TITLE: Pilot 5.2 - Farm of Things in Extensive Cattle Holdings

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1 Introduction

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

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

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

This white paper describes the pilot Farm of Things in Extensive Cattle Holdings, which focuses on improving animals' well-being and health by managing their optimal feeding, and how this can affect the quality of processed products (dairy products and pastries), while considering cereals and eggs as raw materials. This pilot also considers the end-user involvement in quality testing and feedback provision.

2 Importance of digital agriculture

While other clusters focus on on-farm activities and operations, Cluster 5 aims at a cross-sectorial approach to address pre- and post- farm activities, i.e., to address the complete food supply chain. The cluster's four pilots focus on four different areas, considering fruits & vineyards, apiculture, cattle and poultry. Digitalization is crucial for both the supply and demand side of the supply chain, as well as for on-farm management activities.

The adoption of digital technology will be facilitated by the use of interoperability platforms and solutions, already in use in different sectors, such as distributed ledgers in combination with data exchange protocols.

To overcome difficulties in getting farmers to adopt digital technology, the pilots will define experiments in which stakeholders will test technologies and understand their benefits for the management of on-farm and post-farm (supply chain) activities.

3 Pilot Overview

The challenges of the pilot, its main goals and innovations, and the major benefits for participating farms, are described below.

Challenge

Three use cases are being developed in this pilot:

Use case 1 focuses on ensuring the wellness of cows by managing their optimal feeding, where predicting the precise harvest time is a key variable to ensure optimal nutritional levels of the pasture. As harvesting for silage is a complex task, this use case also focuses on improving farm work organization.

Use case 2 aims at improving the production management in a livestock farm integrating new technologies into the daily operations.

Use case 3, the food transparency and user involvement use case, intends to integrate data brokering solutions in current production systems of dairy products and pastries.

This pilot is being carried out in four dairy farms, the Kotipelto farm, which is located in Finland, and three farms located in Spain: Cancho hueco, Dehesa Boyal and Los Camorchones. In total, the pilot involves 360 milking cows and heifers (190 in Finland and 170 in Spain), and 500 ha (200 ha in Finland and 300 ha in Spain).

In addition, some experiments related to the sensorisation of workers' environmental conditions and information flow in the supply chain have been carried out in a food production company in Spain.

Aim of the Pilot

The goals pursued by this pilot are the following: a) to enhance the organization and efficiency of farm activities such as silage harvest, a complex task that involves the coordination of many workers and machinery. For this purpose, the pilot has designed and developed a tool that has been called the *Farmers' Collaboration Tool*; b) to improve the nutrition levels of grass used as fodder and its digestibility (D-value indicator [g of nutrients/kg of dry matter]). The balance between nutrients (proteins and carbohydrates) and fiber is important for a ruminant animal. This value decreases all the time during the growth as culm strengthens. Most farmers have defined the D-value preference value slightly under 700g/kg; c) to guarantee the reliability of animal identification and livestock management as a traceability and animal welfare tool; and finally, d) to improve the efficiency of food production systems, while increasing product information in the supply chain.

Innovations

The main innovations to be achieved by this pilot are: a) to foster interoperability with other smart farming communities (i.e., AFarCloud), that provides many useful product and service concepts to be utilized in this pilot; b) to develop a Farmer Collaboration Tool (FCT) for the organization of farm activities and management of machinery and work forces. FCT helps the farmer firstly to make the harvesting plan in advance, utilizing all available up-to-date field sensor data on the go, but secondly, also to share the work in advance between contractors. Thirdly, especially with silage harvesting, the time is a critical variable. The bigger the farm is, the more it has parcels to be operated and the more workforce and tractors are required to cover the activities in the widening geographical area. With FCT, fluent collaborative execution of pre-planned procedure guarantees the optimal harvest result and minimizes the weather-related risks. With FCT, the farmer has good situational awareness of the process, people and machinery locations and work status per parcel. Similarly, the workers are well aware of the duties and get notifications when it is their turn to start their duties in certain parcels; c) to provide farmers with tools to store, change or update specific information associated with each animal, using voice recognition technologies in the data capture process; and finally, d) to define methods to store and display information about the bakery value chain in a transparent way.

