FLEXIGROBOTS

D2.8 Pilot alignment and joint assessment report 2

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List of Abbreviations

Abbreviation / acronym	Description
AI	Artificial Intelligence
ADS	Agricultural Data Space
API	Application Programming Interface
DIH	Digital innovation Hub
DoA	Description of Action
DSS	Decision Support System
Dx.y	Deliverable number y belonging to WP x
EC	European Commission
EU	European Union
GPS	Global Positioning System
IDSA	International Data Spaces Association
IEC	International Electrotechnical Commission
KPIs	Key Performance Indicators
LPWAN	Low Power Wide Area Network
MCC	Mission Control Centre
ML	Machine Learning
NDVI	Normalised Difference Vegetation Index
OGC	Open Geospatial Consortium
RGB	Red, Green, Blue
RFMS	Robot Fleets Management System
ROI	Return of Investment
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
US	United States
WP	Work Package

Executive Summary

This deliverable D2.8 presents the common methodology that is being followed to ensure the alignment between the three FlexiGroBots pilots (implemented in four locations and addressing three types of crops), reporting about the findings done during the second year of the project. An updated version of D2.8 will be released in December of 2023, at the end of the project.

From the beginning of the project, the task T2.5 has dealt with the alignment of the three pilots, so they would follow a common approach during their development and the platform developed for FlexiGroBots would fulfil the requirements provided by all the pilots.

Deliverable D2.7 already proposed a methodology that includes four phases: standard specification of the pilots and their use cases (through the standard *IEC 62559-2:2015 - Use case methodology*), identification of the datasets used and collected, devices/robots used and developed, and consolidation of the pilots alignment through the definition of specific plans and KPIs. Deliverable D2.8 has updated the information about the proposed requirements, the datasets available after Y2 of the project, hardware used in the pilots (e.g., devices, ground and aerial robots, platforms) and the plans for the next months, encouraging the collaboration between pilots.

This deliverable has a special focus on the way in which the pilots can collaborate and share outcomes, so the others can benefit from the work done. For each pilot, specific elements were identified that could benefit other pilots, articulating the collaboration and interactions that should happen during the next months of the project. Although it reports about ongoing actions, most of these actions are not completed and new ones are required, so the deliverable has updated the release plans of the pilots for Y3.

In line with this aspect, the backlog of the pilots has been updated and the KPIs defined in D2.7 have been evaluated, so it is possible to understand the current status of the project, identifying the main gaps and areas of interest. This information will be used for prioritising specific tasks during the pilots implementation.

In the final iteration of this document, the list of KPIs will be updated considering the progress achieved during the project lifecycle, reporting about the processes followed to obtain the different metrics and about the activities done with respect to pilots collaboration and alignment.

1 Introduction

1.1 Purpose of the Document

FlexiGroBots is an Innovation Action funded by the European Commission that aims at building a platform for the agriculture domain that enables the management of multi-robot environments that can work together in an intelligent and automated way to implement precision agriculture operations. This provides interesting benefits to farmers and other stakeholders, in such a way it is possible to be more efficient and productive, while we increase the protection of the environment.

The implementation of such platform requires to address multiple domains from the technological perspective. First of all, Artificial Intelligence-based models are necessary to enable the smart management of the multi-robot systems (including their interactions. Therefore, it is necessary to deal with a framework for managing AI models. Additionally, the models require the adequate data management capabilities, in order to facilitate the right training and deployment of inference services. Finally, it is necessary to provide the means to interact with the robots, enabling communication channels and automation mechanisms that can make use of the AI models.

The project relies on three heterogeneous real-world pilots, that are used to develop, test and validate the FlexiGroBots platform in four different countries (Spain, Finland, Serbia and Lithuania). This implies to address requirements coming from multiple stakeholders that belong to different environments, even if all of them are related to the agricultural domain. The diversity of the pilots facilitates the exploration of the solutions with different crops, different regulations, different weather conditions and different robots and machinery.

The first pilot is focused on grapevines (in Spain), working in the early detection of diseases (like botrytis), application of phytosanitary treatments and easy collection and transportation of harvested grapes.

The second pilot is located in Finland and it is focused on rapeseeds. It works in operations like seeding, detection of pests, rumex plant weeding, silage harvesting and pesticide spraying with multiple robots.

The third pilot covers locations at Serbia and Lithuania and is focused on blueberries. It proposes to work in operations like early diseases detection (with hyper/multi-spectral images and AI), automated soil sampling, agrichemical spraying and precise fertiliser application.

These three pilots have been developed during the last two years of the project, progressing in the development of many of the proposed operations, in the collection of data and in the usage and testing of some of the solutions already implemented.

A set of Key Performance Indicators were defined in D2.7 [8] in order to follow closely the developments and validation of the solutions, indicators that have been measured periodically for detecting potential deviations from the objectives, so it will be possible to facilitate the exploitation of the results in the near future. One of the purposes of this document is to report about the valuation of those KPIs, evaluated after the work done in the last two years.

Additionally, the activity in which this report is developed is focused on **guaranteeing that there is an adequate convergence and interaction between the pilots of the project, especially from the perspective of the project vision, the implementation architecture, the fleets of robots to be used and other reusable components (such as AI models)**. This document provides a deep analysis of the common elements and activities that the pilots have been doing and future areas of collaboration, with the corresponding plans.

This document provides also information about the mapping between the components identified in the high-level architecture and the implementation done, highlighting the link with WP3 components as well.

During the first 12 months of the project, the work was very focused on the specification and definition of the architecture and the use cases, as well as the preparation of preliminary experiments. During the second year, the pilots worked in the implementation of prototypes and in the collection of relevant datasets, as well as initial tests of some of the solutions implemented. These actions required and intensive work that limited the interaction between the pilots, although some actions were already started. Therefore, this document aims at extending those areas of collaboration with effective plans that will enable the possibility to carry out an adequate evaluation of solutions during the next summer campaign.

1.2 Relation to Other Project Activities

Deliverable D2.8 is the second outcome of *T2.5 - Pilot's methodology, follow-up and alignment* and the seventh of *WP2 - Requirements, architecture and standardization*, after the release in M9 of the project of D2.1 [1] (focused on describing the stakeholders around FlexiGroBots), D2.2 [2] (that provides a list of requirements and a first design of the architecture for the project), D2.7 [8] (that sets the base for this deliverable, identifying initial common elements, relationships with other components of FlexiGroBots, initial plans for the pilots implementation and an extended set of KPIs), D2.3 [9] (that refines the list of requirements, as well as the proposed architecture, with additional details), D2.4 [10] (a document that identifies the main standards that affect the FlexiGroBots project and proposes some activities from the consortium side to adopt them) and D2.6 [11] (a report that analyses different approaches to address ELSE factors in AI, bearing in mind its application to the agriculture domain).

All these deliverables had an influence in D2.8, since their information was used as a base in order to carry out an adequate analysis of all those factors that affect the implementation of the pilots. Of course, other deliverables from the technical WPs have been also key inputs for D2.8, such as those released by the pilots (D4.1 [4], D5.1 [5] and D6.1 [6]). All these deliverables were released in M12 and provide information about the specification of the pilots and their initial activities. This is applicable to D3.1 [12] as well, as it reports about the work done in WP3, detailing how the base infrastructure was designed and planning its implementation. In line with D3.1, D3.2 is released in parallel to D2.8, refining the designs and detailing the implementation of the common components produced by WP3.

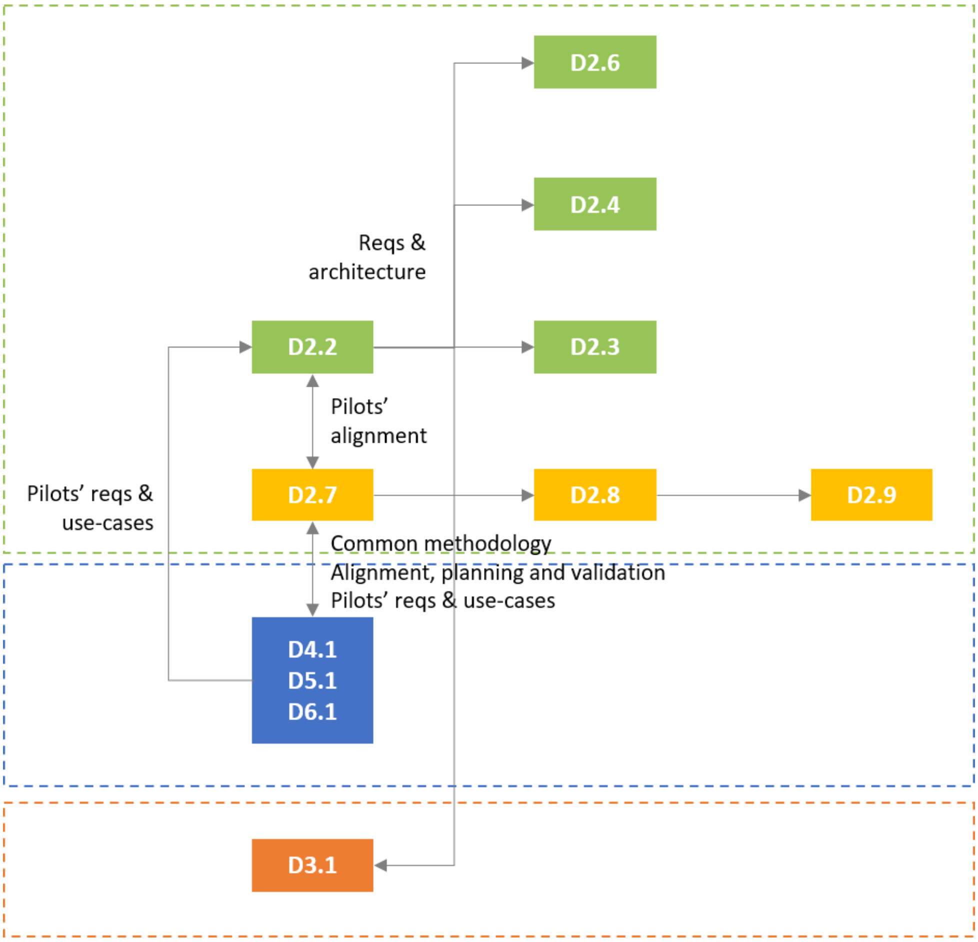

Figure 1 Deliverables linked to D2.8

The role of D2.8 has been fundamental to collect again information from all the pilots in the same format, setting up the methodology for reporting and collaborating. In fact, the analysis of the current situation of the pilots and the KPIs evaluation has led to the definition of a list of activities and plans that will impact the implementation of the pilots.

Such impact will be reflected in the future deliverables of the pilots (D4.2, D5.2 and D6.2), to be released in M27, since they will report about some of the activities planned in D2.8.

The work of T2.5 will continue as the pilots keep progressing, in order to facilitate the implementation and validation of the three pilots. As a result, a final version of this document will be published (*D2.9 - Pilot alignment and joint assessment report final)* at M36, updating the KPIs evaluation and reporting about the work done.

