



Project ID: 2022-1-BG01-KA220-HED-000090004

Project acronym: Drones4GREEN

Project title: Drones for GREEN iNdustry

Deliverable of Activity

A5.1 Drone deployment framework evaluation

A pilot case study on the deployment of drones in the agricultural industrial sector

Programme: Erasmus+

Key Action 2 "KA220-HED - Cooperation partnerships in higher education"

Start date of project: 31.12.2022

Duration: 36 months

Activity Leading Organisation: GEOSENSE

Participating Organisations: DUTH, MINDS, MDS, TUS, SC

Reviewing Organisation: DUTH

Submission date: 30/12/2025

Legal Notice

The information in this document is subject to change without notice.

The Members of the Drones4GREEN Consortium make no warranty of any kind with regard to this document, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose.

The Members of the Drones4GREEN Consortium shall not be held liable for errors contained herein or direct, indirect, special, incidental or consequential damages in connection with the furnishing, performance, or use of this material.

The European Commission is not responsible for any use that may be made of the information it contains.

Table of Contents

List of Figures	4
Acronyms	5
Executive Summary.....	6
1. Introduction	8
1.1 Purpose of the Deliverable	8
1.2 Relation to Other Activities and Deliverables	8
1.3 Structure of the Document	9
2. Pilot Case Study: Operational Validation of the Framework	10
2.1 Pilot Case Study Overview	10
2.2 Case Study Context and Objectives	10
2.3 Alignment of Field Operations with Framework Categories	10
2.4 Role of the Pilot as a Validation Environment	11
3. Alignment of Field Operations with the Drone Deployment Framework	14
3.1 Overview of the Alignment Process.....	14
3.2 Category-by-Category Evaluation	14
3.3 Synthesis of Alignment Outcomes	15
4. Data Management & Analytics as a Validation Component of the Framework.....	16
4.1 Role of Data Management & Analytics within the Framework	16
4.2 Indicative Data Analysis Workflow	16
4.2.1 Mission Planning (Data-Driven Design).....	17
4.2.2 Data Acquisition	18
4.2.3 Data Processing.....	19
4.2.4 Analytical Processing.....	19
4.2.5 Interpretation & Decision Support	20
4.2.6 Feedback and Framework Refinement.....	21
4.3 Educational and Evaluative Value of Analytical Outputs	21
4.4 Reference Implementation and Transferability.....	21
4.5 Summary of Validation Findings	21
5. Quantitative Evaluation Results & Analysis	23
5.1 Participant Profile	23
5.2 Quantitative Validation of Framework Components.....	24
5.2.1 Assessment & Planning.....	25

5.2.2	Operational Workflow	25
5.2.3	Data Management & Analytics	26
5.3	Overall Framework Usability.....	27
5.4	Pedagogical Impact & Bridging the Theory-Practice Gap	27
5.5	Evidence of Framework-Supported Knowledge Transfer	28
5.6	Qualitative Feedback: The Value of Integrated Workflows.....	29
5.7	Validation of the Framework	29
5.8	Summary of Quantitative Findings	30
6.	Lessons Learned from the Pilot Case Study	31
7.	Instructor-Oriented Guidance.....	32
7.1	Role of the Instructor within the Drone Deployment Framework	32
7.2	Instructor-Facilitated Operational and Regulatory Alignment	33
7.3	Instructor-Facilitated Data Processing & Analytics Workflow	33
7.4	Reflection, Feedback and Framework Reinforcement	36
8.	Conclusions & Sustainability Perspective	37

List of Figures

<i>Figure 1: Operational validation briefing and digital mission planning conducted as part of the pilot validation of the DDF.</i>	12
<i>Figure 2: Field deployment and data acquisition activities executed within the pilot validation environment.</i>	13
<i>Figure 3: Indicative data management and analytics workflow illustrating the transformation of drone-acquired data into decision-support information within the Drone Deployment Framework.</i>	17
<i>Figure 4: Indicative mission planning environment.</i>	18
<i>Figure 5: Indicative data acquisition</i>	18
<i>Figure 6: Conceptual RGB / Orthomosaic Representation</i>	19
<i>Figure 7: Conceptual NDVI Map</i>	20
<i>Figure 8: Indicative interpretation and decision-support output.</i>	20
<i>Figure 9: Professional distribution of the pilot case study evaluation.</i>	23
<i>Figure 10: Sectoral and disciplinary composition of the evaluation sample</i>	24
<i>Figure 11: Distribution of prior drone piloting experience among respondents</i>	24
<i>Figure 12: Participant ratings on the clarity and structure of the pre-mission planning phase.</i>	25
<i>Figure 13: Participant ratings regarding the effectiveness of the operational workflow.</i>	25
<i>Figure 14: Participant ratings regarding the understandability of the data processing workflow (from Flight to Analysis).</i>	26
<i>Figure 15: Participant evaluation of the clarity and sufficiency of the regulatory and safety briefing.</i>	26
<i>Figure 16: Participant ratings regarding the overall clarity and usability of the 9-Category Drone Deployment Framework</i>	27
<i>Figure 17: Participant evaluation of the Quality of Instructors</i>	28
<i>Figure 18: Participant evaluation of the Clarity of Briefing/Instructions</i>	28
<i>Figure 19: Quantitative assessment of the training's efficacy in bridging the theory-practice gap.</i>	29
<i>Figure 20: Participant ratings on the utility of the Framework in structuring and organizing the mission</i>	30
<i>Figure 21: Instructor-oriented guidance workflow</i>	32
<i>Figure 22: Indicative orthomosaic and NDVI outputs illustrating the transition from structural reference imagery to analytical vegetation assessment within the Drone Deployment Framework.</i>	33
<i>Figure 23: Comparative visualization of vegetation indices (GNDVI and NDRE) illustrating complementary analytical perspectives for assessing crop physiological status.</i>	34
<i>Figure 24: Indicative transformation of NDRE analytical outputs into discrete management zones, supporting early stress detection and targeted intervention.</i>	34
<i>Figure 25: Indicative conversion of NDVI variability into prescription maps supporting precision input management.</i>	35
<i>Figure 26: Indicative analytical workflow linking GNDVI outputs to targeted intervention planning within a decision-support context.</i>	35

Acronyms

Acronym	Explanation
CONOPS	Concept of Operations
EASA	European Union Aviation Safety Agency
GNDVI	Green Normalized Difference Vegetation Index
ICAO	International Civil Aviation Organization
ICT	Information and Communications Technology
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
NDVI	Normalized Difference Vegetation Index
RGB	Red, Green and Blue (Standard Visual Spectrum)
SOPs	Standard Operating Procedures
SORA	Specific Operations Risk Assessment
WP	Work Package
DDF	Drone Deployment Framework
NDRE	Normalized Difference Red Edge Index
GNDVI	Green Normalized Difference Vegetation Index
EACEA	European Union Aviation Safety Agency

Executive Summary

This deliverable presents the operational validation of the Drone Deployment Framework defined in Work Package 2 (WP2 – *Educational material and curriculum development on Drone Deployment technology*), through its application in a real-world pilot case study. The validation activities were conducted within the broader context of the “Drones4GREEN Training & Multiplier Event,” which provided a controlled operational environment for testing the framework under realistic conditions.

Specifically, the validation was carried out through a dedicated pilot case study entitled “*Crop Stress Detection with Multispectral Drones*,” hosted at the ZEP Campus of the University of Western Macedonia (Kozani, Greece), with field operations executed in local vineyards. Within this context, the training activity functioned exclusively as a validation environment. The scope of this deliverable does not focus on reporting the educational event itself, but on evaluating the Drone Deployment Framework, extracting lessons learned from its practical application, and generating instructor-oriented guidance to support future hands-on drone deployment activities for educational purposes.

The primary objective of the pilot case study was to evaluate the framework’s applicability, scalability, and pedagogical effectiveness within a real-world agricultural setting. By applying the framework in operational conditions, the activity served as a structured stress test, validating both the technical workflow and the framework’s capacity to support knowledge transfer in a controlled, repeatable manner.

The core of the evaluation focused on the robustness and completeness of the nine-category methodology envisaged in Task 2.1.4. The pilot case study was explicitly designed to assess the applicability of all nine categories of the framework, ensuring a holistic validation of the proposed model:

- **Assessment & Planning:** Pre-mission feasibility analysis and site surveys.
- **Technology Selection:** Appropriateness of hardware and sensor selection (e.g., multispectral payloads).
- **Regulatory Compliance:** Adherence to applicable EASA regulations, SORA principles, JARUS guidelines, and CONOPS-related safety considerations.
- **Operational Framework:** Execution of Standard Operating Procedures (SOPs) and structured mission workflows.
- **Sustainability Integration:** Monitoring and promotion of energy efficiency and responsible resource usage.
- **Data Management & Analytics:** Structured workflows for data acquisition, processing, and interpretation.
- **Applications & Use Cases:** Relevance and effectiveness of drone deployments for specific agricultural applications, such as crop stress detection.
- **Evaluation & Reporting:** Mechanisms for collecting feedback, documenting outcomes, and reporting results.
- **Scalability & Expansion:** Assessment of the framework’s potential for broader adoption across different crops, sites, and operational scales.

To assess the effectiveness of these categories, a structured short evaluation instrument was administered following the completion of the pilot activities. The findings confirm that the proposed methodology is both operationally effective and pedagogically sound, demonstrating high levels of clarity and coherence, particularly in the critical phases of mission planning and data management workflows.

