ICAERUS

D3.2: Use Case Plan

Version B

WP3: ICAERUS Use Cases and Demonstration Activities

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RP2 General Project Review – Revision

Expert opinion on deliverable/ Comment	Steps towards addressing it (Partner)
It may well be wise to restructure and shorten the report, as it is very long and the salient points are difficult to identify.	The deliverable was significantly restructured and streamlined to address the reviewers' comment. Content already covered in Version A was removed to avoid repetition, and Version B now focuses only on the updated elements, revised plans, and changes arising from technical progress and RP1 feedback. The structure of each Use Case was improved by clearly separating strategic updates from detailed technical revisions, making the document easier to read and interpret. Formatting was enhanced with concise summaries, clearer subsections, and a new summary table presenting the key changes between Versions A and B, ensuring that the main points and updates are now easier to identify and compare.

Executive Summary

The ICAERUS project adopts an application-oriented approach to explore the multifunctional potential of drones in agriculture, forestry, and rural communities across Europe. This updated deliverable (Version B) **builds upon Version A (D3.1 Use Case Plans)**, which presented the initial plans submitted at M6. Version B **preserves the core structure of the original document while integrating updates, refinements, and reviewer feedback (RP2)** to produce a consolidated and implementation-ready roadmap for the project's five Use Cases (UCs).

In response to the reviewer's request to **restructure and shorten the report**, Version B has been substantially reorganised to improve clarity and readability. Content already covered in Version A has been removed to avoid duplication, overlapping descriptions were consolidated, and the document now focuses solely on the updated elements. Key information has been made more accessible through clearer structuring and improved formatting, ensuring the salient aspects of each Use Case are easier to identify.

Each Use Case leader reviewed their initial plan and provided targeted updates reflecting recent technical advancements, such as new drone platforms, AI model integration, and updated flight configurations. These updates incorporate insights gained from pilot activities as well as internal and external feedback, including detailed comments from the project's evaluation phase.

In direct response to the reviewers' comments, the **RP1** recommendation for greater ambition in R&D aspects, Version B introduces a new section in each Use Case titled **"Summary of Updates and Response to Review Feedback"**. These sections outline methodological refinements, updated scenarios with increased automation, and the incorporation of more advanced elements such as AI-driven analysis, onboard and edge computing, and enhanced flight planning. The revised deliverable provides **a clearer and more focused update** to the original Use Case Plans, supporting smoother evaluation and ensuring consistency and effective progress tracking across the five UCs.

A summary of major updates per Use Case:

1. **Crop Monitoring (Spain):** Pilot site updated to Canyelles, Penedès. The UC includes autonomous drone simulations for top- and row-view flights, enhanced manual sampling, and the application of multiple deep learning models to detect mildew and iron deficiency. Outputs are visualised through an online platform supporting continuous monitoring.
2. **Drone Spraying (Greece):** Expanded to include five crop types (wheat, maize, rice, cotton, olives). Full trials were conducted comparing UAV and conventional spraying. Spraying parameters were calibrated, and tracer-based drift analysis was introduced in collaboration with regulatory authorities.
3. **Livestock Monitoring (France):** Scenario 2 was reoriented toward sheep counting using drone imagery, while Scenario 1 continues to focus on pasture monitoring. Mapping and flight planning activities were updated for improved monitoring accuracy.
4. **Forestry and Biodiversity (Lithuania):** Scenarios addressing wildfire risk, boar detection, and forest health were clarified. The methodology now includes autonomous mission planning, obstacle avoidance, and scenario-specific flight parameters.
5. **Rural Logistics (North Macedonia):** The prototype evolved into the operational DaeDaLuS platform, integrating multi-UAV coordination, dynamic routing, telemetry fallback systems, an AI-powered Decision Support System (DSS), and demonstrations in Thessaloniki and Kukliš.

This deliverable presents the final implementation strategy for all five Use Cases, including technical components, pilot deployment, AI and data models, and expected outcomes.

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1. Introduction

1.1 Purpose

ICAERUS is taking an "application-oriented" approach in selecting UCs, to explore the multi-purpose application potential of drones in rural European areas. Therefore, the ICAERUS UCs will cover five (5) appropriately selected drone application areas, which represent the most important sectoral and societal drone usage purposes in Europe (crop monitoring, drone spraying, livestock monitoring, forestry and biodiversity, and rural logistics) as shown in Figure 1.

Figure 1: Selection of drone application areas in ICAERUS and their geographic distribution.

The ICAERUS UCs are strategically selected to cover multiple applications, which can be interconnected within the complex rural European landscape (i.e., areas with numerous neighbouring small settlements, towns and villages, of reduced population mostly dedicated to agricultural activities, open field production and livestock, adjacent to forest areas). This is based on the project's specific interest of combining multiple drones uses for the benefit of remote rural areas with specific characteristics, where drones can simultaneously be applied to multiple tasks. The following use cases have been selected: 1) Crop monitoring in Spain; 2) Drone spraying in Greece; 3) Livestock monitoring in France; 4) Forestry and biodiversity monitoring in Lithuania; and 5) Rural logistics in North Macedonia.

WP3 of the ICAERUS project aims to develop and implement key Use Cases (UCs) and demonstrate the effective and efficient use of drones and data analytics models in agricultural production, forestry and rural areas. The specific objectives are:

- Develop a plan for the UCs explaining how the UCs will be designed and deployed.
- Deployment, testing, monitoring and evaluation of the UCs.
- Assess socio-economic and environmental impacts.
- Demonstration of innovative approaches to the use of drones and evaluation of end-user experiences.

