D7.1 Demonstration planning

WP7

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Abstract	This document presents the complete planning for the demonstrators in the project. It includes the goals, the demonstration strategy and a detailed description of each demonstrator scenario. The set of key functionalities is described according to the farmer's requirements and the project's goals. Since the AFarCloudld project relies on a modular and incremental approach, the document describes the planning for functionalities' implementation in each demonstrator from local to holistic demonstrators in a yearly basis.

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Definitions and Acronyms

Acronym	***Definition***	***Remark***
AFC	AFarCloud	
CI	Continuous Integration	
CPS	Cyber Physical Systems	
CSV	comma separate values	
DSS	Decision Support System	
ISOBUS	Serial control and communications data network	
ISQTB	International Software Testing Qualifications Board	
KPI	Key Performance Indicator	

LESS	Large Scale Scrum	
MMT	Mission Management Tool	
NDVI	Normalized Difference Vegetation Index	
NIR	Near InfraRed	
NPK	Nitrogen Phosphorous Potassium	
ORP	Oxidate Reduction Potential	
RUAV	Rotary Wing Unmanned Aerial Vehicles	
SW	Software	
TMR	Total mixed ration	
TOF	Time of Flight	
UAV	Unmanned Aerial Vehicle	
UGV	Unmanned Ground Vehicle	
UI	User Interface	
UWB	Ultra Wide Band	
WP	Work Package	
WSN	Wireless Sensor Network	
ROI	Regions of interest	
GIS	Geographical Information System	
CWSI	Crop Water Stress Index	
PLF	Precision Livestock Farming	
DM	dry matter	
PDO	Product Designation of Origin	
PGI	Protected Geographical Indication	
TSG	Tradition Specialty Guaranteed	

1. Introduction

The aim of this document is to describe the planning, the coordination and the execution of the demonstrator activities during the AFarCloud project. In this document are defined the goals that will be achieved for each scenario/year, the Key Performance Indicators (KPIs) that will be evaluated, the demonstrator scenarios giving specific information about their facilities, as well as regulations and legacy systems that are already available. In addition to this, it defines the planning for functionalities implementation in each demonstrator.

The demonstration strategy adopted in AFarCloud relies on a modular and incremental prototyping approach as depicted in Fig 1.; the key functionalities of the project will be deployed within three holistic demonstrators (AS09, AS10, AS11), one for each year of the project, that will include both cropping and livestock management scenarios. The holistic demonstrators will be supported by seven local demonstrators (AS01, AS02, …, AS08) where the AFarCloud solutions will be incrementally prototyped and validated in order to be eventually deployed on a specific holistic scenario. Three demonstrators will be set up every year and the location of holistic and local demonstrators have been selected to have different climate and production areas across Europe (Latvia, Czech Republic, Italy, Spain, Sweden and Finland).

Early in the project it was gathered baseline information for each of them in order to validate the AFarCloud solutions at the end of the project. Following the cloud computing approach provided by the project, data will be gathered among the various demonstrator sites in order to create a knowledge base for the crop and livestock management.

The first year holistic demonstrator will be a dairy farm in Finland where a first set of functionalities related with data gathering will be deployed. For the second year, the holistic demonstrator will take place in a breeder and fattener livestock farm in Spain with the main objective of testing the decision-support software modules from AFarCloud by the farmer, and increase the list of sensors that may be integrated into the project architecture. Finally, in the third-year demonstrator in Italy, will be used to demonstrate the complete set of functionalities validated during the project.

As described so far, there are two scenario categories, cropping management scenarios and livestock management scenarios. Cropping management scenarios encompass a wide variety of species such as berries, fruits, grapes, cereals, and horticultural products in different farms across Europe. These farms include common technologies from the cropping management, such as selective monitoring, pests and illnesses detection and more targeted weed reduction, precision fertilization and harvesting optimization. The main features in crop demonstrators involve real time monitoring and data collection from heterogeneous sensor sources. This information will be used by the AFarCloud decision support system in order to generate smart alerts and indicators that will be used to achieve better results in the production.

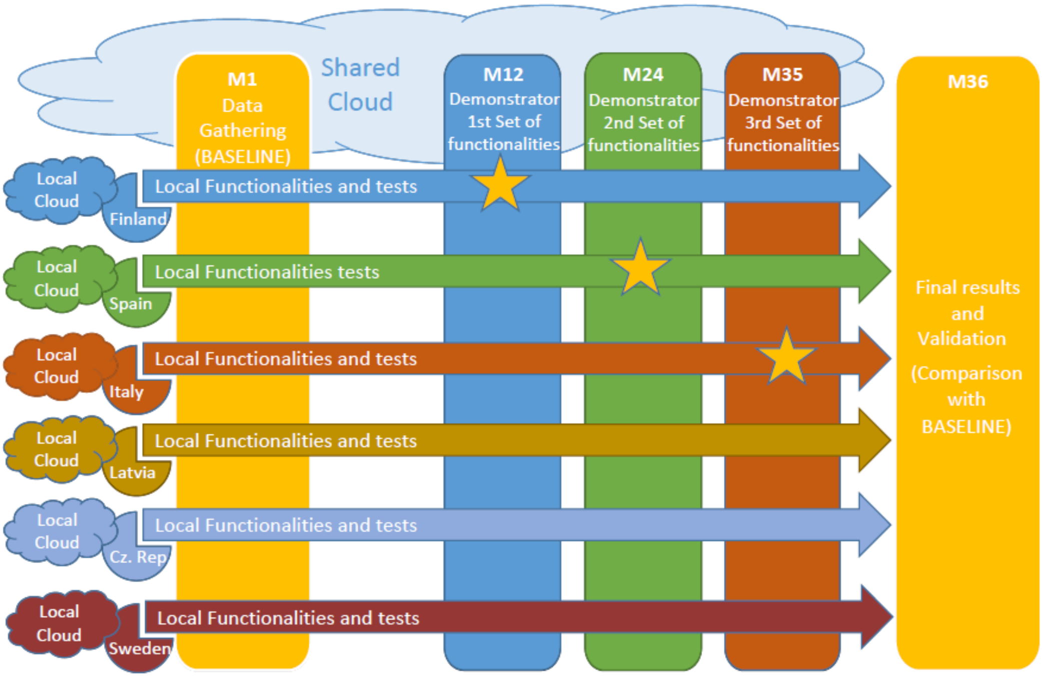


Figure 1 – AFarCloud's demonstration strategy with local and holistic demonstrators

Concerning the livestock management scenarios, the demonstration will be focused on three main topics: feed management, health status and movement control. The livestock feed management will be improved by using a central planning system to determine the amount and the composition of food to be distributed to the animals for their optimal nutrition. This information will be obtained by grass monitoring technologies and NIR silage analysis which data will be elaborated by AFarCloud decision support system to select the optimal feed composition in order to improve the quality and productivity in respect of animals' welfare. Regarding the health status information, this is relevant for detection of animals fertility or illness but even for detecting those close to the calving date and those that are in-heat. Sensors measuring vital parameters such as temperature, pulse, breathing, oxide-reduction potential and pH are used to provide this information. The third factor is the livestock movement control that allows an optimal management of the animals that are grazing by giving information about the location of the animals.

1.1. Goals of demonstration strategy

During the duration of the AFarCloud project, we are committed to achieve the following goals that are summarized in Table 1:

- **G1: Frost effect/impact reduction**: Frosty (radiation frosts) are one of the most dangerous phenomena strongly affecting plants because frosty can occur in spring or even in summertime if appropriate meteorological circumstances arise. In other words, frosty or radiation frost occurs when amount of heat radiated from the plant exceeds amount of heat supplied by air movement (not moving air is a good heat isolator) around the plant. The main prerequisites of frosty are:
    - Windless – no air movement;
    - Dry air (absolute humidity is very low – quick temperature fall initially don't cause condensation);
    - Clear sky without clouds – infrared rays from the ground are not reflected back.

  A particular solution is covering the field with nodes of a Wireless Sensor Network (WSN) early warning system equipped with:
    - Temperature sensor of plant leaves (Close to ground level);
    - Temperature sensor of air – located approximately 0.6-1.0m above the ground/plant leaves;
    - Relative humidity sensors;
    - Wind speed and direction sensors.

- **G2: Improve harvesting**: optimize output of the crop fields (yield), by investigating regularly the fields for non-optimal conditions and trying to propose best solutions to overcome that; optimize the quality of silage (based on laboratory analysis) to provide same quality and quantity of feed less expensive way or detect the proper and precise moments of harvesting of both maize and grass. Also, environment monitoring for crops is relevant: it is a common procedure to inspect the agricultural fields to extract information such as weed infestations, pest infections (insects, fungi, viruses etc), local draught, plants not following it's expected growth curve, etc.

- **G3: Optimize the amount of fertilization**: detect occurrence and risk of occurrence of different kind of pests – illnesses of the plants, invasion of insects, and weeds, etc. Detect fertilization irregularities, which can be detected by making different images (light, NIR, etc.) from above using RUAV and providing different types of image analysis (combining images in parcels, comparing images with older ones, etc.). Tamping level control of harvested maize and grass before fermentation.

- **G4: Achieve the best nutrition components for feeding**: increase the adoption of sensor technology within farm management to monitor cow behaviour to predict issues and give insights into health and recommend solutions for farmers. Introduce two systems to monitor values of pH, temperature and oxide-reduction potential (ORP or redox) inside the bovine rumen.

- **G5: Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality**: This goal is achieved by many multidisciplinary activities: collect movement, vital signs, position data from worn (bovine) sensors, collect nutritional habits: eating and rumination periods. Estimating daily intakes grazing habits, watering habits, and also, ethological factors within the herds that maintain a trustful and productive environment. This goal will achieve a reduction in several aspects: feed costs due to efficient nutrition, losses due to crop and animal diseases, time spent when looking for missing animals, particulate emission for agricultural machinery, and veterinary cost due to early detection of symptoms in livestock. This objective will include the generation of alarms based on the monitoring of the level of gases: ammonia (NH3), methane (CH4), and sulphur containing organic and non-organic gasses (SH-Sulfhydryl).

- **G6: Reducing water waste and cost in horticulture**: one of the most important challenges that the vineyard has to face is the watering optimization. By analysing watering and rainfall with respect to quantify of premium grapes harvested, it is possible to carry out the exact amount of water required for irrigation. This will be achieved my monitoring water, rainfall, soil moisture, conductivity, temperature, incorporating solar radiation drones equipped with multispectral cameras and by remotely analysing this multimodal data.

- **G7: Reducing water waste and cost in greenhouse**: in greenhouses, the use of a round drip irrigation system, which does not water directly the plant leaves, preventing diseases related to wet leaves. Internal humidity must be controlled in order to avoid water waste and plants disease. Sensors (humidity, temperature, both for soil and air, NPK) monitor ground conditions and humidity levels and are directly used by the automatic irrigation control system and by the automatic opening control in order to maintain air temperature and humidity in a controlled range.

- **G8: Plant disease detection**: Plant illness will be detected by analysing leaves and grapes by using a visual camera. Images acquired are processed by a neural network classifier which identifies if the subject of the image is healthy or affected by disease. In the latter a signal is sent from the detection module to alert the farmer of a suspected disease. The neural network engine will be trained to detect main diseases specific to the vineyard scenario and in agreement with the farmer who will suggest the most critical and relevant diseases to be addressed. Training will be performed off-line using a provided annotated dataset (i.e. by the farmer or by an agronomist expert in the field). The inference engine will be integrated to an embedded system. A tractor will be equipped with the image acquisition system. Images to be analysed can be acquired either manually or automatically and sent from the acquisition system to the illness detector system which generate an alert if a disease is detected.

Table 1 – Demonstration goals

Goal identifier	*Goal name*	*Demonstrators*
G1	Frost Effect/impact Reduction	AS01, AS03, AS07, AS11
G2	Improve harvesting	AS02, AS03, AS08, AS09, AS03, AS11
G3	Optimize the amount of fertilization	AS03
G4	Achieve the best nutrition components for feeding	AS09
G5	Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality	AS03, AS06, AS08, AS07, AS09, AS10, AS11
G6	Reducing water waste and cost in horticulture	AS03, AS04, AS05, AS07, AS11
G7	Reducing water waste and cost in greenhouse	AS05
G8	Plant disease detection	AS05

1.2. Demonstrator scenarios and sites

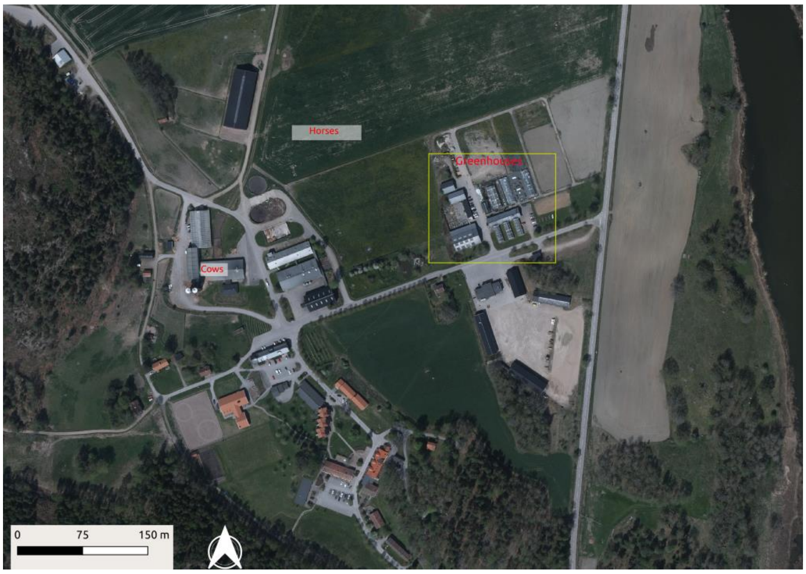
Table 2 shows a short summary of all the demonstration sites or scenarios.

Table 2 – Demonstrator's scenarios

<table>
<tr><td colspan="2">AS01 Latvia</td></tr>
<tr><td>
Cranberry farm</td><td>Cranberry growing farm located in Bīriņi parish Latvia (neighbouring parish of Sēja parish that is farm Robežnieki location). Active growing fields up to 20ha.

Farms manager and owner: Andris Spats

Demonstrator leader: IMCS - Artis Gaujens(artis@latnet.lv)</td></tr>
<tr><td colspan="2">AS02 Latvia</td></tr>
<tr><td>
Dairy farm</td><td>Robežnieki is located in Sēja parish Latvia. The farm is a modern large-sized dairy farm (300 cows in production, already chipped), which produces milk as a main product, and grass and fodder maize for silage for self-consumption (250ha-gras) & 100ha fodder maize). The farms milk production is already fully robotized. The farm employs dairy robotics (Lely) and several high-end tractor vehicles (JD, Valtra, Claas, etc.) with ISOBUS compatibility.</td></tr>
</table>

	Farms manager and owner: Normunds Kalnins Demonstrator leader: IMCS - Artis Gaujens(artis@latnet.lv)
AS03 Sweden	
 *Dairy farm*	Ogesta farm is run by three brothers Gabriel, Mathias, and Henrik Jonsson. They have 1.500 milk cows and 1.500 young cows. The company manages a territory of 2000 hectares of agricultural land, considering pastures and croplands, in order to feed the livestock it has. The fields in Gamleby provides with crops that are exclusively used to feed the cattle. **Farm manager and owner: Gabriel Jonsson** Demonstrator leader: Åke Sivertun <ake.sivertun@ri.se> ➢ **Farm manager and owner:** Gabriel Jonsson ➢ **Rector agricultural school:** Sofie Alvarsson ➢ **Agricultural advisor:**
AS04 Spain	

Dairy farm

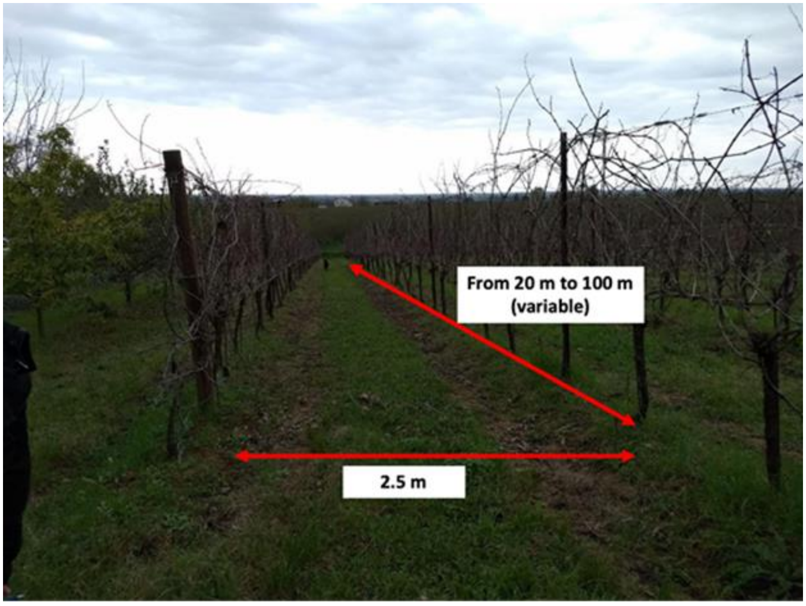
Among the 4,000 ha of vineyards owned by its wineries division, ACC is considering as testing facility the estate of “Caserío de Dueñas”, with an extension of 385 ha, located in the province of Valladolid.

Technical Director: Almudena Alberca. (Technical Agricultural Engineer, Oenologist and Master of Wine).

Demonstrator leader: ACC Fátima Vellisco (

fvellisco.ext@acciona.com)

AS05 Italy



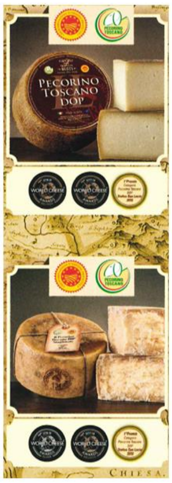
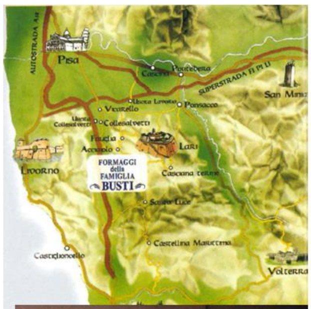
Podere Campaz, located in Emilia-Romagna Region, Italy. The farming company owner of the farm bases its activity on the principles of permaculture. The principal production is wine from vineyards, but other cultures are present. In less than 10ha, Podere Campaz is dedicated to apricot and peaches trees, berries, vegetables, aromatic herbs, lavender and medicinal herbs, saffron, and olive trees. Its production is strictly organic without needs of agrochemicals and synthetic fertilizers. It has a greenhouse of about 200 square meters for vegetables crop.

Farms manager and owner: Nicolò Vanigli

http://www.poderecampaz.com

	Demonstrator leader: CNR - Luca Dariz: l.dariz@imamoter.cnr.it
AS06 Spain	
 *Beef cattle, grazing management scenario*	Mediana and Cabañas are where Sensowave has its own living-labs in Avila, Spain, the first of two breeder livestock farms covering a total area of 1.100ha and 180 cows, from which 90 through the current devices. This is the farm of the Blanco family, which the father manages with the help of his sons. **Farms manager and owner:** Segundo Blanco Demonstrator leader: SENSOWAVE - Carlos Callejero: candres@sensowave.com
AS07 Czech Republic	
 *Experimental farm of IAS, Czech Republic*	IAS is a centre of research into the biological and bio-technological basis of animal science. Research institute IAS (Prague, Czech Republic) has its own comprehensive experimental base and a farmstead with almost 800 hectares of farmland, focusing mainly with dairy and beef cattle pigs, poultry, rabbits, deer, horses, sheep and goats. Demonstrator leader: IAS - Veronika Koukolová: vkoukolova@seznam.cz

AS08 Latvia	
 *Dairy farm, Latvia*	AS08 should be considered as a continuation to AS02, because the demonstration facility is the same farm. AS08 is an attempt to put this farm in a holistic view, by analyzing outputs of the dairy robotics and finding correlation of those outputs with different aspects of crop(food) preparation, which is the task AS02 results. **Farms manager and owner:** Normunds Kalnins Demonstrator leader: IMCS - Artis Gaujens(artis@latnet.lv)
AS09 Holistic Finland	
	Kotipelto farm is a family-owned, modern middle-size dairy farm in Ylivieska, Finland. It produces silage and grains in its over 200ha fields for making fodder for 190 cows. **Farms manager and owner:** Marko Sorvisto Demonstrator leader: CENTRIA - Mikko Himanka Mikko.Himanka@centria.fi
AS10 Holistic Spain	

	Carrera d'en Bas consists of 800 heads of cattle between cows, males and calves. During the first 6-9 months calves are breastfed and they graze until they are weaned and moved to be fattened while the mother prepares itself to give birth to a new calf. The farm covers 500ha between arable fields, pastures, and forest areas, where 93% of the feeder is cultivated in our own fields: Prairies, oats, ryegrass, sunflower and corn **Engineer:** Sergi Pujolriu Masoliver Demonstrator leader: SENSOWAVE - Carlos candres@sensowave.com
AS11 Holistic Italy	
   	San Rossore Park is not a simple “farm”, but it’s a very wide park managed by a Regional Public authority responsible for safeguarding environment and biodiversity inside the territory that covers approximately 24,000 hectares situated with areas of coast from Viareggio to Leghorn. This territory has maintained relevant natural features and agricultural activities. Among the other roles, the park authority is the main actor to promote food products and farming quality and innovation in conjunction with the safeguarding of the nature and organic processes in agriculture and livestock. Farm director: Dr. Luca Gorreri

	Demonstrator leader: CNR -: Massimiliano Ruggeri ruggeri@estetechnology.com

2. General Strategy of Demonstrations

The AFarCloud projects has defined a strategy for demonstrations that can be summarized from three perspectives as described in the following subsections: the project organization focused on demonstrator functionalities, the satisfaction of user requirements and KPIs and a structured approach for demonstration planning during the project's lifecycle.

2.1. Demo-centric project organization

The AFarCloud project's strategy for demonstrators is bottom-up, as depicted in **¡Error! No se encuentra el origen de la referencia.**, in the sense that only the functionality (and SW components) that are tested in local demonstrators will be deployed for the holistic demonstrator:

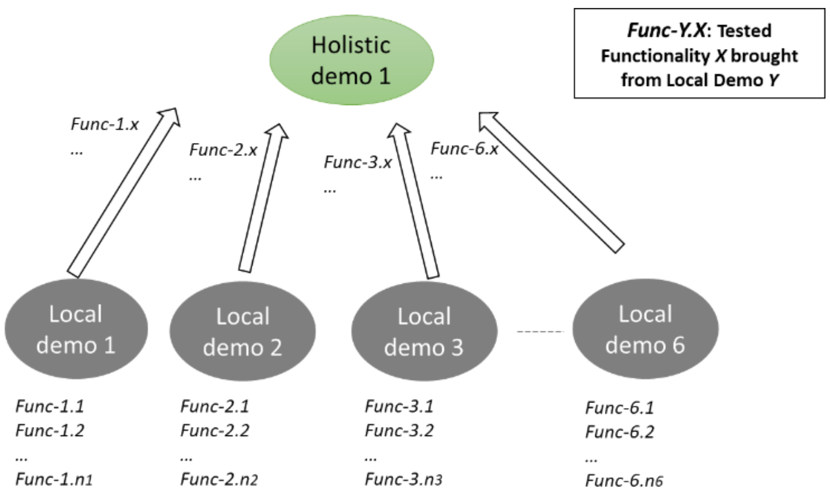


Figure 2 – AFarCloud's bottom-up demonstration strategy

The rationale behind this approach is to select the local demonstrators' functionalities that meet the subset of user requirements that we would like to demonstrate at the holistic demonstrators. Here, a demonstrator functionality (*Func-Y.X*) is a high-level functionality that can be implemented in a demonstrator (it's not a technological functionality) as for example "*Measure the level of soil humidity*". This approach also ensures that the AFarCloud platform's SW components will be sufficiently tested before deploying them in holistic demonstrators. Moreover, it's important to highlight that the project is a Cyber Physical Systems (CPS) project whose priority is to proof that CPS technologies can work in farming environments and meet some KPIs (the list of KPIs is described below and summarized in Table 5).

Within this strategy, a clear well-defined definition of each task in WP2 and WP7 is necessary. As shown in the figure below, WP2 is responsible for delivering a set of user requirements (from the end-user perspective, not technological) and the AFarCloud platform's architecture (i.e., a definition of SW components and their dependencies). These two inputs are taken by WP7 in order to enforce a demo-centric strategy for the project through the 8 local demonstrators and 3 holistic demonstrators.

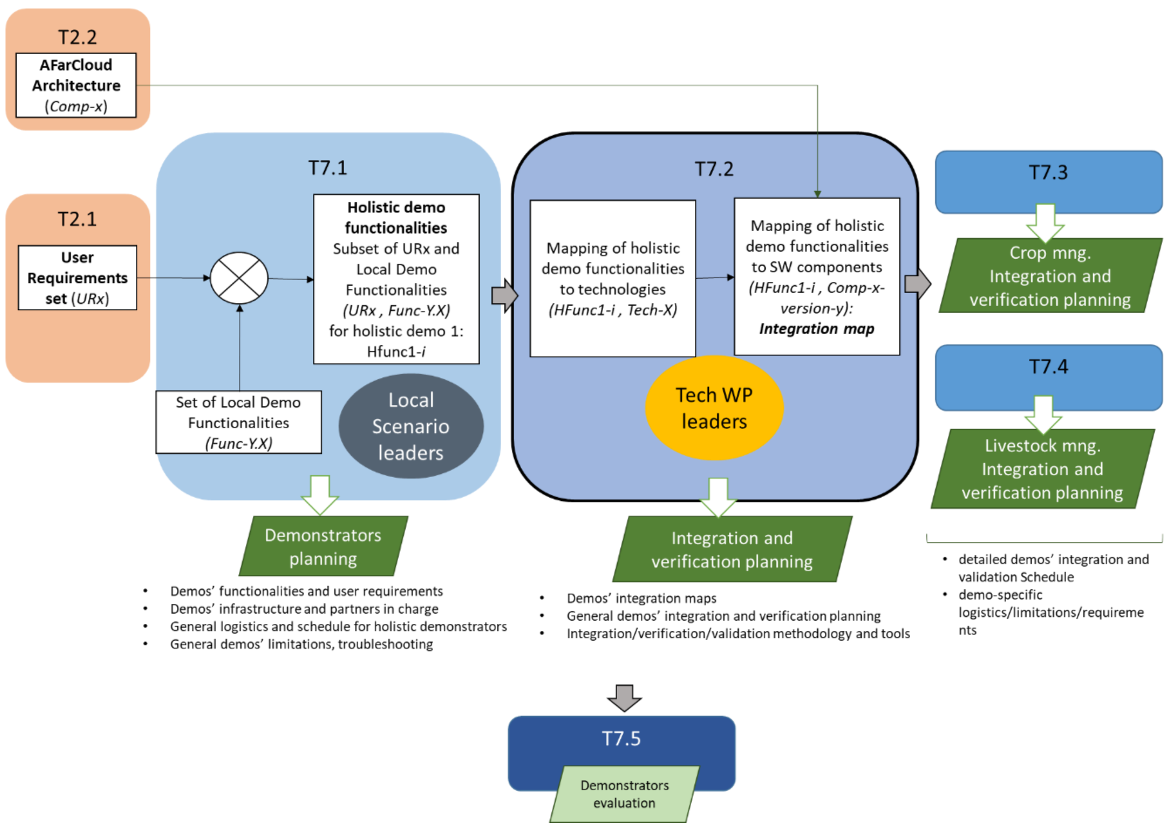


Figure 3 – AFarCloud's demo-centric project organization

Within WP7, T7.1 relies on demonstrator leaders to know the functionalities that can potentially be implemented in each local and holistic demonstrator. From here, a demonstrator plan will be designed for the local and holistic demonstrators. The demonstrator planning explained in this deliverable includes the functionalities and user requirements to be implemented in each demonstrator as well as the general logistics and schedule for all the demonstrators. This deliverable describes the general strategy of all the demonstrators towards the success of the holistic demonstrators. This strategy will be taken by T7.3 and T7.4 as the foundation to elaborate their respective detailed demonstrators planning for the crop management and livestock scenarios, respectively.

T7.2 is the brain of this demonstrator-centric approach. This task will strongly coordinate with technical WP leaders (i.e., WP2-6) to translate the demonstrator strategy from T7.1 into a set of integration maps (one for each demonstrator, each year) that have the ultimate goal to drive local demonstrators towards the holistic one, every year. To this end, the functionalities of each demonstrator provided by T7.1 will be translated to the best technologies with the help of WP leaders. In turn, technologies are implemented by SW components of AFarCloud platform.

Table 3 shows the list of goals and high-level functionalities that will be implemented during the lifecycle of AFarCloud. The strategy is incremental: functionalities are implemented gradually through the lifecycle of the project. Each year, based on the results from the last years, the technologies supporting each functionality are improved and completed. By the last year, all the functionalities will be completely implemented and measured based on business KPIs (as described in this deliverable) and technical KPIs (as described in D7.2). Section 5 describes the implementation planning of these functionalities during the project.

The AFarCloud holistic demonstrators are: AS09 (Finland, 2019), AS10 (Spain, 2020) and AS11 (Italy, 2021). These holistic demonstrators are included in Table 3 since they work as local demonstrations one year before its holistic deployment. The rationale behind is to test functionalities that are local to the demonstrator and be able to collect more precise data before the demonstrator becomes the holistic one. When the demonstrator becomes holistic, it deploys all the possible functionalities, that is, those functionalities that have been validated in other local demonstrators and can be implemented in the demonstrator's farm. Thus, Table 3 shows all the local demonstration sites for each functionality of the AFarCloud platform.

Table 3 – Goals and functionalities for local demonstration scenarios

ID	FUNCTIONALITY DESCRIPTION	Goal	DEMONSTRATORS
F1	Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.	G1: Frost Effect/impact Reduction	AS01, AS03, AS07, AS11
F2	DSS for deciding about if it will be frost or not.		AS01

F3	Detection of cereals nutrients composition (energy, protein and humidity analysis)	G2: Improve harvesting	AS02, AS03, AS08, AS09
F4	Using DSS take decision regarding when and where to harvest		AS02, AS03
F5	Monitor NPK (sensors or imagery)	G3: Optimize the amount of fertilization	AS03
F6	Measure the needs of fertilization with high spatial precision		AS03
F7	DSS for decision about when to fertilize		AS03
F8	Outdoor livestock location tracking	G5: Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality	AS03, AS06, AS10, AS11
F9	Detection of livestock heat		AS10, AS03, AS06, AS11
F10	Detection of livestock calving		AS06, AS11
F11	Detection of livestock rumination and eating		AS06, AS10, AS11
F12	Determination of livestock growth rate		AS10
F13	Inference of the livestock habits patterns for health and reproduction		AS06, AS10
F14	Measure field water content/vigour	G6: Reducing water waste and cost in horticulture	AS03, AS04, AS05, AS07, AS11
F15	Measure water stress		AS03, AS04
F16	DSS for decision about how much water		AS03
F17	Automatic actuation on rooftop (open, close)	G7: Reducing water waste and cost in greenhouse	AS05
F18	monitor greenhouse temperature and humidity		AS05
F19	Using actuators, irrigate with correct amount and location	G6: Reducing water waste and cost in horticulture G7: Reducing water waste and cost in greenhouse	AS05
F20	Detect plant illness (imaginary near infrared)	G8: Plant disease detection	AS05

F21	Monitor Gases	G5: Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality	AS08
F22	NIR silage analysis	G4: Achieve the best nutrition components for feeding	AS09
F23	Livestock indoor positioning	G5: Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality	AS09
F24	Livestock identification		AS09
F25	Nutrition monitoring through rumen scanning		AS09
F26	Extract and analyze data from milking robots		AS08
F27	Livestock digestion monitoring		AS07
F28	Fleet management: tracking of farm vehicles	G2: Improve harvesting	AS03, AS11

2.2. Demonstration goals: user requirements and KPIs

All the high-level functionalities that are implemented during the lifecycle of AFarCloud satisfy certain user requirements defined in D2.1. Table 4 shows the list of functionalities linked to the user requirements as described in D2.1. User requirements not mapped in this table are basic for most functionalities and more linked to technologies used than to the actual functionalities described. Functionalities and user requirements are validated in local and holistic demonstrators.

Table 4 – Mapping between user requirements and demonstrator functionalities

ID	FUNCTIONALITY	USER REQUIREMENTS
F1	Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.	1: Domain specific decision support systems (DSS) are desired by the end-users. Everything from a specific process to a larger process such as dairy supply chains (Medium) 12: Weather and other environmental data are important for the DSS (High)
F2	DSS for deciding about if it will be frost or not.	1: Domain specific decision support systems (DSS) are desired by the end-users. Everything from a specific process to a larger process such as dairy supply chains (Medium) 30: The system should provide support for radiation frost detection and leaf temperatures (High)

F3	Detection of cereals nutrients composition (energy, protein and humidity analysis)	10: The system should be able to visualize information related to crops and livestock that allow farmers to diagnose current situation in the farm, predict future diseases or problems and make decisions (High) 15: The system should provide information for Phenological status, disease/pest diagnosis of the crops, taking care to an extent of each crop specific needs (High)
F4	Using DSS take decision regarding when and where to harvest	1: Domain specific decision support systems (DSS) are desired by the end-users. Everything from a specific process to a larger process such as dairy supply chains (Medium) 14: Farm size distribution, production farm types of each class and common practices in different classes are required to improve current, and develop new services (High) 17: The system should help to know the precise moments of harvesting of both maize and grass (High)
F5	Monitor NPK (sensors or imagery)	18: The system cloud acquires real-time information about crops including gravimetry, NPK, humidity, temperature and control of pesticides, temperature, load and cycle detection, use of water, illumination conditions (Medium)
F6	Measure the needs of fertilization with high spatial precision	2: AFarCloud solutions should be compatible with ISOBUS tractors, and other equipment in a farm. Many farms have already well-functioning equipment, which cannot be omitted (High) 10: The system should be able to visualize information related to crops and livestock that allow farmers to diagnose current situation in the farm, predict future diseases or problems and make decisions (High)
F7	DSS for decision about when to fertilize	1: Domain specific decision support systems (DSS) are desired by the end-users. Everything from a specific process to a larger process such as dairy supply chains (Medium)
F8	Outdoor livestock location tracking	19: The system should help monitor animal health and activity (High) 24: The system should allow locating animals at any time (Medium) 28: The system should be able to identify livestock individually, as well as provide information about parameters such as position/tracking and location or battery lifetime for the tracking functionalities. (Medium)
F9	Detection of livestock heat	20: The system should allow in heat detection of animals (High)
F10	Detection of livestock calving	23: The system should allow knowing the reproduction rates of cows (High) 25: The system should allow prediction of the calving dates of animals (Medium)
F11	Detection of livestock rumination and eating	21: The system should allow the measurement of ruminal conditions of dairy cows by non-invasive methods. Also, the geometry of paralumbar fossa area for determining rumen fullness. (High) 22: The system should be able to retrieve measured data from the rumen (pH, volatile fatty acids, ammonia) and to compare them with other type of data (milk production, milk quality, time of feeding and rumination) (Medium)
F12	Determination of livestock growth rate	29: The system must provide real-time nutrient analysis for the help of ration mixing; at least dry matter and protein content are needed, other parameters give additional value (High)
F13	Inference of the livestock habits patterns for health and reproduction	19: The system should help monitor animal health and activity (High) 23: The system should allow knowing the reproduction rates of cows (High)

F14	Measure field water content/vigour	10: The system should be able to visualize information related to crops and livestock that allow farmers to diagnose current situation in the farm, predict future diseases or problems and make decisions (High) 31: The system must acquire rea-time information about the grapes, mainly soil humidity, vigour and water stress to allow watering optimization and water flow information (High)
F15	Measure water stress	31: The system must acquire rea-time information about the grapes, mainly soil humidity, vigour and water stress to allow watering optimization and water flow information (High)
F16	DSS for decision about how much water	1: Domain specific decision support systems (DSS) are desired by the end-users. Everything from a specific process to a larger process such as dairy supply chains (Medium)
F17	Automatic actuation on rooftop	3: The system should be secure for workers driving or using the machinery (Medium)
F18	monitor greenhouse temperature and humidity	18: The system cloud acquires real-time information about crops including gravimetry, NPK, humidity, temperature and control of pesticides, temperature, load and cucle detection, use of water, illumination conditions (Medium)
F19	Using actuators, spray with correct amount and location of nutrients	2: AFarCloud solutions should be compatible with ISOBUS tractors, and other equipment in a farm. Many farms have already well-functioning equipment, which cannot be omitted (High) 3: The system should be secure for workers driving or using the machinery (Medium) 6: The system should allow certain degree of automation in daily inspection tasks in order to reduce time and costs (Medium) 7: AFarCloud should be interoperable with the current systems in the farm (Medium)
F20	Detect plant illness (imaginary near infrared)	9: The system should provide support to process NDVI as an agricultural index (Medium) 15: The system should provide information for Phenological status, disease/pest diagnosis of the crops, taking care to an extent of each crop specific needs (High) 32: The system should be able to obtain information from leaves so health information can be inferred, and a classification can be established (Medium)
F21	Monitor Gases	13: Offer Environment footprint calculation (EFC), a solution that estimates environmental impact of the production for a single product (High)
F22	NIR silage analysis	10: The system should be able to visualize information related to crops and livestock that allow farmers to diagnose current situation in the farm, predict future diseases or problems and make decisions (High) 29: The system must provide real-time nutrient analysis for the help of ration mixing; at least dry matter and protein content are needed, other parameters give additional value (High)
F23	Livestock indoor positioning	19: The system should help monitor animal health and activity (High) 24: The system should allow locating animals at any time (Medium) 28: The system should be able to identify livestock individually, as well as provide information about parameters such as position/tracking and location or battery lifetime for the tracking functionalities. (Medium)
F24	Livestock identification	19: The system should help monitor animal health and activity (High) 24: The system should allow locating animals at any time (Medium)

		28: The system should be able to identify livestock individually, as well as provide information about parameters such as position/tracking and location or battery lifetime for the tracking functionalities. (Medium)
F25	Nutrition monitoring through rumen scanning	21: The system should allow the measurement of ruminal conditions of dairy cows by non-invasive methods. Also, the geometry of paralumbar fossa area for determining rumen fullness. (High)
F26	Extract and analyze data from milking robots	10: The system should be able to visualize information related to crops and livestock that allow farmers to diagnose current situation in the farm, predict future diseases or problems and make decisions (High)
F27	Livestock digestion monitoring	21: The system should allow the measurement of ruminal conditions of dairy cows by non-invasive methods. Also, the geometry of paralumbar fossa area for determining rumen fullness. (High) 22: The system should be able to retrieve measured data from the rumen (pH, volatile fatty acids, ammonia) and to compare them with other type of data (milk production, milk quality, time of feeding and rumination) (Medium)
F28	Fleet management: tracking of farm vehicles	2: AFarCloud solutions should be compatible with ISOBUS tractors, and other equipment in a farm. Many farms have already well-functioning equipment, which cannot be omitted (High) 5: The system should offer vehicle information (e.g. maintenance parameters, distance driven, operational hours, etc.) (Low) 7: AFarCloud should be interoperable with the current systems in the farm (Medium) 8: Communication is important and sometimes a challenge in rural locations. Thus, different communication solutions, which provide a redundant solution is important (High)

Besides satisfying user requirements, the AFarCloud project’s strategy is aimed to satisfy certain Key Performance Indicators (KPI) that will monitor and evaluate the project progress and the impact. Three levels of KPIs were identified in the DoW:

- KPIs “level 1” is related to specific demonstrators.
- KPIs “level 2” is related to the AFarCloud overall platform.
- KPIs “level 3” measures the contribution for exploitation and the general innovation in modern agriculture, a novel ecosystem.