1. Introduction

1.1 Purpose of the Deliverable

The purpose of Deliverable A5.1 is to evaluate the applicability, usability, and completeness of the Drone Deployment Framework developed in Work Package 2 (WP2), through its implementation in a real-world operational context. The deliverable focuses on assessing whether the proposed framework can effectively support the full lifecycle of drone deployment, from mission planning and regulatory compliance to operational execution, data management, and reporting.

Within this scope, the real case scenario functions as a validation mechanism that enables the practical assessment of the framework under realistic field conditions. The application of the framework in an operational environment allows for the systematic collection of feedback regarding its structure, clarity, and effectiveness, as well as the identification of strengths, limitations, and potential areas for refinement.

It is important to clarify that Deliverable A5.1 does not aim to document or report the execution of a training activity. Instead, it builds upon the practical application of the framework to extract evaluative insights, lessons learned, and instructor-oriented guidance. These outputs are intended to inform future implementations of the framework and to support its educational and operational use across different contexts and industry sectors.

In alignment with the objectives of WP5, this deliverable contributes to bridging the gap between academic knowledge and practical deployment by validating the Drone Deployment Framework as a structured, repeatable, and pedagogically sound methodology for hands-on drone operations.

1.2 Relation to Other Activities and Deliverables

Deliverable A5.1 is closely related to other activities within WP5, particularly Activity A5.4 (Drone Training), while maintaining a clearly distinct role and scope. Activity A5.4 focuses on the delivery of training and the transfer of theoretical and practical knowledge to trainees and professionals. In contrast, Activity A5.1 concentrates on the evaluation of the Drone Deployment Framework itself, using practical application as a means of validation rather than as an end in itself.

The training activity provides the operational context in which the framework can be tested, but the outcomes documented in A5.1 are evaluative and synthetic in nature. Specifically, A5.1 captures insights related to the framework's performance, its alignment with real-world operational needs, and its effectiveness as a guiding structure for drone deployment. This distinction ensures that each activity can stand autonomously as a funded task, while remaining strongly interconnected at a conceptual and methodological level.

Furthermore, Deliverable A5.1 builds upon the educational material and methodological foundations established in WP2 and contributes evaluative feedback that can inform future refinements of the framework. The findings and insights generated through this deliverable are also intended to support downstream activities, including the enrichment of digital educational resources and the long-term sustainability of training and deployment practices.

1.3 Structure of the Document

The structure of this deliverable is designed to reflect the evaluative nature of Activity A5.1 and to provide a clear and logical progression from contextualization to validation outcomes.

Following this introduction, the document presents the pilot case study as a controlled operational validation environment, outlining its role in testing the Drone Deployment Framework under real-world conditions. The subsequent sections focus on the systematic alignment of field operations with the framework's categories, providing a structured assessment of each component of the methodology.

Dedicated sections address data management and analytics as a critical element of the framework's lifecycle, highlighting how data-driven outputs support decision-making and educational objectives. The document concludes with a synthesis of lessons learned and the presentation of instructor-oriented guidance derived from the evaluation process, ensuring that the knowledge generated through the pilot can be transferred and reused in future implementations.

2. Pilot Case Study: Operational Validation of the Framework

2.1 Pilot Case Study Overview

The pilot case study was designed and implemented as a controlled operational environment for the validation of the Drone Deployment Framework developed in WP2. Its primary role was to enable the practical assessment of the framework's applicability, structure, and robustness under real-world conditions, rather than to document the execution of an educational or training event.

The selected use case focused on precision agriculture, specifically crop stress detection using multispectral drone technology. This domain was chosen as a representative industrial application due to its well-established operational workflows, regulatory requirements, and data-driven decision-making processes, which collectively provide a suitable context for testing the full lifecycle of drone deployment.

The pilot implementation allowed the framework to be applied end-to-end, from mission planning and regulatory compliance to data acquisition, processing, and interpretation. By operating in an actual field environment, the case study provided realistic constraints and conditions necessary for a meaningful validation of the framework's categories.

2.2 Case Study Context and Objectives

The pilot case study was structured around a clearly defined operational objective: the execution of a complete drone deployment workflow for the detection and analysis of vegetation stress. This objective enabled the assessment of the framework's ability to guide users through complex operational decisions while maintaining safety, regulatory compliance, and data quality.

Within this context, the pilot served as a stress test for the framework, examining both its technical coherence and its capacity to support structured decision-making. Particular emphasis was placed on evaluating whether the framework could function as a unifying reference for heterogeneous user profiles, including students, researchers, and professionals, without requiring ad hoc adaptations or domain-specific modifications.

The case study was intentionally designed to be reproducible and transferable, ensuring that the validation outcomes would not be limited to a single event or location, but could inform future applications of the framework across different sectors and operational scenarios.

2.3 Alignment of Field Operations with Framework Categories

A central element of the pilot case study was the systematic alignment of field operations with the nine categories of the Drone Deployment Framework, as defined in Task 2.1.4. Each operational phase of the pilot was explicitly mapped to a corresponding framework category, enabling a structured evaluation of the framework's completeness and internal consistency.

The application of the framework encompassed the following categories:

- **Assessment & Planning**, through pre-mission feasibility analysis and definition of operational objectives.

- **Technology Selection**, by aligning sensor and platform capabilities with mission requirements.
- **Regulatory Compliance**, ensuring adherence to applicable aviation regulations and safety principles.
- **Operational Framework**, via the execution of standardized procedures governing flight operations.
- **Sustainability Integration**, addressing energy efficiency and responsible use of resources.
- **Data Management & Analytics**, covering data acquisition, processing, and interpretation workflows.
- **Applications & Use Cases**, validating the relevance of the framework to agricultural decision-making.
- **Evaluation & Reporting**, enabling structured feedback collection and result documentation.
- **Scalability & Expansion**, assessing the potential for adaptation to broader operational contexts.

This alignment confirmed that the framework provides coherent guidance across all phases of drone deployment, supporting both operational execution and post-mission analysis within a unified methodological structure.

2.4 Role of the Pilot as a Validation Environment

It is important to emphasize that the pilot case study functioned exclusively as a validation environment for the Drone Deployment Framework. While the framework was applied in conjunction with hands-on activities, the focus of this deliverable is not on the description of training processes, participant engagement, or instructional methods.

Instead, the pilot enabled the observation and evaluation of how the framework performs when applied under realistic operational constraints. The insights derived from this process form the basis for the evaluative conclusions, lessons learned, and instructor-oriented guidance presented in subsequent sections of this deliverable.

By treating the pilot as a validation mechanism rather than an educational event, the deliverable ensures a clear separation between Activity A5.1 and Activity A5.4, while maintaining a strong conceptual linkage between framework evaluation and practical application.

The operational deployment environment and the spatial definition of the area of interest used during the pilot validation are illustrated in Figure 1 and Figure 2 below.



Figure 1: Operational validation briefing and digital mission planning conducted as part of the pilot validation of the DDF.



Figure 2: Field deployment and data acquisition activities executed within the pilot validation environment.

3. Alignment of Field Operations with the Drone Deployment Framework

3.1 Overview of the Alignment Process

The evaluation of the Drone Deployment Framework was conducted through the systematic alignment of real-world field operations with the framework's nine methodological categories, as defined in Task 2.1.4. This alignment process constituted the core evaluative mechanism of Activity A5.1, enabling a structured assessment of the framework's applicability, coherence, and operational completeness.

Rather than documenting individual actions or operational steps, the alignment focused on examining whether each category of the framework provided sufficient guidance to support decision-making, risk mitigation, and workflow structuring throughout the drone deployment lifecycle. The pilot case study served as the validation context in which this alignment could be practically assessed under realistic conditions.

3.2 Category-by-Category Evaluation

i. Assessment & Planning:

The framework effectively supported the initial assessment and planning phase by providing a structured approach to defining mission objectives, identifying operational constraints, and evaluating site-specific conditions. The inclusion of pre-mission feasibility analysis and risk awareness facilitated informed decision-making prior to deployment, confirming the relevance of this category for both educational and operational contexts.

ii. Technology Selection:

The Technology Selection category proved effective in guiding the alignment between mission requirements and platform capabilities. By framing technology choices as function-driven decisions rather than vendor-specific selections, the framework enabled users to assess sensor characteristics, payload suitability, and system limitations in a methodical manner. This approach enhanced transparency and reduced ad-hoc decision-making during the deployment process.

iii. Regulatory Compliance:

The Regulatory Compliance category provided a clear structure for integrating aviation regulations and safety principles into the deployment workflow. The framework supported awareness of applicable regulatory elements, including operational limitations and risk assessment concepts, ensuring that compliance considerations were treated as integral operational constraints rather than as external or isolated requirements.

iv. Operational Framework:

The Operational Framework category demonstrated strong applicability in structuring field operations through standardized procedures and clearly defined workflows. The use of structured operational logic supported consistency, safety awareness, and repeatability, confirming the framework's effectiveness in guiding practical execution across different user profiles.

v. Sustainability Integration:

The Sustainability Integration category enabled the consideration of environmental and resource-related aspects within the deployment process. By encouraging awareness of energy efficiency, responsible resource usage, and operational optimization, the framework supported sustainability as an embedded operational principle rather than a standalone objective.

vi. Data Management & Analytics:

The Data Management & Analytics category provided a coherent structure for handling the full data lifecycle, from acquisition to processing and interpretation. The framework facilitated a clear understanding of how raw data can be transformed into actionable information, supporting both technical evaluation and educational objectives. This category was identified as a critical enabler for data-driven decision-making within drone-based applications.

vii. Applications & Use Cases:

The Applications & Use Cases category effectively contextualized drone deployment within a specific industrial domain, validating the framework's relevance to real-world agricultural scenarios. By linking operational outputs to concrete application needs, the framework demonstrated its capacity to support meaningful and goal-oriented deployments.

viii. Evaluation & Reporting:

The Evaluation & Reporting category supported structured reflection on operational outcomes through feedback mechanisms and result documentation. This category enabled the systematic capture of insights related to framework usability and performance, contributing directly to the identification of lessons learned and areas for potential improvement.

ix. Scalability & Expansion:

The Scalability & Expansion category facilitated the assessment of the framework's adaptability beyond the immediate pilot context. While large-scale or multi-site deployments were not executed within the scope of the pilot, the framework provided conceptual guidance for future expansion, highlighting its potential applicability across different operational scales and sectors.