<u>Key Benefits</u>

The main benefits to be achieved by the farms participating in this pilot are the following: in terms of improving the efficiency of farm activities, this pilot works to improve the scheduling and coordination of field work. With FCT, the farmer can adjust the optimal harvesting order of parcels carefully based on fresh D-value measurements. When this procedure is executed fluently by using FCT, deviations from the target D-value are minimized. It must be understood that the D-value drops 5 grams every day. This has a direct connection to milk yield, as 10g protein loss drops the milk production approximately half a litre per cow. With a 100 cow farm, this leads to 600€ monthly loss. Therefore, the right timing gives direct financial benefit for the farmer. In terms of improving production in a livestock farm, the pilot is considering safety and time savings for veterinarians and farmers.

Finally, regarding the provision of data brokering solutions in production systems, the aim is to increase product information and user satisfaction (for both workers and consumers).



Image 1: Pilots in use
Image 1: Pilots in use

Image 2-4: Pilots in use

4 DEMETER Integration

<u>**Key technologies employed**</u>

In this pilot, different technologies have been deployed to collect the necessary data sources:

- LoRa sensor networks, to collect soil data and product data;
- Environmental sensors, to obtain information about weather conditions;
- D-value analyzers, to measure grass digestibility;
- Unmanned Ground and Aerial Vehicles (UGVs and UAVs), to collect field data;
- Wearables (smart glasses) to obtain animal identification data.

Data acquisition is done through standard protocols such MQTT, DDS, REST or RFID.

Besides, some external Smart Farming or IoT platforms are also used:

- The AFarCloud[1] middleware: imported from the H2020 ECSEL project AFarCloud, this middleware provides different interfaces that allow the exchange of real-time messages with unmanned vehicles and sensors (used in use case 1). Information is modelled according to the AFarCloud ontology[2].
- FIWARE's Orion Context Broker and QuantumLeap[3]: to register data collected by the sensor networks (used in use case 3). Information is sent in NGSIv2 format.

Apart from this, the pilot uses the Adaptive Visualization Framework[4] (Knowage) as a control panel to monitor various variables, such as weather conditions, pasture nutrient levels, or animal and product related data.

<u>DEMETER enablers and other technologies</u>

The pilot takes advantage of some of the enablers provided by DEMETER. In terms of data management and interoperability, the pilot uses the *Semantic Mappings to AIM enabler* to map AFarCloud data to AIM, and the *Data Preparation & Integration enabler* to automatically translate data collected by the AFarCloud Middleware to the DEMETER ecosystem.

Besides, considering some special needs of the pilot, we have developed three ad-hoc Data Transformation enablers: one to transform AFarCloud-compliant JSON files into DEMETER-compliant JSON-LD files, another to transform observations modelled under the DEMETER-compliant JSON-LD specification into AFarCloud-compliant JSON data, and another to adapt NGSIv2 data generated in food processing facilities to the DEMETER AIM. We have used *the Interoperability Core enabler* to describe the metadata of these enablers.

Moreover, a DEMETER enabler has been developed that queries data from AFarCloud and prepares it to be shown through the DEMETER Adaptive Visualization Framework.

Regarding service discoverability, we are taking advantage of the *DEMETER Enabler Hub (DEH)* and *Brokerage Service Environment (BSE) enablers*, for the registration of the ad-hoc enablers of the pilot. Besides, the pilot uses the *Access Control Core*

[1] Aggregate Farming in the Cloud: The AFarCloud ECSEL Project - https://www.sciencedirect.com/science/article/pii/S0141933120303793

[2] The AFarCloud ontology: https://git.code.tecnalia.com/afarcloud_public/ontology/-/raw/master/afarcloud.owl

[3] FIWARE's Orion Context Broker and QuantumLeap: https://www.fiware.org/catalogue/

[4] DEMETER Advanced Visualization Tool: https://h2020-demeter.eu/wp-content/uploads/2020/02/White-Paper-on-D4.4-Visualisation-1.pdf

enabler to authenticate and authorize this registration. The *DEH Client enabler* is used to monitor the metrics of the Docker containers.

Finally, the pilot has deployed the *Benchmarking enablers* to get an assessment on the farms' productivity compared to other farms, and some security enablers related to access control, to avoid unauthorized access to critical data.

