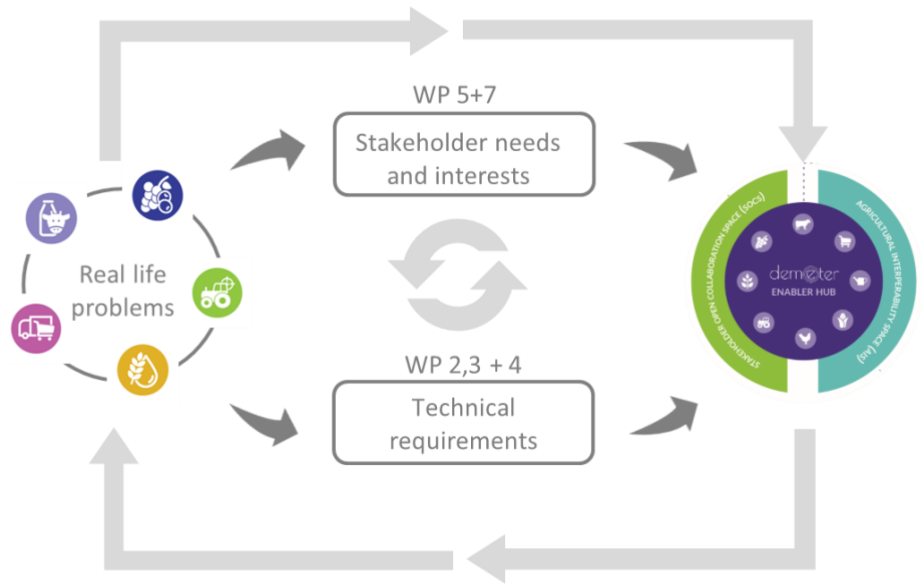


Figure 3 Iterative requirements collection and refinement process

The DEMETER Consortium, with its 60 partners and 20 pilots, already represents a broad spectrum of stakeholders and actors. To ensure a systematic and efficient approach for the successful implementation of the multi-actor concept, the methodology outlined in the following chapters was developed jointly with WP7 (multi actor ecosystem development).

The identification of relevant stakeholders, and the collection and refinement of their requirements, follows an iterative approach, which involves not only the pilots, but also the technical WPs 2, 3 and 4, as well as the MAA, dissemination and exploitation WPs 6 and 7.

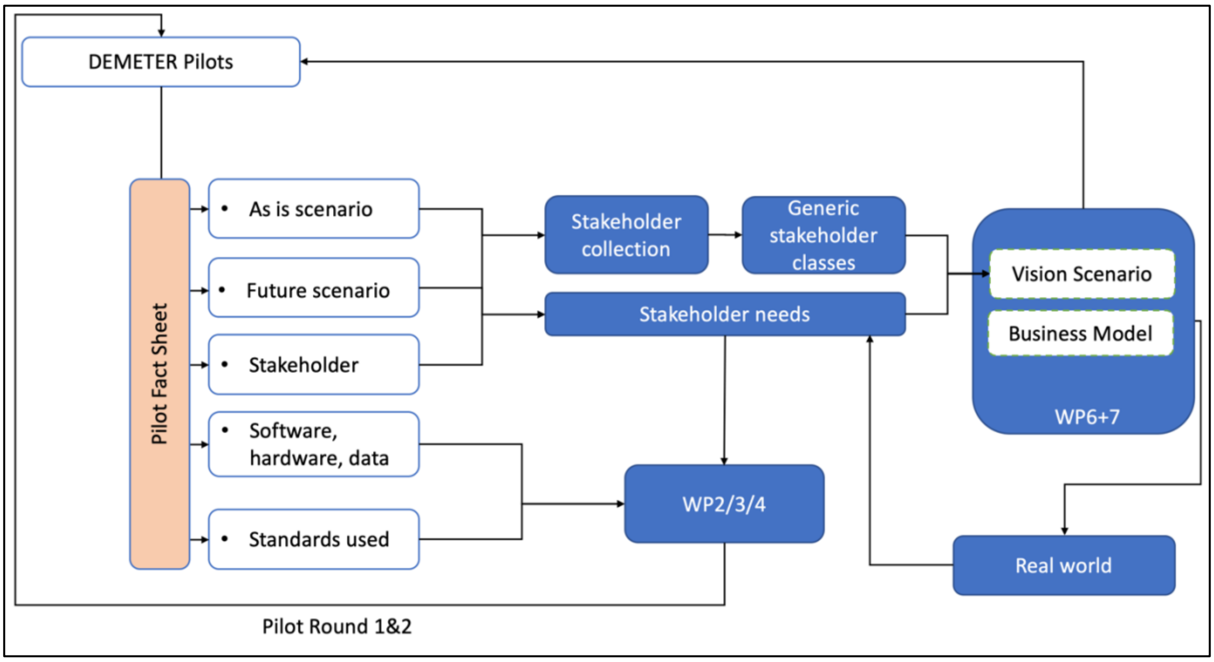


Figure 4: Stakeholder identification and analysis process diagram

To assess the pilots' technical capabilities and requirements, the starting point was a collection of all relevant information that would be needed to start all other WPs' activities in DEMETER. Each WP contributed its initial input requirements to a consolidated common questionnaire, which has been used as a template to collect the necessary information from the pilots' representatives. The templates used were agreed with WPs 2-3-4 to ensure that the information they need for further processing is captured. The main areas addressed were:

- A plain English narrative of what the pilot is about
- A description of the currently encountered challenge
- A description of the envisioned scenario and expected benefits
- The identification of stakeholders, their roles and requirements
- The identification of available and required assets, such as hardware, software, data etc.
- The identification of possible technology, ethical or legal constraints
- The identification of relevant standards

2.1 Methodology for the Identification of Non-Technical Requirements

In order to support the ongoing generation and refinement of the technical requirements (by WPs 2, 3, 4), non-technical i.e., stakeholder needs, and requirements are derived from various MAA activities, i.e., mainly the stakeholder workshop (Section 2.1.1) at M13 and a series of interviews – first, at M21/22 with representatives of each of the five pilot clusters and second, at M26/27 with pilot farmers and developers for the development of the SOCS Co-Creation Application.

The results of those activities also flowed into the development of two farmer survey. The first survey at M17 was DEMETER-internal and sent to participating pilot farmers. The second survey at M27 is external and distributed via the farming organisations associated with DEMETER. While strictly speaking not eliciting new requirements, the surveys help to corroborate the qualitative data in the form of stakeholder needs with quantitative information in the form of rating responses and thus give rise to new activities based upon those results to addressed raised issues. The results of those surveys are presented in separate reports.

As mentioned before, D5.1 and D5.2 already describe in a first version the DEMETER stakeholders and their interests (see below). However, to gain a better understanding of the stakeholders and their interests, descriptions were continuously updated and expanded following the key questions for this analysis:

- Which stakeholders will use the DEMETER platform in the future?
- Which interests motivate potential users to use the platform?
- Which concerns could lead to a negative attitude towards the DEMETER technology?

Table 1: Relevant stakeholder classes

Generic Stakeholder class	Definition
Farmer	This can be a single person, a cooperative or an association, engaged in agriculture, raising living organisms for food or raw materials.
Software Provider	This can be a single person, a company or an association providing software solutions, tools, components, algorithms (if packaged as a software component).
Hardware Provider	This can be a single person, a company or an association providing hardware solutions, such as smart meters, sensors, VRA machines, irrigation valves, milking robots, ...
Agri Suppliers	This can be a single person, a company or an association providing things like feed, seeds, fertilizers, pesticides, fungicides, ...
IT Services	This can be a single person, a company or an association providing services like software integration, data-, processing- or cloud-services.

Advisory Services	This can be a single person, a company or an association providing advisory and consultancy to farmers in terms of rules and regulations, including training to farmers, quality supervision services, lobbying associations, …
Public Authorities	This can be public authorities such as governments, municipalities etc.
General Public	you and me

We have also defined two roles for each stakeholder. Each stakeholder can later use the DEMETER platform as a consumer, or as a technology provider. Under these perspectives we have again analysed the interests of the stakeholders.

As an example, farmers [as consumer] indicate that they would like the DEMETER platform to support them in making decisions to improve efficiency. Of course, this requirement is very prominently represented in our survey, as it is one of the main goals of the DEMETER project. They also expressed the requirement to be able to compare themselves with neighbours or direct competitors. This requirement is no surprise, because benchmarking is also one of the main goals of the project. However, farmers also expressed the requirement to have access to certain data and information. For example, the requirement for information on legal certainty was expressed very specifically. An aspect not raised in the initial survey is marketing. Once brought to the attention of the Pilots, it became apparent that of course there is also an interest of farmers to be able to promote the fact, that their products have been produced in a more sustainable, environmentally, ecologically, or ethical way. But the role of the farmers is not limited to be a consumer, farmers [as provider] also offer to make their data and knowledge available on the platform.

Technology providers [as providers], on the other hand, have an obvious interest in offering software solutions via the platform. This allows the DEMETER portfolio to be extended by additional features and interoperability mechanisms. At the same time, technology providers [as consumers] can also use the platform to obtain information (e.g. practical knowledge from farmers or to determine unmet requirements). Interest in data and in data models developed in DEMETER is also expressed. The results of this analysis are shown as mind maps (Annex A). It summarises the generic stakeholder classes and their general interest in the role as consumer and provider. In the role as a consumer the platform is used to get "something" of interest. In the role as a provider, "something" is made available via the DEMETER platform. The pilots were asked to name "things" that they, as providers, want to make available through the platform and "things" that they as customers of the platform would like to have available. The results show that, besides to the technical developments that are being aimed for in DEMETER, there is a broad interest in information/knowledge, marketing and data.

2.1.1 Clarification of the Stakeholder Analysis

In order to evaluate the generic stakeholder classes, to get a deeper understanding and to identify white spots regarding the stakeholder landscape in DEMETER, an extended stakeholder workshop was initiated in collaboration with WP5, 6 and 7. This workshop (organized and hosted by WP6 and WP7) was successfully conducted on September 4th, 2020. The goal of this workshop was to get a vivid image of the different stakeholder groups involved, their business context, needs, but also attitudes, concerns, and other characteristics relevant to the DEMETER project. The workshop was conducted in a remote co-creation style involving as many DEMETER project consortium partners as possible. Zoom was used to facilitate and host the workshop. To implement a participatory approach, the collaborative online whiteboard application ‘Mural’ was used to collect and organize input provided by participants. Of the 72 registered participants 60 attended the two-hour remote workshop. During the main part three Zoom breakout rooms were set up and facilitated by two members of work packages 5,6 and 7 each. Participants were split randomly into these groups and assigned to one breakout room to work on one of three parallel sessions.

The workshop consisted of three tasks that were prepared on a collaborative Mural whiteboard. In the first task participants were asked to brainstorm and identify as many stakeholders as possible also keeping in mind the generic stakeholder classes defined in previous work. The findings were arranged, filtered, and discussed to clarify, cluster and remove doubles. In the second task participants were asked to classify the stakeholders in the influence-interest matrix which is a key step in the stakeholder analysis and management process. The goal of this task was twofold. On the one hand, the outcome is a visual representation of a stakeholder map which allows to identify key players but also less important stakeholders regarding the DEMETER Project.

This approach reveals information on how particular stakeholders are best managed and gives indications on which stakeholders should be managed more closely compared to others. On the other hand, this task raises awareness on the stakeholder management and engagement process itself in the project consortium. In preparation of the third task participants conducted a dot voting (a democratic voting process where participants express their favour of an idea by casting votes via little dots) and identified the five most relevant stakeholders. The focus on five key stakeholders allowed a more detailed analysis on their needs, interests, and concerns. Comparable to task one, in a mixture of brainstorming, brainwriting, and open discussion every participant was asked to brainstorm needs, interests and concerns for each of the five key stakeholders.

The results were documented together during the workshop by using mural. The mural board of group three, which was filled during the workshop, can be seen as an example Annex A where the case from the third working group is shown, representing the three tasks and the results collected during the extended stakeholder workshop.

This workshop is the basis for follow-up activities that WP6 and 7 will plan and implement together. WP6 will prepare a revised communication and dissemination strategy using a more targeted approach to engage stakeholders (update of D6.1). This will also feed into delivering a roadmap for stakeholder involvement. WP7 will further use the results to plan MAA activities, such as quantitative surveys with external stakeholders to evaluate our initial findings. Focus groups with internal and external stakeholders are also planned to address the most important needs and concerns in more detail, and to jointly design and discuss possible DEMETER solutions.

2.1.2 Identification of the Vision for DEMETER Digital Spaces

The identified stakeholder interests will be considered in the user-centred development of DEMETER Digital Spaces. In addition, based on these analyses, the following steps can also be envisaged:

- Development of stakeholder specific user scenarios describing the process by which the stakeholder uses the DEMETER Platform and the user's motivations.
- Targeted multi-actor approach activities that might focus on a specific stakeholder group to disseminate and to discuss the DEMETER Digital Spaces.
- Targeted dissemination activities can be carried out more effectively by addressing the direct needs of stakeholders.

The work was done in WP7 (Tasks 7.1 and 7.2) in close cooperation with WP5 and WP6. The results of the activities are summarized in the Deliverables D7.3 - MAA Activity and Pilot Report 1 (August 2021) and D7.9 - MAA Activity and Pilot Report 2 (February 2023).

2.1.3 User needs and requirements analysis

In line with the established Usability guidelines and the ISO norm 9241-210:2019 "Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems", stakeholder needs were derived from several sources and MAA activities. Human-centred design aims to make interactive technology useful and usable by focussing on end-users' needs and requirements. Those stakeholder needs and general MAA activity outcomes along with specific user requirements are presented in Section 2.2. The following Section introduces the requirements analysis methodology in DEMETER.

Prior to the requirements analysis, the stakeholder workshops served to understand the stakeholder's needs, concerns, and goals, whereas the interview series at M21/22 focussed more on the concrete context of use and envisioned improvements to current practices. Moreover, the interview series at M26/27 highlighted farmers' attitude towards collaboration with technology providers and reverse in order to gain insights for the development of the SOCS Co-Creation Application for the Stakeholder Open Collaboration Space (SOCS). Finally, focussing on the overall SOCS platform, two workshops were carried out in M27, eliciting user requirements for the SOCS development. From these MAA activities, a number of needs in the form of user stories was derived in the form of, e.g. "As a *farmer*, I need to increase my farm's ecological sustainability." or "As a *technology provider*, I need to have information on and access to interoperable and standardized data". Generally, with needs, the analysis is still detached from the solution space and considers solely the problem space. These needs describe each a condition or prerequisite that fulfils a specific purpose regarding the task, or they capture overarching goals and interests of the stakeholder group. They contain a user story and do not specify the reference of the requirement yet.

Therefore, the stakeholder needs were translated into more concrete, specified user and organisational requirements. *User* requirements tap into the solution space and specify the action that ought to be supported by the system or the information that ought to be provided. They always describe an observable action (e.g. selecting an item) or a cognitive performance (e.g. discerning an information) that helps to satisfy the need with an interactive system. However, the description is agnostic of any specific technology (other than technical requirements are) in the form of, e.g. "The user needs to be able to discern the level of his/her farm's ecological sustainability on the system". The "system" thus refers to any interactive system that satisfies the user need by supporting the user's action or cognitive process. The user requirements are presented in section 2.1.3.

Organisational requirements do not take on the end-users' perspective but are rather broad and focussed on an organisational goal or outcome that must be ensured, yet specify the appertaining stakeholder group, e.g. "The farmer needs to ensure the increase of his/her farm's ecological sustainability." The organisational requirements are part of the overall list of MAA needs and requirements in the annex.

Both user and organisational requirements along with other requirement types (e.g. functional, legal, business) constitute the general requirements specification. This provides crucial information for the development of the technical requirements as the functional specification to meet the former.

Summing up the previous sections, the overall requirements analysis process in depicted in Figure 5 below. Whereas the pilot projects in DEMETER conduct their own pilot-specific user research and requirements analysis involving end-users, which in turn yields the pilot-specific requirements as presented in Chapter 4, WP7 engages end-users of the user groups farmers and technology developers in MAA activities (most of all as part of T7.2 Multi-Actor Approach Animation), in order to elicit DEMETER-overarching user and organisational requirements as explained above. Both types of requirements inform the formation of technical requirements, whereby the DEMETER-overarching requirements are of special importance for the DEMETER components that are not directly related to the pilot development, namely the DEMETER Enabler Hub (DEH) and the Stakeholder Open Collaboration Space (SOCS).

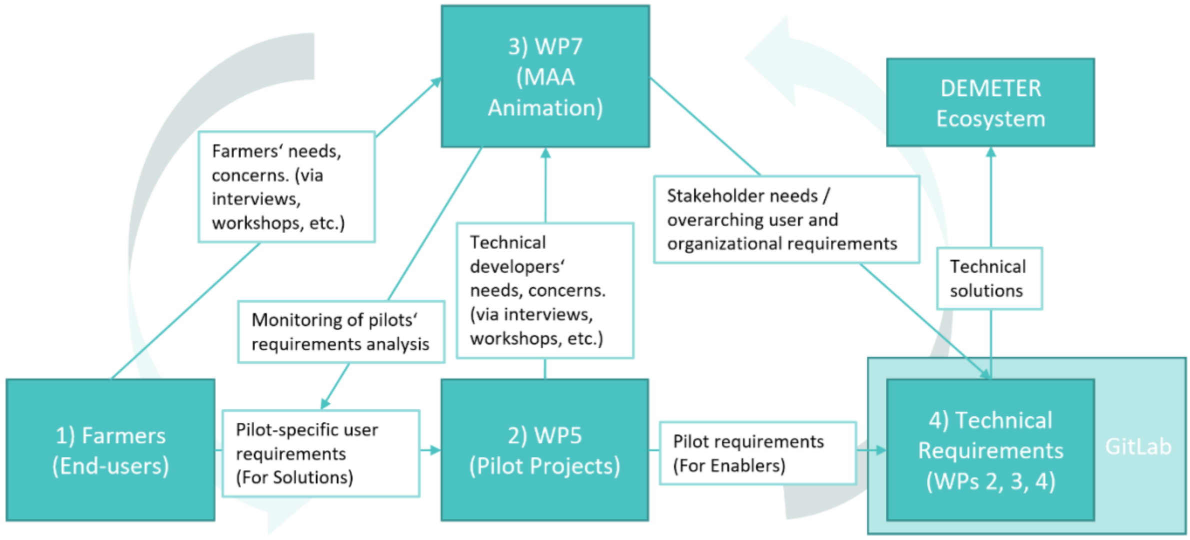


Figure 5: Requirements Analysis Overview

In line with the development of the stakeholder needs and to highlight end-users' needs for the pilot solutions, we conducted an experience mapping for further illustration of the use cases and experience of the farmers based on the first round of interviews in M21/22. The experience maps are presented in Chapter 3, each one linked to the respective cluster that they illustrate. Their methodology is described in the following.

2.1.4 Stakeholder experience mapping

An experience map, presented in chapter 0 on cluster level, is a tool that helps visualising an end-to-end process that a person goes through in order to accomplish a specific goal.[1]

It is a type of journey mapping that, other than a user journey map or customer journey map, is agnostic of a specific product or service. It rather aims at describing a generic person's experience during a journey, starting from the occurrence of a problem until its resolution.

Experience mapping usually starts by plotting several steps of action on a simple timeline from left to right. This timeline can then be expanded top to bottom to describe several dimensions of the experience at the respective stations. This means that, besides the simple description of an action, experience maps can also visualise an individual's emotions as well as touchpoints with people, technology and/or services. Even quotes can be used to generate a deeper understanding for the target group.

For DEMETER, experience mapping is utilised in order to create a deeper understanding of farmers' problems for the project consortium. Three factors are of special interest here:

1. **Whom do farmers talk to during their experience?**
   It is known that a farmer's personal network has a big influence on his/her decision-making in terms of the decision for or against a certain technology. This is reflected in the experience map by the dimension of *stakeholder touchpoints*.

2. **What types of technology do farmers use today that help them solving their problems right now and how do they utilise them?**
   This factor shows how farmers appropriate certain types of technology (e.g., farm management software, weather information systems, sensor readings, etc.) and how they

[1] https://www.nngroup.com/articles/ux-mapping-cheat-sheet/

bring the information of these technologies together in order to make an informed decision. This is plotted on the *ICT touchpoints* dimension.

3. **Which emotions do farmers experience during their journey?**
A major determining factor of every experience and also in UX is the emotional tone or mood that underlies the steps taken und situations occurred during the journey of the user. In this way, the user affect is dependent on the other factors (the steps taken, the stakeholders encountered, and the technology used) and is plotted in the *emotion* dimension.

In conclusion, experience mapping provides a holistic view of an individual‘s end-to-end experience. The several dimensions that can be added to the experience map can help creating an in-depth understanding for the journey of a certain target group in a certain problem setting. For the final experience maps on cluster level, please refer to Section 3.

2.2 Stakeholder needs and requirements analysis on an overarching, non-technical level

The following section describes specific *outcomes* of two rounds of context interview carried out in WP7 whereas aspects related to the methodology are described in Section 2.1, above. The results feed as MAA needs into the DEMETER-overarching requirements analysis. For a close description of the MAA activities so far, please refer to D7.3. However, the MAA activities do not end here. Each of the following MAA activities, which will from this point onwards increasingly focus on evaluation of existing solutions with the help of end-users, yields new insights including stakeholder needs that give rise to new activities and to action plans for turning those needs into requirements that inform the ongoing optimization of the DEMETER components. This is in line with a human-centred, iterative approach.

2.2.1 Use-case interviews

In order to derive overarching and authentic non-technical needs and requirements from the farmer’s perspective, eight interviews with at least one farmer or close representative per pilot cluster were conducted. The farmer perspective was chosen as it is expected to be the largest and most diverse and therefore arguably the most important end-user group of the DEMETER platform. The qualitative exploration of user needs is conducted following DIN ISO EN 9241-210 by exploring the farmer’s point of view in semi-structured interviews. In combination with various information sources (e.g. stakeholder workshops, pilot experience maps, vision scenario) generated in former MAA activities, a set of stakeholder needs and non-technical requirements was derived.

Eight farmers or close representatives (in the following referred to as farmers) with appropriate knowledge in farm management and technology were recruited for the interviews. Following the MAA approach farmers involved in the DEMETER project as well as farmers not directly involved in the DEMETER project were interviewed. The interviewees work in different positions, ranging from managers of large-scale farms (>100 hectares of farmland) to farm workers operating very small-scale farms with less than two hectares of cultivated farmland. The heterogeneity of the user group is further emphasised through the different farm types (e.g. characterised by cultivated plants or type of livestock farming), geographic location, climatic conditions, fragmentation of land, local regulations, attitude and utilisation of digital technologies, openness for innovation, and further characterisation factors.

In general, these variations lead to a variety of specific challenges that farmers in Europe are facing. However, to a certain extent general user needs and non-technical i.e., user and organisational requirements can be derived as it is presented in section 3.4.

The Table 2 provides information about the interviewed farmers and an estimation of the ICT-utilisation level based on the interviews.

Table 2: Information form interviewed farmers and an estimation of the ICT-utilisation level

Cluster	Location	Farm scale	Farm type	Position	Main challenge	ICT utilisation
1	Spain	Large scale	Crops	Management of several farms	Irrigation Management, Interoperability	High
2	Germany	Large scale	Crops	Farm owner & manager	Determination of fertilization requirements & Job cost analysis	Middle
2	Germany	-	-	Research & development of agri-technology in close collaboration with farmers	Job cost analysis and optimisation	-
3	Greece	Small scale	Olives	Farm owner	Decision support & knowledge transfer	Low
3	Greece	-	-	Research & development of agri-technology in close collaboration with farmers	-	-
4	England	Middle scale	Dairy & livestock farm	Research & Farm management	Dairy cow health and well-being improvement	High
5	Montenegro	-	-	Research & development of agri-technology in close collaboration with farmers	-	-
5	Montenegro	Large scale	Vineyards	Farm management	Disease prediction	High

The qualitative evaluation of user needs and requirements was conducted based on the method of semi-structured interviews[2]. After gaining insights into the general context (e.g. farm type, farm scale,

[2] Döring, Nicola / Bortz, Jürgen (2015): Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften. Berlin Heidelberg New York (Springer-Verlag).

general information about location) that the interviewees are embedded in, the farmers and close representatives were asked to frame their current main challenges regarding their day-to-day work. This "As-Is-Situation" is referred to scenario one. Scenario one – the "As-Is Scenario" – puts an emphasis on current challenges, problem exploration pathways, involved stakeholders, ICT touchpoints, and evaluation of problem solutions. After the "As-Is-Situation" was sufficiently explored, the interviewees were asked to describe and imagine how the DEMETER technology could potentially enhance their everyday work. Scenario two – the "To-be Scenario" therefore aims to envision how DEMETER will or might tackle current challenges in the future. During the entire interview, feelings and potential pain points were noted by the interpretation of the narrative by a usability expert. The Table 3 shows an excerpt of the semi-structured interview moderation guideline:

Table 3 Excerpt of the semi-structured interview moderation guideline

Scenario	Index	Section	Key questions
As is	1	What is the current main challenge that you are facing about?	Why is this a problem?
	2	How do you explore the problem?	What is your approach to understand the problem better?
	3	Where are you looking for help in order to solve the problem?	Stakeholder touchpoints?
	4	How do you select a suitable solution?	Under which criteria? Benefits? Disadvantages? Costs?
	5	How do you implement the solution?	Service Providers?
	6	How do you evaluate whether the solution was a success or not?	KPIs?
To be	1	Where, in the process that you just described, does DEMETER provides improvement to the status quo?	Where do you expect DEMETER to provide improvement?
	2	How exactly does this improve your life?	Criteria? Well-being? Time? Profit?
	3	How would you measure such improvement?	KPIs?

Although the interviewed farmers and farmer representatives represent a diverse group of users with a variety of very specific challenges, some general, non-farm-specific main challenges could be analysed and derived from the interviews.

Technology acceptance: Several interviewees mentioned that the acceptance of innovative technologies might be an issue especially for farmers who work and manage farmland based on traditional techniques and/or experience. There seems to be a lack of trust in modern IoT and connected devices and digital technologies in general, which leads to a low adoption of innovations. The reasons behind this are manifold. First, there is a general susceptibility of failure on different levels that many people experienced when getting in contact with digital technology. The reasons behind the failure of technology are less important than the fact that there is a felt inadequate or

International Organization for Standardization (2019). Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems (ISO Standard No. 9241-210:2019). https://www.iso.org/standard/77520.html disappointing reliability when using digital devices. The lack of reliability, which is partly related to internet connectivity issues, is one of the main reasons for missing technology acceptance. Another issue that leads to low acceptance in technology is related to massive usability problems. Many existing systems that aim to improve farmer's productivity are simply too complex and require great time efforts to produce usable results. Some systems require high amounts of initial time investments to learn how these systems operate. Others lead to great changes in working routines, which are in some cases not tolerable. A third reason for low technology acceptance is the fear to be replaced by AI or other modern technologies and to rely on algorithms. A farm worker who makes decisions based on experience built up over several years is in general sceptical to leave important decisions to computer-based algorithms.

Usability issues:

Some interviewees report usability issues related to the complex operation of technological devices and software. These usability problems lead to a high frustration and time consumption when using these technologies. Especially in highly regulated areas where certain regulations, e.g. pesticide or fertilisation, need to be fulfilled, farmers report time-consuming reporting activities. Even highly-trained personnel needs to acquire advisory services to correctly report and calculate e.g. fertiliser requirements. Due to complex reporting schemes, some farmers spend several days of office work per month fulfilling reporting requests.

Internet connectivity:

Many innovative smart-agriculture technologies require stable internet connection to transfer data and operate correctly. In remote areas stable internet connectivity is not always supported. This makes internet-based technologies unusable in areas where internet connectivity cannot be ensured.

Expert knowledge and field-specific recommendations:

Although most interviewed farmers are experts in farming and highly experienced, at some point they feel a need for regular exchange with experts and surrounding farmers. Whether it is a highly specific pest problem or a need for decision support for intervention timing, farmers regularly need expert support and experience exchange with local experts and farmers.

Consequences of climate change:

With the changing global climate, decisions based on long-term experiences are losing reliability. The consequences of climate change leads to an increase in unforeseen extreme weather events which also increase the risk for potential damages by overirrigation or draught. Especially sensible plants are vulnerable to unreliable weather forecasts, sudden extreme weather events and long draught periods. Knowledge applied for several years loses reliability because the climate is changing.

2.2.2 User Interviews for the SOCS Co-Creation Application

Within the scope of the user-centred development of the SOCS Co-Creation Application, at this point, a total of four qualitative semi-structured user interviews were conducted, three of which with farmers from within and outside of the DEMETER project, as well as one interview with a technology developer who is involved in the project.

The goal of the interviews was to gain insights into two aspects: The first aspect is how farmers integrate new technology on their farms (this part of the interview was conducted solely with farmers). The second focus of the interviews was to lay out a prototypical process of technology co-creation between farmers and technology providers.

Interviews lasted between 30 and 60 minutes and were conducted and recorded remotely via MS Teams.

In the first section of the interviews, farmers were asked about their experience with integrating a new piece of technology on their farm. The interviews yielded important insights. For example, the general discovery of a new need for a type of technology is usually triggered through conversations with other farmers from one's own surroundings, but also by visiting trade fairs, or browsing through agricultural magazines. Internet searches are usually conducted after the farmer has made the decision for a certain type of technology and is now looking for different providers of that piece of technology. When deciding for a technology provider, long-term relationships to business partners are usually important to farmers, as this ensures trust between the parties, but also word-of-mouth recommendations from peer-farmers.

In the second part of the interviews, farmers and technology developers were asked about their experience with co-creating new technology. Here, the interviews made apparent that, usually, technology providers are the ones who initiate the contact to the farmers with the intention of improving, testing, or validating a certain technological innovation. Farmers see the added benefit of co-creating technology in lowering the costs due to resource usage on their farms. However, active participation in the process and the fact that farmers' voices are heard make them feel valued. Collaboration agreements between the two parties are usually accompanied by collaboration contracts that specify the business transactions and ownership rights of the technologies in use.

The interviews built the basis for an extensive list of user needs and the subsequently derived requirements that are laid out in the next section.

2.2.3 Elicitation of non-technical user requirements

Based on the needs and concerns gathered from the participants of the stakeholder workshop and the use-case interview series, a list of user and organisational requirements was derived. The user needs of the stakeholder group farmer is presented below. The full list of the stakeholder (farmers and technology providers) needs including derived user and organisational requirements can be found in the Annex B.

Table 4: DEMETER-overarching user requirements

Nr.	The user needs to be able to …
1	… discern the level of his/her farm's ecological sustainability on the system.
2	… discern the level of his/her farm's economic sustainability on the system
3	… discern the strategic development of innovations at any point in time on the system
4	… discern his/her yield output on the system
5	… insert his/her farm's data that is accessible, secure, and comprehensive on the system
6	… discern weather and climate change information on the system
7	… obtain the documentation of his/her farm's operations on the system
8	… discern his/her own farm's performance in comparison with that of other, similar farms on the system
9	… discern his/her yield quality on the system
10	… access extension services (advisory services) on the system
11	… access his/her input usage on the system
12	… access market information on the system
13	… access support for maximizing profit on the system
14	… access support for use on the system
15	… establish contact for knowledge exchange with local farmers on the system
16	… access expert advisory on the system
17	… discern challenges and their specifications on the system
18	… establish contact with local authorities on the system
19	… establish cooperation with other stakeholders (e.g. local authorities, farmers) on the system

20	… discern local regulation for his/her farm on the system
21	… discern the interests and concerns of other farmers in his/her area on the system
22	… access highly individualised, site-specific information and advice on the system
23	… receive decision-making support in the form of recommendations and advice on the system
24	… discern the justification/explanation for why s/he was given a certain recommendation on the system
25	… information from different sources (e.g. weather, soil, plant) integrated at one place on the system
26	… discern when to make an intervention for agriculture on the system
27	… discern the specifics of each field/plot on the system
28	… discern the health of his/her plants/animals on the system
29	… access the data of other farms for comparison on the system
30	… access various KPIs for his farm on the system
31	… discern reliable predictions on the system
32	… discern on the system how reliable the prediction s/he receives are
33	… discern the time s/he spends with each farming activity on the system
34	… insert his/her times spent with each farming activities on the system
35	… discern on the system the locations of his/her installed sensors and technology on the farm
36	… discern on the system how much of his/her resources (e.g. water, pesticides) s/he spends

In addition, the interviews conducted for the SOCS Co-Creation Application yielded additional needs for farmers and technology providers regarding collaboration activities. A total of 36 specific user requirements that are based on specific stakeholder needs (see Annex) were identified. The list of requirements can be considered as 'actionable requirements' that can be directly implemented and go hand in hand with a SOCS Co-Creation Application prototype that was built in WP7 for the software development in WP4. In this way, the requirements analysis did not only yield the requirements but implemented them through an ideation process in a prototyped solution idea.

The first version of the prototype was implemented in Invision as a low-fidelity prototype[3] as well as the final high-fidelity prototype implemented in Figma[4]

For more on the action plan for the human-centred design and development of the SOCS and the SOCS Co-Creation Application, see D4.4. The user requirements for the SOCS Co-Creation Application are listed below.

Table 5: SOCs Co-Creation Application user requirements

Nr.	The user needs to…
37	… be able to enter his/her email-address on the system.
38	… enter his/her password on the system.
39	… be able to select an agricultural category for the challenge on the system.
40	… be able to choose hashtags for the challenge on the system.
41	… be able to upload pictures to a challenge on the system.

[3] low-fidelity prototype of SOCS https://bit.ly/3nLjqe6
[4] High fidelity prototype implemented in Figma: https://bit.ly/3FEN0rQ

42	… be able to post a challenge on the system.
43	… be provided with feedback on the system that the challenge has been posted.
44	… be able to browse through a list of existing needs on the system.
45	… discern whether a challenge is active or not on the system.
46	… be able to order the list of challenges on the system in order to be able to find discern the most upvoted challenges.
47	… be able to order the list of challenges on the system in order to be able to find the challenges that attract the most attention at the moment.
48	… be able to filter the list of existing challenge location on the system in order to find out which challenges occur in his/her region.
49	… discern whether a similar need has already been posted on the system.
50	… be able to filter the list of needs on the system in order to be able to find certain needs more quickly.
51	… be able to upvote a challenge on the system.
52	… be able to indicate on the system that she/he wants to collaborate on a challenge in the future.
53	… be able to indicate on the system that he/she wants to join in on an active challenge.
54	… be able to subscribe to a challenge on the system.
55	… be notified on the system if a challenge that he/she expressed interest in becomes an active challenge (by having at least one farmer and one tech-developer willing to collaborate on the challenge).
56	… be able to agree to actively collaborate on a challenge on the system.
57	… be informed about the challenges that he/she is currently involved in on the system.
58	… be informed on the system about the ongoing activities in within a challenge.
59	… be able to contribute solution ideas to a challenge on the system.
60	… be able to sign a collaboration agreement that regulates legal questions like property rights, business transactions, etc. for the duration of the collaboration on the system.
61	… be able to access the agreement on the system.
62	… be able to discern the company details of technology developers on the system.
63	… be able to discern past co-creation activities from the farmer / technology developer on the system.
64	… be able to contact other collaborators directly on the system.
65	… be able to enter contact details, like name, location, phone number, email address, associated farming organization, etc. on the system.
66	… be able to access information about potential collaborators on the system.
67	… be able to get into direct contact with possible collaborators on the system.
68	… be able to sign a collaboration agreement that regulates legal questions like property rights, business transactions, etc. for the duration of the collaboration on the system.
69	… be able to access the collaboration agreement on the system.

3 Stakeholder requirements on DEMETER Pilot Clusters level

The following sections present the DEMETER Clusters and provide a general overview of their scopes, the challenges in the specific areas and where options of improvement are identified to enhance the stakeholders situations.

The Cluster descriptions are accompanied with analyses done after the first pilot roll out round and the appropriate experience maps are showing the first lessons learned. This experience maps are derived from the interview series with farmers, focussing on the farmer's – as the end users – point of view. The interview series has been carried out by WP7. The experience maps, as described in Section 2.1 'Methodology for the Identification of Non-Technical Requirements', lay out the journey of the user as they carry out typical tasks – which is on specific use case out of one specific pilot project. Hereby, there are two scenarios that together compare the situation experienced by the farmer before DEMETER (As-Is Scenario) with the situation as envisioned by the farmer after the implementation of the respective solution in the DEMETER pilot projects. The differentiation between the As-Is and the To-Be Scenario helps hereby to clearly separate between the current state and the vision. Within the As-Is scenario we pointed at the challenges and problems. The To-Be-Scenario shows the vision and requirements for possible solutions. In this way, the pilot experience maps describe the story that the user experiences when performing a typical task with and without DEMETER support. The form of the text as scenarios describes the contextual environment and user's motivation in a narrative way. These scenarios are deliberately underspecified, meaning that details are to be worked out iteratively later in the respective pilots. They also use natural language to be understood by all stakeholders. At this point, the five experience maps serve to derive general user needs to enrich the list of existing user needs as developed in the course of former MAA activities in DEMETER. Especially in view of the human-centred design of the SOCS co-creation feature (see D7.3), user needs will inform the development of the DEMETER platform, which enables developers and farmers to come together to address farmers' challenges as it is already done in the current pilots. These experience maps go hand in hand with several personas that were developed on the basis of this interview series.

The experience maps consist of the process details as the story that the exemplary user experiences and additionally point out touchpoints with other stakeholders and ICT and the prevalent emotional status at each step in the process. The process is structured along the challenge that gives motivation to the use case, the event or situation that necessitates a solution, the solution sought, and finally the consequences of that applied solution.

3.1 Stakeholder requirements for Pilot Cluster 1 – Arable Crops

Cluster 1 focuses on an efficient water management system, improving the consumption of water, fertilizer, and energy in irrigated arable crops. The cluster 1 pilots use the DEMETER architecture enabling interoperability, secure integration of different platforms and datasets, supporting different technologies combined for interoperable solutions.

The optimization of water quality and quantity is essential for the cluster 1 pilots, considering the water requirements, energy savings and nitrogen levels in different areas of the same crop fields. In this sense, cluster 1 pilots use and incorporate different DEMETER components deploying sensor and farming information systems, and management technologies that allow farmers and cooperatives manage their production more efficiently and combine tools from different suppliers or providers.

The main challenges of Cluster 1 include:

1. Water saving
2. Energy saving
3. Improvement in fertiliser consumption
4. Improving the interoperability of control systems, generating benefits for farmers.

One of the main problems at present is the lack of standardisation in irrigation processes and fertilisation practices as well as in irrigation systems.

Cluster 1 addresses all the six DEMETER objectives with aspects such as decision systems, dashboards to provide useful information, interoperability standards across the different pilots. The graph below shows the different benefits that the DEMETER architecture brings to the farmer:

- Automatic systems retrieve information in a homogeneous way,
- making decisions considering much more information than having to do it manually.
- Savings in water consumption and consequently money for the farmer as the system can consider many more parameters for the estimated calculation.
- Allows remote management of different irrigation control parameters without the need for the farmer's physical presence.

AS IS

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Determination of water use	Incoherent irrigation data	Waste of water via irrigation	Reduced profitability
	For her horticultural and citrus crops, farmer Isabella needs to optimise her use of water resources. She has to determine the right amount of water for irrigating her plants. Since her overarching main goals are profitability and cost reduction, she wants to avoid using more water than necessary. Moreover, the local government has set guidelines and rules for water consumptions in order to forestall expected sustainability problems in the area.	Farmer Isabella goes to the farm and watches the irrigation of her crops. She determines the amount of water based on weather forecasts, her experience and intuition. As a result, farmer Isabella waters the crops much more than is actually needed. However, she is not aware of her mistake. Or: Farmer Isabella checks the amount of irrigation via her irrigation controller and its app. And she checks the moisture on her app for the installed moisture sensors. However, she has trouble integrating both information as she uses closed solutions.	Only later, farmer Isabella notices that she has used too much water, stretching her designated amount of water. She contacts her local agri-cooperative in order to receive help and recommendations for determining the right amount of water. Or: In order to receive help using the various apps and installed hardware, she needs to go to the different technology providers, which is effortful.	The advisory service providers integrate different data in order to make their recommendations. However, they have to integrate the data manually, which makes their services expensive. Because, farmer Isabella used too much water, she suffers a loss in profit. And having the advisory service give recommendations regularly is too expensive for farmer Isabella.
Stakeholder Touchpoints	**Public authority:** Local government	**Advisory service:** Local weather forecasts	**Advisory service:** Local agri-cooperative	**Advisory service:** Local agri-cooperative
ICT Touchpoints		Irrigation systems, weather forecast web service	Irrigation systems	
Emotions	Content	Frustrated	Resigned	Dissatisfied

TO BE

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Determination of water use	Coherent irrigation data	Informed irrigation	Optimal water saving
	For her horticultural and citrus crops, farmer Isabella needs to optimise her use of water resources. Since her overarching main goals are profitability and cost reduction, she wants to avoid using more water than necessary. Moreover, the local government has set guidelines and rules for water consumptions in order to forestall expected sustainability problems in the area.	Farmer Isabella uses a management system that integrates her different hardware (e.g. irrigation control, moisture sensors). She receives even more data from other sources like local weather stations.	With the system, farmer Isabella learns how much water she spends and how this affects the moisture level. Based on all that, she receives specific recommendations regarding how much water to use to irrigate her plants. She is not dependent on external advisory service providers; yet she may consult them because they can also make use of the integrated solution.	Thus, farmer Isabella can optimise her water consumption. Therefore, she can ensure the profitability of her business by using and saving water optimally.
Stakeholder Touchpoints			**Advisory service:** Local agri-cooperative	
ICT Touchpoints		DSS for Irrigation Management 4.B.1, Smart Agriculture platform	DSS for Irrigation Management 4.B.1, Smart Agriculture platform	
Emotions	Content	Interested	Satisfied	Happy

Figure 6: Cluster 1 Arable Crops – Experience Map

3.2 Stakeholder requirements for Pilot Cluster 2 – Precision farming

Cluster 2 focuses on arable crops and especially on the establishment of precision farming and the usage of agricultural machinery improving the efficiency of data acquisition, data sharing and benchmarking on the productivity. An arable crop farmer is creating manually or automatically a big amount of data. The difficulties lie in the automation of the data integration into a Decision Support System (DSS) and the interpretation of the data.