KPIs level 1 are considered the relevant ones in order to organize the demonstrators' planning. The following KPIs level 1 as outlined in section 2.1 of the DoW were identified with estimated benefit from the AFarCloud solutions on demonstrators:

- KPI1: 30% of cost reduction, for the integrator companies that provide the technologies and the services, due to saving in programming, integration and configuration time.
- KPI2: 15-30% increase on crop productivity due to extended use of sensors and CPS unit.
- KPI3: 30% increase of horticultural productivity due to reduce chemical products use.

- KPI4: 20% lower fertilizers usage.
- KPI5: Reduction of soil erosion and soil compaction and improved absorption of water
- KPI6: 15% reduction of losses due to crop and animal diseases or non-optimal conditions
- KPI7: 10% reduction of animal losses due to increased health.
- KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock.
- KPI9: 80% reduction in fuel and time spent when looking for missing animals as well as particulate emission for agricultural machinery.
- KPI10: Up to 10% feed costs

Table 5 shows the KPI identifiers applying in each scenario. However, its percentages of improvement associated are estimated average values for the EU. Since they are country dependent and related to the farm and site conditions, the KPI's per scenario have to be adapted and it is displayed in the "KPI Y1 baseline" column. The strategy to be followed is to start by collecting the information available on the farm about some KPIs from previous years (for example, reproduction rates). As there are some data that have never been recorded (for example the km dedicated to animal search tasks), it will start collecting that data in Y1.

From Y2, it will be possible to begin analysing the results on how AFarCloud improves these KPIs.

It should be noted that in some cases it may be difficult to draw conclusions, since there are external factors to be taken into account because otherwise they could distort the result. For example, the amount of water used could be higher than the previous year in case of low rainfall, even when water consumption has been optimized through precision irrigation.

Table 5 – AFarCloud project KPIs

Scenario	KPI Identifier
AS01: Demonstrator for cranberry protection	KPI1, KPI2
AS02: Silage / Cereal monitoring and control	KPI2, KPI4, KPI10
AS03: Environmental monitoring for sustainable crop production and livestock welfare”	KPI2, KPI4, KPI6, KPI7
AS04: Vineyards monitoring	KPI1, KPI5

AS05: Farming based on permaculture principles	KPI2, KPI3, KPI4, KPI5
AS06: Livestock health and movement	KPI7, KPI8, KPI9, KPI10
AS07: Measurement of health status through ruminal probes On Pasture Monitoring	KPI7, KPI8
AS08: Measurement of health status through dairy robotics and gas monitoring”	KPI7
AS09: Cow nutrition management	KPI1, KPI2, KPI10
AS10: Sustainable livestock farming	KPI1, KPI2, KPI10
AS11: San Rossore Park	KP1, KPI3, KPI4, KPI5, KP6, KPI10

2.3. Demonstration approach

The AFarCloud platform comprises cyber physical systems (CPS) and also a wide variety of equipment such as sensors, wearable, drones, cameras and vehicles. A set of 11 demonstrators will serve to deploy, integrate and validate the services developed during the project. There are three holistic demonstrators (1 per year) and eight local ones. Those functionalities matching with the user requirements and validated in the local demonstrators will be implemented also in the holistic demonstrators.

Figure 3 shows a diagram with the demo planning structure throughout the project. During Y1, the mature equipment will be deployed: static sensors, wearables, and drones/vehicles. The main objective for this first year is to start collecting data being stored in the AFarCloud and to create basic visualization tools and also to acquire images from cameras both fixed and in mobile platforms. In relation to the KPIs, the first year will serve to create a baseline with which to compare the successive years while implementing more functionalities. During year 2, those devices that have been developed during year 1 will be integrated, following the user requirements defined in the project. Once tested successfully in the laboratory, they will be integrated into the local demonstrators.

In parallel, the stored data will be analyzed to calibrate the sensors / images and develop algorithms to decision support systems. The data provided by legacy equipment will also be extracted and analyzed in order to be able to merge data from various sources that enrich the DSS. With the algorithms and the DSS integrated in AFarCloud, it is expected that the platform will already be able to generate notifications and alerts.

Y3, will be used to improve the performance of the DSS and the MMT through the data collected in the different demonstrators, together with the farmers' input. The interface will evolve during the 3 years incorporating new functionalities. The KPI's of the project will be evaluated in Y2 and in Y3 the final conclusions will be presented.

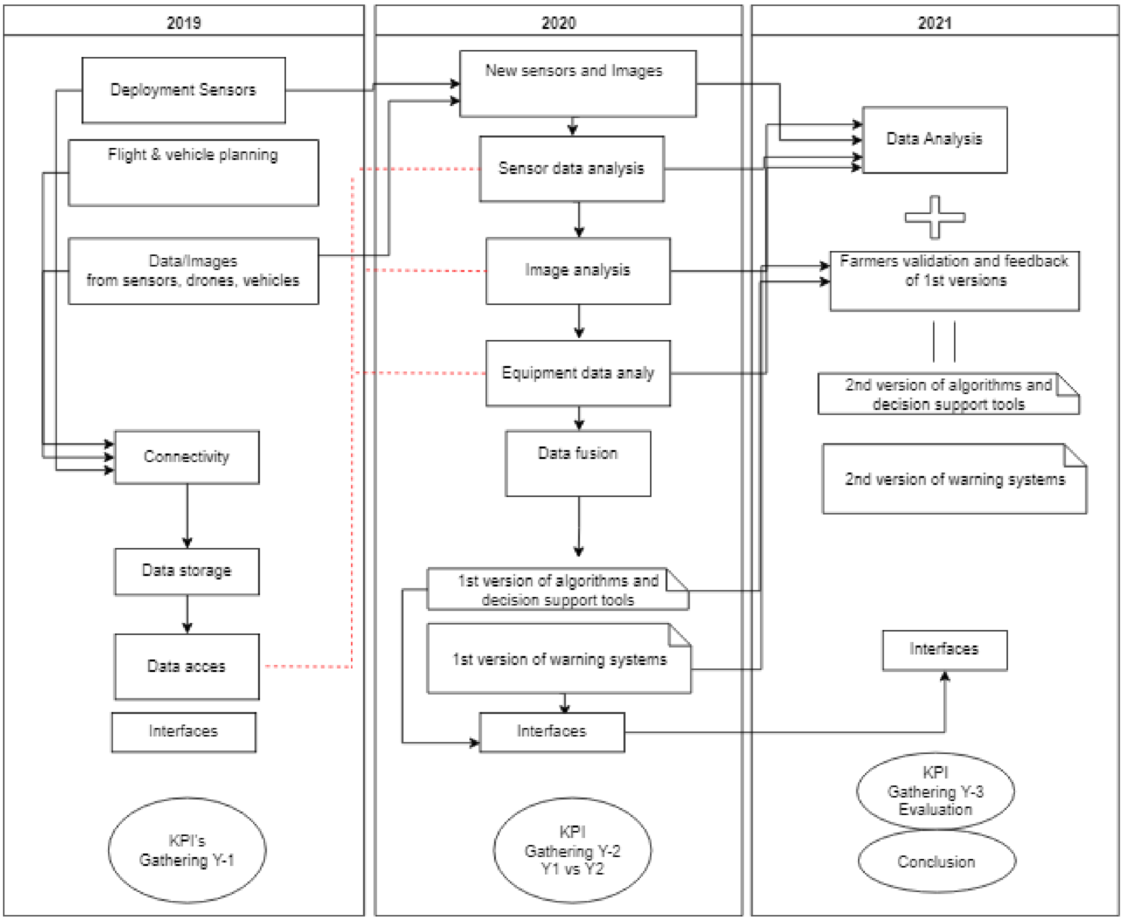


Figure 4 – AFarCloud's planning structure

3. Description of Demonstrators

This section describes in detail all the local demonstrators involved in AFarCloud, including information about their farms, KPIs, goals and functionalities, legal and safety considerations, and infrastructure and logistics. This section also includes the AFarCloud holistic demonstrators, AS09, AS10 and AS11, since these demonstrators will be working as local demonstrator before becoming holistic demonstrators as outlined in Section 2. Moreover, in Section 2, Tables 3, 4 and 5 summarize all the demonstrators' functionalities, association with user requirements and KPIs, respectively.

3.1. AS01

3.1.1. Farm Introduction

Cranberry growing farm located in Bīriņi parish Latvia (neighbouring parish of Sēja parish that is farm Robežnieki location - centre of demonstrations AS02 and AS08). Active growing fields of cranberries are up to 20ha.

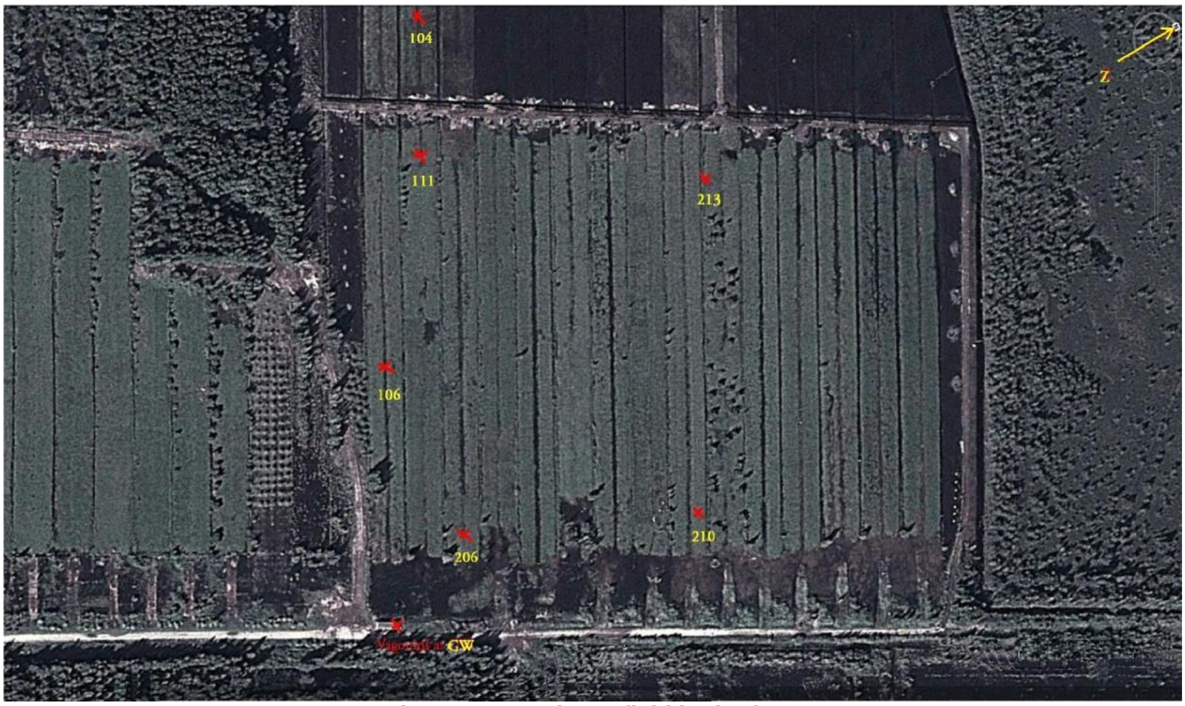


Figure 5 – cranberry field in the farm

The main problem to solve in this local scenario is the Radiation frost, since this is one of the most dangerous phenomena, strongly affecting plants. Radiation frost is not very well known, thus below the main factors that need attention and analysis are mentioned (see ANNEX 1 for a detailed description).

- Radiation frost can happen when ground and air temperature is above 0°C, when conditions are as follows:
  - Windless - no air movement
  - Dry air - absolute humidity is very low
  - Clear sky without clouds.
- Abovementioned circumstances make radiation frost harder to predict.
- During radiation frost losses due to the frost are bigger, because in above 0°C, plants are in blossom and not so protected from the cold.
- Radiation frost can appear very locally (in only some part of the field).

<u>Existing situation:</u>

A particular solution is covering the field with nodes of a Wireless Sensor Network (WSN) early warning system, as part of a local weather station. Nevertheless this solution can fail since the frost can take place in small squares around the whole field directly between all WSN nodes. In this kind of system, the main component is the WSN node (see Fig. 2) itself, containing sensors for different measurements (air relative humidity, air temperature 1m above the ground, cranberry leaf temperature).

Figure 6 – WSN node as part of the local weather station

Main drawbacks of WSN solution:

1) Due to locality of radiation frost, a large number of WSN nodes are required
2) Very rare occasion of radiation frost (in average, one case in a few years) that means keeping large system in working condition, on standby
3) Combination of 1) and 2) makes it a costly and inefficient solution to manage and maintain

Proposed Solution - Produce an early warning system for cranberry protection system based on existing WSN solutions enhanced with rotary unmanned aerial vehicles (RUAV) missions, preferably with (semi-)autonomous systems. Ideally replace the WSN system with monitoring from RUAV

The main advantages of the proposed solution over existing solutions:

1) Reduction of manual operations. Saves manual labour to go to fields and measure temperature. Both when there is a high probability and when there is a low probability one.
2) Minimizing the usage of sensors directly in the field. The number of sensors required for covering a field is proportional to its size, thus there is a considerable cost associated with most fields. In addition, most state-of-the-practice sensors solutions are associated with maintenance costs even if price/unit may be affordable.
3) Occasion of radiation frost is rare, so the equipment, including the RUAV, may not be dedicated. For example, RUAV missions can be used for other monitoring and inspection tasks.

Note that actions to neutralize radiation frost (e,g, ires, smoke machines, spraying water, wind generators) are outside the scope of this monitoring demonstration. (

3.1.2. KPIs (benefits)

Two of the main impacts and benefits from the project are (DoW, Sect. 1.1.4):

- 30% of cost reduction, for the integrator companies that provide the technologies and the services, due to saving in programming, integration and configuration time. (KPI1, Table X below)
- 15-20% increase on crop productivity due to extended use of sensors and CPS units, for early detection and control of weeds and pests. (KPI2, Table 6 below)

Table 6 – AS01 KPIs

KPI1: 30% of cost reduction, for the integrator companies that provide the technologies and the services, due to saving in programming, integration and configuration time. ***(High priority)***
Legacy solutions with WSN have several fall backs, This leads to deploying large number of sensors in the field for a long period of time, which have to be maintained in workable condition in all weather conditions. That leads to high costs for companies providing these services. Cost reduction is done by using RUAV's for this task, which is active on missions only when is the risk of radiation frost. All other time it can be used for other tasks in the farm.
KPI2: 15%-20% increase of crop productivity due to extended use of sensors and CPS unit *(High priority)*
Rise in crop productivity is achieved by decreasing the losses from radiation frosts. We want to achieve close to 100% warning of the radiation frost situation.

3.1.1. Descriptions of goals and functionalities

For frost effect reduction, we have taken into account the user/farmer needs:

- Prediction has to be made 3-4 hours before radiation frost, giving the farmer time for actions.
- We want to achieve a 100% predict Radiation frost, with a less 10% false predictions rate (in time of prediction sometimes situation maybe unclear).
- Use RUAV missions for monitoring, to keep maintenance costs low.
- Minimize RUAV /mission numbers.

That corresponds with common AFarCloud goal **G1: Frost effect/impact reduction**

The demonstrator should be able to present the following features:

1. It is nearly impossible to wait for a radiation frost to happen . Will hve to show correct operation of a system in a simulated situation.
2. Show the possibility of reducing number of WSN nodes.
3. Show the reduction in operational costs

3.1.1.1. G1: Frost Effect/impact Reduction

The achievement of G1 can be seen through a high level scenario (Fig. 7), based on using the following functionalities:

- **F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.**
- **F2: DSS for deciding about if it will be frost or not**

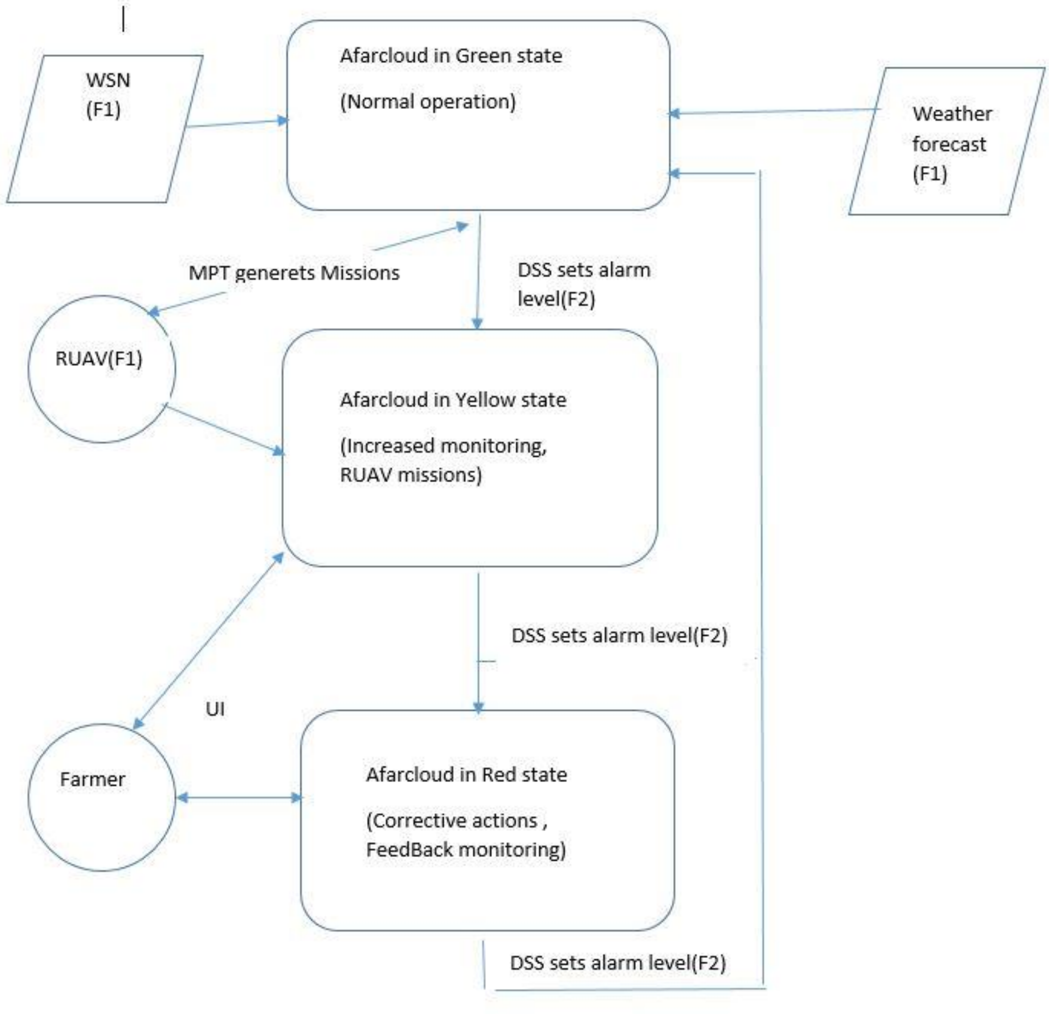


Figure 7 – High level scenario for G1: Frost effect/impact reduction

3.1.2. Legal and Safety, Healthy, Environment (HSE) considerations

Latvia drone regulations (current)

- Pilot on standby
- On eyesight distance or max 500 meters from pilot
- 120m maximal height
- If drone heavier then 1,5 kg, must be insured for possible damages to 3rd persons property
- Rules about flying near special objects (airfields, military objects, banks, etc.), not applicable, because no such objects are located near the farm.

None, regarding other HSE at the moment as this is autonomous operation in the field.

3.1.3. Infrastructure and logistics considerations

Demonstration is based on Autonomous monitoring of the field by RUAV, which has to include the autonomous solution for exchanging data with AFarCloud platform. For building DSS algorithms and calibrating them, legacy WSN will be deployed in the field.

3.1.3.1. Existing infrastructure

Legacy WSN network with WSN nodes containing sensors for measurement of air relative humidity, air temperature 1m above the ground, cranberry leaf temperature.
.

3.1.3.2. Needed infrastructure for the demonstrator

RUAV and RUAV-based mission management solutions, with capabilities described in 3.1.3

3.1.3.3. Logistics

The farm is 40 km from Riga, biggest city in Latvia, and is easy accessible by motorway.

3.2. AS02

3.2.1. Farm Introduction

Testing facility willl be, a milk production farm Robežnieki farm located in Sēja parish Latvia. The same farm is used in AS08 as well:

- Grass harvesting is done by the farm 3 times per vegetation period (3x grass harvesting in latitude of Latvia is available only using an advanced agriculture approach with proper fertilization);
- Grass and maize are locally collected for storage in silage

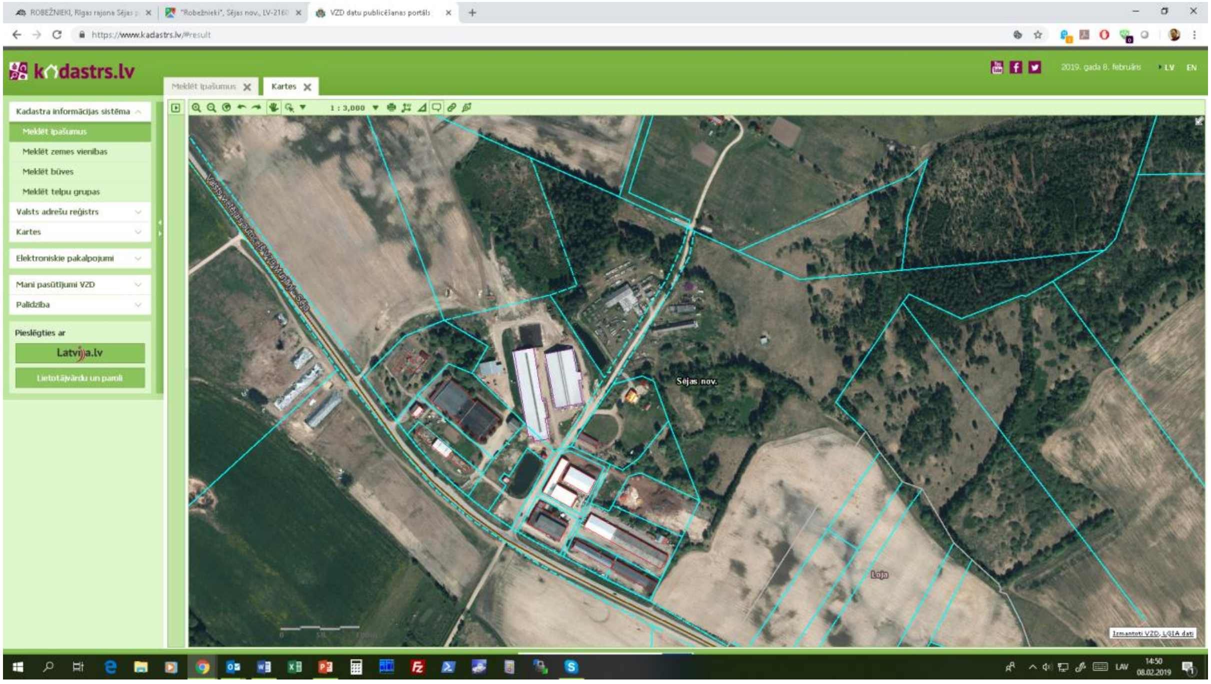


Figure 8 – Latvian cadastre map showing contours of the fields

Task is to optimize these processes without heavy use of machinery, or/and expensive technological procedures as the farm, at this stage, concentrates more on the process of milking. UAV technologies using multispectral imaging are most suited for this problem. Note that the demonstration AS08 is analyzing the results from milking process (extracting data from milking robot) and one of its tasks is to find link from milk quality to silage quality. Thus, there is a strong correlation between AS02 and AS08 (see also AS08 description below).

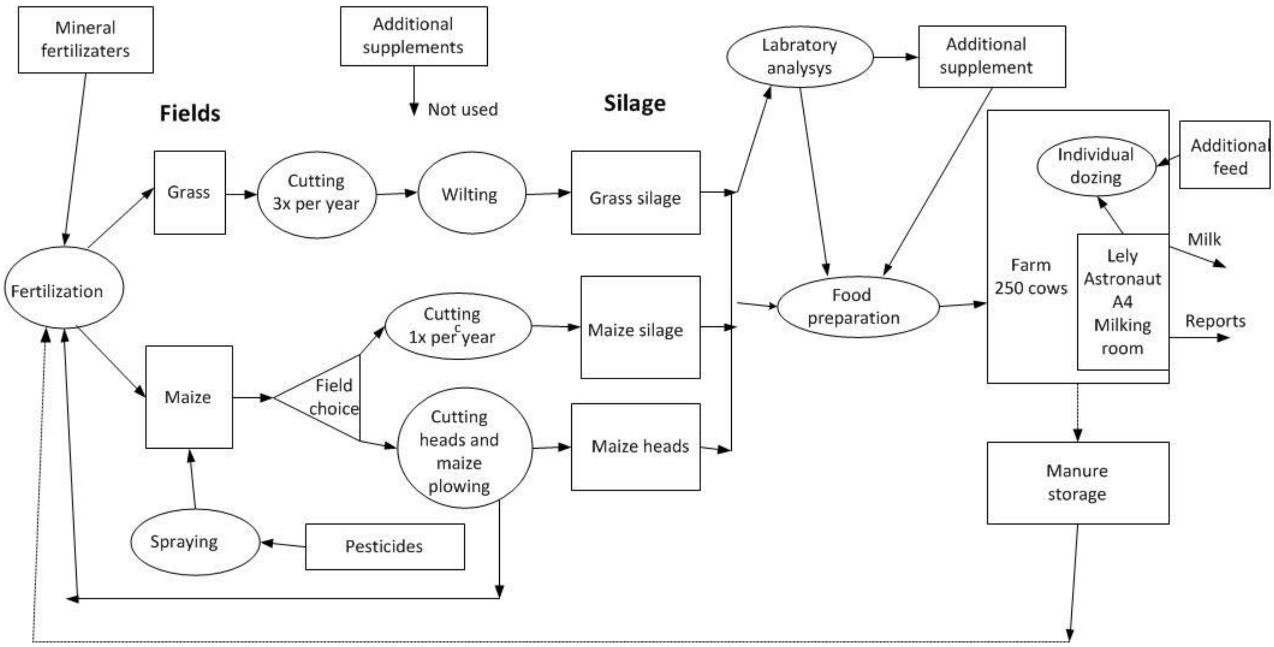


Figure 9 – Farm's chain of operation.

In Fig. 9 the high level functioning of the farm is shown. Analyzing the chain of processes we see that:

- Food preparation is divided in 3 types (grass, maize and maize heads)
- Farm is not using precise agriculture for fertilization control. That is because the process is expensive and there are excess of manure used for fertilization. Instead other inexpensive methods are used. One objective is to try to keep Nitrogen in soil during fertilization, etc.
- For the date of harvesting heuristic algorithms are used based on plant observation by the eye.
- Silage quality is based on the analysis of the samples sent to the laboratory.
- Dosage is determined based on that analysis.

From the diagram we select the processes for monitoring and decision-making points where to influence the decisions with monitoring from RUAV information and predictions based on them:

- Detect fertilization irregularities, which can be solved in future fertilizations.
- Detect occurrence and risk of occurrence of different kind of pests – illnesses of the plants, invasion of insects, and weeds, etc.
- Detect the proper and precise moments of harvesting of both maize and grass.
- Decision about maize spraying.
- Monitoring wilting of grass to get the silage quality.
- Tamping level control of harvested maize and grass before fermentation.

3.2.2. KPIs (benefits)

Two of the main impacts and benefits from the project are (DoW, 1.1.4):

- KPI2: 15-20% increase on crop productivity due to extended use of sensors and CPS units, for early detection and control of weeds and pests.
- KPI10: Up to 10% feed costs

Table 7 – AS02 KPIs

KPI10: Up to 10% feed costs *(High priority)*
Feed cost will be calculated Decrease of feed cost will be achieved by (as most of the feed is produced on the farm) - Increasing the productivity of the fields, so decreasing the cost - Increasing the Nutrition of crops - Due monitor optimal condition for silage
KPI2: 15%-20% increase of crop productivity due to extended use of sensors and CPS unit *(High priority)*
KPI will be achieved by increasing the average productivity from field. That will be achieved using RUAV's making NIR images and analysing them. Due to: - Better prediction of harvesting time (done separately for each field) - Monitor additional information for abnormal conditions in the fields (from above from RUAV); 1) fertilization problems 2) weeds and illnesses - And using this information in decision making process

3.2.3. Descriptions of goals and functionalities

3.2.3.1. G2: Improve harvesting

The task is to optimize the farm's harvesting processes (described above) without heavy use of machinery, or/and expensive technological procedures as the farm, at this stage, more concentrates on the process of milking. UAV technologies using multispectral imaging are most suited for that.

This goal associates with common AFarCloud goal **G2: Improve harvesting** and it will be achieved using functions:

- **F3: Detection of cereals nutrients components (energy, protein and humidity analysis)**
- **F4: Using DSS take decision regarding when and where to harvest**

Goal G2 is complex and is separated in subgoals and subfunctions based on analysis of farms processes (see above), which is subjected per parcel. Data is collected using drone missions with NIR camera:

- Finding Regions of interest (ROI) on the parcel map, where vegetation:
  - Can be detected by weed (F3)
  - Can be effects of diseases (F3)
  - Can be effects of fertilization (F3)
- Monitor cereals Nutrients (F3)
  - Predictions on harvesting time, per parcel (F4)
  - Make assumptions about crop quality (F4)
- Include data from AS08 for analysis (F4)
  - data about milk quality (F32) extracted from milking robot Astronaut A4

3.2.4. Legal and Safety, Healthy, Environment (HSE) considerations

Latvia drone regulations (current)

- Pilot on standby.
- On eyesight distance or max 500 meters from pilot.
- 120m maximal height.
- If drone heavier then 1,5 kg, must be Insured for possible damages to 3rd persons property.
- Rules about flying near special objects (airfields, military objects, banks, etc.), not applicable, because no such objects near farm.

No other HSE considerations.

3.2.5. Infrastructure and logistics considerations

Demonstration is based on Autonomous monitoring of the field by RUAV. RUAV have to include the autonomous solution for exchanging data with AFarCloud platform. UI and AFarCloud platform connection available at every internet access point

3.2.5.1. Existing infrastructure

None required.

3.2.5.2. Needed infrastructure for the demonstrator

RUAV, and Mission management tool, with capabilities described in 3.2.5

3.2.5.3. Logistics

Farm is 40 km from Riga, biggest city in Latvia, easy accessible by motorway.

3.3. AS03

3.3.1. Farm Introduction

The Ogesta estate agriculture company is run by three brothers Gabriel, Mathias, and Henrik Jonsson. They have 1.500 milk cows and 1.500 young cows. The company manages a territory of 2.000 hectares of agricultural land, considering pastures and croplands, in order to feed the livestock it has. The fields in Gamleby provide crops that are exclusively used to feed the cattle. Additionally, on the Gamelby site is the Gamelbygymnasiet, which offers educational programs i.e. in agriculture, animal care, and hunting and game care. See Figure 10 to 12.

Figure 10 – Greenhouses in AS03

Figure 11 – View of the farm from south in Ogesta farm

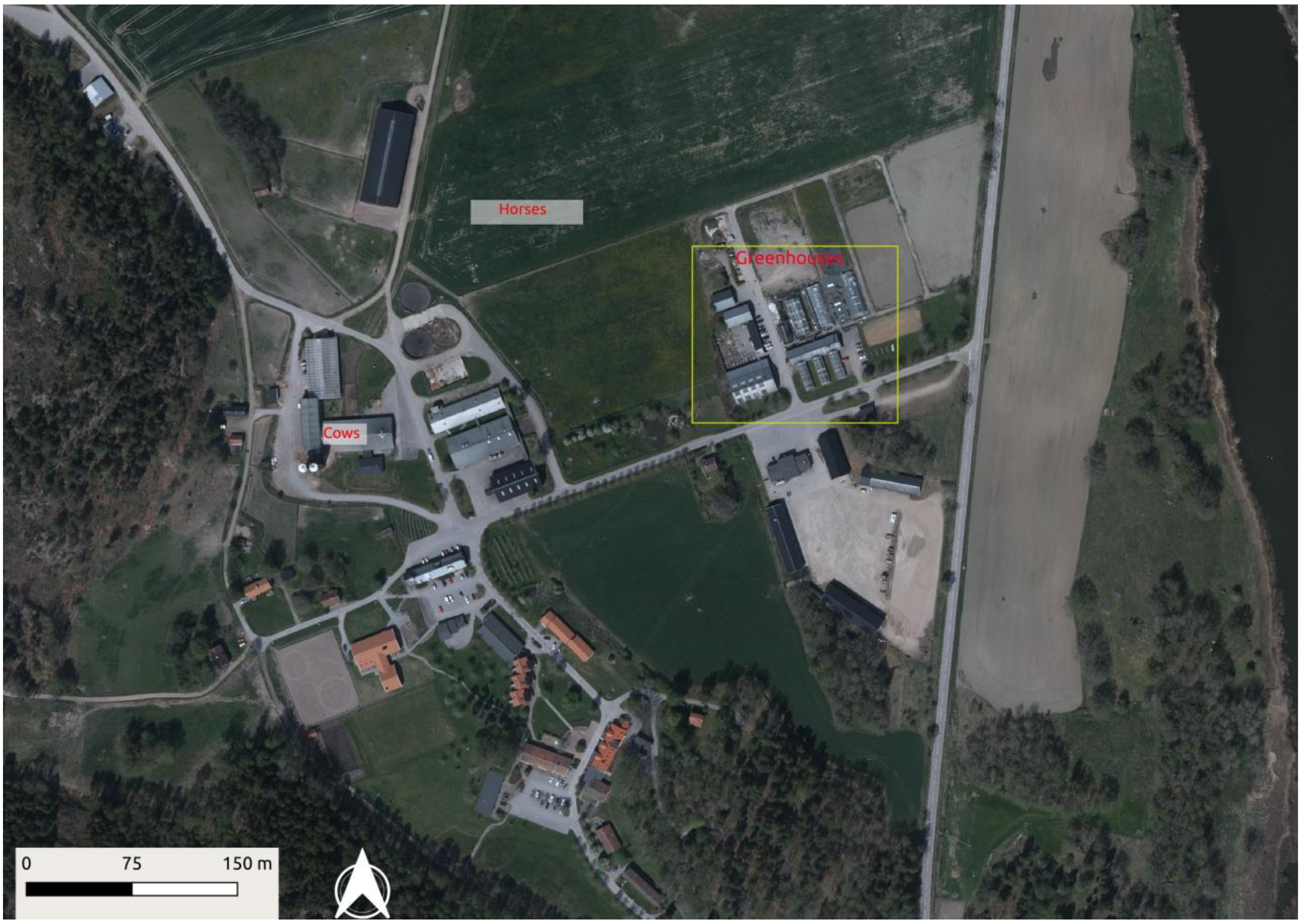


Figure 12 – Aerial view of Gamleby farming school (http://gamlebygymnasiet.nu/).

3.3.1.1. Crops for animal feeding

Arable land is commonly fragmented over the landscape demanding long and time-consuming transports. As the cost for cultivation is almost the same independent of the resulting harvest there is a strong incentive to improve production per hectare. In Sweden, drainage is a major issue but also irrigation could improve production during the commonly dry springs and sometimes summers. Rains in July and August are other problems that can influence the possibility to harvest and the quality of hay and silage. Possibilities to measure the nutrient and protein content in the crop and water content in soil together with factors like pH, nutrients and minerals are other factors valuable to measure.

To be able to analyze remotely sensed data from satellites, airborne sensors and UAVs it is beneficial to have digital soil maps and topographic maps where measurements made in situ with soil samples or measurement probes are shown. In a Geographical Information System (GIS) a number of samples of pH, soil wetness, conductivity etc. can be analyzed and integrated over a whole field with geo-statistical methods like Kriging and Co-Kriging showing the probability of levels in all areas between the sample points. If the result from the remote sensing images shows some unexpected values in such a predictive model this can be used as to suggest additional sampling points to improve the model or find other explanations to the outliers. It is also possible to calculate soil wetness, soil temperature and vegetation indexes only with help of algorithms using existing geographical data. In this way it is together with remote sensing data possible to find anomalies that can indicate diseases or insect attacks on the crop.

There is further a strong movement towards production of maize (corn) and domestic beans to replace imported soya that together with cereals can top up the feed. Those crops also were shown to be quite sustainable towards the heat and draught during the cultivation year 2018. Inspection and treatment of those crops could benefit from use of UAVs as they are extra sensitive to tractors driving in the fields.