3.3 Synthesis of Alignment Outcomes

The category-by-category alignment confirms that the Drone Deployment Framework provides comprehensive and coherent guidance across the full drone deployment lifecycle. The evaluation demonstrates that the framework is capable of supporting structured decision-making, operational execution, and reflective assessment within a unified methodological structure.

The findings from this alignment process form the foundation for the lessons learned and instructor-oriented guidance presented in the following sections, reinforcing the role of the framework as both an operational and educational reference for drone deployment activities.

4. Data Management & Analytics as a Validation Component of the Framework

4.1 Role of Data Management & Analytics within the Framework

Data management and analytics constitute a critical stage of the Drone Deployment Framework, as they represent the transition from operational execution to knowledge generation and decision support. Within the scope of Activity A5.1, this category was evaluated to determine whether the framework provides sufficient methodological guidance for transforming raw sensor data into meaningful and interpretable outputs.

The evaluation focused on the logical structure of the data lifecycle rather than on software-specific implementation details. Emphasis was placed on assessing whether the framework enables users to understand how mission planning, sensor selection, and data acquisition strategies influence the quality and interpretability of analytical results.

Viewed as a whole, the indicative workflow provides instructors with a structured narrative that connects planning, execution, analysis, and reflection within a single methodological framework. By presenting data management and analytics as an integrated lifecycle, instructors can guide learners toward a holistic understanding of drone deployment, consistent with the objectives of Activity A5.1.

4.2 Indicative Data Analysis Workflow

To support the evaluation of the Data Management & Analytics category, an indicative data analysis workflow was examined, illustrating the type of outputs generated at this stage of the framework. In the context of precision agriculture, multispectral imagery and vegetation indices were selected as representative analytical products due to their widespread adoption and relevance to decision-making processes.

The workflow illustrates how raw drone data are systematically transformed into analytical outputs that support interpretation and decision-making, in a manner that is transferable across domains and suitable for instructional use.

The workflow is structured into six interconnected stages, covering the complete data lifecycle from mission design to feedback and refinement. Figure 3 provides an overview of the workflow, while the subsequent subsections elaborate on each stage, including indicative tools and platforms that may support instructional delivery.

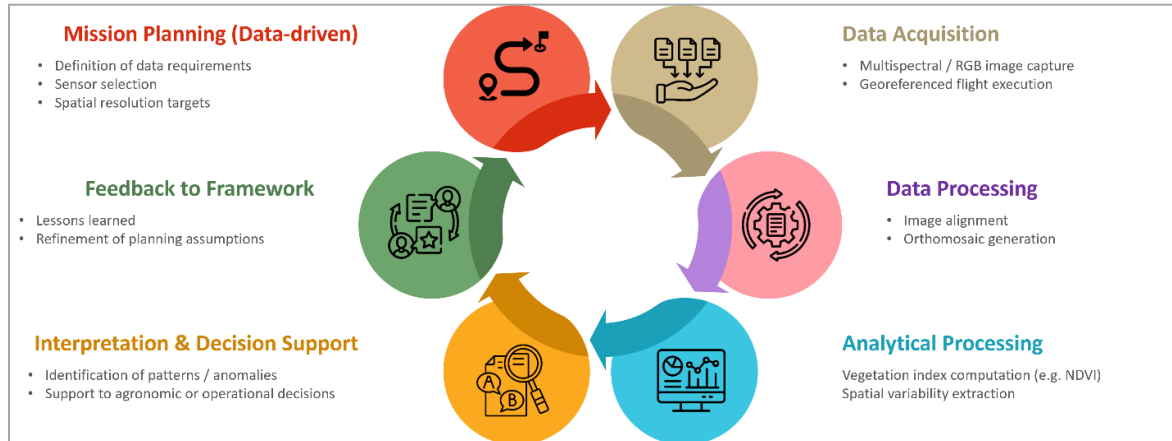


Figure 3: Indicative data management and analytics workflow illustrating the transformation of drone-acquired data into decision-support information within the Drone Deployment Framework.

Note that the figures included in this section and the following subsection, are illustrative and conceptual in nature. They are provided to demonstrate the type of analytical outputs expected at the Data Management & Analytics stage of the Drone Deployment Framework and do not originate from the pilot field operations.

4.2.1 Mission Planning (Data-Driven Design)

The workflow begins with mission planning (Figure 4) driven explicitly by data requirements rather than by flight execution alone. At this stage, instructors should emphasize the definition of analytical objectives, spatial resolution targets, and sensor requirements, ensuring that data acquisition is aligned with the intended analytical outputs.

Indicative hardware platforms may include multirotor or fixed-wing unmanned aerial systems capable of carrying RGB or multispectral sensors. Commonly used sensor types include RGB cameras for visual inspection and multispectral sensors for vegetation analysis.

Indicative software platforms supporting this stage include flight-planning and mission-design tools that allow instructors to demonstrate how altitude, overlap, and coverage influence data quality.



Figure 4: Indicative mission planning environment.

4.2.2 Data Acquisition

During the data acquisition stage, the planned mission is executed, and georeferenced imagery is collected according to predefined parameters. This stage highlights the relationship between operational execution and data quality, reinforcing the importance of adherence to planning constraints.

From an instructional perspective, this step demonstrates how consistent flight execution underpins reliable downstream analysis. Emphasis should be placed on repeatability, sensor calibration awareness, and environmental considerations.

An indicative data acquisition stage illustrating the collection of georeferenced imagery in accordance with predefined mission parameters is illustrated in Figure 5.



Figure 5: Indicative data acquisition

4.2.3 Data Processing

Raw imagery collected during flight is processed into spatially consistent products. This typically includes image alignment, georeferencing, and the generation of orthomosaics or comparable composite outputs.

Instructors may introduce processing platforms that automate these steps to illustrate how raw data are transformed into structured spatial datasets. The focus at this stage is not on software operation, but on understanding the role of processing as an intermediate layer between acquisition and analysis.

Figure 6 presents an indicative RGB orthomosaic representation, illustrating the type of spatially consistent image product typically generated following data acquisition and processing. Such products form the basis for subsequent analytical steps, enabling visual inspection and spatial referencing of the surveyed area.



Figure 6: Conceptual RGB / Orthomosaic Representation

4.2.4 Analytical Processing

Analytical processing builds upon processed spatial data to extract indicators that support interpretation. In precision agriculture contexts, this commonly involves the computation of vegetation indices, such as NDVI, derived from multispectral imagery.

This stage illustrates how spectral information is translated into thematic maps that reveal spatial variability. From an instructional standpoint, it demonstrates the value of drones as data-generation tools rather than solely as flight platforms.

Building upon this intermediate product, analytical processing can be applied to derive indicators that support data-driven interpretation. Figure 7 illustrates an indicative Normalized Difference Vegetation Index (NDVI) map, which represents spatial variations in vegetation vigor through the combination of spectral information from different wavelength bands.



Figure 7: Conceptual NDVI Map

4.2.5 Interpretation & Decision Support

Analytical outputs are interpreted in relation to operational objectives and contextual knowledge. Instructors should emphasize that index maps and analytical layers are decision-support tools, not decisions in themselves.

This stage reinforces critical thinking by linking analytical results to possible operational or management actions, while avoiding automated or deterministic interpretations.

Indicative interpretation and decision-support output illustrating how analytical results are contextualized to support operational decision-making, is presented in Figure 8.

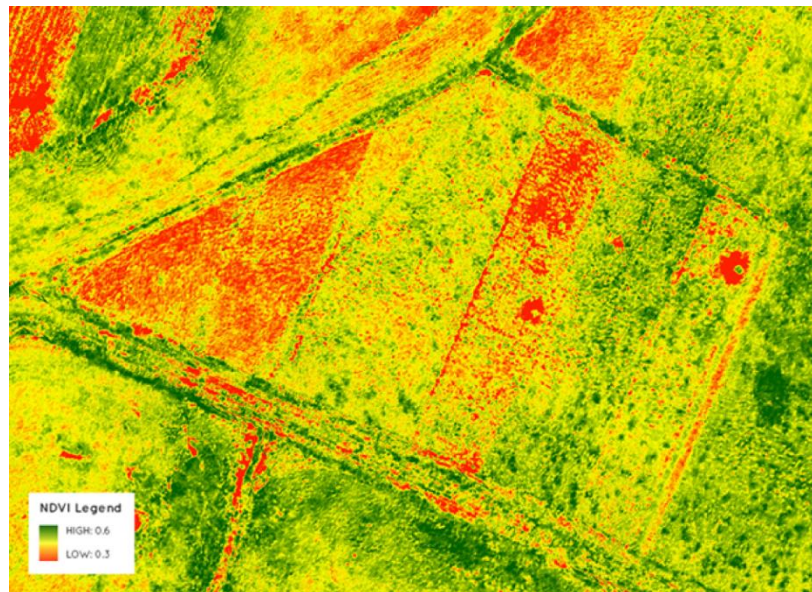


Figure 8: Indicative interpretation and decision-support output.

