



Innovation and Capacity building

in Agricultural Environmental and Rural UAV Services



ICAERUS

D2.4: Analytics Optimisation, Expansion & Scale-up Report

Version A

WP2: Drone Data Analytics Library

Responsible Authors:

Önder Babur (WU), Jurrian Doornbos (WU), Mar Ariza Sentis (WU)



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| EU Project Advisor | Alessandra Sasso |
| Project Coordinator | Spyros Fountas |
| Address | 75 Iera Odos, 11855 Athens, GR Agricultural University of Athens |
| Reply to | sfountas@aua.gr |

| | |
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| Responsible Author | Önder Babur (WU), Jurrian Doornbos (WU), Mar Ariza Sentis (WU) |
| Reply to | onder.babur@wur.nl, jurrian.doornbos@wur.nl, mar.arizasentis@wur.nl |
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| Participants | Contact |
|---|---|
| Agricultural University of Athens (AUA), Greece |  Spyros Fountas sfountas@aua.gr |
| Wageningen University (WU), Netherlands |  Önder Babur onder.babur@wur.nl |
| Foodscale Hub (FSH), Greece |  Grigoris Chatzikostas gchatzikostas@gmail.com |
| Noosware BV (NSWR), Netherlands |  Efstratios Arampatzis sa@noosware.com |
| GeoSense IKE (GS), Greece |  Dimitrios Ramnalis ramnalis@geosense.gr |
| Noumena Design Research Education SL (NMN), Spain |  Aldo Sollazzo aldo@noumena.io |
| Institut De l'Elevage (IDELE), France |  Jean-Marc Gautier jean-marc.gautier@idele.fr |
| ART21 UAB (ART), Lithuania |  Laurynas Jukna laurynas@art21.lt |
| Ecological Interaction (EI), Estonia |  Jonathan Minchin jonathan@ecologicalinteraction.org |
| Hellenic Crop Protection Association (HCPA), Greece |  Francesca Ydraiou fydraiou@esyf.gr |
| AgriFood Lithuania DIH (AFL), Lithuania |  Valdas Rapševičius vrapsevicius@gmail.com |
| AgFutura Technologies (AGFT), North Macedonia |  Blagoja Mukanov blagoja.mukanov@agfutura.com |
| The Open University (OU), United Kingdom |  Giacomo Carli giacomo.carli@open.ac.uk |

Executive Summary

The ICAERUS project advances the capabilities and applications of drones in agriculture, forestry, and rural communities through the development and optimisation of drone data analytics models. This report, "D2.4 Analytics Optimisation, Expansion & Scale-up Report," documents the progress made in optimising and scaling up drone data analytics models within the ICAERUS Drone Data Analytics Library (DDAL) according to Tasks 2.2 and 2.3. Task 2.2 focused on optimising the drone data analytics models identified in Task 2.1. The primary steps involved identifying user needs by engaging with end-users to ensure the models meet their specific requirements, refining models using a Multi-criteria Decision Analysis (MCDA) to enhance transparency and effectiveness for non-expert users, and structuring models and datasets in a standardised format to make them accessible on public platforms such as GitHub and Zenodo. Task 2.3 aimed at expanding the DDAL content and scaling up its usability to a broader audience. This was achieved through PUSH Open Calls, which encouraged the optimisation and introduction of new models, and PULL Open Calls, which focused on testing, evaluating, and validating optimised models in new environments and applications.

Achievements were made in model optimisation and user adaptation. A comprehensive evaluation of 223 models across various use cases—crop monitoring, drone spraying, forestry, livestock monitoring, and rural logistics—was conducted. Key models were optimised for usability, explainability, generalisability, and accuracy. Standardised publishing was facilitated through the development of templates and guidelines for consistent documentation and publication of models and datasets, ensuring ease of use and interoperability. The optimised models are now accessible through the ICAERUS platform, featuring interactive components to support informed decision-making. The scale-up and expansion of the DDAL were supported by extensive outreach and engagement activities. The DDAL was promoted through a dedicated DDAL Week, various outreach activities, and continuous updates on social media and the ICAERUS website. Contributions from Open Call Trials (OCTs) were integrated into the DDAL, enhancing the library's diversity and applicability. Detailed documentation and shareables were prepared to facilitate replication and adaptation across different contexts and regions.