In Nordic climate under drain of the fields is a common method to improve yield especially in fields with clay soil. To inspect where the under drain systems fail is by this reason important and farmers have reported a 10% increase in production of hay and silage by indicating problems with the help of images from UAVs and improvement of the drainage system (Tornerhjelm 2018).

It is also important to inspect the crop regarding content of nutrients to find out when there is optimal time for harvest. Knowledge of the soils and the content of nutrients and minerals as well as the topographic situation of the fields that influence the solar influx and soil moisture are important factors to estimate the yields and quality in a Nordic climate. Farmland in Sweden is often of glacio-fluvial origin and sometimes reclaimed from wetlands. This means that under drainage is beneficial as it transport melting snow-water in the spring and lower the general ground water level in the fields. In this way the root system of the crop can develops deeper that makes the soil moisture, bound in especially clay soil, available for the plant. The water bound to the particles in the soil can actually support one crop during a summer with moderate rain and temperatures. Maintenance and control of the drainage systems is therefore very important. Some farmers are now pumping the surplus water generated during the spring into dams that can be reverted pumping water back through the drainage systems into the fields during dry summers. This is especially rewarding in eastern Sweden that has a low precipitation (ca 600 mm/y) and is dependent on snowmelt and rain from the winter for plant production and other water uses. As general bedrock is crystalline granite and gneiss the groundwater magazine is not so big.

3.3.1.2. Livestock welfare

Livestock and milk-farmers in Sweden have as in many countries problem with the revenue from their business as prices are relatively low for the milk and the cost for production and harvest of fodder is increasing. Furthermore, the unpredictable behavior, and nowadays, changing climate makes the supply of hay and other crops like cereals and beans hard to predict. In Sweden the laws and regulations for husbandry are strict regarding management, veterinary care and animal health as well as the quality of the products. Note that Sweden has statutory requirements for space and care over the EU level. Following rules are by law and in practice:

- Statutory pasture in summer (except for bulls, for safety reasons) and compulsory inspection of the animals that is costly in resources and time and should be able to relieve with new technologies like UAVs.
- The animals always have access to protection for the weather during the cold part of the year. A control program guarantees good animal care in the few cattle herds that only have natural weather shelters.
- The movement of the animals on the bait may not be restricted.
- Almost all animals go loose throughout their lives (during a transitional period, up to now it is allowed with tied up cattle in the winter in older stables, but not calves)
- Always anesthetized before surgery and no antibiotics if not clear indications.
- Both cows and ewes beget loose in a natural way
- Wise breeding that prevents infertility and calving problems
- The major cost items for milk and meat producers are animal feed, labour and depreciation, which often count for two-thirds of the total cost of producing milk. 43% of the total cost of milk production is feed (half of it is roughage). There are often losses in transport, packing, storage and other steps in the whole production circle.

During the last year there was a need to hold the cows in proper body mass and not to overfeed in case feed was available. Control of the proper feed related to the milk production or if the cow is carrying a calf etc. is also important. A system to observe the cows with IR cameras is common at Ogesta farm as well as RFID tags that release individual raisons at feed stations as well as initiate milking robots and treatment in automatic “cow wash” stations.

Grazing is the easiest way to reduce costs during the vegetation period that is widely varying in Sweden according the country´s geographical location. Relaying on grazing is, however, challenging mainly because of the lack of tools to help the farmers to measure available herbage mass and grass intake. Systems to estimate nutrient content in the harvested hay and silage are a requested service.

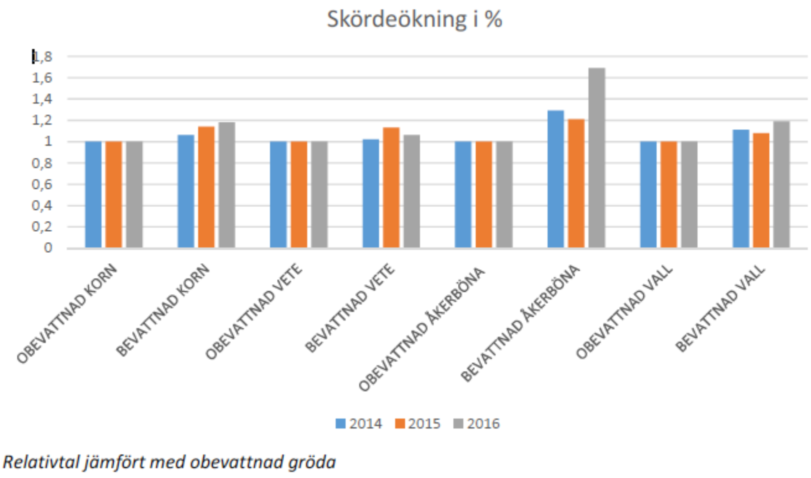
In Sweden there are quite few losses in the herds during the grazing period and at daily inspections problems in severe animal health can be discovered. However, malnutrition and infections, whichfor example lead to lower fertility are more difficult to observe without veterinary examination. Trials that have been made to observe movements and other behaviour that can be signs on health problems with help of Machine Learning are promising.

3.3.2. KPIs (benefits)

Table 8 – AS03 KPIs

KPI10: Up to 10% reduction of feed costs due to efficient nutrition *(High priority)*
At Ogesta estate they have a surplus of natural manure so the question is more to apply it in the right place and right time without too heavy losses of nitrogen and phosphorous to atmosphere and water. Additional nitrogen can support the protein content if it is spread at the right time and in right place. Reduction of kg feed is a blunt measurement but food of right composition in right amount according to the needs and to as low cost (as big harvest per hectare) as possible must be a better measurement for the Swedish farm.
KPI6: 15% reduction of losses due to crop and animal diseases or non-optimal conditions *(High priority)*
Crop diseases must be investigated but are most severe on potatoes, oil seeds and cereals. Contamination of hay from rabbits, snakes, rats or other animals (also sometimes baby dear) hiding in the fields during harvest is a problem that been addressed. Systems to scare those away could have an impact.
KPI7: 10% reduce animal losses due to increased health *(Medium priority)*
In Ogesta they have very few losses in the herd. Better and earlier observations of health problems and inspection of safety issues in the environment and meadows that can result in accidents for the cows.
KPI9: 80% reduction fuel and time spent when looking for missing animals as well as particulate emission for agricultural machinery *(High priority)*
At Ogesta estate the spatial distribution and form of single fields is a problem that perhaps reduce the possibilities to improve driving and transports time and costs. However, information (partly from UAVs) about the soil in the fields capacity to carry the harvesting machines and identification of harvest windows can aid in transport planning and selection of suitable fields and improve the quality of the harvest. Information from drones will surely reduce the time to count and inspect grazing cattle and to inspect the fields before harvest to ensure that no animals are hiding and risk to be killed and contaminating the hey.
KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock *(Low priority)*
This is also a number hard to verify as the focus is on healthy husbandry with focus on a balanced diet according to every cow’s needs.

Table 9 – *Table of cropping scenario objectives and benefits*



The table show the result from project with N and P rich brackish water irrigation for the years 2015 – 2016 – 2017. The crops that improved most was Barley (Korn) with 10-20 %, Beans (Åkerböna) 45 – 65 % and Grass (Vall) 15-20%

3.3.3. Descriptions of goals and functionalities

The goal with the AS03 test bed is to demonstrate how also a modern and generally innovative farm can be developed further with help of Information and Communication Technologies (ICT) and Geographical Information Systems and Remote Sensing from Satellites and UAVs as well as probes in situ for measuring the conditions in every field and advice the farmers what to do under certain conditions. The use of autonomous or AI supported actuators like tractors, harvesters and UAV are other functions that can be tested.

Improved and sustainable growths in production of plants and in husbandry are indicators for a successful demonstrator.

3.3.3.1. G2: Improve harvesting

In order to achieve this goal, the demonstrator will implement the following functionalities:

- F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.
- F3: Monitor cereals Nutrients (energy, protein and humidity analysis)
- F14: Measure field water content/vigor
- F6: Measure the needs of fertilization with high spatial precision

- F7: DSS for decision about when to fertilize
- F15: Measure water stress

F6: Measure the needs of fertilization with high spatial precision
F7: DSS for decision about when to fertilize
F15: Measure water stress

Investigation of the quality and quantity of growing crop is constantly made to decide when the harvest window is open and if there are some actions that have to be taken to support the growing vegetation. Need for more fertilizer is measured many ways. One method is to take soil samples that are analysed in the field or sent to a laboratory. This is now the common method together with measurements of the drop by in situ samples of the plants that are sent to analysis. NPK sensor can also be used from a tractor to measure the chlorophyll content in growing crop and in this way analyse the combination of available fertilizers in the ground. To avoid damages on the crop that is especially significant on growing Maize, UAVs with sensors are suggested to replace manual and ground based methods. Analysis of the harvested crop before it is prepared for storage for the winter to see both moisture and the nutrition content. The harvest is also weighted in the harvester meter by meter with positions from a GPS. These data are analysed together with other measurements to decide how much fertilizers that has to be brought back to the land to balance the outtake. Water content is also important to measure with manual methods, probes or remote sensing from a tractor or UAVs as the balance between soil moisture and nutrients must be balanced to promote the growth and quality of the products. When the climate is wet it is important to have functioning under drainage to keep – especially the clay soil in a preferable wet stage. Under dry conditions irrigation is important to promote the growth but it must also be balanced towards the soil wetness - that can be measured manually, by probes or UAVs and temperature, wind, air pressure, solar influx that are measured with a variety of in situ sensors but some, also with remote sensing. The geographical aspect (orientation in south-North-east.-west) the elevation and slope are also factors that can be calculated in geographical information systems (GIS) with in data in form of land survey, photogrammetry from airplanes or satellites, but often available from national land surveys or private companies.

At a high-level, these functionalities will work as follows:

The Gamlebyviken that is a narrow but deep bay or actually a “fjord” that reach 30 km from Västervik to the Ogesta farm has a high content of Phosphorous (P) and Nitrogen (N) in the bottom sediment that effect the marine life and water quality. The water is slightly salt (brackish) but only 0.003 %. A test has started to use the nutrient rich but brackish water to irrigate the fields close to the bay. To follow up how this effect the crop production but also the binding of the nutrients into the soil versus how much that is lost through evaporation or non point pollution back to the sea an intensive measurement program has started that AFarCloud project can contribute to.

The GIS data base together with existing measures of soil content of minerals and other properties can be used to place probes in such a pattern that a representative picture of the impact can be presented. Soil moisture as well as conductivity and content of N and P can be collected during a longer time to improve the understanding of the physical, biological and chemical processes in such an experiment. Inspections with UAVs with different type of sensors can be used to verify measurements with other methods as well as existing satellite images from CropSat.

Quality of the harvest is as important as quantity of biomass, content of protein and carbohydrate, trace minerals etc are important. There are also harvest windows when there is an optimal balance between those things. If you harvest too early you can miss potential growth but if you harvest to late you will lose quality. During summers as 2018 the damages on the crop was terrible due to heat and missing rains. This resulted in a huge stress to find enough quantities of reasonable good feed. The prices on the marked rose up to hundred times during that year and resulted in bad health both among the animals and the farmers.

F14: Measure field water content/vigor

To measure field water content/vigor is necessary to estimate the balance between needed water for a certain crop (and sometimes a specific type of Wheat or Maize etc) at a certain stage in the growing process and during certain weather conditions (temperature, wind, air pressure, solar influx) and the topographic situation of the field.

Standard soil moisture models that are used to estimate the need for irrigation needs precipitation and evaporation (depending on rain, temperature, air pressure and wind) as well as information about the soil type, nutrient status (N, P, K and other substances) and the status of the crop in an equation suggesting management activities. Environmental factors also influence the possibility to manage the soil, and the crop during all the cultivation phases, like preparing the soil, planting, management, driveability, harvesting etc.

F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.

The F1 function is dependent on other functions as described in Section 5; F3; F6, F7, F14; F15; F16

Environmental monitoring is concerning the status of the fields and the climatic conditions during the cultivation season but also during the winter that can have effect on the crops in both negative and positive ways. Monitoring temperature, wind and moisture/freezing are factors that can be used as input in the farmers decision trees for how to apply different best practises a certain season and on a certain piece of land. Standard soil moisture models that are used to estimate the need for irrigation needs precipitation and evaporation (depending on rain, temperature and wind) as well as information about the soil type, nutrient status (N, P, K and other substances) and the status of the crop in an equation suggesting management activities. Environmental factors also influence the possibility to manage the soil, and the crop during all the cultivation phases, like preparing the soil, planting, management, driveability, harvesting etc.

3.3.3.2. G6: Reducing water waste and cost

This goal is achieved by the functionality F14:

F14: Measure field water content/vigour

The F14 function is dependent on other functions as described in Section 5; F1; F3; F4. This functionality consists of the following tasks:

- Use of basic agricultural maps and UAV data for planning and performance of a test with probes for in situ measurement of soil properties in relation to an irrigation test with N and P rich brackish water Placement and use of probes for a measurement program.
- Collection and interpolation of data for presentation and further analysis
- Collect aerial IR and hyper spectral imaging data and process the hyper spectral raw data into map-projected hyper spectral images
- Sensor and data fusion and analysis of maps and image data for cross validation between manual tests, probes and aerial sensor information.
- Measuring of water properties in the Gamleby bay with help of UAV.

Figure 13 shows the fields for practical experiments on the outcome of different irrigation experiments and will be able to feed models for AI based advice in the several matters we are investigating on water, nutrients and plant production/quality.

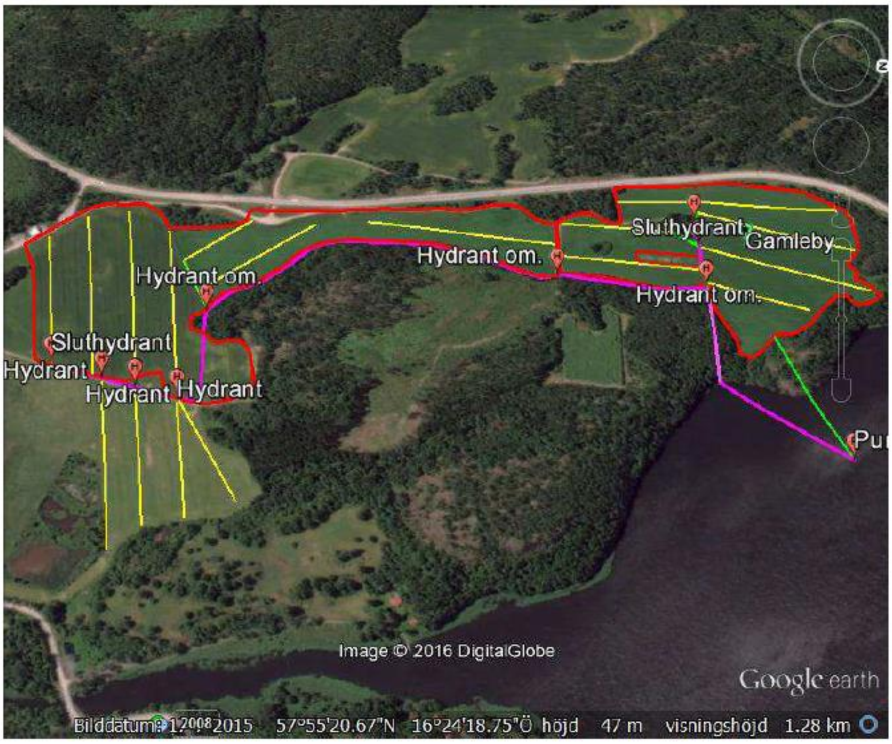


Figure 13 – Most suitable fields to monitor in parallel with an irrigation project

3.3.3.3. G5: Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality by monitoring the nutrient level and composition of the feed.

This goal is achieved by the following functionalities:

- F4: Livestock location tracking
- F28: Tracking of vehicles and mobile equipment

F4: Livestock location tracking

The F4 function is dependent on other functions as described in Section 5; F1; F4, F3, F14

The livestock scenario is one of the starting points for issues and business that we'd like to address in the Swedish demonstrator, and the involved companies have different and often complementing means of collecting and aggregating data, and various post-processes like normalisation, analytics, simulations, predictions and visualisation.

Specific tests expected to be included in the Swedish Demonstrator (AS03) include the following events/actions included in, and leading to an end-to-end scenario running in local and global demonstrators

Data retrieval and aggregation activities

- Collect movement, vial signs, position data from worn (bovine) sensors
- Collect situational and ambient aerial imagery for real-time and post processing/analysis
- Collect data from vehicles and other relevant equipment (e.g., GPS position data, CAN data, etc.).
- Gather data from other sources, e.g. feeding stations, environmental sensors et cetera

Analytics and visualisation activities

- Analyse imagery and visualise temporal herd and individual movements

Livestock behavior and classification

- Monitor movement using an on-collar sensor platform
- Analyse movement data, by comparing with previously recorded, known behaviour and use of modelling (e.g. Gaussian mixed modelling, GMM).

In Y1 demonstrators, focus lies on collecting data for training the model. A capture system is developed to synchronize timestamps for sensor data reading and video capture, allowing data labelling both in real-time and in post-production.

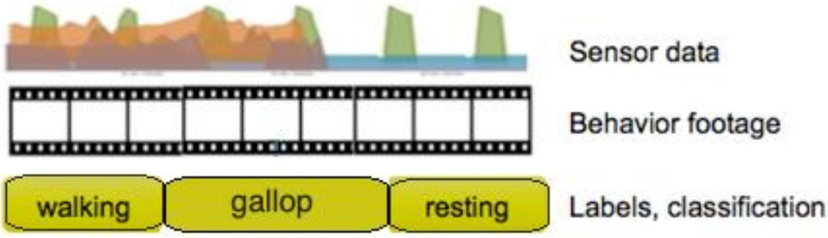


Figure 14 - Scope for the animal tracking study F:4

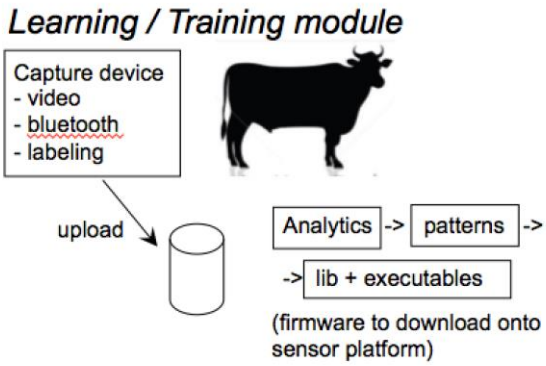


Figure 15 - Learning/training module to build a AI model for automated analysis of milk cow health and desires.

F28: Tracking of vehicles and mobile equipment

- Monitor vehicle movement over LPWAN networking, using line-simplification algorithms.
- For the Y1 demonstrator, a tracking device for positioning data is developed and data collected on-device, allowing routing data to be sent over a LPWAN network (LoRa WAN) with limited bandwidth using line-simplification algorithm (e.g. Peucker-Douglas) to ensure data transfer of the most significant data points, even when the data throughput rate is constrained by blocking geography or longer range. See Y1 demonstrator components (red, dashed ellipsis) in the flowchart below.

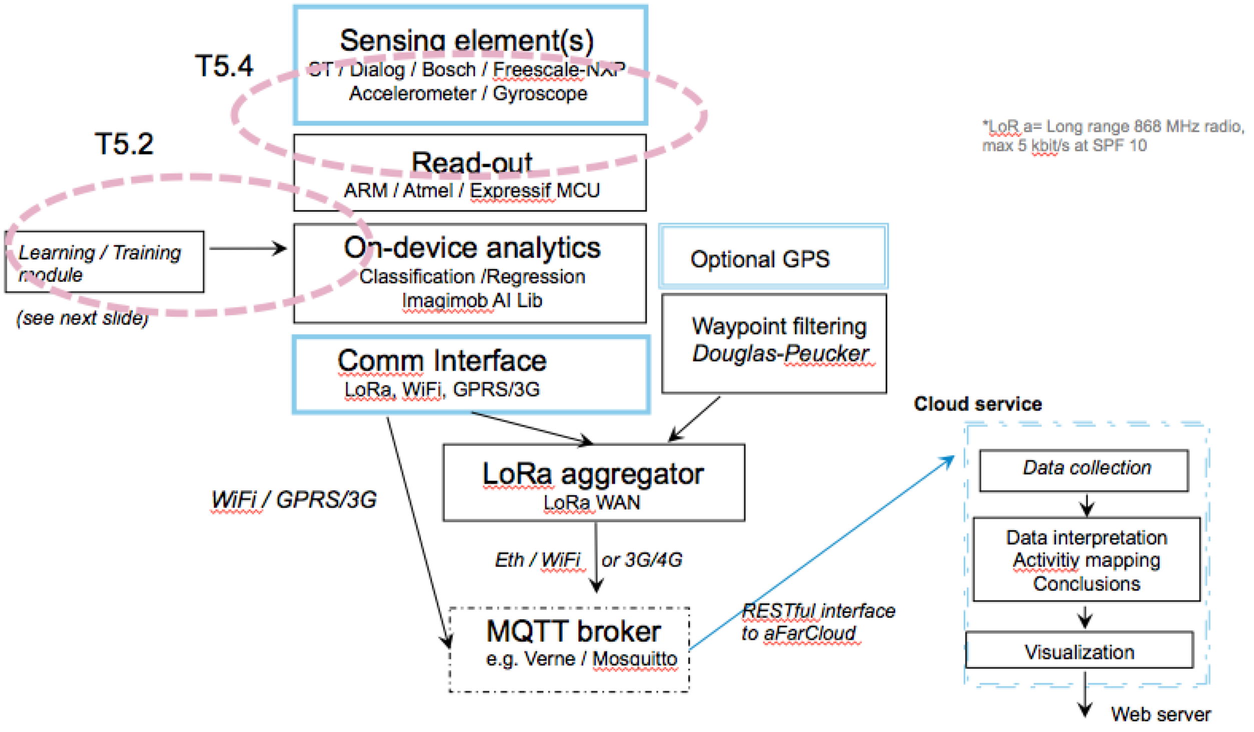


Figure 16 - Diagram of demonstrator and Y1 functionalities. There are two routes; clients are carried by a) bovine or b) legacy equipment/vehicles, the latter having GPS on-board.

3.3.4. Legal and Safety, Healthy, Environment (HSE) considerations

A farm is in many ways a dangerous place. There are many machines that can fail and disable the farmer and visitors so safety considerations must be taken and advice/regulations from the staff been followed at once and in detail. Also animals can sometimes harm persons if they are sick, have their offspring near, get scared from something unknown or other reasons. You have to be careful in contact with them and ask what the roles are. There is also a consideration regarding diseases so if you have spent time with other herds or even single animals these can carry bacteria or viruses so tell in case and we discuss what to do. In fields with growing vegetation or under feed it is forbidden to walk or pass. You can get permission for the demo but it is polite and necessary to ask. Animal corrals are often equipped with electric fences so take care before touching a wire or something that looks like a common string. It can be charged with electricity.

The farm is also the working place and home of the farmer and staff so respect their privacy and don't enter into buildings without announcement and permission.

Fertilisers and other chemicals used in farming and husbandry are toxic or harmful to humans and animals in wrong quantities or concentrations. Don't touch.

In Sweden and most countries nowadays, environmental consideration is common sense. So don't throw things on the ground or elsewhere but recycle things and keep things as clean as possible. This is also the case that you don't enter into buildings with dirty shoes etc. The Nordic countries are besides Japan places where you normally take off your shoes when you enter into a house.

3.3.5. Infrastructure and logistics considerations

3.3.5.1. Existing infrastructure

1. **Telecommunication:** Currently there is Wi-Fi network in the agricultural school and GSM coverage with the main providers Telia, Tele2, Telenor and Tre. Depending on location there is good to moderate connection in 4G and 3G.
2. **Electricity:** There is power supply available. We can support installation of Wi-Fi and other communication links after request.
3. **Web Mapping Services (WMS)** for collection and information about available maps in the area but only for visualisation (to look at or download as a picture)
4. **GSM service GPS-Transponders** for accurate and real time positioning.
5. **Lodging** in the agricultural school in June. Requests must be sent from each partner jointly to ake.sivertun@ri.se to guarantee access. 2 and 1 bed rooms with wifi. Lecture rooms and facilities for the demo at a cost of 1 500 SEK (140 €) per day and one room. Additional rooms for 500 SEK extra each each.
6. A pree-demo will take part 21-22 May 2019. Interested to participate contact ake.sivertun@ri.se

3.3.5.2. Needed infrastructure for the demonstrator

1. LoRa networking; aggregator base station
2. Casings for collar-based sensor measurement
3. DJI Mavic Air Drone equipped with 4K 30fps camera on a 3-axis gimbal. Capable of taking panoramic and sphere panoramic photos.

3.3.5.3. Logistics

Ogesta farm I co-located with the Rural Economy and Agricultural Societies HHSS school in Gamleby south east Sweden. It is further located within the 40 x 60 km wide Västervik test area for Drones, financed by the Swedish Innovation Agency Vinnova (http://www.dronecentersweden.se). The farm is unusual large for Sweden and work mainly with milk production. The farmers are involved in several agricultural projects – as irrigation with nutrient rich brackish (slightly salt) Baltic sea water to improve production of feed for their animals.

Figure 17 – Map with location of the AS03 demonstrator

3.4. AS04

3.4.1. Farm Introduction

The Spanish Local Demonstrator has a testing facility located in Villaverde de Medina, Valladolid (Spain). The winery is called CASERÍO DE DUEÑAS.

Caserío de Dueñas is a singular estate of almost 300 hectares of vineyard in one of the highest quality zones of the Rueda Designation of Origin. It is a unique location, where a profound harmony and a great respect for the land have survived throughout time.

Caserío de Dueñas is not only a manor house but also a chapel. It is living testimony to a unique way of making wine, a different reading of the land in an estate that is truly unique in the area, bringing together best practice in both the vineyards and the winery.

Its history dates back to the start of the 17th Century when these fields were home to a small farming village. In 1800, after Godoy's land disentailment act, the hamlet was transformed into a large estate in which vineyards were planted gradually. Over the decades, more and more land were turned over to vines, as they proved ideally suited to the area.

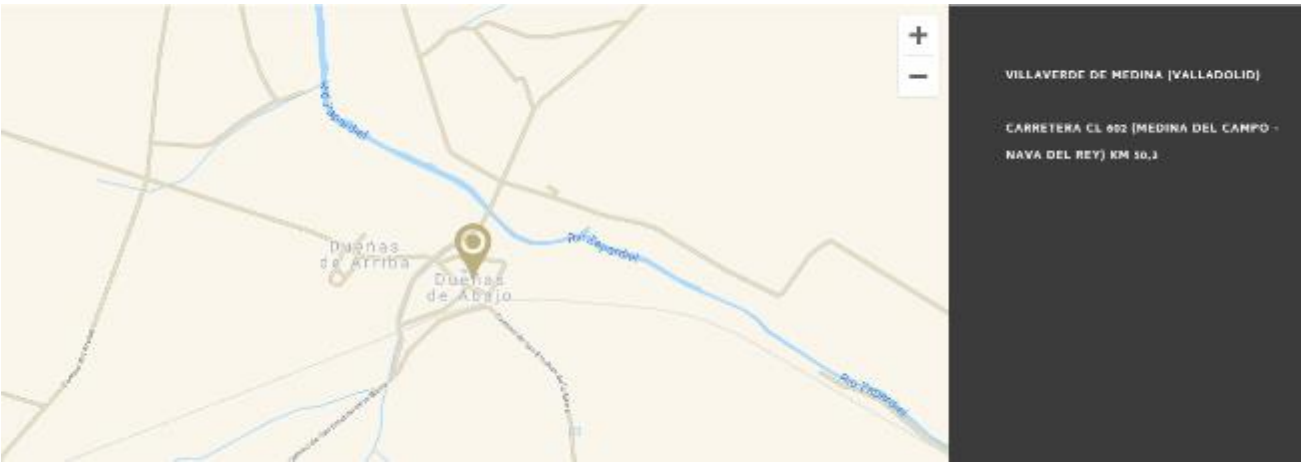


Figure 18. Vineyard location.

Today, in the hands of a team led by Almudena Alberca (Technical Director), Caserío de Dueñas practices a kind of viticulture capable of making the most of the essential values of this location: the proximity and alignment between the vines and the winery, producing wines that are the strongest expression of contemporary knowledge that seeks freshness, complexity and balance.

The objective of this scenario is to improve existing techniques and working conditions of the people in charge of the vineyard, and to improve the watering optimization in order to ensure the final product quality.

Figure 19. Caserío de Dueñas Vineyard I.

Figure 20. Caserío de Dueñas Vineyard II.

Figure 21. Caserío de Dueñas Vineyard III.

3.4.2. Scenario

After a first visit to the vineyard, it was decided to monitor a specific area, that shown in pink colour in Figure 20 below. This area covers about 50 hectares, divided in 5 differenced sectors. In this area, two different premium varieties of grapes (Rueda Verdejo and Sauvignon Blanc) are cultivated.

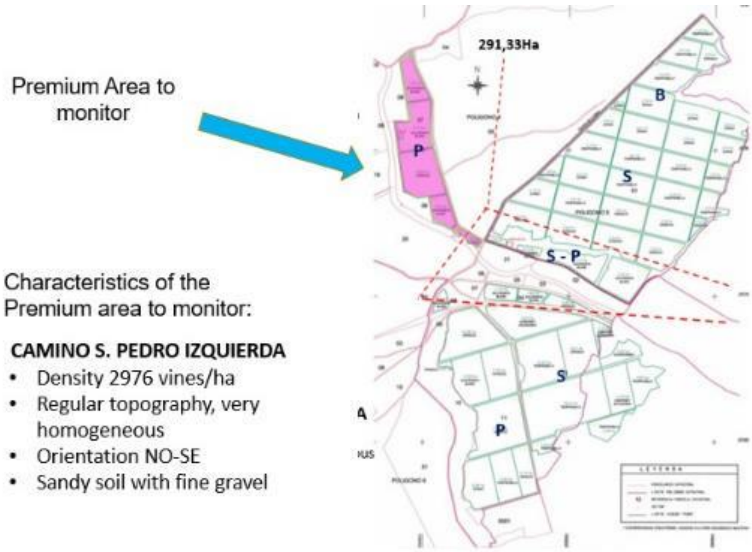


Figure 22. Specific area in the vineyard to monitor.

3.4.3. KPIs (benefits)

Currently, one of the most important challenges that the vineyard has to face is the watering optimization. For this reason, it has been fixed as main KPI the number of cubic meters of water needed to produce one ton of premium quality grapes.

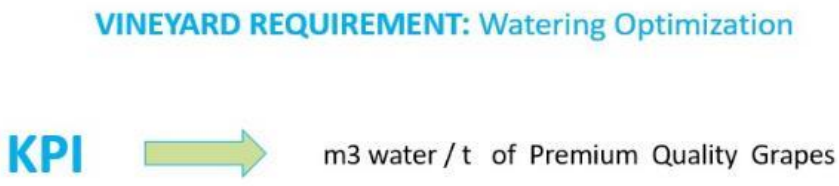


Figure 23. AS04 Main KPI.

.Based on the main KPI, in order to create a base line, a study of the historical data of the monitor area will carried out focusing in two parameters: rainfall and temperature.

The objective is to make a comparison between the historical data and the new data obtained during the project.

In order to compare these data the idea is to create a regression line with the following inputs:

- Watering [W] / Quantify of premium grapes harvested [Q]
- Rainfall [RF] / Quantify of premium grapes harvested [Q]

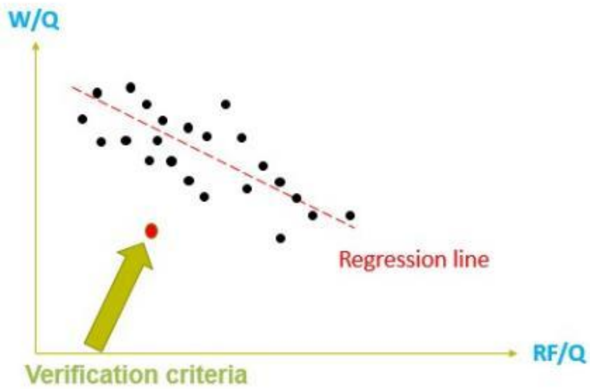


Figure 24. Base Line. Regression Line.

Table 10 – AS04 KPIs

KPI 1: 30% of cost reduction, for integrator companies that provide the technologies and the services, due to saving in programming, integration and configuration time *(Medium priority)*
Having an automatic system for gathering and processing data will help optimize resources related to mobilise workforce to the vineyard.
KPI 5: Reduction of soil erosion and soil compaction and improved absorption of water *(High priority)*
Optimizing the watering in the vineyard, it will mean an important saving of water, especially during Summer period. In addition, it will help (with the periodically monitoring of the field) to control soil erosion, as well as, to avoid runoff in some areas of the vineyard that prevents water from being absorbed by all the zones equally.

3.4.4. Descriptions of goals and functionalities

At this moment, the vineyard is handled following traditional methodologies without using any monitoring technology and all decisions are based on farmer experience.

The following sections it would be described which functionalities would be implemented in Caserío de Dueñas.

3.4.4.1. G6: Reducing water waste and cost in horticulture

This goal is a wide-ranging goal that applies to several demonstrators of the project. In order to achieve this goal within the AS04, the demonstrator will implement the following functionalities:

- F19: Measure of the vine water stress/vigour
- F15: Measure water stress

. Considering the expectation of the farmer, the most important functionality to be implemented in AS04 is F19. The first step, to be carried out during the Y1 of the project, will be gathering multispectral and thermal images of the vines during different period of the year to feed the algorithm developed in the project to assess the vine water stress. The following step will be to try to build weekly water-stress maps of the vineyard sector to make decision on the best watering strategy.

At a high-level, these functionalities will work as follows:

- **F14: Measure field water content/vigour**
  The water content will be analyzed in the vineyard using soil humidity sensors at different depths. They will allow to determine the exact amount of water surrounding the probes. With this information and considering the structure of the soil, it is possible to calculate the content of water in a vineyard.
  The water content and the vigor of the specific crop can be a way to estimate the quality of the vineyard.

Another impact in the crop quality is the detection of the weed presence and dead plants. In AS04, the analysis of the Normalized Difference Vegetation Index (NDVI), which quantifies the quality and development of vegetation, allows the DSS to make a decision on these two aspects. First, multispectral images acquired by a multispectral camera embarked in an autonomous drone will be processed to generate a georeferenced mosaic, and then this will be processed to generate an area mapping with the clustering of detected weed and dead plant by defining of weed and dead plant regions. These indicators will be the metrics that DSS will receive to the evaluation of the quality in the crop.

- **F15: Measure water stress**
  The water stress parameter in the crop will be monitored through the Crop Water Stress Index (CWSI), which was developed as a normalized index to quantify stress and to overcome the effects of other environmental parameters affecting the relationship between stress and plant temperature. This index has been widely used for crop water status monitoring. In AS04, the CWSI index will be estimated using thermal cameras embarked in an autonomous drone. First, a thermal georeferenced mosaic will be generated, then the CWSI map is generated using weather parameters and finally, generating a CWSI map based on areas based on a defined threshold. This indicator will be one of the metrics that DSS will receive to the evaluation of the water stress in the crop.

3.4.1. Legal and Safety, Healthy, Environment (HSE) considerations

All work in the demonstrator will be carried out under the supervision of qualified staff of the vineyard.

It should be paid special attention to the Spanish Law: RD103/2017, which regulates the use of drones in Spain.

3.4.2. Infrastructure and logistics considerations

In the following sections it would be described the infrastructure and logistics considerations for AS04.

3.4.2.1. Existing infrastructure

Power supply: there is power supply in the office buildings.

Connectivity: a Wi-Fi network system exists only in the office buildings of the vineyard. In addition, there is GSM and SigFox coverage.

3.4.2.2. Needed infrastructure for the demonstrator

In order to allow controlling the AUV platforms through the AFarCloud architecture could be necessary to deploy a Wi-Fi network to cover the area to monitor.

3.4.2.3. Logistics

Contact person: Fátima Vellisco (ACC), confirm dates for deployment at least 2 weeks in advance.

Location: Villaverde de Medina, Valladolid, Castilla León, Spain. To reach the vineyard: road CL 602 (Medina del Campo – Nava Del Rey) Km 50.2

Accommodation: the nearest town to the vineyard to book a hotel is Medina del Campo. There are 9 km from Medina del Campo to the Caserío de Dueñas.

3.5. AS05

3.5.1. Farm Introduction

This scenario is based on the farm Podere Campaz, located in Emilia-Romagna Region, Italy. The farming company owner of the farm bases its activity on the principles of permaculture. Permaculture is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems.
Permaculture is intricately related to a domain of science based on systemic approach. Systemic approach relies mainly in the control (modelling) and management (computing capabilities covering end to end processes) of information coming from complex system. Permaculture introduces a systematic approach in order to be a way to more the embrace and fuse technological progress into the biological sphere and the different components in permaculture play an important role and need to be monitored.

Podere Campaz tries to build resilience and it will help to prepare for an uncertain future with less available energy and resources, and to this end it aims to create the conditions to avoid waste. The principal production is wine from vineyards, but other cultures are present. In less than 10ha, Podere Campaz is dedicated to vineyards, apricot and peaches trees, berries, vegetables, aromatic herbs, lavender and medicinal herbs, saffron and olive trees. Its production is strictly organic without needs of agrochemicals and synthetic fertilizers. It has a greenhouse of about 200 square meters for vegetables crop. The farmer has recently acquired a new land in which he expects to grow cereals (e.g., wheat) or legumes (e.g., chickpeas) in the near future, as well as other grapevines and/or use it to feed livestock he will probably have in the future (mainly consisting of milk-producing animals, since he would like to include cheese in its productions). We remark that up to now the farmer has no animals except from poultry.

At the moment, the farmer cannot afford to hire more personnel. Usual needs are related to knowing when to supply water, defend against possible pests (in particular for vineyard disease Golden Flavescence, since the farm is 250 meters far from where the last outbreaks were observed), presence of weeds, macro and micronutrient levels, the best time to harvest, in order to improve the techniques used by Podere Campaz to promote sustainability and permaculture.
The solution can be based on IoT and the use of vehicles to improve activities and reduce human burden in the farm. From a technological point of view, implementation of sensor monitoring and actuator decision support are key roles in the scenario. In particular, it is possible to monitor plants at all the stages of their life.