AIM usage

The Agricultural Information Model is used in the pilot to model observations from sensors and product information. More precisely, the pilot currently manages the following data types:

- Soil, crops and environmental data of fields: used to detect the best moment for harvesting, so that nutrition levels of grass used as fodder are optimal.
- Animal data: information related to animal identification and to their health.
- Farm data: information that identifies a farm and its social information.
- Geospatial data: geographic coordinates of the tractors deployed in the field.
- Environmental data of the food processing facility: obtained from a sensorization board (a DTH-11 module to measure environmental temperature and humidity, and a CCS811 module to monitor the air quality, i.e., equivalent CO2 -eCO2- and total volatile organic compounds -TVOC).
- Production quality and notifications: information about quality processes in food production, which is extended with notifications and messages exchanged between machinery operators regarding production events, maintenance issues, quality of produced food products, and other aspects to consider. Find below an example of how observations of environmental conditions from a food processing facility are modelled in DEMETER:

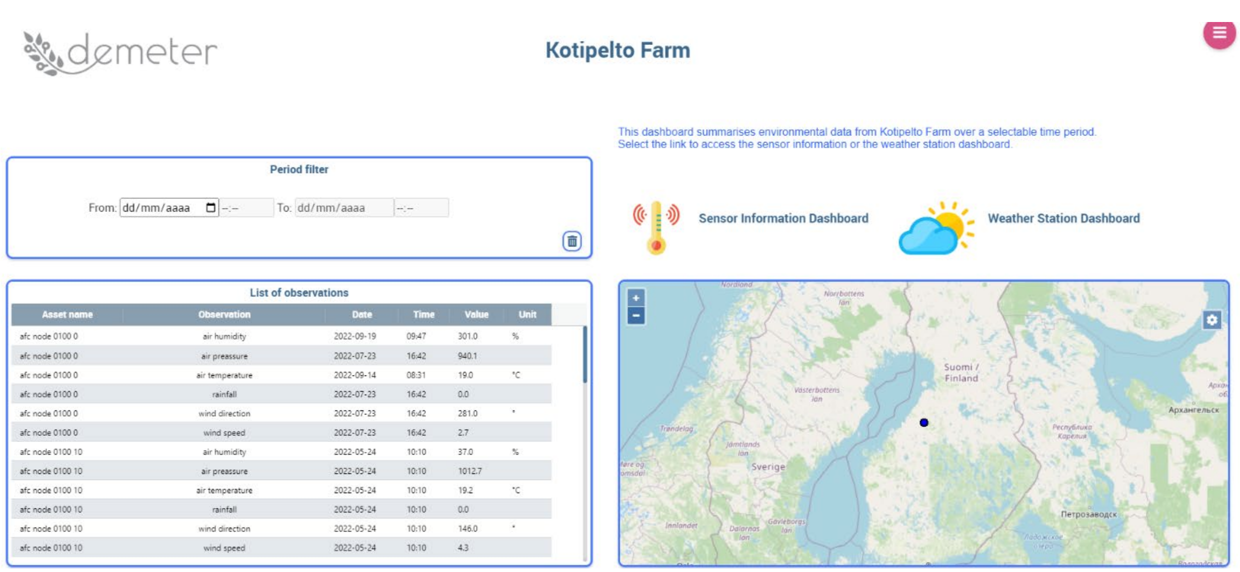

```
{
 "@graph" : [ {
   "@id" : "urn:upm:demeter:p52:node01:pos",
   "@type" : "http://www.opengis.net/ont/sf#Point",
   "http://www.opengis.net/ont/geosparql#wktLiteral" : "POINT(45.75 4.85)"
  }, {
   "@id" : "urn:upm:demeter:p52:node01",
   "@type" : "Sensor",
   "hasGeometry" : "urn:upm:demeter:p52:node01:pos"
 },  {
   "@id" : "urn:upm:demeter:p52:node01:obs-1514810172",
   "@type" : "Observation",
   "hasResult" : ["urn:upm:demeter:p52:node01:obs-1514810172/temp","urn:upm:demeter:p52:node01:obs-
1514810172/hum", "urn:upm:demeter:p52:node01:obs-1514810172/co2", "urn:upm:demeter:p52:node01:obs-
1514810172/tvoc"] ,
   "madeBySensor" : "urn:upm:demeter:p52:node01",
   "resultTime" : "2021-08-01T12:36:12Z"
  }, {
   "@id" : "urn:upm:demeter:p52:node01:obs-1514810172/temp",
   "@type" : "Result",
   "identifier" : "temp",
   "numericValue" : "0.27121272683143616",
```

```
    "unit" : "http://qudt.org/vocab/unit/DEG_C"
   },
  {
    "@id" : "urn:upm:demeter:p52:node01:obs-1514810172/hum",
    "@type" : "Result",
    "identifier" : "hum",
    "numericValue" : "20.27121272683143616",
    "unit" : "http://qudt.org/vocab/unit/PERCENT_RH"
   },
   {
    "@id" : "urn:upm:demeter:p52:node01:obs-1514810172/co2",
    "@type" : "Result",
    "identifier" : "co2",
    "numericValue" : "0.27121272683143616",
    "unit" : "http://qudt.org/vocab/unit/PPM"
   }, {
    "@id" : "urn:upm:demeter:p52:node01:obs-1514810172/tvoc",
    "@type" : "Result",
    "identifier" : "tvoc",
    "numericValue" : "0.27121272683143616",
    "unit" : "http://qudt.org/vocab/unit/MilliGM-PER-M3"
   } ],
  "@context" : [ "https://w3id.org/demeter/agri-context.jsonld", {
    "qudt-unit" : "http://qudt.org/vocab/unit/"
   } ]
}
```