4.2.6 Feedback and Framework Refinement

The final stage closes the loop by feeding insights gained during analysis back into future mission planning and framework application. Lessons learned regarding sensor selection, flight parameters, and data interpretability inform iterative refinement of subsequent deployments.

This feedback mechanism demonstrates the cyclical nature of the framework and highlights its adaptability and scalability across different use cases and operational contexts.

To further support the evaluation of this workflow and its practical applicability, the instructor's role in facilitating and supervising each stage of the data lifecycle was examined. Instructor-oriented guidance derived from this evaluation, focusing on the operationalization of data processing, analytical interpretation, and reflective feedback within the Drone Deployment Framework, is presented in Chapter 7.

4.3 Educational and Evaluative Value of Analytical Outputs

From an evaluative perspective, the indicative workflow demonstrates that the framework supports a coherent progression from data acquisition to result interpretation. The framework encourages users to view analytical outputs, such as vegetation indices, as decision-support tools rather than isolated technical artifacts, reinforcing the integration of analytics within the broader operational context.

From an educational standpoint, this category was identified as particularly effective in bridging theoretical concepts and practical application. By situating analytical outputs within a structured framework, learners are better able to understand the relationship between sensor characteristics, mission parameters, data quality, and the interpretation of results. This approach supports experiential learning by linking abstract analytical principles to concrete operational scenarios.

4.4 Reference Implementation and Transferability

Although illustrated using a precision agriculture use case, the data management and analytics workflow evaluated in this section functions as a reference implementation of the analytical layer of the Drone Deployment Framework. The underlying principles—structured data handling, indicator-based interpretation, and linkage to decision-making—are transferable to a wide range of application domains, including environmental monitoring, infrastructure inspection, and energy-related deployments.

This confirms that the framework provides a domain-agnostic structure for data management and analytics, enabling consistent application across multiple sectors without requiring fundamental methodological changes.

4.5 Summary of Validation Findings

The evaluation of the Data Management & Analytics category confirms that the Drone Deployment Framework successfully integrates analytical reasoning into the drone deployment lifecycle. By providing clear methodological guidance on how data outputs should be generated, interpreted, and contextualized, the framework supports both operational effectiveness and educational value.

The findings of this section reinforce the role of the framework as a comprehensive methodology that extends beyond flight execution, ensuring that data-driven insights form a coherent, reusable, and pedagogically meaningful component of drone deployment activities.

5. Quantitative Evaluation Results & Analysis

The quantitative evaluation of the Drone Deployment Framework was conducted through a structured post-mission questionnaire administered digitally after the completion of the pilot validation activities. Although the pilot involved a total of 25 participants, valid responses were collected from a representative sample of 12 respondents, which was deemed sufficient for evaluating the usability and effectiveness of the framework.

The quantitative evaluation results presented in this section are supported by the graphical representations, as illustrated in *Figure 6* *Figure 9* -*Figure 20*.

5.1 Participant Profile

The respondent group consisted of a balanced mix of user profiles, including students/trainees (41.7%), academic staff or researchers (33.3%), and industry professionals (25%). This composition ensured that the framework was assessed across different levels of professional maturity and practical expectations.

The disciplinary background of respondents was predominantly technical, with participants from ICT and engineering fields accounting for 75% of the sample. The remaining respondents represented agriculture and environmental sciences (16.7%) and business or management disciplines (8.3%). This distribution confirms that the framework can effectively support agricultural drone applications even for users without a traditional agronomy background.

In terms of prior experience with drone operations, the majority of respondents identified as beginners (58.3%) or intermediate users (33.3%), while only a small proportion reported advanced experience (8.3%). This profile validates the framework's accessibility and suitability for users with limited prior exposure to drone technology.

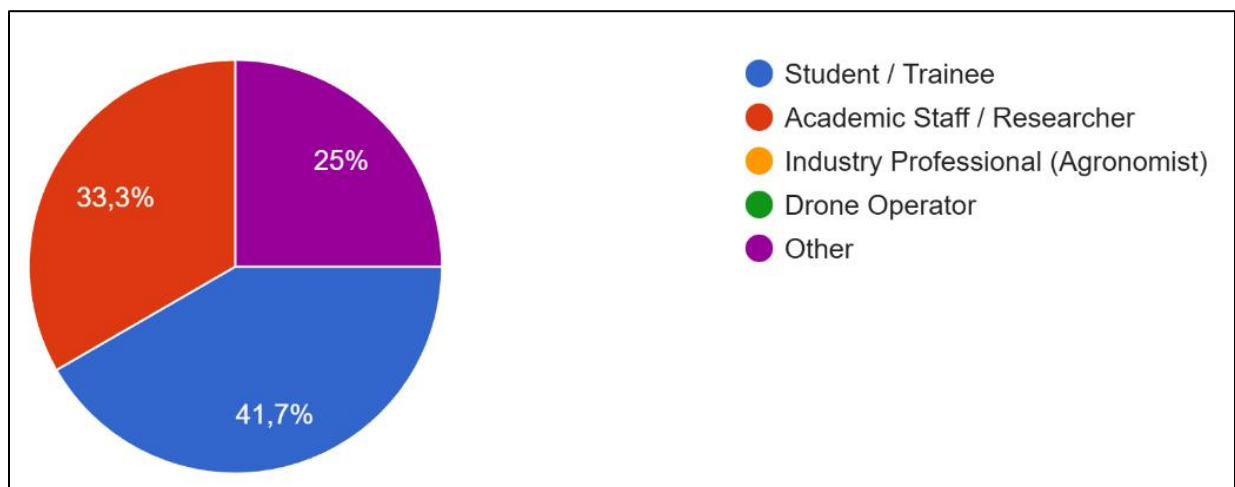


Figure 9: Professional distribution of the pilot case study evaluation.

Regarding disciplinary background, the sample was predominantly composed of individuals from the ICT/Engineering sector (75%), with the remaining participants representing Agriculture and Environmental Sciences (16.7%) and Business/Management (8.3%). This composition is particularly

significant as it validates the framework's ability to transfer specific agricultural technology skills to a technical audience outside the traditional agronomy sector.

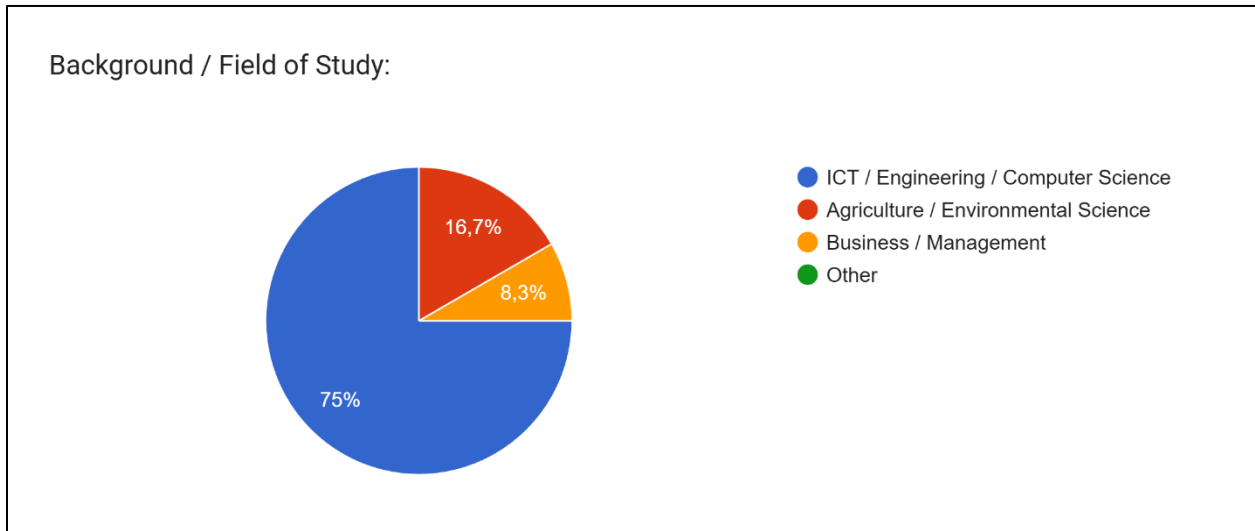


Figure 10: Sectoral and disciplinary composition of the evaluation sample

Furthermore, the framework was stress-tested against a variety of proficiency levels to determine its entry-level accessibility. The evaluation data confirms that the majority of participants identified as Beginners (58.3%) or Intermediates (33.3%), while only a small segment comprised Advanced professionals (8.3%). This distribution provides strong evidence that the proposed methodology is highly effective for training users with limited prior exposure to drone technology.