3.5.2. Scenario

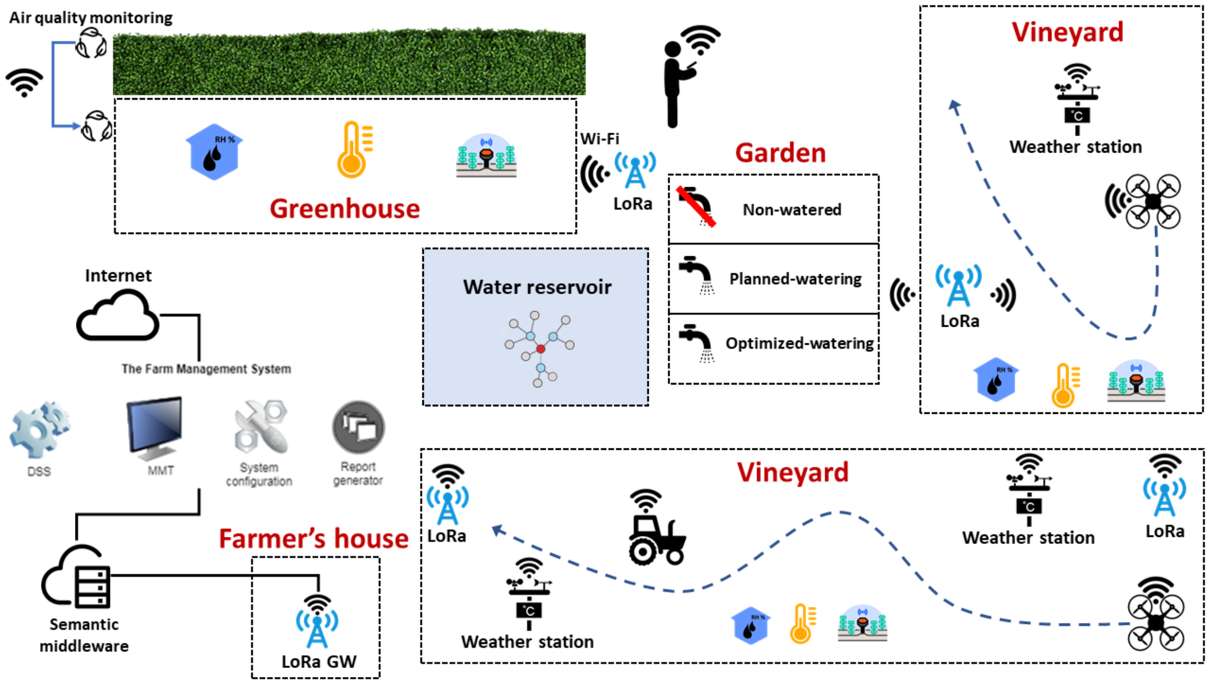


Figure 25 – Global architecture of Italian Demonstrator AS05

As shown in Figure 23, in the farm three scenarios are identified:

- Outdoor garden;
- Greenhouse;
- Vineyard.

The communication between the block is handled by a long-range transmission technology, in the scenario the communication is performed through short range technologies. All the different technologies can communicate using gateways.

3.5.2.1. Outdoor garden cultivation

The garden is currently used to grow vegetables and tomatoes, other cultivations are planned but not established yet; cultivations are usually chosen by "natural selection", that is only the ones that grow better after a trial period.
The garden is currently not irrigated but the farmer is willing to add it. The farmer is also interested in evaluating how adding sensors to the cultivation can improve the outcome, both with and without irrigation. Another desire is to eventually automate the irrigation system,

based on the sensor reading. In detail, during winter season the garden is not cured by the farmer. The vegetable garden is a wide rectangle made up of at least 6 linear pallets approximately sized 60 cm x 50 m, with a central walkway that can be divided into two 25 m-long sections.

Three separate garden areas could be defined (as shown in the picture below):

- an area should be kept as it is, without human intervention as the farmer already does, but monitored with sensors;
- an area should be treated with irrigation and fertilizers, following a pre-defined schedule based on the season and on the weather conditions, and monitored with sensors;
- the remaining part of the garden should be treated with precision irrigation and fertilization, exploiting information coming from sensors.

Comparisons can be made between the scenarios in order to demonstrate benefits and drawbacks of the adopted solutions, and evaluate how much the cultivation can be improved using sensor data. All the data are gathered through short- / middle-range protocol, eventually showed also to the farm on a device such that he can monitor the plants whenever he wants. The data are also gathered to the farmer's house and sent to the farm management system that will take the proper decisions.
Each garden area has it benefits and drawbacks. Evaluate the trade-off between effort and quality of the outcome in the three cases, quantifying the benefit from the information of the sensors and the sensors+irrigation.

The operations performed with tractors and machines will have the goal to test the integration between the on-board ISOBUS system and the AFarCloud middleware, with particular emphasis on data management and decision support systems. For example, the ploughing of the garden collects data from the ISOBUS-enabled tool and feeds the decision-support system that, together with environmental and soil data, allows automatic decisions for irrigation and harvesting.
The risk of damages to the cultivations due to erroneous actuation must be avoided. For example, a daily maximum amount of water could be programmed as a safety measure.

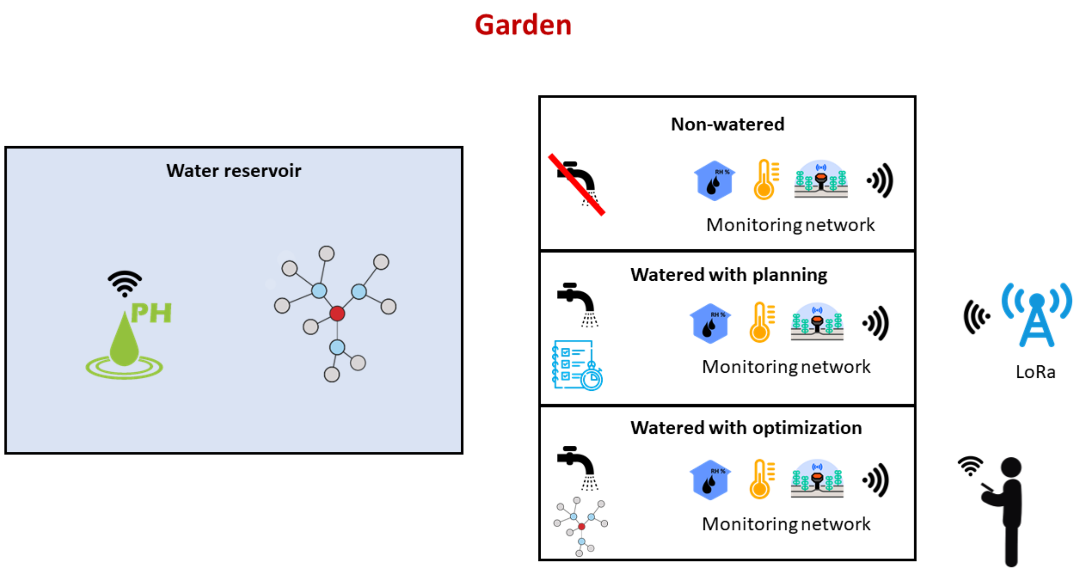


Figure 26 – Garden scenario

3.5.2.1. Greenhouse

The greenhouse hosts a variety of cultivations: tomatoes, peppers, turnips, aubergines, aromatic herbs, lavender, edible flowers and cardiospermum seeds. It already has a ground drip irrigation system, which does not water directly the plant leaves, avoiding the need for diseases related to wet leaves. The internal humidity however must be controlled in order to avoid these problems. There is an opening which is currently operated manually, according to the season and the farmer's personal experience.

It would be very useful for the farmer to automate the opening control depending on some sensor data (e.g. humidity) and to have a cheaper way to analyse the soil.

The opening can be automated, depending on internal humidity, season, training period with the experience of the farmer and so on.

Sensors (humidity, temperature, both for soil and air, NPK) can be installed in the ground without problems since the soil is soft; battery-powered sensors would be preferred to not overload the electric line and to easily move them in case of necessity.

Additionally, there is the opportunity to install an air purification system based on an NTP device, which can be activated when the opening is closed to avoid the diffusion of its effects in the atmosphere outside the greenhouse, which would be a waste.

To assess the effectiveness of the NTP device for purification aims, a "No NTP Zone" could be used as a reference, considering the same cultivation and soil area.

Thanks to the AFarCloud system, the opening of the window of the greenhouse will be automated, with the purpose to avoid in some cases the human intervention, and in any case to be monitored remotely. The farmer will no longer need to always have to manually inspect the greenhouse for controlling the humidity, because he will be able to monitor it remotely and, if necessary, open or close the window.

This decision process will be also integrated into the AFarCloud platform, in particular as part of the Decision Support System.

The risk of damages to the cultivations due to erroneous actuation must be avoided.

The opening of the greenhouse must be avoided entirely when some critical condition is present, even if the automated system would tell it is time to open. Such safety conditions must be decided with the farmer and can be signalled even from the first year to be calibrated.

The system should require the presence of short- / middle-range communication protocols (e.g., Wi-Fi, IEEE 802.15.4) to gather the data “locally”, and a long-range protocol (e.g., LoRa) to aggregate all the data that have to be sent to the cloud.

Near the greenhouse there is a neighbour farm which is not organic. An additional task can be to verify if there is the possibility of contamination due to the different use of chemicals. This is also to be considered since near the greenhouse there is a bee hive, and the honey produced also has the organic label.

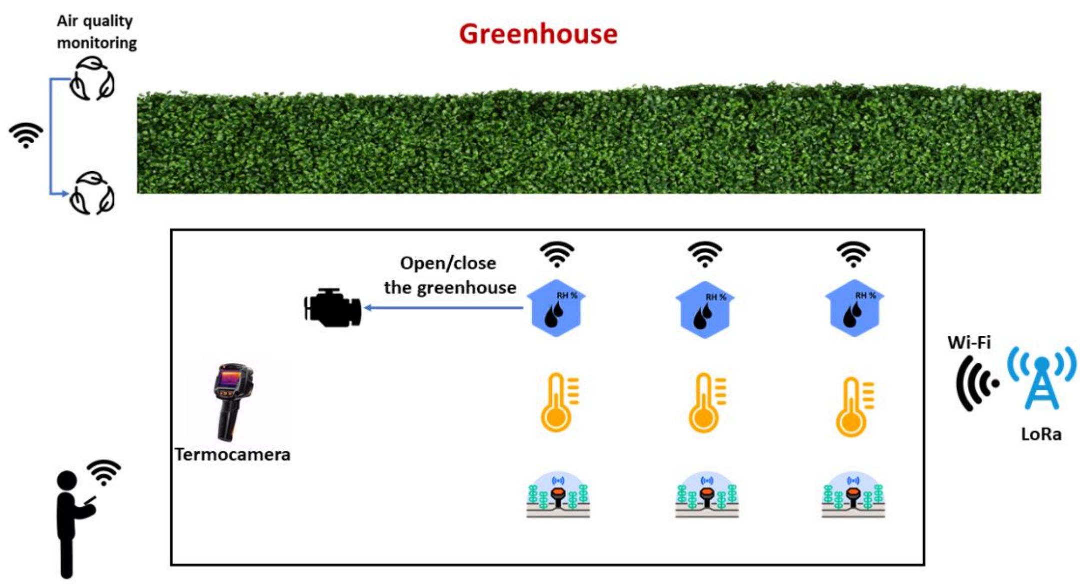


Figure 27 – Greenhouse scenario

3.5.2.2. Vineyard

In the vineyard, different kinds of grapes are grown: Trebbiano, Pignoletto, Albana, Ancellotta (e.g., Sangiovese wine). The plants are artificially stressed to improve the quality of the resulting wine.

The greatest dangers for the vineyard are some diseases, namely Downy mildew and Oidium, Golden Flavescence and "Esca" or Black measles.

The most important support would be in preventing diseases (Downy mildew and Oidium, Golden Flavescence, "Esca" or Black measles).

This can be done by monitoring both the plants (leaves' colour, shape etc) [FBA2] [I.3] and the soil (humidity, NPK, …) also using drones or other vehicles to perform heavier monitoring like leaves status.

In the vineyards, different weather stations will be installed to evaluate if a thunderstorm has different impact on the monitored points. This monitoring system could be further extended using a smartphone-based alert system and implementing some actions taken by actuators.

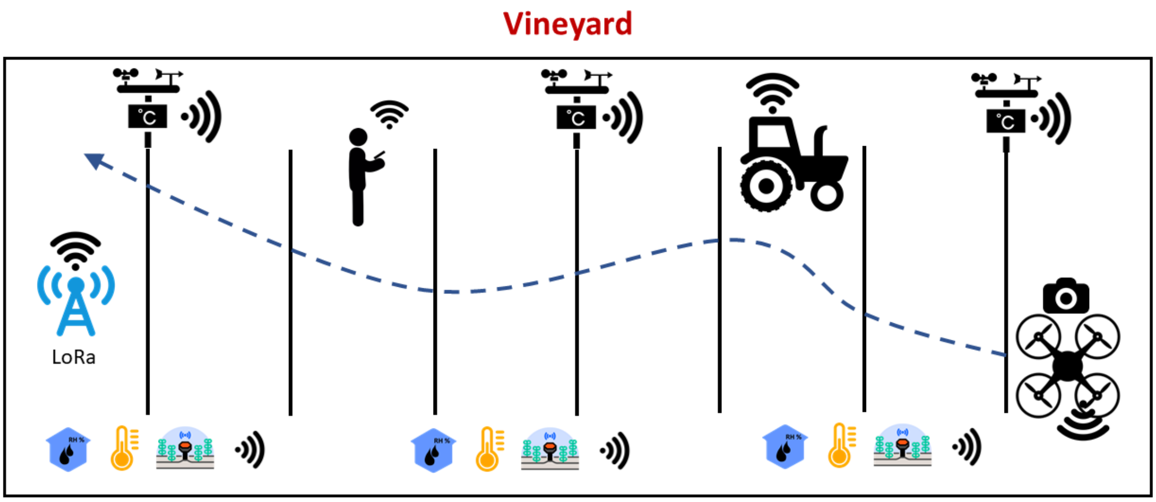


Figure 28 – Vineyard scenario

The farmer would like to be able to avoid the spreading of diseases as soon as possible, even better would be to be able to act before a disease is visible. At the beginning, data will be collected to be able to correlate some characteristics of the data to the health status of the grapes. It is expected, at the end of the project, to be able to act beforehand and avoid waste due to diseases.

The risk of damages to the cultivations due to erroneous actuation must be minimized. In this stage it could be a safe choice to always require manual inspection of a potentially ill plant, to calibrate more accurately the disease detection system.

Plant illness will be detected by analysing leaves and grapes by using a visual camera. Images acquired are processed by a neural network classifier which identifies if the subject of the image is healthy or affected by disease. In the latter a signal is sent from the detection module to alert the farmer of a suspected disease.

The neural network engine will be trained to detect main diseases specific to the vineyard scenario and in agreement with the farmer who will suggest the most critical and relevant diseases to be addressed.

Training will be performed off-line using a provided annotated dataset (i.e. by the farmer or by an agronomist expert in the field). The inference engine will be integrated to an embedded system.

A tractor will be equipped with the image acquisition system. Images to be analysed can be acquired either manually or automatically and sent from the acquisition system to the illness detector system which will generate an alert if a disease is detected.

3.5.3. KPIs (benefits)

Table 11 – AS05 KPIs

KPI2: 15-30% increase on crop productivity due to extended use of sensors and CPS unit.
Currently it is expensive to have a mapping of the nutrients that are in the field and therefore to know when and where it is more appropriate to apply fertilizers in the right measure. Having a system that allows correct decisions to be made will improve the productivity of crops. Throughout the project, the kilograms of crop generated to build the baseline will be quantified and the improvement will be analysed.
KPI3: 30% increase of horticultural productivity due to reduce chemical products use
Prevention in plant diseases thanks to multispectral cameras will reduce the usage of chemical products reducing costs for production. Moreover, an early detection of the disease can reduce the diffusion of the illness.
KPI4: 20% lower fertilizers use
Currently it is expensive to have a mapping of the nutrients that are in the field and therefore when and where it is more appropriate to apply fertilizers in the right measure will save a significant amount of fertilizers. Throughout the project it will be evaluated the saving in the use of fertilizers as precision tools are implemented in the farm. The continuous monitoring of vital parameters and environmental parameters will allow a reduction in chemical nutrients, as well as natural fertilizers

KPI5: Reduction of soil erosion and soil compaction and improved absorption of water
Monitoring water content, water needs and water stress can reduce the water needed in the area, preserving water and reducing water absorption at lower level in the terrain so reducing the risk for erosion.

3.5.4. Descriptions of goals and functionalities

Nowadays Podere Campaz is managed by its owner Nicolò without the help of employees.

The main goals of the Italian demonstrator are the reduction of water waste, the fertilizer optimization and the automation of some tasks performed by the farmer. Thanks to the use of sensors that detect different parameters from the field and inside the greenhouse, it will be possible to manage the operation of the actuators and support the decision-making of the farmer. The automation that will be implemented specially inside the greenhouse and in the irrigation system will reduce the farmer's labour and improve the productivity.

Inside the vineyard drones will be used with a special camera for the detection of plants illnesses. Thanks to this technology it will be possible to block the disease and improve the overall production

3.5.4.1. G6 & G7: Reducing water waste and cost in horticulture and greenhouse

In order to achieve this goal, the demonstrator will implement the following functionalities:

- F14: Measure field water content/vigour
- F17: Automatic actuation on rooftop
- F18: Monitor greenhouse temperature and humidity and quality of the air
- F19: Using actuators, irrigate with correct amount and location
- F20: Detect plant illness (imaginary near infrared)

Podere Campaz offers the possibility of applying different technologies to different scenarios: a greenhouse, a vineyard and a field.

Inside the greenhouse, most of the goals will be implemented. This is the most profitable part of the farm and the one that is most suitable to be monitored and automated.

In the ground, more humidity sensors will be installed in different points of the greenhouse (F14). These sensors will provide data to the decision support system. The soil parameters will be available to the farmer and will drive the automatic irrigation system (F17). Thanks to independent actuators in the irrigation system, it will be possible to irrigate the different parts of the greenhouse with different quantities of water, in accordance with needs of the different types of horticulture.

Greenhouse climatic conditions will also be monitored with temperature, humidity and quality air sensors (F18). These parameters will be used by the DSS.

F14: Measure field water content/vigour and
F19: Using actuators, irrigate with correct amount and location

In AS05 the content of water will be analysed using soil humidity sensors at different depths and in different part of the field and the greenhouse. The soil in a field can be heterogeneous it is therefore important to consider its different depths than different area of it. In this demonstrator it will be used sensors from different suppliers in order to have a more accurate feedback and measure. Each sensor will be connected with a LoRa device that communicates all the data with the gateway. The information provided by the field sensors will be elaborated by a cloud system that drive the irrigation system inside the field or the greenhouse and makes the data available to the farmer.

It will be installed a zoned irrigation system that using different valves and actuators will be able to optimize the use of water by irrigating only the driest areas.

F17: Automatic actuation on rooftop and
F18: Monitor greenhouse temperature and humidity and quality of the air

The main goal inside a greenhouse is to mitigate the internal climate respect to outside, to do that inside the Podere Campaz's greenhouse will be inflated and deflated the rooftop. Inside the greenhouse will be installed air temperature and humidity sensors, which will be used to manage the actuation on rooftop. The rooftop will be deflated for increase heat inside the greenhouse and will be inflated to increase the thermal insulation with the outside and keep a warm temperature inside. It will therefore be necessary to equip the rooftop with pressure sensors and remote controller of the air compressor. The rooftop inflation and deflation will be managed by a decision support system that crosses the data collected from the sensors and different climate profiles set by the farmer based on the cultures present inside the greenhouse. Different types of sensors will also be installed to monitor the quality of the air inside the greenhouse. Podere Campaz is an organic farm, so is important to detect if inside the greenhouse pesticides or chemicals are present. For this reason inside the greenhouse will be installed a cold plasma based system that will be used for cleaning up the air.

F20: Detect plant illness (imaginary near infrared)

The greatest dangers for the vineyard are some diseases, namely Downy mildew and Oidium, Golden Flavescence and "Esca" or Black measles. The most important support to preventing diseases could be monitoring the colour and the shapes of the leaves. This will be done using visual camera applied on drones or tractors. The acquired images will be sent from the acquisition system to the illness detector system that analyses the images and will generate an alert if a disease is detected. Thanks to this functionality the farmer will be able to avoid the spreading of diseases as soon as possible.

3.5.5. Legal and Safety, Healthy, Environment (HSE) considerations

All operations in the field will be executed by workers and especially if machines (tractors, harvesters, sprayers etc.) are used, only people working in the local farms will be allowed to use the machines. All AFarCloud people will be invited to assist to operations in the fields at safety distance from machines.

There is no limitation for visiting farms and livestock for people travelling from EU Countries to Italy, so all technicians and engineers of AFarCloud project will be able to directly install sensors and gateways in the farms. All eventually needed operations in machines, like installation of special gateways or sensors in machines, will be executed only when machines are stationary and at power off.

For special components, like air and water purification systems, a special document form discharge of responsibility must be prepared by companies working with these special systems, in order to be sure that no damages are possible and eventually no fees are charged to AFarCloud project or partners.

Partners will be directly responsible for their workers and employees and they must have their company insurance.

All products that are eventually distributed in the fields and/or in livestock to animals because of indication from an AFarCloud partner or AFarCloud software must be approved by the owner of the farm/livestock with a signed agreement before any operation.

Any other special request or need will be analysed during the first year and during the monitoring phase of the AFarCloud experience and will be documented and discussed with WP leaders and with Coordinator before taking any actions.

3.5.6. Infrastructure and logistics considerations

3.5.6.1. Existing infrastructure

Vineyard

The size of grapevines rows may vary from 20 meters to 100 meters (the farm is not a perfect polygon). The space between two rows is fixed and approximately about 2.5 meters; instead, in a single row, space among two different grapevines is about 1.2 meter. The vineyard expands for 3 ha and includes the following grape species: Trebbiano, Pignoletto, Albana, Ancellotta (e.g., Sangiovese wine).

Fruits

In the farm there is a mixed orchard where peach and apricot trees mainly grow; in another area there are trees of other types of fruits (e.g., apples). For what concerns the conformation of the rows in the orchard, the distance between different rows is about 5 m. Within a single row, the distance between two plants is about 3 m.

Outdoor, not watered vegetable garden

In the farm there is an outdoor, not watered vegetable garden where the only source of water is that coming from the environment. During winter season the garden is not cured by the farmer. The vegetable garden is a wide rectangle made up of at least 6 linear pallets approximately sized 60 cm x 50 m, with a central walkway that can be divided into two 25 m-long sections.

In the garden there grow vegetables such as tomatoes, but the farmer expects to add the cultivation of pumpkins and potatoes in the area closest to the water well in the future. The strategy adopted by the farmer is like a “natural selection” of the best species: he plants something and then does nothing; in the end, he keeps only the seeds from the plants that survived. There is also an area where chickpeas, beans, string beans or, more general, coarse seed plants are cultivated (in clayey soil like that, coarse seed plantation is easier).

Other Areas

In the farm there are some rows of strawberries and small berries (e.g. blackberries without thorns). There is also a pond with fish, frogs. The water to irrigate is taken from this pond and the farmer does not take water from depth ground (<1 m) in order to not leave pond animals without water.

Regarding the current reduced size of the area used as a vegetable garden, in the new farmer portion of property (acquired in May 2018) the owner expects to expand the farm gardens area.

Bees

The farm borders with other farms that apply chemical-based management techniques on their crops that could pollute the air and the fruits in which the bees of the farm fly and settle. In order to maintain his "organic" labelling for honey, in the region of the farm bordering the "polluted" area, the farmer must install (he is obliged) some tree/bush to "shield" harmful substances that may be present.

Greenhouse

- Size: about 194 m2, 9x20 m, height: minimum of 3 m, maximum of 5 m.
- The pallets are 90 cm wide for a maximum length of 4 m; the walkways are 50 cm wide.
- In the greenhouse there are cultivations of different types: tomatoes, peppers, turnips, aubergines, aromatic herbs, lavender, edible flowers, cardiospermum seeds (which are used as a “natural” cortisone).

There is an area that is used as a nursery in spring, with aromatic herbs. The area with raised pallet is used to avoid damage caused by moles/voles that usually "attack" plants such as carrots / potatoes.

The greenhouse is asymmetrical because it is built on uneven ground. The farmer decides where to sow the different crops considering this characteristic:

- In the part where the ground has been moved (harder, placed on the right side looking from the entrance of the greenhouse), plants with a lower vertical development grow;
- In the part where the ground has been reported (softer, located on left part looking from the entrance of the greenhouse), there are plants with taller vertical development (e.g., tomatoes).

However, every year crops are shifted in fields. Only plants that grow better in the shady area of the greenhouse are not: here spinach and chard are always grown.

In winter, the greenhouse is not used (the farmer does not use heating so he cannot anticipate summer crops production). Crops are grown in autumn until they produce. A simple cover, when the plant is already riped, allows to lengthen the harvesting period. The plants are then reseeded again in spring. Typically, the nursery area starts working at the beginning of April. The ground plants area starts around the 20th of April. To conclude, the greenhouse cultivation season starts around mid-April because the risk of frost is higher before.

The watering in the greenhouse is supported by a ground drip irrigation system. Each pallet has a tap from which water coming from the pond exits. Perforated pipes placed on the ground are filled with water and when a certain pressure has been reached, water begins to irrigate the soil upper level (there is no deep penetration of water into the soil).

With this kind of irrigation system plants leaves are not watered, so there is no need to apply chemical treatments to prevent diseases related to wet leaves and afflicting vegetables like tomatoes, peppers and cucumbers.

The estimation of humidity level in the greenhouse is another key point related to wet leaves. It must be controlled in order to avoid previously cited problems (partly solvable by the use of mineral substances, e.g. zeolites). For leafy vegetables, sprinklers based irrigation would be more indicated, even at relatively low height (15/20 cm).

The greenhouse opening and closure are "manual."

- According to the season and based on his personal experience, the farmer decides when to open/close the greenhouse, trying to balance humidity inside it (too much can lead to diseases) and heat necessary to grow plants.
- The mechanical system that manages the opening/closing operations can be made automatic: the greenhouse model is the basic one, but if desired it can be improved with any other control/implementation features.

It might be useful to understand the right moment to open / close according to the greenhouse humidity (e.g., using a humidity sensor) and communicate it to the farmer using some technology, in order to automate the operation (e.g. using a Smartphone notification).

A useful technology that the farmer would buy may be something with which to do soil analysis. Currently, analyses are done on ground samples by expensive laboratories and only return average values between the various samples.

In the farm greenhouse, sensors can be installed in the ground (in the pallet areas) without problems because the soil is soft. Battery powered sensor may be the better choice (e.g. powered by a solar panel) in order to not overload the greenhouse electric line (which is shared with the farmer house).

Manual opening of the greenhouse:

- During spring and autumn, the greenhouse is opened after 8 am and is closed at most at 5 pm, depending on the weather conditions (mainly taking into account the level of humidity inside the greenhouse).
- During summer, starting from the end of June, the greenhouse is always open.

The greenhouse (both walls and roof) is made of two tiers of plastic sheets. The two sheets are separated with air pumped in to create an insulation tier. The power grid of the greenhouse is connected to the one of the houses of the farmer, thus it is better to deploy technologies with low impact on the energy consumption to avoid overload of the electrical system. However, the farmer is available to improve the system by increasing the available power.

Other application can be the use of a spectral camera to monitor photosynthesis status, detect diseases, luminescence. In the past the farmer monitored the mass of compost to test if it was useful to keep the ground temperature above zero and avoiding freezing the ground.

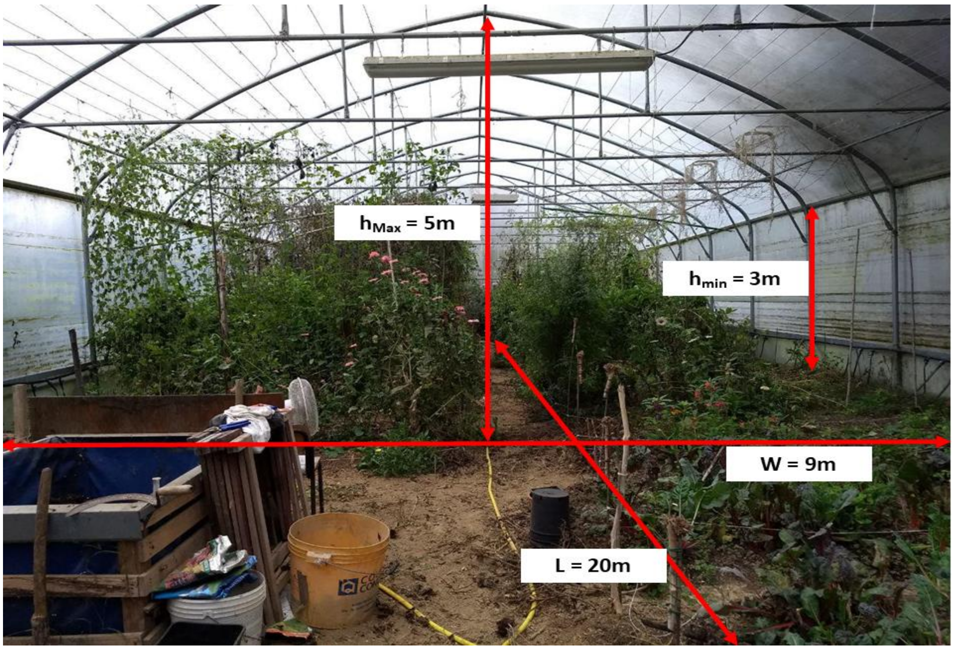


Figure 29 – Photo of the greenhouse

Available Tractors

The farm has two tractors (shown in **¡Error! No se encuentra el origen de la referencia.**) and several tools:

1. FIAT 555C, a crawler tractor
2. Renault 80.14, with the possibility to add a ploughing machine
3. harrow,
4. spray dryer,
5. forklift,
6. vertical pruner,
7. seeder.

Figure 30 – Photo of a) Photo of Fiat 555C b) Renault 80.14 tractor (front) c) (rear)

3.5.6.2. Needed infrastructure for the demonstrator

In order to test systems and applications of AFarCloud Project, the 220 V AC. must be available in the Greenhouse, as well as the connectivity that can be provided both locally and to the internet by AFarCloud partners (Ro Technology, UNIPR, UNIVAQ and ESTE), and eventually a link with WI-FI to the farmers headquarter or house, in order to monitor AFarCloud sensors and actuators.

To actuate the automatic rooftop automation, an electrical motor to inflate air in the rooftop and out of it must be provided by the farmer.

In order to actuate the automatic irrigation system also a new plant to this functionality must be installed, with different sections (non automatic, automatic, and automatic with water treatment (by ARCHA), in order to test both benefits of automatic irrigation and benefits of water treatment.

In the area where automatic irrigation valves are controlled (by ESTE actuator) also the 220 VA.C. must be present.

3.5.6.3. Logistics

Podere Campaz is in an agricultural area with planes and small hills near Faenza City in the Emilia Romagna Region.

Figure 31 – Aerial view of the farm

Podere Campaz is very easy to reach due to the A14 Highway that in less than 1 hour drive allows to arrive in Podere Campaz from the Bologna Airport for people that need to come from EU or from a far location in Italy (Like ST Microelectronics coming from Sicily from Catania Airport).

Bologna Airport offers lots of international flights and it is served both by low cost airlines (Ryanair, Easyjet....) and by Air France, Lufthansa Group, Austrian, British Airways, Lot, Scandinavian Airlines etc..... From Faenza city Centre to Podere Campaz there are only 13 km.

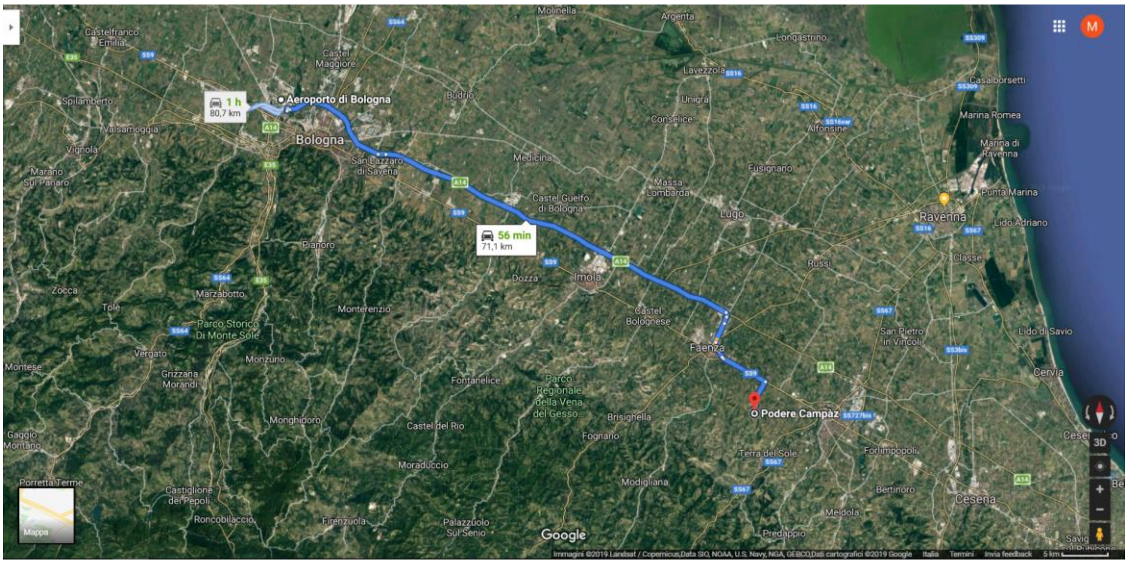


Figure 32 – Map of main road to Podere Campaz

For AFarCloud People it will be also easy to stay in the vicinities due to the near city of Faenza (famous for ceramics, where CNR has an Institute where a meeting or a small conference during the demo days can be also organized. In the figure below an image of the ISTEC Institute of CNR in Faenza is shown. The Institute is 3 km far from the A14 Highway.

Figure 33 – Main building ISTEC in Faenza

In Faenza there are a lot of convenient hotels very near to the highway. In the image below a brief summary of the best hotels that can be found from the Faena city to the Highway is displayed. 39 hotels are available in Faenza at very affordable price. The only condition is to reserve rooms and plan meetings when there is not any big fair in the near Bologna city because during these periods the hotel rate can be five times higher than the normal rate.

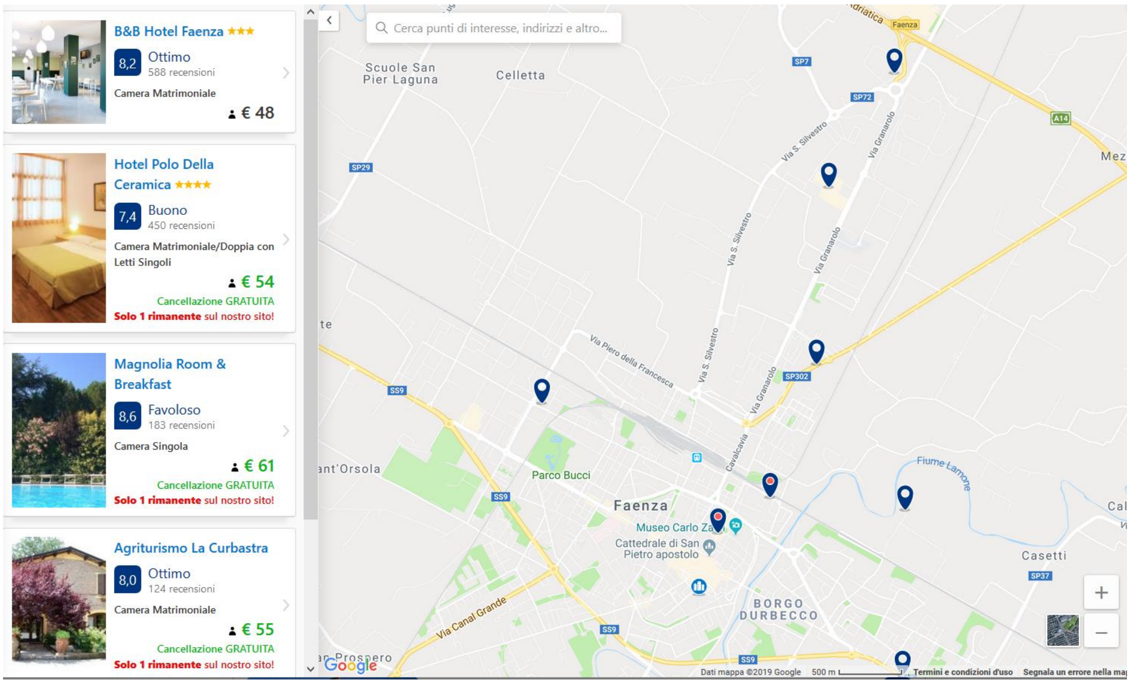


Figure 34 - Image from site "Booking.com" for some hotel near the highway in Faenza with the price for one night rooms.

3.6. AS06

3.6.1. Farm Introduction

In EU-28 there are more than 180M of ruminants. On average a ruminant has a need of grazing surface of 0.66ha, so approximately there are 120ha devoted to grazing. Due to higher consumer demand, land intensification is happening. Grazing improves production, environment and biodiversity. Grazing management systems can maximize livestock production. Through grazing, livestock encourages plant growth, consequently increasing forage production. Grazing also helps to promote the growth of native plants and grasses. Furthermore, the animal's urine and faeces, recycle nitrogen, phosphorus, potassium and other plant nutrients, that return to the soil, to become prosperous and capable for production and stimulating the growth of plant varieties. Additionally, management in many parks makes use of grazing to help lower fire hazards by reducing the amount of potential fuel, such as large build-ups of forage. Grazing management has two overall goals: maintain the sustainability of the pasturage and protect animals' welfare.

However, there are several difficulties in order to use grazing such as: difficulty to control rations and optimize grassland utilization, unstable weather conditions, labour efficiency, etc.