1.3 Structure of the Document

This document is structured in six major sections:

- **Section 1** introduces the objectives and content of this document.
- **Section 2** presents the common methodology followed to specify and prepare the three FlexiGroBots pilots.
- **Section 3** includes an analysis of the mapping of the FlexiGroBots platform and the three pilots.
- The principles of the agile methodology that will guide the pilots' execution and validation will be the main topic addressed in **Section 4**, also including the description of the backlog tasks and the timeline for the execution and validation.
- **Section 5** is focused on the assessment of the KPIs and the discussion about the validation procedures.
- Finally, **section 6** ends the document with the analysis of the obtained results, conclusions and next steps.

1.4 Addressing Comments from the Review Report

After the first project review, several comments were received about the lack of interaction between the different pilots, so it was a topic that required the consortium to do some analysis and plan activities to enable the full collaboration.

One of the comments stated: "*The different pilots look very isolated and seem to have no cooperation, nor technical reuse of components, specifically in relation to common topics defined in the specifications. Pilot AI algorithms looks also very different and isolated. There are several hardware approaches (e.g., UAV) spraying devices, the rationale and relative comparison for having these alternatives devices would be useful*."

The consortium has worked in the identification of commonalities and potential ways to enable a fruitful collaboration between the pilots. Five main areas have been identified for collaboration: datasets, devices/robots, models, usage of horizontal services and validation methodology.

As a result, this document includes details about the specific areas in which such collaboration can be done. Section 3 contains the information about those features that a pilot can integrate from others (subsections 3.1.6, 3.2.6 and 3.3.6).

Another comment related to this report was: "*Relationship between the pilot and the general infrastructure, in particular AI algorithms, tools for labelling (none done at the moment) should be suitably addressed*".

This report includes detailed information in Section 3 about the relationship between the outcomes of WP3 and how they are being used (and will be used) in the context of the pilots.

There is information about the current work in areas like the AI platform, the common data enablers and services, the geospatial enablers and services, the common application services (AI models from WP3) and the Mission Control Centre (MCC).

2 Common methodology for FlexiGroBots pilots' specification and preparation

During the second year of the project, T2.5 has been focused on identifying those common aspects that could be shared between the pilots, as well as on starting activities that would align the implementation of the pilots. There is a large diversity in terms of the types of datasets collected and devices/robots used in the field, but it was necessary to increase the convergence.

The consortium has been following the methodology already presented in D2.7 [8], which is shown in the figure below. The consortium has completed an iteration, going through all the phases at least once.

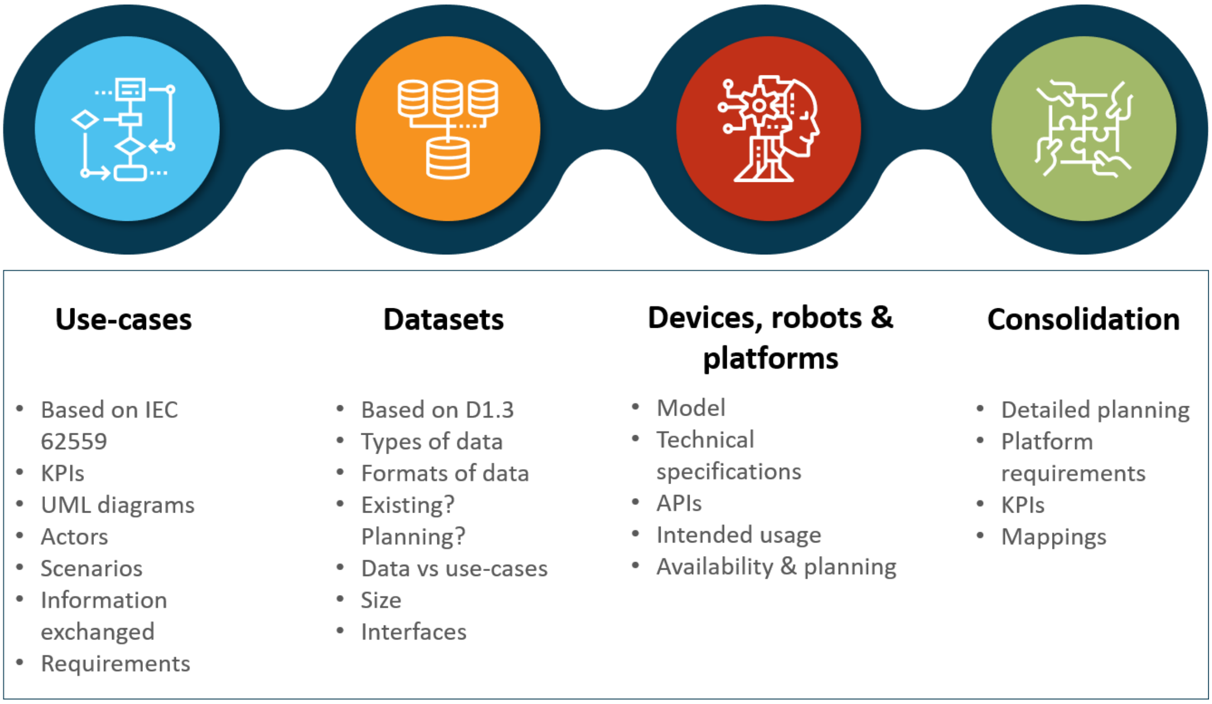

Figure 2 Common methodology for FlexiGroBots specification and preparation

As the third year of the project starts, the methodology is used again, in order to check the use cases specifications, in case these need to be updated, taking into account the findings explained in this deliverable and improving the interaction among pilots.

2.1 Pilots' use-cases specification

The specification of the pilots' uses-cases was done during the first year following the templates of the *IEC 62559-2:2015 Use case methodology* standard [3] in order to guarantee that all the needed aspects were covered in detail for the three pilots. This was documented properly in those deliverables released by WP4, WP5 and WP6 (D4.1 [4], D5.1 [5] and D6.1 [6]).

As mentioned in D2.7 [8], the IEC 62559-2:2015 standard defines a specific template that contains these aspects:

- Objectives and scope of the use case.
- Short and complete descriptions explaining the use case.
- UML use-case diagrams for modelling the functionalities carried out by the actors.
- Identification of the actors involved, including type, description and the group to which they belong.
- Analysis of the scenarios that compose each use-case, providing information like the scenario description, primary actor, triggering event, pre-conditions, post-conditions and exchanges of information.
- Collection of the requirements.
- Common terms and definitions for all the use cases.

The information that was reported in the mentioned deliverables will be updated in the next version of the pilots' deliverables (D4.2, D5.2 and D6.2), to be released in M27. Although not many changes are expected, some of them will be included, as there is now a higher understanding of the stakeholders' needs, the constraints to be faced and the priority features to implement. Additionally, the better understanding of the common aspects of the pilots will have an impact on the scope of the pilots, as some features implemented in one pilot could be shared and incorporated by the others.

2.2 Description of the datasets

The pilot owners already filled in questionnaires about the datasets that would be produced during the project and how these would be made available, as explained in the Data Management Plan (D1.3 [7]). These datasets are very important, since they can be shared among the pilots with different purposes, such as analysing the context of the fields in different locations and times, training AI models and validating some activities.

The purpose of sharing this information among the pilots at this stage is to enable the possibility to reuse the datasets, so certain models may be generalized and, moreover, training and validation of AI models could be more efficient.

The detailed description of the datasets is included in those deliverables released by the pilots (D4.1 [4], D5.1 [5], D6.1 [6]) and it will be updated in M27, as the pilots release an update about the developments done. But, as this is an important aspect to enable collaboration between the pilots and other WPs like WP3, the following table summarizes the current status about the datasets available in the project.

Dataset	Pilot	Size	URL
Sensor and meteorology data	Spain (WP4)	53.000 Meteo observations	Not published.
Late Botrytis disease ground images (AGV)	Spain (WP4)	~3GB	http://dx.doi.org/10.20350/digitalCSIC/14011
Late Botrytis disease aerial videos 2021 (UAV)	Spain (WP4)	~17GB	https://doi.org/10.5281/zenodo.5654707
Late Botrytis disease aerial videos 2022 (UAV)	Spain (WP4)	~197 GB	https://zenodo.org/record/7064895#.Y053lnZBxPZ
Drone images: RGB, multispectral, hyperspectral	Finland (WP5)	~500GB	ftp://flexigrobots.collab-cloud.eu/
Drone images: RGB close up	Finland (WP5)	~80GB	ftp://flexigrobots.collab-cloud.eu/
UGV images/video (RGB)	Finland (WP5)	~1GB	ftp://flexigrobots.collab-cloud.eu/
Tractor vision system images (RGB)	Finland (WP5)	¨1GB	ftp://flexigrobots.collab-cloud.eu/
Satellite images	Finland (WP5)	~100GB	ftp://flexigrobots.collab-cloud.eu/
Application tasks: machinery inputs, navigation routes	Finland (WP5)	~100MB	ftp://flexigrobots.collab-cloud.eu/

Dataset	Pilot	Size	URL
Orthomosaics	Finland (WP5)	~70GB	ftp://flexigrobots.collab-cloud.eu/
UAV images of blueberries in Serbia	Serbia (WP6)	~70GB	Two batches of data available on the links: https://zenodo.org/record/5712792#.YZtTUOTTUWM https://zenodo.org/record/7408689#.Y5B0h2ldeNw
UAV images of blueberries in Lithuania	Lithuania (WP6)	~600GB	http://gofile.me/5G1pV/pbaq96qc5

Table 1 Summary of datasets generated by the pilots in M12

The main update with respect to the summary provided in D2.7 [8] has to do with the size of some datasets, as more data was collected during the last months, especially because of the work done in data collection in the campaign of summer 2022. These updates are very important because they complete the data to be used for releasing models to be validated with the data to be collected in the next summer campaign.

2.3 Description of devices, robots and platforms

This section updates the information about those devices, robots and platforms developed or used in the context of the pilots. Such elements are important because they are part of the backbone of the pilots' implementation, and they can be horizontal to the pilots in some cases. It is up to the pilots to identify to what extent some of these elements can be reused by other pilots.

The initial list was described in the initial deliverables of the pilots (D4.1 [4], D5.1 [5] and D6.1 [6]), so this section provides an updated view of these elements. The list will be updated again in the future deliverables of WP4, WP5 and WP6, in M27.

As described in D2.7 [8], the table provides the following information:

- The technical name of the component used
- The pilot which is using or developing the component
- The type of component (a device, a specific kind of robot, a platform, etc.)
- Indication whether it is a product available in the market (taken as is), or an available product that was improved, or a new product developed in the context of FlexiGroBots
- Indication of the current status of the component in the implementation (if it is already available or if it is planned or ongoing).