Looking ahead, ICAERUS will continue to focus on optimising existing models based on user feedback and technological advancements. Further outreach efforts will aim to expand the contributor base and increase the library's usability and impact. By addressing these objectives, ICAERUS seeks to enhance the transparency, accessibility, and effectiveness of drone data analytics, fostering innovative applications and sustainable practices across Europe. The collaborative and participatory approach of the project ensures that the tools and advancements developed are effectively communicated and utilised to their fullest potential.

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1. Introduction

WP2 “Drone Data Analytics Library” is responsible for the identification, optimisation of existing data analytics models for drones and selection of application-oriented models to build the Drone Data Analytics Library (DDAL). The objectives are the following:

- 1) Identify and assess well-established and emerging drone data analytics models,
- 2) Optimise the most significant models and algorithm to analyse and visualise drone data,
- 3) Create an open-access, free and public DDAL, and
- 4) Expand the DDAL content and scale-up its usability through the open calls.

The core aim of DDAL is to improve and extend the included models, by advancing the state-of-the-art methods in drone-based data modelling, including functionalities for diagnosis, risk assessment and explainability taking into account the economic and human aspects. This will ensure that the new or enhanced versions of these models are engineered to become more transparent, accessible and effective for a wide range of drone users.

The ICAERUS project aims to create a dynamic and scalable DDAL that evolves through continuous updates and contributions. This includes scaling up its usability and content through open calls, inviting broader participation from the research community and stakeholders. By fostering a collaborative environment, ICAERUS aims to boost innovation and the adaptation of drone technologies in varied contexts, ultimately contributing to better-informed decision-making, and increased effectiveness and efficiency.

This report, "D2.4 Scale Up and Expansion Report," documents the activities and achievements under Tasks 2.2 and 2.3 of the project. Task 2.2 focuses on optimising drone analytics models, structuring them in a standardised manner, and making them available on public repositories such as GitHub and Zenodo. Task 2.3 emphasises the expansion and promotion of the DDAL, through outreach efforts and contributions from both internal and external partners. The deliverable reports the strategic efforts to transform ICAERUS into a EU-wide platform, meeting the diverse needs of its stakeholders and maximising the impact of drone data analytics in agricultural, forestry, and rural applications.

By addressing these objectives, ICAERUS seeks to enhance the transparency, accessibility, and effectiveness of drone data analytics, paving the way for innovative applications and sustainable practices across Europe.

This document is structured as follows. Section 2 reports on the optimisation and user adaptation of drone analytics models, including identification of user needs, structuring of open models and datasets in standard ways, and optimisations of those models/datasets with an eye on upcoming planned contributions from UCs. Section 3 depicts the scale-up and expansion of the DDAL, including contributions from the Open Call Trials (OCTs) and outreach activities. The next steps are presented in the conclusion.

2. Optimisation and User Adaptation of Drone Analytics Models (T2.2)

This section describes the optimisation phase of the models within the use cases. It begins with a summary of the previous Systematic Literature Review (SLR) conducted to identify relevant models for each specific use case under Task 2.1. Throughout that stage, the partners examined and evaluated existing projects, identifying their limitations and proposing improvements for their own models. ICAERUS members can use this information as a foundation for their development, enabling a more precise methodology and approach.

To effectively share the new models and databases developed by each member, two tools were configured: the GitHub repository called Drone Data Analytics Models (DDAL) and the Zenodo data repository. Templates and workshops have been created to support document organisation, providing a common structure for sharing models and datasets. Detailed information will be provided in the following sections. Consequently, contributions to both platforms are thoroughly described, including model descriptions, usage instructions, and dataset contents.

The section concludes with a presentation of the planned contributions for the coming months, highlighting the continuous development and improvement of the algorithms.