To date, the only major livestock farming technology on extensive ruminant production is electronic identification. However, managing animals on rangeland requires automatic recording of grazing behaviour and other animal parameters. Rangeland livestock farming solutions have potential impact improving animal welfare by ensuring freedom from hunger and thirst, freedom from pain, injury or disease, freedom from discomfort and freedom from fear and distress and freedom to express normal behaviour.

Sensowave developed a smart collar with GNNS, motion and temperature sensors that allows animal monitoring in livestock farms. This first device was validated in the livestock farm owned by the family Blanco, managed by the father with the help of his sons in Ávila, Spain. They have 2 breeder livestock farms for beef production, with a total of around 180 animals including suckling cows and calves, and covering a total area of 1.100ha. The cows and their calves graze for 3-4 months and are fed by dispersing feed in open fields by using tractors with trailers.

The farm of Mediana is the one that will be used to house the demonstrator AS06. The farm consists of 4 separate areas between which the animals rotate in order to try to take better advantage of the grass resources available:

- zone1: cows without their calf: There is an average of 30 cows and one bull. Grazing is not enough sometimes and the animals are complemented with feed.
- zone2: cows with their calves. There is an average of 30 cows and 2 bulls. The cows have grass and it is not necessary to supplement with feed.
- zone3: heifers, animals waiting to have their first pregnancy and calving. There is an average of 40 females and a bull.
- zone 4: separated from the rest, it includes an area of 35ha with the best pastures where cows are taken with their calves to graze for several weeks in order that the calves grow fat and directly from there they are sold.

The climatology of the zone is cold in winter and hot in summer, and the rainfalls are scarce. Therefore, in summer some water is necessary to fill water dispensers due to droughts in the area. Ensuring access to food and water has a high cost in Ávila and other areas of the Mediterranean area where livestock farms are not too profitable, being the economic viability still closely linked to the support of regional programs and direct payments from EU.

Figure 35 – Google map of AS06 in Mediana (Ávila, Castilla León, Spain)

There are three factors to make this change:

- Labour costs reduction, through a Farm management system accessible for farmers with tools such as Precision Livestock Farming (PLF) avoiding waste of time and fuel trying to locate cattle.
- Reducing animal losses, through early detection algorithms for diseases and aspects related to animal behaviour and the physical environment.
- Increase farm's productivity (fertility) by increasing in heat detection and calving rates

Grazing is the easiest way to reduce costs, but it is challenging for farmers, mainly because of the lack of tools to help them measuring available herbage mass and grass intake. On the other hand, grazing currently has a main disadvantage, animal losses during the grazing period. Not having located or monitored the animal for months, makes it impossible to take preventive actions that mitigate the effects of possible diseases, attacks or lack of adequate nutrition.

IoT and machine learning can offer a breakthrough solution especially to the extensive livestock farmers. Wearables for animals including sensors combined with GNSS technology can provide tracking information related to animal behaviour. Monitoring behaviour is relevant for detection of cow fertility or illness. It is also important for providing information on pasture use density and to manage fields accordingly to the information recorded previously.

3.6.2. KPIs (benefits)

Five of the main impacts and benefits from the project are (DoW, 1.1.4):

1. KPI7: 10% reduction of animal losses due to increased health.
2. KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock.
3. KPI9: 80% reduction fuel and time spent when looking for missing animals as well as particulate emission for agricultural machinery.
4. KPI10: Up to 10% feed costs

Table 12 – AS06 KPIs

<table>
<tr><th>KPI7: Up to 10% reduction of animal losses due to increased health (High priority)</th></tr>
<tr><td>In 2014, the casualty rate in the 2 farms of the Blanco family was 10%. It means, a 10% of the total herd died at the end of the season (18 animals). The causes of these casualties were varied:
Dehydration: especially important in younger calves during summer. Just in the summer of 2014, 10 animals died due to dehydration.
Diseases: that occur during the months of grazing and that due to the lack of monitoring and early attention can lead to serious diseases that cause the death of the animal.
Calving: animals that are left alone during the months of pasture without attention are more exposed to complications that can cause the mother to lose her calf.
Hunting: hunters sometimes shoot animals accidentally.
Predators: the area suffers the attack of a wolf.
Since the first animals on the farm were monitored in 2015, the loss rate has been reduced by 40%, monitoring approximately 20% of the animals. The goal within the AFarCloud project is to reduce an additional 10% the loss rate to reach a 50% reduction compared to the initial situation in 2014. This would mean a saving of more than 10.000€ per year.</td></tr>
<tr><th>KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock (High priority)</th></tr>
<tr><td>The veterinarian goes to the farm mainly for two reasons: diseases and monitoring & confirmation of pregnancies. These costs also include treatments prescribed by the veterinarian. In 2014 these costs amounted to a total of 2.450€ euros. A reduction of 80% would mean another 2.000€ savings.</td></tr>
<tr><th>KPI9: 90% reduction fuel and time spent when looking for missing animals (High priority)</th></tr>
<tr><td>The estimated fuel cost looking for missing animals was 1,500€ in 2014 It has to be taken into account that the Blanco family has its home in Ávila, and that there are 20 km to each of the two</td></tr>
</table>

farms. Once there, they had to travel several km looking for the groups of animals on steep terrain, where fuel consumption soars. The reduction in fuel when all the animals are monitored will be produced by two facts; • It is only necessary to move when any anomaly or event is notified. • The farmer moves directly to the place where the animal is located. In this way, fuel savings and other expenses associated with the vehicle would be considerably reduced, reaching 90%.
KPI10: Up to 10% saving in feed costs *(Medium priority)*
Feeding is the main cost of a livestock farm, being the average annual cost per animal of approximately 150€. Achieving better measures of grazing behaviour that lead to important savings. E.g. a 10% saving in feed costs means 15€/year per animal and seems realistic by providing farmers with a tool to monitor livestock animals grazing behaviour. In a farm with 180 animals it might save 2.700€.

3.6.3. Descriptions of goals and functionalities

AS06 aims to provide solutions for G5: Improving the quality and the productivity with respect to the animals' well-fare and meet quality.

3.6.3.1. G5: Improving the quality and the productivity with respect to the animals' well-fare, and meet quality

This is a very wide goal, aiming at different aspects in the farm. In order to achieve this goal, the demonstrator will implement the following functionalities:

- F8: Outdoor livestock location tracking
- F9: Detection of livestock heat
- F10: Detection of livestock calving
- F11: Detection of livestock rumination and eating
- F13: Inference of the livestock habits patterns for health and reproduction

To start with, the most basic functionality is F9, i.e. to have the animals located 24h/365 days. This will significantly reduce animal losses, especially in grazing farms. In order to increase the number of calves that are born, it is necessary to detect the estrous periods of the suckler cows and the moments before the calving, avoiding complications that can lead to fatal consequences (F9, F10). Animals spend most of the day grazing, chewing and ruminating. F11 will generate the nutritional patterns (calves gain weight every day). Finally, F13 is the tool that integrates all the previous functionalities and allows detecting any anomaly that has to do with the animal's health through the interruption of patterns. In this way, caring for the animal also means improving the productivity of the livestock farm.

At a high-level, these functionalities will work as follows:

F8: Outdoor livestock location tracking

Each animal carries several sensors that allow location, surface temperature and activity monitoring capabilities in order to monitor and locate cattle individually.

The collar has IP65 protection in order to operate in adverse weather conditions, and it does not interfere with the animal´s daily routines.

The collars collect information from sensors, processing it using a microcontroller and send the information by using the communication module to cloud servers. They also contain a high capacity battery that combined with a software power saving mechanism, ensures a battery life over a year. It comes with all the elements for installation on animals.

To send information from collars to the server we have adopted SIGFOX communication network. SIGFOX uses a UNB (Ultra Narrow Band) based radio technology to connect devices to its global network. The network operates in the globally available ISM bands (license-free frequency bands) and co-exists in these frequencies with other radio technologies, but without any risk of collisions or capacity problems. SIGFOX currently uses the most popular European ISM band on 868MHz (as defined by the European Telecommunications Standards Institute, ETSI; and European Conference of Postal and Telecommunications, CEPT) as well as the 902MHz in the USA (as defined by the Federal Communications Commission, FCC), depending on specific regional regulations.

Sensowave will use AFarCloud technologies. An API will be created to communicate with the AFarCloud platform. The cloud server will collect information from all the collars and process it in order to compute the animal location. The farmer through an app will be able to decide the secure areas in the farm and if an anomaly is detected, the app will automatically notify the farmer via mobile phone, tablet, and/or computer.

F9: Detection of livestock heat and
F10: Detection of livestock calving

The functionality will be based on the same collar. The algorithms will compute animal location and activity.

The information will be stored in different types of databases which will be used by several Big Data algorithms in order to determine patterns. These algorithms will analyze data individually, data from the herd and data entered manually by the farmer (last heat date or calving date) in order to detect heat and calving. The farmer will be able to enter data from the animal through an app in the AFarCloud and Sensowave will provide the notification through the API. The AFC visualisation tool will identify animals in heat from the list of animals in the farm or listing the animals in heat as part of the dashboard.

F11: Detection of livestock rumination and eating

A new device will be used for local storage, in order to allow training data labelling of rumination and eating. Later an on-board analytics library will be developed and its integration with Sensowave's collar will be evaluated.

F13: Inference of the livestock habits patterns for health and reproduction

IMAG will develop a device On-collar MCU with local storage. The training data will be time-code synced with video footage Post-capture visualization, in order to allow training data labelling of rumination and eating. Later an on-board analytics library will be developed and its integration with Sensowave's collar will be evaluated.

Once heat, calving, rumination and eating are validated, animals will be more characterized in their daily routines. F13 will take advantage of these data and will generate notifications if the previous patters are broken.

3.6.4. Legal and Safety, Healthy, Environment (HSE) considerations

All the operations with the animals will be carried out by one of the members of the Blanco family, owners of the livestock.

It is possible to make drone flights on the farm as long as you keep direct contact with the drone, the flight is done during the day, and the weight of the drone is less than 20kg.

3.6.5. Infrastructure and logistics considerations

3.6.5.1. Existing infrastructure

Power supply: There is the possibility of using a petrol generator.

Connectivity: There is GSM and Sigfox coverage.

Collars: 58 cows are currently being monitored and providing data regarding activity, location and surface temperature.

3.6.5.2. Needed infrastructure for the demonstrator

There are enough resources for the activities that are going to be done: drone flights and testing collars from Sensowave and IMAG.

3.6.5.3. Logistics

Contact person: Carlos Callejero, confirm dates for deployment at least 2 weeks in advance.

Location: Mediana de Voltoya, Ávila, Castilla León, Spain. The village is accessed from the N-501 national road or from the AP-51 and is 13 km from Ávila and 97 km from Madrid.

Accommodation

There are 3 rural cottages in Mediana de Voltoya with capacity for up to 16 people. Complete rooms, fully equipped kitchen but Avila is just at 5 minutes distance and Madrid airport at 1h and 20 minutes distance.

There are a couple of kilometers from the village to the farm. It is recommended to rent an SUV or 4x4 vehicle, otherwise the transfer will be organized with the Blanco family from Mediana de Voltoya

3.7. AS07

3.7.1. Farm Introduction

The IAS (Institute of Animal Science) is an experimental centre of research into the biological and bio-technological basis of animal science, with a dairy farm with 250 dairy cows, free-stall housing, located near the Institute. For the AFarCloud purposes 4 cows have been equipped with ruminal fistula to provide the *in vivo* environment for the tool development to measure real-time ruminal milieu parameters.

Main benefits of the project would be:

- Development of a new efficient tool for continuous ruminal health monitoring enabling an early detection of nutritional and health issues
- Incorporation of information received from the technology in the farm software
- Interpretation of data in context of info from the other measuring systems (activity of cows, rumination, feeding behaviour, milking parlour)

3.7.2. KPIs (benefits)

Table 13 – AS07 KPIs

KPI7: Up to 10% reduction of animal losses due to increased health
High-producing dairy cows synthetize large volume of milk early after the calving. Consequently, they have high dietary energy requirements. Therefore, diets with higher proportion of concentrate as a source of starch are provided. Starch and sugars support the growth of lactic acid bacteria. When pH of ruminal milieu drops, ruminal microbiota becomes dysbalanced and subacute ruminal acidosis (SARA) occurs. This may lead to reduced feed intake and associated diseases such as ketosis and eventual fatty liver syndrome as well as to hoof corium inflammation due to bacterial endotoxins resulting in lameness. All these disorders may lead to eventual culling of the cow. Early detection of prolonged periods with low ruminal pH will indicate the need of treatment, management measures and dietary changes. Thus, premature culling may be prevented. A precursor for milk fat is acetic acid which is produced in the rumen by fibrolytic bacteria. These microorganisms are pH sensitive and stop growing when pH drops. That is why SARA reduces dietary fibre degradation and thereby causes milk fat content reduction.

Early detection of prolonged periods with low ruminal pH will indicate the need of treatment, management measures and dietary changes. Thus, ruminal pH will be stabilized fibrolytic microflora supported and milk fat increased.
KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock
SARA causes ruminal dysfunction, drop in feed intake and deepens negative energy balance. This may lead to ketosis, immune suppression and poor health. Also, endotoxins dysbalanced ruminal microbiota affect hoof corium leading to inflammation (laminitis) and other hoof diseases, all requiring veterinary treatment. Early detection of prolonged periods with low ruminal pH will indicate the need of treatment, management measures and dietary changes. Thus, consequences of reduced feed intake, impaired health status and high veterinary costs will be mitigated.

3.7.3. Descriptions of goals and functionalities

AS07 goals are:

- Goal 2: Improve harvesting;
- Goal 5: Improving the quality and the productivity with respect to the animals´ welfare, and meat/milk quality.

3.7.3.1. G2: Improve harvesting

To achieve this goal, we will use the functionality:

F14: Measure field water content/vigour:

Fodder growing (as well as in the cultivation of grain) has importance in each stage of plant development - soil moisture and temperature. For example determining the actual soil temperature, which ensures the intake of nutrients by the roots of the plant

The measured values are transmitted and stored in the Senslog database via the IoT network

Main steps:

1. select the required sensors from Commercial off the shelf (COTS)
2. selection of optimal IoT network
3. installation of IoT node (AgroNode) with required sensors
4. configuration in IoT network
5. setting the appropriate data model for SensLog
6. setting of the visualization module IVIS

7. setting of the 2D visualization (isolines)

3.7.3.2. G5: Improving the quality and the productivity with respect to the animals´ welfare, and meat/milk quality.

G5 will be achieved through the implementation of the following functionalities:

- F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.
- F27: Detection of livestock digestion.

F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.

Monitoring of environmental values is divided into 2 areas. The first one is stable environment (welfare of animals) and monitoring of surrounding environment i.e. climate conditions.

We develop and use the IoT such as Indoor Air Quality(IAQ) and Outdoor Air Quality devices installed in indoors and outdoors to measure the environmental information related to the air quality. Then the cloud server will store, manage, and analyze the environmental data collected by IoT devices.

HVAC system (Heating, ventilation and air conditioning) is of interest for many years and most of innovative technological trends in microelectronics and communications are addressing such systems.

Despite the fact that the current stables are equipped with air conditioning with a different level of automation, installation of an independent monitoring system will allow to get current temperature, humidity, CO2 and air information independently of installed systems.

Each place we want to monitor must be equipped with the appropriate sensor, which is connected to the application server using low-energy LoRAWAN network elements. With the use of wireless sensors, no cables are needed. Sensors have very low power consumption and can last for several months to years depending on the frequency of the messages being sent.

F27: Livestock digestion monitoring

Livestock farming in the Czech Republic is based mainly on large-scale operations. Although being to a certain extent supported by direct payments from the EU and national subsidies, the farmers face economic constraints. Therefore, cost-efficiency is the key. Large dairy herds (around 500 cows) are typical for CZ. The demonstrator focuses on the following technologies for production and health monitoring to reduce cost and improve efficiency:

- Development of a new efficient tool for continuous ruminal health monitoring enabling an early detection of nutritional and health issues
- Incorporation of information received from the technology in the farm software

- Interpretation of data in context of info from the other measuring systems (activity of cows, rumination, feeding behaviour, milking parlour, environmental systems)

The expected benefits are:

- Improvement of feed efficiency, reduced feed costs
- Improved health, reduced veterinary costs
- Increased longevity of cows
- Improved animal welfare

The indwelling ruminal probe will monitor important rumen indicators that are reasonable from technical and economical point of view. At the time has been agreed temperature and pH. ORP has been proposed of lower importance and concentrations of acetic and propionic acids are hard to measure with reasonable economic and energy budget.

In year 1 the probe hardware as well as the hardware of the collar retransmitter are not ready. Therefore, the demonstrator will provide simulated data source – a deprecated ruminal probe will emit simulated data. All the rest of the processing chain will work as expected in the final solution. The ground station will collect the simulated ruminal data (RF custom protocol at 433 MHz) and forward them to the cloud via the IoT network using SENSOB protocol to the SensLog application. SensLog stores data in the relational database and provides system of webservices to publish data for further processing. Later on, the users can invoke the collected data, analyse and present them in a user friendly way. For year 1, we plan web-based visualization of time series of data with the ability to arbitrarily zoom in/out in the data and to visually compare data of from different sources and from different time-periods.

3.7.4. Legal and Safety, Healthy, Environment (HSE) considerations

Animal experiments will be conducted in accordance with an experimental project approved by the Ethics Committee and the Ministry of Agriculture of the Czech Republic.

3.7.5. Infrastructure and logistics considerations

3.7.5.1. Existing infrastructure

The Participant IAS (Institute of Animal Science) will contribute to sensor specifications, testing of sensors provided by the partner UWB for livestock health monitoring in dairy cows trial (in the barn) will contribute to overall architecture specification namely from the livestock point of view.

IAS is a centre of research into the biological and bio-technological basis of animal science.

IAS carries out basic and applied research focusing on innovation and the practical use of knowledge in animal science. Nine research departments investigate animal genetics and breeding, bio-technology and reproduction, nutrition, quality of products, animal ethology and welfare, breeding technology, herd management and production economy. We work mainly with dairy and beef cattle, pigs, poultry, rabbits, deer, horses, sheep and goats.

The experimental base, which provides conditions and facilities mainly for research activities of the Institute departments, consists of 23 buildings in Uhříněves, Netluky, Královice and Kostelec nad Orlicí. In addition to providing experimental facilities, the farmstead enables the Institute to test technologies and apply research findings in practice and to demonstrate them for the education and awareness raising purposes of the farming and consulting community. On the basis of cooperation with the Czech University of Life Sciences Prague, students come for internship and specialised training. These locations also organize field trips for primary and secondary schools and specialised training courses for livestock hauliers.

In addition to basic and applied research, IAS carries out other expert activities. One of the most significant is the implementation of the National Programme for Conservation and Utilization of Farm Animal Genetic Resources, where the Institute is an expert reference, coordinator and administrator and also takes care of the related international agenda. The Institute also provides for the activity of the Scientific Board for Animal Nutrition, and has been entrusted by the Ministry of Agriculture to represent the Czech Republic in the European Federation of Animal Science (EAAP).

Research institute IAS (Prague, Czech Republic) has its own comprehensive experimental base and a farmstead and almost 800 hectares of farmland. Currently the farm has: cattle 654 (215 dairy cows), pigs 818 (54 sow), deers 54, and horses 14.

Besides a number of experimental options there is an experimental barn for dairy cows fed from tensiometer cattle-bins of Roughage Intake Control System, feed mill, experimental slaughterhouse, swine AI centre, cryobank.

Figure 36 – Experimental farm of IAS, Czech Republic

Software on our IAS farm/facility/Equipment

- laboratory facilities for feed analysis
- facilities for in vivo, in vitro and in sacco digestibility experiments
- facility for cannulated animals (dairy cows) for the experimental purpose
- tensiometer cattle-bins of Roughage Intake Control System (Feed Control System), milking house, pedometers, etc.
- software of IAS experimental farm: AFIFARM (SW for herd management and parlour and for pedometers (motion activity measurement); SW FARMSOFT (rumination sensors); SW of company INSENTEC for electronic control feed trough (each milking cow has chip and is monitored/ checked for the amount of feed received on the base of dairy yield and monitored for the meal time intervals).
    - Afifarm program – without this program it is not possible to work with this dataset. But the only possibility how to download the data without Afifarm is save them as several .txt or Excel files (not as a whole dataset). We can copy all data from the farm and work with them - including reproduction data, health, treatments, etc. It works through the cows coming twice a day in the milking parlor where they are identified by their foot pedometers, and milk components, somatic cells, weight of the cow and eventually reproductive (heat) activity are measured and data stored in farm computer. The farmer works with the Afifarm program according to actual needs of the herd(s).
    - Farmsoft program - Farmsoft records the time of feeding and rumination (in minutes) + their deviations and physical activity = vitality. There is a possibility of using it as the above-mentioned Afifarm. It reports deviations in vitality, feeding and chewing. But there we have no possibility to interconnect these two licensed programs (Afifarm and Farmsoft) although for the successful herd management it would be very useful to interlink information from both the softwares.

3.7.5.2. Needed infrastructure for the demonstrator

There are enough resources for the activities that are going to be done: development of a new efficient tool for continuous ruminal health monitoring enabling an early detection of nutritional and health issues.

3.7.5.3. Logistics

Contact person: Veronika Koukolová: vkoukolova@seznam.cz % Dana Kumprechtová: kumprechtovad@seznam.cz

3.8. AS08

3.8.1. Farm Introduction

Testing facility willl be a milk production farm: Robežnieki farm located in Sēja parish Latvia. The same farm is used for AS02 for harvesting demonstration, with main features concerning AS08 demonstration.

- Full cycle of milk production (see Fig.33)
- cows in production 250;
- Cows not going outside for grazing
- Already robotized are both milking (use of Lely Astronout AS4 milking robot) and removal of barn manure.

Figure 37 – View inside the barn

Testing facility willl be, a milk production farm Robežnieki farm located in Sēja parish Latvia:

- Full cycle of milk production (Fig. 33)
- Farm with 250 cows
- Already robotized are both milking (use of Lely Astronout AS4 milking robot) and removal of barn manure.

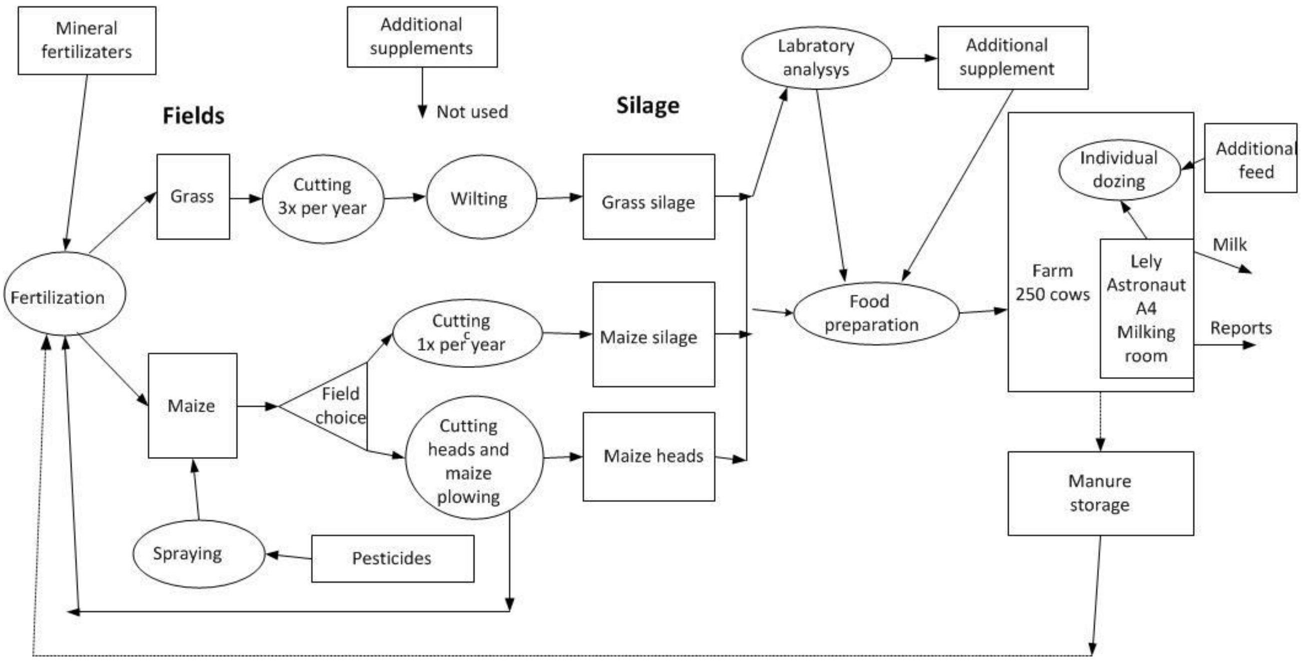


Figure 38 –Chain of operation (left part of the figure until the barn operations)

In Figure 35, the full cycle of farm operation is shown. AS02 is concerned with left side processes till the barn operations, AS08 is concerned with right side processes:

AS08 should be considered as a continuation to AS02, because demonstration facility is in the same farm. AS08 is an attempt to put this farm in a holistic view, by analyzing outputs of the dairy robotics and finding correlation of those outputs with different aspects of crop (food) preparation (given by the AS02 demonstrator). Additionally, those outputs will be made available for other partners for their tasks. Other task is the fulfillment with the Latvian legislation for animal welfare in barn. In this regard, one aspect was chosen – control of the gases in the barn. Currently the control of gasses in the farm is done by the excessively use of ventilation, without the precise control of the levels. Note that it´s a big challenge to develop on the farm an exact control system of the level of gasses.

3.8.2. KPIs (benefits)

One of the main impacts and benefits from the project are (DoW, 1.1.4):

- 15% reduction of losses due to crop and animal diseases or non-optimal conditions
- KPI7: 10% reduction of animal losses due to increased health.

Table 14 – AS08 KPIs

KPI6: 15% reduction of losses due to crop and animal diseases or non-optimal conditions
Latvia have regulations for animal welfare, which include several factors. One of them regulates the level of gasses in the barn. For now, the level of gasses in the barn is controlled manually through the excessive ventilation of the barn, the exact level of gasses is not measured. KPI6 is planned to achieve by working on improving non-optimal conditions in the barn by fulfilling the animal welfare standards Generally, all the norms combined have to give 15% increase of this KPI. The control of the gases is only of the norms in animal welfare , will be a part of the achievement KPI6, but correct number will be hard to access.
KPI7: 10% reduction of animal losses due to increased health.
In AS08 primary is KPI6 as it is achieved directly by improving non-optimal conditions in the barn by fulfilling the animal welfare standards. KPI7 is a secondary achievement by improving animal health by fulfilling the animal welfare standards

3.8.3. Descriptions of goals and functionalities

AS08 is an attempt to put this farm in a holistic view, by analyzing outputs of the dairy robotics and finding correlation of those outputs with different aspects of crop(food) preparation (given by the AS02 demonstrator). Additionally, those outputs will be made available for other partners for their tasks. The milking process is outside AS08 scope.

The main goals of AS08 are:

- Apply Latvian legislation for animal welfare. Most of that legislation is already applied on the farm. An important challenge, in this regard is monitoring the level of the gases (**F26**) for achieving **G6: Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality**
- Provide the data from the milking robot for analysis for other partners (**F32**):
  - Provide data for the AS02 for further analysis, with respect to **Goal 2: Improving harvesting;**
  - Polish partner (DAC) aims to integrate using farm data sources (on-farm measurement devices and systems). Data from these sources will be used in two use cases: *environmental footprint of dairy products* and *animal welfare/milk quality*.

3.8.3.1. G2: Improving harvesting

In the AS08 (using the functionality **F26: Extract and analyse data from milking robots)** data will be collected, but the analysis will be done in AS02 to connect milk quality results with planned activities in AS02 for enhancing the food quality.

AS08 will also work with AS02 to help the implementation of the functionality **F3: Monitor cereals Nutrients (energy, protein and humidity analysis)** by giving the necessary data to be analyse on AS02.

3.8.3.2. G5: Improving the quality and the productivity with respect to the animals' well-fare and milk quality

G5 is achieved by enhancing animal well-fare by using functions:

- F21: Monitor gases
- F26: Extract and analyse data from milking robots

F26 Extract and analyse data from milking robots

Milking is done with the commercial assistance from Lely Astronout A4 milking robot which also includes professional services (veterinary, laboratory). This is a well-established process and outside the scope of this demonstration. The goal is to use the data from this milking process to improve other processes.

On the AS08 with the F32 functionality (extract data from milking robot) the analysis will be done to connect milk quality results with planned activities in AS02 for enhancing the food quality.

Polish partner (DAC) aims to integrate using farm data sources (on-farm measurement devices and systems). Data from these sources will be used in two use cases: *environmental footprint of dairy products* and *animal welfare/milk quality*.

The drawback is that the data is propriety and that can add problems for extraction.

F21 monitoring gases

Latvian animal welfare standards, with respect to keeping an animal in the barn, are essential. Despite high level automation solutions for milk production being currently available in the farm Robežnieki, the levels of ammonia (NH3), methane (CH4), and sulphur, containing organic and non-organic gasses (SH- Sulfhydryl) are not under automatic control, so it's a problem to solve: The anaerobic decomposition of organic wastes and manure stored as a slurry or in anaerobic lagoons, produces methane, carbon dioxide, ammonia, and hydrogen sulphide. Hydrogen sulphide released from actual or stored manure into confined spaces can reach lethal concentrations.

Latvian legislation concerning the allowed levels of those gases in the farms is presented on table 7.

Table 15 – Latvian legislation for allowed levels of gases

Gases	Maximal quantity, mg/l	Comments
CO2	3000	
NH3	20	
H2S	0.5	During short periods of maintenance <5

With this fulfillment farm achieves one of the norms of Latvia animal welfare standard, and that is base to keep animal loses low. The sensors will be provided by the Swedish partner Senseair.

3.8.4. Legal and Safety, Healthy, Environment (HSE) considerations

In the farm demonstration will be supervised by farm workers.

3.8.5. Infrastructure and logistics considerations

3.8.5.1. Existing infrastructure

Main infrastructure is already operating, including barn and cows where milking with Astronout A4 is in operation.

GSM is available.

No dedicated Wi-Fi for the AS08 scenario in the farm

3.8.5.2. Needed infrastructure for the demonstrator

Infrastructure to connect retrieved information with the cloud:

- By Sensors measuring gasses (sensors by Senseair)
- Data from Astronout A4

3.8.5.3. Logistics

Farm is 40 km from Riga, biggest city in Latvia, easy accessible by motorway.

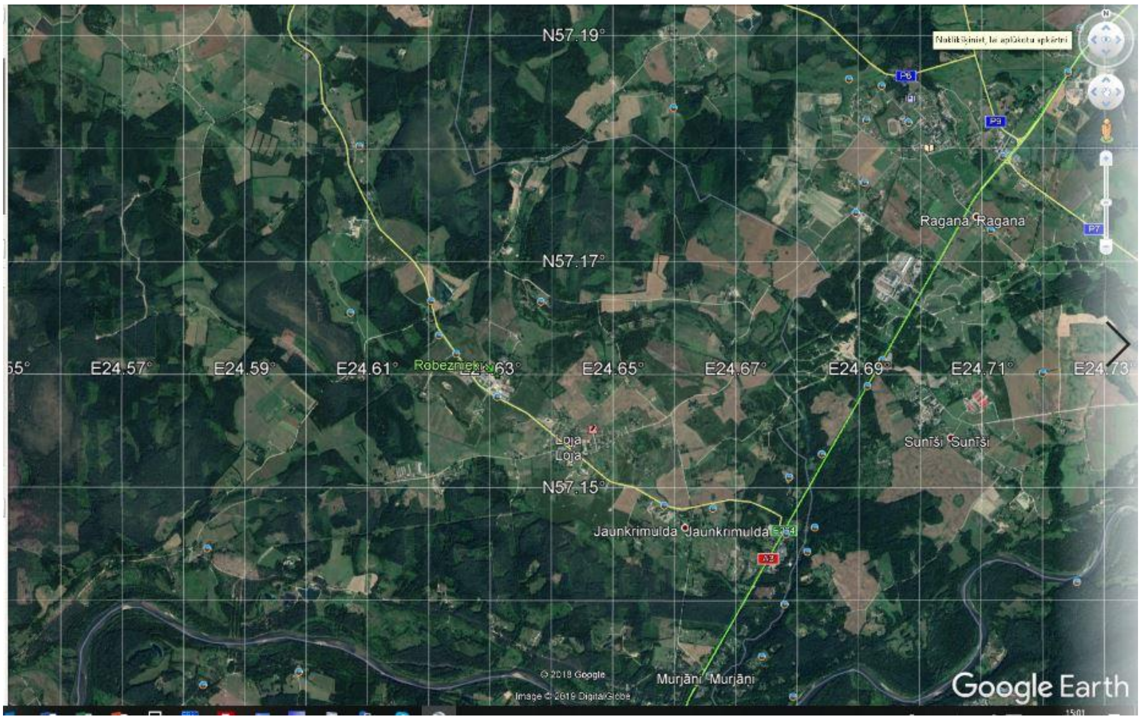


Figure 39 – Location farm in Loja regarding motorway A3

3.9. AS09

3.9.1. Farm Introduction

Objective of this chapter is to describe the status of Finnish local AFarCloud demonstration AS09. Thus, the main emphasis is not in the holistic Y1 activity, although all of the following activities will be demonstrated in Y1 holistic demonstration in their maturity level. However, this chapter describes the AS09 activity in 3-year time span until to the end of the project, presenting the core activities and KPIs under the scope.

During the last decades, dairy farming has been experiencing the major change. Until the 1950´s, the farms were relatively small, having only about 10 cows, using summer grazing in large extent and doing a lot of manual work from milking by hands to ploughing with a horse. Most of the fields were growing dried hay, which was then cut, dried in sun, stored and fed to the animals during the winter.

On the contrary, the modern trends have steered the farms to much more concentrated and automated approach. The major factors for new farms are as follows:

- the number of farms has reduced significantly
- the existing farms get bigger in terms of:
    - from some cows to >100 cows
    - from small to highly increased field areas to feed the animals
    - from grazing to indoor free stall barns, where animals can walk freely

All this has changed the whole concept of farming. While in the old times, the farmer had a relationship with every cow, the modern dairy farming with hundreds of animals and large cultivation areas needs to be based on other kind of awareness. There is a lot of tacit knowledge that must be changed to modern, intelligent functionality controlled by automated processes. As a consequence, many new farming methods have emerged:

- from dried hay to acidic silage stored in bails, silos or piles using automated machinery and powerful tractors
- from separated to totally mixed ration (TMR) feeding supported by the dedicated software
- from hand milking via milking machine to highly sophisticated milking robots
- from manual to strongly ICT-based control and management systems

While many problems have been solved with these innovations of industry 2.0 – 3.0 –level, there are still some areas that lack proper control. The most urgent challenges are:

- Harvesting of large grassland areas at optimal time is challenging. During growing, nutritional properties of grass reach the optimal level, and it should be harvested then before it starts to lose its quality. However, in modern farm with large cultivation areas, different fields become ripe at different times. It is challenging to monitor growing and schedule the harvesting optimally.
- TMR feeding is not totally in control in terms of its nutritional properties. The main reason for this is silage, which has significant fluctuation in its key properties due to differences between different fields and growing / harvesting times. This is partly connected to the previous challenge.
- In the other end of the process, it is hard to monitor, how the individual cow eats and how is it doing. Especially, when there are hundreds of cows, which are walking freely and are milked by robots without direct human observation, the identification of particular animal and awareness of its condition is not complete and fast enough. While there are some indicators

provided by automated systems (milking data from the robot, behavioural data from the collar etc.), the problems are identified too late in too many cases.

Kotipelto farm (http://www.kotipelto.fi/en/) is a good example of all abovementioned changes. The farm has been founded 1781, and Marko Sorvisto is the 9th generation in the same family to run the farm. During the years, the farm has been growing in all aspects especially during the last decades.

At the moment, the farm is strongly dedicated in dairy cows. Hosting the young cattle is outsourced to the neighbour farm, and the large amount of field-work is done by local cultivation contractors. That way the number of milking cows is increasing to close to 200, and the deployment of the 3rd milking robot is prepared. The feeding is totally TMR-based ration feeding, and most of the silage is stored in piles in the backyard of the barn.

3.9.2. KPIs (benefits)

The demonstrator should be able to compare with statistics from other years and quantify the change in the end of the project. In Finnish case, some of the measurable KPIs demand slight adjustment in the AFarCloud impact description. In practice, the indicators to be compared are as follows:

Table 16 – AS09 KPIs

KPI10: Up to 10% reduction of feed costs due to efficient nutrition *(High priority)*
• This must be estimated largely against the milk yield. This means annual average production of milk / kg of feed / animal. The result describes the efficiency of the feed. • As the years are not fully comparable in terms of silage quality, this is not 100% reliable, but still gives clear indication, how the efficiency of the production has changed. • This does not take into account the cost factor directly. Real costs for feeding will be recorded, and if needed accuracy can be achieved, also financial calculation will be performed.
KPI6: 15% reduction of losses due to crop and animal diseases or non-optimal conditions *(High priority)*
• In AS09, this means reduction in nutrition-originated illness cases per animal per year. In particular: ○ Too high energy content during the dry period causes several metabolic problems such as milk fever, ketosis, displaced abomasum, retained placenta, metritis etc. As one key reason for calving is to start a new milking cycle, these problems cause excessive medication, which makes milk non-qualified. Moreover, disturbed milking cycle start due to illness causes interference for the whole milking cycle. Reduced milk production for the whole cycle causes clear financial losses.

◦ Imbalanced DM and/or fibre content in TMR causes bloat, acidosis, laminitis for feet, liver abscesses, off-feed etc. Again, medication makes milk non-qualified. Laminitis typically causes lameness, which affects to eating behaviour and food intake and thus decreases the production. ◦ Cows with too low body scoring (malnutrition) have an increased risk for breeding problems ◦ Imbalance in intake of calcium, potassium and certain vitamins cause hypocalcemia, udder edema etc. • Monitored illness types and severity rates must be defined and monitoring method arranged accordingly. Severe cases (veterinary needed) are easy to monitor, lighter cases need new procedures for recording. • Exact calculation of losses is difficult, but amount of disease incidents together with experience-based estimation of cost per incident give satisfactory indication of results.
KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock (Low priority)
• Easy to monitor, although deviations caused by other external factors must be estimated. If possible, detected influences should be calculated out.
KPI2: 15-20% increase on crop productivity due to extended use of sensors and CPS units (Low priority)
• Easy to monitor, although deviations caused by other external factors must be estimated. If possible, detected influences should be calculated out. • As this is closely connected with KPI10, these KPIs will be analysed together with largely same methods.