Device, robot or platform	Pilot	Type	Commercial, improvement or new product	Availability
Motes and weather stations	Spain (WP4)	Device	Commercial	Yes
DJI Matrice 210 RTK	Spain (WP4)	UAV	Commercial	Yes
DJI Matrice 300 RTK	Spain (WP4)	UAV	Commercial	Yes
DJI Phantom 4 RTK	Spain (WP4)	UAV	Commercial	Yes
Adapted Renault Twizy	Spain (WP4)	UGV	Improvement	Yes
Adapted RB-VOGUI	Spain (WP4)	UGV	Improvement	Yes
Cultiva Decisiones DSS	Spain (WP4)	Digital platform	Improvement	Yes
Robot Tractor	Finland (WP5)	Machinery	Improvement	Yes
CLAAS windrower implement	Finland (WP5)	Machinery	Commercial	Yes
VPZ sprayer	Finland (WP5)	Machinery	Commercial	Yes
Probot UGV	Finland (WP5)	UGV	New product	Yes
LUKE UGV	Finland (WP5)	UGV	Improvement	Yes
Robot arm (weeding tool)	Finland (WP5)	UGV	Improvement	Yes
UGV test platform (Probot)	Finland (WP5)	UGV	Commercial	Yes
DJI Phantom 4 RTK	Finland (WP5)	UAV	Commercial	Yes
DJI Phantom 4 Multispectral	Finland (WP5)	UAV	Commercial	Yes
DJI Mavic Zoom 2	Finland (WP5)	UAV	Commercial	Yes
Parrot Anafi	Finland (WP5)	UAV	Improvement	Yes
DJI Agras T-16	Finland (WP5)	UAV	Commercial	Yes
MyFarm FMS	Finland (WP5)	Digital platform	Improvement	Yes
QGroundController	Finland (WP5)	Digital platform	Improvement	Yes
ISOBUS task controller,	Finland (WP5)	Digital platform	Commercial	Yes

Device, robot or platform	Pilot	Type	Commercial, improvement or new product	Availability
implement controller, EFDI				
Drone service ground station	Finland (WP5)	Device	New product	Yes
Plant-O-Meter	Serbia (WP6)	Device	Improvement	Yes
UGV Soil Sampling	Serbia (WP6)	UGV	New product	Yes
DJI P4 Multispectral	Serbia (WP6)	UAV	Commercial	Yes
VTOL Quantum Trinity F90+	Serbia (WP6)	UAV	Commercial	Yes
DJI Matrice 600 Pro UAV	Lithuania (WP6)	UAV	Commercial	Yes
AgroSense FMIS	Serbia (WP6)	Digital platform	Improvement	Yes
Agrosmart	Lithuania (WP6)	Digital platform	Improvement	Yes

Table 2 Summary of devices, robots and platforms to be used by the pilots

At this stage, the pilots are expected to look at all the elements available and determine whether there are clear collaboration areas between the pilots, that could improve their implementation or even add some features by reusing components as a way to reduce the time required for implementing the expected functionalities.

2.4 Consolidation

In the context of the T2.5 activity, the consortium has collected and analysed information about the current activities of the pilots. Such information has been used to identify collaboration areas, refine some of the use cases of the pilots, evaluate the KPIs previously defined in D2.7 [8] and analyse the impact of the horizontal services.

The analysis of KPIs has provided evidence of the current status of the pilots and what is left to achieve the expected objectives, adapting the plans of the pilots in such a way that the KPIs will be fulfilled.

On the other hand, the current analysis of the pilots and the usage of horizontal services has enabled the possibility to improve their specification and implementation, since there is still time to include improvements and adapt the work plans (reflected in the components backlogs), so they will provide the expected functionalities by the end of the project, taking into account that the project must rely on the next summer campaign to collect additional data and to validate the implemented solutions.

The next sections of this document provide additional details about the consolidation process, current progress and future activities in the context of the pilots.

2.5 Pilots Integration

The pilots implemented in the context of FlexiGroBots address several technical areas, not only incorporating outcomes produced in the context of WP3, but also producing additional components and materials in each pilot.

In some cases, such elements produced by the pilots may be of interest for other pilots, so they can be re-used by another pilot with several benefits. First of all, the implementation time will be reduced, since adopting a solution is usually faster than creating something from scratch. On the other hand, when several pilots use a component, it is possible to enable the generalization of a component and to improve its refinement, thanks to additional validation activities that will notify any bug or problem found, so developments will be modified, and their quality will increase.

Although this may not be applicable to all developments, it may happen with some of them. Therefore, it is necessary to identify those areas where this interaction could happen. The main areas identified for this, so far, are the following:

- **Datasets:** Those datasets produced by a pilot may be reused in other pilots with different purposes (e.g., calculate certain indexes or train AI models);
- **Robots and Devices:** Those robots used in a pilot could be used in another pilot, showing that they are interoperable (like UAVs, or the harvesting robot);
- **Models:** AI models developed for a pilot might be applicable to another pilot (e.g., models for pests and diseases detection, that might be common to some pilots);
- **Usage of Horizontal Services:** The way to use services like WP3 AI models and the MCC;
- **Validation Methodology:** Agree on a common methodology to carry out the validation of the pilots, with the same steps, creating similar outcomes.

The consortium has already identified and started some of the activities. While the validation methodology is still under discussion, the rest of aspects were analysed (checking out their feasibility) and some of the pilots are working in the implementation of some integration tasks (described in the following sections).

The first group of ongoing activities is expected to show results in the following months. Additionally, the consortium agreed to have periodic teleconferences, in which the current tasks and future ones are discussed.

The next group of activities will be agreed in January 2023, as there are already some ideas around the applicability of models to other pilots, and the way to optimize the usage of horizontal services will be clearer in the following months. Such ideas are also described in a new subsection for each pilot.

3 Alignment of the FlexiGroBots Platform and Pilots

3.1 Pilot 1 – Grapevines

3.1.1 AI Platform

At this stage of the project, the FlexiGroBots AI platform provided by WP3 is ready to be used, especially for the creation and execution of AI pipelines. In line with the expectations described in D2.7 [8], this infrastructure (that includes access to GPUs) can be used to facilitate the development of ML models and the publication of inference services (so the trained models infer a result based on the inputs provided through the service exposed). This infrastructure is already in use by some of the horizontal services and the pilot will implement its own pipelines in the following months (e.g., botrytis detection model).

Some AutoML functionality is available, although it is not yet in use. Depending on the results obtained when the first AI pipelines are implemented, data scientists will be able to use AutoML to improve the accuracy of the models.

3.1.2 Common Data Enablers and Services

As described in D2.7 [8], the Agriculture Data Space built is very useful for the grapevines pilot, since it is an adequate way to share data among entities, keeping control of data sovereignty.

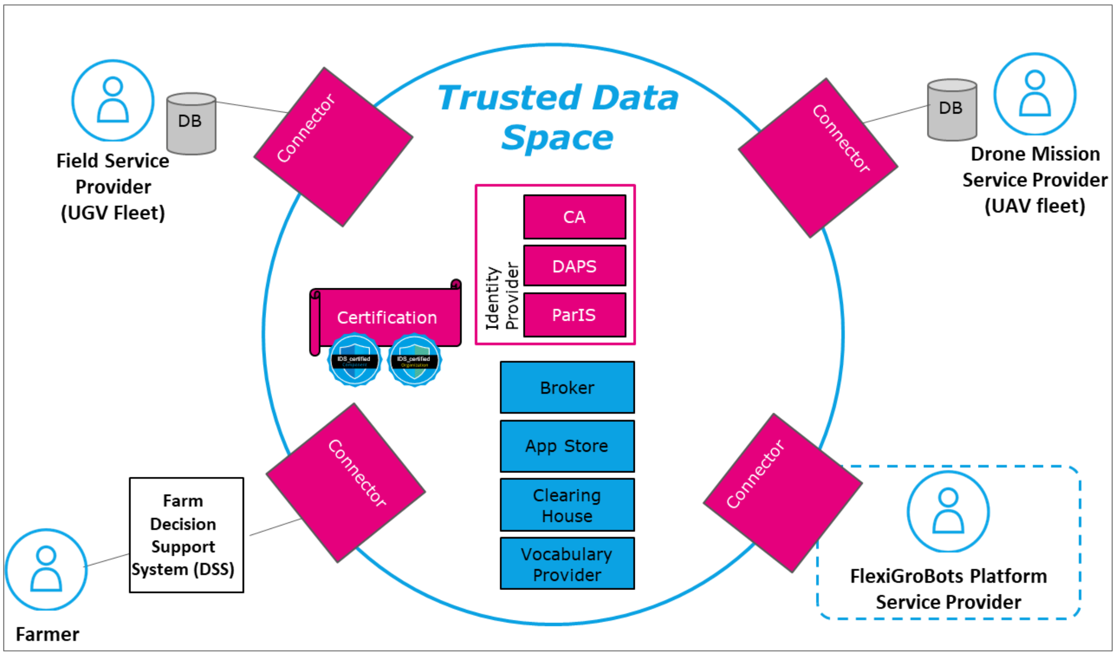

Figure 3 Agriculture Data Space in Pilot 1, as depicted in D2.7

The entities identified as the stakeholders connecting to the IDSA-based data space remain the same: Field Service Provider (UGV Fleet), farmers' Decision Support System (DSS), the FlexiGroBots AI platform Provider and the Drone Mission Service Provider (UAV fleet).

In the context of the pilot 1, there are ongoing works in the connection of the farmers' Decision Support System (DSS). At this stage, the corresponding connector has been implemented and it is already possible to connect from the SERESCO's Farm Information System with the data space. Additionally, it is possible for UAV and UGV providers to connect with the data space and share information.

3.1.3 Geospatial Enablers and Services

The consortium has made available an instance of the Open Data Cube (ODC) that can store and serve geospatial-based datasets, being compliant with the OGC standards. Pilot 1 is making use of this infrastructure of the project to store satellite images (from Copernicus) as well as the images that have been collected with the UAVs during the last campaign.

The structure of the ODC has been adapted to fit with the needs of the pilot and the uploaded datasets are available, including their metadata. The pilot has taken advantage of features like the automatic metadata generation, and the data can be accessed by SERESCO's FIS.

3.1.4 Common Application Services

This pilot has generated some images during the last months that enable the possibility to start testing and using some of the AI models implemented in WP3. Although none of the models is already integrated operationally, some tests have already started with some of them.

Some of the videos recorded in the field have been used with the models for anonymization of workers in the video and detection of distance while harvesting. During the next months, the consortium will work in the line of integrating different models from WP3, like the ones mentioned and objects tracking.

3.1.5 Mission Control Centre

As mentioned in D2.7 [8], pilot 1 can benefit from the MCC when managing a fleet of robots with multiple features, like mission planning and supervision, adaptive planning and alarms notification.

The team of pilot 1 has been involved in the development of the routing mechanism of the MCC, so it will be used to manage the robots.

Before this can be achieved, it is necessary to complete the implementation of the communication mechanism between the pilot robots and the MCC through MQTT. The adaptations required are already ongoing (adding support for MQTT to ROS), so it will be possible to retrieve telemetry and send tasks to the robots in the following months.

3.1.6 Other Pilots

Pilot 1 has common points with the other pilots that can be exploited to add additional features or to implement more efficiently the pilot itself. Due to the nature of the crop, it shares more commonalities with Pilot 3 (blueberries), as both are fruits.