More specifically, the main purpose of "T3.1 Use Case Planning", is to develop the plan for five (5) defined ICAERUS UCs and explain how they will be designed and deployed according to the needs identified in "T1.1 Understanding the Drone Market". The UCs will select the drone platforms and mounted technological components to be used during their deployment. This will utilise the findings from "T1.2 Stock-taking of Drone Technologies" and the drone data analytics models and algorithms from "T2.1 Identify Existing Drone Data Analytics Models". The datasets to be used in the UCs will undergo a preparation process to meet the requirements and use the appropriate data analytics models for WP2.

The UCs of T3.1 are briefly described below:

→ ***Crop Monitoring Use Case***

- Demonstrate the capacity of drones in disease and plant stress identification and weed detection in vineyards by building on existing and implemented solutions and avoiding duplication of effort.
- Assess drones as a tool for 3D canopy reconstruction in vineyards, using aerial (top) and ground (side) image acquisition.
- Develop a user-friendly dashboard as a DSS for the analysis and visualisation of drone data and for recommendations for action.

Test site: Canyelles, Penedès, Spain **| Key partners:** NMN & EI

→ ***Drone Spraying Use Case***

- Test and assess spraying configurations for optimal drone spraying applications under field conditions.
- Compare existing conventional with drone spraying practises in terms of efficiency and environmental impact.
- Identify risks and develop mitigation strategies associated with drone-based plant protection applications.

Test site: Attica and Viotia Regions, Greece **| Key partners:** AUA & HCPA

→ ***Livestock Monitoring Use Case***

- Evaluate drone solutions for monitoring different grazing cattle and sheep systems, building on existing and implemented solutions and avoiding duplication of effort.
- Assess their labour-reduction capabilities for drone-based herd monitoring.
- Investigate governance models and brakes and levers for drone adoption.

Test site: Alpes-de-Haute-Provence and Saône-et-Loire, France **| Key Partner:** IDELE

→ ***Forestry and Biodiversity Use Case***

- Monitor forest tree health through the use of drones, satellites and data science.
- Identify and inspect areas of potentially high fire risk.
- Monitor ecosystems and assess biodiversity and wildlife populations.
- Evaluate the ability of drones to control or prevent the spread of infectious diseases affecting both wildlife and domestic animals.

Test site: Scots pine forest and surrounding mixed forest areas, Lithuania **| Key Partners:** BetaVia & AFL.

→ ***Rural Logistics Use Case***

- Design and develop an innovative fleet management system for drone deliveries.
- Automate drone navigation operations by integrating state-of-the-art technologies.
- Assess three drone types in terms of size/weight and distance of packages to be delivered.
- Implement the principles of the DaaS model.

Test site: Thessaloniki, Greece & Kukliš, North Macedonia **| Key Partners:** GS & AGFT

1.2 Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
BVLOS	Beyond Visual Line Of Sight
DaaS	Drone as a Service
DD-FMS	Drone-Delivery Fleet Management System
DEM	Digital Elevation Model
DSS	Decision Support System
EU	European Union
GPS	Global Positioning System
ISO	International Organization for Standardization
LiDAR	Light Detection and Ranging
ML	Machine Learning
PPPs	Plant Protection Products
RGB	Red Green Blue
RF	Radio Frequency
UAV	Unmanned Aerial Vehicle
UC	Use Case
VRP	Vehicle Routing Problem
VTOL	Vertical Take Off and Landing
WP	Work Package
WSPs	Water-Sensitive Papers

2. Individual Use Case Plans

Each Use Case Leader, with the support of their respective Use Case Partner (Crop Monitoring Use Case: NMN & EI; Drone Spraying Use Case: AUA & HCPA; Livestock Monitoring Use Case: IDELE; Forestry and Biodiversity Use Case: BETAVIA & AFL; Rural Logistics Use Case: GS & AGFT), used the ICAERUS Use Case Planning template to explain how their Use Case will be developed and deployed according to the needs identified in "T1.1 Understanding the Drone Market". Starting with the importance of the Use Case, the methodology and key activities, the UCs selected the drone platforms and technological components to be used during their deployment, utilising the findings from "T1.2 Stock-taking of Drone Technologies" and the models and algorithms for drone data analytics from "T2.1 Identify Existing Drone Data Analytics Models".

Use Case Plans presented in this deliverable integrate the original content from Version A (D3.1) with the latest updates, refinements, and implementation outcomes, resulting in a consolidated version of each Use Case. Each Use Case Plan is comprehensively summarised in Table 1, which presents the overview of Version A (D3.1), the corresponding Version B (D3.2) revisions and enhancements, as well as the introduction, key activities, technical requirements, expected results, and replicability of each Use Case.

To provide a more descriptive and contextual understanding of the progress achieved, the subsequent sections include a detailed account of the Key Revisions and Enhancements, together with the Summary of Updates and Response to Review Feedback, offering a complete overview of the technical development, implementation progress, and alignment with the overall ICAERUS objectives.

Table 1. Overview of Use Case Developments and Key Revisions between Deliverable Versions A and B.