3.9.3. Descriptions of goals and functionalities

3.9.3.1. G5: Improving the quality and the productivity with respect to the animals' well-fare, and meat/milk quality

- KPI10: Up to 10% reduction of feed costs due to efficient nutrition
- KPI7: 10% reduce animal losses due to increased health
- KPI9: 80% reduction fuel and time spent when looking for missing animals as well as particulate emission for agricultural machinery.
- KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock.

F22: NIR silage analysis

This section explains the technical functionalities involved in Silage nutrition analysis as they are planned to be deployed for first year demonstration. High-level objective is to provide real-time nutrient data for the farmer so, that he can adjust the ration mix recipe accordingly. From many potential parameters, dry matter (DM) and protein content has been selected as most essential. Protein is connected to the silage overall quality (strong link to F28), and DM is also affected by the moisture caused by the storing in outdoor environment (melting snow, rainfall etc.). From these reasons, silage quality can fluctuate remarkably day by day. As the advantage of TMR feeding is based on highly optimized fodder ration mixed of many components (straw, water, vitamins, cereals etc.), these silage nutrient variables must be provided real-time so, that the farmer can compensate the revealed deviations in the other ingredients.

The nutrition analyser will be a wireless handheld device, mobile phone acts as UI and GW and the data will be processed in the dedicated cloud backend provided by Spectral Engines. In the Y1 version, farmer makes the measurement manually before TMR mixing, and the data is transferred also to the AFarCloud repository. The ultimate target is also to provide the data from AFarCloud repository to the TMR recipe solver SW, but that will be considered during the next versions.

F3: Detection of cereals nutrients composition

As was described in the F3 chapter, nutrient value of silage typically fluctuates. This is strongly connected to the harvesting time. During the growing process, proteins, carbohydrates and other easily indigestible increase until to the certain point of maturity. After that, the level of ADF, NDF and other fibres starts to increase, which drops the percentage of indigestible ingredients. This is monitored and modelled using different variables in different countries. In Finland, D-value is used as a main indicator, having the typical optimum target in 680-700 g/ kg of DM. Nowadays the growing is monitored using laboratory tests, which have several days delay. There is an urgent need for near real-time solution to provide critical parameters for the decision support for the farmer.

The most sophisticated version would be able to monitor the growing process in different fields, and taken the weather forecasts into account, would then provide an estimation of optimal harvest date and the field sector order for the farmer. Then the sensor device would be attached to the drone, which can transport it over the fields along the defined sampling mission.

In this Y1 version, the dedicated hybrid sensor device is constructed, and the main goal is to make measurements in field environment and gather data for the calibration. The optimal shooting distance from the ground is about 50cm, and the shadowing cloth is used in order to block the surrounding sunlight. As the sensor device is composed of several NIR sensors, hyperspectral camera and a light source, gross calculation and data analytic process is needed for the next steps. The first year version is still made of several heavy parts (total weight about 25kg) and it will not yet be power-optimized so that UAV could carry it. That transition is considered during the next years. During Y1, the measurement procedure itself is in the main focus.

The idea is to experiment the device both as handheld use and as clamped to the UGV provided by Probot. The sensor device and its software is developed by VTT, some of its sensors by Spectral Engines and the field work and integration to the Probot vehicle by Centria.

F23: Livestock indoor positioning

This section explains the technical functionalities of cow indoor positioning. Motivation behind is explained shortly by the number of cows. As the transition to hundreds of cows per farm has been rapid, it is often hard to find a particular individual in the free stall barn, where animals walk freely around the large building.

Centria has developed an UWB-based solution for the animal indoor positioning. This Time of Flight (TOF) -based system consists of number of anchor nodes attached to walls and a collar node transmitting the signal. The new version of the measurement method has been developed during Y1, and the new version with dramatically lower power consumption will be presented in the Y1 demonstration.

F24: Livestock identification

This section explains the RFID reading solution for identifying cows in the farm.

When making animal-related sensoring, it is important to identify the animal in unique way. This ID can then be used as crucial metadata to connect the gathered dataset to the right cow. All cows in the demonstration farm have an eTag in their left ear. This passive tag contains ISO 11784 –compliant 64-bit ID, which is accessed at less than 40 cm distance in normal circumstances. This ID allows an open approach for animal identification. Milking robots identify animals using their own standards, but this information is hard to get out from the system real-time.

Centria has constructed RFID antennas in earlier projects, also for farming animals such as cows, fur animals and lambs. The objective is to develop an antenna, which can read the eTag earmark of bypassing cow and provide this information to the system, which records sensor data from the same animal. The plan is to construct some sort of sensor rig to the milking robot, where cow stands stills several minutes, and this RFID antenna is a crucial part of it.

F25: Nutrition monitoring through rumen scanning

In close connection with F3, it is important to have metrics, which can proof the success of feeding. At the same time, knowing the fullness of rumen gives crucial information of cows' well-being and functionality of digestion system for the farmer. Both the long-term practice and veterinary literature know well, that paralumbar fossa area on upper left side of cow reveal the rumen fullness reliably. The upper part of rumen reaches that area so, that more full it is, the more it bloats the area outside. If that triangular area is deep down, the rumen is empty and cow is hungry. That's why this area is also called “hunger groove”. In old times, farmer observed this area cow by cow. Now, when there are hundreds of cows in the barn, automatic implementation is needed. This area can be scanned using various methods, and with the help of advanced data analytics, smart conclusions can be made in reliable way.

As described earlier, milking station is very suitable location for all kinds of cow sensoring, as the animal stays there still for several minutes. The only challenge is to make the installations in so discreet way, that the cows don't recognize them and start to be afraid of them and the whole milking robot. In order to avoid that kind of disturbance to the farm, the system must be carefully designed and tested prior the real installation.

For these reasons, the Y1 demonstration will be detached from the milking station, and the fake surface will be used. That, in turn, allows also more comfortable demonstration of the overall idea in free and clean environment than when attached to the robot in the barn, when few people can actually see it. The ultimate plan is to reach analytic level, where rumen fill can be described with standard 1-5 scoring, and also automatic alarms can be generated, if sudden change over threshold is identified. The coming project years reveal, how close the development approaches these targets. This Y1 version focuses solely on the scanning method itself and the low-level data processing related to it using fake surfaces. Also the collaboration with AFarCloud farm gateway, animal ID metadata and UI creation is considered as much possible.

3.9.4. Legal and Safety, Healthy, Environment (HSE) considerations

Disease risks

It is well known, that travelling between countries increases risks for animal diseases. Finland is one of the cleanest countries in Europe in this respect. As an example, there are only about 10-15 farms annually having Salmonella epidemy, being under 0,5% of all bovine farms. Thus, there is a strong national interest to maintain this good situation. As a result, there are certain regulatory constraints, which must be taken into account when coming to the demo farm. These are:

- Safety quarantine time of 48h between animal contact outside Finland and entering the barn building / animal contact in Finland. To make this clear, as a general rule, spending 48h in Finland prior activity with animals is advised.

- Entering the barn requires protective clothing. Separate, clean clothing is encouraged as well as disinfection of hands. As a general rule, entering the barn requires permission.
- Same rules of quarantine times and sanitization apply also to all HW equipment having contact with animals or brought barn indoors.

Wireless communication

In Kotipelto farm location, normal 3G/4G network is well covered with high-speed data transfer possibilities. Also NB-IoT is provided by 2 operators, but the frequency band might not be the same. NB-IoT users are advised to contact Centria in order to guarantee the functionality beforehand. Same is advised with LoRa, which is provided nationwide by one operator, and the special contract will be arranged. Sigfox doesn't cover the farm area in normal conditions, but in case there is a strong need for a public provision of Sigfox coverage, request is made for the national operator. At the moment, however, the public access cannot be guaranteed.

Even though Finland follows largely normal EU conventions in regulation or radio transmitters, there are certain specific constraints regarding especially the radiated transmission powers (≤100 mW EIRP for 2,4GHz) and use of SIM cards in drones (forbidden in civil use). Partners having own ISM transmissions planned, are advised to contact Centria beforehand in order to guarantee the compatibility in all of its aspects.

Drones and other mobile robots

Drone regulations in Finland are quite liberal compared to many other European countries. There are still some regulatory guidelines that must be respected. When flying the drone in Finland, it is good to start inspecting Droneinfo: https://www.droneinfo.fi/en , where general instructions, restrictions and recommendations are presented.

Some general limits exist, and activity below them doesn't need any specific permission procedures. This free drone activity has the following constraints:

- max. flying altitude 150m
- max. overall weight 24kg in sparsely populated areas (3kg in urban areas)
- activity is only VLOS –based
- drone doesn't fly above a crowd of people. The minimum safe distance is 50 m.

If these constraints have to be exceeded, special permission is required. Partners in this position are advised to be in contact with Centria. According to preparatory studies, the easiest procedure is to make an airspace reservation for the area. Centria will lead these procedures according to the partners' needs.

Insurance for the drone devices themselves is up to each partner. Third party insurance, however, is recommended for liability regarding damages caused for other buildings, vehicles etc. In particular, some payloads by other partners can be quite expensive (i.e. hyperspectral cameras, scanners), and in case of damaging them due to drone failure, aftermath is somewhat easier to solve. Proactive discussions between partners collaborating with drones carrying expensive devices are highly recommended.

3.9.5. Infrastructure and logistics considerations

3.9.5.1. Existing infrastructure

Kotipelto farm is a typical modern Finnish dairy farm, having high level of automation and powerful machinery to perform the duties with a minimal amount of people. The current machinery and automation consist of following items:

Milking robots

- 2 robotized milking stations, both with Lely astronaut A3 with hoof washers

Vehicles

- Massey Ferguson 7480 (200hv) 2012 with a front loader
- Massey Ferguson 7726 (260hv) 2017 with a front loader and power take-off
- John Deere 7290r (330hv) 2013 with a front loader and power take-off
- JCB telehandler 741-70 2013

Field machinery (no ISOBUS)

- Junkkari Maestro 4m seed drill
- Bögballe fertilizer
- Agronic 20m3 3-axis slurry tanker, disc injectors with crab steering
- Another slurry tanker 2016

3.9.5.2. Needed infrastructure for the demonstrator

All of these machines are in a daily use; they cannot be reserved for the research purposes for a long time. On the other hand, the solution needs completely new devices and technologies, which are to be experimented individually without critical dependency or interference to the everyday tasks of the farm. Therefore, the partner needing the aforementioned equipment for their demonstration activities, are advised to contact the demonstration lead Centria to negotiate the suitable arrangement.

In case there is a need for excessive use of certain equipment, i.e. tractor, there is a possibility to borrow / rent a vehicle locally and use that for demonstration purposes. Again, contact from the partner in need is required.

In terms of AS09 as local demonstration, there are no direct needs for supplementary infrastructure. What comes to the holistic demonstration, the general assumption is, that every partner will provide their own infrastructure and informs AS09 leader Centria, if there are specific needs other than electricity etc.

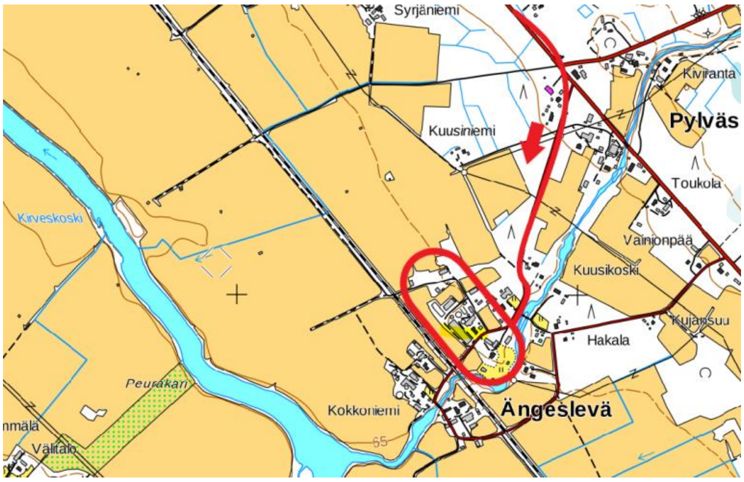


Figure 40 – AS09 location

3.9.5.3. Logistics

Kotipelto farm postal and transportation address: Sari ja Marko Sorvisto, Ängesleväntie 85, 84540 Ylivieska, Finland.

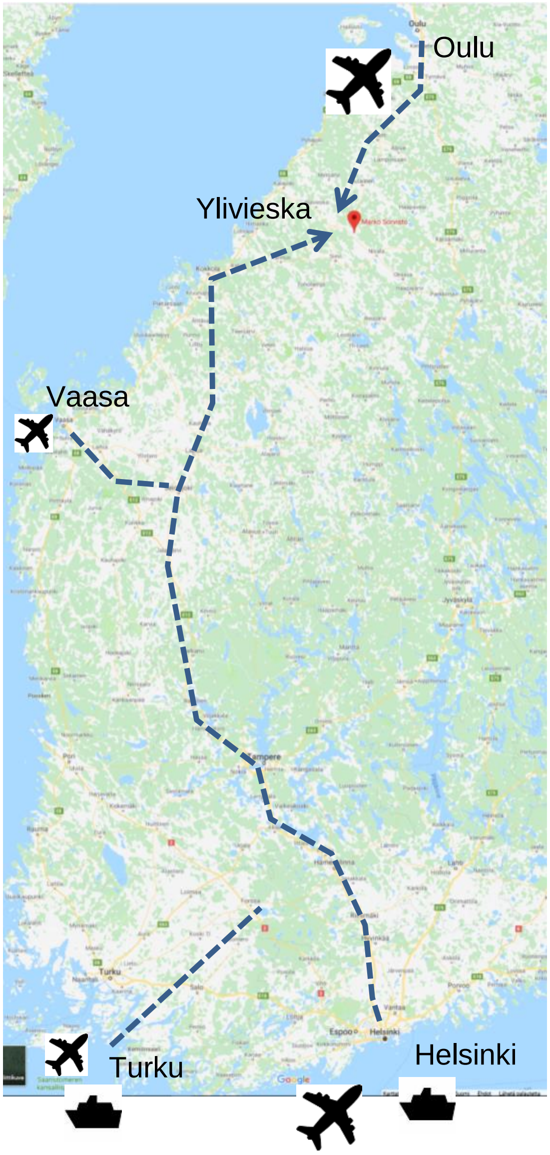
Google Maps link for the farm:

https://www.google.com/maps/place/Marko+Sorvisto/@64.0342636,24.7206378,15.75z/data=!4m5!3m4!1s0x468124a64f98c557:0x2732dfc7cdad10c3!8m2!3d64.0347751!4d24.7213624

Farm can be reached by driving in 6-7 hours both from **Turku** and **Helsinki**, where ferries from Stockholm, Tallinn and Rostock (DE) arrive.

When flying to Finland, the following options are currently available:

- Finnair operates to **Oulu** via Helsinki from many cities in Europe in collaboration with Oneworld alliance (Air France, Iberia, British airways etc.). Finnair covers the most comprehensive service with 10 flights from Helsinki daily.
- Norwegian operates to **Oulu** via Helsinki 4 flights a day from many cities in Europe.
- SAS operates to **Oulu** and **Vaasa** via Stockholm from many cities in Europe in collaboration with Star alliance (Lufthansa etc.), but only 3 flights a week.
- Many companies operate to **Helsinki** such as EasyJet, Airbaltic, Lufthansa, KLM etc. In addition, Wizzair offers flights to **Turku** from Gdansk.



As a conclusion, these arrival cities are suggested:

- Oulu: 1hour by train / 1,5hours by car to Ylivieska
- Helsinki: 5 hours by train / 7 hours by car
- Turku: 6 hours by train / 7 hours by car

Local transportation is planned to be provided by bus. Thus, those visitors renting a car have some more flexibility and freedom.

Regarding accommodation, Ylivieska doesn't have very strong touristic profile, as it is situated 40km from the beach areas in coastline. The main hotel in town is Käenpesä (https://www.hotellikaenpesa.fi/?l=2), which is hoped to be the main place for accommodation in order to arrange bus transportations smoothly. It can host maximum of 55 guests. A special arrangement with discounts will be negotiated for AFarCloud partners and other review guests. There are other smaller B&B places as supplementary services and other hotels in other towns (Nivala 20km, Haapavesi 40km).

3.10. AS10

3.10.1. Farm Introduction

Carrera d´en Bas is an organic farm engaged in the breeding and fattening of calves and in the sale of high-quality pasture beef. The company manages a territory of 500 hectares of agricultural land, considering pastures and croplands, in order to feed the 800 calves and cows. The fields in Mas La Carrera provides with food which is exclusively used to feed the cattle. Mas La Carrera has become the first cattle raising in Spain to be officially accepted by the Aberdeen-Angus Society.

On the farm there are more than 300 cows from different breeds, available to do any type of test and try several types of wearables according with Spanish and EU legislation. The cows are grazing in farm's pastures from April to June and from October to December and during the summer they are grazing in the Pyrenees. Therefore in summer it is harder to get access to the animals and must be taken into account for the demonstration planning. Testing and managing the herd in the farm is also more comfortable than during the months when cows are on the mountain. Another factor to consider facing the grazing season are the reproductive events. Currently reproductive control is done every two months and before grazing, in order to select the batches of animals to be driven up to the mountains and also to control calving to the have the cows together in the same lot.

Figure 41 – AS010 Carrera d'en Bas

Calves are together with cows during the first 6 months of life pasting and nursing. Afterwards, the farm has its own fields where fodder is cultivated for the fattening of calves. Feeding up to the weight of sacrifice is the same and is based on 50% silage of corn, 20% ryegrass silage, 23% cornbread and 7% soybean (this one purchased at the Valley Cooperative. In addition to calves of the own cows, about 400 calves are bought to fatten about 500 - 600 calves a year.

In addition to fattening calves, pure calves are also sold for life (males and females) and embryo treatments are also used to more rapidly multiply the Aberdeen Angus genetics that is available on the farm.

Most of the 500ha. are rented, of which 310ha. are forest. The rest are fields of cultivation, artificial prairies and also natural meadows. Grass farms are found in the area of the Vall d'en Bas (region of La Garrotxa) where there is the farm is located and also in the Camprodon Valley (region of Ripolles) where there are summer mounds and where the mountains rise cows.

The 100 hectares of cultivation is mainly grown in winter, ryegrass, oats, barley and summer corn. The double crop is made to obtain more yield to the land and finally to allocate all the production exclusively to the bait of calves and complement for the cows in winter. There are about 30 ha of irrigated land in sprinkler, which are supplied with a water aqueduct and a well. The rest of the surface is dry, although rainfall in our area is around 1000mm per year and there is enough for dry crockery. In addition to these crops there are a few alfalfa, sorghum and sunflower. Works in the fields are practically done with own machinery and only external services are rented to sow corn and to harvest it.

Livestock farmers, especially in Mediterranean countries such as Spain are not too much profitable, being the economic viability still closely linked to the support of regional programs and direct payments from EU. Grazing is the easiest way to reduce costs, but it is challenging farmers, mainly because of the lack of tools to help them measuring available herbage mass and grass intake. On the other hand, grazing currently has a main disadvantage, animal losses during the grazing period. Not having located or monitored the animal for months, makes it impossible to take preventive action that mitigates the effects of possible diseases, attacks or lack of adequate nutrition.

Figure 42 – Angus cattle grazing in Carrera d'en Bas

To reverse the current situation of farmers in the Mediterranean area it is necessary to address and resolve the following challenges:

- Harvesting of large grassland areas at optimal time is challenging. During growing, nutritional properties of grass reach the optimal level, and it should be harvested then before it starts to lose its quality. However, in modern farm with large cultivation areas, different fields become ripe at different times. It is challenging to monitor growing and schedule the harvesting optimally.
- TMR feeding is not totally in control in terms of its nutritional properties. The main reason for this is silage, which has significant fluctuation in its key properties due to differences between different fields and growing / harvesting times. This is partly connected to the previous challenge.
- Labour costs reduction, through a Farm management system accessible for farmers with tools such as Precision Livestock Farming (PLF) avoiding waste of time and fuel trying to locate cattle.
- Reducing animal losses, through early detection algorithms for diseases and aspects related to animal behaviour and the physical environment.
- Increase farm's productivity (fertility) increasing in heat detection and calving rates
- Optimizing the watering in the fields, it will mean an important saving of water, especially during summer period. In addition, it will help (with the periodically monitoring of the field) to control soil erosion, as well as, to avoid runoff in some areas of the field that prevents water from being absorbed by all the zones equally.
- Optimizing the fertilization of the fields to increase the productivity and reduce the cost of fertilization.

3.10.2. KPIs (benefits)

Eight of the main impacts and benefits from the project are (DoW, 1.1.4):

1. KPI2: 15-30% increase on crop productivity due to extended use of sensors and CPS unit.
2. KPI4: 20% lower fertilizers usage.
3. KPI5: Reduction of soil erosion and soil compaction and improved absorption of water
4. KPI6: 15% reduction of losses due to crop and animal diseases or non-optimal conditions
5. KPI7: 10% reduction of animal losses due to increased health.

6. KPI8: 80% reduction of veterinary cost due to early detection of symptoms in livestock.
7. KPI9: 80% reduction fuel and time spent when looking for missing animals as well as particulate emission for agricultural machinery.
8. KPI10: Up to 10% feed costs

Table 17 – AS10 KPIs

KPI2: 15-30% increase on crop productivity due to extended use of sensors and CPS unit. *(High priority)*
Currently it is expensive to have a mapping of the nutrients that are in the field. Therefore it is difficult to decide when and where it is appropriate to apply in the right measure. Having a system that allows correct decisions to be made will improve the productivity of crops. Throughout the project, the kilograms of crop generated to build the baseline will be quantified and the improvement will be analysed.
KPI4: 20% lower fertilizers use *(High priority)*
Currently it is expensive to have a mapping of the nutrients that are in the field and therefore when and where it is appropriate to apply fertilizers in the right measure will save a significant amount of fertilizers. Throughout the project it will be evaluated the saving in the use of fertilizers as precision tools are implemented in the farm.
KPI5: Reduction of soil erosion and soil compaction and improved absorption of water *(Low priority)*
Mas la Carrera has good water resources throughout the year, thanks to the abundant rainfall and the recent works to improve a pond that ensures water during the summer months.
KPI6: 15% reduction of losses due to crop and animal diseases or non-optimal conditions (Low priority)
Crop diseases in cereals and grass have not been estimated. Contamination of hay from rabbits, snakes, rats or other animals (also sometimes baby dear) hiding in the fields during harvest is a problem that been addressed. Systems to scare those away could have an impact.
KPI7: 10% reduction of animal losses due to increased health (Medium priority)
The causes of these casualties are varied but mainly due to diseases that occur during the months of grazing and that due to the lack of monitoring and early attention can lead to serious diseases that cause the death of the animal.
KPI9: 90% reduction fuel and time spent when looking for missing animals (High priority)

There has always been a pastor on the farm dedicated to locating the animals, the dedication in search tasks has not been measured, which will be part of baseline of year 1.
KPI10: Up to 10% saving in feed costs *(Medium priority)*
Feeding is the main cost of a livestock farm, improving crop productivity, silage and optimizing nutrients, can save a 10% of the total feeding cost.

3.10.3. Descriptions of goals and functionalities

3.10.3.1. G5: Improving the quality and the productivity with respect to the animals' well-fare, and meet quality

F8: Livestock location tracking

Each animal carries several sensors that allow location, surface temperature sensor and activity monitoring capabilities in order to monitor and locate cattle individually. The collars have IP65 protection in order to operate in adverse weather conditions, and they do not interfere with the animal´s daily routines.

Each collar collects information from the different sensors, processing it using a microcontroller and sendign the information by using the communication module to cloud servers. It also contains a high capacity battery that combined with a software power saving mechanism ensures a battery life over a year. It comes with all the elements for installation on animals.

To send information from collars to the server they use SIGFOX communication network. SIGFOX uses a UNB (Ultra Narrow Band) based radio technology to connect devices to its global network. The network operates in the globally available ISM bands (license-free frequency bands) and co-exists in these frequencies with other radio technologies, but without any risk of collisions or capacity problems. SIGFOX currently uses the most popular European ISM band on 868MHz (as defined by the European Telecommunications Standards Institute, ETSI; and European Conference of Postal and Telecommunications, CEPT) as well as the 902MHz in the USA (as defined by the Federal Communications Commission, FCC), depending on specific regional regulations.

Sensowave will use AFarCloud technologies. An API will be created to communicate with the AFarCloud platform. The cloud server collects information from all the collars and processes it in order to compute animal location. The farmer through an app will be able to decide the secure areas in the farm and if an anomaly is detected, the app automatically notifies the farmer via mobile phone, tablet, and/or computer.

F9: Detection of livestock heat and F10: Detection of livestock calving

These functionalities will be based on the same collar. The algorithms will compute animal location and activity.

The information is stored in different types of databases which are used by several BigData algorithms in order to determine patterns. These algorithms analyze data individually, data from the herd and data entered manually by the farmer (last heat date or calving date) in order to detect heat and calving. The farmer will be able to enter data from the animal through an app in the AFarCloud and Sensowave will provide the notification through the API. The AFarCloud visualisation tool will identify animals in heat from the list of animals in the farm or listing the animals in heat as part of the dashboard.

F11: Detection of livestock rumination and eating

IMAG will develop a device On-collar MCU with local storage. The training data is time-code synced with video footage Post-capture visualization, in order to allow training data labelling of rumination and eating. Later an on-board analytics library will be developed and it will be evaluated its integration with the Sensowave's collar.

F12: Determination of livestock growth rate

HIB will work on the classification of animals based on the analysis of video images.

HIB together with Sensowave will work on the development of an algorithm to estimate the weight of the animal. For this, the weight of the animal with images will be estimated and the algorithm will be trained in order to be able to predict the weight of the animal.

F13: Inference of the livestock habits patterns for health and reproduction

Once heat, calving, rumination and eating are validated, animals will be more characterized in their daily routines. F13 will take advantage of these data and will generate notifications if the previous patters are broken. Somehow, F13 is an improvement of the previous functionalities by developing a new anomaly detection algorithm based on the previous functionalities.

3.10.4. Legal and Safety, Healthy, Environment (HSE) considerations

All the operations with the animals will be carried out by one of the members of the Carrera d'en Bas staff, owners of the livestock.

It is possible to make flights on the farm as long as you keep direct contact with the drone, the flight is done during the day, and the weight of the drone is less than 20kg.

3.10.5. Infrastructure and logistics considerations

3.10.5.1. Existing infrastructure

Currently there is Wi-Fi network in the office and in the main barn, and also Sigfox coverage for IoT devices. There is power supply available.

The following equipment is already available at the farm:

- 130 collars monitoring and providing data regarding activity, location and surface temperature.
- 20 ear tags providing data about animal location
- 3 tractors with ISOBUS

Figure 43 – Collars ready in Carrera d'en Bas

3.10.5.2. Needed infrastructure for the demonstrator

We plan to extend the wifi coverage to the barn where the calves are fattened, as well as enable a shed to store the material and load devices.

3.10.5.3. Logistics

Contact person: Sergi Pujolrui to confirm a date on which to make deployments within the range of available dates. sergi.pujolriu@gmail.com.

Address: San Esteban d'en Bas, Girona, Catalonia, Spain

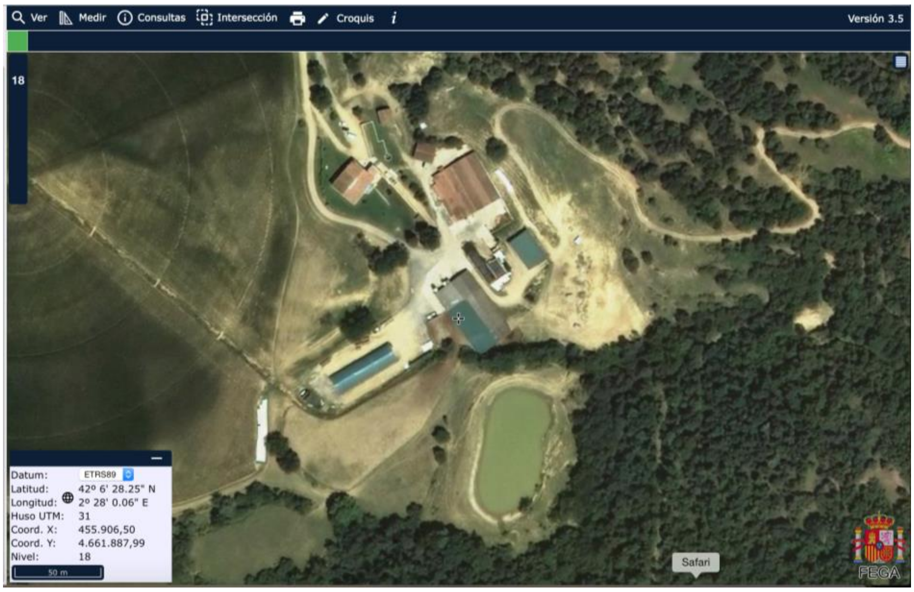


Figure 44 – Aerial view of Carrera d'en Bas

How to get there:

First travel to Barcelona or Girona by plane or Train. At the airport or train station, rent a car (it's the best way because the hotel and the farm are in the countryside. It's about 121km (2 hours) from Barcelona Airport and 50 Km from Girona Airport.

If you want to come by bus you have to check the timetables from Teisa Bus Company webside: http://www.teisa-bus.com This bus operate every day from Barcelona and Girona to La Vall d'en Bas (close to Olot). The bus it's about 2 hours from Barcelona and 1'5 hours from Girona.

Accommodation

Hotel Vall d'en Bas (Mas Can Trona s/n, 17176 Joanetes, Girona, Spain). At the hotel it will be possible to rent single and double rooms and also have Breakfast/Dinner. Accommodation at 80€ per day also include access to the technical facilities as Internet access and possibilities to connect own communication equipment to the fibre optic Internet, conference rooms etc. In this hotel there are 36 rooms (double, triple and quadruple). If the people can sleep in the same room in different beds the hotel can host 80 people. (2km from the farm)

Also, there are a Hostel. Alberg Vall d'en Bas, that have 10 rooms with 5 beds in each room. (1km from the farm)

In Les Preses, that is the town next to Vall d'en Bas, Hotel El Vertisol have several rooms. (5 km from the farm)

In Olot, that is the city 10 km from the farm there are several hotels:

- Hotel La Perla
- Hotel Riu
- Hotel Borell

Conference hall

A conference hall is in the Museum Can Trona that have a place for 134 persons. http://www.cantrona.cat/lloguer-despais.html. It's 100 metres from the the Hotel Vall d'en Bas. (2km from the farm).

Figure 45 – Conference hall for Y3 demo

The social Dinner will take place to Hotel Vall d'en Bas, It's the only place in the valley that have a restaurant for more than 120 persons.

3.11. AS11

3.11.1. Farm Introduction

According to the recent guidelines and study of the Italian Agriculture Ministry[1] the widespread diffusion of precision farming in Italy is actually limited. This is due to several factors, such as the small size of Italian farms, which makes it difficult to support investments for the purchase of new vehicles and technologies, the high average age of farmers with reduced expertise, and infrastructures issues, such as the lack of Internet connection in rural areas (Broadband and ultra-wideband).

it is clear that a strong and a necessary modernization of Italian agriculture is possible through a gradual innovation, new forms of investments driven by opportunities for farmers to know the advantages of technologically advanced solutions.

However, Italy is the European Country with the largest number of PDO (product designation of origin) and PGI (protected geographical indication) agricultural and food products recognised by the European Union. Also Tradition Specialty Guaranteed (TSG) products, that are related to a traditional composition of the product or a traditional/regional method of production, play a peculiar role in Italian Agriculture and for the economy of Italian farms through exports of typical food products.

Moreover, Italian government has recently approved by different Ministries joint work (also Agriculture one) a law to promote and safeguard “made in Italy” brand, as well as innovation and blockchain driven applications.

For these purposes, it's relevant to guarantee both food quality, and product traceability: their implementation is seen not only as the fulfilment of a "mere" legislative obligation but as a tool for creating added value. The implementation of a food certified supply chain provides a control that from the producer reaches the consumer according to a series of stages, from the field to the fork paradigm. Other improvements are based on the greater availability of data and information about crops and raw materials and the possibility of widening the boundaries of traceability itself, creating and transferring value and knowledge along the supply chain.

As explained in the introduction, San Rossore Park is not a simple “farm”, but it’s a very wide park managed by a Regional Public authority responsible for safeguarding environment and biodiversity inside the territory that covers approximately 24,000 hectares situated with areas of coast from Viareggio to Leghorn. Although, there are areas in the middle of a strongly urbanized area, this territory has maintained relevant natural features and agricultural activities. Among the other roles, the park authority is the main actor to promote food products and farming quality and innovation in conjunction with the safeguarding of the nature and organic processes in agriculture and livestock.

The park was already involved in relevant European projects:

- LIFE DUNETOSCA - (cod. LIFE05NAT/IT/000037) (2005 - 2009)

- LIFE+ DEMETRA - (cod. LIFE08NAT/IT/000342) (2010 – 2012)
- bilateral Italy-France Project on Coastal areas “ZOUMate” (2014-1015)

And currently under evaluation;

- LIFE FORWARD - (cod. LIFE18 ENV/IT/000289)
- LIFE SySTEMiC - (cod. LIFE18 ENV/IT/000124)

The San Rossore Park offers a truly and holistic environment *per se*. In fact, it offers to deploy both environmental monitoring actions (e.g. biodiversity and environment quality) and different type of crop and livestock management, due to the richness of biodiversity itself. For instance:

- Forage and other crops for animals (also horticultural ones)
- Autochthonous breed cows (‘mucco pisano’) and horses
- Wheat production for flour and bread
- Livestock and Meat production
- Milk production and different type of cheese
- Different types of vineyards and wine products (also PDO ones).
- Honey production and pine nuts cultivation

San Rossore park authority also promotes a relevant Food value chain, *Farms recommended by the Park*, among different actors in the park territory and Pisa surrounding areas itself (i.e. farmers, wholesalers, agriculture associations, markets and stores, logistics and packaging companies).

In this context, AFarCloud platform and solutions will offer different tools available to support innovation and modernization of processes in Italian farms through the unique panorama available in San Rossore territory, *from the field to the fork*, among different actors in the park territory and Pisa areas itself.

Also AFarCloud will benefit from the San Rossore Park agricultural processes and food value chain, since AFarCloud architecture is modular and the last process and results from crops and livestock solutions (derived from other demonstrators) will be enriched by the final step related to the traceability of food products, like the blockchain solutions.

The clear advantage is the already existing organized chain: Logistics, Packaging, Preservation of food quality companies and services are already organized.

Also the distribution aspect is well already designed: agricultural cooperatives, wholesalers, stores are already involved.

Using this strategy and the opportunities by all the three holistic demonstrators, the overall AFarCloud platform will be designed in order to manage all the different aspects of agricultural processes, from the monitoring of fields and animals, realizing specific actuators and IoT solutions needed to add the precision dimension to crops and livestock, to the complete availability of information on final food product traceability, to certify quality and trust for final consumers.

AS11 demonstrator will be based on the following farms and food chain industries:

1. Fattoria Coltano, owner Mr. Salvadori Furio located inside the park in the area of Coltano (Pisa Province)

The farm owns 100 hectares of extensive agriculture, forage and cereals

Plus 100 cows of different breeds (limousine and autochthonous breed 'mucco pisano').

http://www.fattoriacoltano.it/

2. Farm Valentini Riccardo, located in the municipality of Migliarino Pisano (Pisa province), the farm is specialized in Horticulture in open field, they own 15 hectares (No internet site available for the farm).
3. Official San Rossore farm: it's the flagship farm of the park, 500 hectares of forage and meadows for grazing, crop, grain, alfalfa, peas, rapeseed, barley, wheat, sister crops. They have also livestock with 200 cows (chianina maremmana, mucco pisano) and horses.

http://www.parcosanrossore.org/map.php

4. Cheese organic production firm from Caseificio Busti that obtains milk directly from the farm Ori Martino and Pedrazzi livestock of sheep breeding, since they manage 100 hectares of meadows for grazing for around 3.000 sheep. Pedrazzi has been located in the San Rossore Natural Park for over 70 years and has 400 units sheep, of which around 375 adults. The number of feeding lactating ewes is around 200. All these farms are inside the Park territory and they are certified for organic production.

https://www.caseificiobusti.it/

http://www.aziendaagricolapedrazzi.it/allevamento_5.html

5. Uccelleria winery, vineyards and wine production, all locally. 20 hectares of vineyards

https://uccelliera.com/

It is located not very far from Caseificio Busti (just 4 km).

Needs

The tests in the AS11 are mostly dependent on the internet connection availability in the fields and in the farms.

Since in most of the farms Internet is not available today, the connection will be installed using gateways as in AS05 local demonstrator. Ro Technology gateways are available and the gateways can connect WSN and some Ethernet and WIFI connected units to the Internet, using a modem and a data-Sim. In some other case the connection to the internet is already available in the farms, through a WIFI link provided by farmers.

In the use case related to automatic irrigation system also an plant equipped with electro-actuated valves must be installed and the availability of the grid connection for electrical power is also needed.

In order to evaluate the cost for task execution in crop use cases, tractors with CAN network are needed in order to evaluate the cost of power in the task in the field, as well as machines with ISOBUS could be useful in order to evaluate the amount of nutrients or chemicals distributed per square meter in the field. In case that type of machines will not be available, ESTE company can provide a solution installing a system prototyped for this special case, in order to make a tractor without ISOBUS, ISOBUS equipped. The system is partly made by TopCon and partly designed by ESTE for AFarCloud project.