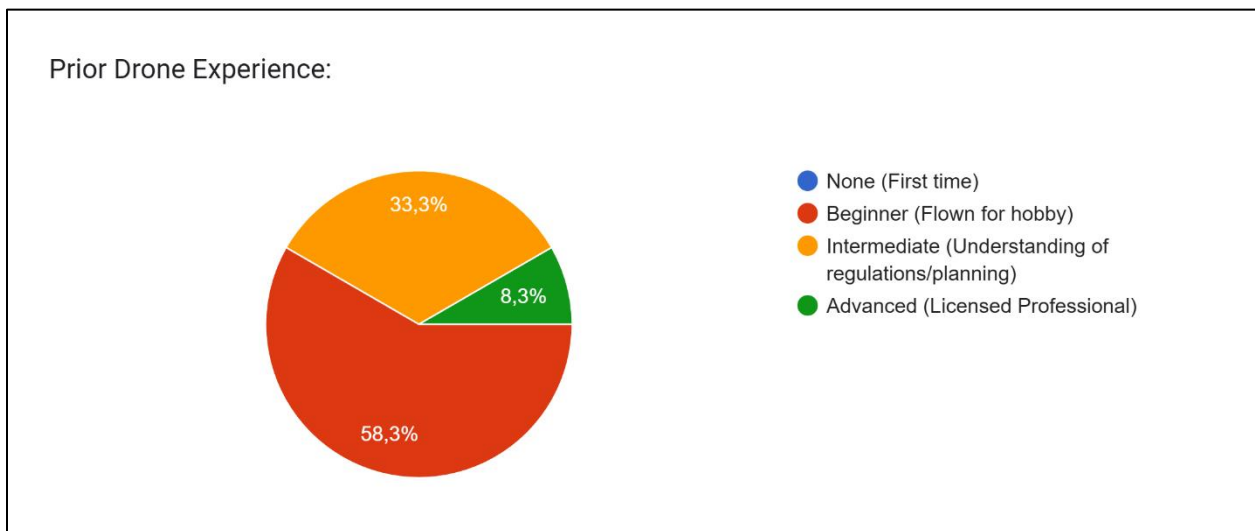


Figure 11: Distribution of prior drone piloting experience among respondents

5.2 Quantitative Validation of Framework Components

Participants evaluated key phases of the Drone Deployment Framework using a 5-point Likert scale, where 5 represents the highest level of agreement.

5.2.1 Assessment & Planning

The clarity and structure of the pre-mission planning phase received an average score of **4.83/5.0**, with the vast majority of respondents assigning the maximum score. This result confirms that the framework provides clear guidance for defining mission objectives and operational constraints prior to deployment.

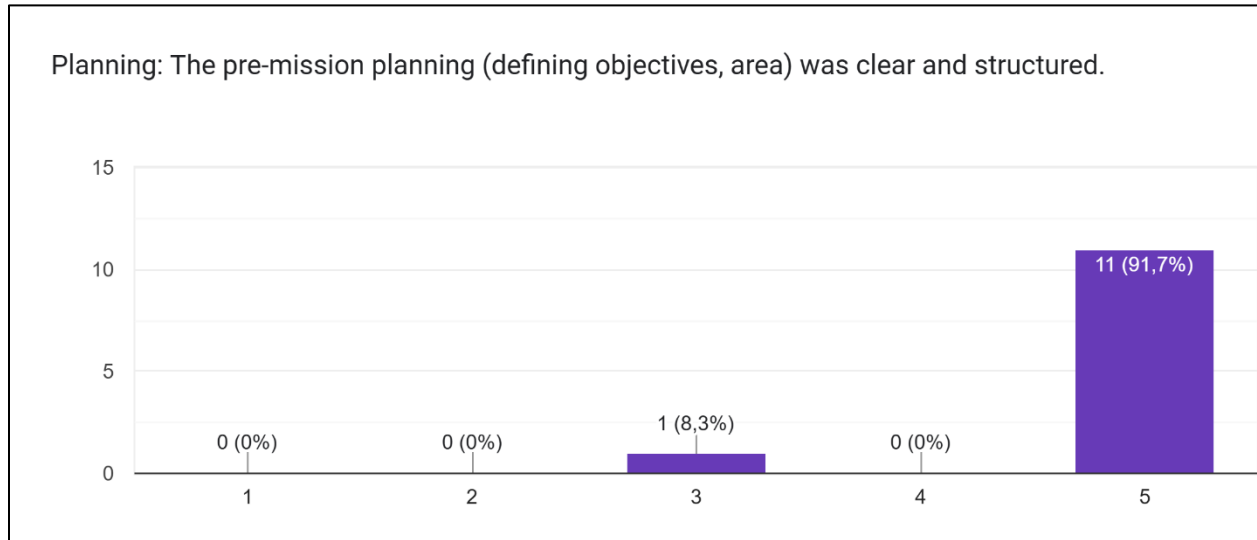


Figure 12: Participant ratings on the clarity and structure of the pre-mission planning phase.

5.2.2 Operational Workflow

The use of structured workflows, including checklists and standard operating procedures, was rated with an average score of **4.75/5.0**. The results indicate that the framework effectively supports the organization and execution of field operations, particularly for less experienced users.

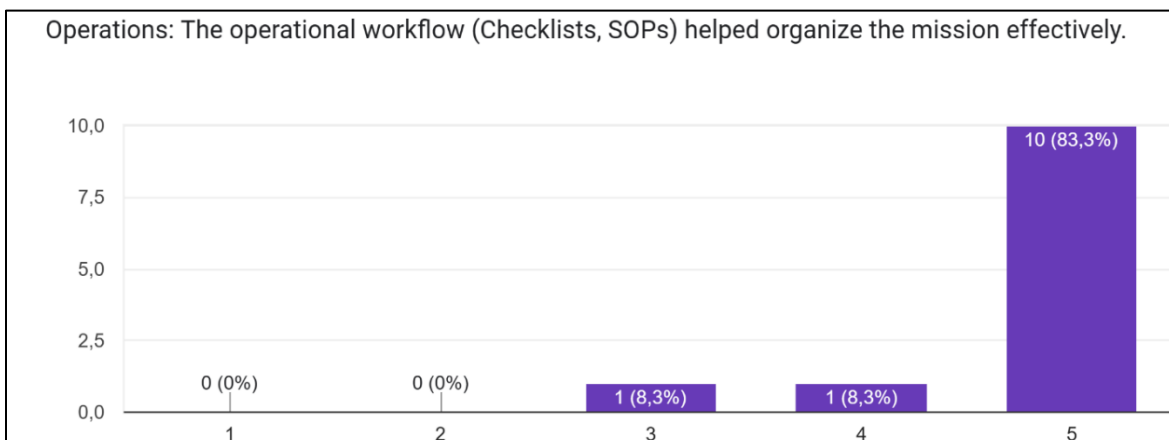


Figure 13: Participant ratings regarding the effectiveness of the operational workflow.

5.2.3 Data Management & Analytics

The end-to-end workflow from flight execution to data analysis was evaluated with an average score of **4.83/5.0**. This finding demonstrates that the framework successfully clarifies the data pipeline, which is commonly identified as a major barrier in drone-based applications.

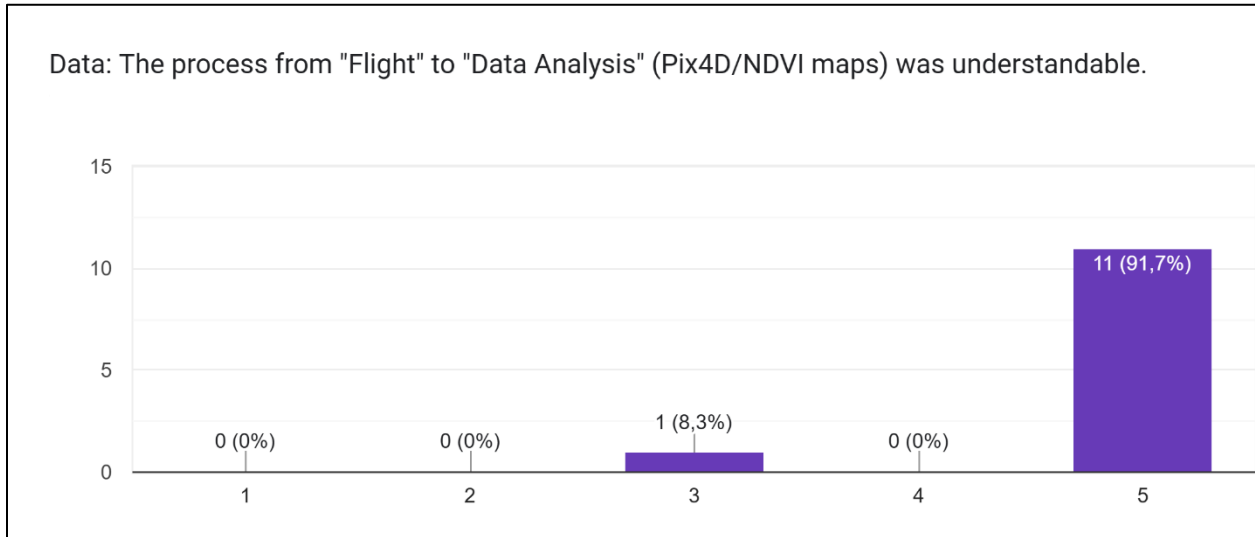


Figure 14: Participant ratings regarding the understandability of the data processing workflow (from Flight to Analysis).