The cluster 2 pilots use multiple layers (weather, field data, soil data, Ag machine motion, economic situation…) to integrated them in a unified layer accessible on DSS, analyse them and visualize the results to take action, such as production technology and management.

All 4 Pilots in cluster 2 provide services for maximising the farm output from the data collected. To reach this objective, several standards will be used like OGC, W3C, ISOBUS and Ag-Gateway.

Cluster 2 will contribute to DEMETER objectives 2 & 3 by enhancing the interoperability space of the Agri-food domain and empowering the farmer to make the best out of his data.

AS IS

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Calculation of job cost	Insufficient documentation	Cumbersome calculations	Loss of time and resources
	Farmer Johannes needs to document his agricultural processes and based on that, calculate the individual job costs. This job cost estimation shows him how profitable a certain crop, field, or purchase is. Thus, he can prepare his annual balance and determine the plans and purchases for the next year. For this, he has to aggregate all the available data of his fields and last-year farming activities.	The farming activities have to be documented all year round. However, there is no coherent documentation system – farmer Johannes does not keep track of how much time he spends on which task or the tractor is in use for a specific job. Also, the documented data are stored decentralised. Bringing all the information together is very time-consuming and complex. Thus, mistakes are easily done. Moreover, the job cost estimation is in the end not site-specific, but rather general.	Farmer Johannes makes the calculations in a large Excel sheet. He also makes use of the advisory service from a local cooperative of agri-businesses to help him with the bureaucracy.	All the bureaucracy demands many days per month from farmer Johannes. Moreover, due to the unavailability of data, the job cost estimation is rather imprecise, which makes future plans for and purchases unreliable or unfounded.
Stakeholder Touchpoints			**Advisory service:** Local agri-cooperative	
ICT Touchpoints				
Emotions	Nervous	Frustrated	Resigned	Dissatisfied

TO BE

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Calculation of job cost	Documentation via tractor	Detailed calculations	Improved decision-making
	Farmer Johannes needs to document his agricultural processes and based on that, calculate the individual job costs. This job cost estimation shows him how profitable a certain crop, field, or purchase is. Thus, he can prepare his annual balance and determine the plans and purchases for the next year. For this, he has to aggregate all the available data of his fields and last-year farming activities.	All year round, all farming activities have to be documented. For this, farmer Johannes as sensors installed in each tractor, which are liked to its terminal. Farmer Johannes can thus automatically collect and later in the John Deere Operations Center access which job he or his workers do, where, and for how long.	In this way, farmer Johannes can keep track of how much time he or his workers spend on which task or the tractor is in use for a specific job. Thus, mistakes are prevented. In this way, the job cost estimation is in the end site-specific and detailed. Farmer Johannes has now enough time to process all the data in detail, assessing his demands per individual field and crop.	Farmer Johannes receives a precise profit calculation. He can make is decisions based on aggregated data, internal and external. He saves time that he does not have to spend on Excel sheets but on farming activities.
Stakeholder Touchpoints		**Farmer:** Tractor operator		
ICT Touchpoints		Detect Crop Type 4.A.4, Deere Operations Center	Detect Crop Type 4.A.4, Deere Operations Center	
Emotions	Nervous	Content	Excited	Happy

Figure 7: Cluster 2 Precision Farming – Experience Map

3.3 Stakeholder requirements for Pilot Cluster 3 – Fruits and Vegetables

The efficient use of resources for environmental and economic purpose requires complex decision-making processes. Especially in uncertain situations, e.g. due to climate change, this is playing an increasingly important role. Cluster 3 focuses on supporting farmers in protecting the health and the quality of production of woody and vegetable crops in several European countries. These crops include olive, grape, orange, apple trees and potato.

Three of the four pilots focus on a single crop, while the other pilot focuses on three different fruit tree crops. The aim of the pilots is to spread ICT solutions in supporting farmers in the decision-making process to address the issues of

- more efficient use of irrigation water.
- More efficient use of nutrients for crop fertilization.
- Monitoring tools to estimate plant phenology, status, and productivity over time, using remote sensing technologies.
- Support integrated pest management by forecasting models, IoT sensors and automatic traps.
- Provide instruments to help farmers in estimating the potential crop yield before harvesting.

To these purposes, several technologies will be integrated: existing digital farming platforms, IoT sensor networks, models and decision support systems, remotely sensed data, advanced data analysis tools and techniques.

One of the main constraints in adopting ICT in agriculture is related to the fragmentation of the available solutions when assessing the complex needs of the farmers. The scope of this cluster is to cross-fertilize each pilot with the solutions and results of other pilots. One example are automatic fruit fly traps tested in orange groves in pilot 3.3, which can also be used in olive orchards in pilot 3.1. The remote sensing solution developed for potato farming in pilot 3.4 can be adapted to fruit tree crops in the pilots 3.1, 3.2 and 3.3. The Olive Fruit Fly model in pilot 3.1 can be applied with precision farming tools from pilot 3.2 etc. (further details on cross-fertilizing are reported in Deliverable D5.5)

The final scope is to give input to technology providers on how to integrate the solutions to improve their business and to farmers on how to manage their decision making and to get answers at their own requests. The cluster groups pilots with different Farm Management Information Systems (FMIS), sensors and related technologies, deployed in different farmers and environments. The cluster will perform several interoperability activities within the cluster and the individual pilots, showing to farmers and providers the advantages of the DEMETER approach in supporting a trusted data sharing (objective 1) and creating an interoperability space for knowledge exchange (objective 2). The adoption of the same technologies in different environments and farming approaches will help to develop a benchmarking mechanism (objective 4).

AS IS

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Irrigation need estimation	Droughts require irrigation	Vague time point estimation	Plant protection at risk
AS IS	Farmer Christos needs to know when he should water his olive trees, which he cultivates for organic olive oil production. Thus, he has needs to know when the trees have need for irrigation. To ensure the natural cultivation of the olive trees, he intends to do as few interventions as possible.	During a drought, the moisture level drops below a critical threshold. This requires Christos to irrigate his trees. However, he does not want to irrigate constantly, as the additional yield is low. Also, he does not always have access to water as water is scarce in his area. Constant irrigation is therefore not sustainable. Olive tree cultivation is very individual, i.e. site-specific, depending on the tree itself, the grove, the climate, and more. It is not practical to apply general procedures for all groves. But the exact time point must be determined, based on subjective appraisal.	Farmer Christos checks current moisture levels of soil and plants and decides whether they need to be watered soon or not. After that he checks the weather forecast (temperature, precipitation) for the upcoming days. Olive trees are adapted to the climate conditions and have need of irrigation only at specific times of drought. To determine the need for water, he checks all olive groves individually. In case of water shortage, farmer Christos must also talk to a water provider (local person) in his community.	Farmer Christos determines the need for water based on moisture level and weather forecast. He misses the right opportunity for irrigation. He has to balance irrigating more than necessary (thereby wasting water but increasing the chance to irrigate correctly) against irrigating only punctually (thereby saving water but possibly missing the right opportunity). Farmer Christos has much effort determining the right irrigation strategy. There is always the risk of missing out on necessary irrigation.
Stakeholder Touchpoints			**Agri Supplier:** Local water provider	**Agri Supplier:** Local water provider
ICT Touchpoints				
Emotions	Content	Stressed	Uncertain	Exhausted

TO BE

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Irrigation need estimation	Droughts require irrigation	Precise time point estimation	Sustainable plant protection
TO BE	Farmer Christos needs to know when he should water his olive trees, which he cultivates for organic olive oil production. Thus, he has needs to know when the trees have need for irrigation. To ensure the natural cultivation of the olive trees, he intends to do as few interventions as possible.	In the course of a drought, the moisture level in the olive trees drops below a critical threshold. Farmer Christos puts sensors on his olive trees that measure the moisture level. He uses the Agricolus© OLIWES platform to gather data from his sensors, weather forecasting and soil probes. He receives information about site-specific weather and climate on the platform.	Farmer Christos receives an alarm for an upcoming drought and low current as well as expected moisture levels for some of his groves. The platform advises him to apply a certain amount of water to irrigate the jeopardised olive trees. The next day, he drives to the affected groves in order to confirm the platform's estimation. He checks the trees and soil and recognises the need for irrigation.	After talking to the local water provider, farmer Christos irrigates his groves, ensuring the right amount of water necessary for them to weather the drought. Thus, the trees stay protected and healthy. Farmer Christos has ensured that he uses as little of an intervention as possible to enable the natural regulation and growth of the olive trees.
Stakeholder Touchpoints			**Agri Supplier:** Local water provider	**Agri Supplier:** Local water provider
ICT Touchpoints		Plant Phenology Estimation 4.A.2, Agricolus OLIWES platform	Plant Phenology Estimation 4.A.2, Agricolus OLIWES platform	
Emotions	Content	Interested	Satisfied	Happy

Figure 8: Cluster 3 (Fruit and Vegetable Production) – Experience Map

3.4 Stakeholder requirements for Pilot Cluster 4 – Livestock

This cluster focuses on supporting farmers for livestock animal health and high quality in the production of animal products with farmers' dashboards that include AI-based prediction and decision support for animal Health and animal products. Three pilots are milk cow oriented with one focusing on AI Machine learning for predictive milk production and dashboard including data flow for invoicing, settlement, accounting, bank and insurance. Two pilots focus on milk quality and animal welfare tracking through health and welfare recording protocols which will be applied using various sensor technologies and digitalised records. The fourth pilot is focusing on chicken health and optimal production. The main aims of the pilots are to contribute to more effective production and animal welfare:

- More efficient methods for measuring production and animal welfare
- More efficient production with Al-based systems and other decision support for farmers and related business.

To these purposes, several technologies and methods will be used: existing digital platform, IoT sensor networks, models and decision support systems, advanced data analysis tools and techniques.

One of the main constraints is related to the fragmentation of the available solutions when assessing the complex needs of the farmers and the related businesses. This will be addressed in the pilots where different stakeholders and the MMA approach will be used. In the cluster there will also be important to cross-fertilize each pilot with the solutions and results of other pilots.

The cluster 4 addresses all the six DEMETER objectives through its full dashboard approach and the objective to support increased animal welfare and efficient production approaches across multiple pilots.

AS IS

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Determination of cow heat	Cow gives indication of heat	Missing heat signals	Deterioration of cow health
AS IS	Farmer Smith needs to know when a cow is in heat in order to fertilise it. In order to do that, he has to sit in front of a monitor or stand on the field and observe his cows. He has to schedule dedicated one-hour time slots per day for this activity. For signaling that she is in heat, the cow shows behavioural patterns, e.g. riding other cows.	Farmer Smith has to observe his cows multiple times a day in order to find out if a cow is in heat. Farmer Smith also has to take care of other things on his farm, so he moves away from the cows. During the night, one of the cows shows behavioural signs that she is in heat (e.g. riding other cows). Farmer Smith is not aware of this, because he is asleep.	The next morning, he starts observing his cows, but none of them show signals of being in heat. Due to farmer Smith's inability to spot the cow's heat, he misses her fertility point. Farmer Smith focusses on monitoring the cows, possibly neglecting other work (especially taking care of the cows' health). **Or**: Farmer Smith calls a provider specialised in fertility. The service provider's employees visit the farm on a regular basis and mark every cow they expect will come into heat.	The cow does not get fertilised; hence, she dries up (loses milk production capacity). Therefore, she has to be put to slaughter - long time before the end of her fertility life-cycle. **Or**: Farmer Smith now knows which cows to watch for heat. These cows are more likely to get fertilised. Having the service provider come to the farm regularly is too expensive for farmer Smith.
Stakeholder Touchpoints			**Advisory service:** Breeding service provider	**Advisory service:** Breeding service provider
ICT Touchpoints	Optional: camera, monitor	Optional: camera, monitor	Optional: camera, monitor	Optional: camera, monitor
Emotions	Content	Tense, angry	Disappointed, resigned	Irritated, dissatisfied

TO BE

Steps	Challenge	Event	Exploring solutions	Consequences
Process details	Determination of cow heat	Cow gives indication of heat	System provides notification	Cow health is ensured
TO BE	Farmer Smith needs to know when a cow is in heat in order to fertilise it. Farmer Smith also has to take care of other things on his farm as well, which is why he does not stay with the cows. For signaling that she is in heat, the cow shows behavioural patterns, e.g. riding other cows.	Farmer Smith puts a sensor on one of his cows. The sensor sends a signal to the farmers management system when it detects movement patterns that show heat. The farmer leaves and takes care of other business. During the night, one of the cows lifts her tail to show that she is in heat. Farmer Smith is not aware of this, because he is asleep.	The next morning, Farmer Smith checks his management system and sees the notification that the cow is in heat. Farmer Smith checks the cow's temperature and confirms her being in heat. Farmer smith calls the service provider for fertilization.	The cow is being fertilized, calves and gives milk. Thus, the cow stays healthy and in the herd for a much longer time.
Stakeholder Touchpoints			**Advisory service:** Breeding service provider	
ICT Touchpoints		Estimate Animal Welfare Condition 4.G.2, SMARTBOW	Estimate Animal Welfare Condition 4.G.2, SMARTBOW	
Emotions	Content	Light-hearted	Excited	Happy

Figure 9: Cluster 4 Livestock – Experience Map

3.5 Stakeholder requirements for Pilot Cluster 5 – Full supply chain, Interoperability, Robotics

While other clusters are focusing on activities and operations taking place on farms, the goal of Cluster 5 has a cross-sectorial focus to address pre and post farm activities, i.e. to address the complete food supply chain.

There are 4 pilots in the cluster focusing on four different areas: fruits & vineyards, apiculture, cattle, and poultry. Both supply and demand sides of the supply chain in addition to the on-farm management activities are addressed, thus contributing to creation of a more transparent supply chain increasingly demanded by consumers as well as legislators.

Cluster 5 pilots will enable validation of interoperability of platforms and solutions used in different sectors as well as validation of interoperability of platforms used for management of on-farm and post-farm (supply chain) activities. The use of distributed ledgers in combination with data exchange protocols designed for the supply chain domain and item level unique identities will be validated in combination with on-farm management solutions.

The complete lifecycle of a product will be covered by inclusion of representatives of the retail, transportation, and recycling industries through an open call. This will allow us to expand the project's impact and better understand challenges and implications of providing traceable information about the food production throughout the value chain. We will also be in position to engage consumers who are one of the very important stakeholder groups increasingly interested to know what they eat, how the food was produced and what impact that production has on natural resources.

The goal of this cluster is to run pilots across several sectors (fruit, vineyards, cattle, poultry) and to address both supply and demand sides of the supply chain. Such approach will enable us to validate interoperability of platforms and solutions used in different sectors as well as to validate interoperability of platforms used for management of on-farm and post-farm (supply chain) activities. The complete lifecycle of a product will be covered by inclusion of representatives of the recycling industry through the open call.

The main aims of the pilot cluster are to contribute to more effective production and animal welfare as well as transparency in the supply chain:

- Disease prediction and supply chain transparency for Orchards/vineyards
- Farm of Things in Extensive Cattle Holdings
- Pollination optimisation in apiculture
- Transparent supply chain in poultry industry

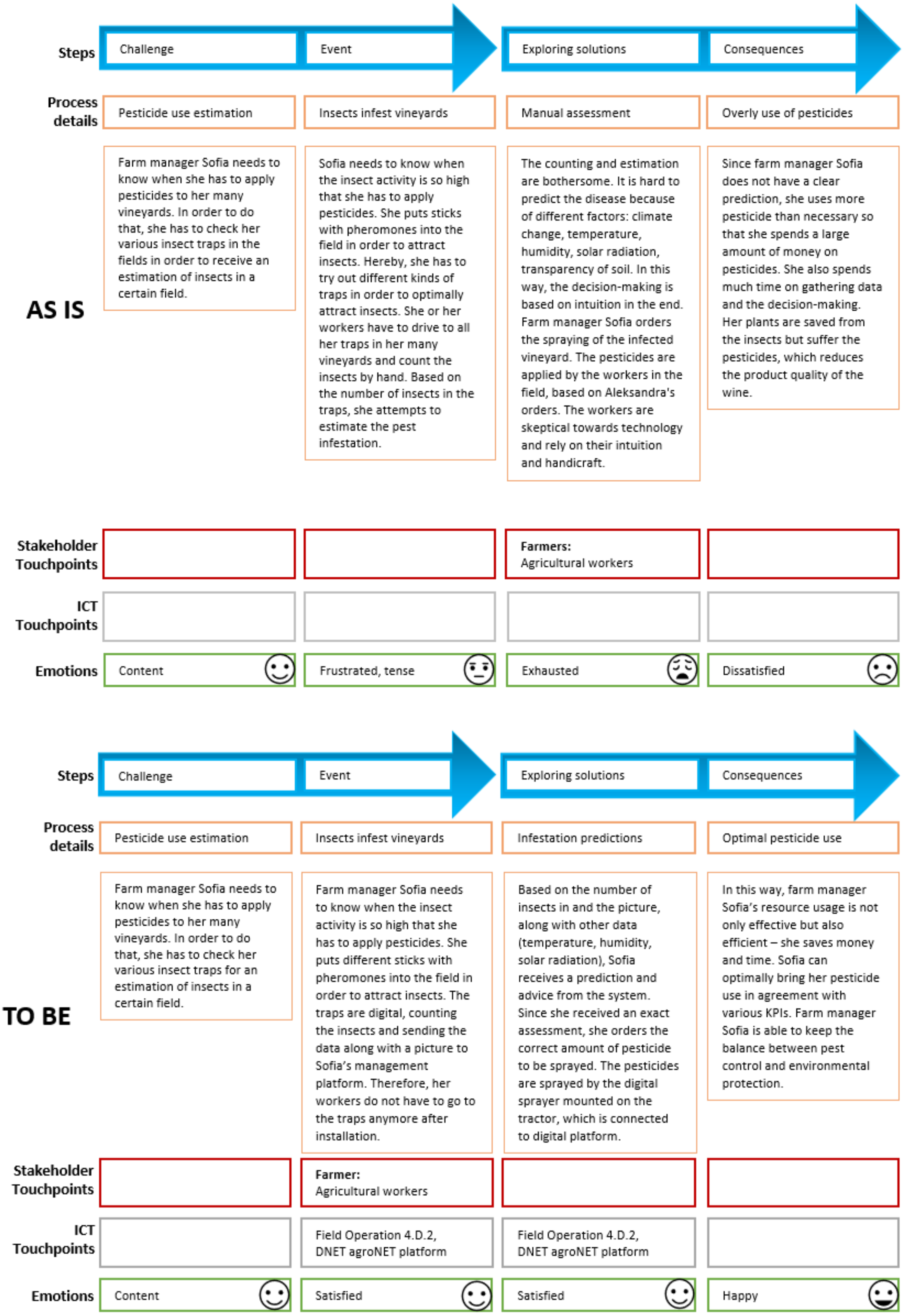


Figure 10: Cluster 5 - Supply Chain – Experience Map

4 DEMETER Pilots design and specifications

In the following sections the pilots are describing their use-cases, appropriate stakeholder requirements and the pilots approach showing how DEMETER components are improving theirs situations. In contrast to the previous deliverables D5.1 and D5.2 major change in this version is that the initially named stakeholders have been translated from what were largely named companies, persons and specific interest to generic stakeholders, roles, and their relationship to generic "building blocks". For the sake of clarity, a shortened comprehensive summary table of the stakeholders and their interest in DEMETER Decision Support Areas is provided for each pilot in Annex A.

A more detailed version of the stakeholder requirements analysis and the mapping to required building blocks and DEMETER Decision Support components are provided for the pilots descriptions. Complementary Stakeholder needs on non-technical level provided in Annex D while Annex A is showing the stakeholder workshop outcomes made in the beginning of the project. Since the pilots are now on an higher development level KPIs had been defined to monitor the success of implementation and listed in Annex C. Detailed information on deployment of DEMETER components are further refined in *D5.6 Testbed, deployment, system extensions and applications for pilot round 2*, which will become available M29/January 2022. The information on provided a clear mapping of stakeholders, their requirements and where these are addressed in DEMETER. It is there for possible to help to narrow down Open Call topics, but also synergy potential between and across pilots and WPs.

The following sections present the results for each pilot. Some explanatory text is intentionally repeated in each pilot description. The idea behind this is to provide self-contained chapters, so that the reader can directly pick his area of interest without missing any relevant context.

To obtain a common understanding of the scope and objectives of the DEMETER pilots, the pilot leaders have been asked to provide a description by addressing the following topics:

- Overview of the pilot's area, how does the current scenario look like and pointing to use case specific requirements,
- The future envisioned scenario,
- The pilots approach showing how the vision is going to be achieved,
- In line with the envisioned scenario the expected benefits after DEMETER implementation,
- A picture of the key stakeholders and the main roles and interests of the stakeholders.
- Finally, a summary of the DEMETER component usage is given.

4.1 Pilot 1.1 & 1.2 - Water and Energy Savings in Irrigated Crops

Pilot 1.1&1.2 aims to increase the production of irrigated crops saving water and energy. The main objective is to optimize irrigation improving the automation of the irrigation zones using interoperable remote-control systems and robust management systems adapted to the each required condition. The of use real time monitoring and control of water supply in combination with energy efficiency improvements, both based on informed decisions from farm to fork, will balance water and energy consumption allowing great water and energy savings.

The Pilot are developing in two sites in Spain (see: Figure 11). One site with focus in the irrigation Community "Left side of Porma River" in the Castilla & León Region. Here the company Tragsa is responsible for the deployment. It comprises 11 irrigation sectors, of which 8 are modernized with pressurized networks. In total, 1.302 hydrants serve 12.500 ha of arable land. A second location is the irrigation Community "Comunidad de Regantes Campo de Cartagena" in the Región de Murcia. Here the company OdinS, in close collaboration with the Universidad de Murcia, is working in the deployment based on a web-based platform called Smart Agriculture. In total, 980 hydrants serve 41.920 ha of arable land (lettuce, melon, artichoke, broccoli and tomato, citrus fruits, etc.) where the irrigation period covers the whole hydrological year. Distribution of water uses quotas based exclusively on plots size and the amount of available water on a system of orders and shifts that follows a restricted number of directives.

Figure 11: Location of Pilot 1.1 and 1.2

4.1.1 Use-case-specific requirements

In the current situation, most of the national modernized irrigation systems already have remote control capacities and irrigation management systems, aimed at more widespread improved water management. But these remote-control systems are closed solutions that do not share software or hardware elements, which limit their possibilities of modification or extension. In addition, these systems are subject to strong wear and tear with about ten years of useful life. Due to these limitations, only gradual renewal of the systems is possible. Often only identical equipment can be used, which has increasingly negative economic repercussions, e.g. when the original supplier no longer exists.

Another important issue is that the existing irrigation systems have not been designed to be interoperable. Since the information the components exchange was not meant to be used by applications other than their own, standardisation of data or interfaces was never considered. Without interoperability, irrigation components that are dependent (such as pumping stations, irrigation branches and hydrants) cannot exchange useful information to optimize exploitation.

All this has an impact on irrigation facilities that are not very efficient in terms of saving water and energy efficiency and will be improved by corresponding DEMETER components.

The irrigation control systems are developed by specific manufacturers, who are reluctant to allow external users or other third parties to modify their configuration or operation mode. Nevertheless, these systems' devices can expose open and standard interfaces (APIs). This fact will allow irrigation communities to expand their systems with different vendors' devices, having a heterogeneous environment but with the capability of interoperating with all the devices responsible for the irrigation.

This pilot addresses summer crops, with the growing season beginning at April–May. Because DEMETER launched on September 2019, the provisional start of Pilot Round 1 according to the proposal (M12, i.e., August 2020) is at the end of the growing season. So, this pilot had a delay as it was impossible to cover the 2020 growing season. Pilot Round 1 was expected to cover the 2021 season. We are currently gathering information from all the partners involved in the Pilot Round 1 in order to provide the actual current situation.

The rest of the activities related to the pilot are expected to be achieved as planned. First, the detailed definition of the pilot will be done thanks to meetings to take the requirements with the maximum detail with farmers and international experts of ISO to address the deployment phase also as planned, although some activities won't start until the growing season. Meanwhile, we will try to get as much data as possible from the last days of the 2020 growing season and work with farmers to make familiar with the software being developed trying to minimize as much problems as possible for the next growing season.

4.1.2 Envisioned Scenario

DEMETER will allow the integration with other partners' technologies and solutions. This will allow the acquisition of data from different sources (i.e. infield IoT devices, weather services, satellite imagery, etc.) to deploy different solutions to be tested in the pilot.

Prietto DEMETER, a lot of manual processing was necessary to set up the irrigation process, requiring the presence of the farmer for manual control of different parameters. On the other hand, the farmer was tied to a specific solution on the market, with problems of updating, maintenance and the existence of offers from different suppliers. Thanks to DEMETER it has been possible to achieve a double objective, on the one hand interoperability that allows a wider range of irrigation systems and on the other hand a greater automation of processes with the consequent benefit for the farmer who avoids having to physically go to the site and on the other hand a consequent saving of water resources.

4.1.3 Expected Benefits

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

The communities of irrigators who for any reason need to make a change in any of the components of their system can now make it more easily, since any system that meets the standards can be integrated without major changes. Even irrigation communities that do not have a management irrigation system yet can safely follow this approach. The risk is lowest, because independence from a single company's proprietary solution is the best long-term investment protection.

The interoperability capability provided by DEMETER will open new solutions based on the exchange of information of platforms and IoT gateways manufactured by different vendors.

Defined Key Performance Indicators (to measure the benefit) are:

- Number of client farmers.
- Volume of data observing.
- Number of data sharing agreements.
- Number of data exchanges (with financial retribution of farmers).
- Cost-benefit analyses on water and energy usage per yield unit and per hectare.

4.1.4 The pilots approach

By the MAA and focusing on the identified farmers' main needs about irrigation water and energy savings, and also about using a field book and having the possibility of analysing the crop status evolution along the seasons, the existing pilot's platforms infrastructures Smart Agriculture and MEGA have been extended, including also different dashboards for farmers using the DEMETER Adaptive Visualisation for Dashboard (Knowage).

To achieve the objectives of the pilot key building blocks have been identified and matched to the decision support area in DEMETER where they are addressed. To provide a base for transferring DEMETER results to relevant stakeholders as part of the MAA activities, internal and external participants in the DEMETER Pilots have been consolidated into generic stakeholder classes. The interest of a stakeholder are shown in the Annex.

An initial list of pilot's stakeholders was compiled in the deliverable D5.1, and latter consolidated into generic stakeholders in the deliverable D5.2. Next, it is described the final list of stakeholder groups shown in the table above:

Farmers. During the first pilot round there has been close cooperation with seven farmers in two Irrigation Communities and fluid feedback has been collected from four of them. For the second round, we have opened the frame to two other Irrigation Communities in the Spanish territory (Mirafles in Jumilla, and Vinalopo in Alicante) to increase the possibilities to impact on more farmers also providing pilot and crop results to prove DEMETER interactions, components, and outcomes.

Software providers. These are the internal DEMETER stakeholders collaborating in the pilot software development and deployment (UMU, TRAGSA).

Hardware providers. This is the internal DEMETER stakeholder collaborating in the pilot hardware development and deployment (OdinS).

Public authorities. The main areas of interest are the Irrigation Communities in the Spanish territory (i.e. Left side of Porma River in the Castilla & León Region, Comunidad de Regantes Campo de Cartagena" in the Región de Murcia, Mirafles in Jumilla, and Vinalopo in Alicante) that have local irrigation authorities that depend on their corresponding regional irrigation authorities. In most cases, they have also dependency on the national irrigation authority when using some types of water resources (i.e. Trasvase Tajo Segura, well for ground water bodies, etc.)

Advisory Service. This is the internal DEMETER stakeholder collaborating in the pilot tests (CENTER). It deals the challenges associated with the planning and management of irrigation, within the framework of sustainable development of the rural environment and integrated management of water resources. It addresses to promote water efficiency and sustainable management of the water-irrigation binomial, and also promote the use of alternative energies and energy efficiency.

General public. Indirect stakeholders that mainly can increase the farmers product's marketing potential. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.1.5 Usage of DEMETER components

In a Scenario including DEMETER components, it will allow the integration with other partners' technologies and solutions. This will allow the acquisition of data from different sources (i.e. infield IoT devices, weather services, satellite imagery, etc.) to deploy different solutions to be tested in the pilot.

This data will also be processed and integrated to bring a DSS on irrigation and energy consumption for farmers. Data analytics and ML algorithms will be applied to data from the pilot and other sources in other different farming conditions to determine their crops irrigation water needs. Benchmarking tools developed within DEMETER will be tested in the pilot's farms (i.e. water used for irrigation), as it is very important to compare the performance after the adoption of new technologies with the previous ones as well as the results with those of other farms with similar crop characteristics of those of the pilot's plots.

Further details on the technical aspects of the testbed deployment are reported in Deliverable 5.6.

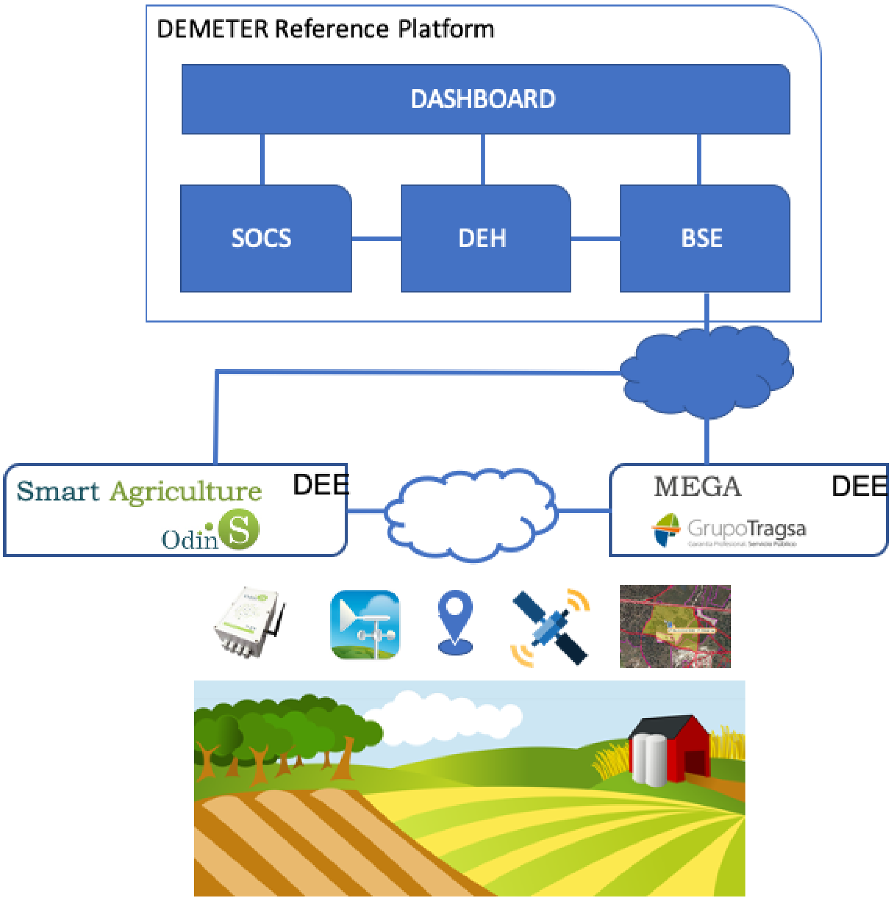


Figure 12: Used DEMETER components in Pilot 1.1&2

Table 6: DEMETER Components for Pilot 1.1&2.

Technical requirement	Component Description
Device Bridge Data DEE	This component will provide the last data available as well as historical data from infield IoT devices (i.e. soil moisture probe data, water counter, weather, etc.) deployed in the plots by two different endpoints (REST API) using DEMETER AIM data model. This component can be configured to get data from the pilot cloud using REST API calls.
Weather Forecast DEE	This component will provide weather forecast information (for the day and for the next 48 hours) provided by external Weather Services an endpoint (REST API) using DEMETER AIM data model. This component can be configured with the geographical coordinates of the plot to get the weather forecast information This component is released as a docker image. Its data is needed as input data for other components like that for evapotranspiration prediction.
Reference Evapotrans	This component will predict the next day reference evapotranspiration prediction for a plot. It will use different ML models (i.e. Naïve, Mean, Neuronal Net, Arima, SNaive

piration Prediction DEE	and ETS) trained with real ETo values as well as the Penman-Monteith model with weather forecast data to get the best final value as the result. It will get weather forecast data from the component WeatherForecast. The predicted value will be available in an endpoint (REST API) using DEMETER AIM data model. This component is released as a docker image. Its data is needed as input data for other components like that for estimation of water irrigation for a crop based on ETo
Crop ETo Water Irrigation Estimation DEE	This component will estimate the next day crop water needs based in the reference evapotranspiration value and in data of the plot (crop and irrigation system information). The predicted value will be available in an endpoint (REST API) using DEMETER AIM data model. This component is released as a docker image. Its data is needed as input data for other components like that for estimation of water irrigation for a crop based on ETo
Soil Moisture Estimation DEE	This component will estimate the soil moisture along the crop soil using a modified OPTRAM model using data from an infield soil moisture probe and Sentinel 2 satellite multispectral imagery. The component will compute a 2D crop soil raster image, the same but as a 2D jpg image, and the average of the estimated soil moisture. The results will be available in 2 endpoints (REST API) using DEMETER AIM data model (computed images will be available via url link). This component is released as a docker image. Its data is needed as input data for other components like that for DSS irrigation
Crop Plant Water Status DEE	This component will provide information about the crop plant water status along the crop using a segmentation model with Sentinel 2 satellite multispectral imagery. The component will compute a 2D jpg image and an average value index. The results will be available in an endpoint (REST API) using DEMETER AIM data model (computed image will be available via url link). This component is released as a docker image. Its data is needed as input data for other components like that for DSS irrigation.
Plot Data DEE	Description of the component: This component will provide information about the plot (i.e. crop, irrigation system, etc.) The results will be available in an endpoint (REST API) using DEMETER AIM data model. This component is released as a docker image. Its data is needed as input data for other components like that for DSS irrigation or CropWaterIrrigationEToEstimation.
DSS Irrigation DEE	This component will provide information about the estimation of irrigation water needed in a plot crop: Predicted data values Final irrigation water needs prediction. Crop irrigation water needs based on ETo prediction. Predicted ETo value. Rainwater forecast. Estimated average soil moisture based on satellite imagery. Estimated average soil moisture based on sensors. Historical Timeseries

	Diary Irrigation water needs prediction Diary irrigation water needs prediction based on ETo Diary rainwater forecast Diary soil moisture prediction based on satellite imagery Imagery Soil moisture Segmented soil moisture Plant water status anomalies Segmented plant water status anomalies It will need data from the other components mentioned before. The results will be available in an endpoint (REST API) using DEMETER AIM data model. This component is released as a docker image. Its data is needed as input data for DEMETER Adaptive Visualisation framework based on Knowage to be visualized for the final user.

4.2 Pilot 1.3 - Smart Irrigation Service in Rice & Maize Cultivation

Pilot 1.3 aims to improve the management and automation of rice irrigation, along with nitrogen zonal fertilisation. Maize is also an important crop for rice growers, as it is included in most crop rotation systems, at least once every three years. Therefore, the present pilot also aims to optimise the management of both water and fertilisation in maize cultivation.

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 11,200 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 with alfalfa. Crop rotation systems are part of the Good Agricultural Practices, since they offer the only way to efficiently control weeds, diseases, and pets. 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 for optimising water quality control (e.g., salinity levels) and quantity is of great importance for the pilot area.

The Pilot is being deployed in one main site in Greece and in several locations around Central Macedonia regions:

- ELGO experimental station—of approximately 50 ha—at Kalochori area (40° 37′ 4.41″ N, 22° 49′ 54.19 ″ E), Thessaloniki, Greece. This is dedicated to both rice and maize crops, where the smart irrigation system is being deployed, tested, and validated.
- At least 10 farmers in the same area of Kalochori and another 10 farmers in other areas will be involved, in order to cover a variable rice and maize environment. These farmers will dedicate fields suitable for testing according to ELGO's and ICCS's plan. Since both maize and rice are spring cereals, testing in real farmers' fields is schedule to start from the 2021 summer period onward.

4.2.1 Use case specific requirements

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 also has substantial needs for irrigated water during the cultivation season. The region of Central Macedonia has a sophisticated irrigation network, which is managed by the Local Irrigation Authorities (TOEV). During the summer growing season, the water is distributed gradually to the different regions of the plain and rotated throughout the season. Currently, farmers manage water only by experience, which leads to poor water use efficiency most of the times, as they pre-emptively reflood the rice paddies to avoid increased salinity, without measuring the latter though. Similarly, maize irrigation is based solely on farmers' experience, without considering the actual crops' water needs or the potential differences between the various farmers' fields. Fertilisation is also managed mostly by experience and frequently excessive amounts of nitrogen are applied to increase yield. Recently, several farmers (or group of farmers) have acquired variable rate application (VRA) machinery. However, they use them only to avoid double spraying (i.e., applying fertilizer on the same region twice as the tractor moves in consecutive parallel lines, in opposite but partially overlapping paths), but not for zonal management based on the real needs of each patch within the field that would fully exploit the potential of such machinery.

4.2.2 Envisioned Scenario

Pilot 1.3 provides a service for maximising water use efficiency in rice and maize, through the deployment of appropriate sensor systems and science-based decision making. Thus, both water quality (e.g., salinity levels) and quantity is being optimised. Since irrigation is tightly linked to fertilisation, a nitrogen fertilisation advisory service is also provided, leading to optimisation of the spatial distribution of nitrogen application based on the real needs of the field. This is achieved through indirect estimation of the plants' nitrogen needs from remotely sensed multispectral imagery, using unmanned aerial vehicles (UAVs) for creating the estimation models, very high-resolution satellite imagery for covering larger areas and empirical decision support systems for providing the spatially variable fertilisation recommendations. Ultimately, Pilot 1.3 envisions that the rice farmer will fully automate and optimise irrigation in rice paddies, monitoring them through the DEMETER dashboard, where he/she will also be able to perform manual adjustments. Accordingly, the user will be able to download the fertilisation recommendations and monitor the direct benefits though the dashboard (e.g., comparing with the common practices, visualising water consumption, etc.).

4.2.3 Expected Benefits

The implementation of the Smart Irrigation Service in rice and maize will achieve increase or standardisation of the crop production and greater efficiencies in the water and nitrogen fertilisation savings, decreasing the carbon and the whole environmental footprint of both crops. The adoption of the Smart Irrigation Service by the farmers creates value and positively impacts the primary sector of agriculture directly. The pilot combines several different technologies to provide a DSS for the holistic management of irrigation water in rice-maize crop rotation systems. The service provides a low maintenance, robust and scalable monitoring system at the farm level and on a per-field basis. Overall, the holistic Smart Irrigation Service can be deployed in other rice producing countries.

4.2.4 The pilots approach

With respect to rice, the automatic Smart Irrigation Service (SIS) is primarily based on a real-time salinity and water height IoT sensor, which was originally developed within the framework of SmartPaddy FP7 project, but significantly improved by adapting the communication system to use a GSM modem instead of Wi-Fi and by adding the height sensor. This new sensor—called WISyNode—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 individual farmers with no automatic smart irrigation system, the service will provide only information/notifications. Weather forecasts are used complementarily, to fine-tune the irrigation schedule. For the second pilot round, an alternative mode of operation is scheduled to be developed, using satellite imagery for estimating salt toxicity in nearby fields without an IoT sensor installed, under a novel data fusion framework. Moreover, the DEMETER system provides a methodology for nitrogen fertilisation management using variable rate application (VRA) technologies, based on spatial information collected by the pilot fields through UAVs. More specifically:

With respect to maize, multispectral and thermal images are collected at predefined points within the cultivation period using UAVs already owned by ELGO and ICCS.

Nitrogen-stressed fields are identified through an automated image processing workflow, as well as through image analysis using innovative techniques, such as machine learning on embedded multicore GPU device for fast decision support.

Data analytics and decision support mechanisms for optimal resource management/allocation are provided (e.g., water use optimization, optimal scheduling of snapshot propagation).

Image processing using machine learning algorithms for analysing plant data linked to the plant's irrigation needs/health.

Support for resource consumption reduction/minimization (e.g., reduction of power consumption on the embedded devices/UAVs to extend battery life).

Usage of machine learning techniques (e.g., suitable neural networks) to forecast optimal irrigation schemes based on data collected on the field along a sufficiently large time period.

Usage of decision support tools (e.g., to support the irrigation-related decisions of producers).