Table 1: Pilot 5.2 DEMETER JSON-LD file with a sensorization sample of the food processing facility

Registration and visualization

The Adaptive Visualization Framework is being used by two of the use cases of the pilot. In Use case 1, to graphically visualize the results of the benchmarking enabler as well as to monitor weather conditions and pasture nutrient levels (measured by AFarCloud compatible sensors) to ensure the right conditions for harvesting. The next figure depicts the information shown to farmers using the dashboards of the Adaptive Visualization Framework:



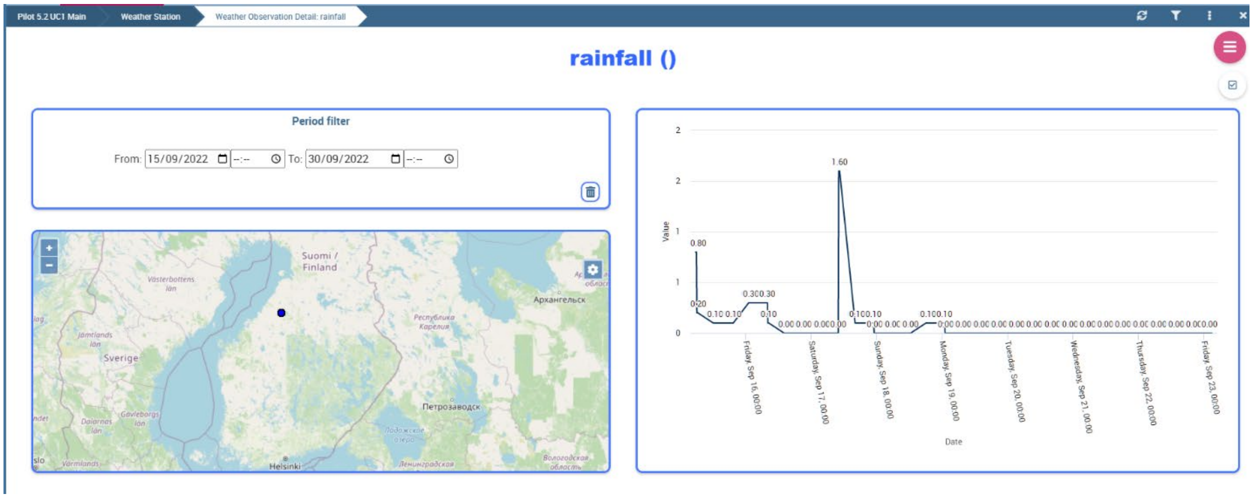
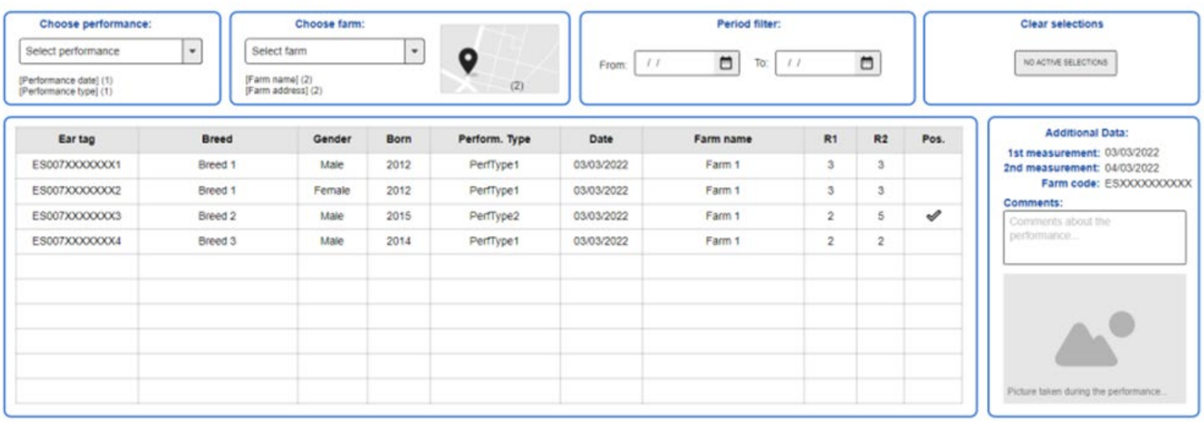


