D2.1 User-centred System Requirements

WP2

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Abstract	This document summarizes end-user requirements collected through questionnaires through Task 2.1 and 7.1. The former directed to the different stakeholders, defined as Category 1-3 users, in the consortium, whereas the latter to the project's demonstration. From a holistic view these two complementary views represent bottom up, and top-down views, which complement each other, also to facilitate the work with the more technical requirements defined in Task 2.2. This document captures also the insights from two other Horizon 2020 projects, DataBio and IoF2020, in order to provide a wider knowledgebase for defining and interpreting the user requirements of the AFarCloud project.

Document History

Version	***Date***	***Contributing partner***	***Contribution***
0.1	9th January 2019	LESP	ToC
0.2	11th February 2019	TECN, INTRA, STM, UPM, MDH, LESP	User-centred requirements methodologies
0.3	12th February 2019	TECN	Summary tables of information gathered from scenario leaders & requirements extraction
0.4	18th February 2019	UPM, AVL-CD	More requirements added, especially from category 2 and 3.
0.5	21th February 2019	MDH, HUA,	The requirements are harmonized.

		TECN	Conclusion is finalized. Texts reviewed.
0.6	26th February 2019	LESP, INTRA, EXODUS, MTECH, BOSONIT, TECN	Completion the T2.1 questionnaire inputs, updating the requirements (by MDH). Section 5, and new requirements added.
0.7	27th February 2019	NURO	Final review
1.0	28th February 2019	MDH	Final corrections

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Definitions and Acronyms

Acronym	***Definition***	***Remark***
DataBio	Data-driven Bioeconomy	https://www.databio.eu/en/
EO	Earth Observation	
DSS	Decision-support system	
HMI	Human-machine interaction	
GNSS	Global navigation satellite system	
IoF2020	Internet of Food and Farm 2020	
ISOBUS	ISO 11783: Tractors and machinery for agriculture and forestry—Serial control and communications data network	
NDVI	Normalized Difference Vegetation Index	
NPK	Nitrogen, Phosphorus, Potassium	Fertiliser
UC	Use case	

1. Introduction

The focus of the task **T2.1 User-centred System Requirements** is to understand the needs of the users that are responsible for the overall management of the operations carried out in a farm, including planning, decision support, and data analysis, as well as environmental monitoring. Also, to understand the needs of the users who are going to interact with the vehicles/UAV, as they will "work on the field" more practically. To extend our knowledge about user requirements, experience from other projects or organisations related to agriculture is considered.

The AFarCloud project will have an impact on various stakeholder groups and some have been identified as future users of the AFarCloud platform. At the first stage of the description of requirements it was necessary to prioritize the users who will have the greatest impact on the definition and development of AFarCloud platform during the project. For this reason, we categorized users into three main groups i.e., (1) farming companies, (2) farming (applied) research institutes including universities, and finally (3) service and technology providers.

Farming companies, especially those that provide the test sites for AFarCloud demonstrator scenarios, are considered to be the users with the highest priority, but it is necessary to consider that activities such as decision support and data analysis are in some cases outsourced. Therefore, we also included the other user groups.

In the first phase of requirements gathering we focus on users who will be able to effectively provide feedback during the early stage of development and testing of the AFarCloud platform. These are users who are members of the AFarCloud Consortium or have a direct link to the members of the consortium. With the advancing activities of the AFarCloud project and the availability of dissemination materials, we are going to focus on wider user base and update the user requirements after performing the first trials.

The deliverable D2.1 is the first output of the T2.1 task. This document will be a living document until the second version, and the process is to discuss the requirements and their implications also after the second and final deliverable. The user requirements of above-mentioned groups will be later reflected in Architecture Requirements and definition (T2.2).

1.1. Document scope

The current document, version 1 of the deliverable, aims at providing user-centric requirements reflecting both the views of the end-users as well as other stakeholders that are located further down in the value chain. In the text below the former is referred to as category 1 users, whereas the latter as the category 2-3 users. The document also provides insights from other initiatives and projects such as Databio and IoF2020, and by that sets the foundations for a more detailed analysis of the requirements throughout the task life time until version 2 at M14.

1.2. Document structure

The document is organised as follows. In Section 2 the methodology used for collecting the requirements is summarized. Section 3 provides the view of the 9 local, and 3 holistic demonstrators. This input from the questionnaires is provided in Task 7.1. Section 4 summarizes the user-centric requirements, whereas Section 5 provides insights from two relevant Horizon 2020 projects. In Section 6 the conclusions are stated, including plausible implications of the two Horizon 2020 projects on the AFarCloud project.

2. User-centred requirements methodologies

The purpose of this section is to examine the different methods in gathering requirements. Requirements are one of the most vital pieces to ensure the success of a system or project, thus the success and the effectiveness of the AFarCloud platform. To ensure the optimal requirements are received, the methods in which those requirements are obtained are equally important.
The first step into this process is to find out, identify and describe who the users of the AFarCloud system would be. One suitable technique for this task is the Persona development.

Persona: A fictional, representative stand-in user for one segment of a systems target audience, helps with making sure you:

- design for the user, not yourself
- see the target users as real people, with real stories
- role-play user behaviour

This preliminary step would better shape the characteristics of the systems' users and ultimately improve the effectiveness of the user requirement gathering process which is the next step of the process. Figure 1, illustrates the different types of requirements. The higher level of requirements are the Business requirements and subsequently User requirements and System requirements. T2.1 focuses on User requirements.