An initial list of pilot's stakeholders has been compiled in deliverable D5.1 and consolidated into generic stakeholders in deliverable D5.2. Here, we report the final list of stakeholder groups, along with some concrete examples:

Farmers. The ultimate—and arguably most important—group of stakeholders. By end of the second pilot round, Pilot 1.3 expects to involve actively at least six individual farmers, farmer groups, and/or farmers' cooperatives.

Research institute/scientific provider. These are DEMETER-internal stakeholders, which comprise the ELGO and ICCS partners, who develop Pilot's 1.3 enablers and services.

Hardware providers. Providers of equipment necessary for implementing the pilot's solution. Concrete examples in Pilot's 1.3 implementation region are:

ExMachina: Greek IoT sensors system provider, which has implemented the WISyNode system (customized salinity and water height IoT sensory system) used in the rice pilots.

ScientAct SA: Provider of specialised sensor systems (e.g., soil moisture sensors, meteorological stations/data loggers) in Thessaloniki area.

Variable rate technology (VRT) machinery providers. They are interested in the provision of the spatially variable nitrogen fertilisation recommendations since this will allow exploiting the full potential of their machinery.

Agri-consultants. This a key stakeholder group for Pilot 1.3. In many cases, agri-consultancy businesses are the direct users of the DEMETER tools and services (e.g., maintaining the field book, planning fertilisations, etc.) and then provide the final recommendations to the farmers (e.g., fertilisation recommendation maps, task schedule, etc.). A concrete example is Ergoplanning Ltd, an agri-consultancy business in Thessaloniki, Greece, which has expressed interest in using the pilot's services.

Data service providers. This is a broader group of stakeholders, which includes all data providers needed for providing the pilot's services in a cost-effective manner. Examples specific to the pilot are:

EO data providers. An example specific to Pilot 1.3 is Planet, which provides the PlanetScope multispectral satellite imagery used. Moreover, the Sentinel-2 data are also used, so Copernicus service providers (e.g., DIAS, MEPs) are also relevant.

Meteorological forecasts providers.

Public authorities. Examples of public authorities in the area of the pilot interested in DEMETER's results are:

Local Irrigation Authorities (TOEV). The Local Irrigation Authorities are the official authorities for controlling the distribution (spatial and temporal) of irrigation water to the farmers.

Regional Irrigation Authority (GOEV). The Regional Irrigation Authority oversees all Local Irrigation Authorities in Central Macedonia.

Agronutritional Cooperation Region of Central Macedonia. Entity within the Regional Government of Central Macedonia, with the objective of promoting the region's agricultural products and ensure sustainable production.

General public. The general public is an indirect stakeholder, since the pilot's services decrease its environmental footprint and inverse its quality (smaller amounts of nitrogen fertilizers used on average). These are a strong motivation for farmers a well since they can use them to increase their product's marketing potential. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.2.5 Usage of DEMETER components

Fertilizer enabler: A module that receives as input several spectral indices obtained by processing multispectral imagery acquired from UAV and satellites and estimates traits related to nitrogen (N) content—such as N uptake and N concentration—in order to support decisions related to the optimal amount of fertilizer to apply. This is achieved using a randomized technique to choose the few most appropriate among all indices and then feed a model that estimates the agronomic traits. For now, two algorithms run independently to provide the desired output: regression modelling and random forests. The first one estimates the desired output as it is, whereas the latter quantizes the output into classes of equal range. Depending on the number of available field data, one of the two algorithms is selected: the regression model approach when there is an adequate volume of data and the random forests one when the number of training samples is limited (which is frequent in most agricultural applications). The N uptake / concentration estimations then drive the fertilisation amount recommendation service (FertiRM, see below).

Maize Irrigation enabler: As far as the maize irrigation is concerned, we have built an application in python, where we feed UAV images and excel files carrying the timestamps of the measurements and the sensors' measurements and we can collect all sensor measurements linked to the area of each image. The collected sensors measurements (such as temperature, wetness, relative humidity, etc.) can then be displayed per image obtained. Moreover, an RNN-LSTM Neural Network has been built and performs forecasts on weather parameters based on historical weather data. It then informs the user if he/she should irrigate the maize sooner than foreseen or delay the irrigation planned because of an anticipated precipitation.

WISyCom: This is an internal interoperability module, which retrieves the WISyNode measurements via the external web platform API, converts them into the internal format used, updates the database, and exports them as a CSV. The latter is then transformed into an AIM-compliant format.

SIS-rice: DSS service for irrigation in rice fields, based on real-time WISyNode measurements and meteorological conditions and forecasts. The service employs empirical rules of when to drain the flooded field (increased salinity or excessive water height) or when to further flood the field (insufficient water height). Meteorological conditions and forecasts are considered for fine-tuning the decision.

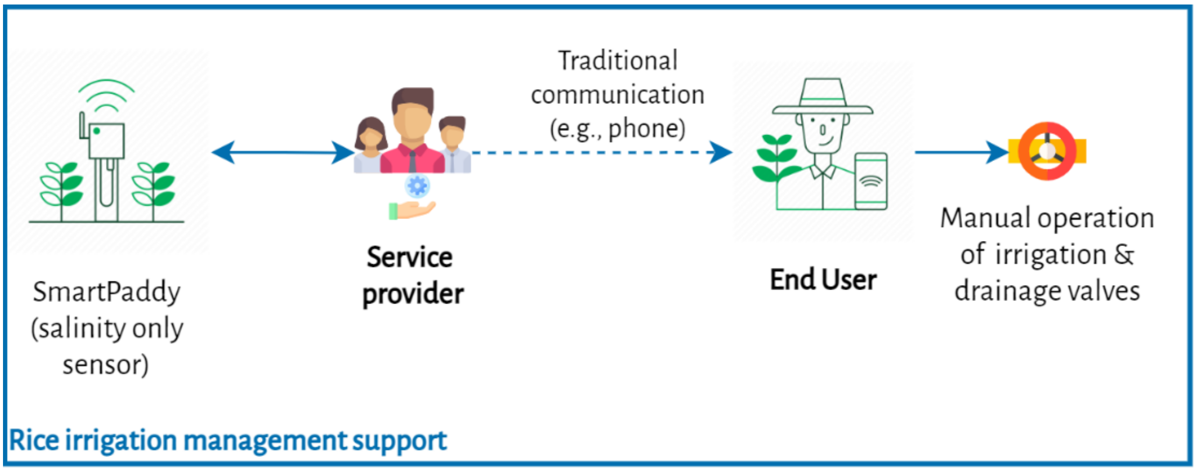
Remote sensing image processing: We have developed an internal module that handles the preprocessing and spectral indices calculation from remote sensing images. It supports certain well-known multispectral sensors for UAVs (Parrot Sequoia, MicaSense RedEdge-MX) as well as satellite imagery (currently, PlanetScope and Sentinel-2). It also performs the segmentation of the field into homogeneous treatment zones. The component is used internally for deriving the inputs for the FertiRM service (nitrogen fertilisation recommendations).

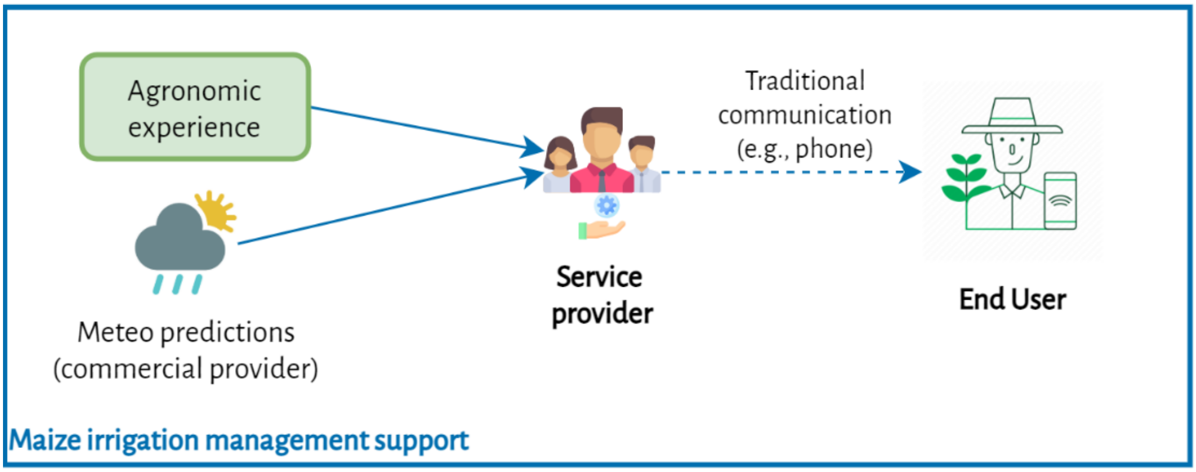
FertiRM: We have developed an empirical N fertilisation recommendation service. The FertiRM service provides spatially variable nitrogen fertilisation recommendations for surface fertilisations in rice and maize. It uses as inputs spectral indices calculated from remote sensing imagery collected at predefined time points within the growing season, which are used to derive nitrogen status estimations from the Fertilizer enabler. These are fused with meteorological data to derive the final recommendation maps, which can then be fed to Variable Rate Technology (VRT) machinery. In the list above the pilot-specific enablers focusing exclusively on pilot round 2 are not fully elaborated yet. On the other hand, enablers that have been integrated and are not pilot-specific include the following:

WP2: Agricultural Information Model (AIM) and Semantic Interop/Mappings to AIM. AIM integration and semantic mappings to/from AIM. We have implemented wrappers for certain data types such as for some images (used in various data analytics enablers) and sensor data (e.g., from ExMachina sensors) to transform them to AIM JSON-LD format and had been tested in pilot round 1. Further developments currently pursued include transforming that data from AIM to other formats, as well as implementing additional wrappers for other data (e.g., pertaining to fertilization). The latter is planned to be fully tested for pilot round 2.

WP3: DEMETER Enabler Hub, Brokerage Service Environment, Access Control Server access and Functional Interoperability Core Enabler. We have used the key functionality provided by WP3, such as registering pilot enablers in (the cloud-based) DEH and BSE, but still need to import security enablers and other components (e.g. the local BSE client). Thus, the work is ongoing.

In Figure 13 the current situation is shown while in Figure 14, we present the workflow of the how the data gathered from sensors and services (e.g., weather service) is then processed using the previous enablers for each of the three applications (SIS-Rice, SIS-Maize and FertiRM). By enabling interoperation of all modules involved through the DEMETER Enabler Hub and using the core enablers provided, it is possible to take the appropriate action which is then transmitted to the actuators (e.g., irrigation and drainage valves). The end user gets all this information via the interfaces provided by the DEMETER dashboard and the appropriate visualization enablers.





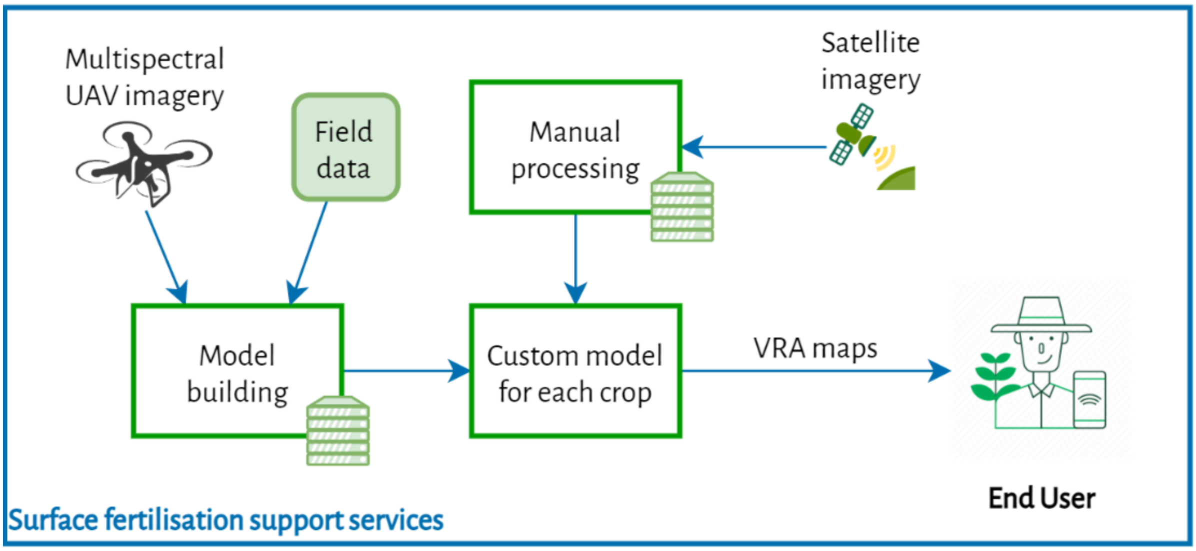


Figure 13: Before DEMETER workflow of the agronomic advisory services of Pilot 1.3.

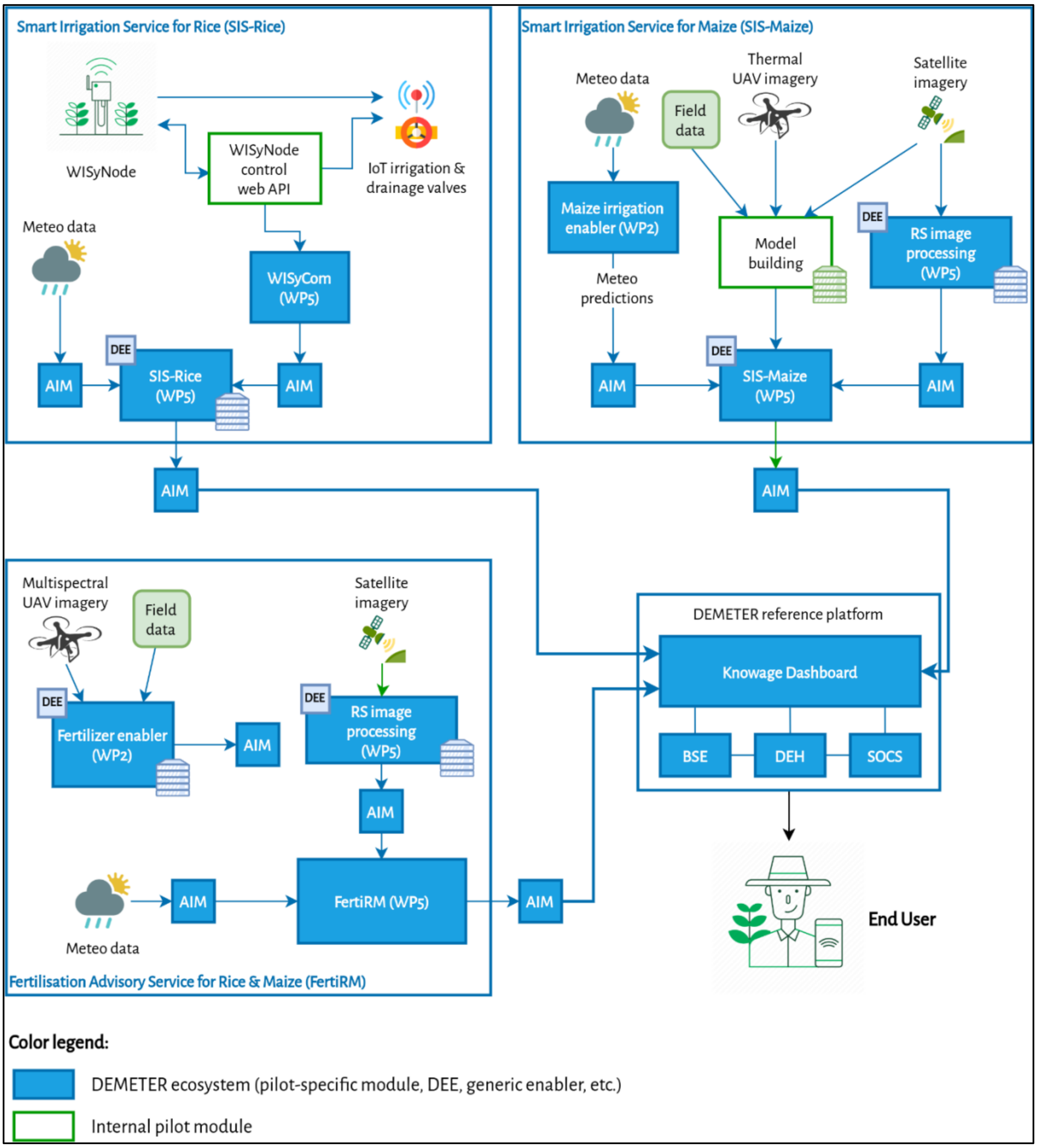


Figure 14: After DEMETER workflow of the three applications developed in Pilot 1.3.

This is to be contrasted with the respective agronomic advisory services ELGO was providing to a limited number of farmers before DEMETER, depicted in . The irrigation management support services were mostly based on expert knowledge, especially in the case of maize crops. For rice, the SmartPaddy sensor did exist, but would only measure salinity (not water height), the farmer was informed (e.g., via phone) when the danger for salt toxicity was high and he/she had to manually drain and reflood the rice paddy to avoid yield losses. The fertilisation support service was in a—relatively—more advanced stage, but still several processes were manual and crop-specific. In all cases, traditional means of communication such as phone or face-to-face meetings were used. DEMETER facilitated automating most processes, refactoring the workflow using components with well-defined input/output interfaces that are generic enough to be used in other services (e.g., the remote sensing image processing module, the fertilizer enabler), and offered an easy way for the end-user to receive the services' outputs without the need for face-to-face meetings.

4.3 Pilot 1.4 - IoT Corn Management & Decision Support Platform

Pilot 1.4 is designed in partnership with the Romanian Maize Growers Association (Asociatia Producatorilor de Porumb din Romania, APPR), our agricultural specialist partner. The pilot will be implemented in locations operated by 15 agricultural farms specialized in field crops, members of APPR, covering roughly 40K hectares.

The geographical coverage will include farms located in the south of Romania that are facing natural or other specific constraints. Due to the different characteristics of chosen regions from the point of view of soil and weather, we are expecting significant variations of collected data that will allow us to better validate the concept. The maps below show the spatial distribution of the pilot parcels (magenta), and the administrative zones (NUTS 5 or LAU2) categorized in colours, based on Less-Favoured Areas (LFA) criteria. The pilot farmers' parcels are distributed in the dark green areas, which represent Areas facing natural or other specific constraints (see Figure 15)

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, Global Navigation Satellite System (GNSS) receivers, GIS tools and Satellite 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, and impacts degree resulted from extreme meteorological phenomena.

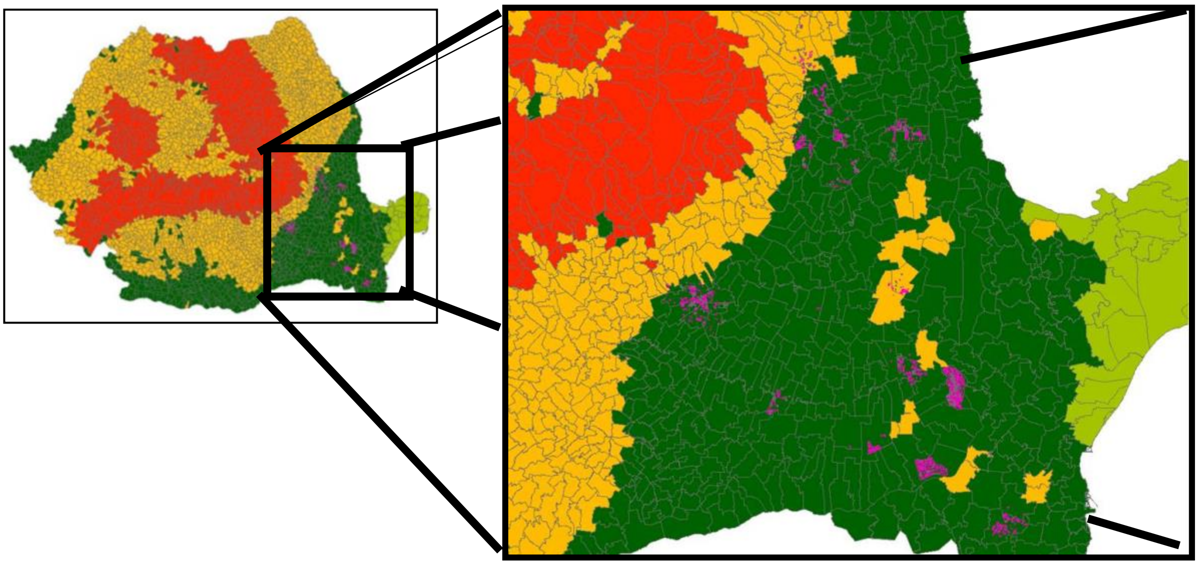


Figure 15: Location of Pilot 1.4 testing parcels

4.3.1 Use case specific requirements

Nowadays, all 15 farms use weather-related data to manage their specific works internally. Some of them use weather stations and basic decision support functionalities on mobile applications. One of the farms uses mobile weather sensors installed on tractors that trigger real-time warnings for the tractor driver, without being connected to a centralized system. Another subset of farms uses soil moisture sensors, but none of them use any automatic crop analysis software for diagnosis or prognosis.

4.3.2 Envisioned Scenario

All farmers are using weather data but only some of the farmers are using sensors to correlate aerial measurements (temperature, air humidity) with real-time and historical data about soil temperature and moisture, crop types and rotations, type of corn hybrids, wind power and direction). Our decision support system will be able to smartly represent this correlated information, offer smart visualizations and trigger real-time or early warning alerts (see Figure 16 and Figure 17). To achieve this, the pilot will:

- collect heterogeneous data from various data sources (sensors, stations, web sites, external imported excel or image files) and various farms
- create farm groups and profiles corresponding to geographical position, and crop types
- offer correlated data to farmers
- improve responsiveness of Inovagria platform by triggering real-time or early warning alerts
- offer simple and intuitive visualizations
- display data at different levels: farm, group of farms, plot of land, several plots
- display the exact or recommended time to execute an agricultural treatment as irrigation, fertilization, bug or weed removal

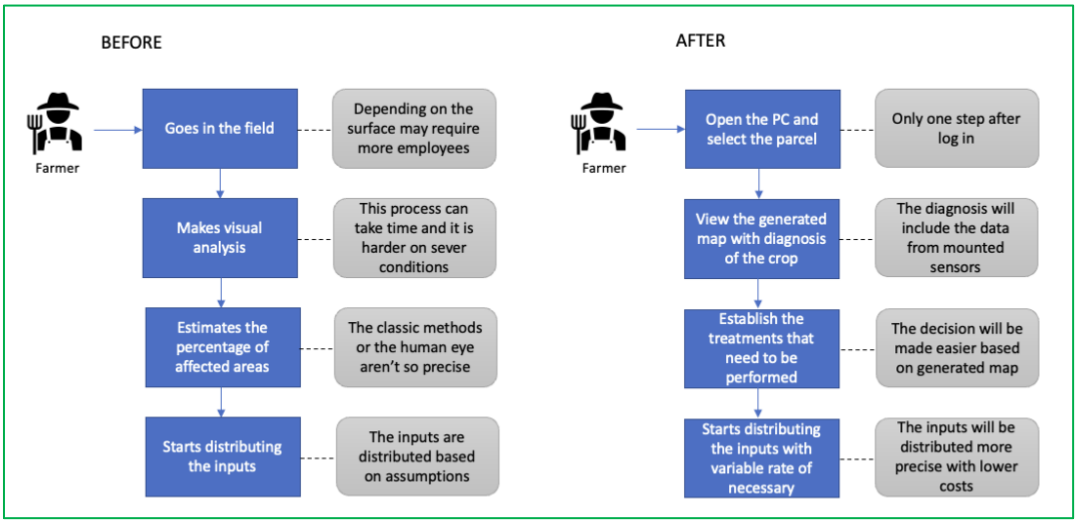


Figure 16: Before & After DEMETER - Component A3 - Plant stress detection

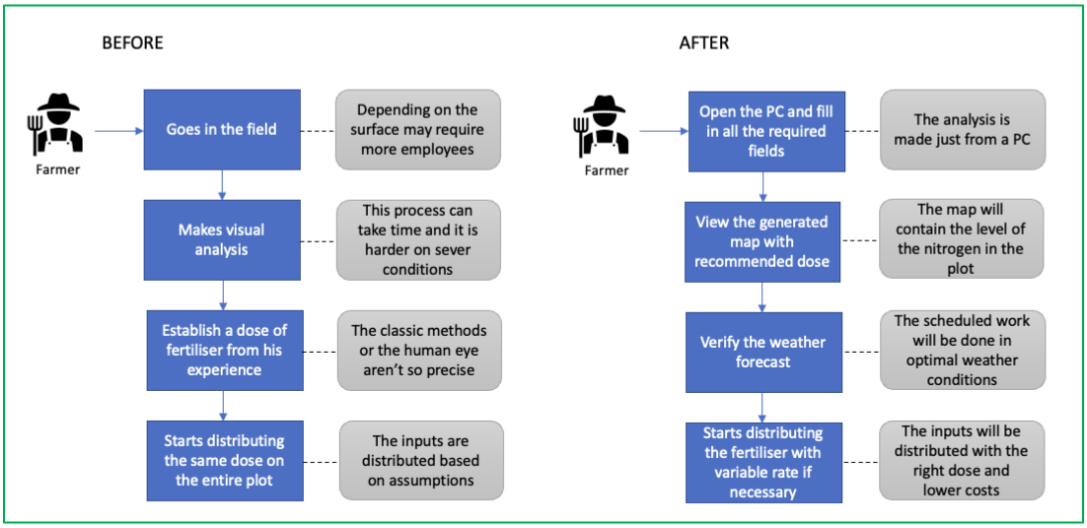


Figure 17: Before & After DEMETER - Component C1 -Nitrogen Balance Model

4.3.3 Expected Benefits

Improve the existing decision support system of Inovagria management platform by extending the number of correlated data types which will trigger a more educated automatic decision and will provide:

- More information to farmers (correlated data: weather, soil properties and hybrid maturities, geo-location, etc.) will facilitate faster and more accurate decisions.
- Real-time warnings and forecasts.
- Increase awareness of the importance of Decision Support Systems.
- Water use, variable rate and inputs optimization.
- Crop works decision time improvement.
- Agricultural system durability stability.
- Profit growth gain through larger and higher quality productions.
- Maintenance of the sustainability for farming systems.

4.3.4 The pilots approach

During the pilot implementation we will carry out the inventory of technical existing assets in the farms (weather stations, sensors, communication facilities, coverage).

An IoT / data source mapping on farms should be conducted to validate the practicality of their current technical inventory. An as-is process diagram will be designed, and a fit-gap analysis will be performed. Consequently, we will choose the participating HW components and we will purchase the missing equipment. Some producers or vendors of IoT devices will be contacted for technical descriptions and offers. The pilot will assign to each farm a specific number and type of relevant sensors / data sources. All IoT components and other sources will be technically enabled to feed the Inovagria platform database instance. All farm profiles, type of crops, rotation schemes, calendars, and statistical/historical data will be loaded in the same instance. The current Inovagria platform will be adjusted to accommodate new capabilities/extensions.

Collect real-time data from IoT devices (sensors and weather stations) and from other data sources (satellite images, geo-location, GIS, statistical data). Improve and extend the existing Decision Support System (DSS) for live support of agricultural processes.

The software application will include 4 segments:

1. Recommendation for fertilization distribution plans;
2. Warnings of severe weather and recommendations for carrying out agricultural works;
3. Diagnosis of soil moisture based on insitu sensors for combating floods and hydric stress;
4. Locating the affected areas of the plot that requires special treatments.

The application segments are described in detail in the following sub sections:

Recommendation for fertilization distribution plans; The principle for realizing the distribution plans of the agricultural inputs is based on capturing the satellite images of the interest area and processing them with the pixel classification method. The classification method is based on the grouping of pixels with close values, represented by a single colour. An image will be divided into 3 classes: Optimum Nitrogen level, Medium and Low. E.g.: Case study, Variable rate fertilization (VRS).

In this case the farmer wants to determine the areas with low potential and apply a larger amount of fertilizer in those areas. Following the processing of aerial images and the classification of pixels, 5 classes are identified, resulting from the application of the NDVI index formula.

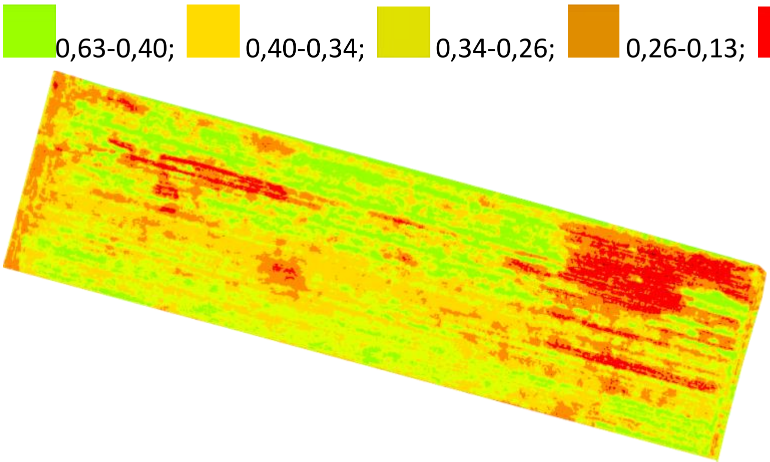


Figure 18: NDVI Example

NDVI (normalized difference vegetation index) is a "unit of measurement" of vegetation development and density and is associated with biophysical parameters such as: biomass, foliar index and percentage of land covered by vegetation. NDVI itself thus varies between -1.0 and +1.0. Following the application of the correlation algorithm, the conditions for distributing the fertilizers corresponding to each area are obtained. The areas represented in red and orange are the most affected and replanting the crop on those areas may be considered. Obtained orthophoto imagery is transformed into vector features, compatible with the GPS system of the agricultural machines. Thus, the guidelines will be followed on the plot, based on the geographical coordinates. The method will be validated with ground readings (N-Tester measurements), in order to calibrate the legend. Based on this principle the following can be determined: Weed areas, areas with hydric stress, areas affected by pests / diseases or extreme weather events.

Warnings of severe weather and recommendations for carrying out agricultural works;

This section is intended for scheduling fieldwork based on agrometeorological diagnoses and forecasts. Phytosanitary treatments must be administered at the optimal time, so the forecast weather widget will help farmers to proceed with the treatments in good climatic conditions.

The determination of the optimal moment is based on ground-mounted sensors that will provide information such as: Air Temperature, Air Pressure, Humidity, Wind Speed, Soil Temperature, Soil Moisture and Precipitation. Another information that will be available in this section will be the intensity of the scorching heat and the winter harshness, represented on a chart with legend. This information is used by farmers to prepare the documentation for the compensation institutions in case of crop damage.

Diagnosis of soil moisture based on in-situ sensors for combating floods and hydric stress;

In the case of extreme weather phenomena such as excessive rainfall, water will accumulate in crops, which harms the optimal development of plants. Thus, to prevent disease, it is recommended to build drains to remove excess water from inside the plot and to be directed to the edge or to build gutters. The hydric stress in the agricultural crops (lack of sufficient water in the soil) can lead to enormous damage, so irrigation recommendations (position and quantity) can be made based on satellite images and ground-mounted sensors. Locating the affected areas of the plot that requires special treatments.

The overall picture of the agricultural crops is very important for farmers who own large areas of land and cannot walk them entirely. The satellite images with a frequency of 2, 3 times a week, helps farmers to have an image on the vegetation state of crops in a very short time. Crop monitoring is done with the help of NDVI images, as they have already passed through a special filter for the vegetation part. The indication of the areas affected by various factors will be highlighted on the map, so that farmers will be able to go to the field and make further investigations to determine the cause. The most common cases are those caused by lack or excess of water, followed by extreme weather phenomena such as strong wind, hail, etc. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.3.5 Usage of DEMETER components

Component A.3 Plant Stress Detection is responsible with detection of plant stress using a combination of remote sensing data, meteorological data and in-situ data. It has the following visualisation objectives: percentage of crops affected by stress compared to total amount of crops (per crop type). Component A.3 needs to interact with the Security Enabler regarding user authentication.

Nitrogen Balance Model estimates crop nitrogen requirements and provides the scheduling for fertilization. The component input uses NDVI images, crop coordinates, field properties and meteorological data (sensor based). Results of the analysis provide the farmers with cartographic plans and recommendations for differentiated fertilization in the same plot in order to obtain a higher yield. Component 4.C.1 will predict and interact with any other component or DEMETER Enabler. The component is the “Pattern Extraction for Optimal Fertilizer Usage". Also, the component needs to interact with the Security Enabler regarding user authentication.

4.4 Pilot 2.1 - In-Service Condition Monitoring of Agricultural Machinery

This pilot aims at demonstrating the potential application of onboard sensors for in-service monitoring, while considering aspects of data management. The Pilot will be deployed in two sites in Germany. 2 farms (250 ha), one site per farm; machine monitoring is independent of land coverage; however farming task and machine load could be an influencing factor.

4.4.1 Use case specific requirements

With European Stage V non-road emission standards, gaseous pollutant emissions must be monitored and documented from 2019 onwards for new combustion engines in use. This must be handled with the usage of portable emission measurement systems (PEMS). These systems need to be attached to nine selected machines in order to analyse the emissions of the vehicles during regular operations. Figure 19 is showing a John Deere 6250R machine with portable emission measurement system. Engine manufacturers are responsible for the execution and must report to legal institutions. At the moment there is no in service-condition monitoring mandatory but it will be with the upcoming European Stage VI non-road emission standards. Upcoming legal requirements with European Stage VI non-road emission standards demand the assurance that engine and after treatment systems of non-road mobile machinery are working properly. This must be ensured by in-service monitoring of machines with which the function of components can be supervised. To be able to meet these requirements the work done during the Demeter project can be beneficial.

Additionally, farmers will be able to check on the conditions of their machines. In case of malfunctions, the monitored data can help to resolve issues easier and faster. This is not only a benefit for the farmer but also for dealers. Machine manufacturers can also take advantage because recorded data can help to compare machines. This enables new possibilities of detecting patterns and improving products.

Figure 19: Emission measurement system

4.4.2 Envisioned Scenario

The envisioned scenario is that engine and aftertreatment data is monitored automatically during machine operation, then the data will be analysed and processed for a virtual feedback to farmers, dealers, and manufacturer. During this process not only the function of the machine will be analysed but there will also be a data quality assessment in order to ensure the validity of the analysis. Integrated in the DEMETER environment the results of the monitoring can be viewed and in case of malfunctions, recommendations will be displayed to support the decisions of further actions.

4.4.3 Expected Benefits

Expected benefits from the pilot are on the one hand the possibility to visualize the engine and after treatment conditions of agricultural machines for farmers, dealers, or the manufacturer. This can help in case of machine issues and offers an improved way of service. Additionally, the work can build a basis for in service-monitoring which will probably be mandatory with upcoming European Stage VI non-road emission standards.

4.4.4 The pilots approach

Using Data from the CAN-Bus, algorithmically ensuring high quality of continuous data streams, and analysing the data by making use of the most appropriate algorithms and technologies, will allow monitoring, documentation, and using the analysis results for further actions.

After transferring the data from the CAN-Bus it will be analysed automatically and the results will be visualized. Showing the results with help of a traffic light system will enable the farmer to see directly if the machine is working properly. In case of malfunctions, there will be actions recommended which can help farmers or dealers to resolve issues faster.

Data quality part

In order to analyse the data from the CAN-Bus it is beneficial to check the data quality in a first step. In the context of Pilot 2.1, we primarily talk about physical sensors. Thus, we will focus on the quality of machine data or sensor data in our context. To put it simply, a sensor measures physical quantities like temperature, gas emissions, light, etc. of a sample (or of surroundings) and convert those quantities into electrical signals.

In general, the starting point for a quality assessment is to identify the quality needs. Those depend – among other things – on the use case and its requirements.

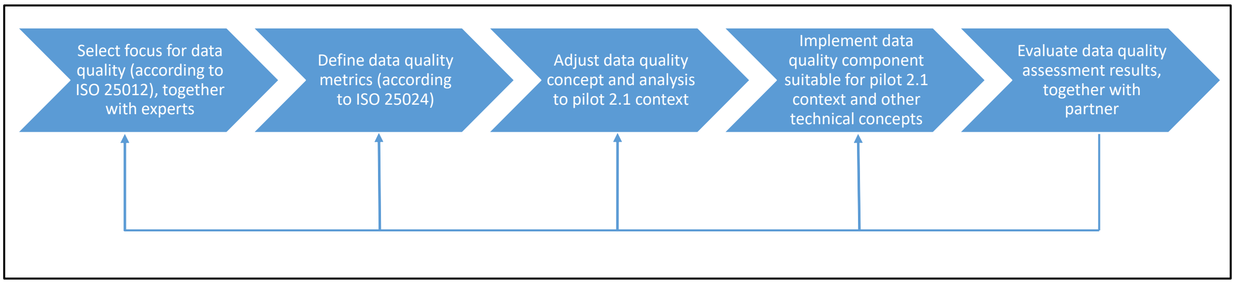


Figure 20: Illustration how the data quality assessment is obtained

In our case, a good starting point (see Figure 20) is the ISO Standard 25012:2008 "Software engineering — Software product Quality Requirements and Evaluation (SQuaRE)". This standard defines a data quality characteristic (sometimes also: aspects or dimensions) as a "category of data quality attributes that bears on data quality". There are the following fifteen quality characteristics: Accuracy, Completeness, Consistency, Credibility, Currentness, Accessibility, Compliance, Confidentiality, Efficiency, Precision, Traceability, Understandability, Availability, Portability, and

Recoverability. We map the characteristics of the ISO 25012 standard to the overall quality needs which the stakeholders of pilot 2.1 are interested in. To do this, we perform interviews or workshops with the pilot partners. Based on those results, we know which data quality characteristics are of importance for the pilot and we study the ISO25024 Standard. This standard defines concrete measurements in order to quantify data quality. Then we discuss the metrics again with our partner to involve the different stakeholders of the pilot again more intensively. This means, we perform additional interviews or workshops in order to assess the priorities of the different data quality characteristics. After gathering all the necessary information, we implement a data quality calculation and discuss how it can be put in the context of the data workflow of the pilot. Finally, we evaluate the result with our partners and adjust the implementation, if necessary. As the pilot is progressing the steps related to the data quality assessment can be performed several times in an evolving process (see Figure 21).

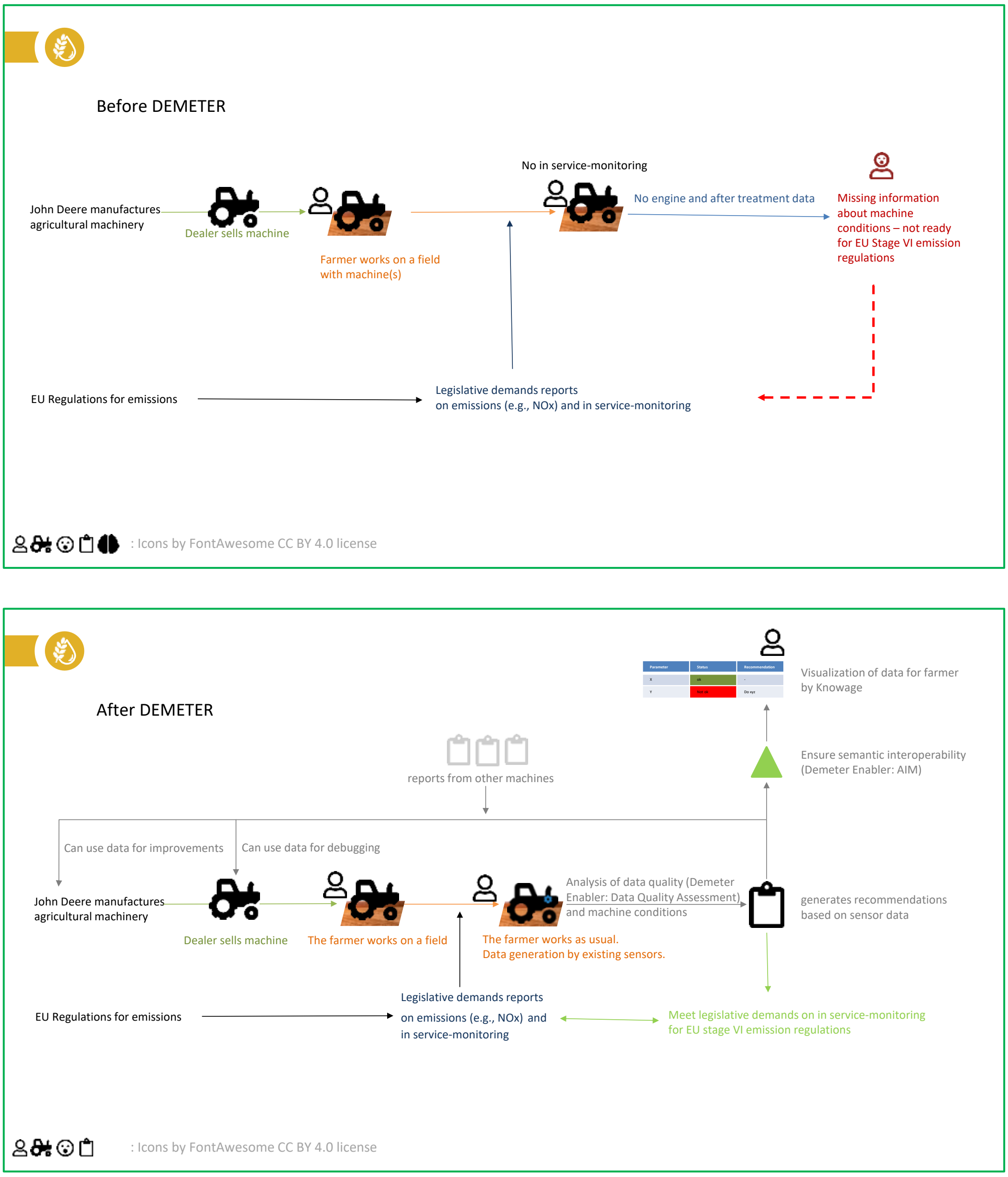


Figure 21: Pilot 2.1 before and after DEMETER showing the expected impact

After the first discussions It turned out very soon that focus of this pilot will be the inherent point of view. The most important characteristics for pilot 2.1 are Completeness and Consistency. This is not surprising because the European Stage VI non-road emission standards demand reliable and solid data. Other important characteristics in the pilot are Accuracy, Credibility, Currentness, Precision and Understandability. The ISO25012 Standard distinguishes between an inherent and a system dependent point of view to describe data quality characteristics (some characteristics cover both point of views). Most of the characteristics stem from an inherent point of view. This is reasonable for pilot 2.1 because the analysis of the data can be done on a local machine and there is no need for a third-party to be involved in the analysis. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.4.1 Usage of DEMETER components

To ensure the monitored data is of high quality, we make use of the Demeter WP2 enabler Data Quality Assessment. Additional enablers will be integrated, such as the Agricultural Information Model (AIM) to ensure semantic interoperability. This enabler allows us to provide the data in an appropriate format for the visualization by Knowage (WP4 task 4.3). Furthermore, the recommendations to support resolving issues faster are part of decision-making activities (WP4).