Figure 2: Pilot 5.2 Use case 1 - Information shown to farmers using DEMETER Adaptive Visualization Framework

In Use case 2, the framework allows the provision of roles to each user and the management of vet visits and treated cows. The figure below shows how users can select and combine filters to see the desired information:



Ear tag	Breed	Gender	Born	Perform. Type	Date	Farm name	R1	R2	Pos.
ES007XXXXXXX1	Breed 1	Male	2012	PerfType1	03/03/2022	Farm 1	3	3	
ES007XXXXXXX2	Breed 1	Female	2012	PerfType1	03/03/2022	Farm 1	3	3	
ES007XXXXXXX3	Breed 2	Male	2015	PerfType2	03/03/2022	Farm 1	2	5	✔
ES007XXXXXXX4	Breed 3	Male	2014	PerfType1	03/03/2022	Farm 1	2	2	

Figure 3: Pilot 5.3 Use case 2 - Knowage filters selection example

5 Feedback from farmers

<u>Farmer interactions</u>

Regarding the interactions with the farmers in the pilot, we have carried out several activities:

On the one hand, we have organized a workshop and several meetings with 5 agri-tech SMEs and the pilot farmer in Finland and his 5 main collaborating farms. The goal of these gatherings was to identify the processes of the collaborative farmer network and gather feedback on the use of digital technologies for collaboration in fieldwork operations. We also held multiple short meetings to collect information on how farm machinery is shared between collaborating farms. As a conclusion of these meetings, we understood that for the farmers it is important to manage collaborative work with other farms on a day-to-day basis. They lack the appropriate tools (they currently use WhatsApp messages and phone calls). So, the use of the Farmers' Collaboration Tool (FCT) will be very beneficial for them. The farmers have already tested a first prototype of the FCT during the summer harvest in 2022. As feedback, they said that they would appreciate extra info about data on fuel consumption and kilometres travelled by tractors per task. As a result, an ISOBUS reader has been developed to read vehicle bus data, which will be an exploitable asset of the project. Finally, last November we held a dinner with 5 farmers, 2 key contractors and 1 MP of the Centre Party of Finland (with good connections to agricultural policy processes), to explain the FCT to them and to plan the upcoming summer activities.

On the other hand, we have organized several meetings and tests in the 3 pilot farms in Spain, where farmers and veterinarians could test pilot solutions (3 farmers and their respective veterinarians participated). Some experiments were also done in the food processing company, where food processing experts had the chance to tests the developments and provide their feedback. In this case, four workshops where done, where more than 40 consumers and more than 10 food processing experts discussed pilot innovations and filled out surveys.

6 Benefits

__Benefits of the pilot__

As mentioned along the previous sections, the farmers will have the Farmers Collaboration Tool that will let them organize the work in the farm in a more efficient way so that they can avoid losing money if the harvesting process is not performed at the right moment. As a result, the overall performance of the farms using FCT to collaborate, to share information, share machinery, etc., can be increased.

Moreover, the tools will ease some tasks that veterinarians carry out in the farm. These tools will reduce time to veterinarians and farmers, and will let provide data in a more reliable, efficient and error free way for further processing.