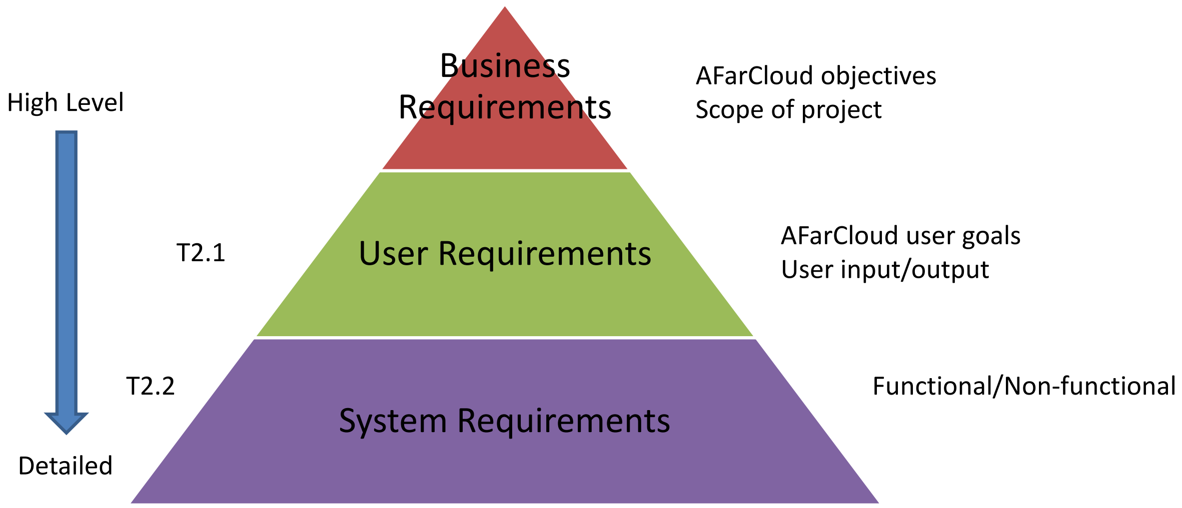

Figure 1: Diagrammatic representation of the different types of requirements

Most observers would agree that many of the errors in developed systems are directly traceable to inadequate efforts in the analysis and design phases of the life cycle. Industry studies show that the majority of systems' problems are based on poor requirements definition. Accurately understanding the users' requirements will help the system-developing team deliver a proper system to the end users. Therefore, for the success and the effectiveness of the AFarCloud platform it is of immense importance to proceed with the process of user requirement gathering in an efficient, coherent and suitable manner, given the limitations that might be implied, in order to address AFarCloud user centred needs.

Next, we describe the users of the AFarCloud system and different methods in user requirement gathering.

2.1. AFarCloud users

In order to gather inputs for D2.1, and more importantly, understand the needs of the different stakeholders, three categories have been identified and a set of questionnaires have been elaborated for each of them:

Category 1: Farming companies. The core of user requirements is focused on **farming companies**, who are considered as main users from our point of view and their requirements will have the biggest impact on AFarCloud platform definition and development.

Category 2: Farming (applied) research institutes including universities. Entities in this category are also considered to be main users, if they are main site partner in one of the demonstrator scenarios. In addition, personnel working at these entities may be involved in other projects in the agricultural domain, which means that they have relevant perspectives in this regard.

Category 3: Service and technology providers. This category of entities refers to companies that supply or support entities in Categories 1 and 2, which means that they do have a clear understanding of the challenges in agriculture processes. This category is highly relevant in this context since their success is closely linked with the emerging business opportunity, to some extent through innovations, connected with AFarCloud platform. Services and products in this context may be software solutions, hardware or mechatronics systems and various kinds of advisory, analytical, or other services to farms during or after the AFarCloud project.

It is important to highlight that in one company, or entity, there may be people with different roles. For this purpose, the Categories 1 - 3 are further divided into roles.

Table 1. Explanation of the categories and roles

Categories	Role index	Role explanation
Category 1: Farming companies	1.a	**Company owner/manager.** This person (i) runs the company in an economically sustainable manner, (ii) maintains good working environment, (iii) in lines the operations in an environmentally sustainable manner.
	1.b	**An agronomist/biologist/livestock specialist/researcher.** This is a skilled person who understands one sub-part of a process or the

Categories	Role index	Role explanation
		complete process based on his/her expert area.
	1.c	**The worker.** This person is working concretely in the processes e.g., driving the tractor, using a drone to collect data, inspecting the animals by eye.
Category 2: Farming (applied) research institutes including universities	2.a	**Project/group leader** with objectives that correspond to a manager. This role is similar to 1.a.
	2.b	**Senior researcher.** A person who designs and coordinates experiments and other research activities, evaluates the result, etc. This role is similar to 1.b.
	2.c	**Junior researcher or technical personnel**. A person who usually does routine research tasks. This role is similar to 1.c.
Category 3. Service and Technology providers to categories 1-2 above	3.a	**Company owner**/manager. Corresponds to 1.a
	3.b	**Agriculture domain specialist**. A person with strong experience in the agriculture sector or with agricultural background working for service and technology providers. Corresponds to 1.b or 2.b.
	3.c	**Engineer working with R&D&I**. A person who is involved in research, development or running the services. People with this role usually need assistance from 3.b for at least part of their work, if they design product or services for farms.

Note: In some companies one person can have multiple roles. Similarly, in some cases, one question may be relevant for several roles represented by different individuals.

2.2. Users' requirements gathering methods

There are many methods to collect information. This section describes some of the most basic and widely adopted ones.

2.2.1. Interviews

Interviewing is one of the primary ways to gather information about an information system. A good system analyst must be skilful at interviewing and no project can be conducted without interviewing. Interviews are great for getting an overall understanding of what stakeholders do and how they might interact with the system. Structured, unstructured or semi-structured interviews. In a group or one-on-one and often a combination of observation and interview. It is a good strategy for the reviewer to try to ask questions that allow the collection of “stories”. This will help the reviewer to gain insight of the value of the project and its required capabilities.

Some general directions for an effective and successful interview are tabulated below:

- What are the biggest challenges in your role? (may trigger stories)
- What does a dream solution look like? (ensures focus on future solution and not current state)
- What problems is the technology trying to address? Follow-up in regard to a need or feature (e.g. sensor data aggregation and processing or planning of periodic processes):
  - Is this feature a process and, if so, what are the steps?
  - How might we meet this need?
  - Where would the user access this feature?
  - When will this feature be used?
  - Where would the results be visible?
  - Who will use this feature?
  - What is the end result of doing this?
  - What needs to happen next?

Interviews can be One-on-One Interviews or Group Interviews.