4.5 Pilot 2.2 - Automated Documentation of Arable Crop Farming Processes

The Pilot develops two systems for processing farming data on 3 farms. One of the API in this pilot enables the Job Cost estimation and potentially prediction for Fertilizing and Spraying Jobs to support the farmers' decision on cost monitoring. It will include capturing high precision data, merging with data from farms / machines, and deriving required cost estimation and documentation parameters via data analytics and knowledge management techniques. The second part of the pilot focuses on developing an automated job documentation. GPS-records which were collected during field operations are combined with background information to identify the location of a performed job, as well as temporal and statistical data. But automated documentation three questions will be answered automatically regarding a detected job. It will be identified where the job has been applied, when it took place and what has been done. Eventually the objective is to facilitate the documentation of agricultural processes and make it more efficient.

4.5.1 Use case specific requirements

Current farming process documentation usually involves a high amount of self-management and time dedication on the farmer's side to fulfil the specific needs of this topic. Most farmers mainly rely on their own analogue information or other analogue resources possibly impairing quality and quantity of the documentation. In addition to that, processes are often documented with a considerable delay, thereby increasing inaccuracies even more. Cost monitoring of field operations in farming practices is vital. Nowadays with precision crop farming vast amount of data are being gathered. This data can be used to help farmer on observing the costs of individual applications and consequently support them in making better decisions. Costs of a job depend on various factors like the fuel consumption of a machine, labour time and the efficiency of the job. Due to these and more influences occurring over a period of several months, farmers cannot assess the total cost of a job.

4.5.2 Envisioned Scenario

Future farming processes that are supported with this pilot solution are enabled to exploit the automatically collected movement and circumstantial data of the process itself. The automated documentation ensures consistency in the documentation processes and relieves the farmer of this time-consuming task. The aim is to achieve a process documentation that is as accurate as possible, which largely eliminates the need for manual documentation. The job cost estimation derived from the documented data will help the farmer to learn where he or she can optimize the revenue. This information will be helpful to support future application decisions.

4.5.3 Expected Benefits

Having a calculation on job cost calculation enable key to farmers for making a better decision particularly nitrogen application rate. Farmers can get knowledge for cost savings (reduced costs for fertilisation), and Investments into farming activities:

- Environmental benefits (e.g. improvements of the biodiversity, water quality),
- Cost savings for the farmer (reduced costs for fertilisation), and
- Investments into farming activities.

As well as they can get to know the main negative impacts resulting from agricultural activities on water bodies. The over use or misuse of pesticides and other agricultural formaldehyde (such as fertilizers) can allow these chemicals to enter surface and ground water. Progression, evaporation and wind disintegration can carry pesticide debris into the air. From there they can fall in rain to pollute lakes. While most environmental risk come from the active ingredient in a pesticide, the way its formulation interacts with the environment determines the overall hazard of a pesticide.

The objective is to support farm management with a job cost estimation model based on a data-sharing platform including data analytics and data integration. The model will be derived from an economic analysis of cost and revenues and further historical farm data. An overall aim will be the development of a job cost prediction model to optimize job quality and to increase productivity. Besides the job costs, the last area of focus will be the enhancement of documentation processes through smart automation of GPS-records combined with background information.

4.5.4 The pilots approach

In this pilot, two main aspects will be developed for the farmers, i.e. “Job cost calculation and prediction concepts” and “Automated documentation of arable crop farming processes”. These two parts are further supported by a “data quality assessment service” - the third contribution of this pilot. John Deere focus on job cost calculation for spraying and fertilization applications. m2Xpert focus on automated operational job recognition of farming processes and automated documentation in farm management systems. Fraunhofer IESE will develop a method for assessing data quality in the context of agricultural data.

The focus of the job cost calculation will be on fertilization and spraying applications for winter wheat. These jobs are done several times in the year and will therefore deliver more data than seeding or harvesting, which are only executed once per field. For the development of a job cost estimation model, it is necessary to concentrate on two similar jobs, since the number of influencing factors for all jobs concerning farm work would be too high to include in one model. For the development of an automated documentation tool, the detection of the difference between fertilization, spraying, tillage, and seeding jobs will be the most challenging part of job identification. It is based on sensor data from machines and external sensors such as satellites (e.g. sentinel) and on data from weather stations. This information is intelligently linked and interpreted in the respective context such as location, time, activity, or crop.

- Job cost calculation and prediction concepts
- The data used for job cost calculation is as follows:
- Fixed cost data
- Fixed machine cost: Sum of fixed machine costs
- Fixed labor cost: Sum of labor costs
- Variables cost data
- Variable machine cost: Sum of variable machine costs
- Variable labor Cost: Sum of labor costs
- Service: Sum of services costs
- Application costs
- Spraying: Sum of spraying applications costs

- Nitrogen application: Sum of nitrogen applications costs

Measuring the success of decision is a crucial task that develops the farmer understanding for optimizing the decision further. The enabler of a decision support system (DSS) for the farmer is the calculation of job costs. Measuring a sequence of the job costs helps the farmer to evaluate his decision within that sequence. Since farmer deploy AutoTrac machinery (e.g. John Deere Tractors) technology in order to apply his decision in the field a vast amount of data is generated. Such data contains location (latitude and longitude) and attribute information that represents information such as name of the application, date, amount of applied rate. Indeed, Global Navigation Satellite Systems (GNSS) provide autonomous geo-spatial positioning information. It allows small electronic receivers to determine their location (longitude, latitude, and altitude/elevation) to high precision using time signals transmitted along a line of sight by radio from satellites. These data are produced once the farmer preforms an operation in the field. The data is normally transmitted via a 4G network to my John Deere operation Centre that utilized a cloud service for data storage. Afterward the data will be available in ESRI shape file format. The calculation of job cost in relevance of the above information will be done by the following function.

$$C = \sum_{i=1}^{n} x_i \quad i = 1,2,3, \dots, n$$

Where C is the sum of all costs and, x_i and n are each feature dataset defined above and number of feature dataset respectively. The output can be for the total cost for the given farm, and per field costs for that farm.

This information provides the farmer a better insight on the costs and support him on making decision for further investments. To retrieve information about a performed job, position and movement data is analysed. Once it has been detected that an action has taken place, the according GPS data and its meta-data is used to identify the boundaries of the area where the job has been executed and the time period of the execution. Additionally, statistical data, such as average speed or the total distance of the operation's trajectory, is extracted. The last step will be the automated job identification. To achieve this, background knowledge combined with information from additional sources needs to be included. The identification process will take advantage of satellite and weather data. Additionally, the Demeter Enabler "Detect Crop Type" can be used to support the identification process. For testing and demonstration purposes, the pilot's own GPS data trackers are used as input data source for the automated job documentation component. The data flow is represented in Figure 19.

Figure 22: Data flow of Automated Job Documentation with provided GPS data

However, the GPS data source is not specified by the component internally but can be substituted. Thus, for achieving interoperability within the Demeter context the input data format will be modelled using AIM as well as the output data. The latter also offers the possibility for registration in DEH and visualization of the documentation results on the Knowage dashboard. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.5.5 Usage of DEMETER components

The pilot's solution is supported by the data quality assessment to evaluate the incoming data. In addition, the crop type detection enabler from WP4 will be potentially used. To ensure interoperability within DEMETER and to be able to make use of the Knowage Dashboard, the pilot will use AIM as data model.

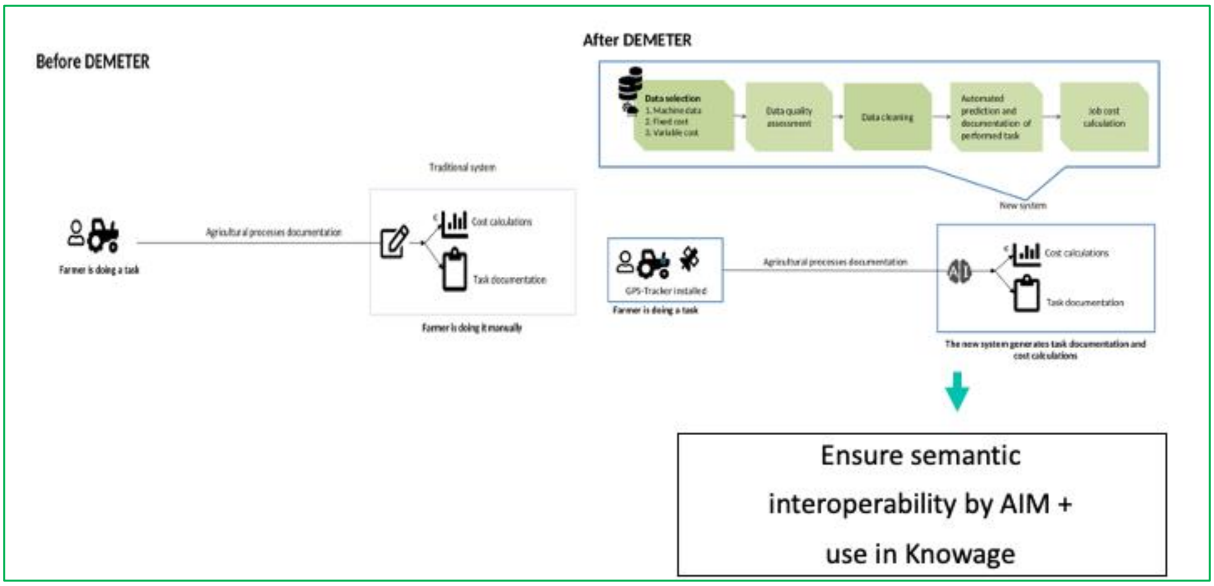


Figure 23: Situation before and after DEMETER showing the expected impact

4.6 Pilot 2.3 - Data Brokerage Service and Decision Support System for Farm Management

This pilot will 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, and that will include both a technical platform, and advisory services that will ensure easy adoption of data and technology by farmers.

The objective is to use data integration, analysis, and visualization applications for a decision support system. The Pilot will initially be deployed in minimum on 6 sites in the following countries:

- Czech Republic – 2 farms,
- Poland – 2 farms,
- Latvia – 1 farm or regional organization,
- Norway – 1 farm.

4.6.1 Use case specific requirements

Farmers are using many information and technical systems and technologies for:

- Data collection, analysis, extracting, and data preparation for farm use
- Farm work organization.
- Control of farm processes and control of machines.
- Farm life organization, planning, prognosticating.
- And for data storage and archiving.

Many times, these systems and services are developed or operated by various companies., are using independent communication protocols, and based on it – a system of all devices are not able to organize the farm data brokerage. Based on this reality description it is necessary to look for solutions that will improve this status. It is necessary to look for a common solution when the farmer will be able to have access to the complete data.

There is already existing many 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 APIs. Many times, these systems and services are developed or operated by various companies., are using independent communication protocols, and based on it – a system of all devices are not able to organize the farm data brokerage.

Based on this reality description it is necessary to look for solutions that will improve this status. It is necessary to look for a common solution when the farmer will be able to have access to the complete data. 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 APIs.

4.6.2 Envisioned Scenario

The aim of Pilot 2.3 is to support the efficiency of farmers; work by making data, information derived from this data, visualization, and analysis based on this data available to them through a single web-based application.

There are several key aspects to consider when looking for data that is useful to farmers:

- thematic aspect,
- a spatial aspect,
- and temporal aspect.

In general, farmers need to work mainly with data about their farm and the region where the farm is located, which come from external sources, or which is generated in various ways directly at the farm.

Some data at the state or global level, and information on legislation that is binding on the farmer are also relevant.

Farmers need both the latest data and historical data for their decisions. The latest data helps the farmer know what is happening right now, and analysing historical data in the context of current data allows farmers to predict what will happen in the future. The basic requirement of most farmers is to minimize the number of applications, desktop or web-based, they need to access relevant data from different sources, access visualizations, and analysis based on this data.

The required level of data integration that farmers need for their work varies according to the purpose for which the data is used. For some purposes, data visualization in one application is sufficient, although the data is not integrated. A typical example might be the various background and thematic map layers that are made available through web services like WMS and provide the farmer with a basic overview or additional information. Although farm management and agronomists use decision support systems based on statistical methods and artificial intelligence, simply looking at the data combined with the good knowledge of local conditions that agronomists have is still an important part of their day-to-day decision-making.

A certain level of integration is needed for the data from different data sets, which are used as input for various analyses or further processing and deriving new data sets and information. Mapping between different data models is very useful in this case.

The DEMETER project will facilitate the achievement of these goals, as the DEMETER Agriculture Information Model (AIM) is based on a semantic mapping between different data models and standards, and the Demeter Enabler hub and Brokerage Service Environment allows users and data or service providers to discover and use other Demeter enablers that provide data or allows to use data mapped to AIM in the various analysis performed by other DEMETER enablers.

4.6.3 Expected Benefits

The expected benefits are to use data integration, brokerage service, analysis, and visualization applications for a decision support system on the farms. Farmers will have access to the complete data, and they will be able to provide integration of this data into on support, information, and decision-making system. Farmers currently do not have this option. This farm support, information, and decision-making system will have a positive influence on current waste eliminations, increasing efficiency, time, effort, and expenditure saving.

4.6.4 The pilots approach

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 have also incorporated the Demeter enablers which will support its functionality. This data market will consist of both a technical platform and advisory services that will ensure easy adoption of data and technology by farmers. To reduce the number of web-based applications that a farmer must use, the solution of pilot 2.3 will integrate with the FOODIE Smart AgriHub. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.6.5 Usage of DEMETER components

Our approach is to continue using and further developing existing solutions as much as possible and use Demeter Enablers where we need access to data or services made available through the Demeter Enabler hub, or where we need to publish data or services through the Demeter Hub.

Demeter AIM, which will help solve problems with semantic interoperability, is an important element for the use of data from various sources in analysis and decision support.

4.7 Pilot 2.4 - Benchmarking at Farm Level Decision Support System

This pilot aims at developing services to support the benchmarking on the productivity and sustainability performance of the farms, leveraging and extending existing decision support system for farmers (DSS). This will involve monitoring different conditions and parameters affecting such indicators, collecting the data and integrating it in a unified layer accessible by the DSS.

The Pilot will be deployed in 10 sites with different farms sizes:

- 5 small farms
- 3 medium farms
- 2 big farms

4.7.1 Use case specific requirements

Jan Nowak (52 years) is a farmer and runs a medium-sized farm, has a secondary agricultural education and many years of experience in farming. On the farm with an area of about 30 hectares, only plant production is carried out. The main crops are: winter wheat (10 ha), winter rape (10 ha), sugar beet (5 ha) and spring barley (5 ha). The yield level of cultivated plants is above average, i.e.: winter wheat - 70dt / ha, winter rape seed - 40dt / ha, sugar beet - 700dt / ha and spring barley - 50dt / ha. This ensures a high cultivation culture and good soil conditions. The farm is dominated by soil classes III and IV. The farm is equipped with the necessary machinery and equipment for growing plants, which makes it self-sufficient in this respect. Farmer Jan earns an income that allows him to support his family and make the necessary investments, but he does not have a full overview of the economic situation of his farm. In addition, he makes some calculations, but they are not very precise. The farmer is aware that other farmers also perform well, but due to the lack of appropriate tools it is not possible to compare them. Jan does not know if and which his actions are optimal and which can be improved.

4.7.2 Envisioned Scenario

Jan Nowak, the same farmer, gets a new tool from his advisor Marek. Marek explains to Jan, that he can compare his farm situation with the other farmers from his region and similar production profiles. Jan open the tool with a browser. After log in, system asked Jan for few more information and enable him to determine farm economic size. After that Jan have access to reports on farms similar to his farm. Software offer to Jan collecting data from his farm and enters it into the system. Some of the data could be also taken from Jan's farm devices if possible (he is consulting it with platform technical support).

System also enable more environment data, like meteorological or soil condition. His advisor checks that all needed data is in the system. Now the farmer can compare his chosen parameters with the results of other farms thanks to the new tool, which enables:

- making calculations according to a uniform scheme enabling analysis of the results obtained,
- comparison of the results with the results of farms of similar agricultural type and economic size,
- making rational decisions regarding your business.

After some time Jan calls to Marek and asks him about the best fertilizer (recommended from outside database for example FOODIE database) for the next treatment. Marek, thanks to integration with farm data collected by DEMETER, checks Jan's farm situation and gives advice to Jan. Figure 25 shows a diagram describing the situation before and after.

The target users have been divided into 3 groups and 3 different scenarios:

1. **A beginner farmer (not FADN, not VAT) browses FADN data in his type / size, without comparing**

User enters the platform. Then he introduces the necessary data to determine the type of farming and economic size of his farm. In the next step, the system determines the type and economic size, which includes the given farm. After determining the type and economic size of the farm, the farmer has the opportunity to see the results of other farms in the type and size of his choice. In addition, the farmer has the opportunity to see the results in terms of economic and financial parameters of interest, e.g. wheat yield, cow yield, fertilization costs or agricultural income.

2. **An advanced user (not FADN, VAT) wants to verify / compare several parameters, e.g. yield, costs**

Some time ago the user started using the application and viewing data on similar farms. Now the application has offered him the opportunity to enter his own data and thus compare himself in a specific group. User Jan wanted to check whether the crop from his crops is high or low and to be able to get this information in the application, he entered data on the corn crop in his fields for 2018 and 2019. The application saved these data, and Jan received the result in the form of a tabular comparison comparing his data with the average yield values on FADN farms and prices on the local and national market. Jan observed that his yield was lower. He noticed, however, that the graph and table present an additional value - precipitation in its location presented in averaged form for individual months of the year. He decided to analyze the situation, but he was still sure that his farm could prosper in the current weather conditions. Therefore, he decided to seek information from Adviser, which he could change or improve.

3. **FADN user, wants to compare individual report with the group**

The farmer receives an individual report on FADN accounting, he is specified in terms of the size and economic type of the farm. Thanks to these baseline data, it can compare with the data from the FADN Database, specifying exactly the parameters that the farmer would like to pay attention to (e.g. income, costs, productivity ...) Thanks to the compatibility of the database and the report, user can precisely compare the data.

The decision support system in the pilot 2.4 will be based on the eDWIN system designed under another project. Its main functionalities will be:

- Calculation of the economic size of the farm on the basis of dedicated algorithms and instructions,
- Presentation of graphs showing the current and historical state of affairs for farms of similar economic size,
- Presentation of information on prices of agricultural products and agricultural materials needed for production in subsequent years; support for decision on the place of purchase (reference to the lowest or average market prices)

4.7.3 Expected Benefits

Facilitation of farm management at various levels of production volumes and types is expected to help with decision making for farmers by using a broad spectrum of data. This will also improve farmers' access to comparable data from his own farm with others. Data will be aggregated at the farm advisory system level. All activities are also aimed at increasing the knowledge of farmers and accessibility of digital skills.

4.7.4 The pilots approach

Provision of a simple to use benchmarking system that would allow 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).

Table 7: Overview of the identified stakeholders and interests for Pilot 2.4

Number #	Name (function)	Internal or External?	Role (short description)
01	WODR	internal	government entities service advisors
02	PSNC	internal	supplier of hardware and IT solutions for farmers and advisory centers
03	IERiGZ (The Institute of Agricultural and Food Economics)	internal	service advisors, other: research institute, benchmarking models
04	farmers	internal and external	costumer for benchmarking platform tester end user

Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

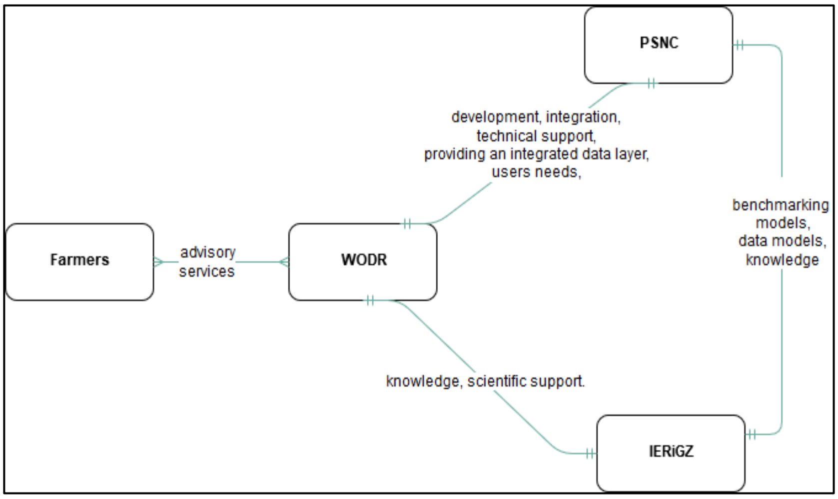


Figure 24: Diagram showing the relationships between the stakeholders

4.7.5 Usage of DEMETER components

Agricultural Information Model (AIM)

Now we have 3 areas: FADN EU and polish data model (at now work on EU data structure model) , FMS (eDWIN Virtual Farm) data model to be used in Demeter - it is now what we are working about - to implementation is AIM in data collection component. Third topic is implementing a data model in eODR (advisory platform) for market information modules that we produced so far.

Semantic Interop/Mappings to AIM

Integrating elements of pilot 2.4 with DEMETER enablers (namely Benchmarking Enabler among others) requires representing necessary objects by using AIM models. Mapping of objects such as field description: crop type and subtype, area cultivated, geographical representation to AIM is expected.

Data Security & Privacy

- Early integration. Data preparation & integration
- Planned to implement in round 2.

Data quality

WP3 access and security enablers, DEMETER Enabler Hub. Components are prepared for integration on an ongoing basis together with the parallel eDWIN project and the integration of individual components, microservices and applications.

Using a separate, dedicated Red Hat Keycloak authentication and authorization solution, instead of a building tightly integrated in-house solution in the eDWIN Virtual Farm app, allows to easily customize authentication and authorization to the needs of the application. This approach increases the overall security of the system by separating the security domain of the single sign-on service in eDWIN (eDWIN-SSO) from the security areas of individual eDWIN applications or the Virtual Farm itself, as well as the use of authentication and authorization mechanisms based on standards such as SAML v2.0, OpenID Connect v1. 0 and OAuth v2.0. In addition, it provides applications with a set of pre-built features such as identity brokerage, integration with social identity providers, two-step verification (2FA), or even a detailed authorization framework. The following example (Figure 25 and Figure 26) shows the flexibility of this approach:

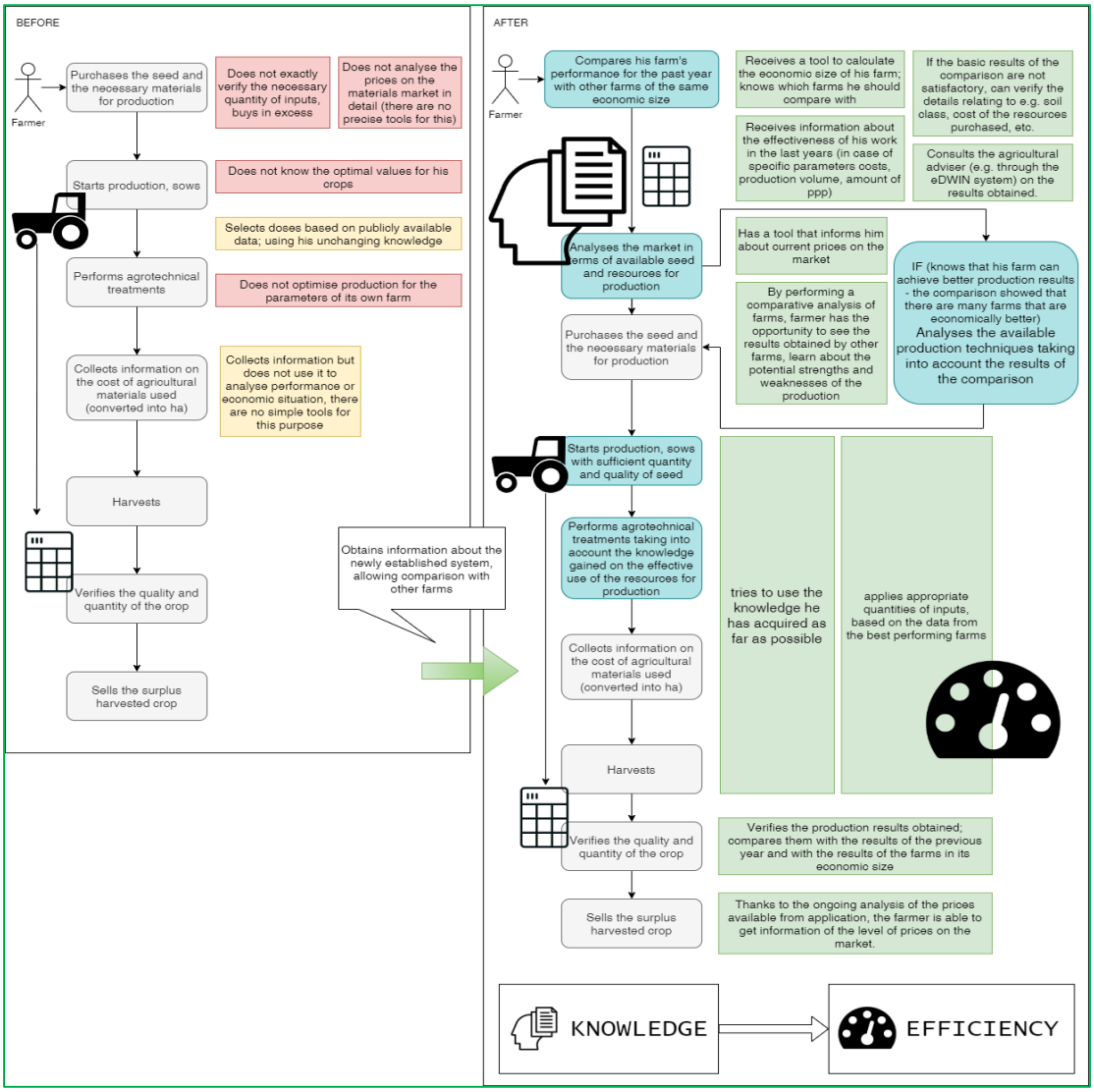


Figure 25: Before and after DEMETER showing the expected impact

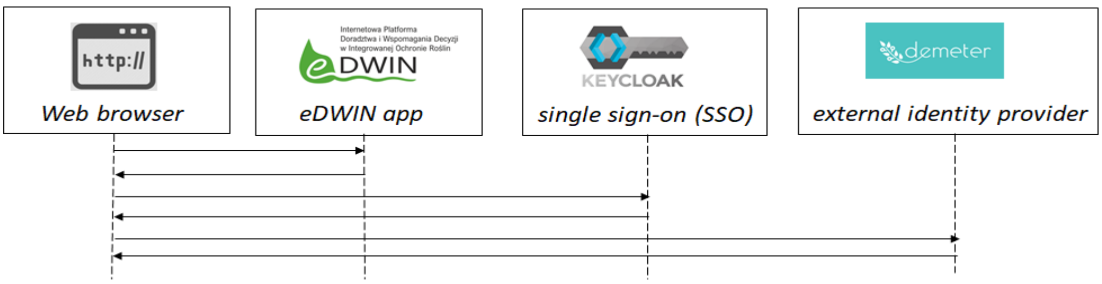


Figure 26: Connectivity of different compartments

The architecture of the system enables the use of the existing authenticationand authorization system to which all components of the created application that require security will be connected. Such a service, called an identity provider (IdP), was implemented in the eDWIN project, allowing the authorization of users who already have an identity in the DEMETER space.

Field Book (also case of eDWIN platform)

This component is currently implemented in new eDWIN advisory platform (march 2021 – pre beta test phase), after that it will be integrated with Demeter.

3 benchmarking models as shared pilot enablers

The models are in pre-implementation state. For operational preparation of models it is necessary to connect and collect many sources and data sets. The current state is: EU FADN - done, local FADN - in progress, eDWIN DSS components - in progres (external project), meteo database - nearly ready to integrate with Demeter pilot, tool for farm internal data collection - for advisors - done in beta version, for farmers - to be done. For market information: local market - component for advisors in progress, other sources to be done.

The three models are:

1. **Calculation of the economic size of the farm:**

Input: number of ha of the fields, number of animals, type of productions, yearly income, profits,

Output: economic size of the farm,

2. **Farm management decision support of the current and historical state of affairs for farms of similar economic size:**

Input: economical of technological parameters to benchmark compatible with agriculture information model, year, date range, region, economic size of the farm, FADN datesets, meteo datasets, technological DSS from eDWIN component outputs,

Output: current and historical state of the farm - dataset and dashboard,

3. **farm management decision support on market information prices of agricultural products and agricultural materials needed for production in subsequent years:**

Input: product parameters to benchmark compatible with agriculture information model, year, date range, region, economic size of the farm, ma

Output: current and historical state of the market state for the product - dataset and dashboard.

Pilot Software Components:

1. **Farm data collection tool - advisors component**

This component consists of few views accessible from an advisor's position. Tool is integrated inside the eDWIN project. Advisor has a possibility of introducing incurred costs in various categories for farmers assigned to him. Whole operation starts in a farmer selection view, which includes a list of names of farmers who are assigned to the logged in advisor. After selection of a farmer, the advisor needs to enter a desired category of costs. List of available categories is based on FADN apportionment. Next view shown after entering the chosen category consists of a list of already added costs and a row designed for introducing new costs. Default view shows costs grouped by certain subcategories, however seeing detailed history of added costs is also possible, simply by switching tab from "General view" to "Detailed view". Inside it, the advisor can see a whole history of costs added to the current farmer's profile in the chosen category, edit and delete each entry.

2. **Market data collection tool - advisors component**

This component is supposed to let advisors introduce prices on local markets for each product produced by farmers. Categories in which advisors introduce prices do not necessarily differ on a list of products but also on additional characteristics of buyers which may influence price of a product, like a daily trading volume. Although this tool is not yet ready for use, it is in an advanced development stage.

Market data integration components:

1. **FADN data integration component**

The FADN data for Pilot 2.4 is necessary to provide all product related vocabularies with which the Demeter modules will produce aggregated comparative data. Data in the eODR system will be collected based on the definition of dictionaries derived from FADN. Data will then be aggregated based on the same dictionaries. FADN data structure and data model has been included into the AIM.

In that case it will be also based on the same dictionary, will be readable by other entities. A mechanism providing linked-data will be used to read the FADN data (using AIM enablers) on the eODR application side and the Virtual Farm.

2. Farm Management information tool – farmers component

This component is being implemented as a part of Virtual Farm FMS produced in eDWIN project. At this moment (march 2021) it is in pre-beta test version. When the Virtual Farm application interface will be finished (may 2021) the benchmarking component will be developed. Now it is in the mockup phase.

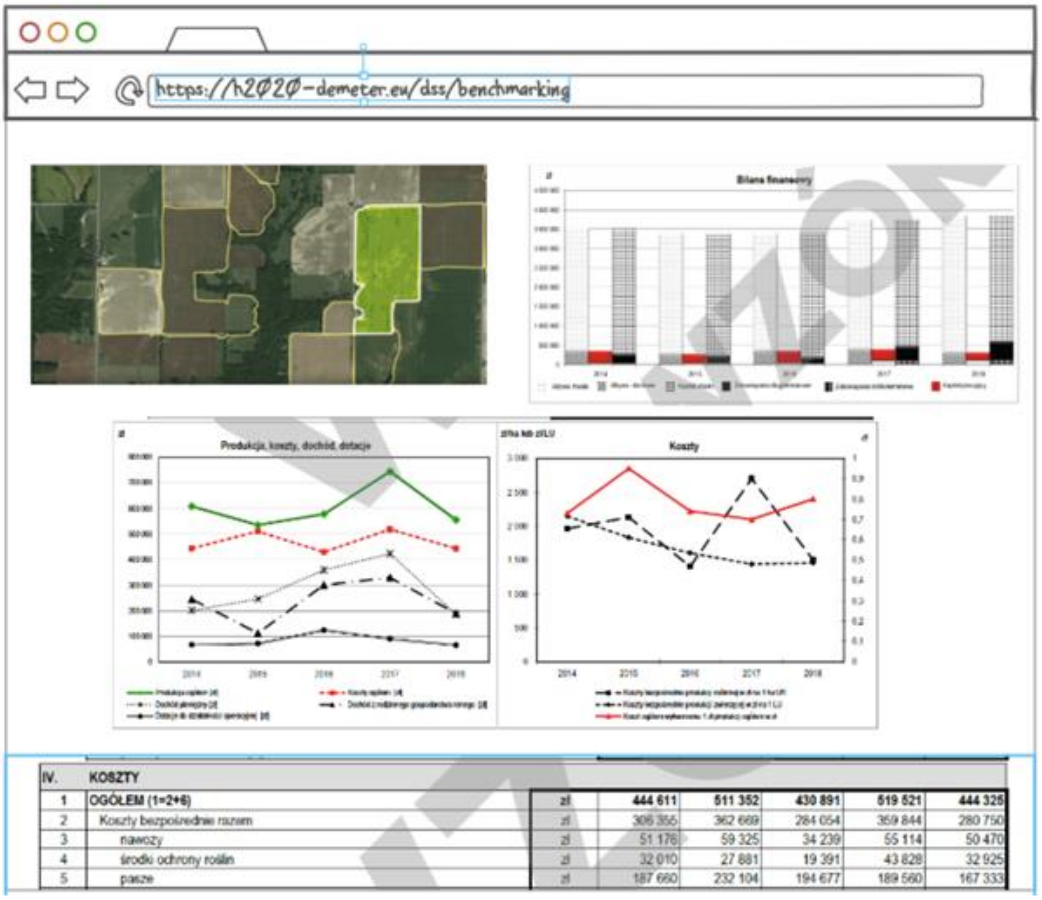


Figure 27: Overview – environment for algorithm development and web application front-end for benchmarking

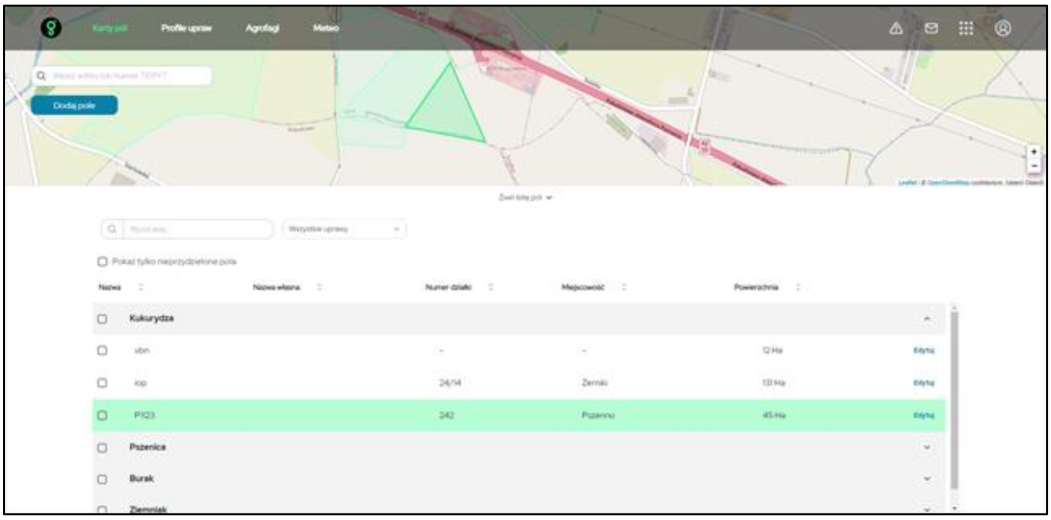


Figure 28: Overview of the eDWIN Virtual Farm beta test interfase

3 benchmarking model – enablers

Described above

eDWIN integration components – integration with advisory platform

Systems produced in Pilot 2.4 are being integrated with a platform implemented in the eDWIN project. While the eDWIN platform is currently intended to be used by farmers for plant protection, the long-term plan is for the eDWIN project's application to cover an increasingly wide range of agricultural areas. The platform consists of a number of applications dedicated to farmers, advisors, but also other actors who may be interested in using the data produced within eDWIN.

The topics to be covered by eDWIN applications will, as mentioned, primarily related to plant protection but also, in future, to i.e. fertilisation or just statistical information about the farms. This last assumed functionality is provided by modules designed and implemented within the DEMETER Pilot 2.4 (described in above paragraph).

Integration of the systems produced under pilot 2.4 and the eDWIN project consists in building the DEMETER farm data collection module into the application intended for advisors. The data that is collected within this module finally will be processed by designed benchmarking models and then, as aggregated data, can be sent to farmers who will gain the possibility to directly compare themselves based on the data collected in the system dedicated to them. Data for the benchmarking process will also be collected from other modules integrated in the eDWIN platform. Market data, that is collected through the eODR system, while all benchmarking and comparisons will be performed in a separate service dedicated to aggregation calculations. The location of the integration is shown in the following summarised architecture diagram.

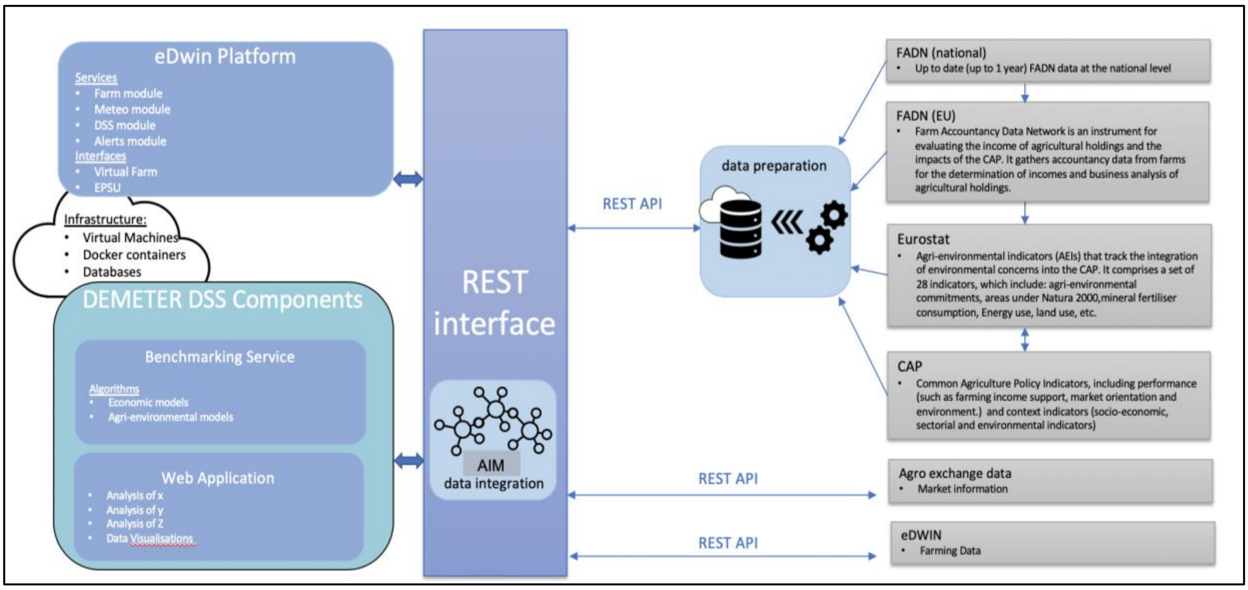


Figure 29: Deployment testbed of the pilot

4.8 Pilot 3.1 - Decision Support System to Support Olive Growers

The efficient management of olive orchards requires complex decision-making processes because of the uncertainty and risk associated with olive fruit and olive oil production – due to weather conditions, soil variability and pest infestations. In this sense, Decision Support System (DSS) and modelling may contribute to ameliorate on-farm agronomic management and decision process, predicting the likely occurrences of specific crop-related attributes in advance. The quality of decision making plays an important role, even in uncertain situations. Despite DSSs may help farmers in implementing climate smart agricultural practices and resource optimization, their use among olive growers is limited due to the lack of user-friendly interfaces and easy-to-interpret outcomes. The aim of this pilot is to develop and demonstrate a DSS for olive growers, advisors and agri-food processors to address common issues associated with olive tree growing and olive oil production, including fertilisation, irrigation and integrated pest management. The DSS will integrate a farm management information system, a modelling platform to support agronomic practices, in-field and remotely sensed data, combining weather patterns and soil information with crop traits, to foster the sustainable production of olive orchards.