2.1. Identification of User Needs and Selection of Models

With the development of Deliverable 2.1, a comprehensive document was created to encompass the collection of the most notable models involving the use of drones in the field of agriculture. This effort set various objectives, including identifying emerging drone analytics models and configuring the Drone Data Analytics Library to integrate, improve, and scale these models. The methodology for this development was based on Kitchenham & Charters' (2007) "Guidelines for Performing Systematic Literature Reviews in Software Engineering," and aimed to identify the algorithms related to different use cases. The following steps outline the employed methodology:

- **Selecting appropriate research questions** to guide the analysis and identify key areas for examination.
- **Searching databases** to find relevant studies on drone data analytics models, ensuring a broad literature base.
- **Selecting studies** based on specific criteria (e.g., publication date, study quality, relevance) to select the most pertinent studies.
- **Assessing the quality of the studies** based on the evaluation of methodological rigor and validity, with a provided guide of questions to identify the models' potential or limitations and areas for improvement.
- **Extracting data** by collecting information from the selected studies on models, algorithms, data sources, and results, recording this information on a shared spreadsheet for organisation.

The results are presented as a taxonomy of techniques, categorising the different models used in ICAERUS use cases and outlining various approaches for each scenario. Each use case participated in this task, detailing how they applied the previous methodology in their search. An exhaustive study was conducted, and the results were shared in an Excel file containing technical and detailed information on each model found. This document included information about the authors, research topics, quality of methods developed, algorithms, and limitations. Additionally, it provided specific information about data extraction, such as tools used, dates, weather conditions, altitude, speed, and other relevant features or comments. Regarding hardware, the document included details about the drones and mounted

components / payload used, as well as the generated models. For the software aspect, it detailed the problem definition, type of algorithm used, performance metrics, model availability, and other processes carried out.

In total, each use case scrutinised the subsequent number of models, summing up to a total of 223 models analysed:

Table 1: Total of models analysed per use case

| Use Case | Total Models Analysed |
|---------------------------------|-----------------------|
| UC1 - Crop Monitoring | 60 |
| UC2 - Drone Spraying | 38 |
| UC3 - Forestry and Biodiversity | 37 |
| UC4 - Livestock Monitoring | 45 |
| UC5 - Rural Logistics | 43 |

An evaluation method was introduced, to conduct a final evaluation of the top-performing models for each use case. Each partner selected the most suitable models for their specific case and addressed the following topics to gain deeper insights into end-user needs and drive advancements in drone-based agriculture projects:

- **Model description:** this encompassed delineating the purpose of the drone data analytics model, its applications, operational aspects, main components, use cases, and insights.
- **Databases:** where it was defined the data collected to train the specific model, including processing techniques, data augmentation methods, and dataset size.
- **Model performance:** this included answering questions about the model's operation and the validation metrics used in training.
- **Limitations:** the limitations that may have significantly affected the model's results or applicability were identified by the UC partners to get a better understanding of the overall results.
- **Recommendations for improvement:** in this part, consortium members pinpointed areas where the applicability and performance of the model could be enhanced.

This comprehensive evaluation facilitated an understanding of each model's capabilities, limitations, and potential, enabling informed decisions regarding their implementation and optimisation. Moreover, it assisted in identifying potential areas for improvement and inherent challenges, enabling proactive measures to address them.

The evaluation results, upon taking into consideration the application scenarios and nature of each UC and their respective models, underscored several key conclusions:

- Dataset size and the number of iterations or experiments exert a notable influence on outcomes. Similarly, a lack of diversity in training data can compromise training quality.
- Some models exhibit limitations in data generalisation, indicative of issues like overfitting or interpretability challenges.

- The applicability of results may be constrained by specific study conditions, including limitations associated with drone flights, which curtail data collection scope and process.

To mitigate these challenges, there were proposed several recommendations, such as:

- Enhance dataset size and diversity to bolster model generalisation.
- Implement techniques like cross-validation and regularisation to mitigate overfitting and enhance model robustness.
- Automate certain processes and integrate diverse data sources such as satellite imagery and 3D mapping technologies to bolster model accuracy.
- Utilise BVLOS (Beyond Visual Line of Sight) technologies to broaden the spectrum of application possibilities.