One-on-one interviews are the most common technique for gathering requirements, as well as one of the primary sources of requirements. To help get the most out of an interview, they should be well thought out and prepared before sitting with the interviewee. The analyst should identify stakeholders to be interviewed. These can be users who interact with the current or new system, management, project financers or anyone else that would be involved in the system. When preparing an interview, it's important to ask open-ended questions, as well as closed-ended questions. Open-ended questions generally help in obtaining valuable information, based on various individuals and the way the different way they interact with, or view, the system. These types of questions require the interviewee to explain or describe their thoughts and cannot be simply answered with a “yes” or “no”. Asking the interviewee what they like about the current system or how they use it would be examples of open-ended questions. These types of questions can allow the consultant to further probe for more detail with follow up questions, in order to get more details. An example open-ended question would be “What are some of the problems you face on a daily basis?” Close-ended questions can also be useful, when the interviewer is looking for a specific answer. They can provide specific answers for the interviewee to choose from, in formats including true or false or multiple choice. Although close-ended questions do not provide as much detail as open-ended, they can be useful to cover more topics in a shorter amount of time. An example of a close-ended question would be “How many animals are treated per day?” Once the questions have been established, it is a good practice to provide the questions to the interviewee prior to the interview, in the event that the interviewee needs to prepare. During the interview, the interviewer should obtain permission from the interviewee that recorders may be used, to ensure that if details are missed while taking notes, they could easily be retrieved. At the end of the interview, the results should be provided to the interviewee, for confirmation of their responses.

Group interviews are similar to one-on-one interview, except there is more than one person being interviewed. Group interviews work well when the interviewees are at the same level or position. A group interview also has an advantage when there is a time constraint. More thoughts and discussions can be generated, as someone in the group may state or suggest an idea that may have been overlooked by others, which in turn can lead to a discussion or provide more information on a particular issue. The interviewer can gauge which issues are more generally agreed upon, and which issues differ. A major disadvantage can be scheduling the interview. When more than one person is involved, it may be difficult, or become time consuming, to establish a date and time that works well for all parties.

2.2.2. Questionnaires/Surveys

Questionnaires have the advantage of gathering information from many people in a relatively short time and of being less biased in the interpretation of their results. This is especially helpful when stakeholders are spread out geographically, when there are dozens to hundreds of respondents whose input will be needed to help establish system requirements.

Choosing right questionnaires respondents and designing effective questionnaires are the critical issues in this information collection method. People normally use only part of all the functions of a system, so they are just familiar with a subset of the system functions or processes. In most situations, one copy of questionnaires obviously cannot fit to all the users. To conduct an effective survey, the analyst should group the users properly and design different questionnaires for different groups. In Table 1, the different group types for the AFarCloud system are tabulated. However, questionnaires and surveys fall under the quantitative methodologies and as such they are fixed and offer less flexibility compared to the qualitative methods, e.g. interviews. When constructing the questionnaire, general guidelines to determine the questions would be to ask “how, where, when, who, what, and why.” For how: “How will you use this feature?” “How might we meet this business need?” “Where would the user access this feature?” etc. When designing questionnaires, the analyst should concern the following issues at least:

- The ambiguity of questions.
- Consistence of respondents’ answers.
- What kind of question should be applied, open-ended or close-ended?
- What is the proper length of the questionnaires?

2.2.3. Users' observation

People are not always very reliable informants, even when they try to be reliable and tell what they think is the truth. People often do not have a completely accurate appreciation of what they do or how they do it. This is especially true concerning infrequent events, issues from the past, or issues for which people have considerable passion. In addition, observation facilitates in assisting the analyst by getting a full grasp of how the user interacts with the system, first-hand. When the objective is to improve a task, the analyst can observe the user and how their surroundings affect their interaction with the system. Sometimes stakeholders may find it difficult in explaining what exactly their tasks consist of and what their requirements may be, observing the user in cases like these will help to provide the requirements. Therefore, analysts can supplement and corroborate what people say by watching what they do or by obtaining relatively objective measures of how people behave in work situations. However, observation can cause people to change their normal operation behaviour. It will make the gathered information biased. Furthermore, observation preferably has to be performed in session and this requires a substantial amount of time.

2.2.4. Examine existing systems and documentation

By examining existing systems and organizational documentation, system analysts can find out details about current systems and the organization these systems support. In documents analysts can find information, such as problems with existing systems, opportunities to meet new needs if only certain information or information processing were available, organizational direction that can influence information system requirements, and the reason why current systems are designed as they are, etc.

However, when analysing those official documentations, analysts should pay attention to the difference between the systems described on the official documentations and the practical systems in the real world. For the reason of inadequacies of formal procedures, individual work habits and preferences, resistance to control, and other factors, the difference between so called formal system and informal system universally exists.

2.2.5. Prototyping

Prototyping is a means of exploring ideas before you invest in them. Most system developers believe that the benefits from early usability data are at least ten times greater than those from late usability data. Prototyping allows system analysts to quickly show users the basic requirement of a working version of the desired information system. After viewing and testing the prototype, the users usually adjust existing requirements to new ones. The goal of using prototyping to support requirement determination is to develop concrete specification for the ultimate system, not to build the ultimate system from prototyping. Prototyping is most useful for requirements determination when user requirements are not clear or well-understood, one or a few users and other stakeholders are involved with the system, possible designs are complex and require concrete forms to fully evaluate, communication problems have existed in the past between users and analysts, and tools and data are readily available to rapidly build working systems, etc. For the AFarCloud system context, prototyping is not a suitable and viable solution to be adopted for all the identified user categories. However, regarding the technical and development specific users' teams, it can be a suitable addition to enhance the effectiveness and the accuracy of the ultimate product (component, service).

When adopting prototyping, analysts should concern about the potential problems about this requirements determination method, such as informal documentation, ignored subtle but important requirements, etc.

When we choose a requirements determination method for a specific project, there are seven aspects we should consider. These are: Information Richness, Time Required, Expense, Chance for Follow-up and probing, Confidentiality, Involvement of Subject and ultimately Potential Audience.

Table 2 provides a comparison of the five previously discussed requirements determination methods based on these aspects.

Table 2: User requirements methods comparison

Characteristic	Interviews	Questionnaires	Observation	Existing system analysis	Prototyping
Information Richness	High	Medium to low	High	Low (passive) and old	Medium to High
Time Required	Can be extensive	Low to moderate	Can be extensive	Low to moderate	Moderate and can be extensive
Expense	Can be high	Moderate	Can be high	Low to moderate	High
Chance for Follow-up and probing	Good	Limited	Good	Limited	Good
Confidentiality	Interviewee is known to interviewer	Respondent can be unknown	Observee is known to interviewer	Depends on nature of document	Usually know each other
Involvement of Subject	Interviewee is involved and committed	Respondent is passive, no clear commitment	Interviewees may or may not be involved and committed depending on whether they know if they are being observed	None, no clear commitment	Users are involved and committed
Potential Audience	Limited numbers, but complete responses from those interviewed	Can be quite large, but lack of response from some can bias results	Limited numbers and limited time of each	Potentially biased by which documents were kept or because document not created for this purpose	Limited numbers; it is difficult to diffuse or adapt to other potential users

2.2.6. Gathering methods used in AFarCloud

In AFarCloud we have used a combination of the aforementioned techniques to gather meaningful, useful and effective user requirements. First, one-on-one interviews were organised with the scenario leaders of the 11 use cases. Next, questionnaires were prepared and sent to the partners in the project that fit under one of the user categories defined as AFarCloud users in Table 1. Regarding users' observation, we consider that this input is covered by the farming research institutes and service and technology providers that are part of AFarCloud as they are used to working closely with farmers. Finally, the documentation from other projects and initiatives like DataBio and IoF2020 has been analysed.