4.8.1 Use case specific requirements

Agricolus Oliwes is providing a cloud ecosystem to support olive growers, agronomists, agri-food processors and other agricultural operators in optimizing agronomic practices with the most modern technologies of data collection, analysis and visualization, combined in a user-friendly interface. The functional characteristics of Agricolus Oliwes platform are divided in the following areas:

Farm management information system (FMIS): tools for the governance of the farm including the management of farm centers and fields, integration of agro-meteorological data from different providers, recording of field operations and work assignments, shown in Figure 30.

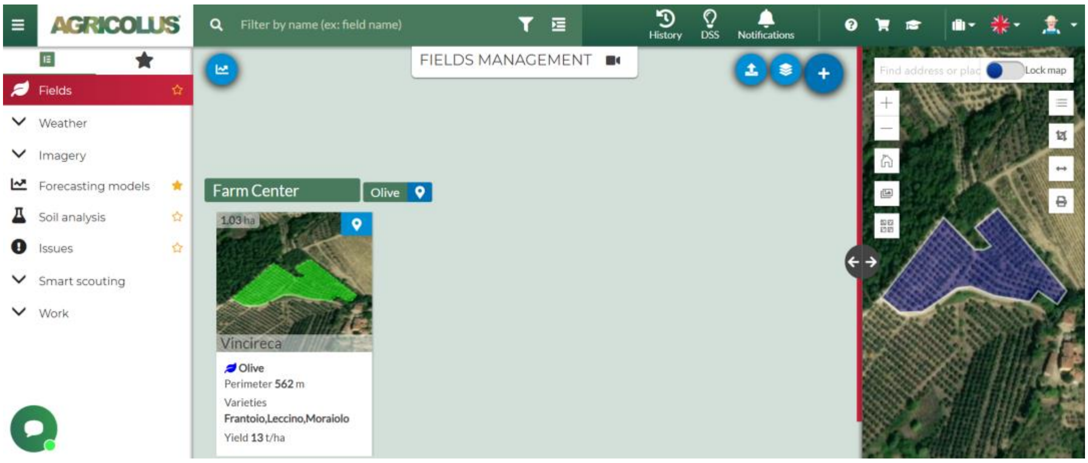


Figure 30 Farm and field management section

Smart scouting support: tools to enter and register geolocalized data about observation on traps and pest catches, pests and diseases, crop damages and crop phenology. The tools are also available in a mobile app to record the results of observation directly in the field.

Models: this section includes (i) integrated pest management models for the estimation of the risk of olive fly infestation according to the weather conditions, (ii) olive tree phenology model to simulate the development during the season, (iii) water balance model to determine the irrigation requirements and to guide the farmers to optimize the use of water (see Figure 31), (iv) fertilisation model to assess macro-nutrients needs of the olive orchard and optimize the use of external input (See Figure 32)

Remote sensing: analysis and elaboration of remotely sensed data to visualize and compare vigour indices, chlorophyll indices and water stress indices.

Decision Support System: dashboard for the visualization of the whole framework, structured in decisions to be taken for pest control, irrigation, and fertilization.

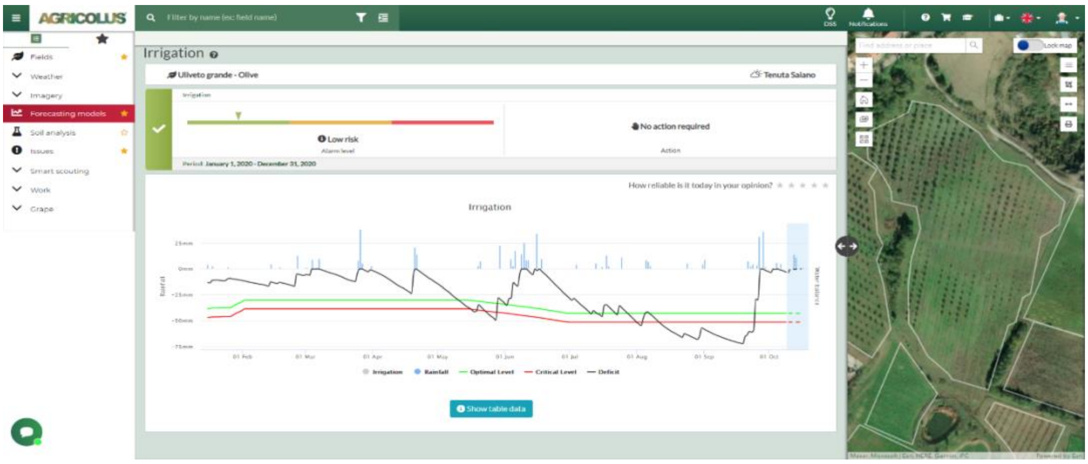


Figure 31 Water balance model supporting irrigation scheduling in Agricolus Oliwes, section forecasting models.

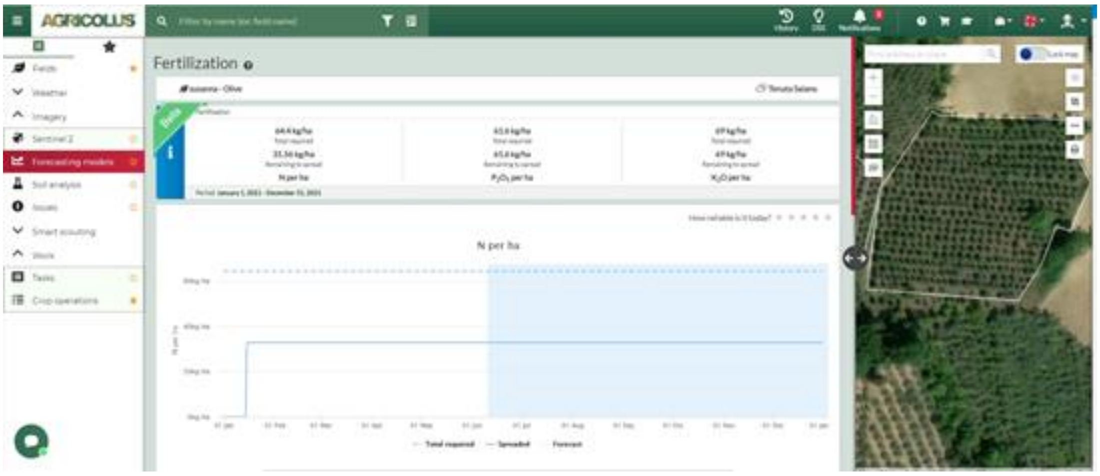


Figure 32 Nutrients balance model supporting fertilization scheduling in Agricolus Oliwes, section forecasting models.

4.8.2 Envisioned Scenario

DEMETER will increase interoperability of the existing and used components and allow the integration of Agricolus Oliwes with other solutions and technologies provided by other partners. In addition, DEMETER will impact Agricolus capability of integration, inducing benefits not only in Agricolus Oliwes, but also on Agricolus ecosystem. This will foster the adoption of data coming from different sources (field sensors, open source weather data, open spatial data, IoT devices) to deploy integrated data-model solutions to be tested in the pilot. Field-specific model and sensor data can be processed and integrated in the platform to deliver tailored advices to farmers and advisors on irrigation and fertilization requirements and scheduling, as well as integrated pest management. 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, through the adoption of technology-based solutions to finely determine olive orchard needs, with the aim of achieving sustainable production targets.

Benchmarking components developed within DEMETER will be tested in the farms engaged in the pilot about their agronomic, environmental and economic performance. In particular, DEMETER benchmarking components address three types of comparison: generic (requiring a minimum set of data), neighbour and technology benchmarking to help farmers and stakeholders in evaluating the impact of a technology.

FMIS of Agricolus Oliwes allows the registration of data during the season such as of crop yield, operations, amount and type of fertilizer used in each field, volume of water used for irrigation, pesticide use, other farm economic data, required for benchmarking purpose.

Figure 33: Before and after DEMETER components implementation

4.8.3 Expected Benefits

The expected benefits to the olive growing delivered by the outcomes of this pilot meet the requirements of farmers and advisors about the optimization of the use of external inputs, thus protecting farm profit and the environment. In particular, the DSS will guide farmers in (i) taking data driven decisions about irrigation and fertilisation, boosting their efficiency and meeting the requirements of external input optimization; (ii) applying integrated pest management strategies (i.e., the use of forecasting models and pest monitoring) to promote preventive measures in crop protection thus reducing the probability of fruit damage and increase the quality of the production; (iii) support long term data record at the farm scale to be used for time series analysis and provide tailored advice; (iv) comparing farm performance (in agronomic, environmental, economic sustainability) and learning from comparison, in order to improve and ameliorate behaviour and working activities.

Benefits are measured comparing farm performance through agri-environmental and economic indicators integrated in the benchmarking components supporting the evaluation of the farm performance respect other similar farms and after technologies adoption.

In comparing indicators, for instance, the volume of irrigation water per season, before and after the adoption of a technology (e.g., water balance model), it is important to outline that crop water requirements may vary a lot according to year weather conditions. Following are listed Key Performance Indicators (KPI) to measure the benefits:

- Number of involved farms that have accessed the system and used the DSS;
- Volume of irrigation water used per year (m^3 ha^{-1});
- Amount of Nitrogen used for fertilisation per year (kg ha^{-1});
- Average yield (ton ha^{-1}).

4.8.4 The pilots approach

The pilot aims to deploy and configure Agricolus Oliwes in selected olive farms of two countries to address different climatic and farming conditions: Italy and Greece. In Italy, four small-medium farms have been engaged: one in the North (Emilia-Romagna region), two in the Center (Tuscany and Marche region) and one in the South (Puglia region). In Greece, 15 small organic farms located in Crete island belonging to Agroecologiki association have been engaged as well as the association advisors. Private or public agrometorological stations have been connected to Agricolus Oliwes to properly run the model with real time local data. Private accounts to Agricolus Oliwes have been created for all farms and advisors, training sessions for the use of the platform have been held at the beginning of 2020 and 2021 season. The farmers are using the DSS, populating the FMIS with their data. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.8.5 Usage of DEMETER components

The DEMETER components installed or being installed are: (i) Agricultural Information Model (AIM), Data security & Privacy from WP2; (ii) Brokerage Service Environment (BSE), DEMETER Enabler Hub (DEH), Access Control Server (ACS), Security Core Enabler from WP3; (iii) Indicator Engine for Benchmarking Purpose, Generic Farm Comparison, Plant Phenology Estimation, Estimate temperature-related events, Technology benchmarking from WP4.

4.9 Pilot 3.2 - Precision Farming for Mediterranean Woody Crops

Mediterranean Woody Crops have been severally affected by several challenges such as climate change (water scarcity), pests and diseases. Most of the farms specialising in these crops are small, low on profit and technology, and face high labour costs. Furthermore, Mediterranean Woody Crops owned by medium/small farmers have limited access to technology, due to the associated costs, and the low levels of systems interoperability. These farmers need simple, intuitive, and cost-effective technologies to help them overcome the challenges outlined and become more profitable by maximising the use of smart and precision agriculture.

This pilot aims at promoting technology, methods and IoT solutions to optimise precision farming practices of Mediterranean Woody Crops (Apple, Olive and Grape), considering the small farmers' economic constraints. The proposed solutions (IoT and Ground Robots) will enable a more efficient usage of inputs such as water, energy, macro-nutrients, and pesticides, thus increasing the profits of small farmers and reducing their environmental impact.

4.9.1 Use case specific requirements

On the farmer side, the most common technological solution found in Mediterranean Woody Crops are weather stations and soil sensors, and irrigation controllers. These sensors and controllers can supply relevant information to the farmer, however:

1) These systems are not able to supply information about crop state (e.g. Leaf Area Index, Normalized Vegetation Index), diseases and pests (e.g. digitalization of chromotropic traps, bugs growing), and yield prediction (e.g. count the number of tree fruits and their grow), neither to be expanded with optical sensors. There is a strong requirement to consider optical sensors on static spots and on top of machinery to collect information that cannot be collected by remote sensing.
2) These systems are closed solutions that do not share software or hardware elements, which limit their possibilities of modification or extension. In addition, these systems are subject to strong wear and tear with about ten years of useful life. Due to these limitations, only gradual renewal of the systems is possible. Often only identical equipment can be used, which has increasingly negative economic repercussions, e.g. when the original supplier no longer exists.

On the technological requirements side, pilot 3.2 we will deploy AgIoT and AgRobotics based solutions. AgIoT and AgRobotics provides cost effective IoT and Robotics solutions to collect in-situ data and to apply variable rate technology concepts to existing machinery. However:

1) These optical based solutions provide a huge amount of data and requires large bandwidth communication solutions and data storage. This requires that at communication level to use 4G, WiFi and Ethernet based infrastructures.
2) This optical solution can provide more detailed information about the crop but will require ground-truth data and advanced processing components (based in AI techniques).
3) Besides, these AgIoT and AgRobotics solutions requires bidirectional communication for self-configuration and for soft real time adjustments, this may impact on AIM and DEMETER middleware developments.

4.9.2 Envisioned Scenario

DEMETER will allow the integration with other partners' technologies and solutions. This will allow the acquisition of data from different sources (i.e. infield IoT devices, weather services, satellite imagery, etc.) to deploy different solutions to be tested in the pilot.

DEMETER Pilot 3.2 will increase interoperability of the existing and used components and allow the integration of AgIoT with other solutions and technologies provided by other partners. In addition, DEMETER will enable to increase the TRL's levels of AgIoT and AgRobotics ecosystem.

Figure 34: AgIoT and AgRobotics deployed at pilot 3.2

These solutions, installed in static spot, on tractor and on robots, will acquire optical and in-situ information about crops pests, grow and yield at low cost. This will foster the adoption of data coming from different sources (field sensors, machinery sensors, open-source weather data, open spatial data, IoT devices) to deploy integrated data-model solutions to be tested in the pilot.

The from this data, we will reach enhanced yield model solution to give tailored advice to farmers for the optimization of field management practices (optimal harvest date, right time for pests treatments, variable rate soil treatment, variable rate fertilization, irrigation advice).

4.9.3 Expected Benefits

This pilot expects to gain better insights on:

- the use of optical sensors and robotics to collect information about crop, meteo, soil parameters and field management practices, and their impact on the final yield;
- the use of Modular Variable Rate Technology for precision application; and,
- to provide advice to farmers on how to optimize their current field practices in order to increase their yields in a sustainable way.

This should contribute to the increased uptake of precision agriculture techniques, which should lead to higher yields and lower environmental impacts. To measure the pilot's contribution to reaching these goals, the following Key Performance Indicators have been defined:

- Pest and Diseases early detection and chemical products use reduction,
- Variable rate fertilization: Amount of fertilizer used,
- Variable rate irrigation: Amount of water used for irrigation
- Average yield (ton/ha)
- Accuracy of predicted yields

Sharing data, that will be promoted by a Portuguese Datacenter (placed at INIAV and INESC TEC servers), in a controlled way is essential when developing applications for farmers. The number of stakeholders linked to measured yield data, or number of applications developed using measured yield data as input are Key Performance indicators that can be used to measure progress at the level of data sharing.

4.9.4 The pilots approach

The pilot aims to support better knowledge about Mediterranean woody crops grow and diseases and improve solutions for pest management and fertilization practices such as about pesticide and fertilization application, by using cost effective IoT solutions and Robotics and upgrading conventional technology and machinery. AgIoT is the INESC TEC IoT solution that collects data from static spots and from the field machinery and robots using 4G, LoRa and WiFi communication and makes the data available to Portuguese DEMETER Cloud.

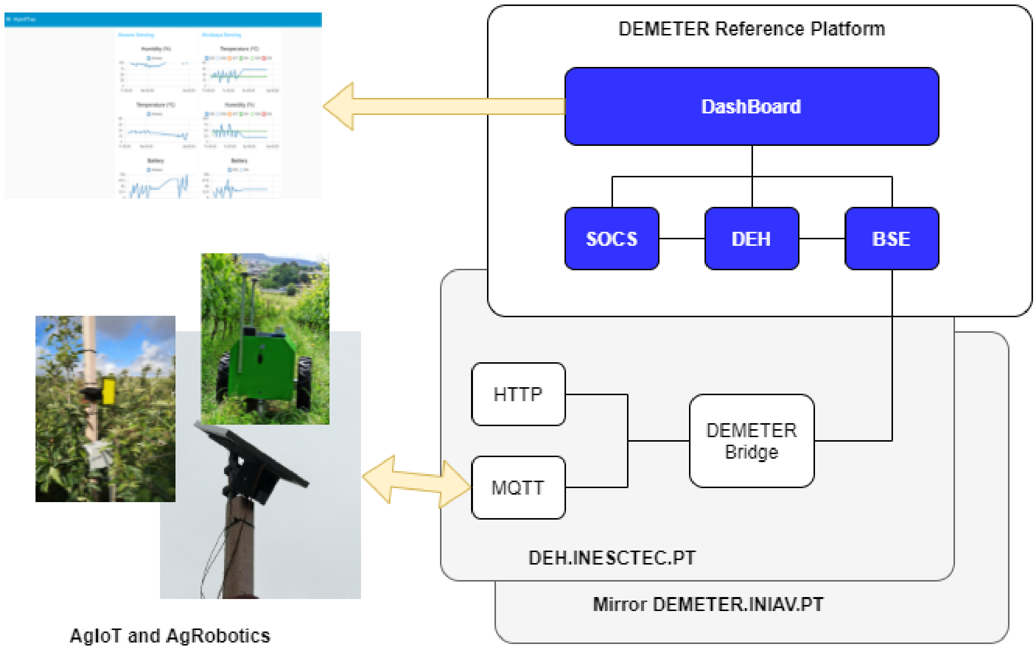


Figure 35: Envisioned deployment of DEMETER components for pilot 3.2

In this pilot, data from AgIOT and AgRobotics deployed in the Portuguese DEMETER Pilot cloud will be made accessible in AIM format (Agricultural Information Model) through DEMETER components to develop data-driven yield and pests prediction models using Machine Learning. This task will be closely linked to the developments on AI-based decision making from DEMETER WP 4. The enhanced crop status, pests and diseases and yield prediction models will help to give specific advice to farmers on how to optimize field management practices, e.g. by offering variable rate task maps. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.9.5 Usage of DEMETER components

The DEMETER components installed in Pilot 3.2 data cloud being installed are:

- Agricultural Information Model (AIM),
- Data security & Privacy from WP2,
- Brokerage Service Environment (BSE),
- DEMETER Enabler Hub (DEH),

- Access Control Server (ACS) Security Core Enabler from WP3
- Indicator Engine for Benchmarking Purpose,
- Generic Farm Comparison,
- Plant Phenology Estimation,
- Estimate temperature-related events,

Finally, the pilot is using components developed in WP4, such as the:

- Plant yield estimation (4.A.1)
- Plant Phenology Estimation (4.A.2)
- Variable Rate Applications (4.D.3)
- Weather information (2.C.2.b)
- Water Balance featuring (4.B.2)
- Nitrogen Balance Model (4.C.1)

The final end users will be able to access the components through Knowage and NODERED. Knowage will also be used to visualize the results. These components will be installed in two Portuguese servers at INIAV and INESCTEC facilities.

4.10 Pilot 3.3 - Pest Management Control on Fruit Fly

This pilot aims at providing a set of tools to monitor and manage the Mediterranean fruit fly (Ceratitis capitata) which is dangerous pest with a wide range of distribution and host plants. Automatic capture traps and remote sensing technologies will be employed to predict and support in taking decision and tested in citrus farms in Valencia region. The pilot is being deployed in Valencian Community region with more than 170.000 hectares involved.

4.10.1 Envisioned Scenario

The Ministry of Agriculture in the Valencian Community has a network composed of 938 Nadel traps that are reviewed weekly. Nadel traps consist of a white container in which a male sex attractant and an insecticide pill are introduced. Adults fall into the trap, are captured and die. The monitored citrus area covers more than 170,000 Hectares, so there is a work team composed of seven field inspectors who review the traps weekly. All the collected catches are sent to the Evolutionary of Moncada (Valencia), where two laboratory assistants identify and count the wild and sterile flies.

In addition to knowing the population levels throughout the year, the General Monitoring Network serves to evaluate the proper functioning of the Sterile Insect Technique Program, which runs in the Valencian Community. In this program, sterile flies are set free in the citrus zone by means of small planes and later their dispersion, longevity and proportion are evaluated through the recaptures obtained in the Monitoring Network. Also, it would be very important to know the information about the maximum activity of flies during the year and depending on the latitude, altitude and climatic conditions in order to define sterile male liberation as it must coincide with the moment of maximum activity of the fly in the field.

The development of automatic counting traps would allow a high reduction in workers and vehicle costs. It would also allow a better monitoring of the sterile males liberations and therefore a better design of the liberation strategy, and a general improvement in the results of the pilot.

It is important to research in the methodology and technologies used for the *C. capitata* monitoring as the last significant changes have been the introduction of the use of the GIS and the databases for effective information management. The sterile fly is easily identifiable thanks to the color emitted by fluorescein when it is illuminated with ultraviolet light. The inclusion of a sensor to detect such coloration could allow the sterile flies identification in the field. This technology could also be used for routine laboratory quality controls or for other species such as the tiger mosquito (Aedes albopictus).

On the other hand, by means of a modification in the design of the trap, a trap version without an insecticide tablet can be made so that adults can be captured but do not die. In this sense, the flies could be analyzed for quality controls (longevity, copulation competitiveness ...).

In DEMETER different technologies can be studied and investigated as infrared LED sensors, meteorological data sensors, facilities for power supplies of the traps, integrated GPS receivers, facilities for automatic collection and emission of data, weatherproof materials, etc.

The smart pest management application decides on the best places to install the traps, and optimal areas for sterile fly releases. In this way, the different traps catch different flies taking real time photos that will be sent to the automatic insect recognition system. Based on the data obtained, decisions will be made about the number and location of sterile flies to be released.

Also, it will be possible to visualize historical data related to the fly classification performed by the automatic detection system (see Figure 36).

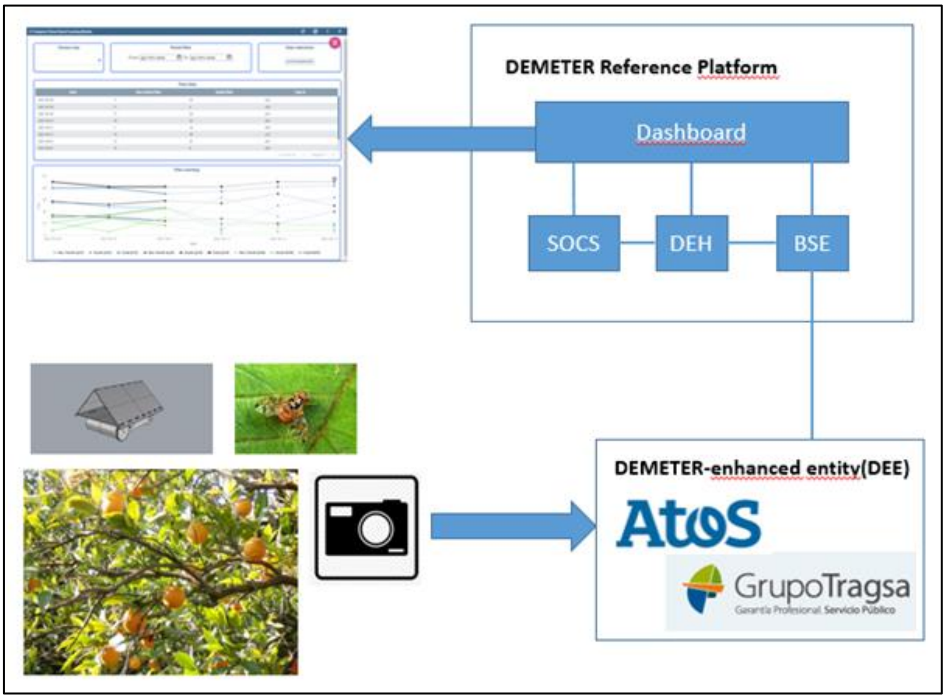


Figure 36: Envisioned deployment of DEMETER components for pilot 3.3

4.10.2 Expected Benefits

The pilot aims to support better knowledge about Mediterranean fruit fly and improve solutions for plague management practices such as about pesticide and fertilization application, by using cost effective IoT solutions and upgrading conventional technology and systems.

Firstly, an initial definition of the pilot and a market study of the trap to be installed in the citrus groves was carried out, taking into account its technical and functional characteristics as well as its cost. Secondly, an advanced image recognition software has been developed, based on computing learning, which allows an automatic counting of sterile and wild flies from the photos taken in the traps installed in the field. This software is integrated with the DEMETER ecosystem core enablers and will allow the deployment of services in the pilot testing phase.

Once round 1 is being finished, an evaluation of the results obtained will be supported in order to optimize them in the next round 2, where improvements and visualization systems will be implemented in order to obtain conclusions based on the solutions.

4.10.3 The pilots approach

Tragsa has been entrusted with the monitoring of the Mediterranean fruit fly C. capitata by the Department of Agriculture in the Valencian Community. This assignment includes monitoring by means of a network of 938 Nadel traps that are checked weekly. Nadel traps consist of a white container in which a male sex attractant and an insecticide tablet are placed. Adults fall into the trap and are trapped and killed.

The citrus area monitored covers more than 170.000 hectares, which means that there is a work team composed of 7 field inspectors who check the traps on a weekly basis. All the collected captures are sent to the Evolutionary of Moncada (Valencia), where two laboratory assistants identify and count the wild and sterile flies.

In addition to knowing the population levels throughout the year, the General Monitoring Network is used to evaluate the correct operative of the Sterile Insect Technique (SIT) Program, which has been implemented in the Valencian Community since 2007. In this program, sterile flies are released in the citrus-growing area by means of light aircraft and, through the recaptures obtained in the Monitoring Network, their dispersion, longevity and proportion of sterile flies with respect to the wild population are evaluated. However, sterile flies are released three times a week in the same citrus-growing area, so that weekly counts do not allow adequate traceability of the quality parameters of each flight (in which 12 million flies are released), since the captures correspond to more than one release.

Likewise, obtaining weekly information on the population dynamics of C. capitata prevents us from knowing its peak activity times. This information varies throughout the year depending on latitude, altitude and climatic conditions, and its knowledge is of vital importance to define the release strategy of sterile males, since the release must coincide with the time of maximum activity of the fly in the field. The development of automatic counting traps would allow a high reduction in labour and vehicle costs, as well as a significant reduction in the carbon footprint since each field inspector travels an average of 1.200 km per week. It would also allow a better monitoring of sterile male releases and therefore a better design of the release strategy. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.10.4 Usage of DEMETER components

Next, there is a list with a brief description of the implemented DEMETER Pilot Software Components (DEMETER Enhanced Enablers).

Table 8: Usage of DEMETER components in Pilot 3.3

Requirement	Description
Pattern Extraction with Computer Vision	This component, developed in WP2, aims to detect patterns inside of pictures, using as a base a pre-trained model. Users can create their own model (that depends on the quality and size of a labelled image dataset to train the model) or can reuse an existing one coming from the MLFLOW framework. The input and output data are based in the AIM format. The component is deployed within a docker container and is needed by other components that need pattern extraction capabilities in order to work properly (i.e. Pest Estimation with Sterile Fruit Flies component described below).
Pest Estimation with Sterile Fruit Flies	The objective of this component, developed in WP4, is detecting the amount of sterile/normal fruit flies inside of traps able to take pictures of the captured specimens. The component uses the "Pattern Extraction with Computer Vision" component to detect the amount of flies inside of such images,

	stores the data collected in a database and can give an estimation of the near-future captures (in a daily estimation). The component is deployed within a docker container and uses the AIM format.

4.11 Pilot 3.4 - Open Platform for Improved Crop Monitoring in Potato Farms

One of the biggest challenges for farmers is to increase production using fewer resources while at the same time reducing negative environmental consequences. Precision agriculture technologies offer promising solutions but in practice, the uptake is still rather low in Europe. Key factors that could stimulate the uptake are (i) the availability of connected machinery for variable rate planting, fertilization, spraying, irrigation and harvesting whereby data are exchanged with DSS in an automated and standardized way and (ii) DSS that provide actionable advice to farmers on how to optimize field management practices. However, to develop these DSS, massive amounts of field data are needed, data collected by farmers. For farmers to share their data, the farmers need to get a leading role in controlling access to and use of the data from their farms. This should ensure that the data are used to their benefits.

This Pilot aims at integrating field machinery data with remote sensing, meteo and soil data into the WatchITgrow (WIG, watchitgrow.be) platform for crop monitoring. 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 and predict yields. The in-field data could allow the development of a purely data-driven model instead of fine-tuning 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).

4.11.1 Use case specific requirements

In the base scenario WatchITgrow uses remote sensing data from 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 to needs to be manually fine-tuned for every species and variety, using a limited set of ground truth data. This lack of sufficient ground truth data like 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.

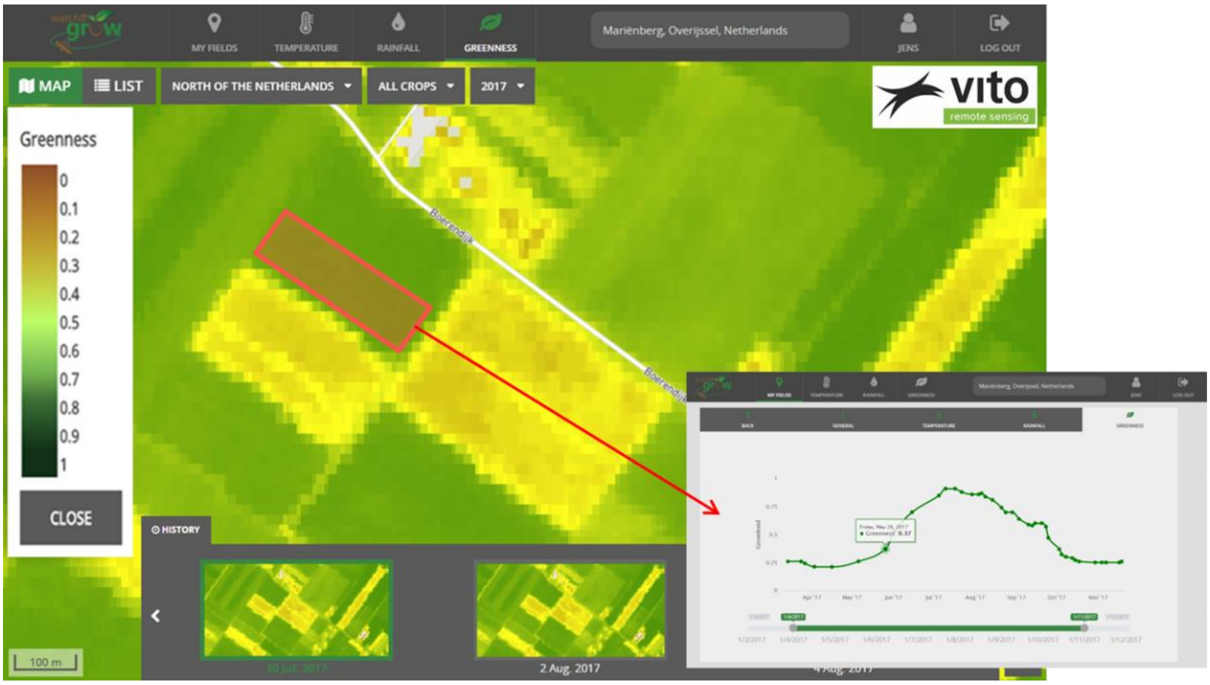


Figure 37: WatchItGrow web application for visualization of Satellite data and crop growth data

4.11.2 Envisioned Scenario

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. The enhanced yield model will be embedded in the WatchITgrow platform to give tailored advice to farmers for the optimization of field management practices (optimal harvest date, variable rate haulm killing, variable rate fertilization, irrigation advice).

Figure 38: AVR Puma 4.0 potato harvester with GPRS/4G data connection

4.11.3 Expected Benefits

This pilot 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.

This should contribute to the increased uptake of precision agriculture techniques, which should lead to higher yields and lower environmental impacts.

To measure the pilot's contribution to reaching these goals, the following Key Performance Indicators have been defined:

- Number of WIG users with AVR connection: these can be considered as users that are applying precision agriculture techniques in some way
- Variable rate fertilization: Amount of fertilizer used
- Variable rate irrigation: Amount of water used for irrigation
- Variable rate Haulm killing: Amount of haulm killing product used
- Average yield (ton/ha)
- Accuracy of predicted yields

Sharing data in a controlled way is essential when developing applications for farmers. The number of stakeholders linked to measured yield data, or number of applications developed using measured yield data as input are Key Performance indicators that can be used to measure progress at the level of data sharing.

4.11.4 The pilots approach

AVR Connect is the recently started IoT cloud platform that collects data from the field machinery (potato planters, yield sensors on the potato harvesters) using 4G communication, and makes the data available to third parties. Geotagged yield data will be collected at a frequency 1Hz, which leads to very detailed yield maps.

AVR Field machinery data, automatically uploaded to AVR Connect Cloud using 4G:

- Geotagged and timestamped planting data (planting distances)
- Geotagged yield data collected at a frequency of 1Hz using yield sensors on the field machinery

WatchITgrow data:

- Remote Sensing data: NDVI and FAPAR timeseries per field, using a combination of Sentinel-1 SAR data and Sentinel-2 images to create uninterrupted timeseries with daily values, also for cloudy days (VITO "CropSAR" service)
- Soil type from soil type maps for the Flanders region
- Meteo data at 5x5km resolution from the Belgian National meteo service (KMI)
- User input on field activities (crop protection, crop damages, fertilization)

In this pilot, data from both the AVR machinery (potato planters and harvesters) and the WatchITgrow platform will be made accessible in AIM format (Agricultural Information Model) through DEMETER components to develop data-driven yield prediction models using Machine Learning. This task will be closely linked to the developments on AI-based decision making from DEMETER WP 4. The enhanced crop status and yield prediction models will help to give specific advice to farmers on how to optimize field management practices, e.g. by offering variable rate task maps. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.11.5 Usage of DEMETER components

This pilot implements Demeter Enablers from WP2, mainly related to data standardization, such as the Agricultural Information Model (AIM, 2.A.1), including Semantic Interop/Mappings to AIPM (2.A.2), and to Data security & Privacy (2.D) and Data Management (2.B.1).

Further, the following modules / enablers from WP3 are or will be implemented: the Brokerage Service Environment (3.B.1), the Functional Interoperability Core Enablers (3.B.2 – to do), the Access Control

Server (3.D.1), the Security Core Enabler (3.D.2 – to do), the Communication & Networking Core Enabler (3.D.3), the Demeter Enabler Hub (3.E.1) and the DEH Client Core Enabler (3.E.2 – to do).

Finally, the pilot is using components developed in WP4, such as the Plant yield estimation (4.A.1) component or the yield model, which is the core of the pilot, and the Variable Rate Applications (4.D.3) component. The use of the Weather information (2.C.2.b) and/or Water Balance featuring (4.B.2) is considered to be an optional extension to enhance the yield estimation enabler. The final end users will be able to access the components through Knowage. Knowage will also be used to visualize the results.

4.12 Pilot 4.1 - Dairy Farmers Dashboard for the Entire Milk and Meat Production Value Chain

This pilot focuses on a 1) farmer's digital dashboard for a better view/outlook over the farm activities and the farmer's cooperation with both private and public actors, more efficient use of digital tools the farmer applies and better and more customized decision support for each farmer, including 2) decision support based on AI Machine learning from sensor data, and also the possibility to select and configure further components and services into various customie

The focus is primarily on dairy farms but the concept will include all types of farms in Norway.

The main partners in the pilot are as follows:

- **Agricultural Dataflow** - a Norwegian company that develops and maintains standards and infrastructure to streamline central data flows and provide better decision support for farmers and the agricultural industry in Norway.
- **Mimiro** - a Norwegian technology company that works with a data platform and digital solutions for more efficient and environmentally friendly milk and other food production.
- **SINTEF** - a large, independent research institution in Norway with around 2000 employees and 1400 researchers. The institute involved in DEMETER is SINTEF Digital, which provides expertise on the relevant technologies as well as innovation management. **TFoU** - a small research company in Norway with 15 employees in social sciences and expertise in analysing user needs for farmers and other relevant actors in the society, is now a part of SINTEF.

Agricultural Dataflow will provide a Farmer's Dashboard supported by the Agricultural Dataflow platform demonstrating interoperability interfaces for different digital farm systems in the value chain. Agricultural Dataflow will build data infrastructure and models of farmers dashboard in a co-creational process based on the Agricultural Dataflow infrastructure today, specially related to the companies' authentication and authorization systems, with farmers and related partners and industries in Norway. Mimiro is one of these partners.

Mimiro will provide AI-based Prediction systems for milk production using data from sensors on animal milk production and health, collected and provided through the Mimiro data collection platform, where the farmer will own his own data. They will work with the data infrastructure from Agricultural Dataflow and get their own data infrastructure to function and facilitate efficient production of milk and meat. The research partner SINTEF will work with user needs and responses from the farmers to the provided solutions, as well as wider stakeholder involvement, contribute to the exploration of innovation potential and new business models, and assess economic and social benefits for the farmer, the involved partners, the agricultural sector and the society.

Since it will be important to involve many different partners through the support for many different components/decision support services, hopefully both in and outside Norway, the multi actor approach in DEMETER is a preferred tool. The Farmer´s Dashboard environment will be connected to the DEMETER Enabler Hub (DEH) for the selection of components that can be made available and configured through the Farmer´s Dashboard.

All partners in the pilot (Agricultural Dataflow, Mimiro and SINTEF), will have the responsibility of involving other partners/contributors from their respective networks and work fields. Farmers in Norway own both Agricultural Dataflow and Mimiro through the farmer-owned industry. Hence, the two companies are in contact with many of the key stakeholders in Norway, and they will involve these in the pilot. SINTEF will contribute with involvement of farmers/end-users in Norway, evaluate versions of the farmers dashboard, produce easily understandable information from different stages in the pilot and complement existing research of best practices.

- **Standards used:** ISO/IEC AWI 21823 Internet of Things; ISO/IEC 19944:2017 Cloud computing; ISO/IEC 19941:2017 Cloud computing; ISO/IEC AWI 23053 Artificial Intelligence (under development); ISO/IEC 2382, Artificial Intelligence; ISO/IEC 29182, Sensors; Recommendations from AIOTI WG03.
- **Data exploited:** Cow sensor data – feed, temperature, Movement, Milking robot production data, Milk fat, Economic data and other data available through further selected components.

Mimiro will develop digital solutions for more efficient and environmentally friendly food production. Mimiro is also aiming at app support for Norwegian farmers, with easier registration and insight to continuously improve production. At the same time, we are building a digital ecosystem for agriculture, for external suppliers, researchers and advisors. Mimiro's platform already represents a significant user base, as today, active users are existing solutions. Based on TINE and Felleskjøpet, Mimiro is established to take on the company's long-standing experience. Our mandate is to think again with our old history, to develop solutions for tomorrow's agriculture. Mimiro will develop services that make the farmer's data relevant, in completely new ways. The goal is to create agility in agriculture by linking the various players together.

The intention with the farmers dashboard is to create a flexible and customisable farmer´s dashboard that easily can integrate and configure various relevant components and services from the DEMTER ecosystem based on the preferences of each farmer. In addition to being able to use the common interoperability mechanisms of DEMETER it is further also an aim to be able to take advantage of existing user interfaces components from various technology providers – in a way were the investments in user interface development for various components and services can be preserved.

4.12.1 Use case specific requirements

The dataflow for farmers is a big challenge and opportunity for business development in the sector. Today digital solutions for agriculture do not interoperate optimally and are not largely based on the needs of the individual farmer. The farmer has a lot of app's, ICT-programmes, farm management systems, digital solutions and dashboards to cope with and all actors the farmer collaborate with want to have a part of the farmers attention and "clicks/likes/touch". The farmer gets lost in a complex digital landscape and misses essential information and the overall picture for his farm management.

Good forecasting models for milk production are essential to be able to plan and optimize production in terms of economy, animal numbers, milk quality and feed production. Forecasting models must be developed at different aggregated levels from single animals, herd groups, herd level, regional level and national level.

Nevertheless, the starting level is the individual animal and that means you need data from single animals. In Norway a very extensive data material is available through the national herd recording system (NHRC). The NHRC includes individual cow data related to milk performance, milk quality, health, genetics and feed intake. The NHRC covers 98.6% of the Norwegian cow population and 98% of the dairy farms. In the last 15 years there has been a major technological change in Norwegian dairy production and today about 50% of the cows are milked by a milk robot (AMS). Mimiro has developed a data platform that receives daily milk production from the AMS and this means a 80-fold increase in data points compared to today. Further services that the farmer's have expressed a need for in the farmer´s dashboard include a climate calculator (offered by Landbrukets dataflyt), and planning (JD), as well as other relevant services such as weather forecast, soil workability and others.

4.12.2 Envisioned Scenario

Agricultural Dataflow is in the process of designing a "farmers dashboard" that will integrate various stand-alone dashboards, farm management systems, app's and ICT-programs for the farmer in a common framework. The aim for the solution is to:

- present essential decision support for individual farmers and be an entrance to other and more specific farm management systems which the farmers use seeking to optimize their farms productivity.
- streamline the digital everyday life for the farmer and try to get better collaboration between different web-sites, app's, programs etc the farmer uses
- get better interaction between private and public digital interfaces for the farmer

The company also develops a system for data collection, modelling and calculation of greenhouse gas emissions on farm level included in a climate calculator. This tool will also be a part of the overall picture in the farmers dashboard and will be integrated with other farm management systems for optimizing the farm productivity with the Agricultural dataflow infrastructure.