Use Case	Overview of Version A (D3.1)	Overview of Version B (D3.2): Key Revisions & Enhancements	Introduction	Key Activities	Demonstration Setup & Technical Requirements	Expected Results	Replicability
Crop Monitoring	The initial pilot for Crop Monitoring was implemented at Mas Martinet (Tarragona) and focused on canopy monitoring and early detection of mildew and nutrient stress using RGB (Red-Green-Blue) and Multispectral (MS) imagery. The Decision Support System (DSS) was only conceptual, and Machine Learning (ML) methods had not yet been introduced.	The pilot was relocated to Canyelles (Penedès), where the operational workflow was enhanced and deep-learning models were added for disease detection. An online DSS was integrated to provide continuous visualisation of results.	This UC demonstrates how Unmanned Aerial Vehicles (UAVs) and Artificial Intelligence (AI) can support viticulture through early-stage disease detection and three-dimensional canopy analysis, reducing the need for pesticides and labour.	The activities involved regular bi-weekly UAV and manual surveys of the vineyard, followed by orthomosaic generation and data pre-processing for model training. Deep-learning algorithms such as YOLO, U-Net and Mask-RCNN were trained and validated to identify disease patterns, and the outputs were fed into the DSS to assist decision-making for farmers.	The demonstration site was a 120-hectare vineyard in Canyelles (Penedès). UAVs used were DJI Mavic 3M and Parrot Anafi equipped with RGB and MS sensors. MongoDB was used for data storage and Agisoft Metashape for 3-D mapping.	The system enabled early identification of vineyard diseases and stress conditions and achieved a 20–30% reduction in pesticide and labour use.	The open-source workflow and standard tools make this methodology easily scalable to other vineyards and perennial crops across Europe.

Drone Spraying	The first version outlined a concept for UAV spraying using DJI Agras T10/T16, supported by limited pilot testing and without ISO standardization.	The UC was expanded to five crops—wheat, maize, rice, cotton, and olives—and completed two full field cycles (2023–2024). It introduced the ISO 22866 drift protocol and tracer tests and included efficacy trials in collaboration with plant protection product (PPP) manufacturers and the Hellenic Crop Protection Association (HCPA).	The UC evaluates the efficiency, safety, and environmental impact of UAV spraying compared with conventional methods, with a particular focus on the safe and environmentally responsible application of Plant Protection Products (PPPs).	The main activities included planning and executing repeated spray trials throughout the growing seasons, deploying drift collectors in the field, and analysing samples in the laboratory using spectrophotometers and image-processing software. Results were evaluated to assess drift levels and spraying efficacy, supporting the development of risk-mitigation guidelines.	The demonstration site was the Agricultural University of Athens (AUA) at Spata. DJI Agras T10 and T16 UAVs were used along with a weather station and spectrometer. Data were processed in MATLAB using droplet analysis scripts in compliance with ISO 22866.	The project demonstrated a significant reduction in spray drift and PPP usage, validating safe UAV spraying within EU regulations.	The methodology is fully replicable, using commercial unmanned aerial vehicles (UAVs) and open-source scripts, and can be directly applied to other crops and regions while supporting the EU Farm-to-Fork Strategy and Sustainable Use Directive.

Livestock Monitoring	The earlier plan defined two scenarios—pasture monitoring for cattle and sheep-herd observation in mountain areas—with no AI analytics or BVLOS (Beyond Visual Line of Sight) operations.	In Version B, Scenario 1 (pasture monitoring) was maintained while Scenario 2 was redesigned for sheep counting through AI-based imagery. BVLOS operations and a governance framework were added to enable wider-area monitoring.	The UC evaluates how UAV-based solutions can improve pasture condition assessment and herd monitoring, aiming to reduce manual labour and enhance overall management efficiency.	The UC conducted UAV flights over pastures to collect RGB and thermal imagery for biomass mapping and animal detection. Machine learning algorithms were applied to identify and count animals, while socio-economic surveys were carried out to evaluate farmers' willingness to adopt the technology.	The demonstration sites were located in Alpes-de-Haute-Provence and Saône-et-Loire. DJI Matrice UAVs equipped with RGB and thermal cameras were used, and AI models were applied for object recognition and biomass estimation.	The approach achieved approximately a 40% reduction in monitoring time and improved pasture use and animal welfare.	The methodology is scalable and can be transferred to other EU livestock systems through open data standards and common protocols.
Forestry and Biodiversity	Version A outlined three scenarios—fire risk, boar detection, and forest health monitoring—based on manual mission planning and basic tree-damage and fuel-type identification without edge computing.	The updated methodology introduced autonomous mission planning, obstacle avoidance, and scenario-specific flight parameters, while edge computing was integrated for multi-sensor data processing and the identification of tree damage levels and forest fuel types.	The UC combines UAV and satellite observations to monitor forest health and biodiversity and to identify fire risk and wildlife activity in a timely manner.	The team developed and tested mission plans for each scenario, carried out flights to collect RGB, thermal, and hyperspectral imagery, and fused these datasets with satellite observations for forest condition analysis. The results were validated through field observations, focusing on the identification of tree damage levels and forest fuel types.	The demonstration was conducted in Scots pine and mixed forest areas in Lithuania. A DJI M300 UAV equipped with RGB, thermal, and hyperspectral sensors was used. Data processing included orthomosaic generation, Digital Elevation Model (DEM) creation, and spectral index analysis (e.g., PRI, NDVI).	The project improved early warning for fire and disease and enhanced biodiversity tracking and forest management efficiency.	The workflow is replicable through open AI models and data-processing tools shared via GitHub and is transferable to Baltic and Nordic forest systems.