In conclusion, while the studies show significant advancements in the use of drones in precision agriculture, certain limitations directly affect the reliability and applicability of these models. Therefore, it is crucial to address these issues with the proposed recommendations to advance and improve the development of this research area.

2.2. Structuring the Open Models and Datasets

In our effort to standardise and streamline the publication of open models and datasets, we have developed a range of resources and tools to guide users through this process. These resources include detailed tutorials, standardised templates, and JSON files. This approach ensures a common structure across all use cases, facilitating their integration with the ICAERUS platform. We have also created specific guidelines for the format to be used on GitHub and Zenodo, along with their associated templates. Additionally, we have configured JSON files that organise information about models and datasets in a structured manner. Below, we explain the resources developed:

2.2.1. Templates

We have designed templates to simplify the organisation and presentation of information. These templates ensure that all published models and datasets contain the essential elements and follow a uniform format. Specifically, the following templates have been developed:

1. **GitHub template:** this template is located at the beginning of the ICAERUS-EU repository. It outlines the code sets that should be copied by each use case (UC) into their individual repository to maintain a consistent format. This includes:
 - Configuration of headers, index, and descriptions.
 - The README.md template to ensure uniform organisation of each section.
 - Requirements for the repository, along with explanations and organisation of folders.
 - The format for adding authors and acknowledgments.

The images below showcase a section of the template available on the main [GitHub ICAERUS-EU](#) page, accessible to all users. Additionally, this page contains a collection of tutorials on managing files and folders within each UC.



ICAERUS GitHub Tutorial

Tutorial to use the ICAERUS github.

[Report Bug](#) - [Request Feature](#)

downloads no releases found contributors 1  Forks 0  Stars 0 issues 0 open license GPL-3.0

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- [Summary](#)
- [Join ICAERUS-EU GitHub](#)
- [Add your Use Case repository to ICAERUS-EU GitHub](#)
- [Add-the-README-template](#)
- [Repository requirements](#)
- [Managing your repository](#)
- [Adding new models](#)
- [Authors](#)
- [Acknowledgements](#)

Figure 1: GitHub main page template for each Use Case.

Add the README template

Update your readme with this template and fill it with your UC information.

Header

You can copy-and-paste the header and shields directly into your own readme file (please change the `repo-title` in the urls to the correct ones).

```

<div align="center">
  <p>
    <a href="https://icaerus.eu" target="_blank">
      </a>
    <h3 align="center">TITLE OF YOUR REPO/PROJECT 🟢</h3>

    <p align="center">
      Short description of the content/subject matter in the repository
    <br/>
    <br/>
    <a href="https://github.com/icaerus-eu/repo-title/wiki"><strong>Explore the wiki »</strong></a>
    <br/>
    <br/>
    <a href="https://github.com/icaerus-eu/repo-title/issues">Report Bug</a>
    -
    <a href="https://github.com/icaerus-eu/repo-title/issues">Request Feature</a>
  </p>
</div>

! [Downloads] (https://img.shields.io/github/downloads/icaerus-eu/repo-title/total) ! [Contributors] (https://img.shield
    
```

Figure 2: GitHub header template for each Use Case.

Table of contents

We also expect a Table of Contents directly after the header, with linked section like the one in this repo, some ideas for sections are given below.

```

## Table Of Contents
- [Summary](#summary)
- [Introduction](#introduction)
- [Installation](#installation)
- [Usage](#usage)
- [Configuration](#configuration)
- [Contributing](#contributing)
- [Development](#development)
- [Testing](#testing)
- [Documentation](#documentation)
- [License](#license)
- [Support](#support)
- [Security](#security)
- [Acknowledgments](#acknowledgments)
- [Resources](#resources)
- [FAQ](#faq)
- [Gallery](#gallery)
- [Deployment](#deployment)
- [Demo](#demo)
- [Dependencies](#dependencies)
- [Known Issues](#known-issues)
- [Roadmap](#roadmap)
    
```


Figure 3: GitHub table of contents template for each Use Case.