4.12.3 Expected Benefits

DEMETER is expected to contribute in many different ways when it comes to developing knowledge and solutions as what are the main decision variables for each farm and farmer and how can the farmer focus on these variables in respectively a milk prognosis component and one overall dashboard. How to put together each farmer´s «own» dashboard for respectively a milk prognosis and a overall dashboard, and how can we use the technology making these solutions? How to get system suppliers and the partners of the farmers to cooperate and interact sharing data and web-interfaces – competitive and organizational issues? What business models for the milk prognosis component and one overall dashboard can be used and what is the cost-benefit for the farmer, related business and the society?

KPIs are:

- Farmers that try the new milk prediction component will have net economic benefits during the pilot period.
- Farmers that try the new farmers dashboard will have more overview of the total production than other comparable farmers during the pilot period.
- Farmers that try the new farmers dashboard will increase their use of the dataflow, more than other comparable farmers during the pilot period.
- Farm-related organisations will have benefits of milk prediction for planning purposes during the pilot period.
- Farm-related organisations will have benefits of increased dataflow that the new dashboard will generate during the pilot period.
- The society will have positive net benefits, when we sum up cost and benefits for developers and user during the pilot period.

4.12.4 The pilots approach

Mimiro develops products and services based on the optimization and analysis of the farmers data, solutions that are easy to use in the daily life of the farm while providing concrete advice the farmer can act based on, rather than displaying information. And an important principle is fundamental: The farmer owns his own data. Mimiro creates an ecosystem for data that researchers, advisors and external service providers can benefit from. Mimiro will collaborate with anyone who adds data or another user value. Data that the farmer wishes to share anonymously will be available to external suppliers, thus providing better services back to the farmer. Increased data access will strengthen the possibilities for developing effective forecasting models with a higher degree of precision and accuracy. Mimiros experience with the use of ML and AI makes it interesting to use these methodologies in developing the next generation of milk forecast models. The objective of this sub-project is to develop ML based milk forecast models as the basis for a farmer's planning and decision support tools. In the project, conceptual work will also be carried out with farmers to ensure user participation and a high value for the farmer. We will also study how forecasting data can be integrated with other models/applications for economy, feeding and feed production. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.12.5 Usage of DEMETER components

The farmer´s dashboard which is the focis on the 4.1 pilot will use the architecture of the DEMETER platform and infrastructure to support the ease of new components and services into the farmer´s dashboard.

The 4.1 pilot will implement Demeter Enablers from WP2, mainly related to data standardization, such as the Agricultural Information Model (AIM) including mappngs for the milk prediction yield component, with Semantic Interop/Mappings to AIM.

Further, the following modules / enablers from WP3 will be used: the Demeter Enabler Hub (3.E.1)for selecting among available components for the farmer´s dashboar and the DEH Client Core Enabler for resource consumption metrics, the Brokerage Service Environment (BSE) for service registration, discovery and communication with DEMETER-enabled resources, the Functional Interoperability Core Enabler to verify the compatibility in BSE service registration with the BSE model itself. For the Authentication mechanism the Farmer´s Dashboard will use the Norwegian national MyID authentication system based on OAuth2 – the same standard that has been selected also for the DEMETER Authentication services. This will be an interesting opportunity to explore the interoperability feasibility of the DEMETER platform in this area.

Finally, the 4.1 pilot is using components developed in WP4, in particular the Milk production yield prediction component. By using the Mimiro's AI-based Prediction component for milk prediction we had made a web component in react and published it in our dashboard toolkit. In addition the component has been described and enabled in the DEMETER Enabler Hub, and also mapped into AIM. The Farmer´s Dashboard architecture is based on use of Micro front-end technologies, in particular with the use of the Web components micro frontend technology, as a setup which allows for ease of integration of existing user interfaces from many different user interface frameworks – such as React, Angular and Vue etc. We will also relate this to the Knowage user interface framework approach.

A Climate calculator component developed in a collaboration with Landbrukets dataflyt will be used as an additional component in the Farmer´s dashboard. The climate calculator will be related to the WP4 Indicator Engine for Benchmarking Purpose: to be used in "generic farm comparison" to calculate results in particular related to environmental climate impact, such as CO_2 emission, and agronomic sustainability of farms.

4.13 Pilot 4.2 - Consumer Awareness: Milk Quality and Animal Welfare Tracking

The pilot focuses on implementing an information flow optimization across different actors of the milk supply chain – from farmers to consumers – ensuring the transparency of all stages.

The Pilot will be deployed in two sites in Italy (Lazio region):

- One farm, Maccarese SpA, with 1450 Friesian dairy cows, 600 fattening calves and 3.240 hectares of land, it represents one of the largest in Italy for the number of cows and site's extension. For the execution of the Pilot, 100 cows from the herd were selected as a representative sample.
- One processing company, Latte Sano SpA, which deals with the distribution and processing of milk, collecting 200 tons of milk daily in the region.

4.13.1 Use case specific requirements

The farmer already monitored animals by using different smart devices, but collected data were scattered and prevented him from an overall vision of the most important animal welfare and milk yield indicators. Filling this lack of information has become increasingly urgent as a result of pressure brought by processing companies, willing to know data relating to the milk's quality levels and by the consumers, claiming for more transparency regarding the food they eat.

The farmer has to carefully monitor all the relevant parameters (both related to animal welfare and milk quality) captured in different files or provided by different systems in order to monitor his herd health and prevent or significantly reduce the use of antibiotics.

The processing company intends to know the milk quality levels since he pays to farmers a variable premium based on pre-defined quality indicators of milk. Considered these needs, we have identified with our end-users the requirements show in Table 9.

Table 9: Identified Stakeholder Requirements

Id	Title	Description
1	DSS on Animal Welfare - data input	The DSS on Animal Welfare will enable the farmer to enter data concerning the fat/protein ratio, the electrical conductivity, the total daily rest for each animal of his/her livestock.
2	DSS on Animal Welfare - monitor pathologies	The DSS on Animal Welfare will provide the farmer with graphical widgets to monitor the current health status of the livestock with respect to the following pathologies: lameness, ketosis and mastitis
3	DSS on Animal Welfare - recommended actions	The DSS on Animal Welfare should display recommended actions to correct and improve animal welfare measures
4	DSS on Milk quality prediction - data input	The DSS on Milk quality prediction will enable the user to enter data concerning the samples' analysis obtained through the FTIR (Fourier Transform InfraRed Transform) spectroscopy
5	DSS on Milk quality prediction - monitor milk quality	The DSS on Milk quality prediction will provide the processing company with graphical widgets to monitor the current level of milk quality (high, medium or low) for the raw and processed milk
6	DSS on Milk quality prediction	The DSS on Animal Welfare should display recommended actions to correct and improve milk quality
7	Interoperability	The new solutions should be interoperable with existing systems
8	Data collection	Data coming from heterogeneous sources should be saved and made consistent.
9	Data integration	The different types of incoming data should be integrated

10	Data security	Data from IoT devices should be used in a secure manner, protecting them from any tampering and/or alterations. All approaches will be valid, such as secure communications between applications (legacy or web) and/or software infrastructures
11	Milk Traceability - Web Application	The traceability system will provide the end customer with the possibility to visualize all the steps involved in the milk production
12	Milk Traceability - QR Code	The traceability system will provide the customer with a QR code on the bottle of milk in order for them to scan it and reach the web application
13	Milk Traceability - Blockchain	The traceability system will use the Blockchain technology

4.13.2 Envisioned Scenario

This pilot focuses on implementing an information flow optimization across different actors of the supply chain – from producers to consumers – ensuring the transparency of all stages. Specifically, it aims to make effective the information flow through the following processes:

- **Breeding and milking**, with a specific focus on animal welfare metrics collection and relative optimization of farm's activities; to this aim, Maccarese has acquired new devices for rumination, eating habits and respiration monitoring (**AfiCollar**[5]) and technologies for the separation of dairy yield (**AfiLab**) to be applied to milking machines (in order to optimize the milk separation process of higher and lower quality already in milking). These data will be harmonized with data already available in the farm: **Pedometer** (AfiActII) which mainly monitors the rest of the animal that is strictly connected to the lameness risk; **Milking robot** that is a device which provides information on electrical conductivity, parameter correlated with the incidence of mastitis; **Data Log** devices for temperature control.
- **Transportation of milk**: to guarantee the traceability of the milk collected; Latte Sano will install automatic lactating devices (**Milk Box MKII**) on the tank of the truck for Maccarese. This is a device allowing a fully automatic solution for milk composition analysis for payment and dairy herd improvement and for temperature monitoring.
- **Processing**: to optimize the daily samples analysis collection and storage; Latte Sano will install on the machinery, in the processing plant, equipment (**MilkoScan FTIR**[6]) to analyse the characteristics of all milk collected.
- **Tracking**: this process uses the Blockchain technology to track date, time and phase and additional data (if needed) of the milk production process with the aim of giving the consumer awareness of the milk supply chain.
- **Labelling**: the traceability system will cover all the processes including labelling, by printing a QR code that will lead to the web application.

Data already available before DEMETER and data from the envisioned scenario will be used to feed the following solutions developed within this pilot:

- **Estimate Animal Welfare Decision Support System (DSS)**: which gives integrated insight on animal welfare and suggest corrective actions to the breeding farmer.

[5] https://www.tdm.it/en/project/afi-collar/
[6] https://www.fossanalytics.com/en/products/milkoscan-ft1

- **Milk Quality Prediction Decision Support System (DSS)**: which offers to the processing company a milk quality assessment taking into consideration the analysis of the raw milk coming from the dairy farms and the analysis of the processed milk samples.
- **Traceability System**: which provides the consumer with the means to inspect, on a user-friendly dashboard, all the phases of the milk life cycle, in order to promote the awareness of the final product, through the information of date and time which demonstrate the care and commitment that is dedicated to the milk supply chain.

4.13.3 Expected Benefits

The solutions developed for this pilot in the DEMETER project, such as Animal Welfare DSS, Milk Quality Prediction DSS and Traceability System, designed based on real needs expressed by end users, aim at increasing the awareness of the end-users communities about the potential and the benefits of smart agriculture solutions and their trust in sharing their data.

The farmer and the processing company won't need to look at several files, but they will be able to easily monitor livestock health status and milk quality level through user-friendly dashboards which aggregate all the relevant data.

The implementation of standards-based and interoperable elements will enrich the overview of the animal welfare and milk yield indicators, easing the extension of the information flow to new data sources and optimising the availability of scattered data in a single access point. This will result in a higher quality of milk and a fairer price for producers. It will lead to greater transparency on milk production and animal health for farmers and processors. For consumers, it will deliver improved transparency on product nutritional values, origins and animal welfare.

4.13.1 Stakeholders

An initial list of pilot's stakeholders was compiled in the deliverable D5.1, and latter consolidated into generic stakeholders in the deliverable D5.2. Next, it is described the final list of stakeholder groups shown in the table above:

Farmers. Pilot's activities has been characterised by a close cooperation with one farmer Maccarese situated in Lazio region.

Processing company. Pilot's activities has been characterised by a close cooperation with the processing company Latte Sano, which deals with the distribution and processing of milk, collecting milk from Maccarese

Software providers. These are the internal DEMETER stakeholders collaborating in the pilot software development and deployment (ENG, Rotechnology).

Hardware providers. These are the external stakeholders providing sensors and tools to be used in the different phases of the milk chain.

Farmer's organisations. This is the internal DEMETR stakeholder, Coldiretti.

Public authorities. The public authorities involved as external stakeholders are: ALS – Veterinary Services, Lazio region, Arsial (the public Agency of the Lazio Region), Italian municipalities, Zooprophylactic institute.

Advisory Service. The advisory consultants involved as external stakeholders are: the network of Coldiretti and the Italian breeders' association (AIA). They carry out controls of animal productivity for all breeds involved in animal production and are responsible for performing promotional, technical, economical and scientific activities for the breeders' sake.

4.13.2 The pilots approach

Frequent meetings have been organized involving all the pilot partners to understand current contexts, needs and share the DEMETER challenges. After the identification of needs with the farmer and the processing company, pilot developers started the design of the solution and the implementation activities which have foreseen a preliminary study of the most reliable Artificial Intelligence (AI) algorithms (i.e. Machine Learning) to use for the data analytics. On the site, new wearable devices for animals have been installed and their data have been integrated with data coming from sensors already existing on the pilot farm in order to optimise data quality & processes. DSS dashboards have been created through the DEMETER Adaptive Visualisation framework based on Knowage technology. Deployed solutions have adopted standards protocols and DEMETER AIM to enable interoperability. Moreover pilot 4.2 intends to validate some DEMETER enablers, indeed in the first round our components have been registered in the DEH as well some enablers have been integrated in our solution (details have been included in D5.5). Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.13.3 Usage of DEMETER components

The integration of pilot 4.2 with the DEMETER ecosystem entails lots of benefits that are reported briefly in this section. Details will be included in D5.6. Here the DEMETER components fully integrated in round 1 (M21):

- Agricultural Information Model (AIM): to increase pilot interoperability;
- Data Security & Privacy: to encrypt important data, and decrypt when necessary;
- Data management: for pilot DEMETER-enabled resources integration with DEMETER framework;
- Brokerage Service Environment: for service registration, discovery and ultimately communication process for pilot DEMETER-enabled resources in a secure and privacy preserving manner;
- Functional Interoperability Core Enabler: to verify the compatibility in BSE service registration of Animal Welfare and Milk Quality services with the BSE model itself;
- Access Control Enabler: to allow pilot user account registration and access to the other core and advanced DEMETER enablers, and for secure channels communication.
- DEMETER Enabler Hub: to promote pilot solutions;
- DEH-Client Core Enabler: for resource consumption metrics monitoring;
- Estimate Animal Welfare Condition: to determine the health status of cows in terms of nutrition, hygiene, rest and movement;
- Milk quality Prediction: to determine the quality level of the milk, thus identifying the goodness both of the milk arriving from the farmer and of the processed milk ready for packaging, in order to understand what choice to make in order to improve its quality.

The DEMETER components which will be integrated by the end of round 2 (M28) are:

- Indicator Engine for Benchmarking Purpose: to be used in “generic farm comparison” to calculate results related to economic, environmental and agronomic sustainability of pilot stakeholders
- Generic Farm Comparison: which interacts with the Indicator Engine which extracts the indicators in AIM format which are then displayed, through the adaptive visualisation framework.

In the following picture a representation of the main peculiarities of pilot 4.2 before and after DEMETER is shown.

In the “Before DEMETER scenario”, Maccarese monitors its herd through the usage of IoT devices and the collected data are saved on-premises. Latte Sano carries out daily analysis on incoming milk to determine milk quality but the related information is not stored. In both cases, there is no data interchange, a holistic view is prevented and the decision making activity is based only on human expertise.

In the "After DEMETER scenario", new sensors and devices are introduced to collect more data that then are shared in the cloud. This allows the use of pilot data by the DEMETER DEEs, the integration into the DEMETER environment and the interchange of data and services between Maccarese and Latte Sano.

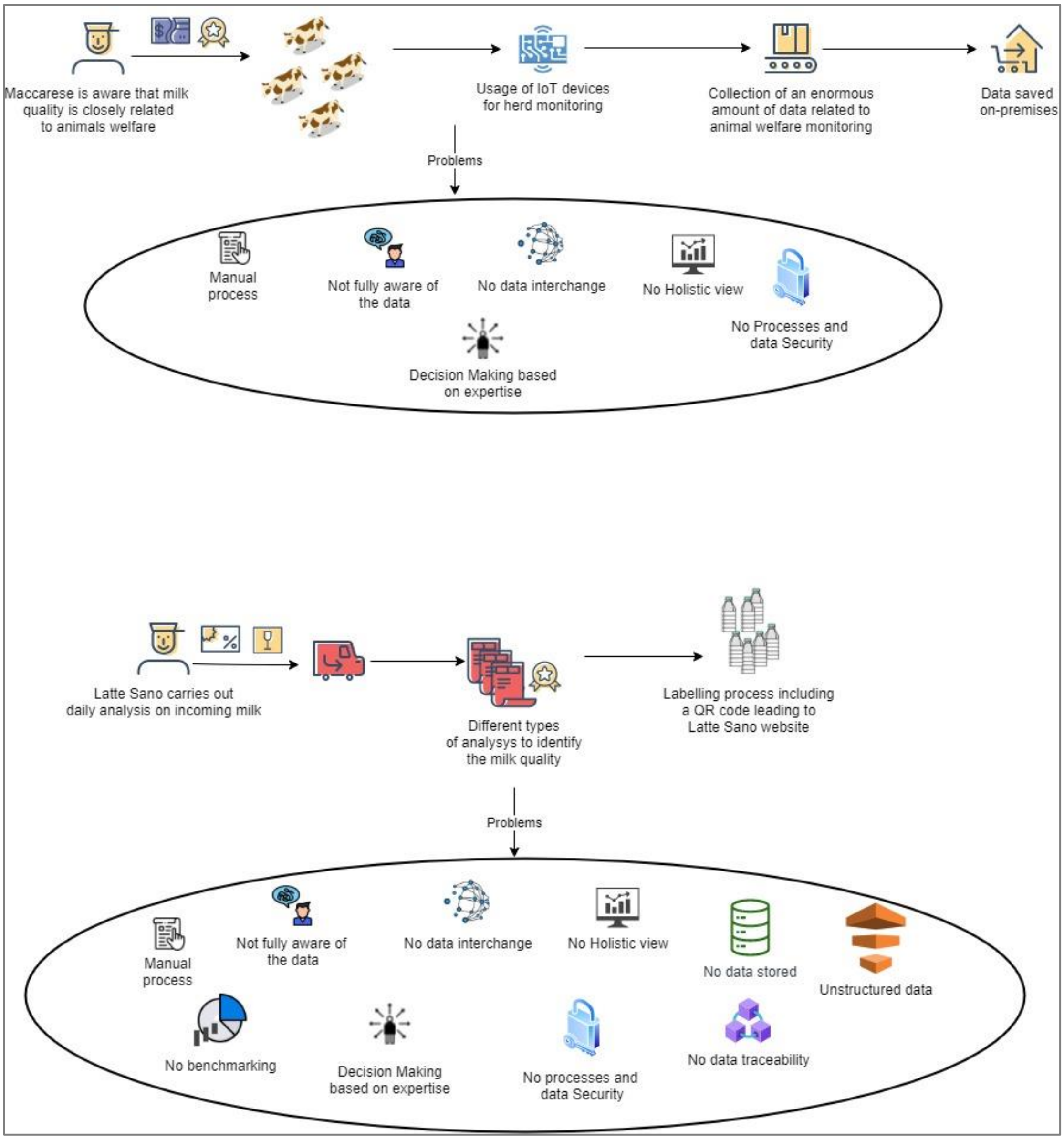


Figure 39 Pilot 4.2 Before DEMETER

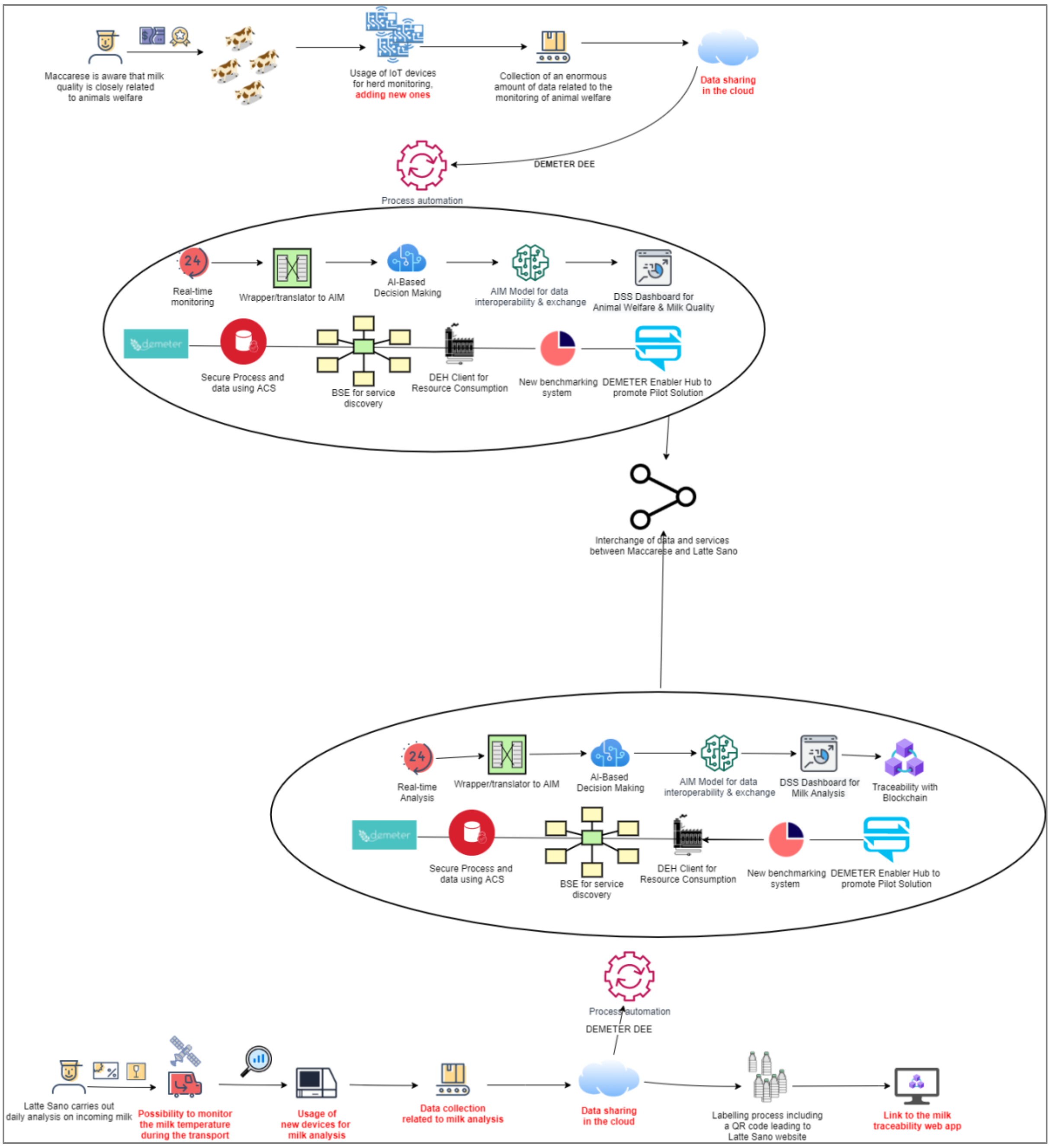


Figure 40 Pilot 4.2 after DEMETER

4.14 Pilot 4.3 - Proactive Milk Quality Control

To obtain a common understanding of the scope and objectives of the DEMETER pilots, the pilot leaders have been asked to provide a description by addressing the following common questions:

What is the pilot about? This Pilot will focus on using new and appropriate ICT tools to measure relevant parameters of animal behaviour and physiological status on a continuous, real time basis. This animal behaviour and physiological data will be integrated to develop prediction models of cow welfare and health. A decision support aspect will allow the end-user, e.g. farmer or vet, to identify when intervention to the animal is necessary. This information can then be fed into a welfare and health scoring frame-work which will act as a record of animal well-being standards being met/ exceeded and will ultimately contribute to improving animal well-being standards on dairy cow farms.

4.14.1 Use case specific requirements

How does the current scenario look like? Traditional farming involves management systems based on direct observation of animals and intuitive decision making by the farmer. Larger animal numbers and reduced available time of the farmer are necessitating changes, potentially resulting in less available time to observe and detect welfare and health issues of individual animals. At the same time, societal expectations are increasing in terms of animal well-being and animal health, together with an expectation of significantly lower use of antibiotics in animal treatments. Thus, it is necessary to develop alternative mechanisms to predict welfare and health issues.

Technology now presents a solution by enabling different animal characteristics to be monitored continuously in a real-time manner. This pilot will generate a system capable of providing a continuous status of dairy cow well-being, thus allowing development of a model to predict welfare or health issues, with biochemical tests to confirm health status. Thus, the IoT will be used in establishing a system for the future dairy farm that will

1. predict when an animal is not "functioning" properly;
2. establish a target that e.g. 97% of cows had no significant issue throughout their lactation; and
3. satisfy claims of the well-being of animals.

4.14.2 Envisioned scenario

How can a future scenario look like? The overall challenge is to integrate animal behaviour and physiological data into a welfare and health scoring frame-work with progression to a reference system to increase animal well-being standards on dairy cow farms. In order to achieve this, a number of objectives will need to be achieved. Firstly, the current animal welfare scoring systems that are available internationally will be reviewed. Secondly, different behaviours and physiological states that can reflect or impact on welfare and health of dairy cows will be identified. Thirdly, appropriate ICT tools to measure relevant parameters on a continuous, real time basis will be identified. Fourthly, 'gold standard' measurements/ indicators of welfare and health of cows will be put in place. Fifthly, a data fusion platform where the data from different sensors will be integrated will be created and a predictive model for various well-being characteristics of the cow will be developed. Finally, a well-being audit for dairy cows will be created 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 product (milk).

4.14.3 Expected Benefits

What are the benefits for the pilot? There are several drivers for improving the health and welfare of farm animals. But a key driver is that society is increasingly concerned about the health and welfare of farm animals from (a) an ethical viewpoint and (b) a human health viewpoint. Firstly, it is now considered important to conform to high ethical standards in animal management. Secondly, a positive health and welfare status of animals can be directly linked to a reduction in antimicrobial usage, a reduced risk of antimicrobial resistance and an overall healthier and safer environment for humans. Expected benefits from this research will include:

- Improved dairy cow health and well-being through an early warning system, meaning early intervention during health/welfare challenges, resulting in:
- rapid disease detection
- potentially less animal suffering,
- less medication, including antimicrobials,
- less need to incur expense of vet/medication etc.,
- more efficient use of time/less time spent on sick animals/administering medication (resulting in less stress)

- Documentation, enabled by data capture, analysis and record keeping developed in this study will allow transparency in animal health and welfare status and management on-farm. This documentation can contribute to reference systems to improve animal well-being standards on farms, e.g. this documentation could establish and meet a target that e.g. 97% of cows had no significant health or welfare issue throughout their lactation.
- Outcomes from this study using precision technologies to generate informed, real-time solutions will provide real benefits in profitability and an improved system to the farmer. It will help achieve national objectives around continuous quality assurance and better welfare standards for cattle.

4.14.4 The pilots approach

How do you want to achieve this? This planned work is associated with animals in an indoor system. The use of ICT tools for capturing data and monitoring animals has developed faster with indoor systems, i.e. where animals are housed for much of their lifetime.

The overall approach that will be used in this work is as follows: A number of cow behaviour characteristics and physiological states that can reflect or impact on welfare and health of dairy cows will be identified. This will be achieved through the knowledge of informed research and extension personnel. Example behaviour characteristics to be monitored may include cow feeding 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). This data capture system will focus on real-time, directly measured information. The performance of the cow (milk yield, composition and conductivity) may be measured within a sufficiently automated milking system.

Tyndall will develop a disease specific portable diagnostic platform and use it to provide bio-chemical data from stress and disease related bio-markers. These markers are known to vary when animal well-being and welfare is compromised. 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.

Some sensors not previously validated will need to be examined against 'gold standard' measures. Cow behaviour data, e.g. feeding time and rhythms, rumination time and rhythms, activity and movement will be examined in terms of characterizing what is normal for the individual animal within the herd, how that deviates from other herd members, and how this could be an indicator of some potential problem. The 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. A degree of decision support will also be involved. For example, the cow behaviour, milk yield and bio-chemical data may all indicate a problem, but this data could be indicative of a cow in heat or with udder health issues. The conductivity data may be used to make this decision. A reactive function can also be created from data coinciding in animal illness indication. This function may take the form of an alert to the farmer/ vet of the animal requiring assistance. The data can also be interrogated for its potential to provide a descriptive function of the well-being of the cow. This can be integrated into an audit system that would act as a guarantee of animal well-being standards being met/ exceeded (to satisfy ethical requirements) and for marketing of both animal and animal products. An example of this may be that udder health of 99% of a cow herd was not compromised at any point during the lactation, which could be used for marketing purposes. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.14.5 Usage of DEMETER components

3.B.1 Brokerage Service Environment:

The Brokerage Service Environment (BSE) is a core module of DEMETER architecture, which facilitates the registration, discovery, and ultimately communication process for the DEMETER-enabled resources in a secure and privacy preserving manner. In the framework of DEMETER, a resource coupled with the necessary enablers (core and advanced) is named a DEMETER enhanced entity (DEE). A DEE, once authenticated and authorized by the BSE can register as a service with the BSE specific registry. Subsequently, it becomes discoverable by all the other registered DEE's. Finally, based on the suitable core and advanced enablers that each DEE implement and after resource provisioning information from the BSE, DEE's can communicate directly with each other. In addition to the functionalities, BSE can interconnect (interface) with DEMETER HUB in case a user flow is identified or required.

The BSE is implemented as a self-contained application that enables an external party to deploy it as a complete brokerage service solution. Each DEMETER-enabled application should utilize at least one BSE. The BSE accompanied by a publish-subscribe communication mechanism that addresses the required communication data throughput realizes the backbone of the DEMETER reference architecture.

3.D.1 Access Control Server

The security components provide the following three functionalities to other DEMETER components and pilots implementations:

Authentication

- Authorization
- Traceability

These functionalities have been implemented in six main security components: Identity Manager, XACML PDP, Capability Manager, PEP Proxy, Traceability Agent, and Traceability blockchain repository. These components expose methods using a REST API as described in the following sub-sections.

3.E.1 Demeter Enabler Hub

The DEMETER Enabler HUB (DEH) is one of the most crucial components of the DEMETER project; it represents the digital space dedicated to (technically capable) end-users of DEMETER where they are able to create and register their own resources. Users have two roles; they act as DEMETER Provider and DEMETER Consumer. A DEMETER Provider is able to offer and manage his resources (components, services, data sources, devices, platforms, etc), while DEMETER Consumers will be able to browse it and find suitable resources matching their requirements. In order to support this, the DEH involves communication between various DEMETER components. Taking this into account, each component inside DEH exposes endpoints through their internal API's. Data entities from any Platform, Thing, Application, Service will be managed through these API's, but for the sole purpose of discovery and management of the resource registry maintained by the DEH. To make the solution more flexible and easier to maintain, all components inside the DEH will be developed as separate services and deployed as standalone Docker containers. The DEH Dashboard (DEH Dymer sub-component described below), provided as an external component communicates with Resource Registry Management (RRM), which is composed out of 3 logical modules: Compatibility Checker, Resource Management, and Discovery Management.

Secured communication among all components will be provided by a Security Enabler, more specifically by the Identity Manager, and Access Control Server (Capability Manager) components.

The DEH Dashboard communicates with Resource Registry Management (RRM), where all data related to future DEH Resources is inserted by the user, and passed to be verified by Compatibility Checker, and if the data satisfies all necessary requirements, it will be stored inside the DEMETER Resource Registry. In the end, the DEH Dashboard is able to show these resources to the end-users of DEMETER, who intend to view them.

3.E.2 DEH Client Core Enabler

The DEH Client Enabler Module is a core component of DEH (Demeter Enabler Hub) architecture, this module enables us to discover, monitor, and generate resource consumption metrics of DEH Service containers deployed on a Docker Host. The metrics thus generated are periodically updated to the DEH Resource Registry Management (RRM) and the metrics data is visualized with the DEH Dashboard. Here Docker Host represents a host or server running docker daemon service hosting Docker Containers and a resource represents DEH Core Modules deployed as Docker Containers i.e., DEH Service Containers on a Docker Host. This communication between DEH Client Module and Docker Host happens over a secured channel.

To encapsulate DEH Client Module as a flexible, lightweight, portable, across various environments (e.g., dev/test/qa/prod), and self-sufficient/ self-contained solution, the same is deployed as Docker. This would enable an external party to deploy DEH Client solution as a stand-alone Docker Container and start monitoring containers on any Docker Host hosting DEH Service Containers.

Estimate Animal Welfare Condition

Animal welfare condition will be estimated initially according to :

The transition period of a cow is defined as the 6 wk period encompassing the calving event. Transition dairy cows experience many potential stressors that may alter their behavior and predispose them to illness. Expected biomarkers of poor transition period adaptation may include indicators of metabolic maladaptation (e.g., BHB), indicators of inflammation (e.g., haptoglobin and C reactive protein), and indicators of stress (e.g., cortisol and substance P). Other biomarkers such as behavior, rumination time, milk production and body condition score may also be important indicators that could be used to support the classification of transition period maladaptation. The use of behavior as an indicator of poor transition period adaptation is of interest because automated monitoring of behaviour is a feasible option for a practical metric to identify individual animals and farms that may have compromised animals from a functional welfare perspective. We hypothesise that the behaviour of dairy cows showing poor transition adaptation across the transition period could be clearly differentiated from cows showing good transition adaptation based on mean concentrations of metabolic, inflammatory, and stress biomarkers in milk around calving and clinical conditions

4.15 Pilot 4.4 - Optimal Chicken Farm Management

This Pilot focuses on poultry farm management, from providing guidance and support regarding biosafety and feed mixture preparation to continuous monitoring of environmental conditions, operations and animal welfare. DEMETER needs to provide an integrated management overview of the chicken production system. It must identify and provide algorithms that are able to analyse and process large amounts of data relating to the stress level monitoring for poultry farms, which will be ensured through this use case.

Devices for measuring environmental conditions (air temperature, air humidity, CO2/NH3 level) and for recording chicken behavior and vocalization are used to collected relevant data. poultryNET platform is used as main decision support system providing advices according to gathered data analyzed through embedded expert modules. Chicken vocalization and behavior will be used for early detection of stress issues.

4.15.1 Use case specific requirements

Traditional poultry breeding involves direct observation of animals and intuitive decision making by the farmer. In many cases, it is not possible to assess the well-being of poultry without veterinary expert, which is time consuming, expensive and cumbersome for most of the farms. The farmers need to have insights about the poultry well being in real-time so as to be able to efficiently manage the farm processes. The storage and condition in which poultry is kept are becoming more important, making different stakeholders concerned what they eat, how the poultry was breed. Further to this, it is not possible to know when to apply antibiotics. Thus, it is necessary to develop alternative mechanisms to predict welfare of the poultry and to provide a mean for this information to be available to a large and diverse number of stakeholders. There is many information that can be monitored, to come to a conclusion about the poultry well-being. Parameters such as poultry feeding, poultry stress, power losses as well as environmental showed as a stressful factor that significantly impacts the poultry well being.

The pilot has a specific functionalities that needs to achieve provided in form of the following requirements:

Table 10: Identified Stakeholder Requirements

ID	Title	Description
4.8.14	Stress recognition and weight estimation	The DSS needs to provide assessment of the animal stress and estimation of the chicken weight.
4.7.6	Silo condition detection	The amount of feed in silos has to be continuously monitored and notifications issued when a defined threshold is reached.
4.7.4	Environment condition assessment	The DSS needs to continuously monitor environmental parameters (temperature, humidity, movements, co2, light) and generate notifications when defined thresholds are reached and/or in line with more complex rules defined by farmers.
4.7.5	Power losses	The DSS must monitor energy supply/consumption and generate notifications in care of power interruptions.

4.15.2 Envisioned Scenario

A flexible and modular solution leveraging open interfaces and standardized data formats is deployed on farms providing a holistic overview of all farm operations and just in time decision support to the farmers, from the preparation of the buildings to finishing breeding period and delivering chicken to the next stakeholder in the supply chain. A particular attention is being paid to ensuring animal wellness, including automatic wellness/stress detection based on chicken vocalization and video processing.

A range of IoT devices is used to collect data about relevant environmental parameters as well as of various activities being undertaken on the farm. The collected data is processes and analyzed resulting in recommendations and advices given to farmers using a number of interaction channels. Overall, the farms will be run more efficiently resulting in increased profit and improved animal well-being.

The pilot will contribute towards validation of the current functionality, improvement of AI models for wellness detection as well as extension of the deployed solutions to enable their interoperability with other solutions through the use of DEMETER interfaces and data formats.

4.15.3 Expected Benefits

The main benefits are production costs optimization, better product quality, and improved animal welfare.

What are the benefits for the pilot?

Having in mind that global population will increase by 2 billion over the next 30 years, the food demand, especially for dietary animal proteins will grow, thus creating significant increase in demand for poultry meat and products. Comprehensive solutions enabling holistic chicken farm management will be needed to support such growth in sustainable manner, i.e. without wasting natural resources, while taking care of the animal wellbeing at the same time. Farmers will benefit from the increased production, providing high quality products to consumers, while lowering impact on the environment. Expected benefits from this research will include:

- Improved poultry production and well-being through an early warning system, meaning early intervention during health/welfare challenges, resulting in:
  - Preventive disease detection
  - More efficient use of medication (resulting in less stress)
  - Potentially less animal suffering
  - Less expenses – no need of vet/medication etc.

4.15.4 The pilot approach

Chicken farms in general do not have integrated farm management systems that can provide a holistic view of the farm activities. In many cases, partial solutions exist, enabling farmers to see raw measurements indicating the current temperature, humidity etc. using sensors provided by vendors of the farm equipment (for example Big Dutchman, Fancom, etc.). Usually, these measurements are available on-site only, thus limiting their usability. Further to that, rather frequent problems with electricity (power cuts), especially on smaller farms in rural areas, are a source of potentially huge losses for the farmers (ventilation not working, feeders not running, etc.) due to lack of notifications.

DNET's poultryNET platform will be used as the basis for the pilot. New IoT devices are installed, and sensors already existing on the pilot farms integrated. Throughout the pilot duration, data will be collected, processed and insights generated. Deployed solution will be improved and extended using DEMETER defined APIs and data formats to enable its interaction with other relevant IT systems.

The final list of stakeholder groups is stated below and in Annex B:

Farming equipment vendors: providers of farming equipment like air conditioning, feeders, drinkers etc.
Sensing and computing equipment vendors: vendors of various sensor devices with adequate communication capabilities as well as vendors of edge computing devices.
Software providers: internal DEMETER stakeholder collaborating on the development of the pilot software and provision of digital solutions used in the pilot farm management (DNET).
Farmers: during the first round there has been close cooperation with farmers, both DEMETER partners (Agroprodukt) and external to DEMETER (Matijevic, Radinovic, Sandor).
Food and retail companies: interested in receiving timely information about the growing process to plan own activities (e.g., slaughtering) as well as to provide additional services to their customers.
Researchers: external stakeholder (research veterinarian institute) have been involved in data analysis and service expanding.
System integrators and service providers: internal stakeholders (ITC, UDG, DNET) who provide deployment, integration and support services. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.15.5 Usage of DEMETER components

The pilot 4.4 will use DEMETER Enablers to ensure the secure exchange of data, the interchange mechanisms, and the semantic interoperability by guaranteeing the AIM format. In particular, user credentials and geospatial information (recognized stress, the amount of the food in the silo, environment parameters, power losses) will be directly modelled according to AIM, as defined in D2.1.

Therefore, the integration of pilot 4.4 with the DEMETER fully integrated in round 1 (M21) was done as follows:

- Agricultural Information Model (AIM): to increase pilot interoperability.
- Animal well-being: to enable detection of the poultry well-being

- Animal feeding: to enable detection of the level of food in silo

The DEMETER components which will be integrated by the end of round 2 (M28) are:

- Brokerage Service Environment: for service registration, discovery and ultimately communication process for pilot DEMETER-enabled resources in a secure and privacy preserving manner.
- Functional Interoperability Core Enabler: to verify the compatibility in BSE service registration with the BSE model itself.
- Access Control Enabler: to allow pilot user account registration and access to the other core and advanced DEMETER enablers, and for secure channels communication.
- DEMETER Enabler Hub: to promote pilot solutions.
- DEH-Client Core Enabler: for resource consumption metrics monitoring.
- Data Security & Privacy: to encrypt important data, and decrypt when necessary.
- Data management: for pilot DEMETER-enabled resources integration with DEMETER framework.

4.16 Pilot 5.1 Disease prediction and supply chain transparency for Orchards/vineyards

This pilot will address both on-farm and post-farm activities, from technical and business perspectives. Data analytics modules will reason over acquired sensor data and suitable advices given to farmers. Product passports will be created for wine production and supply chain stakeholders (retailers, consumers) engaged.

Pilot 5.1 aims to provide decision support in pest and disease management as well as 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. Pilot is deployed at four locations in vineyards and apple orchards. Environmental data collected and used as inputs in pest and disease prediction models are used to create advices and instructions to the farmers. 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 data exchange protocol (OriginTrail) will be used to ensure trust and transparency between actors in the value chain.

The deployment and installation included devices for measuring environmental parameters (air temperature, air humidity, rainfall, leaf wetness, radiation, wind speed); as well as data about the crop (Crop type and planting date). Further, job orders/spraying configurations will be send to the orchard/vineyard sprayers in the field, and once executed, the result of the spraying operation will be made accessible to the cloud.

Installation was done in 14 vineyards (more than 2500 ha) and 3 apple orchards (around 30 ha) in the following countries: Georgia, Slovenia, Montenegro and Serbia.