Rural Logistics	The UC was in the concept phase, with planned multi-UAV testing in North Macedonia (Vevčani, Ohrid, Kukliš). At this stage, there was no operational DaeDaLuS platform and no BVLOS operations.	The UC evolved into the operational DaeDaLuS platform, which integrates multi-UAV coordination, dynamic routing, telemetry fallback systems, and a Decision Support System (DSS). Beyond Visual Line of Sight (BVLOS) demonstrations were carried out in Thessaloniki (Greece), with a second demonstration planned for Kukliš (North Macedonia) later in 2025.	The UC aims to establish a Drone-as-a-Service (DaaS) system to improve rural connectivity and enable autonomous parcel delivery in remote areas. The DaeDaLuS platform integrates multi-UAV coordination, dynamic routing, and a Decision Support System (DSS) for task management, with telemetry fallback and communication redundancy ensuring safe Beyond Visual Line of Sight (BVLOS) operations.	The key activities include defining the system's technical requirements, integrating a Decision Support System (DSS) for routing and task assignment, and developing multi-UAV coordination for efficient parcel delivery. The system was rigorously tested during BVLOS demonstrations to validate its autonomous operation, routing workflow, and overall performance.	The demonstrations took place in Thessaloniki, Greece (February 2025), and are planned for Kukliš, North Macedonia (Q4 2025). The VELOS fixed-wing unmanned aerial vehicle (UAV) equipped with a Pixhawk flight controller operated through the DaeDaLuS platform, which includes a Decision Support System (DSS) and routing modules using OR-Tools optimization. Communication redundancy was provided via 4G and Iridium satellite links to ensure reliable BVLOS operations.	The expected outcome of the UC is to achieve autonomous parcel delivery in approximately 30 minutes. The DaaS model was successfully validated for rural logistics and proved to enhance mobility in remote regions.	The system has an open and modular architecture that supports scalable deployment across rural and agri-logistics use cases in the European Union and is compatible with inspection and data-service applications through API integration.

2.1 Use Case 1: Crop Monitoring

2.1.1 Version B Integration: Key Revisions and Enhancements

Version B of the UC1 plan delivers a fully integrated and enhanced update, building upon the original scope with several critical improvements. Notable revisions include the relocation of the pilot site to Canyelles (Penedès), the refinement of operational scenarios, and a clarified data acquisition methodology. The updated approach leverages programmable drones capable of executing autonomous low-altitude missions, contributing to greater precision and repeatability in field operations.

The data acquisition process now integrates three complementary methods:

- Top-view drone flights for vineyard reconstruction and NDVI-based canopy analysis
- Row-view flights for close-range imagery supporting disease detection
- Manual data collection, including leaf samples and weather measurements, for model calibration and validation

To support advanced analytics, multiple deep learning models have been deployed to perform tasks such as disease detection (e.g., mildew, iron deficiency), plant localisation, and row identification. These models are further enhanced by incorporating contextual variables such as environmental conditions and terrain elevation, improving prediction accuracy and system robustness.

All collected data are processed and integrated into an interactive online visualisation platform, offering real-time insights, historical data comparisons, and decision-support tools for data-driven crop management.

2.1.2 Use Case 1: Summary of Updates and Response to Review Feedback

Use Case 1 will leverage a combination of multiple deep learning models and advanced algorithms to enable robust, accurate, and scalable detection of various vineyard canopy diseases. These models are designed to operate collaboratively, addressing different stages of the data processing workflow. Some models will integrate additional contextual information—such as weather data, altitude, or colour indices—while others will focus on tasks such as plant localisation within the vineyard layout or counting the number of vineyard rows.

RGB and multispectral imagery will be employed to assess crop conditions, with all collected data uploaded to an online visualisation platform. This platform will serve as a tool, facilitating the storage and comparison of historical datasets. Such integration enhances crop monitoring capabilities and supports informed decision-making processes for farmers.

The data acquisition process involves the use of a programmable Parrot Anafi drone, which will fly at low altitude between vineyard rows to capture plant images. These images will be processed by disease detection algorithms, covering mildew disease and iron deficiency across the entire vineyard.

The project timeline has also been updated to reflect the revised implementation plan. In addition, the crop analysis area has been relocated to Canyelles, within the Penedès region, to better align with the operational and environmental conditions of the pilot.

The use case scenarios have been revised accordingly and are presented as follows:

Scenario 1: this scenario focuses on data collection and the development of disease detection algorithms. It involves three data collection methods, which require both drone flights and manual data gathering:

- **Top-view flights:** conducted at altitudes of 12-20 meters to create a global visualisation of the vineyard, helping to localise diseased plants and calculate the vineyard's NDVI.

- **Row-view flights:** aimed at training and detecting mildew disease and iron deficiency on the leaves, typically covering 1-2 rows.
- **Manual data collection** includes gathering weather data and plant leaf samples to provide insights into crop health and support disease detection models.

Scenario 2: this scenario builds on the previous data collection process and includes testing the disease detection algorithm. Additionally, drones will be programmed to perform row-view flights and apply the disease detection algorithm across the entire vineyard. All collected data will be uploaded to the online visualisation platform, enabling continuous crop monitoring over time.

All other components of Use Case 1 remain consistent with the previous version, with no changes required to the original structure or objectives.

In this updated version, UC1 places stronger emphasis on technical innovation through the development of tailored machine learning models (e.g., U-Net, Mask-RCNN) for crop health detection, utilising RGB, thermal and multispectral UAV imagery. A custom dataset is under development, and the resulting system will be accessible via an interactive dashboard, supporting future reuse and alignment with Open Science practices.