In the area of datasets sharing, this pilot is collecting aerial images from the rest of pilots. The consortium is working on the development of a precision agriculture technique that will allow a quick evaluation of the images captured by the drone, so that the ground robot can have information regarding the spatial variability of the vegetation of the field almost in real-time, to be able to start working. It is a technique that will generate maps to assess the spatial variability much faster, but also less accurately, therefore it is a complementary technique to the usual photogrammetric processes for the generation of orthomosaics. In this way, the information of each image is analysed individually using map algebra operations (vegetation indices), and then using geostatistical procedures, the information of each image is related based on its position, in order to generate the spatial variability map of the plot. The main advantage of this technique is its low computational cost and its speed compared to conventional photogrammetric processes. The main disadvantage is that its accuracy will be lower. This is an ongoing work, and its outcomes will be reported in detail in D4.2.

This pilot can benefit from devices developed in the context of pilot 3. The robot that collects and analyses soil samples may be used in the context of fields of vineyards, to analyse the soil properties whenever needed. As the logistics to use such robot in the Spanish fields is complicated, the consortium has agreed to test such robot in vineyards in Serbia, in order to check whether it would be feasible to integrate the robot in such environment.

From the models perspective, the weed detection model implemented in pilot 3 may be applicable in the context of pilot 1. Such model can detect weeds to be removed in the field by using a camera in a UGV (as aerial images may not be able to detect weeds because they are hidden), and such weeds are similar to those that grow in the Spanish pilot area. It may not be applicable to other regions in Spain, but it may be possible to obtain good results in the Galicia region. Therefore, the consortium will test this model in the context of pilot 1 and will integrate it in the pilot use cases in case the results are good enough.

Finally, the concept of image mission (in which there is image processing and analysis pipelines) could be shared among pilots. Therefore, this pilot can benefit from the processes already done in the context of pilot 2.

3.2 Pilot 2 – Rapeseeds

3.2.1 AI platform

This pilot also defined how it can benefit from the AI platform in deliverable D2.7 [8]. At this stage of the project, the pilot is working in the model for rumex plants detection, and it also collaborates with WP3 in the definition and implementation of the ML model for pests detection (based on the bugs counted in traps).

The pilot will implement the corresponding AI pipeline for the rumex plant detection in the early part of project year three, so it will be possible to train and serve the model using the AI platform. In the case of the pests detection model, WP3 team will take care of it.

On the other hand, the pilot will explore the possibility to use the AI platform to optimize the model for objects tracking, with the purpose of obtaining a fast and accurate model.

3.2.2 Common data enablers and services

In line with the work that pilot 1 has done, once the FlexiGroBots agricultural data space is available, the work to integrate the IDSA-based platform with the pilots has started. This is also the case for pilot 2. Although it is necessary to face some technical issues, the work is ongoing and it is expected that the connection will be running by January 2023.

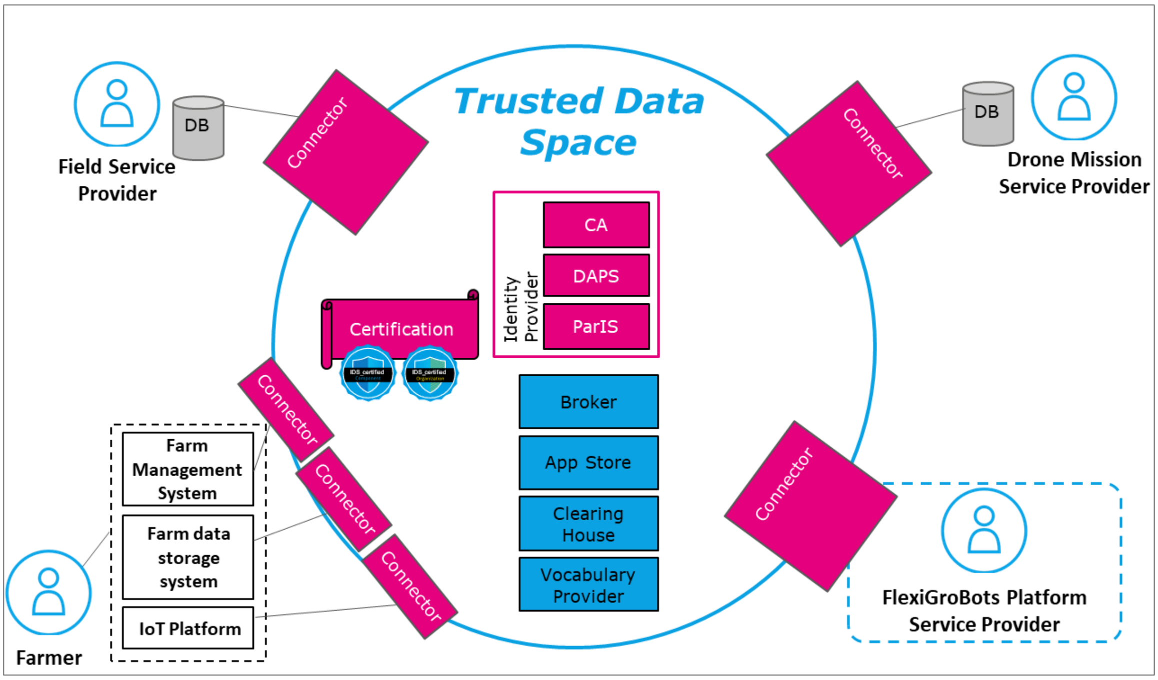

Figure 4 Depiction of the embryonic Agriculture Data Space in Pilot 2, as depicted in D2.7

It is worth mentioning that the case of this pilot is a bit more complex than the previous one, since it requires to deal with more connectors (deliverables D2.7 [8] and D2.2 [2] provide more details). The main focus of the current work is on the connection with the farm management system and farm data storage systems.

3.2.3 Geospatial enablers and services

As pilot 2 has its own infrastructure in place for storing and accessing geo-localized datasets, the consortium agreed that this pilot will not use the geospatial services provided by WP3 (the ODC instance), as it is not necessary and the integration will be more efficient with the system the pilot already has in place.

3.2.4 Common application services

This pilot had identified three main AI models to incorporate to the pilot: rumex detection, rapeseed pests identification and objects tracking for situational awareness.

During the last months, the work was focused on the last two models (pests identification and objects tracking). There has been significant progress in the area of objects tracking, as WP3 used some datasets provided by the pilot 2, together with other sources, to train a model in such a way it is able to detect the automated tractors in the field.

The consortium has already done some testing and a demo in which a drone is tracking a tractor moving in the field. It is still necessary to do more progress to identify more objects and consolidate the integration, expecting to have the model integrated by M25.

On the other hand, some testing was done with the pests detection model based on datasets provided by pilot 2. One of the lessons learnt was that it seems unfeasible to detect pests directly in the plants (as bug are really hard to detect in such environment). The proposed solution is to analyse the traps in such a way that, if the number of bugs trapped is high, we may infer that there is a pest. The work will continue during the next months, since this model is in an early stage, also from the WP3 perspective.

3.2.5 Mission Control Centre

In the previous deliverable (D2.7 [8]), the relationship between the rapeseed pilot and the MCC was already described, clarifying how some of the use cases would make use of this tool (mentioning pest management, rumex weeding and silage harvesting.

Since the MCC is still under development, although the works have already started, it was not possible to have a full integration yet. The main work with respect to this component and this pilot integration is focused on enabling the connection with the robots in the field, so it will be possible to collect data from them and to send them requests to perform operations and move through the field.

This work is already started and a first integrated prototype is planned to be available by M26, with one example working. Additionally, the pilot will collaborate for the implementation of simulated devices as well, together with WP3.

3.2.6 Other Pilots

This pilot has a clear relationship with the rest of pilots as well, especially in the areas of the models and the devices/robots used.

From the data perspective, aerial images from the other pilots may be interesting for their usage with the weeds detection model, improving the training and inference of the model, especially if it is applied to other fields. The AI pipelines will benefit from the data shared among the pilots in this concrete area. Additionally, new datasets could be used to detect nitrogen differences, being able to identify in which areas this element should be spread in the future.

In the area of the models, the main collaboration with other pilots is related to the weed detection. Although pilot 2 has been developing a model for weed detection, the one developed in the context of pilot 3 is for a different type of weeds and they may be complementary. Therefore, the consortium is planning a testing with such model to check how adequate it may be in pilot 2.

While the pests detection model is under development with the main collaboration of pilot 2, and it could be applicable to the other pilots, in the case of crop diseases, as rapeseed can be affected by botrytis as well, the consortium will check out whether the model developed in pilot 1 can be used with good results. It will be important to check if there is the required data in order to do so, both for an adequate training and validation.

When looking at the robots and devices available, pilot 2 does not share as many commonalities as the other two pilots, but still it has some common points to be exploited. The soil sampling robot implemented in pilot 3 is useful in the context of pilot 2, facilitating some of the tasks in the field. On the other hand, harvesting related devices are not so useful in this case. Another area to explore is the usage of multiple UAVs, also those already used in other pilots, in a multi-robot environment.

Finally, as all the pilots will share information and good practices about the usage of the horizontal services, it will be possible for pilot 2 to benefit from those good practices as well. Each pilot may do a particular use of these services and all of them can incorporate the lessons learnt to their implementation.

3.3 Pilot 3 – Blueberries

3.3.1 AI platform

As described in D2.7 [8], pilot 3 requires using the AI platform from WP3 in order to carry out image analysis that can detect weeds and plant diseases. Because of the type of problem addressed (that requires some specific calibration of parameters), the pilot has stated that it is necessary to use the AutoML feature as well.

The pilot has already started the implementation of an AI pipeline in the AI infrastructure to train one of the models. The pipeline is not complete yet and, later on, it will be necessary to make use of the service for publishing the inference service. The consortium plans to have the AI pipeline working in the near term (during M25 and M26), so it will be possible to also start using the AutoML feature that is available.

3.3.2 Common data enablers and services

Deliverables D2.2 [2] and D2.7 [8] already provided details about the way in which pilot 3 is integrated with the agriculture data space implemented in the context of WP3 (depicted in Figure 5). In this case, it is very similar to the context of pilot 1, but one of the connectors is not needed (as the roles of drone mission and field service provider are merged).