The main technical development in the pilot are as follows:

- **IoT Devices:** for collecting various data from the field (temperature, humidity, rain perception, machinery data, leaf wetness, soil moisture, insect count)
- **agroNET platform** - agriculture platform for monitoring on parameters in field using sensors (temperature, humidity, rain perception leaf wetness, soil moisture), pheromone traps with cameras to detect number of insects, advanced algorithms for providing instructions to farmers

- **Product Passport** - platform for generation of unique item-levels identifiers used on each separate product based on GS1 digital link standard. The product passport platform has its end user application with the ability to scan each tag on product and providing traceability information to the consumer
- **FEDE Machinery control** exercised by Fede *Specialty Crops Platform* (SCP) that links via GPRS to the tractors and sprayers in the field.
- **FleetNET platform** - fleet monitoring platform for tracking of vehicles GPS location, and collection of various statistics for vehicle over the CAN interface
- **Farmers and end user application**: to provide data about irrigation instructions, disease prediction as well as data about product's authenticity and proof of origin together with the usual information about the products

4.16.1 Use case specific requirements

The current agricultural system relies heavily on pesticides, which control weeds, kill insects and control appearance of fungi. There is no ability to monitor the machinery fuel consumption nor machine working condition (idle, working, turned off). The consumers also do not have information about the vine quality, and cannot justify the traceability of the purchased product. Accordingly, it is necessary to have ability to monitor an environmental parameters in the field to predict occurrence of fungi, to assess the location of the vine produced, as well as to provide relevant traceability data on simple scan of the final product.

The pilot produces crop water status and irrigation requirements at a daily time step, as well as temporal patterns of soil moisture level. The pilot will use/produce different data and the main requirements are as follows:

ID	Title	Description
4.9.1	Product passport: production place, harvest time	The DSS should enable unique identification of selected products, automatic capturing and recording of important events (e.g., harvest time, field activities done, etc.) and enable exposure of such data to different stakeholders via an API and by scanning tags attached to products (e.g., wine bottles).
4.8.15	Disease recognition	The DSS must provide instructions to farmer when to spray based on fungal disease forecasts. The instructions also have to include other recommended measures leading to prevention of the disease or reduced impact of the disease.
4.1.4	Machinery/sprayer control	Based on the disease predictions, the machinery should receive spraying instructions. The activities done by the machinery must be imported to the DSS and adequately reported.
	Digital twin	A digital twin model for vineyards should be created to facilitate efficient and streamlined description of processes, allocation of tasks and exchange of data.
	Supply chain transparency	Enable sharing of production data with other supply chain stakeholders, ensure immutability of information and make information searchable.

4.16.2 Envisioned Scenario

Pest and disease appearance and spreading is one of the main problems in fruits/grapes production. Disease controlling is usually based on experience instead of hard facts, although there are available prediction models. However, those models provide general instructions instead of precise advises for each user. Additionally, there is a lack of evidence about the pesticides and other resources usage required by consumers willing to have an insight into whole production process and health safety of what they are eating.

A comprehensive platform providing decision support to the farmers, as well as collecting data through the whole supply chain providing relevant information to each stakeholder. IoT devices are used to collect data about environmental parameters and insects' activities. The collected data is used as inputs in prediction models resulting in advices given to farmers regarding pest and disease controlling. Improving pest and disease management, including the usage of cloud-controlled sprayers, will result in optimized and traceable pesticide usage which consequently will improve of crop quality.

The pilot will contribute towards validation of the current digitized prediction models, their improvement and adding new ones covering the main pests and diseases in various orchard/vineyards in different regions through the use of DEMETER interfaces and data formats.

4.16.3 Expected Benefits

The main expected benefits are pesticide usage optimization, cost decrease and increasing the fruits/grape quality. The pilot will ensure trustworthy supply chain based on collected information from all stakeholders. Before all, one of the most important benefits for the involved stakeholders is the ability to establish transparency of the supply chain (Product passport: production place, harvest time ID4.9.1). This is achieved by tracing the production place, environment data, time of harvest, disease model, storage, transport condition provided by different devices, platforms and systems. The actual tracing of an item is done using unique item-level identification provided by Product Passport platform based on GS1 digital link standard. The main benefits from farmer are met using the fungus disease prediction which can predict based on a model for specific pest/disease, number of detected insects (counted using AI). The data about fungi prediction is used as an input instructions for machinery, by sending Job Orders to Operators and Machinery in the filed via FEDE *Specialty Crop Gateways* (SCGs) installed on tractors.

4.16.4 The pilots approach

DNET's agroNET platform was used in the initial phase. New IoT devices are installed and existing devices integrated. Throughout the pilot duration data are collected, processed and insights generated. The deployed solution was improved and extended using DEMETER defined APIs and data formats to enable its interaction with other relevant IT systems, like Fede's *Specialty Crops Platform* (SCP), responsible for the data exchange to and from the cloud connected sprayers in the field. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.16.5 Usage of DEMETER components

The pilot will use DEMETER Enablers to ensure the secure exchange of data, the interchange mechanisms, and the semantic interoperability by guaranteeing the AIM format. In particular, user credentials and geospatial information (location, farm boundaries, crop-specific information) will be directly modelled according to AIM, as defined in D2.1. Information from IoT sensors and weather station will be remodelled via AIM-compliant wrappers. Information provided by devices deployed on field, are data about the soil that are used for formulation of the watering recipe together with the data about humidity, temperature, etc. will be processed internally and adapted and integrated into the AIM facilitating adapters for specific ontologies related to agriculture features, crops, alerts, properties, and systems. Therefore, the integration of pilot 5.1 with the DEMETER fully integrated in round 1 (M21) was done as follows:

- Agricultural Information Model (AIM): to increase pilot interoperability.
- Field operation: to determine the driver behavior and amount of machinery resources consumed
- WP2 Data analytics for optimal pesticide usage: to provide input for spraying

The DEMETER components which will be integrated by the end of round 2 (M28) are:

- Brokerage Service Environment: for service registration, discovery and ultimately communication process for pilot DEMETER-enabled resources in a secure and privacy preserving manner.
- Functional Interoperability Core Enabler: to verify the compatibility in BSE service registration with the BSE model itself.
- Access Control Enabler: to allow pilot user account registration and access to the other core and advanced DEMETER enablers, and for secure channels communication.
- DEMETER Enabler Hub: to promote pilot solutions.
- DEH-Client Core Enabler: for resource consumption metrics monitoring.
- Data Security & Privacy: to encrypt important data, and decrypt when necessary.
- Data management: for pilot DEMETER-enabled resources integration with DEMETER framework.

4.17 Pilot 5.2 - Farm of Things in Extensive Cattle Holdings

Pilot 5.2 focuses on improving animals' well-being and health, and how this can affect the quality and information of processed products, considering also cereals and eggs as raw materials. This pilot also considers end-user involvement in quality testing and feedback provision.

4.17.1 Use case specific requirements

Three use cases are being developed in this project:

1. UC#1: Ensuring the wellness of cows by managing their optimal feeding. To accomplish this, crops (that will be used as fodder) and soil properties will be measured. The use case will also focus on improving farm work organization.
2. UC#2: Improve the production management in a livestock farm integrating new technologies into the daily operations.
3. UC#3: Ensure food transparency and user involvement through integration of data brokering solutions in current production systems of dairy products and pastries.

4.17.2 Envisioned Scenario

Regarding the optimal feeding of cows (UC#1), the growing process described above requires a new level of precision in the awareness of status in various sectors of farming. Optimization of activities both in field work and in the cattle activities are needed. This means not only new sensor and camera solutions, but also processes that filter, pre-process and present the gathered data so, that it benefits the farmer to the maximum.

In addition, modern farming has generated new contracting networks, where farms support each other and exploit subcontracting opportunities in various areas. This enables new highly specialized business, where service providers can focus on dedicated processes within fieldwork, harvesting and animal care. In the future, it is expected that new technologies will raise up new entrepreneurship around drones, robotics, sensor networks, etc. The management of this network of resources is becoming increasingly challenging. Not only contracting itself, but also work scheduling and delivery of data needed for the contracted work must be managed.

Moreover, the inclusion of new advanced RFID devices will assure animal traceability from farm to fork (UC#2). RFID identification is presently the safest method to guarantee the whole food chain. Advanced RFID devices bring a new level of information management. The new ISO 14223, in which these new devices are based on, will let farmers, veterinarians, markets, fairs and abattoirs to manage new information stored in these new transponders.

The capability to save, store, change, update and delete specific information associated to every animal, makes the electronic reader a very useful management tool and surely, a very interesting device to be acquired.

Sensitive information regarding animal health will be protected from manipulation or deletion.

The information written by all these actors in the supply chain can be monitored and offered to the final consumer. With sanitary purposes, the introduction of voice recognition technologies in the data capture process will let the farmer handle the animal freely and register the animal data through his/her voice.

The food transparency and user involvement use case (UC#3) 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, which participates 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.

4.17.3 Expected Benefits

- Production costs optimization, better product quality, improved crop and soil measurements and better farm work organisation (UC#1).
- Reliability of the animal identification and livestock's management as a tool of traceability, animal welfare and food security (UC#2).
- Electronic identification as a revolution in the livestock sector, which will allow the agri-food sector to go beyond the current barriers that technology has now (UC#2).
- Increase of end-user involvement for the proposal or improvements of recipes, quality of ingredients and social awareness (UC#3).
- Improvement of production platform with extended product information and provision of new production batch to test information transmission along the supply chain (UC#3).

4.17.4 The pilots approach

The Kotipelto farm (Ylivieska, Finland) will be present in the UC#1, which will be supported by an extensive platform, where a customizable GUI will be provided both for the farmer and the contractor network, as well as tools for managing the work. The aim is to provide a refined and smart view to the farm data, having the main emphasis in the easy use and applicability of multitude of heterogeneous data sources. New sensor and surveillance systems will be developed based on the farmer needs. Regarding animal identification (UC#2), the goal is to introduce in this pilot -and in the market- advanced animal identification devices under ISO 14223, 1-3 standards. As manufacturers are not developing commercial devices yet, since the approval of ISO 14223 regulation is very recent and the number and characteristics of the data fields in the transponders are yet under discussion, we will base our work on prototypes first.

The line of attack of this pilot regarding data capture is initially testing the technology, so new software on smart glasses and a smart watch will be developed. If the results are good enough, the development will be extended to more fields in data capture. Regarding the provision of food transparency (UC#3), the producers' platform will be extended to support information generated in the previous steps in the pilot's value chain, allowing the generation of a new batch of products with better labelling, that will be provided to a retail facility to complete the supply chain. Regarding the provision of techniques to involve end users in the production of food, consumer workshops will be organized in Codan Park (Madrid, Spain), where the process of elaboration and processing of products will be explained, and an initial interaction of these groups will be provided. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.17.5 Usage of DEMETER components

The pilot will use DEMETER Enablers to protect access to back-end systems thanks to the authentication and authorization mechanisms provided by Demeter ACS, share data models and access points through the Brokerage Service Environment and achieve semantic interoperability thanks to providing the information through the AIM model.

Particularly, information from IoT sensors deployed in farms and the ones that are being deployed in production facilities are modelled according to AIM, as defined in D2.1, by using AIM-compliant wrappers. Final applications such as the data transformation enabler from AFarCloud to the DEMETER AIM, the production manager for livestock farm systems, the Offering-demand sharing platform and the interoperability dashboard will be published in the DEMETER Enabler Hub to be discoverable by the ACS-enabled DEMETER stakeholders.

Below we provide a short description together with the list of planned components.

From WP2:

- 2.A.1 Agricultural Information Model (AIM): used to model observations from sensors and product information.
- 2.B.2 Data preparation & integration: used to automatically translate data collected by the AFarCloud Middleware (UC#1) to the DEMETER ecosystem.
- 2.D Data security & Privacy: in progress. It will retrieve authentication tokens that will validate the data flows generated by the components deployed in pilot 5.2.

From WP3:

- 3.B.1 Brokerage Service Environment: used to deploy the enablers used in the use cases for data interoperability in AIM format.
- 3.B.2 Functional Interoperability Core Enablers: in progress. It will be used to describe the services and metadata of the enablers developed in UC#1.
- 3.D.1 Access Control Server: used for authenticated access to other DEMETER components, and also for generating credentials in provided enablers.
- 3.E.1 Demeter Enabler Hub: used to register the enablers developed in UC#1 and UC#3 (data transformation enablers and data preparation & integration enabler).

Besides, the intention of the Pilot is ***to review and use the following enablers*** (WP3 and WP4), although the status of this task is pending:

- 3.D.2 Security Core Enabler
- 3.E.2 DEH Client Core Enabler
- 4.A.1 Plant Yield Estimation: to review
- 4.A.2 Plant Phenology Estimation: to review
- 4.C.1 Nitrogen Balance Model: to review
- 4.C.2 Nutrient Monitor: to review
- 4.D.2 Field Operation: to review
- 4.D.3 Variable Rate: to review
- 4.I.0 Indicator Engine for Benchmarking Purpose: to review
- 4.I.1 Generic Farm Comparison: to review
- 4.I.3 Technology benchmarking: to review

4.18 Pilot 5.3 - Pollination optimisation in apiculture

In pilot 5.3, a pollination optimization service will be developed and made available. The service will combine the farm management system with the apiary management system with advisory and decision support services. The aim of integrating different farming systems will be to enable better communication between farmers and beekeepers, protect the bees and optimize the pollination of crops to increase their yields. Four beekeepers and three farmers will participate in the pilot project, and tests and validation will be carried out on arable crops.

4.18.1 Use case specific requirements

In the present situation in Poland, we are dealing with a low degree of penetration of the agricultural market by farm management systems, especially when it comes to the cultivation of honey plants by farmers and the management of apiaries by beekeepers.

Sample scenario based on the available technical solutions before the start of the Demeter project:

- Jan the beekeeper runs a medium-sized itinerant apiary in Greater Poland (approx. 40 hives). He cooperates with the farmer Michał, and transports his hives to Michał's fields for pollination. They usually contact by phone to arrange the transport of the hives and inform about the planned spraying. Recently, Jan bought several tamper sensors with a GPS locator for his hives to protect them against theft and to inform about damage caused by animals (e.g. woodpeckers, wild boars). The system shows him the location of the hive and sends alerts when a change in the position of the hive is detected.
- The farmer, Michał, runs a medium-sized farm in Greater Poland and cooperates with the beekeeper Jan in order to pollinate crops by bees. I communicate with him directly or by phone. Michał makes notes about his fields, crops and pesticides used (manually or in an excel file), but he does not currently use any farm management software. Uses the app to communicate with the counselor and receive notifications from the regional counseling center (WODR).

Based on the survey we realise that the biggest beekeepers needs is a scenario related to the prediction of spraying date. Even beekeepers who work on station apiaries, and they are not interested in moving apiaries according to agreement about pollination optimization, due that feature could be involved in providing information about their apiaries. That information could be crucial to calculate fields pollination needs based on apiaries neighbourhoods.

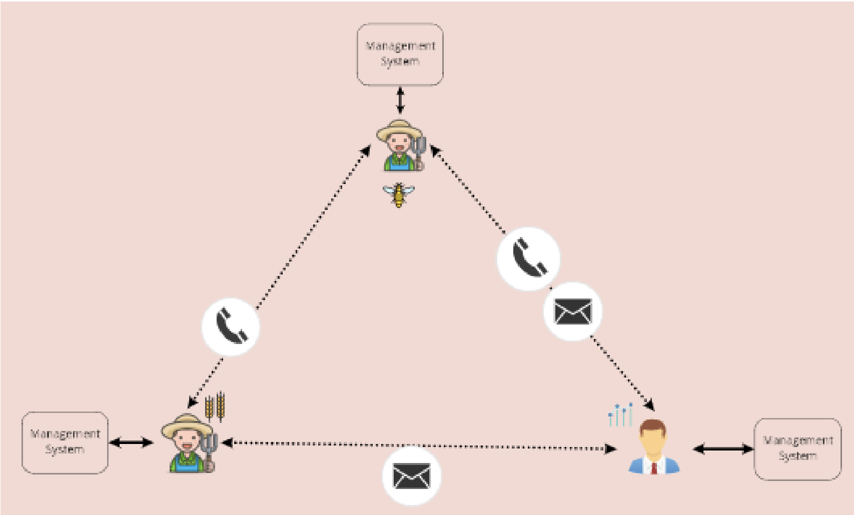


Figure 41:Before Demeter Pilot 5.3 communication between main actors/stakeholders

4.18.2 Envisioned Scenario

It is important to encourage beekeepers to increase the number of mobile apiaries and to move their hives more often to the forage in order to increase the yield of crops and to ensure greater efficiency and diversity of honey production.

The envisioned future scenario story in the pilot is the following:

- Jan the beekeeper runs an itinerant apiary in Greater Poland (about 40 hives). It uses the apiary management system (in the pilot ControlBee), which is integrated with DEMETER with the pollination optimization service.
- Jan implemented an apiary management system based on a network of sensors in the apiary because it protects the hives against theft and the ability to remotely monitor the condition of the hives (e.g. temperature, hive weight gain). This equipment allows you to monitor the entire apiary, as opposed to GPS sensors supporting the monitoring of a single hive.
- Jan is connecting to pollination optimization services pollination optimization (developed in DEMETER) and reported alert and warning function. The apiary management system now displays the area where its hives are located. Jan has the opportunity to find honey crops nearby and establish contact with the farmer through the Demeter Pilot 5.3 system. It will also receive warnings, e.g. about planned spraying near the apiary.
- Farmer Michał uses the farm management system (in the eDWIN pilot), which is an integrated system for planning and recording activities on the farm, e.g. for planning plans or constructing planned sprayings on his crops.
- As a bee-friendly farmer, he joins the pollination optimization service. Using the system, he can inform beekeepers about his honey-bearing crops and invite them to cooperate. The system makes it easier to establish contact with a beekeeper who operates a nearby mobile apiary. The DEMETER decision support services integrated with Pilot 5.3 assist the farmer in determining the need for polinators, i.e. the number of hives.
- When adding information about planned spraying, the farmer is alerted if there are apiaries registered in the system nearby. The system also sends a spraying notification to beekeepers, who have hives nearby.

- Thanks to the analytical modules, Michał can monitor the impact of placing an apiary near the field on production efficiency.

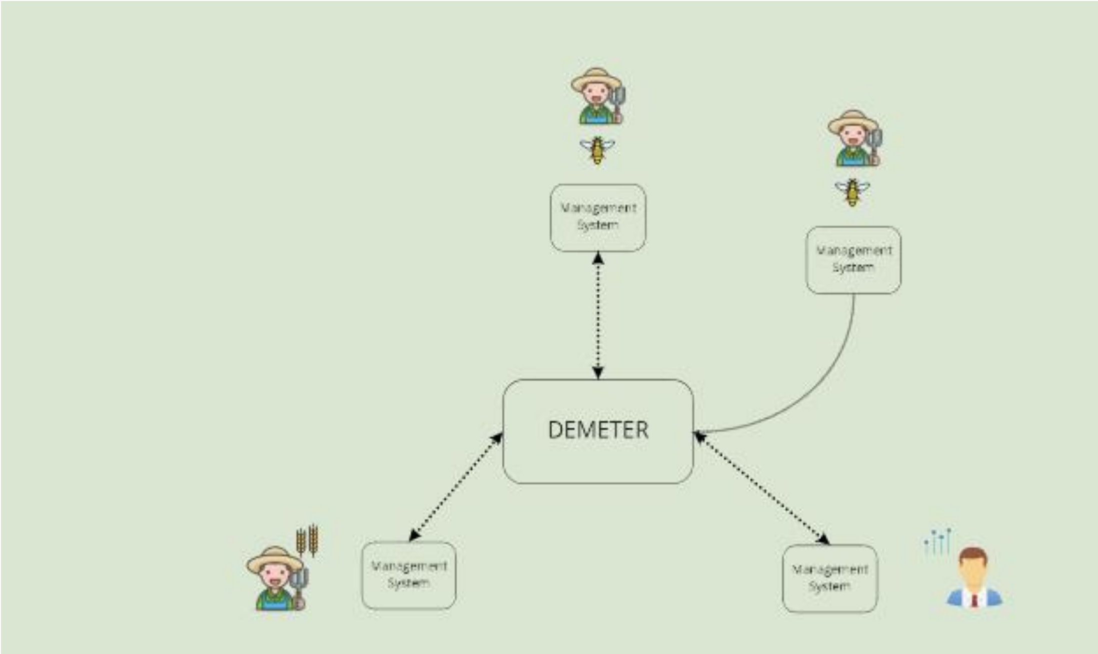


Figure 42: After Demeter Pilot 5.3 communication between main actors/stakeholders

4.18.3 Expected Benefits

Expected benefits include:

- better communication between farmers and beekeepers,
- better control and management of pollinators,
- better spraying control and bee protection,
- increasing yields and quality,
- monitoring and management of saturation of fields with bees,
- better gains for beekeepers.

4.18.4 The pilots approach

The pilot will develop and provide service for the pollination optimization. The service will connect farm management system with apiary managements system with advisory and decision support services. The goal of the integration of different agriculture systems will is to enable a better communication of farmers and beekeepers, to protect bees and to optimise pollination of crops with the aim of improving their yields.

In particular, the pilot will connect the farm management system (eDWIN Virtual Farm) created by the regional agriculture advisory centre (WODR) and apiary management systems (provided by ControlBee) and DEMETER DSS services to manage beekeeping information, including apiaries and farming activities like planned fertilizations (based on the information from farmers), and to provide new advisory services. Existing systems will be improved with new functionality, enabling the collaboration scenario without the need of using new system. Moreover, existing sensors will be improved and new apiary sensors will be developed to allow remote monitoring of mobile apiaries. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.18.5 Usage of DEMETER components

The use of DEMETER Enablers guarantees interoperability and the possibility of future cooperation with other systems for apiary management or farm management than the ControlBee (AMS) and edWIN (FMS) systems used in the remote control. The modelling according to AIM of the information exchange format is intended to ensure interoperability.

The use of dedicated decision support services provided by Estimate Beehive Component 4.A.5 will allow farmers to estimate the number of pollinators needed. And the components responsible for comparing the efficiency of agricultural production, will allow to assess the profit resulting from the optimization of pollination.

DEMETER components integrated in Round 1:

- The AIM model was integrated.
- The integration of a test instance of the system with locally running DEH and BSE components was carried out to an advanced degree.
- Integration with Access Control Server is implemented at FMS level (Demeter ACS will be available as IdP Interoperability in the eDWIN)

The AIM communication schema with Estimate Beehive Component 4.A.5 was developed in Round 1 and the integration itself will be carried out in Round 2.

4.19 Pilot 5.4 - Transparent supply chain in poultry industry

This pilot will address the post farm activities of a poultry farm. It will validate both performance regarding technical features as well as feasibility of business models. Product passports will be created for poultry products and supply chain stakeholders (retailers, consumers). The pilot will ensure transparency in supply chain for poultry industry, providing information about animal wellbeing and resources used during the production, thus creating a basis for the traceability of the data in such scenario. To be able to meet requirements, uniquely identification of products on item level and data integrity across the value chain as well as prediction of disease, assessment of travel and environmental condition to create instruction for consumers must be met. The algorithms that are able to analyse and process large amounts of data relating to the feeding and stress level monitoring for poultry farms are developed. The detection of elevated stress levels currently exists as a functionality from the poultryNET service, so it is a requirement that will be fulfilled during the pilot development phase to adapt machine learning algorithm to correlate the onset of raised stress with events detected by other sensors, such as video feeds, feeding conversion, etc. 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.

Activities are focusing on collecting data related to on-farm activities (environmental data, animal wellbeing, medical treatment, food and water consumed) and post-farm activities (condition during the transport) providing relevant data to the consumers. Product passport platform will be used for gathering relevant information from different farm management platforms about the supply chain activities (production, transport, retail). A blockchain-based data exchange protocol (OriginTrail) will be used to ensure trust and transparency between actors in the value chain.

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 are taken from the pilot 4.4 to complement the product passport data.

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.

4.19.1 Use case specific requirements

Currently, poultry is transported from different points in the production chain where it is not possible to assess the quality of the environmental parameters, both for live poultry as well as in different meat production phases. Producers, transport providers and retailer needs mechanisms to guarantee quality of the environmental parameters during the transport. Therefore, this pilot has a specific functionality that needs to achieve the following requirements:

- Environment condition assessment ID 4.7.4
- Product passport ID 4.9.1

4.19.2 Envisioned Scenario

Supply chain in poultry industry is covering data from farm activities as well as post-farm collected from several involved stakeholders. However, there is a lack of information about transport condition of poultry required by stakeholders, especially consumers. Even if some of that information exists, they are isolated without an integrated overview of the complete supply chain, from breeding process to transport, retail and consumers.

Providing a transparent and trustworthy insight into the whole meat production process including information from all involved stakeholders is the main challenge. Information about each step of chicken, production, from feed intake, medical treatments, conditions provided during the production, used resources, feed origin etc. to transporting to the slaughterhouse and after to the consumers will be collected and recorded enabling a transparent supply chain.

4.19.3 Expected Benefits

The main benefits are increased transparency of the complete supply chain, providing trustworthy information to consumers about the production process.

Improved transparency in the poultry supply chain by collecting relevant information for different sources and during different stages of the life cycle of the poultry industry resulting in:

- Increased transparency to consumers
- Potentially less animal suffering
- Increased quality of the product

4.19.4 The pilot approach

DNET's poultryNET platform will be used for gathering data from the breeding process perspective, including the amount of feed. Inputs and feedback from the farmer will be used to improve and validate the functionality. The outputs of poultryNET will be combined with information provided by fleet management systems delivering the feed and transporting chicken. All information will be summarized and stored in the Product passport and forwarded to a distributed ledger using OriginTrail protocol. Tables of stakeholder requirements and appropriate DEMETER components in Annex B and Annex E.

4.19.5 Usage of DEMETER components

The DEMETER Enablers will ensure the secure exchange of data, the interchange mechanisms and the semantic interoperability by guaranteeing the AIM format. In particular, user credentials (username, password and company name) and geospatial information (poultry GPS location, farm GPS location, product related information) will be directly modelled according to AIM, as defined in D2.1. Therefore, the integration of pilot 5.4 with the DEMETER fully integrated in round 1 (M21) was done as follows:

- Agricultural Information Model (AIM): to increase pilot interoperability.

- 4.H.2 Transport condition: to determine the transport condition of the vine, as well as location

The DEMETER components which will be integrated by the end of round 2 (M28) are:

- Brokerage Service Environment: for service registration, discovery and ultimately communication process for pilot DEMETER-enabled resources in a secure and privacy preserving manner.
- Functional Interoperability Core Enabler: to verify the compatibility in BSE service registration with the BSE model itself.
- Access Control Enabler: to allow pilot user account registration and access to the other core and advanced DEMETER enablers, and for secure channels communication.
- DEMETER Enabler Hub: to promote pilot solutions.
- DEH-Client Core Enabler: for resource consumption metrics monitoring.
- Data Security & Privacy: to encrypt important data, and decrypt when necessary.
- Data management: for pilot DEMETER-enabled resources integration with DEMETER framework.

5 Conclusion

This deliverable is showing the Final Stakeholder Requirements as a result of common work effort of the entire consortium. Due to the harmonization of the work packages and established synergies in between of the consortium, a common understanding of the DEMETER approaches has been developed and constantly refined for this final Stakeholder Requirements report, which is reflected in the evolution of this deliverable D5.4.

The before after scenarios of the pilots are showing the strong positive impact that DEMETER will have on the agriculture sector in very different use cases. Described in more detail in D5.5 the synergy among all the DEMETER pilots is visible already within this stage of the project where DEMETER components are already realised from the technical work packages and deployed into the DEMETER pilots. Due to the improved and effective requirements and experiences mapping an intense codesign exchange had been established.

The evolution of the Clusters and corresponding pilots based on the Stakeholder requirements makes the strong impact of the DEMETER project visible. DEMETER is working at the core of the challenge aiming to lead the Digital Transformation of the European Agrifood sector. This description of the final stakeholder requirements including the technical components meanwhile developed and partly implemented is showing the DEMETER ambition to increase performance in multiple aspects of farming operations and assure the viability and sustainability of the sector in the long term. Technical components are addressing the stakeholder requirements while it is visible that the project takes advantage of the rapid adoption of advanced technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, Decision Support Systems (DSS), Benchmarking or Earth Observation (EO). The described stakeholder requirements and their corresponding digital technologies at the service of farmers are co-created using a human-in-the-loop approach, the MMA, with a constant focus on mixing human knowledge and expertise with digital information. Therefore, DEMETER is user centric and technical solutions are developed tailored to the stakeholder requirements. Several approaches like farmer surveys, usability and acceptance studies, improvements loops, or assessments of the DEMETER component implementation has been guiding to this final stakeholder requirements and has been serving as a base for a sustainable impact of the DEMETER project to contribute to the Digital Transformation of the European Agrifood sector.

Annex A Stakeholder Workshop outcomes

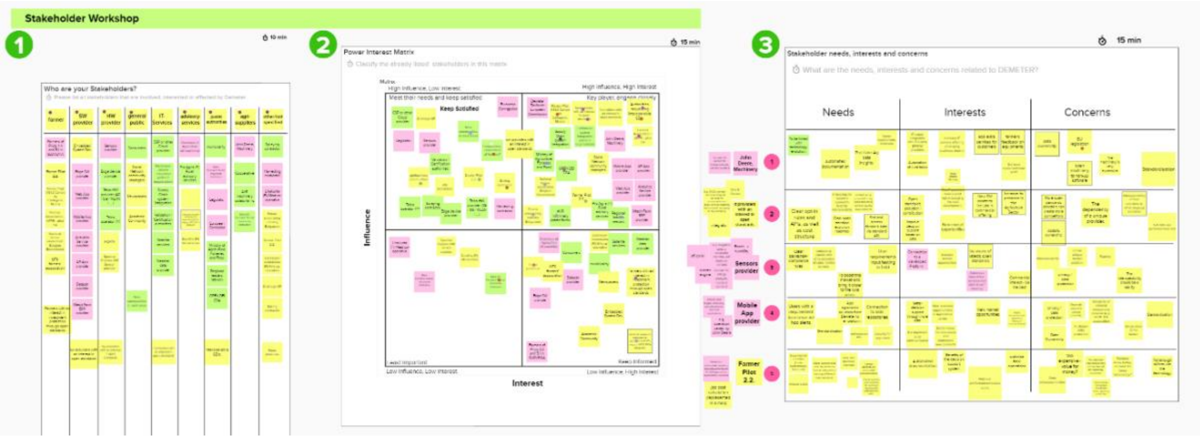


Figure 43: Screenshot of Mural Board Stakeholder Groups and Interests.

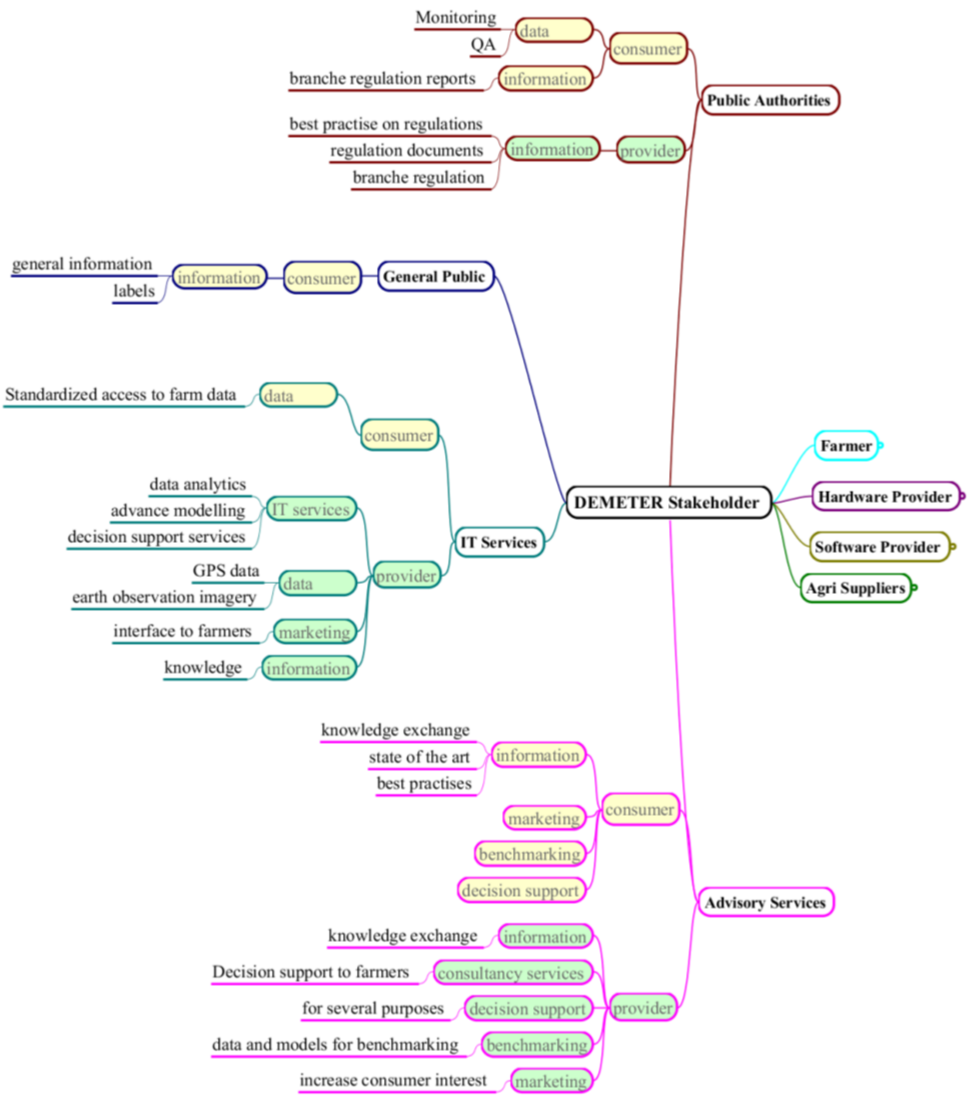


Figure 44: Stakeholders using DEMETER platform as provider

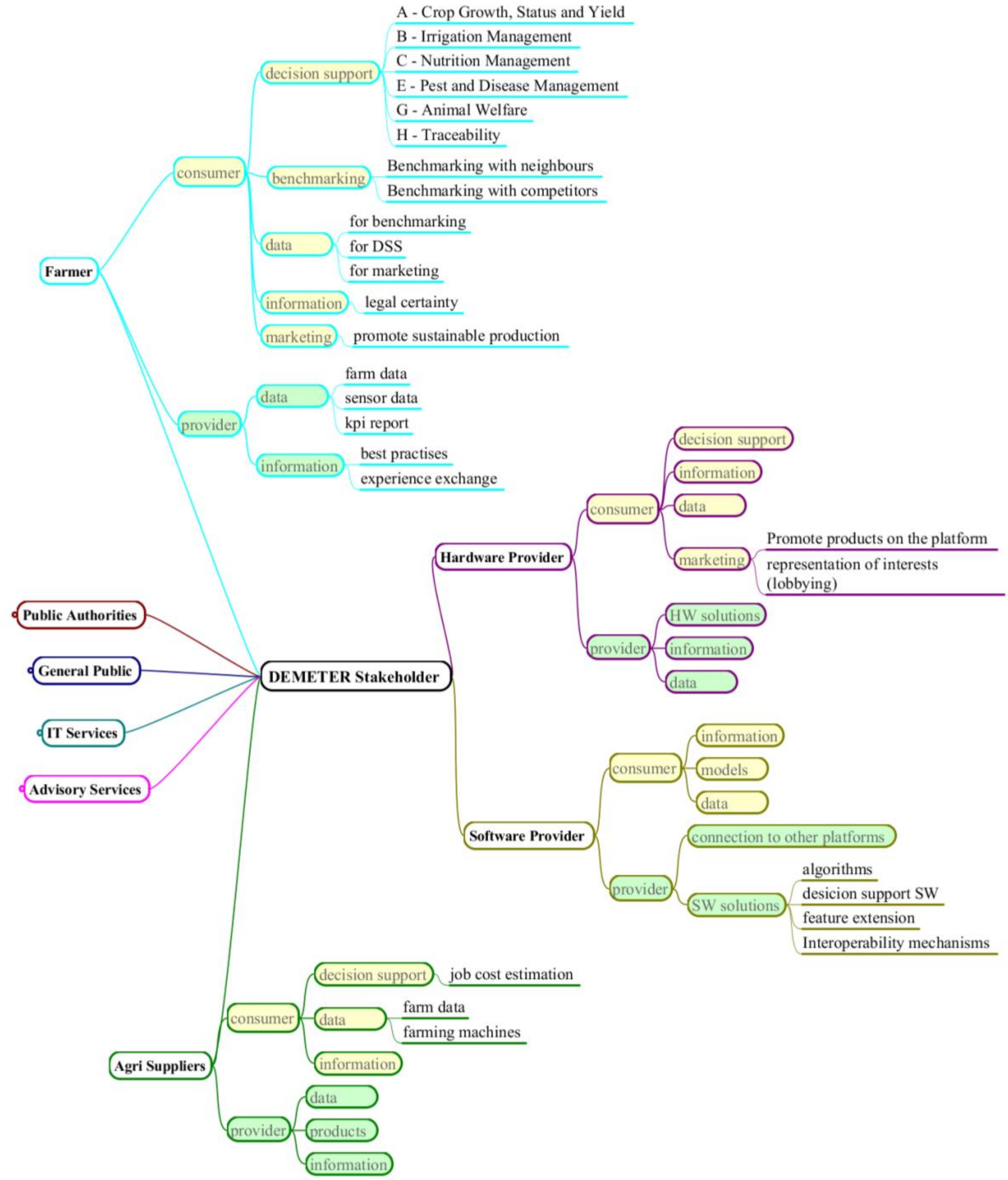


Figure 45: Stakeholder using DEMETER platform as consumer

Annex B Stakeholder requirements

To achieve the objectives of the pilot key building blocks have been identified and matched to the decision support area in DEMETER where they are addressed. To provide a base for transferring DEMETER results to relevant stakeholders as part of the MAA activities, internal and external participants in the DEMETER Pilots have been consolidated into generic stakeholder classes. The interest of a stakeholder can be as consumer (c), provider (p) or combined consumer/provider (c/p) of a building block.