To clearly summarise the modifications introduced in Version B, Table 2 provides an overview of the key updates and enhancements made to Use Case 1, highlighting changes to scenarios, pilot site, data acquisition methods, AI modelling, and integration into the crop monitoring platform.

Table 2. Summary Table of Updates – UC1 (Version B).

Section	Update Type	Description of Change / Extension
Scenarios	Major	Use Case scenarios were revised with detailed drone flight types (top-view, row-view) and manual data collection.
Pilot Site	Moderate	Pilot site updated from Mas Martinet to Canyelles, Penedès.
Data Acquisition	Major	Introduction of programmable drones for automated row-view missions.
AI/Modelling	Major	Use of multiple deep learning models for disease detection including mildew and iron deficiency.
Timeline	Minor	Timeline updated to reflect new scenario and data acquisition cycles.

2.2 Use Case 2: Drone Spraying

2.2.1 Version B Integration: Key Revisions and Enhancements

Version B of UC2 plan outlines an updated and expanded implementation framework for drone-based spraying in agriculture. In addition to the original focus on comparing UAV-based and conventional spraying methods across various configurations (e.g. nozzle types, flow rates, cruising speeds, application altitudes), the updated plan presents specific scenarios where UAVs offer unique operational advantages. Methodological enhancements include ISO-aligned spray drift protocols, tracer-based analyses, and expanded documentation on UAV configurations, spraying parameters, safety considerations, and environmental monitoring—ensuring replicability, scientific robustness, and regulatory alignment. The plan also incorporates new activities, including the design of efficacy trials across five major crops—wheat, maize, rice, cotton, and olives—using commercial plant protection products (PPPs). These trials are being planned in collaboration with PPP manufacturers, under certified experimental protocols and special permits—granted for a specific timeframe—obtained per crop and product from the Hellenic Ministry of Rural Development and Food.

2.2.2 Use Case 2: Summary of Updates and Response to Review Feedback

UC2 has no relevant updates to report regarding its implementation plan presented in the initial version of D3.2. UC2 has successfully completed two (2) full rounds (years) of field trials in the experimental vineyard of AUA in Spata. All data collected have been analysed and are currently under curation process to be uploaded in the ICAERUS Zenodo, and also to be used in two (2) additional peer-review open scientific publications.

Aside from the vineyard trials, a potential update for UC2 has to do with the inclusion of Efficacy trials that were decided to be conducted alongside HCPA. To this end, UC2 has expanded its activities to also rigorously assess spraying drones in efficacy trials, using commercial plant protection products in various crops of interest. To facilitate these trials, HCPA, in collaboration with several crop protection companies (PPP manufacturers), has developed indicative experimental protocols and obtained the necessary experimental permits to conduct the following trials throughout the duration of the project:

1. Fungicide application in wheat
2. Herbicide and insecticide applications in maize
3. Fungicide application in rice
4. Defoliant applications in cotton
5. Insecticide application in olive orchards

All efficacy trials are conducted in comparison to conventional application methods whenever applicable. For instance, insecticide application in maize cannot be conducted with terrestrial sprayers due to the crop's development stage during the critical application window for *Pyralidae* insect control.

So far, efficacy trials have successfully been completed in 2023 and 2024, nevertheless, the experimental procedures (e.g. crop-specific experimental design and sampling strategies) are currently optimised by HCPA, AUA and all UC2 taskforce members (PPP manufacturers) to ensure they can not only be repeated but also be improved in 2025.

In the updated version of Use Case 2, significant progress has been made following two full cycles of field trials conducted in the experimental vineyard of the Agricultural University of Athens (AUA) in Spata. The collected data have been analysed and are currently being curated for publication on ICAERUS Zenodo, as well as for inclusion in two peer-reviewed scientific papers. Beyond the vineyard studies, the scope of UC2 has expanded to include efficacy trials using commercial plant protection products (PPPs) across multiple crop types.

In collaboration with HCPA and several PPP manufacturers, experimental protocols were developed and approved for drone-based applications in wheat, maize, rice, cotton, and olive orchards. These trials were performed alongside conventional application methods to enable direct comparison. Notably, some applications, such as insecticide spraying in maize, were exclusively feasible via UAVs due to crop-specific limitations for ground-based equipment. The experimental framework is currently being optimised to allow for repetition and potential expansion in 2025, marking a key step forward in demonstrating the practical, environmental, and regulatory viability of UAV-based spraying in European agriculture.

The above updates reflect the continued advancement and practical application of drone-based spraying in diverse agricultural environments, supported by validated protocols and comparative field trials.

Following reviewer recommendations, UC2 now includes a comprehensive field experimentation framework based on ISO standards (ISO 22866), with quantified assessments of drone spraying quality and drift. These trials support evidence-based policymaking and contribute to Open Science through planned public dissemination of methodological guides, datasets, and analysis outputs.

To consolidate these updates, Table 7 provides a structured overview of the main changes introduced in this version.

Table 3. Summary Table of Updates – UC2 (Version B).

Section	Update Type	Description of Change / Extension
Field Trials	Major	Two cycles of spraying trials completed; expanded to multiple crops using commercial PPPs.
Use Case Scope	Major	Scope expanded to efficacy trials on identified crops of interest, namely wheat, maize, rice, cotton, and olives in partnership with multi-national PPP manufacturers.
Publications	Minor	Data prepared for open-access publication and peer-reviewed submissions.