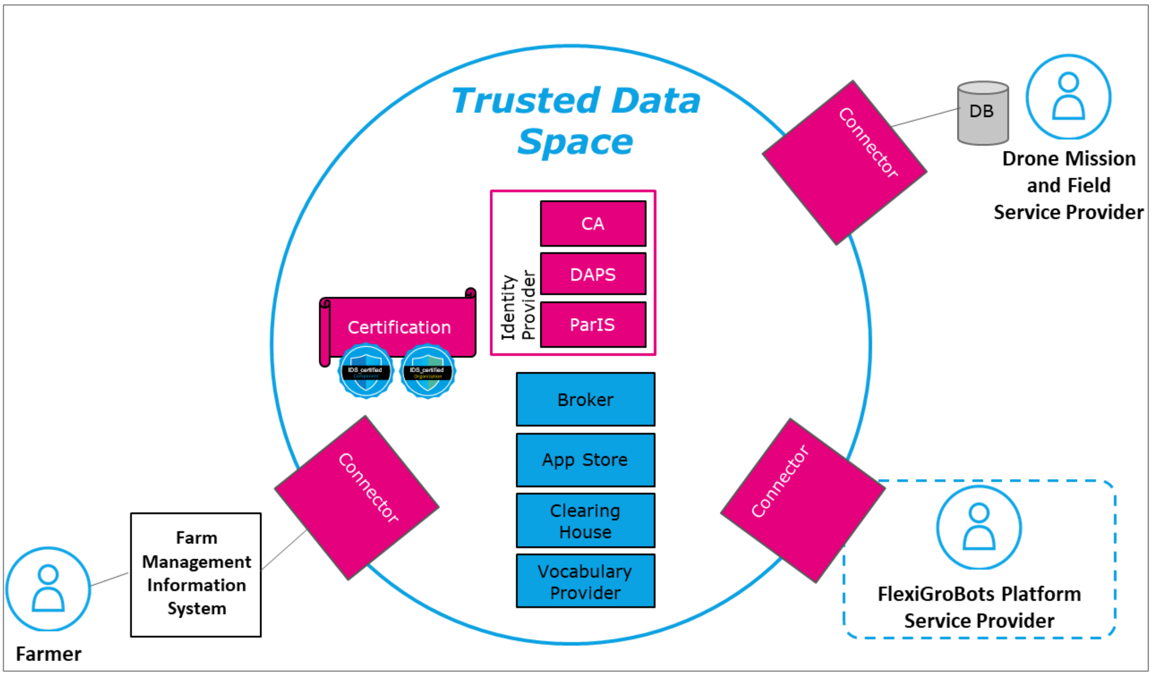

Figure 5 Depiction of the embryonic Agriculture Data Space in Pilot 3

The consortium is already working in the integration of the corresponding connectors and some progress has been done (some datasets were uploaded from the perspective of the 'Drone Mission and Field Service Provider').

The team is facing issues related to network constraints to access the required ports, but the work is progressing and they are expected to complete such integration no later than M26.

3.3.3 Geospatial enablers and services

As it happened with pilot 2, this pilot has the required infrastructure in place for storing and accessing geo-localized datasets, so the consortium agreed that this pilot will not use the geospatial services provided by WP3 (the ODC instance), as it is not necessary.

3.3.4 Common application services

This pilot has been focused on developing the model for weeds detection, so their progress integrating other common models is limited. There is specific interest in incorporating models for objects detection and diseased areas highlighting, but these activities are not started yet. The consortium has planned to start such activities from M25 on, reusing as many features as possible, in line with the lessons learnt from the other pilots.

3.3.5 Mission Control Centre

The current status of pilot 3 with respect to the MCC is the same as in the other pilots. The MCC development is ongoing and the main activity done from the pilot perspective is to enable the communication channel between the robots used in the context of pilot 3 and the MCC. That means the need to enable MQTT communication between the different elements of the pilot.

Once such feature is available (so robots can be controlled from the MCC), the pilot will continue with the integration of other features, like mission planning for UAVs and UGVs.

3.3.6 Other Pilots

This pilot is in a position to share its outcomes with the other pilots. This is the case of the soil sampling robot, the rows detection AI model and the weeds detection model.

The pilot can also benefit from the work done in the rest of pilots. A good example has to do with the data to be used for improving the training of the weed detection AI model. Pilot 2 and Pilot 1 can provide the aerial images that could be used for generalizing the usage of the proposed model.

From the robots and devices perspective, pilot 3 could benefit from the developments in pilot 1, especially in the area of harvesting. The harvesting method for blueberries and grapevines is not very different, so the same type of robot could support such activity in pilot 3. Because of the complexities in the logistics to move robots among pilot locations, the consortium has proposed to test the usage of the harvesting robot in blueberries fields in Spain, in order to show its utility.

In the area of models, this pilot may benefit from the work done in the botrytis disease detection developed under pilot 1, although it may require specific training when applying it to the blueberries. Additionally, the pest detection mode, under development between WP3 and pilot 2, could be applied if the scenario is adapted to include the traps.

The last point of interaction, as in the case of the other pilots, is related to the lessons learnt and good practices with respect to the usage of horizontal services, like the MCC (e.g., image missions), so the implementation of use cases will be optimal.

4 Detailed planning of FlexiGroBots pilots

Since the first year of the project, the pilots have been following an agile approach for developing the components they required. Therefore, a detailed backlog was set up, in which all the tasks related to components design and development were including, keeping track of the activities done during the last months of the project and managing those tasks as required (bearing in mind the different priorities they may have.

WP leaders have been managing the backlog and sprints in line with the agile methodology and this will continue during the last year of the project. The following subsections update the information about the tasks that are in the backlogs of the pilots, as well as a planning of features to be implemented during the next months, also reporting about the status of the activities planned for 2022.

Further details will be provided from the pilots perspective in those deliverables to be released in M27: D4.2, D5.2 and D6.2.

4.1 Pilot 1 – Grapevines

4.1.1 Product Backlog

User story ID	User story	Priority	Story points	Status
US_01_01	Creation of an IDSA connector for the DSS	High	2	Developing
US_01_02	Integration of Mission Control Centre with DSS	High	4	To Do
US_01_03	Development of algorithm for detection of high-risk areas from UAV	High	9	Developing
US_01_04	Development of software solution for visual confirmation of botrytis attack from UGV	High	8	Developing
US_01_05	Field validation of risk detection algorithm (from UAV)	High	3	Pending
US_01_06	Field validation of botrytis detection algorithm (from UGV)	High	3	Pending
US_01_07	Validation & KPI measurement for harvesting assistance use case	High	2	Pending

User story ID	User story	Priority	Story points	Status
US_01_08	Design and development of the Botrytis treatment equipment (UGV)	High	5	Developing
US_01_09	Field validation of botrytis treatment equipment (from UGV)	High	2	Pending
US_01_10	End-to-end integrated pilot test & demonstration	High	5	Pending
US_01_11	Pilot reporting: D4.3 & D4.4	Medium	3	Pending

Table 3 Product backlog for pilot 1

4.1.2 Release Plan and its Implementation

The first table shows the progress done with respect to the plans presented in D2.7 [8], describing the implementations that were done during the last year.

Timeline	Goals
Q1 2022	First studies of the correlation of variables in datasets for detection (remote and proximal sensing) of Botrytis Definition of the botrytis detection (remote and proximal sensing) algorithms.
Q2 2022	1st phase of ground inspection (UGV) to detect Botrytis in Terras Gauda plots. Definition of the botrytis detection algorithms for remote and proximal sensing respectively. Visualisation of telemetry data in DSS web app.
Q3 2022	DSS web platform stable implementation. 2nd phase of drone flights to detect Botrytis in Terras Gauda plots. 2nd phase of harvesting field tests in Terras Gauda plots. First Steps of *D4.2 Technical report on the demonstrator-specific components (CSIC, R, PU, M27).*
Q4 2022	DSS web platform tests. Labelling of images and videos (UAVs and UGVs) of the second field test slot. 2nd datasets analysis tests. Initial version of aerial Botrytis detection algorithm integrated into DSS web platform. First version of *D4.2 Technical report on the demonstrator-specific components (CSIC, R, PU, M27).*

Table 4 Release plan implementation for pilot 1 in Y2

The next table shows the current plans and releases to be done during the next year.

Timeline	Goals
Q1 2023	IDSA connector implementation. Integration of MCC with DSS Integration UGVs and UAVs to the MCC through the Robot Fleets Management Systems (RFMS) connected to the DSS platform.
Q2 2023	Finished development of the high-risk area detection algorithm (UAV) Finished development of the Botrytis detection algorithm (UGV) Implementation of the Botrytis detection algorithm in the UGVs Finished development and implementation of Botrytis precision treatment equipment (UGV) Visualisation of robot telemetry data in the Decision Support System.
Q3 2023	Field validation for high-risk areas detection algorithm (UAV) Field validation for Botrytis detection algorithm (UGV) Field validation for Botrytis treatment solution (UGV) Field test and KPI measurement of harvesting assistance solution (UGV) Test and validation of final version of DSS web app (stable implementation) Dissemination event in Terras Gauda
Q4 2023	End-to-end test and pilot demonstration Pilot reporting: final version for deliverables D4.3 and D4.4 Project closure

Table 5 Release plan for pilot 1 in Y3

4.2 Pilot 2 – Rapeseeds

4.2.1 Product Backlog

User story ID	User story	Priority	Story points	Status
US_02_01	Vision system for the tractor is developed.	Medium	5	Done
US_02_02	The robotized tractor drives a complete field mission without machinery.	High	8	Done
US_02_03	The suitable application task is developed by using project specific tools. This will be done for the spraying drone and for the ISOBUS-sprayer.	Low	5	Done

User story ID	User story	Priority	Story points	Status
US_02_04	The complete mission flow is demonstrated with a spraying application.	Low	5	Done
US_02_05	Data according to best practices will be collected above the windrower missions	Medium	1	Done
US_02_06	Testing of separate components for situation awareness service	High	5	Done
US_02_07	The algorithms for the Rumex cluster detection based on orthophotos will be developed.	Medium	5	Done
US_02_08	General classification methodologies and data collections for grass fields and rapeseeds	Medium	3	Done
US_02_09	Data collection for pest detection	High	3	Done
US_02_10	Methodologies for image capture mission	Low	5	Done
US_02_11	Control and communication of weeding UGV	High	5	On-going
US_02_12	Rumex weeding tests and demonstration, first iteration	Medium	5	On-going
US_02_13	Digestibility data collection	Low	3	Done
US_02_14	Digestibility and yield classification methodology developed	Medium	8	Done
US_02_15	Integrated situation awareness service	Medium	8	Pending
US_02_16	Digital infrastructures with robot operators' tools for pilot 2 up and running	Low	3	Pending
US_02_17	Digital infrastructure for farmer in pilot 2	Low	3	Pending
US_02_18	Links to FlexiGroBots data space for data sharing operational	Medium	4	Pending
US_02_19	Complete mission flow for Rumex weeding using MCC	High	10	Pending
US_02_20	Complete mission flow for pest management using MCC	High	10	Pending

User story ID	User story	Priority	Story points	Status
US_02_21	Complete mission flow for silage harvesting using MCC	High	10	Pending
US_02_22	Disseminate the results from all use cases to external partners (videos, code, documentation)	Low	5	Pending
US_02_23	Improving exploitability of developed new platforms (tractor, field robot, etc.)	Medium	5	Pending

Table 6 Product backlog for pilot 2

4.2.2 Release Plan and its Implementation

The first table shows the progress done with respect to the plans presented in D2.7 [8], describing the implementations that were done during the last year.