Pilot 1.1& 2		Stakeholders						
DEMETER Area	Interest	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	General Public
	Irrigation water prediction	c	p					
	Soil moisture estimation	c	p	p				
	Crop anomalies detection	c	P					
	Weather forecast service	c	p					
	Interoperable interfaces	c	p	p				
	Soil sensors	c	c	p				
	DSS for irrigation	c	p	P				
	Kpi data export	p	c		c	c		
	Benchmarking report module	c				c		
	Marketing label / tracing	p	p	p				c
	Marketplace	c/p	c/p	c/p		c/p	c/p	p
	Knowledge base Rules and Regulations	c			c/p	p		
Pilot 1.3		Stakeholders						
DEMETER Area	Required Building Blocks	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	General Public
Pilot 1.3 - Irrigation B / X2	smart water meter	c		p				
	smart electricity meter	c		p				
	interoperable interfaces	c	p	p				
	soil parameter sensors	c	c	p				
	weather forecast service	c	c					
	irrigation requirements model	c	c/p			p		
	model for efficient use of resources	c	c/p			c/p		
	IoT monitoring system	c	p	p			c/p	
	EO Imagery Analysis	c				c/p	p	

Pilot 1.3 - Fertilisation	D / X2	VRA machinery	c		p		p	p	
	C / X2	EO Imagery Analysis	c				c/p	p	
		fertilisation model	c				p		
	L	kpi data export	p	c	p	c	c		
		benchmarking report	c	c/p			c/p		
	X1 / H	marketing label / tracing	p	p	p				c
	X1	marketplace	c/p	c/p	c/p	p	p		c
	X4	knowledge base	c/p	c/p	c/p	p	c/p		c
		Pilot 1.4	Stakeholders						
DEMETER Area		Required Building Blocks	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	General Public
B / C / X2		recommendations for water/fertilizer management	c	p					
		early warning system	c	p					
		data export	c	p					
		soil parameter sensors	c	p	p				
		weather forecast service	c	p		p		p	
		weather station / integration	c	p	p				
		real-time data	p	c					
		web processing services / EO Imagery		c				p	
		generic data gateway	c/p	c/p	p			p	
L		academic research	c/p	c	c		c/p		
		real-time data	p	p	p	p	c/p		
		generic data gateway	c/p	c/p	c/p	c/p	c/p	c/p	
		kpi data export	p	c	p	c	c		
		benchmarking report	c	c/p			c/p		
X1 / H		marketing label / tracing	p	p	p				c
X1		marketplace	c/p	c/p	c/p	p	p		c
X4		knowledge base	c/p	c/p	c/p	p	c/p		c
		Pilot 2.1	Stakeholders						
DEMETER Area		Required Building Blocks	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	agri-suppliers
D		farming machines	c						p
		machine sensor data	p	c			c		c
		efficiency modelling	c	p			c		p
		emissions modelling		p					

	data quality assurance					p		
X3	Operational Regulations and Reporting	c			c/p			c/p
Pilot 2.2		Stakeholders						
DEMETER Area	Required Building Blocks	Farmer	SW provider	HW provider	Public Authoriti	Advisory Service	IT Services	agri-suppliers
A, C, E	job cost estimation modelling	c	c/p			c	c	c
	historical farm data	p				c	c/p	
	data exchange platform	c				p		
	data brokering service		c			p		
D	GPS Tracker	p		p		c		
	Machine Sensors	p				c		p
H	data quality assurance		p			p		
L	job cost reporting / prediction	c				p		
Pilot 2.3		Stakeholders						
Interests		Farmer	SW provider	HW provider	Public Authoritie	Advisory Service	IT Services	General Public
Access to data and analysis for decision support relevant to the farm		p	c	c				
Entering own data into the system		p	p	p				
Implementation of the created data collection system		p	p	p				
Including shared- tools and information in the decision-making process		c	c					
Functionality analysis		c						
Testing the usefulness of management using the created system		c	c/p					
Analysis of the benefits of using tools and information in farm management		c	c/p					
Presentation of results		c	p					
Pilot 2.4		Stakeholders						
DEMETER Area	Required Building Blocks	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	agri-suppliers
L	economical data input and analysis	p				p		
	DSS Farm Management Models		c			p		
	Agriculture Cloud			p				

		Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	General Public
	Farm accountancy data network					p		
	Farm Management System Software	c	p				p	
Pilot 3.1		**Stakeholders**						
Interests		Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	General Public
soil and crop information		p	c	p				
remote sensed data		c	p	p				
interoperable interfaces		c	p	p				
weather forecast service		c	c					
olive fruit fly forecasting models		c						
fertilization requirements model		c	c/p					
irrigation requirements model		c	c/p					
decision support platform		c	p					
knowledge base						c/p		
kpi data export		p	c		c	c		
benchmarking report		c	c/p			c/p		
marketplace		c/p	c/p	c/p	p			c
knowledge base		c/p	c/p	c/p	p			c
Pilot 3.2		**Stakeholders**						
Pilot 3.3		**Stakeholders**						
Interest		Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	General Public

Pattern Extraction Computer Vision		p		c		c	
Pest Estimation Sterile Flies	c	p	p	c			
Manufacture of fly traps	c	c/p	c/p				
DSS for irrigation	c	p	p				
Kpi data export	p	c		c	c		
Benchmarking report module	c				c		
Marketing label / tracing	p	p	p				c
Marketplace	c/p	c/p	c/p		c/p	c p	p
Knowledge base Rules and Regulations	c			c/p	p		

Pilot 3.4		Stakeholders						
DEMETER Area	Required Building Blocks	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	agri-suppliers
A	Decision Support platform for crop monitoring	c	p			c/p	p	c/p
A	Variable rate application maps	c	p			c/p	p	c/p
A	Crop type maps	c	p			c/p	p	c/p
A	Yield predictions	c	p			c/p	p	c/p
A	Generic farm data	p	c			c	c	c
A	IoT machinery data	p	c			c	c	c
D	Connected machinery	c						p
X2	Standardized data exchange	c/p	c/p			c	c/p	c

Pilot 4.1	Stakeholders						
Interests	Farmer	SW provider	HW provider	Public Authoriti	Advisory Service	IT Services	agri-suppliers
Dashboard	c	p					

DSS Benchmarking Component		p		c			
DSS System	c	p			c		
Operational data	p	c				p	
Data Hub	p	p		c	c/p	p	
Pilot 4.2	Stakeholders						
Interests	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	agri-suppliers
Cow Health Prediction	c	p			c	p	p
Stress Detection	c	p	p		c/p		
Data Hub	c/p	c/p					
Milk Quality Prediction		p			c		
Traceability System	c/p	p	p	c	c	p	c
Benchmarking report module	c				c		
KPI data export	p						
Marketplace	c/p	c/p	c/p		c/p	c/p	p
Knowledge Base - Rules and Regulations	c			c/p	c		
Pilot 4.3	Stakeholders						
Interests	Farmer	SW provider	HW provider	Public Authoriti	Advisory Service	IT Services	agri-suppliers
Predictive Data Analytics		p	p		c		
Biomarker Sensors	c		p				
Behavioural Sensors	c		p				
DSS Animal Welfare Alerts	c	p			c/p		
Data Filtering and Processing Module		p					
Data Hub	p	c/p	p		c		
Marketplace	c	c/p	c/p		c/p		
Benchmarking report module	c				c		
KPI data export	p						
Knowledge Base - Rules and Regulations	c			c/p	c/p		
Pilot 4.4	Stakeholders						

Interests	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	agri-suppliers
Dashboard	c	p					
DSS Benchmarking Component		p		c			
DSS System	c	p			c		
Operational data	p	c				p	
Data Hub	p	p		c	c/p	p	
Pilot 5.1	Stakeholders						
Interests	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	IT Services	agri-suppliers
Dashboard	c	p					
DSS Benchmarking Component		p		c			
DSS System	c	p			c		
Operational data	p	c				p	
Data Hub	p	p		c	c/p	p	
Pilot 5.2	Stakeholders						
Interests	Farmer	SW provider	HW provider	Public Authoriti	Advisory Service	IT Services	agri-suppliers
Farmers' Collaboration Platform	c	p					p
Production management in livestock farm		p		c	c		
Offering-demand sharing platform	p/c					p	c
Interoperability dashboard	c	p	p				
Pilot 5.3	Stakeholders						

Interests	Farmer	SW provider	HW provider	Public Authorities	Advisory Service	General Public	IT Services
Hive sensors	c		p				
Hive Health Model		p					p
Hive Management Software	c	p					
Pollination Service Matching	c				p		
Pesticide Alerts	c				p		
Data Hub		p					p
Knowledge Base - promote sustainable bee keeping	c				p	c	
Knowledge Base - Promote pollination benefits	c				p	c	
Marketplace	c	p	p		p		p

Pilot 5.4	Stakeholders						
Interests	Farmer	SW provider	HW provider	Public Authoritie	Advisory Service	IT Services	agri-suppliers
Dashboard product passport	c	p					p
DSS Benchmarking Component		p		c			
DSS System	c	p			c		
Data Hub	p	p		c		p	

Annex C Pilots KPIs

KPI Pilot 1.1-1.2	**Time bound**	**Target**
Reduction of energy consumption in pumping water derived from a better monitoring of water consumption (kW h/ha)	yearly	>2,5%
Reduction of water consumption in crops derived from better follow-up and monitoring of them (m3/ha)	yearly	>2,5%
Cost savings in crop production due to a reduction in water and energy consumption (€/ha)	yearly	>5%
Investment savings in the renewal of irrigation remote control systems (€/ha)	Every 10 years	>10%
Cost savings in crop production derived from more efficient irrigation management by integrating management systems and remote control systems from different manufacturers: reduction of operating times, integration of data related to irrigation, better monitoring of breakdowns,. (€/ha)	yearly	>3%
Reduction of the exchange of data exchanged in the irrigation management and control system (number of data/ha)	monthly	>5%
Number of users/farmers/plots with access to DEMETER DSS for Irrigation	End of project	+20
Improve the efficiency of the evapotranspiration estimation	End of project	>5%
Improve the efficiency of the irrigation water estimation	End of project	>5%
Improve the efficiency of the soil moisture estimation	End of project	>5%
Reduce false positives in crop water status anomalies detection	End of project	>5%
KPI Pilot 1.3	**Time bound**	**Target**
• **Decrease in irrigation water consumption** *Detailed description:* The use of the SIS-Rice or the SIS-Maize service leads to a decrease in water consumption (measured in total m^3/ha for the whole cultivation season), compared to the average of fields at similar conditions (e.g., crop variety, soil composition, meteorological conditions throughout the season) that do not employ the services.	Yearly	≥ 10%

• **Water salinity in rice crops is detained below a critical threshold** *Detailed description:* The use of the SIS-Rice service avoids water salinity exceeding the high-risk threshold (3 dS/m according to Best Practice Guides for rice) upon which yield is expected to be negatively affected.	Yearly	Water salinity does not exceed 3 dS/m for at most one day at any point within the growing season
• **Reduced costs for fertilisers, compared to the average of conventionally treated fields** *Detailed description:* The use of the FertiRM service leads to a total net reduction of cost for fertilisers per unit of yield obtained, compared to the average of fields at similar conditions (e.g., crop variety, soil composition, meteorological conditions throughout the season) that do not employ the service. Measured in €/kg yield.	Yearly	≥ 15%
Pilot 1.4 KPI	**TIME BOUND**	**TARGET**
Reduction in the time allocation for visually (on-site) assessing problems affecting the plants.	Weekly	50%
Increase precision of fertilizer applications based on an agronomic formula which incorporates the following parameters: soil type, crop type, previous crop, etc.	Yearly	20% (this one is more qualitative then quantitative)
Increase precision of plant stress appraisal (for improving crop health).	Weekly	20% (this one is more qualitative then quantitative)
Increase precision in determining the area that has a nitrogen deficit level in the plot.	Monthly	20%
Pilot 2.1 KPI	**TIME BOUND**	**TARGET**
Reduce time to check machine condition	Monthly	5%
Safe time for maintainance through simplified fault analysis	Yearly	5%
Reduce costs for machine maintainence	Yearly	3%
Reduce environmental impact in case of engine or aftertreatment malfunction	Yearly	10%
Pilot 2.2 KPI	**TIME BOUND**	**TARGET**

Reduce time spent on documentation	Monthly	
Reduce time on job cost calculation	Monthly	25%
Implementation of data quality measurements	n/a	20
KPIs for pilot 2.3	**Time bound**	**Target**
The solution that allowed the farmer to have access to the complete data from one point (Farmers are using much independent information, technical systems, and technologies systems)	End of project, daily	Access from one point into +10 sources
The solution allowed the farmer analysis, visualization, and decision support system from one point	End of project, daily	Number of countries involved + 4
Reduction of necessary time duration for data management with the same amount of farm staff	End of project, daily	-30% of
Number of involved farmers (users) that have access to the Demeter Data Brokerage Service for Decision Support System and for Farm Managemen	End of project, daily	Access +10
KPIs for pilot 2.4	**Time bound**	**Target**
Number of economical models for benchmarking of farms	Total	*3*
Number of economical data and datasets avaiable for bechmarcking for farmers Number of farmers, that have access to new data in their digital tool or new digital tools,which is usefull for economical benchmarcking	Yearly	*+90%*
• Number of systems reusing/integrating Pilot 2.4 solutions	Yearly	2+
• Increasing the economic efficiency of farms Measured as the potential and possibilities calculated / indicated in decision support by benchmarking methods. It can be also mesaured as a number of farmers that implement the benchmarcking DSS.	Total	+10%
KPI Pilot 3.1	**TIME BOUND**	**TARGET**
Number of involved farms which have accessed the system	end of project	110
Number of farms which complete the data entering to use the DSS	end of project	45

*Decrease the volume of irrigation water used per year (mm ha^{-1})	year	10%
*Decrease the amount of Nitrogen used for fertilisation per year (kg ha^{-1})	year	10%
Improve water (irrigation) use efficiency (ton mm^{-1})	year	10%
*Increase average yield (ton ha^{-1})	year	10%
*Reduce the number of control treatments (olive fruit fly)	year	10%
* For the KPIs referring to the reduction of input it is extremely difficult to see any significant reduction within the project period. The amount of irrigation water used during the season and its variation over the years, for instance, depend only in part on the use of DSS and the correct evaluation of the crop requirements. Important role is played by the weather pattern and disturbance regime, which may bias comparison between growing seasons.		
KPI Pilot 3.2	**TIME BOUND**	**TARGET**
Number of involved farms which have accessed the system	end of project	50
Number of farms which complete the data entering to use the DSS	end of project	30
*Decrease the volume of irrigation water used per year (mm ha^{-1})	year	10%
*Decrease the amount of Nitrogen used for fertilisation per year (kg ha^{-1})	year	10%
Improve water (irrigation) use efficiency (ton mm^{-1})	year	10%
*Increase average yield (ton ha^{-1})	year	10%
*Reduce the number of control treatments (scaphoideus titanus fly)	year	10%
KPI PILOT 3.3	**TIME BOUND**	**TARGET**
Increase the monitoring surface with the same project staff *Detailed description:* the use of automatic traps allows sending daily data on the status of captured insects, thus avoiding the need for operators to go to the traps to check their status.	Monthly	≥ 50%
Possibility of short-term reaction to an outbreak of fruit flies *Detailed description:* Fruit fly pest monitoring provided by automatic traps and sensors allow to manage alerts that inform about pest increases and act more quickly.	Monthly	20%
Reduction in the use of pesticides	Yearly	≥ 30%

Detailed description: A better management of the fruit pest, with automatic traps, sending updated information daily, and the use of alerts or alarms, allows a more precise release of sterile males based on the sterile insect technique and a reduction in the use of pesticides in general.		
KPI PILOT 3.4	**TIME BOUND**	**TARGET**
Number of WIG users that have access to Demeter yield predictions	End of project	+50
Number of WIG users with AVR connection: these can be considered as users that are applying precision agriculture techniques in some way	End of project	+10
Number of additional stakeholders (research organisations, application developers,…) using shared yield data	End of project	+2
Average increase of yield (ton/ha) by adopting Demeter services	End of project	+2%
Increase of accuracy of predicted yields using Demeter data-driven model (%)	End of project	+10%
KPI PILOT 4.1	**TIME BOUND**	**TARGET**
Animal welfare **% of healthy cows** (no ketosys, no lameness, no mastitis)	monthly	>80%
Animal mortality % of deaths	yearly	<5%
Increase milk production Kg of raw milk	monthly	+2%
Increase Milk quality % of milk protein content	monthly	3,3
Increase Milk quality % of milk fat content	monthly	3,8
KPI PILOT 4.2	**TIME BOUND**	**TARGET**

• Animal welfare % of healthy cows (no ketosys, no lameness, no mastitis)	Montly	>80%
• Animal mortality % of deaths	Yearly	<5%
• Increase milk production Kg of raw milk	Montly	+2%
• Increase Milk quality % of milk protein content	Montly	3,3%
KPI PILOT 4.3	**TIME BOUND**	**TARGET**
Biomarkers developed successfully *Detailed description: Validated behaviour data recorded which will contribute to the detection of health score system.*	Yearly	*100%*
Correct predictions of ill animals based on behaviour parameters *Detailed description: Detailed description: This is achieved by the developed algorithm using the cow behavioural data collected from the Smartbow ear tag and bio markers.*	Yearly	*95%*
Percentage of cow herd healthy over entire lactation *Detailed description: Milk produced from healthy cows over the entire lactation with 98% healthy cows.*	Yearly	98%
Reduced use and cost of animal treatment *Detailed description: Reducing manual labour for the tracking and checking each cows health. Early illness detection will keep the cost down. This is all achieved by using algorithm that is been developed.*	Yearly	10%
KPI PILOT 4.4	**TIME BOUND**	**TARGET**
Reduced manual labor *Detailed description: Reduced manual labor for repetitive tasks (checkig conditions into poultry barn, recording relevant parameters) thanks to real time insight into environment conditions as well as automated recording relevant data through simple mobile application.*	Yearly	*30%*
Flock uniformity improvement *Detailed description: Improved homogeneity (weight) of birds thanks to everyday measurements by using ML service.*	Yearly	*20%*

Reduce mortality *Detailed description: Reduced mortality rate thanks to optimized environment conditions into poultry barns.*	Yearly	10%
KPI PILOT 5.1	**TIME BOUND**	**TARGET**
• **Supply chain transparency** *Detailed description: information about field of origin, chemical treatments, water/energy used available on blockchain and accessible via unique codes.*	Yearly	>10000 bottles labelled
• **Consumer engagement** *Detailed description: consumers interacting with labels providing supply chain information.*	Yearly	> 500
• **Decreased pesticide usage** *Detailed description: The use of pest and disease prediction models leads to decreased number of pesticide spraying* in comparison to the average over previous 5 years.	Yearly	20%
• **Decreased water usage** *Detailed description: The use of irrigation expert module helps in optimized number of irrigation cycles leading to decreased water usage comparing to* the average over previous 5 years.	Yearly	10%
KPI PILOT 5.2	**TIME BOUND**	**TARGET**
UC#1		
KPI name	**Time bound**	**Target**
Improve the amount of data available to calculate the nutrients (or D-value) of the grass, or to know when to harvest.	End of the project	Around 10%
Reduction of Whatsapp/SMS messages and telephone calls per grass harvesting procedure. Messages are related to 1-pre-ordering for contractors, 2-real execution requests when the time is up, 3-discussion of when, by who, how much, machine got broken, etc.	End of the project	20%
Data from the Finnish Weather Service (weather stations) and from field will be used to provide the farmer with better information for harvesting	End of the project	>=2
UC#2		
KPI name	**Time bound**	**Target**

Reduction in the number of staff needed to carry out livestock sanitation (UC#2)	monthly	<10%
More efficient and streamlined work of veterinarians (UC#2)	monthly	15%
Improved data collection and accurate in livestock sanitation (UC#2)	weekly	>10%
UC#3		
KPI name	**Time bound**	**Target**
Reduction in unitary annual number of thermal discomfort episodes	6 months	> 10%
Improvement in the users' satisfaction and QoE (shopping experience)	6 months	Significant at p < 0.005
Reduction in the reaction time to users' demands and opinions	6 months	> 15%
Reduction in the cost of supply processes	6 months	> 5%
Reduction in the number of shortage in the food supply chain	Year	20%
Reduction in the cost of strategic decisions	Year	> 10%
Improvement in users' satisfaction and QoE (global, trustworthy and transparent information)	6 months	Significant at p < 0.005
KPI Pilot 5.3	**TIME BOUND**	**TARGET**
Improving pollinated crop yields An increase in rape yield from fields optimally occupied by bee colonies of at least 10 % compared to the previous years (based on similar weather conditions during the growing season)	Yearly	+ 10%
Response time to infringements Reduction in the time from the occurrence of the problem to in monitored hives to intervention by notification system alerts (triggers: change of location, internal temperature, shock)		< 2 days
Increase in bee families survival rate Increase the survival rate of colonies monitored for intra-hive parameters over the winter period by 25% compared to unmonitored hives.	Yearly	+ 25%
Hive sensor data availability Collection of data samples from sensors running in hives and connected to the AMS.	Monthly	> 90%

KPI Pilot 5.4	TIME BOUND	TARGET
• **Supply chain transparency** *Detailed description: Relevant data (farm of origin, environmental parameters over time related to the animal wellbeing, vaccines, transport conditions, slaughter time) available on blockchain and accessible via unique codes.*	Yearly	*> 10 batches labelled*
• **Consumer engagement** *Detailed description: Consumers interacting with labels providing supply chain information.*	Yearly	*> 300*

Annex D Stakeholder Needs

ID	Stakeholder/-group	Need	User Requirements	Organisational Requirements
NEEDS DERIVED FROM STAKEHOLDER WORKSHOP NEEDS:				
N-001	Farmer	As a farmer, I need to increase my farm's ecological sustainability.	The user needs to be able to discern the level of his/her farm's ecological sustainability on the system.	The farmer needs to ensure the increase of his/her farm's ecological sustainability.
N-002	Farmer	As a farmer, I need to increase my farm's economic sustainability.	The user needs to be able to discern the level of his/her farm's economic sustainability on the system.	The farmer needs ensure the increase of his/her farm's economic sustainability.
N-003	Farmer	As a farmer, I need to be involved in the strategic development of innovations from the beginning of the process.	The user needs to be able to discern the strategic development of innovations at any point in time on the system.	The farmer needs to ensure influence over the strategic development of innovations from the beginning of the process.
N-004	Farmer	As a farmer, I need to increase yield output.	The user needs to be able to discern his/her yield output on the system.	The farmer needs to ensure the increase of his/her yield output.
N-005	Farmer	As a farmer, I need my farm's data to be accessible, secure, and comprehensive for me.	The user needs to be able to insert his/her farm's data that is accessible, secure, and comprehensive on the system.	The farmer needs to ensure that his farm's data are accessible, secure, and comprehensive.
N-006	Farmer	As a farmer, I need to have access to weather and climate change information.	The user needs to discern weather and climate change information on the system.	
N-007	Farmer	As a farmer, I need automated documentation of my farm’s operations.	The user needs to obtain the documentation of his/her farm’s operations on the system.	
N-008	Farmer	As a farmer, I need to compare my farm's performance to the performance of other, similar farms.	The user needs to be able to discern his/her own farm's performance in comparison with that of other, similar farms on the system.	
N-009	Farmer	As a farmer, I need to increase yield quality.	The user needs to be able to discern his/her yield quality on the system.	The farmer needs to ensure the increase of his/her yield quality.

N-010	Farmer	As a farmer, I need to have access to extension services (advisory services).	The user needs to be able to access extension services (advisory services) on the system.	
N-011	Farmer	As a farmer, I need to have access to feasible and affordable technology (provided by DEMETER).		The farmer needs to ensure that s/he has access to feasible and affordable technology (provided by DEMETER).
N-012	Farmer	As a farmer, I need to optimize input usage.	The user needs to be able to access his/her input usage on the system.	The farmer needs ensure optimisation of his/her input usage.
N-013	Farmer	As a farmer, I need to have access to market information.	The user needs to be able to access market information on the system.	
N-014	Farmer	As a farmer, I need support for maximizing profit.	The user needs to be able to access support for maximizing profit on the system.	
N-015	Technology provider	As a technology provider, I need to have information on and access to interoperable and standardized data.	The user needs to be able to access information about interoperable and standardized data on the system.	The technology provider needs ensure that data is interoperable and standardized.
N-016	Technology provider	As a technology provider, I need to better know and understand farmers' needs in order to come up with new and broader business opportunities.	The user needs to be able to access his/her farmers' needs in a detailed and understandable way on the system.	
N-017	Technology provider	As a technology provider, I need advanced, data-driven services that I cannot develop myself.	The user needs to be able to access advanced, data-driven services on the system.	
N-018	Technology provider	As a technology provider, I need to interact with farmers to improve my solutions.	The user needs to be able to establish contact with his/her farmers on the system.	
N-019	Technology provider	As a technology provider, I need to	The user needs to be able to receive decision-making support on the system.	

		improve my decision-making based on data.		
NEEDS DERIVED FROM STAKEHOLDER WORKSHOP CONCERNS:				
N-020	Farmer	As a farmer, I need the fit of the technology with current technological developments.		The farmer needs to ensure the fit of the technology with current technological developments.
N-021	Farmer	As a farmer, I need ensured privacy and data protection.		The farmer needs to ensure privacy and data protection.
N-022	Farmer	As a farmer, I need my new technology to be compatible with my already-used technology.		The farmer needs to ensure that his/her new technology is compatible with his already-used technology.
N-023	Farmer	As a farmer, I need the necessary skills to be able to use or operate new technology.	The user needs to be able to access support for use on the system.	The farmer needs to ensure the development of his/her skills for using the technology.
N-024	Technology provider	As a technology provider, I need ensured privacy and data protection.		The technology provider needs to ensure privacy and data protection.
N-025	Technology provider	As a technology provider, I need independence from monolithic data architecture.		The technology provider needs to ensure independence from monolithic data architecture.
NEEDS DERIVED FROM USE-CASE INTERVIEWS: (regarding SOCS)				
N-026	Farmer	As a farmer, I need knowledge exchange with local farmers in order to increase yield output and quality.	The user needs to be able to establish contact for knowledge exchange with local farmers on the system.	
N-027	Farmer	As a farmer, I need expert advisory in order to be able to face new, unforseen or highly-specific challenges.	The user needs to be able to access expert advisory on the system. The user needs to be able to discern challenges and their specifications on the system.	

N-028	Farmer	As a farmer, I need highly-adapted solutions / advisory services in order to deal with challenges regarding regional conditions and individual problems.		The farmer needs to ensure the adaptability of the solutions / advisory services regarding regional conditions and individual problems.
N-029	Farmer	As I a farmer, I need close cooperation with local authorities and other farmers in order to comply with local regulations.	The user needs to be able to establish contact with local authorities on the system. The user needs to be able to establish cooperation with other stakeholders (e.g. local authorities, farmers) on the system. The user needs to be able to discern local regulations for his/her farm on the system.	
N-030	Farmer	As a farmer, I need to know the interests and concerns of other farmers in my area in order to coordinate our farming activities.	The user needs to be able to discern the interests and concerns of other farmers in his/her area on the system.	The farmer needs to ensure that he coordinates his/her farming activities with the interests and concerns of other farmers in his/her area.
NEEDS DERIVED FROM USE-CASE INTERVIEWS				
N-031	Farmer	As a farmer, I need highly individualised, site-specific information and advice in order to apply it to my crops.	The user needs to be able to access highly individualised, site-specific information and advice on the system.	
N-032	Farmer	As a farmer, I need decision support in the form of recommendations and advice in order to optimise my farming.	The user needs to be able to receive decision-making support in the form of recommendations and advice on the system.	wie N-019 (TP)

N-033		As a farmer, I need to know why I was given a certain recommendation in order to be able follow it.	The user needs to be able to discern the justification/explanation for why s/he was given a certain recommendation on the system.	
N-034	Farmer	As a farmer, I need all the information from different sources (e.g. weather, soil, plant) at one place in order to integrate it efficiently.	The user needs to be able to access information from different sources (e.g. weather, soil, plant) integrated at one place on the system.	
N-035	Farmer	As a farmer, I need to know when I have to make an intervention for his agriculture in order to achieve the best results.	The user needs to be able to discern when to make an intervention for agriculture on the system.	
N-036	Farmer	As a farmer, I need to know the specifics of each field/plot in order to know which interventions to apply.	The user needs to be able to discern the specifics of each field/plot on the system.	
N-037	Farmer	As a farmer, I need to know how healthy my plants/animals are in order to to know which interventions to apply.	The user needs to be able to discern the health of his/her plants/animals on the system.	
N-038	Farmer	As a farmer, I need to convince my fellow workers and farmer of the usefulness of technological solutions in order to apply them in my business.		The farmer needs to ensure that his/her fellow workers and farmer recognise the usefulness of technological solutions.
N-039	Farmer	As a farmer, I need to compare my farm's data with that of other farms in order to understand and optimise my agriculture.	The user needs to be able to access the data of other farms for comparison on the system.	
N-040	Farmer	As a farmer, I need KPIs in order to know	The user needs to be able to access various KPIs for	

		how to optimise my cost and output.	his/her farm on the system.	
N-041	Farmer	As a farmer, I need my technology to work (including internet connection) location-independently.		The farmer needs to ensure that his digital devices work (including internet connection) location-independently.
N-042	Farmer	As a farmer, I need reliable predictions in order to apply my interventions.	The user needs to be able to discern reliable predictions on the system. The user needs to be able to discern on the system how reliable the prediction s/he receives are.	The farmer needs to ensure that the prediction s/he receives are reliable
N-043	Farmer	As a farmer, I need to have time savings regarding the times that I spend with different farming activities in order to prioritise the time that I spend with crucial, meaningful farming activities, rather than mundane ones.	The user needs to be able to discern the time s/he spends with each farming activity on the system. The user needs to be able to insert his/her times spent with each farming activities on the system.	The farmer needs to ensure that s/he saves time on mundane farming activities.
N-044	Farmer	As a farmer, I need to know where all the installed sensors and technology are on my farm in order to take care of them.	The user needs to be able to discern on the system the locations of his/her installed sensors and technology on the farm.	
N-045	Farmer	As a farmer, I need to know how much of my resources (e.g. water, pesticides) I spend in order to ensure I do not deplete them.	The user needs to be able to discern on the system how much of his/her resources (e.g. water, pesticides) s/he spends.	The farmer needs to ensure that s/he does not deplete his/her resources (e.g. water, pesticides).
NEEDS DERIVED FROM CO-CREATION INTERVIEWS				

N-046	Farmer / Technology provider	As a farmer / technology provider, I need to be able to safely log into the system.	The user needs to be able to enter his/her email-address on the system. The user needs to enter his/her password on the system.	
N-047	Farmer / Technology provider	As a farmer / technology provider, I need to be able to post a challenge.	The user needs to be able to select an agricultural category for the challenge on the system. The user needs to be able to choose hashtags for the challenge on the system. The user needs to be able to upload pictures to a challenge on the system. The user needs to be able to post a challenge on the system. The user needs to be provided with feedback on the system that the challenge has been posted.	
N-048	Farmer / Technology provider	As a farmer, I need to be able to be aware of challenges that others posted.	The user needs to be able to browse through a list of existing needs on the system. The user needs to discern whether a challenge is active or not on the system. The user needs to be able to order the list of challenges on the system in order to be able to find discern the most upvoted challenges. The user needs to be able to order the lost of	

			challenges on the system in order to be able to find the challenges that attract the most attention at the moment. The user needs to be able to filter the list of existing challenges location on the system in order to find out which challenges occur in his/her region. The user needs to discern whether a similar need has already been posted on the system. The user needs to be able to filter the list of needs on the system in order to be able to find certain needs more quickly.	
N-049	Farmer / Technology provider	As a farmer / technology developer, I need to be able to express interest in others' challenges.	The user needs to be able to upvote a challenge on the system.	
N-050	Farmer / Technology provider	As a farmer / technology provider, I need to be able to express that I want to collaborate on a challenge.	The user needs to be able to indicate on the system that she/he wants to collaborate on a challenge in the future. The user needs to be able to indicate on the system that he/she wants to join in on an active challenge. The user needs to be able to subscribe to a challenge on the system.	

N-051	Farmer / Technology provider	As a farmer / technology provider, I need to be able to take part in the creation of novel smart-farming solutions.	The user needs to be notified on the system if a challenge that he/she expressed interest in becomes an active challenge (by having at least one farmer and one tech-developer willing to collaborate on the challenge). The user needs to be able to agree to actively collaborate on a challenge on the system. The user needs to be informed about the challenges that he/she is currently involved in on the system. The user needs to be informed on the system about the ongoing activities in within a challenge. The user needs to be able to contribute solution ideas to a challenge on the system. The user needs to be able to sign a collaboration agreement that regulates legal questions like property rights, business transactions, etc. for the duration of the collaboration on the system. The user needs to be able to access the agreement on the system.	

N-052	Farmer / Technology provider	As a farmer / technology provider, I need to be able to build a personal connection to and trust with other collaborators.	The user needs to be able to discern the company details of technology developers on the system. The user needs to be able to discern past co-creation activities from the farmer / technology developer on the system. The user needs to be able to contact other collaborators directly on the system.	
N-053	Farmer / Technology provider	As a farmer / technology provider, I need to be able to provide others with my contact details and company specifics.	The user needs to be able to enter contact details, like name, location, phone number, email address, associated farming organization, etc. on the system. The user needs to be able to access information about potential collaborators on the system. The user needs to be able to get into direct contact with possible collaborators on the system.	
N-054	Farmer / Technology provider	As a farmer / technology provider, I need to have an official collaboration agreement.	The user needs to be able to sign a collaboration agreement that regulates legal questions like property rights, business transactions, etc. for the duration of the collaboration on the system. The user needs to be able to access the collaboration agreement on the system.	

Annex E User driven Stakeholder requirements

Title	Description	Relevant for pilots	Optional infos
DSS on Animal Welfare-data Input	The DSS on Animal Welfare will enable the farmer to enter data concerning the fat/protein ratio, the electrical conductivity, the total daily rest for each animal of his/her livestock.	4.2	corresponding to 4.G.1 Estimate Animal Welfare Condition
DSS on Animal Welfare - monitor pathologies	The DSS on Animal Welfare will provide the farmer with graphical widgets to monitor the current health status of the livestock with respect to the followig pathologies: lameness, ketosis and mastitis.	4.2	corresponding to 4.G.1 Estimate Animal Welfare Condition
DSS on Animal Welfare - recommended actions	The DSS on Animal Welfare should display recommended actions to correct and improve animal welfare measures	4.2	corresponding to 4.G.1 Estimate Animal Welfare Condition
DSS on Milk quality prediction - data input	The DSS on Milk quality prediction will enable the user to enter data concerning the samples' analysis obtained through the FTIR (Fourier Transform InfraRed Transform) spectroscopy	4.2	corresponding to 4.H.1 Milk Quality Prediction
DSS on Milk quality prediction - monitor milk quality	The DSS on Milk quality prediction will provide the processing company with graphical widgets to monitor the current level of milk quality (high, medium or low) for the raw and processed milk	4.2	corresponding to 4.H.1 Milk Quality Prediction
DSS on Milk quality prediction -	The DSS on Animal Welfare should display recommended actions to correct and improve milk quality	4.2	corresponding to 4.H.1 Milk Quality Prediction
Milk Traceability - Web Application	The traceability system will provide the end customer with the possibility to visualize all the steps involved in the milk production	4.2	
Milk Traceability - QR Code	The traceability system will provide the customer with a QR code on the bottle of milk in order for them to scan it and reach the web application	4.2	
Milk Traceability - Blockchain	The traceability system will use the Blockchain technology	4.2	
DSS for Irrigation Management: User data input	This DSS uses agronomic data of the plot (i.e. about the crop, the soil and the irrigation system) that will be introduced by the farmer and available in the pilot cloud infrastructure to be exposed in DEMETER by the WP2 Pilot Plot Bridge DEE.	1.1_1.2	corresponding to 4.B.1. DSS for Irrigation Management

DSS for Irrigation Management: Automatic data input	This DSS uses local and remote sensing data about the plot (i.e. about the soil moisture, weather, and satellite multiespectral imagery) that will be registered and available in the pilot cloud infrastructure to be exposed in DEMETER by the WP2 Pilot Device Bridge and Weather Forecast DEEs.	1.1_1.2	corresponding to 4.B.1. DSS for Irrigation Management
DSS for Irrigation Management: Predicted information about irrigation.	This DSS wil provide graphical widgets to provide information about the predicted evapotranspiration (exposed by the WP4 4.B.2 Reference Evapotranspiration Prediction DEE), rainwater forecast (exposed by the WP2 Weather Forecast DEE), the estimated average soil moisture (exposed by the WP2 Pilot Device Bridge and by the WP4 4.B.3 Soil Moisture Estimation DEE), images with estimation of soil moisture (exposed by WP4 4.B.3 Soil Moisture Estimation) and images about crop anomalies detection (exposed by WP4 4.B.4 Plant Water Status Anomalies Detection). This information will give the farmer an overview of the estatus of the crops from the point of view of the irrigation to consider more options for the irrigation planing.	1.1_1.2	corresponding to 4.B.1. DSS for Irrigation Management
DSS for Irrigation Management: Timeseris information about irrigation.	This DSS wil provide graphical widgets to provide historical timeseries with information about the irrigation water, the evapotranspiration, the rainwater and the estimated average soil moisture. This information will give the farmer an overview about the crop frame evolution and so have more options to take into account for the next decissions.	1.1_1.2	corresponding to 4.B.1. DSS for Irrigation Management
DSS for Irrigation Management: Recomendation actions.	This DSS will provide recomendations about the amount of water needed for the irrigation of a crop in a plot (exposed by the WP2 Crop Irrigation Water Estimation DEE) for the farmer to save resources and so energy.	1.1_1.2	corresponding to 4.B.1. DSS for Irrigation Management
Agricultural Field Notebook	This component will provide a frontend to the farmer to work with an Agricultural Field Notebook for the crops.	1.1_1.2, 2.4	corresponding to H.3. Field Book and FaST
Predictive Data Analytics	Data analysis will allow predictions on animal welfare parameters to be made	4,3	corresponding to 4.G.1 Estimate Animal Welfare Condition

Biomarker Sensors	Biomarker sensors will validate the relationship between welfare and behaviour parameters	4,3	corresponding to 4.G.1 Estimate Animal Welfare Condition
Behavioural Sensors	These senaors will collect real-time data	4,3	corresponding to 4.G.1 Estimate Animal Welfare Condition
DSS Animal Welfare Alerts	The DSS should display when attention to animal is required	4,3	corresponding to 4.G.1 Estimate Animal Welfare Condition
Data Filtering and Processing Module	Necessary for collation and data management	4.3, 2.4	corresponding to 4.G.1 Estimate Animal Welfare Condition
Data Hub	Will be used to assemble all data for analysis	4.3, 2.4	
Marketplace		4,3	
Benchmarking report module	Benchmarking will be of benefit to stakeholders for improvement	4.3, 2.4	
KPI data export	KPIs required for benchmarking	4,3	
Knowledge Base - Rules and Regulations		4,3	corresponding to 4.G.1 Estimate Animal Welfare Condition
Stress recognition (ID 4.8.14)	The DSS needs to provide assessment of the animal stress using a data from camera: sound and image	4,4	corresponding to 4.G.2 Estimate Animal Welfare Condition
Silo conditions detection (ID 4.7.6)	The sensors will collect the level of the food in the silo	4,4	corresponding to 4.F.2 Poultry feeding
Environment condition assessment (4.7.4)	The DSS needs to provide assessment of the animal stress using a set of quantified parameters: temperature, humidity, movements, co2, light	4,4	corresponding to 4.G.2 Estimate Animal Welfare Condition
Power losses (ID 4.7.5)	The DSS needs to have the ability to detect a power losses as on of the important parameters for the poultry stress	4,4	corresponding to 4.G.2 Estimate Animal Welfare Condition
Environment condition assessment ID 4.7.4	The pilot needs to provide the assessment of the conditions in which the poultry is transported	5,4	corresponding to 4.H.2 Transport conditions
Product passport	The pilot will provide interoperable set of data (pilot 4.4) and enable expousure of such data to different stakeholder on simple scan of the barcode	5,4	corresponding to 4.H.2 Transport conditions and Product passport ID 4.9.1
Disease recognition ID4.8.15	The DSS should be capable to provide instruction to farmer when to spray based on a fungal disease forecast using temperature and humidity as parameters	5,1	Corresponds to WP2 Data analytics for optimal pesticide usage
Machinery/sprayer control ID 4.1.4	Based on disease prediction, machinery should receive the autonomous input for spraying	5,1	corresponfing to 4.D.2 Field operation

Location assessment ID 4.1.8	Location of the product can be determined by using phone scanning the smart tag	5.1 5.4	corresponding to 4.H.2 Transport conditions
DSS for olive fruit fly management	Models estimating the risk of infestation from the olive fruit fly and tools for monitoring the start of infestation	3,1	corresponding 4.E.2 Estimate temperature-related pest events
Olive DSS for irrigation	Determine olive orchard irrigation needs according to evaporative demand, crop traits and water supply.	3,1	
Olive DSS for fertilisation	Determine olive orchard macro-nutrients needs according to crop traits, soil analysis, expected yield and weather data.	3,1	
Benchmarking tools	Compare olive farm yield, profit and costs with similar farms; determine the benefit of technology adoption in input optimisation	3,1	corresponding to 4.I.2 Neighbour Benchmarking and 4.I.3 Technology Benchmarking
Data Brokerage tool - Minimizing the number of software platforms	Farmers and agronomistswant to minimize the number of platforms they have to use. For this reason, integration with existing systems is desirable.	2,3	
Data Brokerage tool - Relevance of datasets	Users need to find datasets that are temporally, spatially and thematically relevant.	2,3	
Data Brokerage tool - Relevant level of dataset integration.	In some cases, it is sufficient if the data relevant to the farm area are simply visualized, for example in the form of a WMS. Integration is required for those datasets that are used in the same analysis.	2,3	
Detect plant stress	Diagnosis of agricultural crops in terms of agropedoclimatic parameters	1,4	corresponding to 4.A.3 Plant Stress Detection
Identify fertiliser need for crops	Identify fertiliser need for crops from different data sources available	1,4	corresponding to 4.C.1 Nitrogen Balance Model
Determination of nitrogen level	Determination of nitrogen level according to NDVI, using methods like: pixel classification, agronomic algorithm and data from in situ sensors and weather forecast	1,4	corresponding to 4.C.1 Nitrogen Balance Model
DSS for potato farmers	Variable rate task maps for irrigation and/or fertilization, based on EO images and (predicted) yield maps	3,4	corresponding to 4.A.1 Plant Yield Estimation and 4.D.3 Variable Rate
Standardized exchange of data and services	Standard AIM format for data exchange	3,4	corresponding to 2.A.1 Agricultural Information Model (AIM)
Connected field machinery	Automatic upload of field machinery data to cloud, and of task maps from cloud to machinery	3,4	

Ensure animal wellness by managing their optimal feeding	Measure crops (that will be used as fodder) and soil properties to determine their necessities: e.g., irrigation or fertilization need	5,2	
Improve farm work organization	Provide the farmer with tools to coordinate work teams, e.g., determine who is doing what or what machinery is available at any moment.	5,2	
Automated arable crop farming documentation API	Enables automated documentation of field operations in precision crop farming	2,2	
Job cost calculation Data Integration Service(DIS)	Enables cost monitoring of field operations in precision crop farming	2,2	
DSS for Pest Estimation with Sterile Fruit Flies	Detecting the amount of sterile/normal fruit flies inside of traps that are able to take pictures of the captured specimens	3,3	corresponding to 4.E.1 Pest Estimation with Sterile Fruit Flies
Machine Monitoring	Monitoring and analyzing of engine and after treatment data during operation -> Feedback to Farmers, Dealers, Manufacturers	2,1	corresponding to 4.D.1 Emissions
Data logging	Logging data for further analysis and the possibility to analyse changes over time	2,1	corresponding to 4.D.1 Emissions
Automated support for farmer/dealer/manufacturers	Give status of machine or even recommendations to resolve (upcoming) issues	2,1	corresponding to 4.D.1 Emissions
Maize irrigation	Decide when to irrigate the maize or hasten an irrigation using input from several sources (weather data/forecast, sensors and UAV images).	1,3	addressed by 2.C.3 (targeted data analytics) enablers
Rice water irrigation (determined by salinity) and crop type identification	Estimate water salinity on rice fields and identify rice crop subtype; then decide whento wash (i.e. change the water in) the rice field.	1,3	addressed by 2.C.3 (targeted data analytics) enablers
Estimation of nitrogen level	Estimation of nitrogen level according to vegetation indices, using imagery and environmental data	1,3	addressed by 2.C.3 (targeted data analytics) enablers
DSS on Optimal Fertilizer Usage	Provide the farmer with insights about the correct amount of fertilizer to be used, based on the status of the plant with respect to the following indices and traits: nitrogen level/concentration, chlorofyll, biomass, etc.	1,3	