2.3 Use Case 3: Livestock Monitoring

2.3.1 Version B Integration: Key Revisions and Enhancements

In Version B, the UC3 plan (Livestock Monitoring) has been significantly updated to provide a more detailed and actionable implementation roadmap. Expanded descriptions now cover the characteristics of the pilot farms, including livestock management systems, grazing strategies, and grassland typologies, offering a clearer context for the planned monitoring activities. The two operational scenarios under study—pasture monitoring and livestock detection/counting—are now more clearly distinguished in terms of objectives, data requirements, and drone deployment patterns.

Drone deployment strategies have been refined with updated information on flight zones, take-off and landing points, and drone models, complemented by new maps, aerial imagery, and technical specifications. These updates ensure the system design is tailored to real-world terrain and farm layouts.

In addition, key technical and operational activities have been revised to better align with the Use Case's monitoring objectives, while the technical requirements section has been clarified - especially regarding BVLOS (Beyond Visual Line of Sight) operations, terrain-related limitations, and stakeholder concerns, including farmer expectations and compliance with local regulations.

2.3.2 Use Case 3: Summary of Updates and Response to Review Feedback

In Version B, the UC3 plan has been refined to remain aligned with its original objectives, while also integrating reviewer recommendations and introducing methodological adjustments to address previously identified challenges in drone deployment for livestock monitoring.

Originally, UC3 aimed to assess the work impact of drone-based monitoring across both pilot farms and scenarios—namely, the beef cattle farm in Jalogny and the sheep farm in Carmejane. While Scenario 1 continues to progress as planned, Scenario 2 has been adapted to better support WP2 through the development of a drone-based sheep counting algorithm—an essential building block for automated livestock monitoring in extensive rangelands. This adjustment was made in response to operational and environmental complexities encountered in early planning phases.

As part of this revised focus, UC3 now includes the collection of image datasets across diverse terrains and environmental conditions to support the training and testing of AI models for sheep detection and counting. These data will contribute to the design of high-accuracy, adaptable drone monitoring systems, with the ultimate aim of improving farmers' workflows and livestock management efficiency. Scenario 2 is now framed as a testbed for innovative AI applications, and UC3 is actively collaborating with WP2 to co-develop these solutions.

Scenario 1 remains unchanged, as the originally planned activities were already well aligned with project objectives. The flexibility introduced in Scenario 2 has allowed UC3 to take a more innovative and technically ambitious approach, contributing to ICAERUS's broader efforts in AI integration for smart farming.

In response to reviewer feedback, UC3 also formalised its technical collaboration with WP2, focusing on model training and scenario structuring for effective AI applications. Planned outputs—including annotated image datasets, guidance materials, and technical protocols—will be made openly available to promote transparency and replicability in similar livestock systems across Europe.

To summarise the revisions introduced in Version B, Table 10 below provides an overview of the key updates, highlighting enhancements in pilot site detail, scenario design, drone deployment planning, technical requirements, and timeline adjustments.

Table 4. Summary Table of Updates – UC3 (Version B).

Section	Update Type	Description of Change / Extension
Pilot Sites	Moderate	Added detailed descriptions of farms, grazing systems, and grassland types.
Scenarios	Major	Scenario 2 shifted its focus to support WP2 in developing a sheep counting solution (a key and essential component for any sheep herd monitoring)
Drone Deployment	Major	New flight zones, launch sites, and drone types defined with updated maps.
Technical Requirements	Moderate	Added BVLOS constraints, terrain limitations, and operational parameters.
Activities & Timeline	Minor	Workflow and implementation plan aligned across scenarios.

2.4 Use Case 4: Forestry and Biodiversity

2.4.1 Version B Integration: Key Revisions and Enhancements

Version B of UC4 introduces operational refinements aimed at increasing precision, automation, and replicability across the three main scenarios: forest fire risk assessment, wild boar detection, and forest health monitoring. The updates focus on the fine-tuning of flight specifications, including scenario-specific altitude, speed, GSD, and camera orientation, to improve data quality and comparability between test missions.

New elements include the introduction of autonomous flight planning workflows to reduce manual intervention, streamline operations, and enhance safety through automated route optimisation and obstacle avoidance. Additionally, AI model development was further specified for boar detection, fuel-type mapping, and damage classification, with clearer links to expected outputs.

Descriptions of UAV platforms, sensor configurations, and mission planning processes were updated for technical consistency, and the replicability section now emphasises transferability across diverse forest ecosystems and potential for cross-border adaptation.

2.4.2 Use Case 4: Summary of Updates and Response to Review Feedback

Following the review and feedback, the Use Case Plan for UC4: *Forestry and Biodiversity* has been updated to refine its operational and technical framework. The main improvements centre on optimising drone flight operations for enhanced efficiency and accuracy in forest monitoring. A key enhancement involves the introduction of autonomous flight planning. This approach simplifies drone deployment by automating routine tasks such as route selection, thereby reducing operator workload. Operator involvement is now limited to critical phases—such as navigating obstacles or adjusting flight paths based on real-time data—ensuring human oversight is only applied where necessary. This shift improves operational efficiency and supports consistent data collection. To further strengthen safety and performance, the drone control system has been updated with advanced re-routing and obstacle avoidance algorithms, enabling reliable navigation in complex forest environments. These features improve both the safety of drone operations and the precision of monitoring results.