Timeline	Goals
Q1 2022	Vision system functioning, The Zed 2 – AI stereo camera-based imaging system will detect solid or moving objects in front of the robotized tractor, the first iteration. Preparation of digestibility datasets available for the project. The algorithms for the Rumex cluster detection based on orthophotos will be developed. Weeding UGV construction continues.
Q2 2022	General grass and rapeseed field classification algorithms for anomaly-detections will be developed. Additional dataset collection for all of the use cases will be done. Weeding robot platform ready.
Q3 2022	Additional dataset collection for all of the use cases will be done. The robotized tractor drives a complete field mission (without machinery). Data according to best practices will be collected above the windrower missions. General rapeseed field classification algorithms for anomaly-detections and flowering states will be developed.
Q4 2022	The situation awareness solution is integrated.

Table 7 Release plan implementation for pilot 2 in Y2

The next table shows the current plans and releases to be done during the next year.

Timeline	Goals
Q1 2023	The situation awareness solution is demonstrated. Verify the best parameters for the pest imaging. First version of *D5.2 Technical report on the demonstrator-specific components (PRO, R, PU, M27).* Complete weeding robot system including robot platform and weeding tool AI services integrated into Pilot 2 use cases Digital infrastructures needed for pilot 2
Q2 2023	Data sharing solution using data space integrated in pilot 2 Complete situation awareness service demonstrated Complete mission flow with MCC integrated into pilot 2
Q3 2023	Complete mission executions in Rumex weeding, silage harvesting and pest management use cases
Q4 2023	Rumex weeding demonstration as a distributable video and implementation descriptions Pest management demonstration as a distributable video and implementation descriptions Silage harvesting demonstration as a distributable video and implementation descriptions

Table 8 Release plan for pilot 2 in Y3

4.3 Pilot 3 – Blueberries

4.3.1 Product Backlog

User story ID	User story	Priority	Story points	Status
US_03_01	Zone delineation algorithm developed for determining soil sampling points	Medium	2	Done
US_03_02	Robotic arm for soil sampling upgraded	High	5	Done
US_03_03	Image segmentation algorithm prototype developed for blueberries	High	8	Done
US_03_04	Field testing of soil sampling module	Medium	3	Done

User story ID	User story	Priority	Story points	Status
US_03_05	Database of UAV images from Serbia acquired	Low	3	Done
US_03_06	Database of UAV images from Lithuania acquired	Low	3	Done
US_03_07	Robotic sprayer arm developed	High	8	In progress
US_03_08	Integration with Mission Control Centre	Medium	5	In progress
US_03_09	Further image processing algorithms training with newly acquired data	Medium	2	Done
US_03_10	Robotic sprayer arm integration with UGV	Medium	5	In progress
US_03_11	Field testing of robotic sprayer	Medium	3	In progress
US_03_12	Integration with IDSA	Medium	5	In progress

Table 9 Product backlog for pilot 3

4.3.2 Release plan

The first table shows the progress done with respect to the plans presented in D2.7 [8], describing the implementations that were done during the last year.

Timeline	Goals
Q1 2022	Development of individual components of the robotic soil sampler in the lab. Initial development of the UAV-based AI model for the use-case of early-stage blueberry disease detection.
Q2 2022	Data acquisition in Serbia (starting in April). Acquisition of UAV imagery for model training; lab analysis of soil and leaves. Data acquisition in Lithuania (starting in May). Acquisition of UAV imagery for model training; lab analysis of soil and leaves. Initial development of the UAV-based AI model for the use-case of yield prediction. UGV soil sampler prototype assembly.
Q3 2022	Upgrade of image recognition system. Further development of advanced image recognition algorithms. UGV soil sampler lab testing and upgrades.
Q4 2022	UGV components prototype upgrade. Upgrading soil sampler according to the field test takeaways.

Table 10 Release plan implementation for pilot 3 in Y2

The next table shows the current plans and releases to be done during the next year.

Timeline	Goals
Q1 2023	Initial development of a UGV-based image recognition system for blueberry diseases/weeds. Formation of the pipeline and achieving initial results. Development of the robotic sprayer prototype. Robotic arm for target spraying of weeds and diseased leaves.
Q2 2023	Final field tests and UGV components prototype upgrade. Upgrading soil sampler / robotic sprayer according to the field test takeaways. Data acquisition in Serbia (starting in April). Acquisition of UAV imagery for model training; lab analysis of soil and leaves. Data acquisition in Lithuania (starting in May). Acquisition of UAV imagery for model training; lab analysis of soil and leaves. First version of D6.2 Technical report on the demonstrator-specific components (BIO, R, PU, M27).
Q3 2023	Final testing and field deployment.
Q4 2023	Pilot assessment, final strategy for technology transfer and exploitation of the results. Final version of D6.3 Pilot 3 Demonstrator integration, testing and deployment (ART, R, PU, M34) Final version of D6.4 Pilot 3 assessment (ART, R, PU, M36)

Table 11 Release plan for pilot 3 in Y3

5 FlexiGroBots validation and Key Performance Indicators (KPIs)

Section 5 is devoted to a detailed analysis of the validation mechanisms that will be applied in each one of the pilots to evaluate the corresponding KPIs proposed in the Description of Action (see Annex 1). Some additional indicators have been added in light of the more accurate specification of the use-cases. At the end of the section, a matrix is included to show which KPIs are addressed by each pilot.

5.1 Pilot 1 – Grapevines

KPI ID	Description	Validation mechanism	Success criteria	Current Value
KPI3	Demonstrators using more than 90% of the MCC services	The list of MCC services used within the pilot compared to the total list.	= 1	0
KPI6	Number of data sets shared within the pilots	Pilot 1 shares datasets on Zenodo and other public repositories.	>= 4	5
KPI7	Number of pilots using georeferenced agriculture-related data analytics	Pilot 1 uses georeferenced agriculture-related data, for instance, image segmentation.	= 1	1
KPI8	Number of datasets shared with third parties via ADS	Datasets are accessible to external entities to the project through FlexiGroBots IDSA compliant ADS.	>= 2	0
KPI9	Number of novel agricultural AI methods or Machine Learning (ML) models	Botrytis detection uses ML models both by remote sensing and proximal sensing.	>= 2	1
KPI10	Number of potential new products and services based on those new AI methods / ML models	Pilot 1 develops products to detect Botrytis with image segmentation and robotics-assisted harvesting.	>= 2	1
KPI12	Pilots for Assessment List of the Ethics Guidelines for Trustworthy AI	Assessment List of the Ethics Guidelines for Trustworthy AI is completed for pilot 1. Design,	= 1	1

KPI ID	Description	Validation mechanism	Success criteria	Current Value
		implementation and execution following the guidelines.		
KPI14	Platform assessment (cross-pilot)	FlexiGroBots platform used and assessed in pilot 1	= 1	0
KPI15	Demonstrators incorporating both UAV and UGV robotic platforms	Use UAV to generate the risk map and UGV to corroborate and apply the pesticide	= 1	0
KPI16	Number of robots taking part in demonstrated multi-robot systems	Multiple UAVs for different dataset acquisition and one UGV for ground validation	>= 2	4
KPI17	Number of DIHs with the capability of demonstrating FlexiGroBots pilots the project ends	Technologies involved in the use-cases are shared with DIHs. Material to support demonstrations is prepared: trainings, technology demonstrators, etc.	>=1	0
KPI18	Number of real-world pilots	Pilots are executed in the fields with conditions similar to production scenarios.	= 1	1
KPI19	Numbers of regions where the FlexiGroBots demonstrators are deployed and run	Pilot conducted in Spain	= 1	1
KPI21	Demonstrators showing AI4EU marketplace use cases	Pilot's demonstrators will integrate components published in the AI4EU marketplace.	= 1	0
KPI22	Number of agricultural Machine Learning (ML) models contributed to the AI4EU marketplace	Botrytis detection and generation of risk map, and harvest aid	= 3	1
KPI26	Number of DIHs actively engaged in pilots' development and demonstrations	AIR4S and Robocity2030	= 2	1
KPI28	Average percentage of improvement in the	Time to execute the tasks will be measured prior to the adoption of FlexiGroBots technologies.	> = 25%	Pending

KPI ID	Description	Validation mechanism	Success criteria	Current Value
	performance of tasks by robots	Measurements will be repeated at the end of the project.		
KPI29	Cost savings per season (Botrytis detection, phytosanitary treatments, transport)	Costs will be measured prior to the adoption of FlexiGroBots technologies. Measurements will be repeated at the end of the project.	>= 20%	Pending
KPI32	Number of different tasks robots are able to carry out	Botrytis detection, treatment application, harvest support.	>= 3	4
KPI33	Number of new different services offered to farmers	Botrytis detection, treatment application, harvest support.	>= 3	3
KPI34	Single pilot duration	Time of single autonomous robot operation in the demonstration.	>= 1 hour	Pending
KPI37	Number of components compatible with IDSA and OGC standards implemented and/or integrated within the system	Botrytis detection and pesticide application use georeferenced information following the OGC standard, while the ingestion of UAV/UGV data relies on the IDSA standard.	>= 5	0
KPI38	Reduce the use of the phytosanitary product, minimize costs and environmental damages	Use within pilot / regular use	>= 20%	Pending
KPI39	Reduce the cost of grape transport	Comparing production costs (staff costs, fuel costs…) between one of the plots used in the pilot and one of the other plots on the farm. These two plots should have a similar surface, slope, and distance to the winery.	Baseline: 220€/h per season Improv: 11% Target: 195 €/ha per season.	Pending
KPI40	Reduce time of grape transport	Comparing the time costs between one of the plots used in the pilot and one of the other plots on the farm, within a	Baseline: 180 min	Pending

KPI ID	Description	Validation mechanism	Success criteria	Current Value
		defined period. These two plots should have a similar surface, slope, and distance to the winery.	Improv: 50% Target: 90 min	
KPI43	Reduction of pesticide usage	Comparing expenditure on plant protection products between one of the plots used in the pilot and one of the other plots on the farm. A representative sample of an equal number of plants must be taken for both plots.	Baseline: 155€/h per season Improv: 9% Target: 141 €/ha per season	Pending
KPI48	Reduce inspection costs	Visual validation. Within a representative sample of plants, comparing between operator detection and algorithm prediction. Comparing yield loss between one of the plots used in the pilot and one of the other plots on the farm. These two plots should have similar surface and slope.	Baseline: 86€/ha. Improv: 30% Target: 59,5 €/ha	Pending

Table 12 Validation of relevant KPIs for pilot 1 after Y2

5.2 Pilot 2 – Rapeseeds

KPI ID	Description	Validation mechanism	Success criteria	Current Value
KPI3	Demonstrators using more than 90% of the MCC services	The list of MCC services used within the pilot compared to the total list.t	= 1	0
KPI6	Number of data sets shared within the pilots	Data sets shared as open research data from pilot 2. Number of data sets with DOI.	>=2	0