5.2.3.1 Regulatory Compliance & Safety

Navigating the complex regulatory landscape, encompassing EASA guidelines, SORA methodologies, and JARUS protocols, presents a significant challenge for new operators. However, the pilot results demonstrate that the framework’s approach to compliance was highly effective. Participants rated the statement "The regulatory & safety briefing (EASA/ICAO & local) was clear and sufficient" with an average score of **4.67 / 5.0**. The results indicate that complex regulatory requirements can be effectively integrated into operational workflows through a structured methodological approach

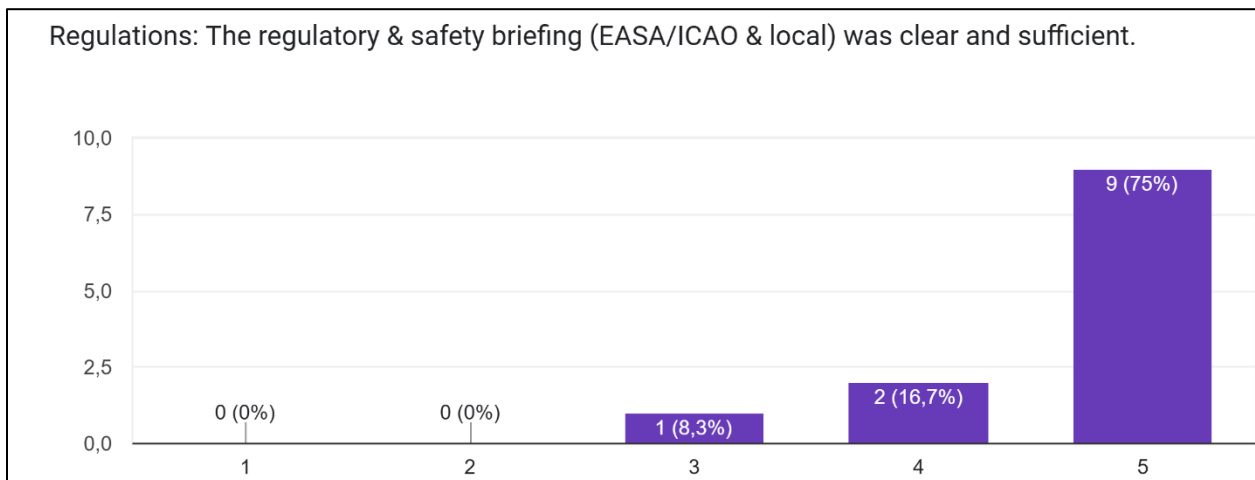


Figure 15: Participant evaluation of the clarity and sufficiency of the regulatory and safety briefing.

5.3 Overall Framework Usability

Beyond the specific operational phases, a pivotal component of the evaluation was the assessment of the Drone Deployment Framework itself as a structural tool. Participants were asked to rate the clarity and usability of the 9-Category model on a 5-point scale.

The results indicate a strong validation of the proposed methodology, with an average rating of **4.75 / 5.0**. Specifically, the data reveals that 75% of respondents awarded the maximum possible score (**5/5**), characterizing the framework as "Very Clear/Usable." The remaining 25% rated it highly (**4/5**). The absence of any negative or neutral responses (scores 1-3) confirms that the modular approach adopted in WP2 is practically applicable for organizing complex drone missions.

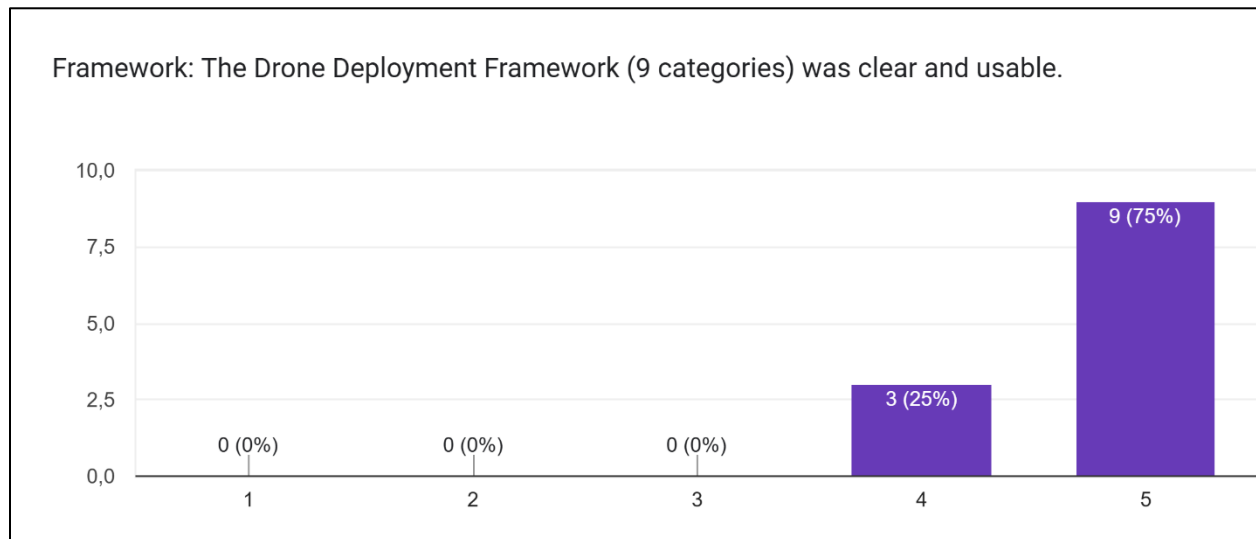


Figure 16: Participant ratings regarding the overall clarity and usability of the 9-Category Drone Deployment Framework

5.4 Pedagogical Impact & Bridging the Theory-Practice Gap

The operational success of the pilot case study was intrinsically linked to the efficacy of the knowledge transfer mechanisms employed. The evaluation data explicitly validates the pedagogical approach, highlighting both the technical expertise of the trainers and the structural logic of the training delivered.

Participants reported exceptional satisfaction with the delivery of the training. Quantitative analysis reveals that **75%** of the group rated the "Quality of Instructors" with the maximum score of **5/5**, with the remaining participants awarding high marks. Similarly, the "Clarity of Briefing/Instructions" received near-perfect validation, with **83.3%** of respondents giving the top rating. These metrics confirm that complex technical concepts, ranging from EASA regulations to multispectral analysis, were communicated with the necessary clarity and precision.

Crucially, the Kozani pilot case study successfully navigated a common challenge in vocational training: reconciling academic depth with hands-on utility. The evaluation data confirms that the event execution achieved a 100% optimal balance between theoretical instruction and practical application. Participants indicated that the specific schedule of the trial successfully avoided the extremes of "too much theory" or

"too much practice," a strategic balance that proved to be a decisive factor in the overall operational success of the validation

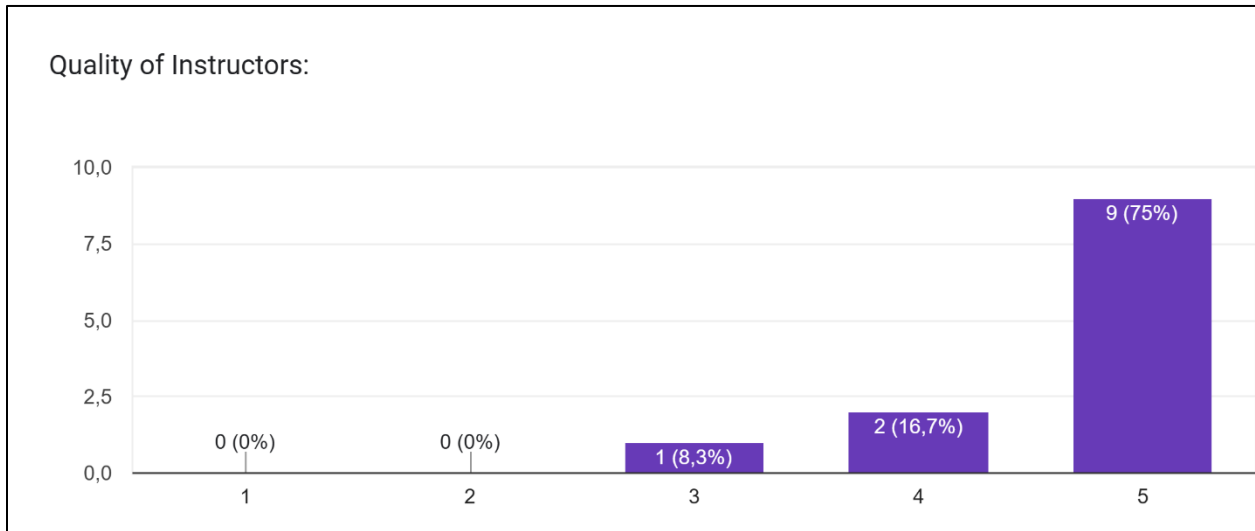


Figure 17: Participant evaluation of the Quality of Instructors

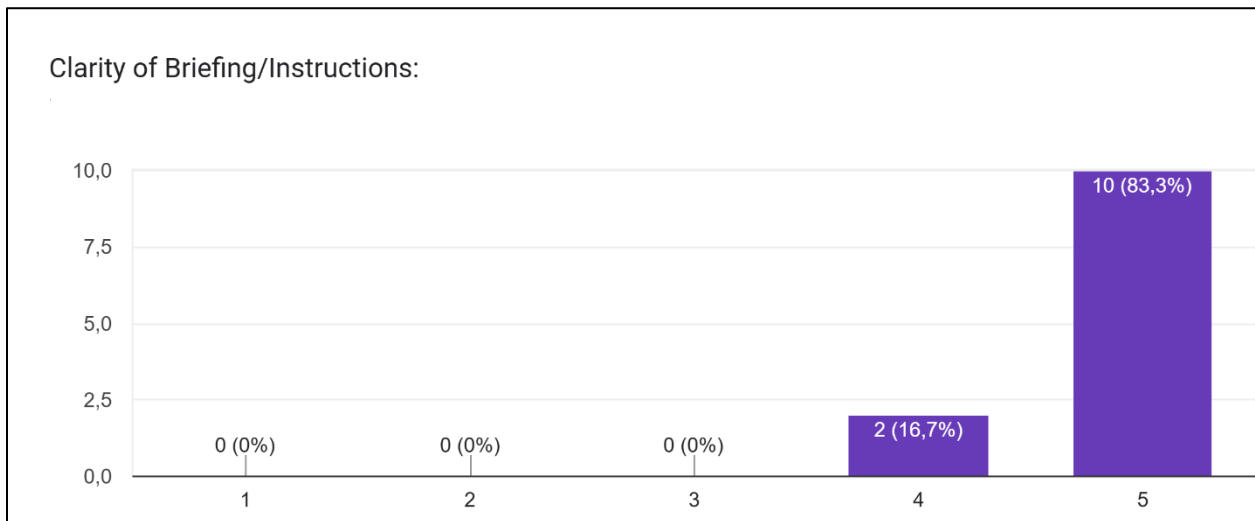


Figure 18: Participant evaluation of the Clarity of Briefing/Instructions

5.5 Evidence of Framework-Supported Knowledge Transfer

The evaluation results confirm that the framework effectively supports the transition from theoretical understanding to practical application. An overwhelming majority of respondents (**91.7%**) reported that the framework significantly facilitated this transition, while the remaining respondents indicated a moderate positive effect. No negative responses were recorded.