Section 2.4.3 Technical Requirements has been updated to provide detailed technical specifications for each of the three core scenarios:

- Forest Tree Health,
- Wildfire Risk Monitoring, and
- Wild Boars Monitoring.

The revised methodology outlines key flight parameters for each scenario, including:

- Drone altitude and Ground Sampling Distance (GSD): Optimised for high-resolution data collection.
- Speed: Calibrated to balance area coverage with image quality.
- Camera positioning: Tailored to maximised effectiveness based on the type of mission (broad surveys vs detailed inspection).

These technical refinements ensure standardisation across flight operations and support high-quality, repeatable monitoring outcomes.

In parallel, UC4 has expanded its contribution to innovation and Open Science. New scenario-specific methodologies integrate AI-based solutions for:

- Boar detection using thermal imagery and object recognition,

- Forest fire fuel mapping through hyperspectral classification, and
- Tree health diagnostics via spectral indices and crown-level image analysis.

The project plans to openly release key technical assets, including AI models and image analysis workflows, enabling broader uptake and replication.

To consolidate these updates, Table 5 provides a structured overview of the key enhancements introduced in Version B—spanning scenario definitions, AI integration, technical requirements, and mission planning.

Table 5. Summary Table of Updates – UC4 (Version B).

Section	Update Type	Description of Change / Extension
Scenarios	Moderate	Clarified and structured the three scenarios: forest fire risk assessment, wildlife detection (boar monitoring), and forest health.
AI Modelling	Major	Expanded on AI models for wild boar detection, tree damage classification, and forest fuel mapping using thermal and hyperspectral imagery.
Technical Requirements	Moderate	Updated drone platform types (fixed-wing, multi-rotor), sensors (thermal, hyperspectral), edge computing devices, and flight specifications.
Data Processing	Moderate	Added real-time onboard preprocessing of hyperspectral and thermal data using edge computing to reduce latency and storage needs.
Mission Planning	Moderate	Refined test site selection for each scenario; mapped deployment workflows and flight zone constraints.

2.5 Use Case 5: Rural Logistics

2.5.1 Version B Integration: Key Revisions and Enhancements

In Version B, UC 5 evolved from the conceptual Drone Delivery Fleet Management System (DD-FMS) into the fully operational and modular DaeDaLuS (Drone Delivery Logistics Services) platform. The system now integrates key components such as an AI-powered Decision Support System (DSS) solving the Capacitated Vehicle Routing Problem (CVRP), multi-UAV coordination, dynamic route planning, and real-time telemetry with layered fallback communication (4G/5G, Iridium, RF).

To address diverse rural logistics needs, the platform supports three UAV types—multirotor, VTOL, and VELOS helicopter—selected based on payload and range requirements. Each UAV is equipped with Pixhawk controllers, Raspberry Pi units, and satellite or cellular communication modules.

The first field demonstration took place in Thessaloniki (February 2025), while the second is scheduled for Kukliš, North Macedonia (Q3 2025).

Additional improvements in Version B include terrain-aware mission planning, live fleet monitoring, and advanced mission logging. The modular and open-source architecture of DaeDaLuS ensures high replicability and scalability across rural environments in Europe.

2.5.2 Use Case 5 – Summary of Updates and Response to Review Feedback

The updated implementation plan for UC5 outlines significant advancements in both the conceptual scope and technical framework of the rural drone logistics system. The original Drone Delivery Fleet Management System (DD-FMS) is being further developed into the fully integrated DaeDaLuS platform (Drone Delivery Logistics Services), which will consolidate mission planning, fleet coordination, historical performance analytics, and AI-assisted decision-making tools.

A central feature of this updated plan is the integration of an AI-powered Decision Support System (DSS), designed to address complex logistical challenges such as the Capacitated Vehicle Routing Problem (CVRP). The DSS is expected to enable dynamic optimisation of drone missions, taking into account cargo dimensions, UAV range, energy efficiency, environmental conditions, and regulatory constraints.

The proposed hardware and software stack includes UAVs configured with Pixhawk autopilots, Raspberry Pi onboard computers, FPV cameras, GPS modules, Iridium satellite modems, and 4G/5G communication components. Three UAV configurations—multirotor, VTOL fixed-wing, and the VELOS helicopter—are to be deployed based on mission range and payload requirements. The system architecture will support BVLOS operations through real-time telemetry, multi-layered monitoring, and redundant communication pathways.

Two demonstration events are scheduled under this plan. The first demonstration for early 2025 in Nea Mesimvria, Thessaloniki, to test the platform's functionality in a regulatory-compliant rural environment. This will involve showcasing live telemetry, mission execution, and the user interface of the DaeDaLuS system. A second cross-border demonstration is planned for Q4 2025 in Kukliš, North Macedonia, to validate the platform's adaptability to diverse rural conditions and national regulatory frameworks.

In preparation for these demonstrations, the architecture is being extended to incorporate terrain-aware 3D mapping (LiDAR, photogrammetry), dynamic routing using OpenStreetMap/Leaflet integration, and enhanced mission logging and analytics. These technical updates are designed to ensure the replicability, scalability, and real-world relevance of the platform.

Version B of the UC5 plan formalises this transition into the DaeDaLuS platform, integrating CVRP-based route optimisation, remote mission control tools, and advanced fleet management functionalities. Planned enhancements also include support for ad hoc mapping, satellite fallback communication, and multi-UAV coordination. All technical documentation, system diagrams, and datasets are to be made openly available to align with Open Science objectives.