3. Information from scenario leaders

3.1. Crops and vineyards

The end user requirements in crop management vary depending on the climate of the country, the type of crop and the degree of digitalisation of the farm. Table 3 summarizes the information gathered from three farms in Latvia, Spain and Italy. The three main aspects considered as critical or important were frost detection, humidity and disease/pest diagnosis. All three farms considered weeds detection as not important.

Table 3. Crops management

Crops management	AS01	AS04	AS05
Type of crops	berries	grapes	grapes, berries, vegetables & legumes, fruits
Size (ha)	25	300	3
Country	Latvia	Spain	Italy
Critical information	Frost detection	Humidity	Humidity, Disease/pest diagnosis
Useful information		NPK, Disease/pest diagnosis, control of pesticides	Gravimetry, NPK, temperature, Frost detection To know the general status of cultivation, to allow for selective interventions (e.g. irrigation or fertilization)
Info considered as not important		Gravimetry, temperature, Frost detection, weeds detection	Weeds detection, control of pesticides
Issues that worry most	Radiation frosts protection of a particular field	Water stress, grapevine vigour	Grapes illness, cost of soil analysis (now is done only on samples), humidity control in

			greenhouse

Table 4 and

Table 5 summarize the information related to the farms that grow cereals and grass to feed animals, either dairy cattle or beef cattle. In these cases, on the contrary, weeds detection is considered as a critical or important aspect. It is also of interest the disease/pest diagnosis and to know the precise moments of harvesting of both cereals and grass.

None of the farms interviewed had a tool for soil monitoring.

Table 4. Grass and cereals for dairy or beef cattle (1 of 2)

Crops management	AS02	AS03	AS03
Type of crops	Cereals and grass	Cereals and grass	Grass
Size (ha)	350	1600	38
Country	Latvia	Sweden	Sweden
Critical information	Disease/pest diagnosis, weeds detection	Weeds and pesticides	NPK, temperature, disease/pest diagnosis, frost detection, weeds detection
Useful information		NPK, Disease/pest diagnosis, weeds detection and control of pesticide	Gravimetry, NPK, humidity, control of pesticide To know when the best time is for harvesting grass
Info considered as not important		Humidity, temperature and frost detection	
Issues that worry most	To know the precise moments of harvesting of both maize and grass; detect occurrence and risk of occurrence of different kind of pests – illnesses of the plants, invasion of insects, and weeds, etc.; tamping level control of harvested maize and grass before fermentation		Weed control, moisture and NPK nutrients

Table 5. Grass and cereals for dairy or beef cattle (2 of 2)

Crops management	AS07	AS09	AS10
Type of crops	Cereals and grass	Cereals and grass	Cereals and grass
Size (ha)	726.3	200	700
Country	Czech Republic	Finland	Spain
Critical information		Nutrient composition; evolution of protein/fibre – balance during the growing process in order to determine the optimal harvesting schedule	Gravimetry, NPK, humidity, temperature, Disease/pest diagnosis, Frost detection, control of pesticides
Useful information	NPK, temperature, disease/pest diagnosis, weeds detection and control of pesticides	Gravimetry, NPK, humidity, temperature, disease/pest diagnosis, control of pesticides	Weeds detection
Info considered as not important	Gravimetry, humidity, frost detection	Frost detection, weeds detection	
Issues that worry most	Dry season, low forage feeds	Growing and an optimal harvesting time of silage in terms of nutrients	

3.2. Livestock

The end user requirements in livestock management have been grouped by dairy cattle and beef cattle farming.

Table 6 summarizes the information related to dairy cattle farming. In these cases, farmers were interested in health monitoring and in heat detection. The quality of silage in terms of nutrients and the low forage in dry seasons are also important issues for them.

Table 6. Dairy cattle

Livestock management	AS07	AS09

Dairy farmer		
Country	Czech Republic	Finland
No. animals	220	190
Production system	Intensive	Intensive
Litres/cow/day in average	24.71	34.2
Useful information	Health monitoring, measurement of ruminal conditions of dairy cows by the ruminal probes	Heat (inflammation) detection, indoor positioning and fast animal identification, rumen fullness (nutritional status)
Info considered as not important	in heat detection	
Issues that worry most	Dry season, low forage feeds, subacute ruminal acidosis	Growing and an optimal harvesting time of silage in terms of nutrients

Table 7 summarizes the information related to beef cattle farming. In all cases, farmers were interested in monitoring animal welfare and in monitoring animal weight. Besides, detecting when animals are in heat and the reproduction rates is very important for them. They all monitor the losses per year and the amount spent on medicines/vaccines.

Table 7. Beef cattle

Livestock management	**AS03**	**AS06**	**AS10**
Country	Sweden	Spain	Spain
Farming Type	Beef cattle Fattener 22 nursing cows, 6 calves	Beef cattle Breeder and fattener 200 nursing cows, 130 calves	Beef cattle Breeder and fattener 300 nursing cows, 600 calves
Size (ha)	200	1200	700
Critical	To detect when animals are in heat, know the	In heat detection	Reposition rate

Livestock management	**AS03**	**AS06**	**AS10**
information	reproduction rates		
Useful information	To locate animals at any time, know the reposition rate, detect the calving dates of animals		Detect when animals are in heat, detect the calving dates of my animals Automatic reproductive control, know the father of the calves
Already known info	Animal losses per year, amount spent on medicines/vaccines	Location of cows at any time, animal losses per year, detect when animals are in heat, detect calving dates of the animals, the reproduction rates	Location of the animals at any time, animal losses per year, reposition rate, reproduction rates, amount spent on medicines/vaccines
Info considered as not important		The reposition rate	
Issues that worry most	The calving process and the health of the cattle	The reproduction rates Too many animal losses, too much spent on medicines/vaccines	To detect healthy problems in the fattening farm, to monitor young calves the first 6 months when they are outside in the pastures with the cow