Qualitative feedback reinforces these findings, with respondents consistently emphasizing the value of integrated workflows linking mission planning, field execution, and data analysis. This feedback

demonstrates that the framework promotes a holistic understanding of drone deployment as a complete operational lifecycle rather than a sequence of isolated tasks.

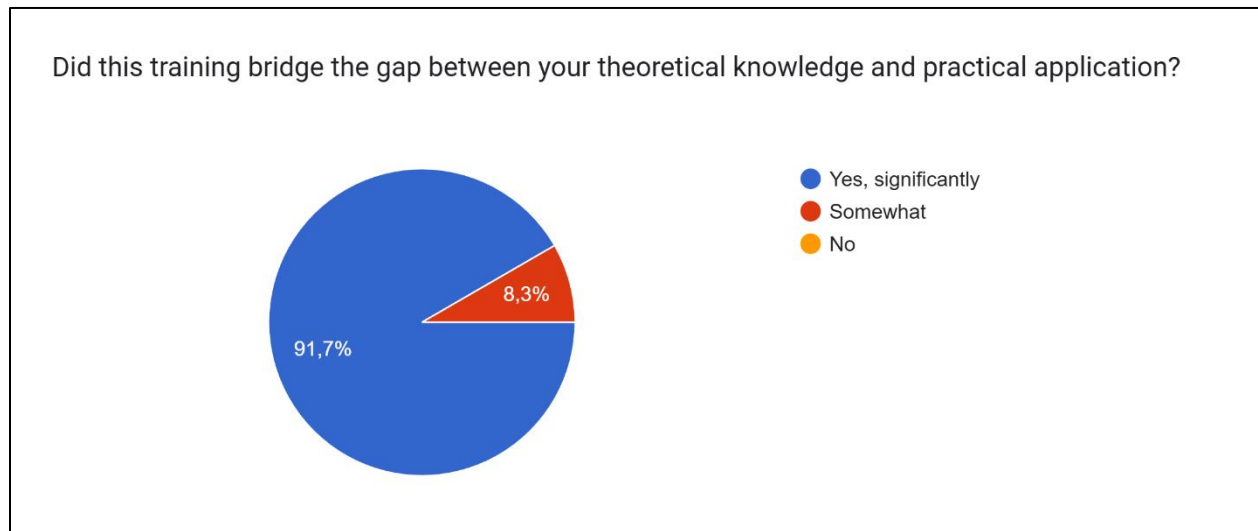


Figure 19: Quantitative assessment of the training's efficacy in bridging the theory-practice gap.

5.6 Qualitative Feedback: The Value of Integrated Workflows

To understand why the gap was bridged, the evaluation analyzed open-ended responses regarding the "most valuable part of the experience".

The feedback indicates that participants did not view the drone merely as a flight platform, but as a data generation tool. The responses heavily prioritized the analytical components of the workflow, with specific mentions of:

- *"The hands-on opportunity to fly... and instantly analyze the multispectral data."*
- *"Flight planning and data analysis."*
- *"Analyzing the collected data and computed related indexes."*
- *"Real-time index calculation and understanding their practical interpretation."*
- *"Understanding the framework through action: going from the office to the field, and back to the office to have results."*

This qualitative data indicates that the Pilot Case Study successfully shifted the participants' focus from simple flight mechanics to a holistic understanding of the complete operational lifecycle. By explicitly linking the office-based planning and analysis phases with field execution, the training cultivated the necessary agronomic intelligence, validating the framework's ability to guide users through the end-to-end workflow required for precision agriculture.

5.7 Validation of the Framework

Finally, the utility of the Drone Deployment Framework (9 Categories) was assessed as a holistic structural entity. Participants were asked to rate the efficacy of the 9-category structure in organizing and executing the mission.

The results demonstrate a strong validation of the methodology:

- 66.7% of participants awarded the maximum score (5/5 - Very Useful).
- 25% rated it highly (4/5).
- Only 8.3% gave a neutral rating (3/5), with no negative ratings recorded.

This quantitative success is reinforced by the qualitative feedback. When explicitly asked, “What aspects of the Framework or Training need improvement?”, the respondents did not identify any structural deficiencies. Instead, the feedback emphasized the robustness of the model, with one respondent stating: “I do not have something to improve here. I think that all aspects of both Framework and Training are excellent”. This confirms that the structured, categorical approach is effective for managing the complexity of real-world drone missions without requiring immediate modification.

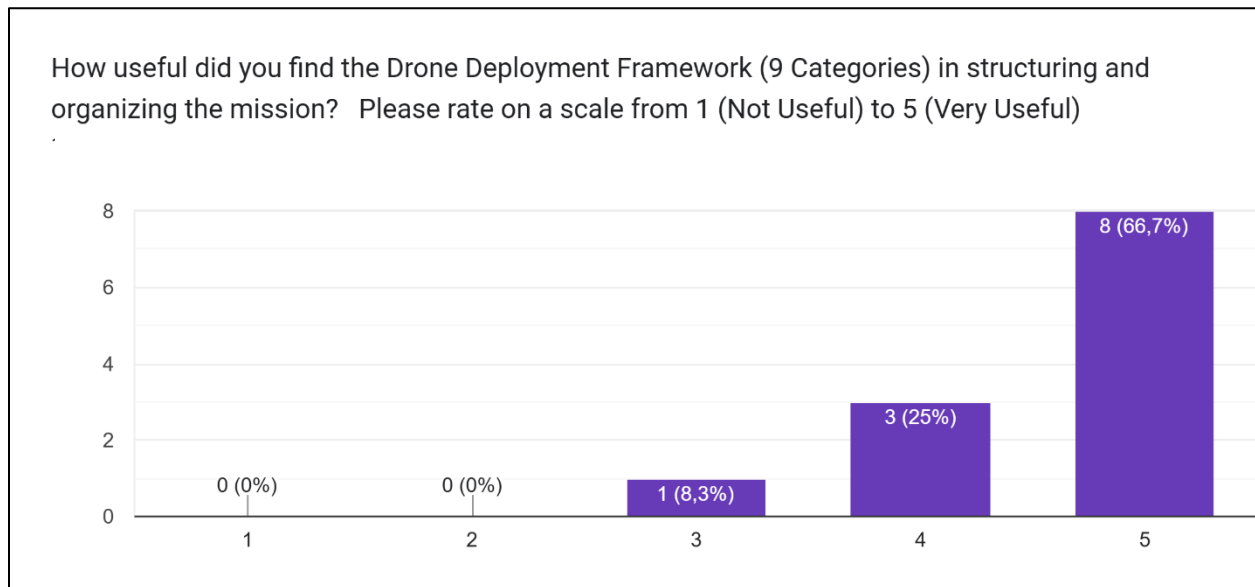


Figure 20: Participant ratings on the utility of the Framework in structuring and organizing the mission

5.8 Summary of Quantitative Findings

The quantitative evaluation results provide strong evidence that the Drone Deployment Framework is clear, usable, and effective in real-world operational contexts. The consistently high scores across framework components confirm its suitability for supporting both operational decision-making and structured knowledge transfer, directly contributing to the evaluation objectives of Activity A5.1.

6. Lessons Learned from the Pilot Case Study

The pilot validation of the Drone Deployment Framework provided clear evidence regarding its strengths, limitations, and areas of practical impact when applied in a real-world operational context, generating a set of cross-cutting lessons that extend beyond the specific agricultural use case and are directly relevant to the broader deployment of drone technologies in green industry applications.

A primary lesson learned is that the structured, category-based approach of the framework significantly reduces operational ambiguity, particularly for users with limited prior experience. The clear separation of planning, operational, regulatory, and analytical phases enabled participants to approach complex drone missions methodically, minimizing uncertainty and ad-hoc decision-making.

The evaluation confirmed that early-stage phases (Assessment & Planning) are critical for the overall success of the deployment. High ratings in this category indicate that explicitly guiding users through objective definition, site assessment, and feasibility analysis establishes a strong operational foundation and improves downstream performance.

Another key finding concerns the integration of data management and analytics within the deployment lifecycle. Treating data processing as a core operational phase, rather than a post-flight technical add-on, proved essential for enabling data-driven reasoning. This approach helped users understand the value of drone operations beyond flight execution, reinforcing the framework's end-to-end logic.

The pilot also demonstrated that regulatory compliance and safety considerations can be effectively operationalized when embedded directly into the deployment workflow. Presenting regulatory requirements as actionable steps, rather than abstract legal constraints, increased user confidence and reduced perceived complexity.

From an educational and operational standpoint, the framework was shown to successfully bridge the gap between theoretical knowledge and practical application. The alignment between office-based planning, field execution, and post-mission analysis enabled participants to internalize the full operational lifecycle, supporting meaningful skill acquisition.

Finally, the lessons learned indicate that the framework is robust and adaptable, with no immediate structural modifications required following validation. Feedback did not identify missing categories or critical weaknesses, suggesting that the framework is mature enough for reuse and extension to other domains and operational scales.

7. Instructor-Oriented Guidance

This chapter provides instructor-oriented guidance derived from the operational validation of the Drone Deployment Framework. The purpose of this guidance is to support instructors in delivering hands-on drone deployment activities that are coherent, structured, and aligned with the framework, without prescribing a fixed curriculum or training syllabus.