Also, food producers will have a service-based ecosystem that can facilitate the acquisition of environmental measurements, and the management and visualization of alerts, notifications and food quality properties being generated in real-time.

Finally, customers will benefit from other tools of this pilot that let know diverse information of the raw materials (eggs, flour, etc.) that have been used in the elaboration of different final products.

KPIs

Find below the list of KPIs defined for this pilot. The first three are related to the Farmers' Collaboration Tool, in terms of number of datasets aggregated by DEMETER, optimal harvest time calculation and improvement of communications during the harvesting activities. The next two KPIs are related to efficiency and accuracy of the work of the veterinarians in livestock farms. Finally, the last two are related to the improvement of working conditions of the food processing scenarios, as well as to the improvement of user satisfaction by having more accurate information from the food supply chain.

1. Increase by at least 2 the number of datasets aggregated by DEMETER to obtain better data for harvesting. Currently, only soil sensor data is available. Baseline: 0 datasets. KPI: 4 datasets. The Finnish Weather Station was aggregated in month 31 of the project. The work to aggregate 4 more datasets (field imagery by drone-IR, NIR, NDVI, RGB; location and monitoring of tractor status; and field data by sensors embedded in a UGV and D-value measurements from the fields during the period of 2 weeks before the harvest) is in progress.
2. Improve by 10% the number of D-values available to calculate the optimal harvest time for the grass to reach its maximum nutrition level. Baseline: 2. KPI: the end result will be calculated in mid of June 2023. Substantial increase is expected.
3. Improve communications - reduce by 20% the no. of messages and calls per harvesting procedure. Baseline: 200 calls estimated per harvest. KPI: the end result will be calculated in mid of June 2023.
4. Improve data collection and accurate in livestock sanitation by > 10%. KPI: 10% (it was achieved in month 30).
5. More efficient and streamlined work of veterinarians by 15%. KPI: 15% (it was achieved in month 30).
6. Reduction in personnel perception of thermal discomfort episodes by 10%. KPI: 10% (it was achieved in month 26).
7. Improvement in the users' satisfaction and QoE (shopping experience), significant at $p<0.005$. KPI: $p<0.001$ (it was achieved in month 26).

Next steps

As mentioned before, the FCT was shown to Finnish farmers during summer 2022 harvest, and they declared they were very interested in it. Moreover, they suggested several improvements. By the time being, the farmers in Finland are planning the coming season and the new version of FCT, supporting most of the enhancements suggested, is being used from the beginning, and will be used during all the farming tasks till next summer harvest in July 2023. As a result, we expect to get a version of the FCT ready to be used in other farms.

The DEMETER enablers fostering data integration among diverse agri-food platforms and providers, mentioned in previous sections, enable different research an innovation initiatives in order to participate in further projects and extend already existing products.

More details

Below are some links to dissemination activities in form of blog articles and videos:

- Description of pilot 5.2 in DEMETER website: https://h2020-demeter.eu/pilots-overview/pilot-cluster-five/farm-of-things-in-extensive-cattle-holdings/
- Blog - Fostering interoperability between DEMETER and other smart farming communities: the AFarCloud use case: https://h2020-demeter.eu/fostering-interoperability-between-demeter-and-other-smart-farming-communities-the-afarcloud-case/
- Sirvoz+ in the DEMETER project: https://youtu.be/YFWTdShkF-Q
- Digitization of the supply chain: https://www.youtube.com/watch?v=__jj9AKWRaU

7 Conclusion

Pilot 5.2 is being very useful in terms of improvement of the scheduling and coordination of field work, efficiency and streamlined work of veterinarians and provisioning of a variety of solutions by means of the DEMETER enablers covering interoperability, AI algorithms, monitoring and visualization tools.

From the point of view of use case #1: the growing process and optimal feeding time has achieved a new level of precision in the awareness of status in various sectors of farming. Activities both in field work and in the cattle activities have been optimized. 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 in a maximum way.

From the point of view of the use case #2, the introduction of voice recognition technologies in the data capture process has let the farmer handle the animal freely and register the animal data through his/her voice.

Also, considering food transparency and user involvement in use case #3, the integration of DEMETER platform and other FI-WARE enablers reduced personnel perception of thermal discomfort episodes allowing better working conditions, as well as improving consumer's satisfaction thanks to the increased information related to production and food supply chain.

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