4. Requirements

The requirements were collected through two separate sources (summarized in Table 8). Firstly, in T7.1, demonstration leaders have answered a specific questionnaire to gather information about their farm, the issues that worry them most and their main interests. Secondly, in T2.1, a separate questionnaire has been prepared, and distributed to the whole consortium. The following requirement list below does not include technical requirements as that is the scope of D2.2. Instead, it solely contains the end-user perspective and their expectations from the system, thus technical details in order to achieve these objectives are omitted. As explained above, for allowing detailed analysis of the answers, three user categories, and roles within them have been defined. Most of the AFarCloud consortium partners can be identified to belong to one of these categories:

- Category 1: Farming companies
- Category 2: Farming (applied) research institutes including universities
- Category 3. Service and Technology providers to categories 1-2 above

Users of the Category 1 are of course critical, since this group represents the farmers. However, considering different needs, also assuming beyond the lifetime of the project, and taking a more holistic view, inputs from categories 2-3 are also relevant.

In the T7.1 questionnaire the priorities associated with the requirements have been asked explicitly (defined as: high, medium, low). This is because they are answered by the demonstrator leaders. In the T2.1 questionnaire, however, the priority question has been omitted. In order to harmonize the inputs in this regard, UPM, TECN, and MDH have tried to define the missing priorities based on the correlation between inputs from both sources, and discussions with relevant partners. Since these priorities are not explicitly mentioned in the T2.1 questionnaire they are in parentheses (see the Priority column in Table 8).

The following requirement list will be a live check list, i.e., it will be discussed, re-evaluated, and improved throughout the first year of the project until the second and last version (M14). This plan assumes also incorporating lessons learned from the first-year holistic demonstrator as well as all local demonstrators until M12.

Table 8. End-user requirements come from two sources of questionnaires: Source I (T7.1) and Source II (T2.1). The priorities describing Source II are in parentheses since this question was not asked explicitly, instead the given priorities has been deduced. In Application domain "Generic" refers to answers that do not explicitly refer to any of the project's application domains specifically.

Req. id	Source	User category	Req. description	Application domain	Priority
1	II	3	Domain specific decision support systems (DSS) are desired by the end-users. Everything from a specific process to a larger process	Generic	(Medium)

			such as dairy supply chains.		
2	I, II	1-3	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.	Generic	(High)
3	II	3	The system should be secure for workers driving or using the machinery.	Generic	(Medium)
4	II	3	The system should offer user-friendly solutions e.g., specialized HMI. Remember also that the environment is specific (hazardous, dusty, etc.).	Generic	(Medium)
5	II	3	The system should offer vehicle information (e.g. maintenance parameters, distance driven, operational hours, etc.)	Generic	(Low)
6	II	3	The system should allow certain degree of automation in daily inspection tasks in order to reduce time and costs.	Generic	(Medium)
7	II	3	AFarCloud should be interoperable with the current systems in the farm.	Generic	(Medium)
8	II	3	Communication is important and sometimes a challenge in rural locations. Thus, different communication solutions, which provide a redundant solution is important.	Generic	(High)
9	I	2	The system should provide support to process NDVI as an agricultural index.	Generic	(Medium)
10	I, II	1-3	The system should be able to visualize information related to crops and livestock that allow	Generic	(High)

			farmers to diagnose current situation in the farm, predict future diseases or problems and make decisions		
11	II	2	The Hyperspectral image system should have highly accuracy. The type and quality of data must be discussed with the end-users before deployment (important measures are: grass height, illumination conditions, spectral data, etc.)	Generic	High
12	II	3	Weather, and other environmental data are important for the DSS.	Generic	High
13	II	3	Offer Environment footprint calculation (EFC), a solution that estimates environmental impact of the production for a single product.	Generic	High
14	II	3	Farm size distribution, production farm types of each class and common practices in different classes are required to improve current, and develop new services.	Generic	High
15	I	1, 3	The system should provide information for Phenological status, disease/pest diagnosis of the crops, taking care to an extent of each crop specific needs.	Crops	High
16	I	1	The system should detect weeds in cereals and grass.	Crops	High
17	I	1	The system should help to know the precise moments of harvesting of both maize and grass	Crops	High
18	I, II	1, 3	The system could acquire real-time information about crops including gravimetry, NPK, humidity, temperature and	Crops	Medium

			control of pesticides, temperature, load and cycle detection, use of water, illumination conditions.		
19	I	1	The system should help monitoring animal health and activity.	Livestock	High
20	I	1	The system should allow in heat detection of animals.	Livestock	High
21	I, II	1, 2	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.	Livestock	High
22	II	2	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).	Livestock	(Medium)
23	I	1	The system should allow knowing the reproduction rates of cows.	Livestock	High
24	I	1	The system should allow locating animals at any time.	Livestock	Medium
25	II	1	The system should allow prediction the calving dates of animals. A DSS may be needed in this case.	Livestock	Medium
26	II	3	The system must be able to detect animals that may pose a threat during harvest (deer, rabbits) or farm animals (wild boar). The former group can destroy the equipment, contaminate the crops, strass the livestock, etc. The latter group can be a great danger	Livestock	(Medium)

			to the livestock, since attacking the livestock is part of their behaviours.		
27	I	1	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).	Livestock	High
28	II	3	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.	Livestock	(Medium)
29	I	1,2	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.	Livestock	(High)
30	I	1	The system should provide support for radiation frost detection and leaf temperatures.	Vineyard	High
31	I	1	The system must acquire real-time information about the grapes, mainly soil humidity, vigour and water stress to allow watering optimization and water flow information.	Vineyard	High
32	II	3	The system should be able to obtain information from leaves so health information can be inferred, and a classification can be established.	Vineyard	(Medium)

5. Requirements and experiences from other projects

To extend our knowledge about user need of farming companies, and other stakeholders, in the agriculture sector we have created a brief overview of pilots from two Horizon 2020 projects, in which the focus partially overlaps with the AFarCloud project. These projects are **The Data-Driven Bioeconomy project (DataBio)** and **Internet of Food and Farm 2020.**

Note that, the information extracted from these projects will not be reflected in AFarCloud architecture explicitly. However, general trends identified in these projects, the main objectives of the pilots, required datasets, data analysis and key technologies are valuable inputs, which can tell us what topics we should pay attention to when looking for ways to effective exploitation of the AFarCloud project results, so that the impact exceeds the scope of AFarCloud demonstrator scenarios.