KPI ID	Description	Validation mechanism	Success criteria	Current Value
KPI7	Number of pilots using georeferenced agriculture-related data analytics	Pilot 2 uses georeferenced image segmentation.	= 1	1
KPI8	Number of datasets shared with third parties via ADS	Datasets are accessible to external entities to the project through FlexiGroBots IDSA compliant ADS.	>= 2	0
KPI9	Number of novel agricultural AI methods or Machine Learning (ML) models	Publication of the ML models in FlexiGroBots AI platform.	>= 3	0
KPI10	Number of potential new products and services based on those new AI methods / ML models	Silage harvesting, pests' management, rumex weeding.	>= 2	3
KPI12	Pilots for Assessment List of the Ethics Guidelines for Trustworthy AI	Assessment List of the Ethics Guidelines for Trustworthy AI is completed for pilot 2. Design, implementation and execution following the guidelines.	= 1	1
KPI14	Platform assessment (cross-pilot)	FlexiGroBots platform used and assessed in pilot 2	= 1	0
KPI15	Demonstrators incorporating both UAV and UGV robotic platforms	Number of final demonstrations in pilot 2 where UAVs or UGVs are involved.	= 1	3
KPI16	Number of robots taking part in demonstrated multi-robot systems	Aerial and ground robots worked together in robotics missions.	>= 4	2 (simultaneously) 7 (total)
KPI17	Number of DIHs with the capability of demonstrating FlexiGroBots pilots the project ends	Technologies involved in the use-cases are shared with DIHs. Material to support demonstrations is prepared: trainings, technology demonstrators, etc.	= 1	2
KPI18	Number of real-world pilots	Pilots are executed in the fields with conditions similar to production scenarios.	= 1	2

KPI ID	Description	Validation mechanism	Success criteria	Current Value
KPI19	Numbers of regions where the FlexiGroBots demonstrators are deployed and run	FlexiGroBots results are demonstrated in conditions similar to production scenarios and involving local stakeholders.	= 1	1
KPI21	Demonstrators showing AI4EU marketplace use cases	Pilot's demonstrators will integrate components published in the AI4EU marketplace.	= 1	0
KPI22	Number of agricultural Machine Learning (ML) models contributed to the AI4EU marketplace	Number of methods used in pilot 2 demonstrations that are distributed via AI4EU	>=3	0
KPI28	Average percentage of improvement in the performance of tasks by robots	Time to execute tasks within the pilot will be measured prior to the usage of FlexiGroBots technologies. The time will be measured again at the end of the pilot.	<= 50%	NA yet
KPI32	Number of different tasks robots are able to carry out	For instance: rumex identification, rumex removal, rumex transportation, pests' detection, pest's spraying. survey missions.	>= 5	NA (yet)
KPI33	Number of new different services offered to farmers	For instance: harvesting planning, situation monitoring, pests' management, rumex weeding.	>= 6	9
KPI34	Single pilot duration	Time of single autonomous robot operation in the demonstration.	>= 30 minutes	10 min
KPI37	Number of components compatible with IDSA and OGC standards implemented and/or integrated within the system	Components' prototypes are used in the pilot through dedicated deployments or called following "as a service" paradigm.	>= 5	5
KPI42	Autonomous tractor operation	Autonomous operation validated in demonstration activity	= 1	1
KPI43	Reduction of pesticide usage	The applied pesticide amount compared to normal use.	<= 75%	NA (yet)

KPI ID	Description	Validation mechanism	Success criteria	Current Value
KPI48	Work efficiency. The utilization of robot tractors in silage fleet shall decrease the need for human labour when the robotized tractor supervisor can simultaneously operate another working unit.	Work effort needed per autonomous tractor in autonomous harvesting task compared to traditional harvesting task.	<= 50% per added simultaneously operating working unit.	NA (yet)
KPI49	Decrease environmental load saving pesticides	Area of the field sprayed vs. area of the whole field.	<= 75%	NA (yet)
KPI50	Increased safety. Robotics together with an External situation monitoring system has the capability to create a more comprehensive view of the situation	The ratio of detected hazard situations vs. combined robot detected hazard situations.	>= 1	NA (yet)
KPI51	Rumex mapping. The existence of Rumex-weeds enables targeted weeding operations thus decreasing manual labour needs	The amount of detected Rumex spots vs. the amount of Rumex spots detected by manual operation.	>= 80%	NA (yet)
KPI52	Less laborious manual work for pests mapping	Automated identification time compared to the estimated time taken by manual detection. (mapping flight time + setting up the drone system vs. walking time through the mapped area).	<= 50%	NA (yet)
KPI53	Identification comparison to manual detection of pests.	Number of detected pest invasion areas compared to manually detected pests.	>= 90%	NA (yet)
KPI54	The harvesting timing can be improved thus providing more digestible dry matter.	Mathematical estimate of yield increase with changed harvesting order.	>= 1 % more digestible dry matter from	NA (yet)

KPI ID	Description	Validation mechanism	Success criteria	Current Value
			selected fields	
KPI55	Weeding efficiency	Ratio of weeded Rumex and manually detected Rumex.	>= 50%	NA (yet)

Table 13 Validation of relevant KPIs for pilot 2 after Y2

5.3 Pilot 3 – Blueberries

KPI ID	Description	Validation mechanism	Success criteria	Current Value
KPI3	Demonstrators using more than 90% of the MCC services	The list of MCC services used within the pilot compared to the total list	= 1	0
KPI6	Number of data sets shared within the pilots	Pilot 3 datasets shared on Zenodo or other public repositories.	>= 2	2
KPI7	Number of pilots using georeferenced agriculture-related data analytics	Pilot 3 using georeferenced image segmentation	>= 2	1
KPI8	Number of datasets shared with third parties via ADS	Datasets are accessible to external entities to the project through FlexiGroBots IDSA compliant ADS.	>=2	0
KPI9	Number of novel agricultural AI methods or Machine Learning (ML) models	Blueberry plant detection and weed/disease detection algorithms developed. Publication of the ML models in FlexiGroBots AI platform.	>= 2	2
KPI10	Number of potential new products and services based on those new AI methods / ML models	Weeds and diseases monitoring and detection, smart soil sampling, precision spraying.	>= 2	1
KPI12	Pilots for Assessment List of the Ethics Guidelines for Trustworthy AI	Assessment List of the Ethics Guidelines for Trustworthy AI is completed for pilot 3. Design, implementation and execution following the guidelines.	= 1	1

KPI ID	Description	Validation mechanism	Success criteria	Current Value
KPI14	Platform assessment (cross-pilot)	FlexiGroBots platform used in pilot 3	= 1	0
KPI15	Demonstrators incorporating both UAV and UGV robotic platforms	Number of final demonstrations in pilot 2 where UAVs or UGVs are involved. For instance, using UAVs for mapping and UGV for actions	= 1	0
KPI16	Number of robots taking part in demonstrated multi-robot systems	Aerial and ground robots worked together in robotics missions.	>= 2	2
KPI17	Number of DIHs with the capability of demonstrating FlexiGroBots pilots the project ends	Robotics DIH Belgrade, Agri-Food DIH BioSense	>= 2	2
KPI18	Number of real-world pilots	At least one field is analysed in Serbia and another in Lithuania. Pilots are executed in the fields with conditions similar to production scenarios.	2	2
KPI19	Numbers of regions where the FlexiGroBots demonstrators are deployed and run	Pilots conducted in Serbia and Lithuania	= 2	2
KPI20	Number of demonstrators deployed and running in different regions	The same technology working successfully in both Serbia and Lithuania	= 1	1
KPI21	Demonstrators showing AI4EU marketplace use cases	Blueberry data and algorithms shared through the AI4EU framework	= 2	0
KPI22	Number of agricultural Machine Learning (ML) models contributed to the AI4EU marketplace	Blueberry plant detection and weed/disease detection algorithms present at AI4EU	>=2	0
KPI26	Number of DIHs actively engaged in pilots' development and demonstrations	Robotics DIH Belgrade, Agri-Food DIH BioSense	= 3	3
KPI28	Average percentage of improvement in the	Soil sampling time sped up.	> = 25%	25%

KPI ID	Description	Validation mechanism	Success criteria	Current Value
	performance of tasks by robots	Pesticide amount reduced. Baseline will be measured prior to the adoption of FlexiGroBots technologies.		
KPI29	Cost savings per season (Botrytis detection, phytosanitary treatments, transport)	Baseline will be measured prior to the adoption of FlexiGroBots technologies.	> = 30% per crop season	To be evaluated in Y3
KPI32	Number of different tasks robots are able to carry out	Soil sampling and pesticide spraying functionalities developed	>= 2	To be evaluated in Y3
KPI33	Number of new different services offered to farmers	Weed/disease spraying, soil sampling operational	>= 2	0
KPI37	Number of components compatible with IDSA and OGC standards implemented and/or integrated within the system	Weed/disease maps, georeferenced soil samples and targeted pesticide application following the OGC standard, while all UAV/UGV data following IDSA standards	>= 5	0
KPI43	Reduction of pesticide usage	Comparison between "blanket" application vs. targeted application of pesticides	40%	To be evaluated in Y3
KPI45	Reduce cost soil sampling	Commercial cost per soil sample compared to the cost of robot operation	35%	To be evaluated in Y3
KPI46	Reduce the cost of potential damages from sub-optimal pesticide application	Calculation of the typical costs of weed/disease damages vs. the cost of robot operation + raw materials (pesticides)	25%	To be evaluated in Y3

Table 14 Validation of relevant KPIs for pilot 3 after Y2

5.4 Summary of the relevance of KPIs for pilots

KPI ID	Description	Pilot 1	Pilot 2	Pilot 3	Overall value
KPI3	Demonstrators using more than 90% of the MCC services	= 1	= 1	= 1	3

KPI ID	Description	Pilot 1	Pilot 2	Pilot 3	Overall value
KPI6	Number of data sets shared within the pilots	>=4	>=2	>=2	>= 8
KPI7	Number of pilots using georeferenced agriculture-related data analytics	= 1	= 1	= 2	= 4
KPI8	Number of datasets shared with third parties via ADS	>=2	>= 2	>=2	>= 6
KPI9	Number of novel agricultural AI methods or Machine Learning (ML) models	=>2	> 3	>=2	>= 7
KPI10	Number of potential new products and services based on those new AI methods / ML models	>=2	=> 2	>=2	>= 6
KPI12	Pilots for Assessment List of the Ethics Guidelines for Trustworthy AI	= 1	= 1	= 1	= 3
KPI14	Platform assessment (cross-pilot)	=1	= 1	= 1	= 3
KPI15	Demonstrators incorporating both UAV and UGV robotic platforms	=1	= 1	= 1	= 3
KPI16	Number of robots taking part in demonstrated multi-robot systems	>= 2	>= 4	>= 2	>= 8
KPI17	Number of DIHs with the capability of demonstrating FlexiGroBots pilots the project ends	>=1	= 1	>= 2	=> 4

KPI ID	Description	Pilot 1	Pilot 2	Pilot 3	Overall value
KPI18	Number of real-world pilots	1	1	2	= 4
KPI19	Numbers of regions where the FlexiGroBots demonstrators are deployed and run	1	1	2	= 4
KPI20	Number of demonstrators deployed and running in different regions			1	= 1
KPI21	Demonstrators showing AI4EU marketplace use cases	= 1	= 1	= 2	= 4
KPI22	Number of agricultural Machine Learning (ML) models contributed to the AI4EU marketplace	= 3	>=3	>=2	>=8
KPI26	Number of DIHs actively engaged in pilots' development and demonstrations	= 2		=3	= 5
KPI28	Average percentage of improvement in the performance of tasks by robots	> = 25%	>= 50%	> = 25%	Use-case dependent
KPI29	Cost savings per season (Botrytis detection, phytosanitary treatments, transport)	>= 20%		> = 30% per crop season	Use-case dependent
KPI32	Number of different tasks robots are able to carry out	>= 3	>= 5	>=2	>= 10
KPI33	Number of new different services offered to farmers	>= 3	>= 6	=>2	>= 11