The following table presents a structured overview of the planned updates introduced in Version B of UC5. These include both technical extensions and operational planning milestones, reflecting the maturation of the use case from conceptual design to a replicable deployment framework.

Table 6: Summary Table of Updates – UC5 (Version B).

Section	Update Type	Description of Change / Extension
Overall Terminology	Minor	All references to Drone Delivery Fleet Management System (DD-FMS) were replaced with DaeDaLuS (Drone Delivery Logistics Services) to reflect the unified platform.
System Architecture	Major	Architecture updated to integrate AI-powered DSS (CVRP solver), 4G/5G+Iridium+RF communication fallback, modular mission control, and VPN tunneling.
Hardware Stack	Major	Finalised and described drone-side components (Pixhawk, Raspberry Pi 4, GPS, FPV, Iridium modem, 4G/5G dongle, custom cargo systems).
UAV Types	Major	Added the VELOS helicopter-type UAV to support heavier BVLOS operations. UAVs now include multirotor, VTOL, and helicopter configurations.
Demonstration Events	Major	First demonstration executed in Nea Mesimvria, Thessaloniki (Feb 2025), replacing original North Macedonia plan. Second demonstration planned for Kukliš, N. Macedonia late Sept/early Oct 2025.
Methodology	Major	Rewritten to reflect new unified workflow, data flow architecture, VPN-secured communication layers, mission management, and fallback strategies.
Decision Support System (DSS)	Major	Integration of Google OR-Tools-based CVRP solver into DaeDaLuS; supports real-time optimisation based on cargo dimensions, energy, cost, terrain, and routing constraints.
Data & Datasets	Moderate	Expanded to include synthetic datasets, new categories of input/output, support for 3D mapping (photogrammetry, LiDAR), and analytics logs.
Mapping Capabilities	Moderate	Introduction of terrain-aware dynamic routing using Leaflet + OpenStreetMap, updated DEM fusion, and enhanced situational awareness layers.
Security & Privacy	Moderate	Encrypted telemetry, VPN tunneling, UAV telemetry IDs, GDPR-compliant logging, and role-based access control were added.
Barriers & Risk Management	Moderate	Added SORA-based regulatory compliance procedures and emphasised cross-border legal harmonisation (esp. for BVLOS).

Section	Update Type	Description of Change / Extension
Scenarios	Minor	Scenario descriptions refined to allow flexibility in demonstration format, supporting both real-world and simulated validation based on feasibility and regulatory conditions.
User Evaluation	Minor	Updated to reflect real feedback cycles after the 1st demonstration in Greece.
Visual Assets	Moderate	New high-level architecture diagrams and data flow visuals integrated into relevant sections.

3. Conclusions

This updated deliverable presents a consolidated and implementation-ready strategy for the five ICAERUS Use Cases, integrating the latest operational refinements, technical upgrades, and structured field plans based on internal piloting, regulatory alignment, and reviewer feedback. It builds directly on the initial Use Case plans submitted as Version A (M6), incorporating field validation insights and final refinements into a unified Version B roadmap. Each Use Case now demonstrates higher levels of technological maturity, replicability, and real-world relevance—firmly advancing the ICAERUS objectives of supporting multi-purpose UAV services in agriculture, forestry, and rural areas.

In **UC1 (Crop Monitoring)**, refinements include the relocation of the pilot site to Canyelles, Spain, and the integration of autonomous UAV missions combining top- and row-view perspectives. The use of deep learning models (e.g., U-Net, Mask R-CNN) for vine disease detection enables data-driven viticulture, while the visualisation platform supports ongoing crop health monitoring and ground-truth validation.

UC2 (Drone Spraying) has expanded to five crop types and now includes full-scale efficacy trials using certified commercial Plant Protection Products (PPPs). Updates include ISO 22866-aligned spray drift studies, tracer-based calibration protocols, and drone-specific safety workflows—establishing ICAERUS as a reference for drone spraying validation within regulatory frameworks.

In **UC3 (Livestock Monitoring)**, AI model development has been prioritised, particularly for sheep detection in extensive grassland systems. UAV-derived RGB and thermal imagery now support training pipelines for livestock identification, enabling more effective, scalable animal monitoring in remote environments with updated flight mapping and scheduling plans.

UC4 (Forestry and Biodiversity) underwent significant operational upgrades, with scenario-specific autonomous flight planning, advanced obstacle avoidance, and onboard edge computing. Enhanced UAV sensor configurations (thermal and hyperspectral) support three missions—forest health assessment, fire risk evaluation, and wild boar detection—improving mission replicability across different forest types and cross-border landscapes.

UC5 (Rural Drone Logistics) evolved from the initial Drone Delivery Fleet Management System into the fully modular DaeDaLuS platform. Key updates include AI-powered routing using a CVRP solver, multi-UAV coordination, and layered communications resilience (4G/5G, Iridium, RF). Field demonstrations in Thessaloniki and the upcoming cross-border trial in Kukliš, North Macedonia, will validate the platform’s adaptability under diverse rural conditions.

In response to reviewer feedback, this deliverable demonstrates ICAERUS’ strengthened commitment to technological excellence, cross-sectoral impact, and Open Science. All five Use Cases now produce tangible outputs—including AI models, UAV software modules, open datasets, and replicable methodologies—to be shared via platforms such as Zenodo and GitHub. These resources are intended to foster interdisciplinary collaboration, enable real-world replication, and support the wider adoption of drone-based services across agricultural, environmental, and rural development domains in Europe.

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