5.1. DataBio

The main goal of the DataBio project is to show the benefits of Big Data technologies in the raw material production from agriculture, forestry and fishery/aquaculture for the bioeconomy industry to produce food, energy and biomaterials responsibly and sustainably [1].

5.1.1. A brief Overview of the DataBio Pilots

Agriculture pilots in the DataBio are organized in three tasks: Precision Horticulture including vine and olives (A), Arable Precision Farming (B), Subsidies and insurance (C).

A1.1 Precision agriculture in olives, fruits, grapes (Greece) A smart farming pilot to promote sustainable practices by providing policy advice on irrigation, fertilisation and pest/disease management. The exploitation of heterogeneous data, facts and scientific knowledge is aimed to facilitate decision-making and ensure smooth implementation of policy advice in the field. Deployed at three different sites in Greece, the pilots target olives, peaches and grapes.

A1.2 Precision agriculture in vegetable seed crops (Italy): Harvesting plants at the right stage of maturity is vital to ensure the seed produced of high quality. Currently, it is up to the farmers, with the help of seed experts, to decide about harvesting and this is usually based on experience and observations. The scope of the pilot is to support farmers with the use of satellite telemetry.

A1.3 Precision agriculture in vegetables seed crops (Netherlands): Potato growers aim to furnish them with higher and more predictable yields in a sustainable manner. Farmers will use a crop monitoring and benchmarking system using satellite data that provides information on the crop status based on weather data and greenness index data.

A2.1 Big Data management in greenhouse eco-systems (Italy): This pilot implements genomic selection models, with particular focus on tomatoes, to support the greenhouse horticulture value chain.

B1.1 Cereals, biomass and fibre crops (Spain): Using Earth Observation imageries and Internet of Things (IoT) sensor data, the pilot will map different areas in Spain and set up an informative management system for irrigation and early warning of heterogeneities or malfunctions of irrigation systems. The users of this service will be farmers, irrigation communities and public administrations.

B1.2 Cereals, biomass and fibre crops (Greece): A smart farming pilot to promote sustainable practices by providing policy advice on irrigation. The exploitation of heterogeneous data, facts and scientific knowledge is aimed to facilitate decision-making and ensure smooth implementation of policy advice in the field. The target crop type is cotton.

B1.3 Cereals, biomass and fibre crops (Italy): The pilot uses remote and proximal sensors for biomass crop prediction and management. The biomass crops include sorghum, fibre hemp and cardoon that can be used for several purposes including biofuel, fibre, and biochemicals respectively.

B1.4 Cereals, biomass and fibre crops (Czech Republic): To develop the web-based webGIS platform for mapping crop vigour, this pilot integrates Earth Observation data as a support tool for variable rate application of fertilisers and crop protection. This includes identification of crop status, mapping of spatial variability and delineation of management zones.

B2.1 Machinery management (Czech Republic): This pilot is focused mainly on collecting telematic data from tractors and other farm machinery to analyse and compare with other farm data. The main goal is to collect and integrate data and receive comparable results. A challenge associated with this pilot is that a farm may have tractors and other machinery from manufacturers that use different telematic solutions and data ownership/sharing policies.

C1.1 Insurance (Greece): To promote a damage assessment methodology, and services dedicated to the agricultural insurance market. This pilot will eliminate the need for on-the-spot checks and to speed up the claims pay-out process. It uses data from Earth Observation platforms and Internet of Things agro-climate sensors to assess the impact of climate-related systemic perils (e.g. high/low temperatures, flood, drought) on high-value crops.

C1.2 Farm Weather Insurance Assessment (Italy): The aim of this pilot is to provide and assess a test area of services for the agriculture insurance market, in particular risk assessment related to weather conditions and damage assessment. It is based on the analysis of satellite data, which is correlated with meteorological data and other ground-available data.

C2.1 Common Agricultural Policy (CAP) Support (Italy and Romania): The objective of this pilot is to support the CAP by utilising Earth Observation data to identify the crop types in farm areas. Products and services will be fine-tuned to achieve requirements set out in the 2015-2020 EU CAP policy. The pilot will provide information layers and indicators to support European Paying Agencies with different levels of aggregation and details up to farm level.

C2.2 Common Agricultural Policy (CAP) Support (Greece): This pilot evaluates a set of Earth Observation-based crop classification services, which deal effectively with the newly introduced CAP demands for systematic multi-crop agricultural monitoring, tracking and assessment of eligibility conditions. The proposed services use "traffic lights" colour-coding to protect the farmers against errors during the submission of greening applications. [2]

5.1.2. Requirement specifications from DataBio pilots

The use cases in DataBio that have some relation with the work to be done in AFarCloud are those from tasks A and B, i.e. Precision Horticulture including vine and olives (A) and Arable Precision Farming (B).

Deliverable D1.1 Agriculture Pilot Definition [5] (led by LESP) from DataBio specifies the pilot case definitions, requirement specifications, as well as implementation and evaluation plans. From this document, we have extracted the end-user requirements identified for each use case and checked if similar requirements in AFarCloud also address these challenges.

[A1.1] Precision agriculture in olives, fruits, grapes

Requirements in DataBio	**1)** Reduce costs and improve farm productivity **2)** Identify crop pests and diseases
Goals in DataBio	To provide smart farming advisory services (focusing on irrigation, fertilization and pest/disease management), based on a set of complementary monitoring technologies, in order to increase farm profitability and promote sustainable farming practices
Similar AFarCloud requirements	**Requirement ID: 1)** 1, 6, 10, 14. **2)** 11, 12 Comment: Only a selection of requirements have been mentioned here since most AFarCloud requirements address similar challenges as A1.1.

[A1.2] Precision agriculture in vegetable seed crops

Requirements in DataBio	To know the right time of harvesting for the achievement of seeds of good quality: if too early the vigour of the seed harvested will be affected; if too late the mature seeds are going to drop to the ground and the best part of harvest get lost.
Goals in DataBio	To monitor the maturity of the seed crops throughout the season with satellite imagery and produce a modelling in order to predict the right time for harvesting, optimize field operations and get high quality of the product.
Similar AFarCloud requirements	**Requirement ID:** 17, 18, 9-13, 15-18 Comment: Many AFarCloud requirements address A1.2. This is done by approaching the same problem from different aspects.