3.11.2. KPIs (benefits)

KPI1: 30% of cost reduction, for the integrator companies that provide the technologies and the services, due to saving in programming, integration and configuration time.
Feduction of water usage in the horticulture due to continuous environmental parameters measurement and automatic irrigation system
KPI3: 30% increase of horticultural productivity due to reduce chemical products use
A prevention in plant diseases thank to multispectral cameras will reduce the usage of chemical products.
KPI4: 20% lower fertilizers use
Currently it is expensive to have a mapping of the nutrients that are in the field and therefore when and where it is more appropriate to apply fertilizers in the right measure will save a significant amount of fertilizers. Throughout the project it will be evaluated the saving in the use of fertilizers as precision tools are implemented in the farm. The continuous monitoring of vital parameters and environmental parameters will allow a reduction in chemical nutrients, as well as natural fertilizers
KPI6: 15% reduction of losses due to crop and animal diseases or non-optimal conditions (Low priority)
Crop diseases must be investigated but are most severe on potatoes, oil seeds and cereals. Contamination of hay from rabbits, rats or other animals (also sometimes baby dear) hiding in the fields during harvest is a problem that been addressed. Systems to scare those away could have an impact.
KPI7: 10% reduction of animal losses due to increased health

Crop diseases must be investigated but are most severe on potatoes, oil seeds and cereals. Contamination of hay from rabbits, snakes, rats, moles or other animals, hiding in the fields during harvest is a problem that been addressed. Systems to scare those away could have an impact.
KPI10: Up to 10% saving in feed costs *(Medium priority)*
Feeding is the main cost of a livestock farm, the average annual cost per animal is approximately 150€. Achieving better measures of grazing behaviour that can be used by farmers to help them manage grazing, both from an economic and environmental. A 10% saving in feed costs means 15€/year per animal and seems realistic by providing farmers with a tool to monitor livestock animals grazing behaviour. In a farm with 200 animals it might save 3.000€. The KPI evaluation is exactly the same as AS10 because it is made with the same systems provided by the group that work on AS10, the test in a different area with different type of animals will enforce and validate the solution at least at European level.

3.11.3. Descriptions of goals and functionalities

There are four main use cases well identified with the support of the Park Authority:

Scenario # 1:

Sheep [Simbolo] milk [Simbolo] cheese (farms: ORI/Pedrazzi, BUSTI)

Scenario # 2:

Cows husbandry [Simbolo] meat and its sub-products (Farms: Salvadori, Park farm itself)

Scenario # 3:

Horticulture monitoring and Wheat [Simbolo] flour and horticulture sub-products [Simbolo]bread and pasta (Valtentini Riccardo Farm in Coltano area near the Park)

Scenario # 4: Vineyards Monitoring (fattoria Uccelliera)

The expected functionalities from the AFarCloud project are inherited from the solutions of other demonstrators (in particular the local Italian demonstrators AS05 and the other holistic demonstrators) development of the required sensing and IoT devices, data will be gathered, and combined with the use of cameras, drones, ISOBUS engineered vehicles and innovative algorithms will be developed to determine:

- Nutritional habits: eating and rumination periods, and to estimate daily intakes grazing habits, watering habits,
- Heat and calving detection

- Social behaviour and location
- Crops parameters: soil moisture, light and radiation sensors (like ultraviolet radiation, photo-synthetically active radiation , i.e.. PAR), electrical conductivity, temperature, humidity and other weather conditions).

The principal technological pillars for AS11 are related to main concept of Farm activities as a set of services:

- Precision agriculture for crops and livestock monitoring
- Support sustainable farming activities
- Digitalization of the agrifood chain related to the *Farms recommended by the Park* initiative
- Traceability and certified creation of agrifood/farming value chain
- Blockchain and smart contracts to certify the products of San Rossore
- Extension of the AFarCloud platform to insert blockchain technology as a Service

The scenarios and the technicalities will be well harmonized with the general architecture proposed for AFarCloud, as depicted in the following figure:

3.11.3.1. G2: Improve harvesting

F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.

Environmental monitoring is concerning the status of the fields and the climatic conditions during the cultivation season but also during the winter that can have effect on the crops in both negative and positive ways. Monitoring temperature, wind and moisture/freezing are factors that can be used as input in the farmers decision trees for how to apply different best practises a certain season and on a certain piece of land. Environmental factors also influence the possibility to manage the soil, and the crop during all the cultivation phases.

F28: Fleet management: tracking of farm vehicles

Tracking vehicles is an important parameter to understand fuel consumption and time used to work in the different lands. Also tracking vehicles is an important parameter to certify mechanical tasks executed with machines in the field to certify, as an example, mechanical weeding, in order to protect bio-cultures (as in San Rossore Park). Monitor of new and old vehicles will be performed using a CAN/internet gateway capable of collecting data from tractors and implements (both ISOBUS or NON

ISOBUS) provided by ESTE Technology. Two versions of the product will be tested: one using a WI-FI link and another using a 3G/4G modem and a SIM.

3.11.3.2. G5 Improving the quality and the productivity with respect to the animals' well-fare, and meet quality

F8: Livestock location tracking

Each animal carries several sensors that allow location, surface temperature sensor and activity monitoring capabilities in order to monitor and locate cattle individually. The collars (by SENSOWAVE) have IP65 protection in order to operate in adverse weather conditions, and they do not interfere with the animal´s daily routines.

Each collar collects information from the different sensors, processing it using a microcontroller and sends the information by using the communication module to cloud servers. It also contains a high capacity battery that combined with a software power saving mechanism ensures a battery life over a year. It comes with all the elements for installation on animals.

To send information from collars to the server they use SIGFOX communication network. SIGFOX uses a UNB (Ultra Narrow Band) based radio technology to connect devices to its global network. The network operates in the globally available ISM bands (license-free frequency bands) and co-exists in these frequencies with other radio technologies, but without any risk of collisions or capacity problems. SIGFOX currently uses the most popular European ISM band on 868MHz (as defined by the European Telecommunications Standards Institute, ETSI; and European Conference of Postal and Telecommunications, CEPT) as well as the 902MHz in the USA (as defined by the Federal Communications Commission, FCC), depending on specific regional regulations.

Sensowave will use AFarCloud technologies. An API will be created to communicate with the AFarCloud platform. The cloud server collects information from all the collars and process it in order to compute animal location. The farmer through an app will be able to decide the secure areas in the farm and if an anomaly is detected, the app automatically notifies the farmer via mobile phone, tablet, and/or computer.

The same applies to a new LoRa + GPS experimental collar that ST Microelectronics will test in Y2 and will finalize in Y3 for animal location.

F9: Detection of livestock heat and F10: Detection of livestock calving

These functionalities will be based on the same collar. The algorithms will compute animal location and activity.

The information is stored in different types of databases which are used by several BigData algorithms in order to determine patterns. These algorithms analyze data individually, data from the herd and data entered manually by the farmer (last heat date or calving date) in order to detect heat and calving. The farmer will be able to enter data from the animal through an app in the AFarCloud and Sensowave will provide the notification through the API. The AFarCloud visualisation tool will identify animals in heat from the list of animals in the farm or listing the animals in heat as part of the dashboard.

F11: Detection of livestock rumination and eating

IMAG will develop a device On-collar MCU with local storage. The training data is time-code synced with video footage Post-capture visualization, in order to allow training data labelling of rumination and eating. Later an on-board analytics library will be developed and it will be evaluated its integration with the Sensowave's collar.

F12: Determination of livestock growth rate

HIB will work on the classification of animals based on the analysis of video images.

HIB together with Sensowave will work on the development of an algorithm to estimate the weight of the animal. For this, the weight of the animal with images will be estimated and the algorithm will be trained in order to be able to predict the weight of the animal.

3.11.3.3. G6: Reducing water waste and cost

F14: Measure field water content/vigour

The content of water will be analyzed in fields using soil humidity sensors at different depths. They will allow determining the exact amount of water in surrounding the probes with this information and considering the structure of the soil it is possible to calculate the content of water in a field.

The water content and the vigour of the specific crop can be the way to estimate the quality of the cereals.

3.11.1. Legal and Safety, Healthy, Environment (HSE) considerations

All operations in the field will be executed by workers and especially if machines (tractors, harvesters, sprayers etc.) are used, only people working in the local farms and livestock will be allowed to use the machines. All AFarCloud people will be invited to assist to operations in the fields at safety distance from machines.

There is no limitation for visiting farms and livestock for people travelling from EU Countries to Italy, so all technicians and engineers of AFarCloud project will be able to directly install sensors and gateways in the farms and in livestock. All eventually needed operations in machines, like to install special gateways or sensors in machines, will be executed only when machines are stationary and at power off.

For special components, like air and water purification systems a special document form discharge of responsibility must be prepared by companies working with these special systems, in order to be sure that no damages are possible and eventually no fee are charged to AFarCloud project or partners.

Each partner will be directly responsible for their workers and employees and they must have their company insurance.

All products that are eventually distributed in the fields and/or in livestock to animals because of indication of AFarCloud partner or AFarCloud software (DSS) must be approved by owner of the farm/livestock with a signed agreement before any operation.

Any other special request or need will be analyzed during the first year and during the monitor phase of the AFarCloud experience and will be documented and discussed with WP leaders and with Coordinator before taking any actions.

3.11.2. Infrastructure and logistics considerations

As explained before, San Rossore is a wide area managed by a regional public authority with the objective to safeguard natural and biodiversity resources, as well as agriculture and promote a local food chain in its territory. The park has different infrastructures and agreements with farms and companies in order to offer accommodation.

As shown in the map of Figure 42, the heart of the park, where the big (500 hectares) farm “Tenuta di San Rossore” is very near to Pisa municipality, where AFarCloud people can locate the hotels and other accommodation useful to reach daily the park area and farms in order to carry out the activities. All farms are easily reachable from Pisa and are located in the Migliarino area, Coltano area and San Rossore area.

The advantage to be near Pisa, famous for its monuments and the leaning tower, is relevant because a lot of B&B facilities, hotels and structures are present in the territory. In particular different agreements among operators and the park can be established. In general the following logo is used when a specific accommodation is recommended by Park

Figure 46 – Map of the San Rossore area and surrounding estates

:

In the following URL it is possible to find some proposals for accommodation:

http://www.parcosanrossore.org/dormire.php

3.11.2.1. Existing infrastructure

The park owns many buildings with both meeting rooms and restaurants.

Figure 47 – San Rossore headquarter with administrative offices and facilities

In the figure below a small conference room is shown, a meeting room for 80 people.

Figure 48 – San Rossore conference room

The “Sala Gronchi” is a meeting room for more than 100 people, useful for AFArCloud needs.

Many of farms and industries for the production of final products are depicted in the following pictures. Wi-Fi network are located in the offices. Some sensors are present in Caseificio Busti to monitor environmental parameters during the production. There is power supply available in all the farms. We plan to extend the Wi-Fi coverage to the barn (in Salvadori) and vineyards, as well as using a shed to store the materials and devices.

An 802.15.4 / 6lowPan antenna is located in the park facilities.

Networks different from that one needed for the AFarCloud Tests will be described in the needed infrastructure paragraph.

FARMS and LIVESTOCK DESCRIPTION

Caseificio Busti collaborates with ORI Martino and Pedrazzi farms with some autochthonous breed sheep (i.e. pecora massese)

Figure 49 – Some autochthonous sheep in Ori and Pedrazzi farm

Uccellieria farm: it is located in Fauglia Lorenzana near Busti and the estate is 240 hectares extended with 20 hectares of vineyards. It is certified as producer for Chianti PDO Colline Pisane. It has an accommodation with rooms and restaurant for typical dishes.

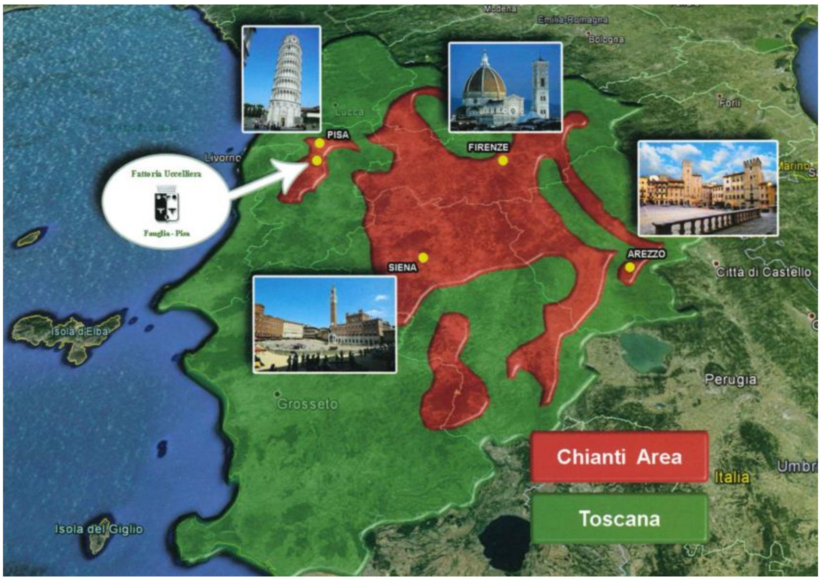


Figure 50 – Uccelliera farm is located in Chianti Area

Figure 51 – Uccelliera farm environment

Salvadori Furio farm is an organic farm where livestock and production of cereals and forage for cows are the first type of crop. There is a shop where meat and other subproducts can be purchased.

Figure 52 – Salvadore Furio, Uccelliera farm environment Cows barn

Busti sheep cheese producer has a lot of types of chees like Pecorino Toscano PDO and Pecorino del Parco (specific product with the collaboration of the Park authority). It has also a shop for final consumers and a restaurant where it is possible to taste typical dishes.

Figure 53 – Busti specific equipment and warehouse

3.11.2.2. Needed infrastructure for the demonstrator

CROP USE CASE:

For crop case all the activities will be executed using drones and agricultural machines, so the need for infrastructure is related to a garage where AFarCloud engineers can work on machines to install the new electronic control systems and the new sensors. Also the drones can be charged, maintained and eventually repaired.

About the Internet connection, during tests sessions, some gateways will be installed near the fields where tests will be executed, to interface sensors and drones to the network.

Tractors will be equipped with a gateway between CAN Network and the Internet provided by ESTE.

HORTICOLTURE USE CASE:

In order to test systems and applications of AFarCloud Project, the 220 V A:C. must be available in the fields for horticulture. The same applies for connectivity, which can be provided both locally and to the internet by AFarCloud partners (Ro Technology, UNIPR, UNIVAQ and ESTE), and eventually a link with WI-FI to the farmers headquarter or house, in order to monitor AFarCloud sensors and actuators.

In order to actuate the automatic irrigation system in horticulture, also a new implant must be installed, with different sections (non automatic and automatic), in order to test both benefits of automatic irrigation. Both are to be connected to sensors in the field and to the gateways, In the area where automatic irrigation valves will be controlled (by ESTE actuator), the 220 VA.C. must also be present.

LIVESTOCK USE CASE:

The air purification system by ARCHA needs the grid 200V AC electrical power and it needs an Ethernet connection to be interfaced to the internet, so that in the milking room in the livestock must be equipped of both power and internet connections. Both must be provided by the farmer in order to test benefits of the Automatic air purification system.

To collect data from collars installed in animals, a Wi-Fi gateway in the livestock must be installed, and it can be a commercial one, directly connected to Ethernet connection.

In the farms chosen no internet connection is available, but in Livestock and horticulture the electrical power (220 V AC 50 Hz) is always available.

3.11.2.3. Logistics

San Rossore park is located near the city of Pisa in the Tuscany region of Italy. And the distance from the Pisa city centre is 5 km (as indicated on the map below).

Pisa has its own airport with local flights from other relevant cities of Italy (i.e. Catania) and from the most important European destinations (Paris, London, Munich, Dusseldorf, Prague, Valencia, Madrid, Barcelona, Oslo, Vienna, Gothenburg, Amsterdam, Dublin, Brussels, Toulouse, Cologne, Bucharest, Nantes, Bordeaux, etc.). The airport is less than 5 km distant from the city centre.

Car rentals are available at the airport and also a bus shuttle service for the Pisa City. As an alternative both Roma Fiumicino Airport is an option or Genova Airport is another option to easily reach the Pisa City from other airports in Italy. Highways are available to move from Roma and Genove in the direction of Pisa.

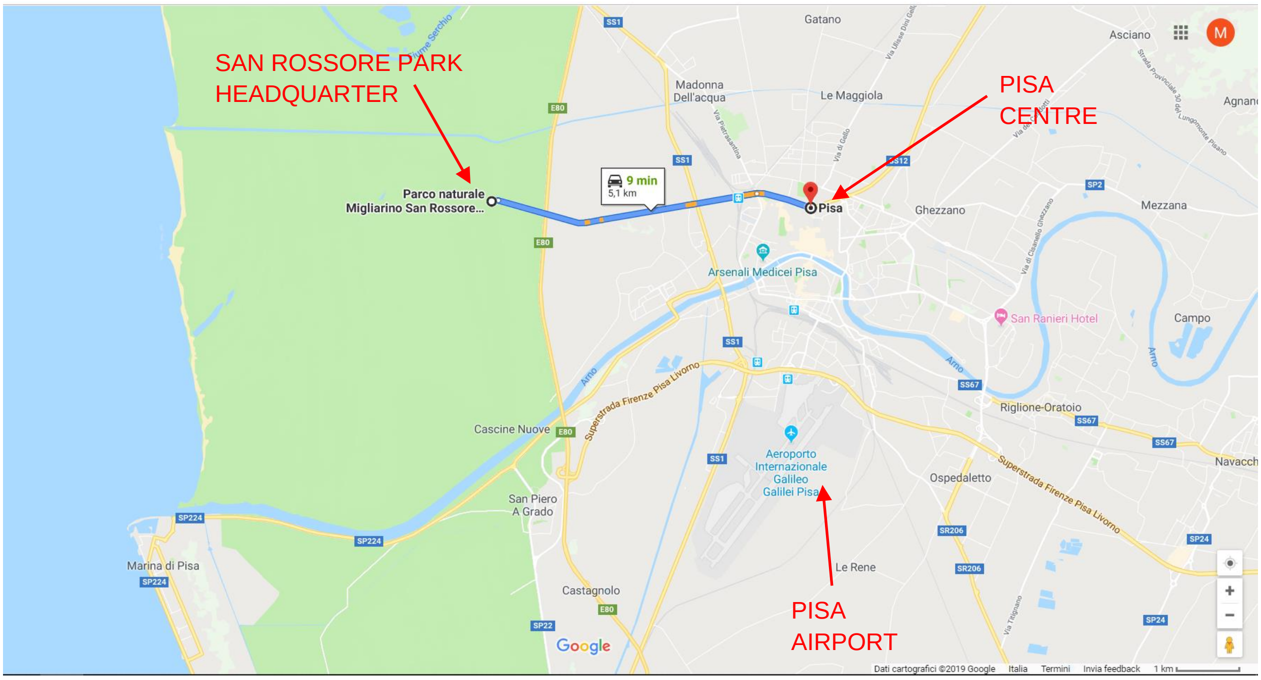


Figure 54 – Map with San Rossore Park location

4. Role of AFarCloud platform

The AFarCloud platform is being defined within WP2. A preliminary architecture is depicted in Figure 14. Technical WPs (WP2, WP3, WP4, WP5 and WP6) implement the different components of the platform that are shown in Figure 14. These components are grouped into the three pillars of the platform: the Farm Management System, the Semantic middleware and the Hardware System. The Hardware System's components are deployed in the farm and include all components installed in vehicles, drones, sensors, GWs and any edge computing device. The Semantic Middleware's components will use semantic models, specified by an ontology to abstract the heterogeneity of the underlying hardware, and to ensure that all information is stored according to a common information model that guaranties interoperability. The semantic middleware will act as a communication centralizer, disseminating messages between the Farm Management System and the devices deployed in the Hardware System. The Farm Management System's components will offer a Mission Management Tool (MMT), a Decision Support System (DSS), a system configurator and applications for the user to access the whole system, make high-level and task plans for future missions, configure and coordinate (semi)-autonomous systems and legacy systems, and make decisions.

The AFarCloud platform is fully configurable so that components can be chosen based on the specific needs of each demonstrator. Each demonstrator will only deploy the components of the platform that support their required functionality. Thus, each demonstrator will have its own configuration of the AFarCloud platform that may even change over the lifecycle of the project due to two reasons: either the demonstrator add new functionalities or some functionality is improved/completed by requiring new platform components during the project.

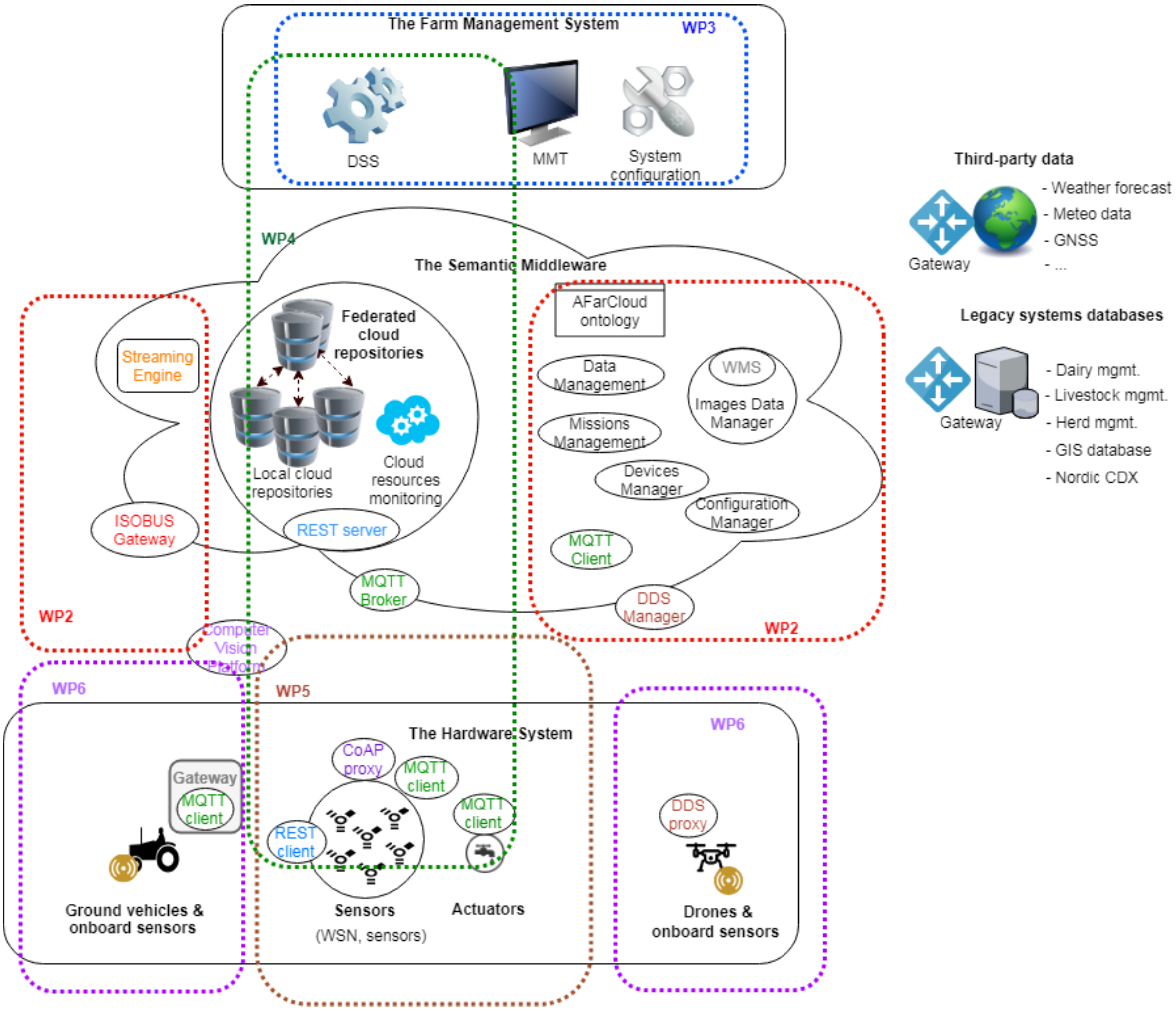


Figure 55 – AFarCloud architecture

5. Demonstration strategy and planning

This section describes the general demonstration planning of AFarCloud. Section 5.1 explains the overall planning and Section 5.2 describes the technical evolution of all demonstrators during the lifecycle of the project.

5.1. Overall planning

The AFarCloud platform comprises cyber physical systems (CPS) and also wide variety of equipment such as sensors, wearable, drones, cameras and vehicles. Eleven demonstrators will serve to deploy, integrate and validated the services developed during the project through a bottom-up strategy, as introduced in Section 2.

The demonstrator functionalities will be first implemented in the local demonstrators, in order to:

- Ensure that the AFarCloud platform's SW components are tested in a real scenario.
- Check that the tested functionalities meet the user requirements and KPI's of farmers.

Functionalities satisfy user requirements and are validated in local demonstrators before being implemented in the holistic demonstrators.

The holistic demonstrators are: AS09 (Finland, 2019), AS10 (Spain, 2020) and AS11 (Italy, 2021). These holistic demonstrators work as local demonstrations before its holistic deployment. The rationale behind is to test functionalities that are local to the demonstrator and be able to collect more precise data before the demonstrator becomes the holistic one. When the demonstrator becomes holistic, it deploys all the possible functionalities, that is, those functionalities that have been validated in other local demonstrators and can be implemented in the demonstrator's farm. Thus, AS09, AS10, and AS11 become local in 2019 before hosting the holistic deployment in 2019, 2020 and 2021, respectively.

Figure 53 shows the timeline of all the AFarCloud demonstration sites. This timeline is tentative since the planning may change due to logistics or weather constrains in farms. Blue lines indicate yearly releases of the AFarCloud platform and hence the deadline to integrate and deploy this platform release in local demonstrators. Every year a version of the AFarCloud platform will be released, offering the necessary software components to reach the degree of maturity foreseen for each of the general user functionalities defined. Green cells are holistic demonstrations and orange triangles indicate that yearly holistic reviews. Red lines represent the project's milestones based on the integration, deployment and validation of holistic demonstrators:

- MS4: 1st holistic demonstrator (M12). Successful integration of the AFarCloud platform core components. Fulfilment of the 1st set of requirements. Since this holistic demonstration has been postponed one month due to logistics requirements, this milestone has been split into two sub-milestones: MS4.a constitutes the successful implementation of all functionalities in the holistic AS09 and MS4.b constitutes the evaluation of this implementation.

- MS5: 1st holistic demonstrator (M24). Successful integration of the AFarCloud platform core components. Fulfilment of the 2nd set of requirements.
- MS6: 1st holistic demonstrator (M35). Successful integration of the AFarCloud platform core components. Fulfilment of the complete set of requirements.

Note that during this first year, from M1 to M10, data in demonstrators have been collected to generate a baseline with which to compare the data collected by the successive AFarCloud Platform releases.

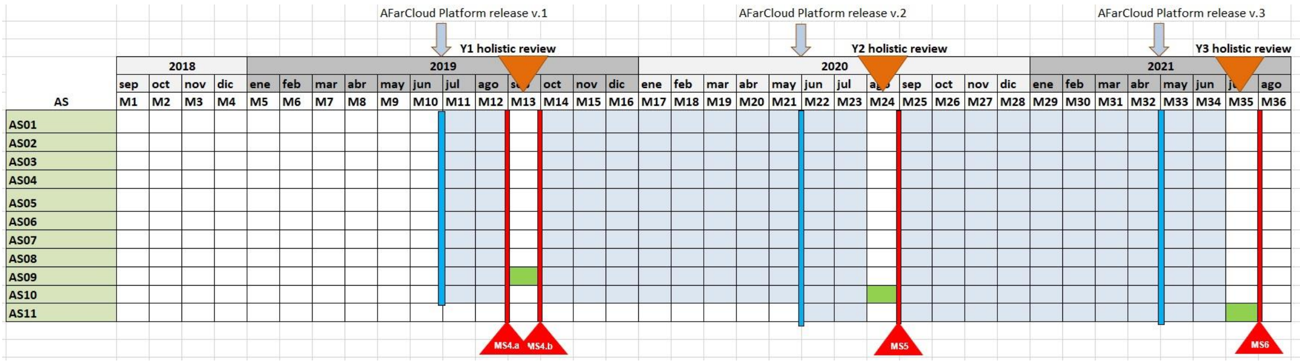


Figure 56 – Demonstrator plan

Table 8 shows the functionalities and the local demonstrators where these functionalities will be implemented during the lifecycle of the project. Some functionalities will be implemented in different local demonstrators that correspond to different types of farms. In some cases, there will not be many differences between the different ways of implementing the functionality as for example F1 that deals with environmental monitoring. In other cases, however, the differences between the implementation of a same functionality in several farms can be much stronger, since farms can be radically different. For instance, water monitoring in a vineyard in Spain is drastically different than water monitoring in a cereal field in Latvia. Moreover, functionalities are evolving over the years in each demonstrator, as described in more detail in Section 5.2.

Table 18 – Demonstration planning based on functionalities

	FUNCTIONALITY DESCRIPTION	Y1 local demonstrators	Y2 local demonstrators	Y3 local demonstrators
F1	Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.	AS01, AS03, AS07, AS11	AS01, AS03, AS07, AS11	AS01, AS03, AS07, AS11
F2	DSS for deciding about if it will be frost or not.	AS01	AS01	AS01
F3	Monitor cereals Nutrients (energy, protein and humidity analysis)	AS02, AS03, AS08, AS09	AS02, AS03, AS08, AS09	AS02, AS03, AS08, AS09
F4	Using DSS take decision regarding when and where to harvest		AS02, AS03	AS02, AS03
F5	Monitor NPK (sensors or imagery)	AS03	AS03	AS03
F6	Measure the needs of fertilization with high spatial precision	AS03	AS03	AS03
F7	DSS for decision about when to fertilize	AS03	AS03	AS03
F8	Livestock location tracking	AS06, AS10	AS06, AS10, AS11	AS06, AS10, AS11
F9	Detection of livestock heat	AS03, AS06, AS10	AS03, AS06, AS10, AS11	AS03, AS06, AS10, AS11
F10	Detection of livestock calving	AS06, AS10	AS06, AS10, AS11	AS06, AS10, AS11
F11	Detection of livestock rumination and eating	AS10	AS06, AS10, AS11	AS06, AS10, AS11
F12	Determination of livestock growth rate		AS10	AS10
F13	Inference of the livestock habits patterns for health and reproduction		AS06, AS10	AS06, AS10
F14	Measure field water content/vigour	AS03, AS05, AS07, AS11	AS03, AS05, AS07, AS11	AS03, AS05, AS07, AS11
F15	Measure water stress	AS03	AS03	AS03
F16	DSS for decision about how much water	AS03	AS03	AS03
F17	Automatic actuation on rooftop (open,close)		AS05	AS05
F18	monitor greenhouse temperature and humidity	AS05	AS05	AS05
F19	Using actuators, irrigate with correct amount and location	AS04, AS05	AS04, AS05	AS04, AS05
F20	Detect plant illness (imaginary near infrared)	AS04	AS04	AS04, AS05
F21	Monitor Gases	AS08	AS08	AS08
F22	NIR silage analysis	AS09	AS09	AS09
F23	Livestock indoor positioning	AS09	AS09	AS09
F24	Livestock identification	AS09		
F25	Nutrition monitoring through rumen scanning	AS09	AS09	AS09
F26	Extract and analyze data from milking robots	AS08	AS08	AS08
F27	Livestock digestion monitoring	AS07	AS07	AS07
F28	Feet management: tracking of farm vehicles	AS03	AS03, AS11	AS03, AS11

In the AFarCloud demonstration planning, it is crucial to define which functionalities are going to be integrated in each year's holistic demonstrator. Table 8 shows the AFarCloud functionality-centric strategy for the three holistic demonstrations. This planning ensures that, each year, all the implemented functionalities can be presented in the project's holistic review. The determining factors to decide whether or not a functionality will be integrated in the holistic demonstration is the type of the holistic demonstration's farm. For instance, a functionality addressing a vineyard cannot be demonstrated in Finland in September because there is not any vineyard. Table 8 indicates whether or not each functionality can be supported in the three holistic demonstrations. If the functionality can not be supported, the alternative(s) for showing a remote demonstration of the functionality in other farm or for implementing the functionality in the holistic demonstrator with some variations is indicated.

Table 19 – Demonstration planning for holistic demonstrators. AS09/AS10/AS11 Support is yes (Y) or no (N). If Yes, the demonstration strategy is indicated. If No, the alternative for remote or local demonstration is indicated.

FX	FUNCTIONALITY DESCRIPTION	Farm Target	Hw Involved	AS09 Support	AS10 Support	AS11 Support
F1	Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.	Cranberries, Ceral, Vineyards	Sensor Drone	**No** **Proposal 1: monitor other plants** **Proposal2: Demonstration in exhibition**	**No** **Proposal 1: monitor other plants such as cereals** **Proposal2: Demonstration in exhibition room**	**No** **Proposal 1: monitor other plants such as grapes** **Proposal2: Demonstration in exhibition room**
F2	DSS for deciding about if it will be frost or not.	Cranberries		**No** There MIGHT be frost at AS09 week already. Potato would be a good application, since they suffer from frost, but they may be harvested already then. **Proposal1: Demonstrate in exhibition as lab concept** **Proposal2: remote viewing**	**No** frost at AS10 until winter **Proposal1: Demonstrate in exhibition room as lab concept** **Proposal2: remote viewing**	**No** frost at AS11 until winter **Proposal1: Demonstrate in exhibition room as lab concept** **Proposal2: remote viewing**
F3	Detection of cereals nutrients composition (energy, protein and humidity analysis)	Cereals		**Yes** All cereals have been harvested before AS09 week, so no field vegetation available. Cereal storage can be arranged. **Proposal: demonstration in exhibition with harvested cereals**	**Yes** Demonstration on field will depend on final date **Proposal: demonstration in exhibition with harvested cereals in feeding corner**	**Yes** Demonstration on field will depend on final date **Proposal: demonstration in exhibition with harvested cereals in feeding corner**
F4	Using DSS take decision regarding when and where to harvest	Cerals Grass		**Yes** Again, all harvesting done before AS09 week. **Proposal: Demonstration in exhibition with existing data from the summer's harvesting weeks**	**Yes** Demonstration on field will depend on final date, **Proposal: Demonstration on demonstration field added with exhibition room presentation**	**Yes** Demonstration on field will depend on final date, **Proposal: Demonstration on demonstration field added with exhibition room presentation**

F5	Monitor NPK (sensors or imagery)	Soil	Sensor Drone	**Yes** Demonstration field can be provided for soil monitoring. Only grass fields available on AS09 week. **Proposal: Demonstration on demonstration field**	**Yes** Demonstration field can be provided for soil monitoring.. **Proposal: Demonstration on demonstration field**	**Yes** Demonstration field can be provided for soil monitoring.. **Proposal: Demonstration on demonstration field**
F6	Measure the needs of fertilization with high spatial precision	Cerals Grass	Sensor Drone	**Yes** Demonstration field can be provided for nutrient monitoring. Only grass fields available on AS09 week. **Proposal: Demonstration on demonstration field added with exhibition presentation**	**Yes** Demonstration field can be provided for nutrient monitoring. **Proposal: Demonstration on demonstration field added with exhibition room presentation**	**Yes** Demonstration field can be provided for nutrient monitoring. **Proposal: Demonstration on demonstration field added with exhibition room presentation**
F7	DSS for decision about when to fertilize	Cerals Grass		**Yes** Demonstration field can be provided for soil monitoring. Only grass fields available on AS09 week. **Proposal: Demonstration on demonstration field added with exhibition presentation based on summer's growing season data**	**Yes** Demonstration field can be provided for soil monitoring. **Proposal: Demonstration on demonstration field added with exhibition room**	**Yes** Demonstration field can be provided for soil monitoring. **Proposal: Demonstration on demonstration field added with exhibition room**
F8	Outdoor livestock location tracking	Livestock grazing	Sensor Drone	**Yes** There is a pasture reserved for demonstrator farm's young cattle. **Proposal: Demonstration on grazing demo site**	**Yes** **Proposal: Demonstration on grazing demo site**	**Yes** **Proposal: Demonstration on grazing demo site**
F9	Detection of livestock heat	Livestock grazing	Sensor	Yes There is a pasture reserved for demonstrator farm's young cattle. **Proposal: Demonstration on grazing demo site**	**Yes** **Proposal: Demonstration in exhibition room with real data gathered**	**Yes** **Proposal: Demonstration in exhibition room with real data gathered**
F10	Detection of livestock calving	Livestock grazing	Sensor	**Yes** Only young cattle grazing. Calving moment is hard to arrange… **Proposal1: Demonstrate in exhibition room as lab concept, barn's cows can be used for sensoring and data gathering**	**Yes** **Proposal: Demonstration in exhibition room with real data gathered**	**Yes** **Proposal: Demonstration in exhibition room with real data gathered**
F11	Detection of livestock rumination and eating	Livestock grazing	Sensor Camera	**Yes** Barn cows available for demonstration. **Proposal1: Demonstrate in exhibition room as lab concept, barn's cows can**	**Yes** **Proposal: Demonstrator on grazing field added with exhibition room with real data**	**Yes** **Proposal: Demonstrator on grazing field added with exhibition room with real data**

				be used for sensoring and data gathering		
F12	Determination of livestock growth rate	Livestock	Sensor Camera	**No** **Proposal1: Demonstrate in exhibition as lab concept in exhibition, barn's cows can be used for sensoring and data gathering**	**Yes** **Proposal: Demonstrate in fattening farm area**	**Yes** **Proposal: Demonstrate in fattening farm area**
F13	Inference of the livestock habits patterns for health and reproduction	Livestock grazing	Sensor Camera	**No** Barn cows available for demonstration. **Proposal1: Demonstrate in exhibition room as lab concept, barn's cows can be used for sensoring and data gathering**	**Yes** **Proposal: Demonstrator on grazing field added with exhibition room with real data**	**Yes** **Proposal: Demonstrator on grazing field added with exhibition room with real data**
F14	Measure field water content/vigour	Vineyard Horticulture	Sensor Drone	**Yes** Demonstration field can be provided for soil monitoring. Only grass fields available on AS09 week. **Proposal: Demonstration on demonstration field**	**Yes** **Proposal: Demonstrator on demo field**	**Yes** Demonstration field can be provided for soil monitoring. **Proposal: Demonstrator on demo field**
F15	Measure water stress	Vineyard Horticulture	Sensor Drone	**Yes** Demonstration field can be provided for soil monitoring. Only grass fields available on AS09 week. **Proposal: Demonstration on demonstration field**	**Yes** **Proposal:Demonstration field can be provided for soil monitoring.**	**Yes** **Proposal: Demonstration on demonstration field**
F16	DSS for decision about how much water	Vineyard Horticulture		**Yes** Demonstration field can be provided for soil monitoring. Only grass fields available on AS09 week. **Proposal: Demonstration on demonstration field**	**Yes** Other plants available depending of final date **Proposal: Demonstration on demonstration field**	**Yes** Demonstration field can be provided for soil monitoring. **Proposal: Demonstration on demonstration field**
F17	Automatic actuation on rooftop (open,close)	Greenhouse	Actuator	**No** greenhouse available. Small temporary one can be arranged. **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**No** Demonstration field can be provided for soil monitoring.	**No** greenhouse available. **Proposal 1: Demonstrate in exhibition room as lab concept supported with real data Proposal 2: Demonstrate remotely with AS05**
F18	monitor greenhouse temperature and humidity	Greenhouse	Sensor	**No** greenhouse available. Small temporary one can be arranged.	**No**	**No** greenhouse available

				Proposal: Demonstrate in exhibition as lab concept supported with real data	**Proposal: Demonstrate in exhibition as lab concept supported with real data**	**Proposal 1: Demonstrate in exhibition room as lab concept supported with real data Proposal 2: Demonstrate remotely with AS05**
F19	Using actuators, irrigate with correct amount and location	Greenhouse	Sensor Actuator	**No** greenhouse available. Small temporary one can be arranged. **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**No** greenhouse available **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**No** greenhouse available. **Proposal 1: Demonstrate in exhibition room as lab concept supported with real data Proposal 2: Demonstrate remotely with AS05**
F20	Detect plant illness (imaginary near infrared)	Greenhouse	Sensor Camera	**No** greenhouse available. Small temporary one can be arranged. **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**No** greenhouse available **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**No** greenhouse available **Proposal 1: Demonstrate in exhibition room as lab concept supported with real data Proposal 2: Demonstrate remotely with AS05**
F21	Monitor Gases	Indoor facility	Sensor	**Yes** Barn can be used for IAQ monitoring **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**Yes** Fattening farm area **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**Yes** **Proposal: Demonstrate in …………**
F22	NIR silage analysis for nutrient composition	Silage	Sensor	**Yes** Local silage piles available for measurements. **Proposal: Demonstration on TMR corner**	**Yes** Local silage piles available for measurements. **Proposal: Demonstration silage**	**Yes** Local silage piles available for measurements. **Proposal: Demonstration ….**
F23	Livestock indoor positioning	Livestock Indoor facility	Sensor	Barn cows can be used for sensoring **Proposal: Demonstrate in exhibition as lab concept supported with real data from barn**	**Yes** Fattening farm area **Proposal: Demonstrate on the field added by exhibition room**	**Yes** Fattening farm area **Proposal: Demonstrate on the field added by exhibition room**
F24	Livestock identification	Livestock Indoor facility	Sensor	**Yes** Barn cows can be used for sensoring **Proposal: Demonstrate in exhibition as lab concept supported with real data from barn**	**Yes** Fattening farm area **Proposal: Demonstrate on the field added by exhibition room**	**Yes** Fattening farm area **Proposal: Demonstrate on the field added by exhibition room**
F25	Nutrition monitoring through rumen scanning	Livestock Indoor facility	Sensor 3D scanner	**Yes** Barn cows can be used for sensoring **Proposal: Demonstrate in exhibition as lab concept supported with real data**	**Yes** **Proposal: Demonstrate in exhibition room as lab concept supported with real data**	**Yes** **Proposal: Demonstrate in exhibition room as lab concept supported with real data**

F26	Extract and analyze data from milking robots	Dairy cattle Milky robots		**Yes** Milking robots can be used for sensoring, the real implementation must be discussed carefully. **Proposal: Demonstrate in exhibition as lab concept supported with real data / real milk**	**No** **Proposal: Demonstrate in exhibition room as lab concept supported with real data / real milk**	**Yes** **Proposal: Demonstrate in exhibition room as lab concept supported with real data / real milk**
F27	Livestock digestion monitoring	Livestock	Ruminal probes	**No** Ruminal probes require the application of animal testing permission, which is possible only if the probe is already quite final. We are very late for that process already now. **Proposal: Demonstrate in exhibition as lab concept**	**No** Proposal: Demonstrate in exhibition as lab concept	**No** Proposal: Demonstrate in exhibition as lab concept
F28	Feet management: tracking of farm vehicles	Vehicles	Sensor	**Yes** Farm vehicles can be used for demonstration, provided that there's not much interference for the normal farm duties **Proposal: Demonstrate in exhibition using map UI**	**Yes** Farm vehicles can be used for demonstration, provided that there's not much interference for the normal farm duties **Proposal: Demonstrate in exhibition using map UI**	**Yes** Farm vehicles can be used for demonstration, provided that there's not much interference for the normal farm duties **Proposal: Demonstrate in exhibition using map UI**

5.2. Demonstration sites' implementation planning

This section describes the evolution of the AFarCloud functionalities in each local demonstration site over the lifecycle of the project. Functionalities are gradually implemented and validates over the years as described in the following subsections. As described in Section 5.1 and Section 2, the gradual implementation of each year's functionality will be deployed and evaluated in the holistic demonstration of this year.