KPI ID	Description	Pilot 1	Pilot 2	Pilot 3	Overall value
KPI34	Single pilot duration	>= 1 hour	>= 30 minutes		Use-case dependent
KPI37	Number of components compatible with IDSA and OGC standards implemented and/or integrated within the system	>= 5	>= 5	>=5	>= 15
KPI38	Reduce the use of the phytosanitary product, minimize costs and environmental damages	>= 20%			Use-case dependent
KPI39	Reduce the cost of grape transport	Baseline: 220€/h per season Improv: 11% Target: 195 €/ha per season.			Use-case dependent
KPI40	Reduce time of grape transport	Baseline: 180 min Improv: 50% Target: 90 min			Use-case dependent
KPI42	Autonomous tractor operation		= 1		Use-case dependent
KPI43	Reduction of pesticide usage	Baseline: 155€/h per season Improv: 9% Target: 141 €/ha per season	<= 75%	40%	Use-case dependent

KPI ID	Description	Pilot 1	Pilot 2	Pilot 3	Overall value
KPI45	Reduce the cost of potential damages from sub-optimal pesticide application			35%	Use-case dependent
KPI46	Reduce the cost of potential damages from sub-optimal pesticide application			25%	Use-case dependent
KPI47	Work efficiency.		<= 50% per added simultaneously operating working unit.	.	Use-case dependent
KPI48	Reduce inspection costs	Baseline: 86€/ha. Improv: 30% Target: 59,5 €/ha			Use-case dependent
KPI49	Decrease environmental load saving pesticides		<= 75%		Use-case dependent
KPI50	Increased safety. Robotics together with an External situation monitoring system has the capability to create a more comprehensive view of the situation		>= 1		Use-case dependent
KPI51	Rumex mapping. The existence of Rumex-weeds enables targeted weeding operations thus decreasing manual labour needs		>= 80%		Use-case dependent
KPI52	Less laborious manual work for pests mapping		<= 50%		Use-case dependent

KPI ID	Description	Pilot 1	Pilot 2	Pilot 3	Overall value
KPI53	Identification comparison to manual detection of pests.		>= 90%		Use-case dependent
KPI54	The harvesting timing can be improved thus providing more digestible dry matter.		>= 1 % more digestible dry matter from selected fields		Use-case dependent
KPI55	Weeding efficiency		>=50%		Use-case dependent

Table 15 Global KPIs of the project

6 Discussion and conclusions

This document presents the methodology that has been followed during the first two years of the project in order to identify and maximise the synergies between the three pilots, and to work towards an adequate convergence, in such a way that the project can reach a common ground in terms of requirements, designs and implementations. Such convergence is a key enabler for implementing very complete pilots with high levels of maturity and innovation, achieving important objectives like multi-robot scenarios.

The methodology proposed initially was based on using the IEC 62559 for specifying the use cases, so it would be possible to identify the requirements of the pilots in a homogeneous way. The following phases detailed some technical aspects from the pilots (like the datasets and the robotic systems). Later on, as part of the consolidation phase, the consortium has identified some common elements in several areas: from datasets (used and collected) to devices used (both robots and other types of devices), as well as the AI models (that could be implemented in the context of a pilot or just adopted from the WP3 outcomes).

The impact of these last three aspects (data, robots/devices and models) is very relevant, since sharing them among the pilots can lead to more efficient AI models (that can be trained with more data and can be validated in more environments), more complex scenarios implementation (using AI models and devices from other pilots) and more ambitious multi-robot systems (as using together robots from multiple pilots enable the possibility to implement more complex and realistic scenarios).

Although the progress in the collaboration activities is starting, there is already some ongoing work and clear plans, not only for the integration of pilots' outcomes, but also to complete the integration with other outcomes from WP3 that, in many cases, are also common to the three pilots (especially in the areas of the Mission Control Centre and the adoption of the AI services implemented). Having this in mind, the plans proposed in D2.7 [8] have been updated and future deliverables from WP4, WP5 and WP6 should already reflect the proposed changes.

Looking at the work done during the last year, the KPIs proposed in D2.7 [8] have been evaluated. Such evaluation indicates that, although some work is ongoing, there is still a lot to do until the end of the project. In the case of pilot 1, 29% of the KPIs were achieved, while it was 33% for pilot 2 and 40% for pilot 3. There are some KPIs that could not be evaluated due to the ongoing works in the implementation. The plans proposed will address these aspects, in such a way it will be possible to reach a fulfilment of the 100% of the KPIs defined.

The future steps in the context of T2.5 are to monitor the planned actions through periodic teleconferences, to re-evaluate the common activities in the next months (in order to identify new interactions as soon as possible) and to plan additional actions before the next summer campaign. The task will be monitoring the KPIs in order to determine whether more activities need to be planned in order to achieve the expected results, enabling a continuous evaluation of the alignment of pilots and the project evaluation. The results of these activities will be reported in deliverable D2.9 by the end of the project.

References

[1] FlexiGroBots deliverable D2.1 - Stakeholder view to FlexiGroBots system scenarios.

[2] FlexiGroBots deliverable D2.2 - Requirements and platform architecture specifications.

[3] International Electrotechnical Commission Standard IEC 2559-2:2015 Use case methodology - Part 2: Definition of the templates for use cases, actor list and requirements list. https://webstore.iec.ch/publication/22349

[4] FlexiGroBots deliverable D4.1. - Pilot 1 objectives, requirements and design.

[5] FlexiGroBots deliverable D5.1. - Pilot 2 objectives, requirements and design.

[6] FlexiGroBots deliverable D6.1. - Pilot 3 objectives, requirements and design.

[7] FlexiGroBots deliverable D1.3 - Data Management Plan.

[8] FlexiGroBots deliverable D2.7. - Pilot alignment and joint assessment report.

[9] FlexiGroBots deliverable D2.3 - Requirements and platform architecture specifications final.

[10] FlexiGroBots deliverable D2.4 – Standardisation activities report 1.

[11] FlexiGroBots deliverable D2.6 – ELSE factor analysis and guidelines.

[12] FlexiGroBots deliverable D3.1 – FlexiGroBots platform v1.

Annex 1 – FlexiGroBots KPIs (DoA)

KPI ID	KPI Description	Success criteria	WP(s) Responsible
1	Mission Control Centre (MCC) reference architecture	1	WP2
2	MCC solution building block implementations	>= 8	WP3
3	Demonstrators using more than 90% of the MCC services	>= 3	WP4, WP5, WP6
4	Agricultural Data Space (ADS) reference architecture	>=1	WP2, WP3
5	ADS solution building blocks	>= 12	WP3
6	Number of data sets shared within the pilots	>= 6	WP4, WP5, WP6
7	Number of pilots using georeferenced agriculture-related data analytics	>= 2	WP4, WP5, WP6
8	Number of datasets shared with third parties via ADS	>= 4	WP4, WP5, WP6
9	Number of novel agricultural AI methods or Machine Learning (ML) models	>= 6	WP4, WP5, WP6
10	Number of potential new products and services based on those new AI methods / ML models	>= 2	WP4, WP5, WP6
11	Graphical user interface for the human operator to oversee and be engaged in the control loop	>= 1	WP3
12	Pilots for Assessment List of the Ethics Guidelines for Trustworthy AI	>= 3	WP2, WP4, WP5, WP6
13	Platform assessment (cross-pilot)	>= 1	WP2
14	Numbers of crops addressed in the pilots	>= 3	WP4, WP5, WP6
15	Demonstrators incorporating both UAV and UGV robotic platforms	>= 3	WP4, WP5, WP6
16	Number of robots taking part in demonstrated multi-robot systems	2	WP4, WP5, WP6
17	Number of DIHs with the capability of demonstrating FlexiGroBots pilots the project ends	>= 3	WP4, WP5, WP6, WP7
18	Number of real-world pilots	3	WP4, WP5, WP6
19	Numbers of regions where the FlexiGroBots demonstrators are deployed and run	4	WP4, WP5, WP6

KPI ID	KPI Description	Success criteria	WP(s) Responsible
20	Number of demonstrators deployed and running in different regions	1	WP6
21	Demonstrators showing AI4EU marketplace use cases	>= 2	WP4, WP5, WP6
22	Number of agricultural Machine Learning (ML) models contributed to the AI4EU marketplace	>=6	WP3, WP4, WP5, WP6
23	Number of new integrations of the AI4EU marketplace with other Agricultural Data Space (ADS) enablers (following the FlexiGroBots reference architecture)	3	WP3, WP4, WP5, WP6
24	Guidelines and recommendations to address ELSE in AI-driven robotics in Agri-Food	>= 1	WP2, WP7
25	Number of workshops or webinars made through the AI4EU Observatory	>=3	WP7
26	Number of DIHs actively engaged in pilots' development and demonstrations	>= 6	WP4, WP5, WP6, WP7
27	Number of DIH networks engaged to maximise long-term sustainability	>=3	WP7
28	Average percentage of improvement in the performance of tasks by robots	> = 25%	WP4, WP5, WP6
29	Cost savings per season (Botrytis detection, phytosanitary treatments, transport)	> = 30% per crop season	WP4, WP5, WP6
30	Number of DIHs with capability of demonstrating FlexiGroBots pilots after the end of the project	>=3	WP7
31	Number of joint business models proposed	>= 2	WP7
32	Number of different tasks robots are able to carry out	>= 2	WP4, WP5, WP6
33	Number of new different services offered to farmers	>= 2	WP3, WP4, WP5, WP6
34	Single pilot duration	>= 1 hour	WP4, WP5, WP6
35	Availability of online platform services within Mission Control Centre and Data Space	>= 95%	WP3
36	Full integrity with the current ISOBUS standard	1	WP3

KPI ID	KPI Description	Success criteria	WP(s) Responsible
37	Number of components compatible with IDSA and OGC standards implemented and/or integrated within the system	>= 10	WP3, WP4, WP5, WP6
38	Reduce the use of the phytosanitary product, minimize costs and environmental damages	0,09	WP4
39	Reduce the cost of grape transport	0,11	WP4
40	Reduce time of grape transport	0,5	WP4
41	Used time and accuracy for multi-robot fleet management systems	0,05	WP5
42	Autonomous tractor operation	1 driver's cost	WP5
43	Reduction of pesticide usage	0,75	WP5
44	Number of end users adopting Pilot 2 technology solution	1 end user	WP5
45	Reduce cost soil sampling	0,35	WP6
46	Reduce cost of potential damages from sub-optimal pesticide application	0,25	WP6
47	Cut in pesticide application	0,4	WP6