[A1.3] Precision agriculture in vegetables_2 (Potatoes)

Requirements in DataBio	Farmers monitor their crops just by their own observations and samples, which is time consuming. Deviations in growth within the field are hard to observe. They need to be more conscious of the energy and other resources that they use in producing their crops.
Goals in DataBio	Improve farming practices by providing benchmark information to the farmers. To identify the potential of using of satellite data and machine learning to benchmark and optimize the yield and quality of the potato crops through the development of a monitoring and yield prediction model based on weather and EO data.
Similar AFarCloud requirements	**Requirement ID:** 1, 2, 4, 6, 13-15

[B1.1] Cereal, biomass and cotton crops_1

Requirements in DataBio	Early warning of heterogeneities in crops related to irregular irrigation, mechanical problems affecting irrigation systems, incorrect distribution of fertilizers or any other sources of inhomogeneity that could explain crops growing differences.
Goals in DataBio	To develop an accurate "irrigation maps" and "vigour maps" (combining EO data and sensors data) and set up an informative and management system for early warning of heterogeneity or malfunction of irrigation systems and devices.
Similar AFarCloud requirements	**Requirement ID:** 1, 9-12, 17, 18, 31

[B1.2] Cereal, biomass and cotton crops_2

Requirements in DataBio	Increase yield and improve farm productivity. Increase profits following sustainable agriculture practices over a better control and management of the resources (water).
Goals in DataBio	To provide smart farming advisory services (focusing on irrigation), based on a set of complementary monitoring technologies, in order to increase farm profitability and promote sustainable farming practices.
Similar AFarCloud requirements	**Requirement ID:** 1, 9, 12-14, 31, 32

[B1.3] Cereal, biomass and cotton crops_3

Requirements in DataBio	To know the right time for actions.
Goals in DataBio	To use satellite imagery and/or telemetry IoT to monitor the growth of biomass crops throughout the season to evaluate the right time for possible actions like fertilizing, irrigation, crop protection, and harvesting, optimize field operations and save money and time.
Similar AFarCloud requirements	**Requirement ID:** 1, 10, 15, 16

[B1.4] Cereal, biomass and cotton crops_4

Requirements in DataBio	To know the crop status to evaluate possible actions like fertilizing and crop health measures.
Goals in DataBio	Develop a platform for mapping of crop vigour status by using EO data (Landsat, Sentinel) as the support tool for variable rate application (VRA) of fertilizers and crop protection.
Similar AFarCloud requirements	**Requirement ID:** 1, 10, 15-18

[B2.1] Machinery management

Requirements in DataBio	Track tractors which might be made by different manufacturers; have an overview of the location and movement of tractors; evaluate economic efficiency of machinery usage and crops profitability.
Goals in DataBio	To collect telemetry data from machinery and analyse it in relation with other farm data.
Similar AFarCloud requirements	**Requirement ID:** 2-7

5.1.3. Lessons learned from the DataBio pilots

The findings in this section were obtained from the DataBio public deliverables and direct experience of some AFarCloud consortium members from the DataBio project. Although the main focus of the DataBio pilots is different from focus of AFarCloud demonstrator scenarios and DataBio lacks pilots directly focused on livestock production, we have concluded that the following findings can be relevant to AFarCloud.

The data most frequently used in the agricultural pilots in DataBio are Earth Observation data (EO), especially data from the Copernicus programme, but other EO data are also used. 11 out of 13 DataBio agriculture pilots use them as one of the inputs. Many DataBio pilots use EO data along with various types of sensor data, agrometeorological data or on-site observations and measurements [3].

The main advantage of using freely available EO data in agriculture is that you can get some information about each field at very low cost, if you have effective pipelines for obtaining, processing, analysing this data. The price of advisory and other services is a very important factor in commercial operation in agriculture. In some cases, more accurate results could be obtained by other ways, **but the price may be a limiting factor for the commercial success.**

The information contained in these EO data is not always accurate enough for the user to make decisions based only on this information, however, in combination with other data or analyses, it is often used to support decision-making. Even where information derived from EO data is not accurate enough, it can help to save costs for farmers or other users e.g., **to select suitable locations for sensor placement, on-site measurements, or select fields or parts of fields that may be appropriate to monitor by other methods.** This may be relevant, for example, for using drones that allow you to obtain more accurate results than EO, but with considerably higher costs.

5.2. IoF2020

The IoF2020 project is focused on internet of things (IoT) and its potential in the agriculture. It is focusing on smart web of sensors, actuators, cameras, robots, drones and other connected devices, which aims at allowing for "an unprecedented level of control and automated decision-making" for the European food and farming industry. In this direction, there is a large overlap with the AfarCloud Project. IoF2020 does not define an overall architecture, and pilots are operating as standalone activities. In IoF2020 project there are 19 different use cases divided into following groups: arable, vegetable, meet, fruits, and dairy.

IoF2020 uses a lean multi-actor approach focusing on user acceptability, stakeholder engagement, and the development of sustainable business models. Each of the 19 use cases in IoF2020 develops and tests its own IoT-based solutions over several implementation cycles, where each cycle results in a so-called minimum viable product.

5.2.1. IoF2020 Use cases

The goals of the use cases are listed below:

- Arable: Add IoT technology to existing networks and databases to enable precision farming.
- Dairy: Use real-time sensor and location data to create added value in the dairy chain.
- Vegetables: Combine sensor data to execute cultivation patterns automatically.
- Fruits: Use data to increase fruit quality, yield and product traceability from farm to shelf.
- Meat: Optimize animal health, production chain transparency and traceability.

Arable land related UCs:

UC1.1: Within-field Management Zoning; defining specific field management zones by developing and linking sensors and actuators with external data

UC1.2: Precision Crop Management; smart wheat crop management, through the use of sensors data embedded in a low-power, long-range network infrastructure

UC1.3: Soya Protein Management; improving protein production by combining sensor data and translate them into effective machine task operations

UC1.4: Farm Machine; enabling the Interoperable data exchange between field machinery and farm management information systems, in order to support cross-over pilot machine communication

Dairy related UCs:

UC2.1: Grazing Cow Monitor; monitoring and managing the outdoor grazing of cows, using GPS tracking within ultra-narrow band communication networks

UC2.2: Happy Cow; improving dairy farm productivity, using 3D cow activity sensing and cloud machine learning technologies

UC2.3: Silent Herdsman; herd alert management by a high node count distributed sensor network, and a cloud-based platform for decision-making

UC2.4: Remote Milk Quality; remote quality assurance of accurate instruments and analysis & pro-active control in the dairy chain

Fruit related UCs:

UC3.1: Fresh Table Grapes Chain; real-time monitoring and control of water supply and crop protection of table grapes and predicting shelf life.