5.2.1. AS01

Table 20- AS01 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.	Demonstrations of drone missions with use of NIR camera(locally) (same as in AS02). That will provide experimental measurements for F1	Collecting of data for the Y2 full season. Integration with AFarCloud	Full tests
For both F1 and F2	Integration of legacy WSN sensors, for data collection and calibration		
F2: DSS for deciding about if it will be frost or not …..	Gathering requirements for DSS	Development of DSS for deciding about if it will be frost or not	Full tests

F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.

Monitoring will be done by using autonomous RUAV's using multispectral camera. In Y1 those components will be developed and tried including obtaining NIR images. in Y2 data from RUAV missions will be systematically collected (multispectral images) for full season. Functions will be integrated with the cloud. In Y3 data for Y3 collected, compared to Y2 results, monitoring functions tested in full operation (including Data Analysis, User Interface, Mission planning) from AFarCloud

F2: DSS for deciding about if it will be frost or not

In Y1 will be collected configuration data (regarding fields, historical results, etc) and requirements for DSS in Y2 DSS will be developed. In Y3 DSS will tested in full operation (using the monitoring data from F1) .

5.2.2. AS02

Table 21 - AS02 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F3: Monitor cereals Nutrients (energy, protein and humidity analysis)	Demonstrations of drone autonomous missions (Local) with experimental use of sensors (multispectral images), (same functions as in AS01)	Collection of multispectral images for all fields	Full scale data collection for Y3 Testing with AFarCloud platform
F4: Using DSS take decision regarding when and where to harvest	Gathering requirements for DSS	Development of DSS	Full scale testing of DSS

F3: Monitor cereals Nutrients (energy, protein and humidity analysis)

Monitoring will be done by using autonomous RUAV's using multispectral camera. In Y1 those components will be developed and tried including obtaining NIR images. in Y2 data from RUAV missions will be systematically collected (multispectral images) for full season. Functions integrated with the cloud. In Y3 data for Y3 collected, compared to Y2 results, monitoring functions tested in full operation (including Data Analysis, User Interface, Mission planning) from AFarCloud

F4: Using DSS take decision regarding when and where to harvest

In Y1 will be collected configuration data for DSS (fields, crops, historical results, etc.) and requirements for DSS. In Y2 DSS will be developed. In Y3 DSS will tested in full operation (using the monitoring data from F3)

5.2.3. AS03

Table 22 - AS03 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.	Data gathering	Data analysis and integration/fusion	Reasoning on evaporation, soil wetness, frost for DSS
F3: Monitor cereals Nutrients (energy, protein and humidity analysis)	Data gathering with manual methods in parallel to observations with UAVs	Sensor integration and communication to the Cloud	Data analysis and measuring models verification
F4: Using DSS take decision regarding when and where to harvest	Investigate relevant methods to investigate harvesting windows	Doing tests with methods and fusion of RS and ins situ methods	Contribution to F4: DSS
F5: Monitor NPK	In situ or Remote Sensing (RS) methods	Correlation with measures outcome of harvest	Contribution to F4: DSS
F6: Measure the needs of fertilization with high spatial precision	Implement UAV RS for measurement of low grow related to low fertilizer	Investigate the possibility to do this with 3D hyper spectral scanner	Contribution to F4: DSS
F7: DSS for decision about when to fertilize	Data sensor fusion to identify spatial dynamics in fields	Correlation between measured differences in crop related to soil factors	System for advice about where, when and what fertilizers to apply
F8: Livestock location tracking	Improving the knowledge on the whereabouts of mobile assets, and their operational modus.	Improve well-being of livestock through more knowledge on behaviour and habits	UAV systems for Search and Rescue of animals
F14: Measure field water content/vigor	Investigate in situ vs UAV and RS methods to measure field water/wetness	Investigate need for irrigation and drivability in different fields related to field water and soil	Support management of cultivating procedures and management

F15: Measure water stress	Investigating relevant methods to measure soil water and plant identified water stress	Measuring soil water and plant identified water stress	Support DSS for management of irrigation and under drainage
F16: DSS for decision about how much water	Investigate relevant models to measure water related stress	Investigate the usability of different methods for identifying water stress. Identify problems with under drainage systems	Support DSS for management of irrigation and under drainage
F28: Fleet management: tracking of farm vehicles	Provide access to UNIBUS vehicles	Provide early experiment to guide fleet 3.3.3	Support implementation fleet management systems

F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.

- During Y1: Collection data of temperature moisture wind, solar influx, air pressure in resolution and detail as possible with available multi sensor probes
- During Y2: Analysis of data series and integration with soil moisture values
- During Y3: Reasoning about evaporation, soil wetness and frost for DSS

F3: Monitor cereals Nutrients (energy, protein and humidity analysis)

- During Y1: Data collection with manual methods in parallel to observations with UAVs
- During Y2: Sensor integration manual tests with UAV data to the Cloud
- During Y3: Data analysis and measuring methods and models verification

F4: Using DSS take decision regarding when and where to harvest

- During Y1: Identify relevant parameters to decide suitability in entering into fields with heavy machines like tractors or harvesters. Start collecting stable factors like soils, steepness or other factors
- During Y2: During Y2: Collect dynamic data like weather and status of the crop
- During Y3: Combining those factors to be integreated in a DSS for harvesting Window

F5: Monitor NPK

Today manual soil samples are selected to find out the pool of NPK in the soil. Sensors that measure the content based on observation from a tractor or observations from UAVs are suggested to observe signs in deficiencies in macro and micro minerals.

- During Y1: Initial collection of manual collected data and sensor data from UAVs Investigate relevant methods for NPK measurement Samples or sensors on tractors or UAV
- During Y2: Collect and compare the NPK models in relation to harvested outcome
- During Y3: Monitor and evaluate the result of the measurement methods to find a reasonable mix

F6: Measure the needs of fertilization with high spatial precision

- During Y1 : Find out if the spatial dynamic in and between the fields is so big that these measurements should be made with high spatial precision.
- During Y2: Identify anomalies and possible causes in the relation between outcome and nutrients by weighting the harvest in the harvester and add quality parameters
- During Y3: How can actuators like manure spreaders be supported by calculated need for fertilizers

F7: DSS for decision about when to fertilize

- During Y1: Adjust the model depending of what type of manure that is used with respect to risk for nutrient losses
- During Y2: Modify the model according possible unbalance between N,P,K and other nutrients
- During Y3: Include all those parameters in the model and evaluate the outcome. Contribute to System for advice about where, when and what fertilizers to apply

F8: Livestock location tracking

Daily inspections of animals in a herd on feed are time-consuming and ineffective. Could monitoring be made with sensors on the cows or by sensors from UAV this should improve animal safety and health. By also register movements that differ from the normal signs of illness can be observed early and treatment introduced. Knowledge of moving patterns can also be used for planning of feed and improvement of fences to prevent the animals from escape.

- During Y1: Improving the knowledge on the whereabouts of mobile assets, and their operational modus of a collar worn by the cattle to collect accelerometer and gyroscope data
- During Y2: Improve well-being of livestock through more knowledge on behaviour and habits Training data is time-code synced with video footage. An on-board analytics library, that after training classify behaviour types. The behaviours is transferred to AFarCloud servers.
- During Y3: Implement equipment also carries the client hardware, but with added GPS/GNSS hardware. Connectivity is tested via LoRa radio, only position data for AS03. (also recording vehicle “behaviour” is targeting for Y2-3 demonstrators).

F:14 F:15 Measure field water content/vigour / Measure water stress

- During Y1:
  - Application of Soil sensors and preliminary collection of data, correlate with precipitation and added irrigation water
  - Drones sensor collection of soil wetness and signs of crop damages
  - Estimation of geo-referenced NDVI data integrated on a map database to be compared with wetness and climate parameters.
- During Y2:
  - Data processing of wetness data from the soil sensors. Try to find the relation between added water, water absorbed by the vegetation and losses like evaporated water and run off
  - Cross validation with other in situ data
  - Cross validation with drone sensor images (Hyper-spectral or IR)
- During Y3:
  - Validation of the processed data gathered from soil sensors related to soil.
  - Validation of in situ crop measurements related to dry/wet conditions
  - Validation of drone data in relation to wet/dry conditions and yield
  - Contribution with data to builders of DSS for crop cultivation

F16: DSS for decision about how much water

A DSS for how much water that should be added or drained from the fields and to the crop must include all the factors for understanding what is needed by the crop in relation to the evaporation, consumption of the plants available nutrients etc.

- During Y1: Investigate relevant models to measure water related stress.
- During Y2: Investigate the usability of different methods for identifying water stress. Identify problems with under drainage systems in open fields.
- During Y3: Support design of DSS for management of irrigation and drainage systems in open fields

F28: Fleet management: tracking of farm vehicles

- During Y1: Investigation to what extent existing systems on the tractors can be used to monitor their moments and fuel consumption and what additional systems can contribute with. Monitor vehicle movement over LPWAN networking, using line-simplification algorithms. A tracking device for positioning data is developed and data collected on-device, allowing routing data to be sent over a LPWAN network (LoRa WAN) with limited bandwidth.

- During Y2: Evaluate the driving habits and contribute to those that want to build a model of the use of vehicles in agriculture and estimate possible benefits that could be found by introducing a fleet management system.

- During Y3: Estimate potential benefits by calculation transports and movements in the fields, between fields and for other transports

5.2.4. AS04

Table 23 - AS04 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F19: Measure field water content/vigour	Soil sensors deployment integration and communication to cloud. Preliminary gathering and processing data with drone sensors onboard	Data analysis in order to provide the first results of the gathered data.	Validation of the data comparing the Y3 vs Y1 and Y2.
F20: Measure water stress	Preliminary gathering and processing data with drone sensors onboard.	Analysis of the vegetation index	Validation of the data comparing the Y3 vs Y1 and Y2.

F19: Measure field water content/vigour

- During Y1:
  - Soil sensors physical deployment and preliminary gathering data.
  - Drones flights to collect images of the crop with regard to the evolution of the crop.
  - Generation of the georeferenced multispectral mosaic.
  - Estimation of the NDVI in a mosaic.
  - Preliminary version of clustering algorithms based on area.

- During Y2:
  - Data processing from the soil sensors.
  - Drone flights to collect images of the crop with regard to the evolution of the crop.
  - Development of dead plant algorithms based on an image processing software.
  - Development of weed algorithms based on an image processing software.
  - Final version of clustering algorithms.

  - Development of the preliminary communication protocols between the Computer Vision Platform and the Semantic Middleware.

- During Y3:
  - Validation of the processed data gathered from soil sensors.
  - Drone flights to collect images of the crop with regard to the evolution of the crop.
  - Final review of dead plant algorithms based on an image processing software.
  - Final review of weed algorithms based on an image processing software.
  - Final review of clustering algorithms.
  - Development of the final review of the communication protocols between the Computer Vision Platform and the Semantic Middleware.

F20: Measure water stress

- During Y1:
  - Drone flights to collect images of the crop with regard to the evolution of the crop.
  - Generation of the georeferenced thermal mosaic.
  - Preliminary version of clustering algorithms based on area.

- During Y2:
  - Drone flights to collect images of the crop with regard to the evolution of the crop.
  - Development of the water stress estimation algorithms based on the CWSI parameter.
  - Final version of clustering algorithms.
  - Development of the preliminary communication protocols between the Computer Vision Platform and the Semantic Middleware.

- During Y3:
  - Drone flights to collect images of the crop with regard to the evolution of the crop.
  - Final review of the water stress algorithms based on the CWSI parameter.
  - Final review of clustering algorithms.
  - Development of the final review of the communication protocols between the Computer Vision Platform and the Semantic Middleware.

The following figure shows the AS04 timeline:

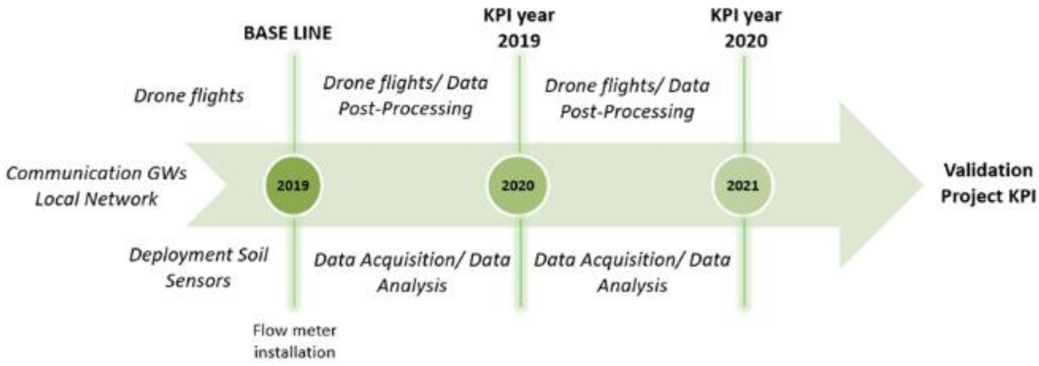


Figure 57. AS04 Timeline overview

5.2.5. AS05

Table 24 - AS05 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F14: Measure field water content/vigour	Installation of sensors and data acquisition	Data acquisition and comparison of Y1 vs Y2	Data acquisition and evaluation of water savings
F17: Automatic actuation on rooftop (open,close)		Installation of automatic inflation and deflation system	Optimization of actuator driver algorithm and evaluation of man-hours saved
F18: "monitor greenhouse temperature and humidity and quality of the air	Installation of sensors and data acquisition	data acquisition and comparison for temperature constant level maintenance	data acquisition and comparison for temperature constant level maintenance
F19: Using actuators, irrigate with correct amount and location	Test with NTP device for sanification, installation of actuators in the irrigation system.	Data acquisition and comparison of Y1 vs Y2 and productivity first comparison with manual irrigation system.	Data acquisition and productivity evaluation with respect to humidity and temperature
F20: Detect plant illness (imaginary near infrarred)			Using Visual Camera for Plant Illness detection

5.2.6. AS06

Table 25 - AS06 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F8: Livestock location tracking	Map positioning and visualization via AFarCloud app	Map positioning and visualization via AFarCloud app. Creation of enclosures	Map positioning and visualization via AFarCloud app. Creation of geofencing rules
F9: Detection of livestock heat	Visualisation of cows in heat on the map	Visualisation of cows in heat on the map	Visualisation of cows in heat on the map
F10: Detection of livestock calving	Visualisation of calving cows on the map	Visualisation of calving cows on the map	Visualisation of calving cows on the map
F11: Detection of livestock rumination and eating	Off line data gathering	Identification of rumination and eating and data storage in AFarCloud cloud repositories	Visualization of rumination and eating activity
F13: Inference of the livestock habits patterns for health and reproduction	Off line data gathering	Data storage in AFarCloud cloud repositories	Creation of anomaly rules

F8: Livestock location tracking

During Y1 an API will be created to communicate with the AFarCloud platform and the animal location will be displayed on a map. During Y2 the farmer will be able to create the secure areas and in Y3 he will be able to create also geofencing rules that will automatically notify the farmer via mobile phone, tablet, and/or computer in case of anomaly

F9: Detection of livestock heat and **F10: Detection of livestock calving**

The functionality will be based on the same collar. The algorithms will compute animal location and activity. These algorithms for the heat detection and calving are part of SensoWave's background prior to the AFarCloud project, so that it will work during the project in its integration in AFC. The visualization application used for the location will show if any animal is in heat or in calving.

F11: Detection of livestock rumination and eating

During the first year, data will be collected for subsequent labelling. In Y2 you will have a first version of the classified algorithm to be validated and in Y3 the farmer can see the time the animal has been eating and ruminating

F13: Inference of the livestock habits patterns for health and reproduction

In Y1 gather data through its collar device. Later an on-board analytics library will be developed and it will be evaluated its integration with the SensoWave's collar.
Once heat, calving, rumination and eating are validated in Y2, animals will be more characterized in their daily routines. F18 will take advantage of these data and will generate notifications if the previous patters are broken in Y3.
Somehow, F18 is an improvement of the previous functionalities by developing a new anomaly detection algorithm based on the previous functionalities.

5.2.7. AS07

Table 26 - AS06 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast	Transfer environmental data from LoRa sensors temperature, humidity, CO2 to IMALoRaWAN cloud Azure server. Data will be stored, managed, and analyzed to monitor the status of the environment, data visualization and transfer to SensLog (UWB/LESP server). Monitoring outdoor meteo conditions, transfer to Senslog, visualisation	Monitor temperature and humidity in farmer buildings to ensure a healthy environment, comfortable indoor spaces for animals and people. Continuous monitoring meteo outdoor meteo conditions, transfer to Senslog, visualisation, connection to weather forecast system	Continuous monitoring meteo outdoor meteo conditions, transfer to Senslog, visualisation, including weather forecast system
F27: Livestock digestion monitoring	Ruminal probes for the transmission of emulated data (temperature, pH, redox). A base station will produce data in CSV format and send them out overall serial line (RS232). The data will be forwarded into the cloud. Data transmitting from collar sensors to SensLog.	Continuous monitoring of rumen parameters. Sensor integration and communication to cloud.	Presentation of completed ruminal sensors. The collected data will be analyzed and presented in a user-friendly way.
F14: Measure field water content/vigour	Monitoring field water content/vigour conditions, transfer to Senslog, visualisation	Continuous monitoring of field water content/vigour.	Continuous monitoring of field water content/vigour.

5.2.8. AS08

Table 27 - AS08 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F3: Monitor cereals Nutrients (energy, protein and humidity analysis)	Prepare algorithms	First data from AS03. Analyse Data analysis	Full operation Validation of data
F21: Monitoring of gasses	CO2 sensor integration and communication to the cloud	Sensors for other gases	Full operation
F26: Extract and analyse data from milking robots …..	Extract data from milking robot Lely Astronout A4	Analyse data from milking robot - DAC tasks - IMCS tasks	Full operation

F3: Monitor cereals Nutrients (energy, protein and humidity analysis)

Function F3 in AS08 is developed only as an information link for the scenario AS02. In Y1 no data yet available from AS02.So the function development is planned in Y1.. In Y2 first data from AS02is available. Data analysis algorithms are tested. In Y3 full operation is performed including testing and data validation.

F21: Monitoring of gasses

In Y1 Monitoring for CO_2 gas will be provided. In Y2 monitoring for other gases (NH_3, H_2S) will be provided. In Y3 testing of fully developed function

F26: Extract and analyse data from milking robots

In Y1 data extraction from milking robot Lely Astronout A4 will be provided and exploration of available data. In Y2 data analysis from milking robot Astronout A4 will be provided for (DAC tasks, IMCS tasks). In Y3 testing of fully developed function.

5.2.9. AS09

Table 28 - AS09 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F22: NIR silage analysis	Sensor integration and communication to cloud	Data analysis and user interaction, enhanced calibration	Reasoning and integration to the recipe DSS and TMR equipment
F03: Detection of cereals nutrients composition (energy, protein and humidity analysis)	initial testing with the 1st POC, initial calibration and collaboration with the UGV	Enhanced UGV/sensor integration, mission management. Evolved data analytics and accuracy, possibly tests with drones	Final version with finalized UI and automated mission management.
F23: Livestock indoor positioning	initial testing and feasibility analysis	Enhanced accuracy and user interface	data analytics for long-term positioning
F24: Livestock identification	Deployment, aim is to finalize the technology. Only small antenna-based adjustments for next years		
F25: Nutrition monitoring through rumen scanning	Initial feasibility test with the selected technology	installation to the milking station and data gathering, data analytics	enhanced data analytics and UI + automated alert functions.

F22: NIR silage analysis

High-level objective is to provide real-time nutrient data for the farmer so, that he can adjust the ration mix recipe accordingly. The nutrition analyser will be a wireless handheld device, mobile phone acts as UI and GW and the data will be processed in the dedicated cloud backend provided by Spectral Engines. In the Y1 version, farmer makes the measurement manually before TMR mixing, and the data is transferred also to the AFarCloud repository. The ultimate target is also to provide the data from AFarCloud repository to the TMR recipe solver SW, but that will be considered during the next versions.

F03: Detection of cereals nutrients composition (energy, protein and humidity analysis)

There is an urgent need for near real-time solution to provide critical parameters for the decision support for the farmer. The most sophisticated version would be able to monitor the growing process in different fields, and taken the weather forecasts into account, would then provide an estimation of optimal harvest date and the field sector order for the farmer. Then the sensor device would be attached to the drone, which can transport it over the fields along the defined sampling mission.

In this Y1 version, the dedicated hybrid sensor device is constructed, and the main goal is to make measurements in field environment and gather data for the calibration.

F23: Livestock indoor positioning

This section explains the technical functionalities of cow indoor positioning. Motivation behind is explained shortly by the number of cows. As the transition to hundreds of cows per farm has been rapid, it is often hard to find a particular individual in the freestall barn, where animals walk freely around the large building.

Centria has developed an UWB-based solution for the animal indoor positioning. This Time of Flight (TOF) -based system consists of number of anchor nodes attached to walls and a collar node transmitting the signal. The new version of the measurement method has been developed during Y1, and the new version with dramatically lower power consumption will be presented in the Y1 demonstration.

F24 Livestock identification

All cows in the demonstration farm have an eTag in their left ear. This passive tag contains ISO 11784 –compliant 64-bit ID, which is accessed at less than 40 cm distance in normal circumstances. This ID allows an open approach for animal identification. Milking robots identify animals using their own standards, but this information is hard to get out from the system real-time.

F25 Nutrition monitoring through rumen scanning

The Y1 demonstration will be detached from the milking station, and the fake surface will be used. That, in turn, allows also more comfortable demonstration of the overall idea in free and clean environment than when attached to the robot in the barn, when few people can actually see it. The ultimate plan is to reach analytic level, where rumen fill can be described with standard 1-5 scoring, and also automatic alarms can be generated, if sudden change over threshold is identified. The coming project years reveal, how close the development approaches these targets. This Y1 version focuses solely on the scanning method itself and the low-level data processing related to it using fake surfaces. Also the collaboration with AFarCloud farm gateway, animal ID metadata from F30 and UI creation is considered as much possible.

5.2.10. AS10

Table 29 - AS10 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F8: Outdoor livestock location tracking	Map positioning and visualization via app in the AFarCloud	Map positioning and visualization via app in the AFarCloud. Creation of enclosures in AFarCloud	Map positioning and visualization via app in the AFarCloud. Creation of geofencing rules
F9: Detection of livestock heat	Visualisation of cows in heat on the map	Visualisation of cows in heat on the map	Visualisation of cows in heat on the map
F10: Detection of livestock calving	Visualisation of calving cows on the map	Visualisation of calving cows on the map	Visualisation of calving cows on the map
F11: Detection of livestock rumination and eating	Visualisation of calving cows on the map	Visualisation of calving cows on the map	Visualisation of calving cows on the map
F12: Determination of livestock growth rate	Off line data gathering	Identification of rumination and eating and data storing in the AFarCloud	Visualization of rumination and eating activity in the AFarCloud
F13: Inference of the livestock habits patterns for health and reproduction	Off line data gathering	Data storing in the AFarCloud	Creation of anomaly rules

F8: Livestock location tracking

During Y1 an API will be created to communicate with the AFarCloud platform and the animal location will be displayed on a map. During Y2 the farmer will be able to create the secure areas and in Y3 he will be able to create also geofencing rules that will automatically notify the farmer via mobile phone, tablet, and/or computer in case of anomaly

F9: Detection of livestock heat and **F10: Detection of livestock calving**

The functionality will be based on the same collar. The algorithms will compute animal location and activity. These algorithms for the heat detection and calving are part of Sensowave's background prior to the AFarCloud project, so that it will work during the project in its integration in AFC. The visualization application used for the location will show if any animal is in heat or in calving.

F11: Detection of livestock rumination and eating

During the first year, data will be collected for subsequent labelling. In Y2 you will have a first version of the classified algorithm to be validated and in Y3 the farmer can see the time the animal has been eating and ruminating.

F12: Determination of livestock growth rate

This functionality will provide an algorithm to estimate the weight of the animal.

F13: Inference of the livestock habits patterns for health and reproduction

In Y1 gather data through its collar device. Later an on-board analytics library will be develop and it will be evaluated its integration with the Sensowave's collar.
Once heat, calving, rumination and eating are validated in Y2, animals will be more characterized in their daily routines. F18 will take advantage of these data and will generate notifications if the previous patters are broken in Y3.
Somehow, F18 is an improvement of the previous functionalities by developing a new anomaly detection algorithm based on the previous functionalities.

5.2.11. AS11

Table 30 - AS11 functionality planning for yearly demonstrations

FUNCTIONALITY	Y1	Y2	Y3
F1: Monitor environment: temperature (ambient, and the plant), wind, and weather forecast.	Sensor installation and communication to cloud	Data analysis and parameters to be linked to production	Reasoning on DSS functions to forecast production parameters correction
F8: Livestock location tracking		Map positioning and visualization via app in the AFarCloud	Map positioning and visualization via app in the AFarCloud. Creation of enclosures in AFarCloud
F9: Detection of livestock heat		Visualisation of cows in heat on the map	Visualisation of cows in heat on the map
F10: Detection of livestock calving		Visualisation of calving cows on the map	Visualisation of calving cows on the map
F11: Detection of livestock rumination and eating		Visualisation of calving cows on the map	Visualisation of calving cows on the map
F14: Measure field water content/vigour	Sensor installation and communication to cloud	Data analysis and parameters to be linked to production	Reasoning on DSS functions to forecast production parameters correction
F28: Fleet management: tracking of farm vehicles		Sensor installation and communication to cloud	Data analysis and comparison in respect to Y2 to measure benefits of new field management

Y1 or Y2 are needed to create the baseline for the single functions; the next year is needed to validate the choice of parameters and to test the first decision on the strategy to control the function in an active way, using DSS or simple functions as a function of problem complexity. Year 3 is needed to validate the DSS decisions and to check for increment in production or in losses reduction both in horticulture, crop and livestock.

6. Conclusions

AFarCloud aims to be a distributed platform for autonomous farming that will allow the integration of agriculture Cyber Physical Systems in real-time in order to increase efficiency, productivity, animal health, food quality and reduce farm labor costs. It will provide farmers with an integrated farm management software and support monitoring and decision-making solutions. The lack of interoperability of current solutions, just available for specific tasks, causes additional work and costs without the ability to create a holistic view of agricultural processes. Therefore it is justified the existing need for a holistic and systematic approach, whose purpose is to facilitate the development of technologies and services matching the requirements of the several users involved.

This document, together with the specification of user requirements, is therefore key to the successful execution of the project, since it explains the aforementioned holistic approach, also as part of the demonstration strategy, as well as the set of functionalities to be offered to the users, which in this case are the farmers. These functionalities have been chosen together with the demonstrator leaders and the farmers, based on the nature and characteristics of the farms represented in the project. While it is true that other functionalities may exist, the objective of the project is to include only the functionalities that are primordial in the project's farms. Having said this, it is proven that the most important functionalities are included, through their direct relationship with the objectives of the project, which are clearly recognized by the sector. The document has described the overall strategy and planning of the AFarCloud project's demonstration. It includes crucial information for the whole project and consortium, mainly including: a) the demonstration sites (i.e., the farms), their goals, scope and logistics/regulatory information, b) the project's demonstration goals, functionalities and KPIs, c) the functionalities for each demonstrator, d) the implementation planning for each demonstrator and e) the overall strategy from local demonstrators to each year's holistic demonstration. This deliverable along with D7.2 "Verification and Validation methods" establishes the grounds for the whole consortium to work efficiently towards the successful planning, implementation and evaluation of the AFarCloud project's demonstrators.

ANNEX AS01 – The Frost versus Frosty

The Frost versus Frosty or Radiation Frost.

There are two natural phenomena affecting plants by cold – the frost and radiation frosts or frosty. Both of them are means cold but they have absolutely different physics. The frost arise when cold air (<<0ºC) massive flows in the particular region brings cold and freezing everything around – It's typical for winter time in the North or intermediate regions like Baltics-Lithuania, Latvia, Estonia, north of Poland etc. The frost is not highly dangerous for vegetation because plants are prepared for winter they are in deep hibernation or other biological state with very slow metabolisms and high resistance to cold.

Frosty (radiation frosts) are one of the most dangerous phenomena strongly affecting plants because frosty can occur in spring or even in summertime if appropriate meteorological circumstances arise. The main prerequisites of frosty are:

- Windless – no air movement;
- Dry air (absolute humidity is very low – quick temperature fall initially don't cause condensation);
- Clear sky without clouds – infrared rays from the ground are not reflected back.

In other words frosty or radiation frost occurs when amount of heat radiated from the plant exceeds amount of heat supplied by air movement (not moving air is good heat isolator) around the plant.

Frosty can occur even when surrounding air temperature are essentially above 0ºC. It is well known that air temperature during the frosty could stay +5ºC while leaves of plant could be down about -7ºC. The nature of frosty is even more surprising. Radiation frost occurs hardly ever in large areas; it usually appears as smaller or larger spots in the whole field. Nevertheless these spots of frosty (frozen plants) could make tremendous impact on the yield and farmers business accordingly.

Plant protection against radiation frost is complicated because there no need to identify existing frost – it's too late. Identification of probability of radiation frosts must be proactive; farmer have to know about it appropriate time before temperature of plant bodies becomes dangerous low to deploy appropriate defensive actions (smoke from bonfire, artificial fog, water sprinkling, fan actuation etc.). False forecast is costly.

Existing practices.

Because of nature of Radiation Frosts protection of particular field is challenge. Particular solution is covering the field with nodes of Wireless Sensor Network (WSN) early warning system equipped with:

- Temperature sensor of plant leaves (Close to ground level);
- Temperature sensor of air – located approximately 0.6-1.0m above the ground/plant leaves;
- Relative humidity sensors;
- Wind and wind direction sensors.

The set of the sensors provide comprehensive temperature, wind, and air humidity monitoring and sends control data on minute's bases. These senor data is being routed to some computing facility with implemented algorithms/intelligence for two different temperatures, humidity, and wind mutual behavior Real Time analysis with aim to forecast and evaluate probability of Radiation Frost occurrence. As it is shown in Fig. 55 before radiation frost curves of two temperatures at particular moment intersect. An amount of time later the moment of beginning of frosty is identified by relative humidity; at this moment it finally approaches to 100%.

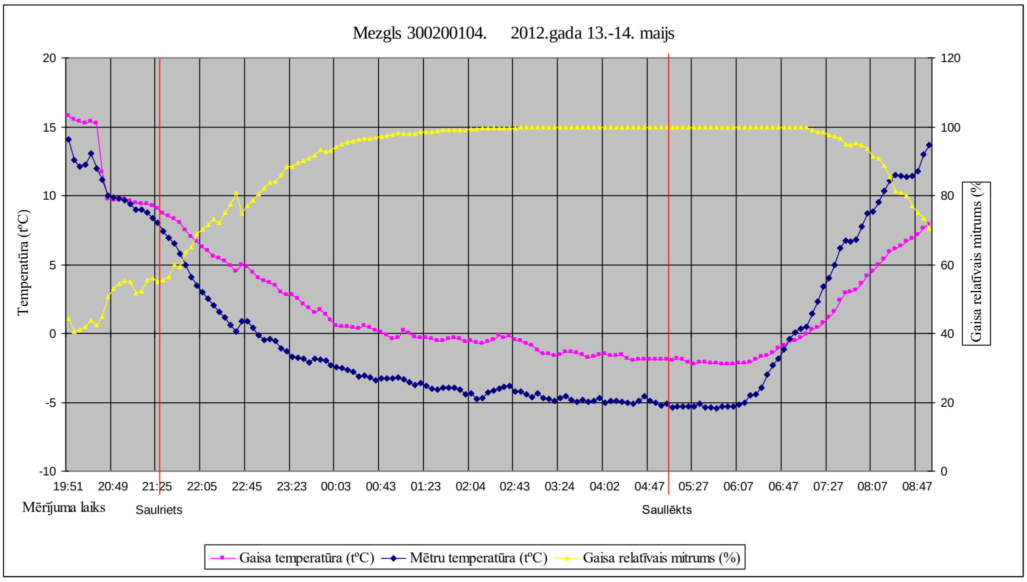


Figure 58 - Curves of temperatures of plant leaves, air 80cm above leaves, relative humidity during a frosty

<u>Drawbacks of WSN frost protection systems.</u>

Because of locality of frosty the main problem is complete coverage of the field. The solution can be some monitoring with aggregate data fusion over the field, nevertheless it could fail, because frosty can take place in small squares around the whole field directly between all WSN nodes, see Fig 56. Amount of fails deployment of WSN based early warning system could make economically non-effective.

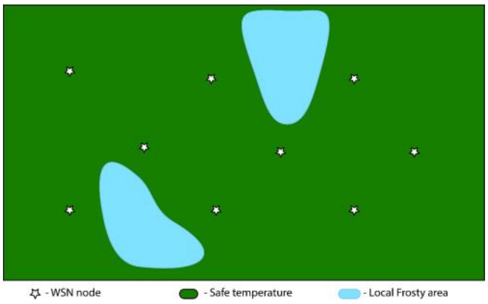


Figure 59 - Local character of Frosty (Radiation Frost)