To support instructors in operationalizing the Drone Deployment Framework in educational contexts, an instructor-oriented guidance workflow is provided. As illustrated in Figure 21, the workflow outlines a structured sequence of actions that guides instructors from the definition of learning objectives through field execution, data interpretation, and reflective evaluation, ensuring methodological consistency and alignment with the framework.

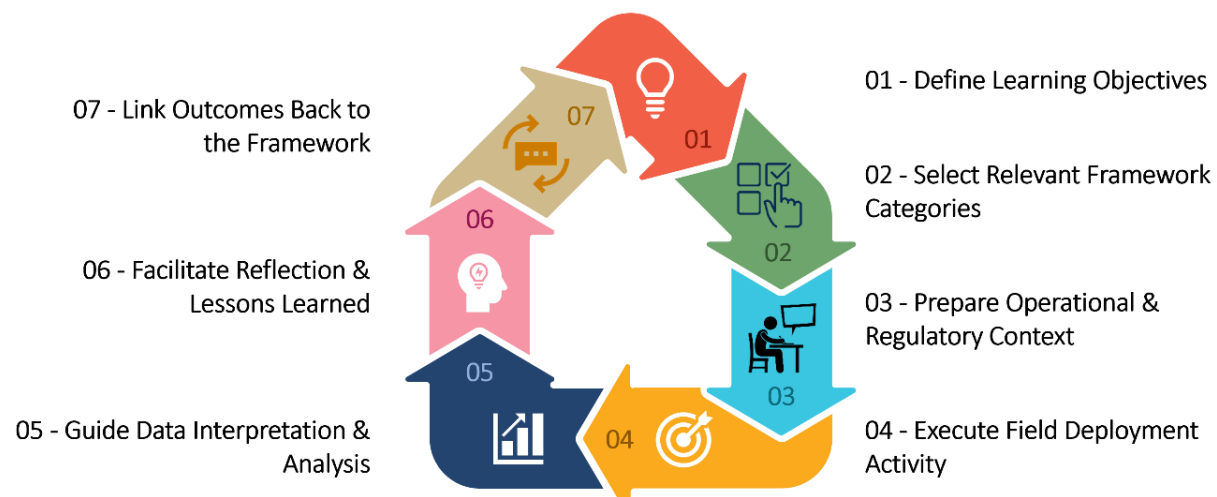


Figure 21: Instructor-oriented guidance workflow

7.1 Role of the Instructor within the Drone Deployment Framework

The operational validation demonstrated that the instructor plays a critical role in maintaining methodological coherence across all phases of drone deployment. Rather than acting solely as a technical facilitator, the instructor is responsible for ensuring that planning, execution, data handling, and interpretation are explicitly connected to the framework's categories.

Particular emphasis should be placed on the Assessment & Planning phase, as the pilot validation demonstrated that this stage strongly influences overall operational success. Instructors should ensure that learners clearly define mission objectives, assess site-specific constraints, and consider feasibility and risks before any field activity. Reinforcing disciplined pre-mission planning cultivates operational awareness and reduces downstream errors during execution.

7.2 Instructor-Facilitated Operational and Regulatory Alignment

The integration of regulatory compliance and safety considerations should be treated as an intrinsic part of the deployment workflow. Instructors are advised to translate regulatory requirements into actionable operational practices, embedding them within planning and execution phases. This approach shifts regulatory awareness from theoretical compliance to practical responsibility, enabling learners to operate confidently within complex legal and safety frameworks.

The use of standardized operational procedures, including checklists and structured workflows, was identified as a key enabler for effective learning. Instructors should promote the consistent application of such procedures to reduce cognitive load, support repeatability, and instill operational discipline, particularly for users with limited prior experience.

7.3 Instructor-Facilitated Data Processing & Analytics Workflow

Another critical instructional area concerns data management and analytics. The pilot validation confirmed that learners benefit significantly when data-related activities are framed as an essential component of the mission rather than as an isolated post-flight task. Instructors should explicitly connect sensor selection, mission parameters, and data acquisition strategies to the interpretation of analytical outputs, reinforcing a data-driven understanding of drone operations.

The instructor-facilitated processing and analytics workflow illustrates how raw drone-acquired data are progressively transformed into decision-support outputs within the Data Management & Analytics category of the Drone Deployment Framework.

Processed orthomosaic products provide the structural spatial reference required for subsequent analytical interpretation, as illustrated in Figure 22, which demonstrates the transition from RGB orthomosaic imagery to analytical vegetation assessment.

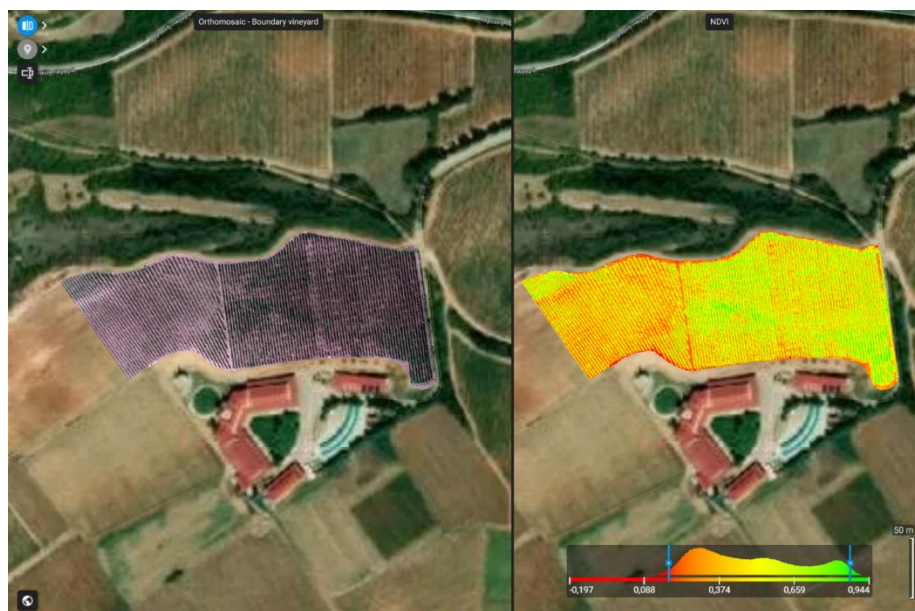


Figure 22: Indicative orthomosaic and NDVI outputs illustrating the transition from structural reference imagery to analytical vegetation assessment within the Drone Deployment Framework.

Instructors should encourage comparative analytical reasoning through the use of multiple vegetation indices or equivalent analytical indicators. Figure 23 illustrates how different indices provide complementary perspectives on crop physiological status, supporting deeper analytical interpretation beyond single-metric analysis.



Figure 23: Comparative visualization of vegetation indices (GNDVI and NDRE) illustrating complementary analytical perspectives for assessing crop physiological status.

Analytical outputs should then be translated into actionable representations. Continuous analytical gradients may be segmented into discrete management or intervention zones, supporting targeted decision-making. This process is illustrated in *Figure 24*, *Figure 25*, and *Figure 26*, which demonstrate indicative transformations from analytical indices to operational prescription maps.



Figure 24: Indicative transformation of NDRE analytical outputs into discrete management zones, supporting early stress detection and targeted intervention.



Figure 25: Indicative conversion of NDVI variability into prescription maps supporting precision input management.



Figure 26: Indicative analytical workflow linking GNDVI outputs to targeted intervention planning within a decision-support context.

Throughout this phase, instructors should emphasize that analytical outputs function as decision-support tools, not automated decisions. Cross-referencing analytical maps with orthomosaic imagery remains essential for identifying artefacts and contextual factors unrelated to the phenomenon under investigation.

7.4 Reflection, Feedback and Framework Reinforcement

Instructors are encouraged to facilitate reflective learning by prompting learners to relate practical activities back to the framework's categories. Structured reflection, both before and after field operations, helps consolidate understanding and supports the transfer of acquired skills to different application domains and operational contexts.

Finally, instructors should maintain a balanced instructional approach that integrates theoretical grounding with practical application. The validation activities demonstrated that learning outcomes are maximized when conceptual explanations are immediately reinforced through hands-on deployment and subsequent data interpretation. This balance supports effective knowledge transfer while preserving the operational focus of the framework.

8. Conclusions & Sustainability Perspective

The validation of the Drone Deployment Framework through a real-world pilot case study confirms that the proposed methodology constitutes a coherent, robust, and practically applicable approach for supporting the full lifecycle of drone deployment. The framework successfully integrates planning, regulatory compliance, operational execution, data management, and evaluation within a unified structure, enabling systematic and repeatable drone operations.

The findings demonstrate that the framework is effective not only as an operational reference but also as an educational and capacity-building instrument. Its category-based structure supports structured decision-making, reduces operational ambiguity, and facilitates the transfer of theoretical concepts into practical deployment scenarios. The quantitative and qualitative evaluation results jointly confirm that the framework can be reliably applied by users with varying levels of experience and professional backgrounds.

From a sustainability perspective, the framework supports the responsible adoption of drone technologies by promoting standardized procedures, efficient resource utilization, and data-driven decision-making. By embedding sustainability considerations within the operational workflow, the framework contributes to reducing unnecessary flights, optimizing data acquisition strategies, and enhancing the overall efficiency of drone-enabled processes.

Looking forward, the validated framework provides a solid foundation for continued use and expansion beyond the specific pilot context. Its modular and domain-agnostic design enables adaptation to additional green industry applications and supports long-term continuity through integration with digital educational resources and future training and deployment initiatives.