UC3.2: Big Wine Optimization; optimizing the cultivation and processing of wine by sensor-actuator networks, and big data analysis within a cloud framework.

UC3.3: Automated Olive Chain; automated field control, product segmentation, processing and commercialization of olives, and olive oil

UC3.4: Intelligent Fruit Logistics; handling the fresh fruit logistics through virtualization of fruit product s by intelligent trays within a low-power long-range network infrastructure.

Vegetable related UCs:

UC4.1: City Farming Leafy Vegetables; innovating the vegetables value chain for leafy vegetables in convenience foods integrating indoor climate control and logistics.

UC4.2: Chain-integrated Greenhouse Production; integration of the value chain and quality innovation, using a full sensor-actuator based system in tomato greenhouses

UC4.3: Added Value Weeding Data; boosting the value chain by harvesting weeding data of organic vegetables obtained leveraging advanced visioning systems.

UC4.4: Enhanced Quality Certification System; enhanced trust and simplification of quality certification systems by use of sensors, RFID tags and intelligent chain analyses

Meat related UCs:

UC5.1: Pig Farm Management; optimizing pig production management through interoperable on-farm sensors and slaughter house data.

UC5.2: Poultry Chain Management; optimizing production, transport and processing of poultry meat by automated ambient monitoring & control and data analyses.

UC5.3: Meat Transparency and Traceability; enhancing transparency and traceability of meat based on a monitored chain event data. [4]

5.2.2. Lessons learned from the IoF2020

IoF2020 has developed an approach for structuring key functionalities for IoT based solution developments i.e., an architectural functional view, which was mapped to the hierarchical layers of the IoT reference model.

Gap analysis in IoF2020, which was done on the base of existing use case analysis might be an important lesson for AFarCloud. The main gaps in UCs identified by IoF2020 project are:

1. Incomplete UC specifications,
2. Unclear security requirements,
3. Unclear privacy/data ownership requirements,
4. Lack of details in the data models,
5. Lack of knowledge about possible performance of IoT products in UC conditions,
6. Uncertainty about fitness of USs with product/technology roadmaps,
7. Need for support in choosing (or developing) components for specific needs or problems of UCs.

These gaps should be taken into consideration, when defining the architecture in the AFarCloud project in T2.2. Due to the fact that every IoF2020 UC is partly independent, it is not trivial to recommend some direct transfer of user requirements into the AFarCloud project. On the other hand, the analysis of the detailed specifications of the IoF2020 UCs may help to find answers to questions that will arise during the AFarCloud architecture definition process.

6. Conclusion

Depending on the position in the value chain, a company's needs and requirements can be very different. The intention of adapting the categories and the roles was to extract this aspect. There is an ongoing work within the European Union regarding harmonization of the agricultural processes e.g., for guaranteeing a certain level of quality, every country, habitat, the farm itself, and the business reality of the farming company is unique. As a result, there may be considerable differences between user requirements between companies active in the same application domain i.e., livestock, vineyards, and crops. The ambition of D2.1 has been to identify these factors (Sect. 4), and also look at other important sources (Sect. 5).

The implications of the above are that both generic and highly specialized technological solutions are needed whether the company is large or a small family owned business. Two important requirements have been identified: **interoperability** with heterogeneous (also non-standardized) data sources and third-party systems, and also **user-friendly solutions**. The former is important since many farms have investments that cannot be replaced or omitted just because new machines and systems are added to the machine park. The latter is a central remark, in addition to assuming depopulation of the rural areas, and finding qualified workers. **Early detection of abnormalities** is also important in cases when large economical loss is at stake, like in the case with the **vineyards**. A similar logic applies to **livestock** as well, since early detection of health-related issues means also the reduction of the use of antibiotics, in addition to animal welfare and economical dimensions. **Prediction** of critical events are also mentioned as an important service. Although **location of individual animals** is not a critical requirement, in cases when the animals move freely in a pasture, knowing their locations and the surrounding wild animals, carnivores, is critical in order to mitigate the risks for an attack. **Detection of small animals** (rats, rabbits, etc.) is also critical in order to eliminate the risk for crops and the infrastructure. **Water management and irrigation** is critical especially in the vineyards. Solutions to increase the precision of these processes are important.

Real-time data analysis when required is important, as well as **minimizing the time for offline (after the mission) data processing**. Image data in combination with long recordings can result in large amount of data. Post-processing of data can thus take as much time as the data collection mission itself. **Mobile coverage** in remote locations, and domain specific (specialized) **autonomous data collection** solutions are highly desired as well. Another key requirement related to inaccessibility is **battery time** of various sensors and devices. Remember also that every crop is different, **Domain specific solutions** are critical for success. These solutions aim at **increasing the productivity**. Another service for increasing the productivity is various **decision-support systems (DSS)**. These services are mentioned by many, and the common point is to have solutions that are specific so that a real and relevant problem can be addressed.

ISOBUS is considered as a critical technology for many, and in line with this opinion it is stated that the limitations are mostly created by the functionalities of the vehicles (i.e. interfaces, backbone, mounting and integration possibilities) is also mentioned. Another challenge is the weather and the environmental considerations, which assume robust and **smart (novel) technological solutions**.

From a purely business perspective we see that it is important to provide a solution that is in line with the technical requirements mentioned above. In addition, a solution must be **easy to understand**, and make **measurable impact** on the business of the farm, for acceptance. Also, these factors are mentioned explicitly as technical requirements. Other generic requirements, or opinions, are **insufficient planification**, and **bad communication** between different stakeholders.

There are plausible implications of the DataBio project to the AFarCloud project, although as mentioned in Section 5 these projects are not directly comparable. Domain specific data i.e., freely available (lower accuracy) Observation data (EO), especially from the Copernicus programme, has been identified as critical in the DataBio project. Cutting the costs is essential for the agricultural service providers, also identified in the DataBio project. This trade-off between low cost and high quality must be considered in the AFarCloud project as well. Still, in combination with other inputs, low quality EO data can be useful to select suitable locations for sensor placement, on-site measurements, or select fields or parts of fields that may be appropriate to monitor by other methods.

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