2. **Zenodo template:** for uploading datasets to Zenodo, it is important to maintain a consistent description across all datasets. Therefore, the following template is used:

□ Small introduction (1-2 lines) about what will be found in the dataset and what is the dataset about (classification, detection, segmentation, for building orthomosaics, parameters). This dataset encompasses the following data:

- *Folder: description (number of images / subfolders, type of images, size of images, tables, parameters).*
 - *Subfolder: description (number of images, type of images, size of images, tables, parameters).*
 - *Folder: description (number of images, type of images, size of images, tables, parameters).*
 -
3. **Model template:** when uploading a new model into the UC repository, the README file must contain a description that outlines the model's main characteristics and an image of the expected results. In this case, the ICAERUS members follow the formats shown in Figures 4 and 5.

UC1_Crop_Monitoring / models / 01_plant_disease_detection_yolov8_v1 /

 **EstherNoumena** [Comment and fix bugs #12](#)






| Name |
|---|
|  .. |
|  README.md |
|  best.pt |
|  plant_disease_detection_yolov8_v1.ipynb |
|  requirements.txt |

Figure 4: Example of a UC model.

The use of these templates allows for the standardisation of information and their visualisation, while also enhancing the accessibility of the available models.

2.2.2. Workshops and guides

To ensure and facilitate the publication of new models developed by ICAERUS Use Cases, two workshops were conducted. These tutorials covered everything from data preparation to format documentation, ensuring that UC members can follow a clear and standardised process. The first workshop, held in January 2024, included the following information:

- Definition of the GitHub repository structure, including the template description shown in the previous section.
- Configuration of headers, indexes, and general descriptions.
- Development of README associated with each specific UC repository.
- Explanation about different basic functionalities, such as adding your own GitHub repository to DDAL, uploading local files or downloading them from the web repository.

The second workshop was organised last March 2024 and involved the next topics:


- Organisation and description of the Zenodo datasets following the previous template.
- Definition of a clear structure for uploading models to GitHub, specifying the naming conventions and file organisation. An example of this structure is provided below, where each model has a dedicated README, as shown in Figure 3, along with a clear naming convention, versioning, and codes specific to each model.

- - **01_cow_detection_v1/**
 - README.md
 - best.pt
 - dataset_loader.py
 - training_code.py
- **01_cow_detection_v2/**
 - README.md
 - best.pt
 - dataset_loader.py
 - training_code.py
- **02_sheep_detection_v1/**
 - README.md
 - best.pt
 - dataset_loader.py
 - training_code.py

□

- Explanation of the UC repository structure to clearly organise the uploads of contents. As shown in Figures 6 and 7, the repository includes key folders such as data, models and top_view, which corresponds to a set of specific preprocessing codes. Additionally, the repository features a platform.json file, which will be explained in detail later.

README
✎ ☰



UC1: Crop Monitoring

This repository contains Crop Monitoring models developed with drone Images and computer vision

[Report Bug](#) - [Request Feature](#)

downloads
no releases found
contributors: 1
forks: 0
stars: 0
issues: 13 open
license: not specified

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- [Structure](#)
- [Models](#)
- [Authors](#)
- [Acknowledgements](#)

Summary

Within this repository, you'll discover various models and computational tools designed for crop monitoring purposes. These resources can be used for predicting the health status of vineyards using images captured by drones.

Structure

The repository folders are structured as follow:

- **data**: here you should add the [UC1 GITHUB DATA FOLDER](#) that you could download from Zenodo.
- **top_view**: It has some top-view level calculations for vegetation analysis.
 - `calculate_vegetation_indexes`
 - `create_grid`
 - `extract_vineyard_data`
 - `top_level_detection`
- **models**: models developed for crop monitoring
- **platform.json**: organized information about the models

Figure 6: README example for the main UC GitHub repository.

Models

The [models](#) developed are the following:

Row-view disease detection model with YOLOv8

This model has been trained with YOLOv8 and is able to detect the plants and provide information about its health status from a plant-view level.

Plant locator from row-view to global-view

This algorithm contains the complete workflow from detecting a plant in a row-view image to locate this plant in the global-view orthomosaic to visualize its health status at a global scope. It also locates the drone positions.

Authors

- **Esther Vera** - *Noumena* - [Esther Vera](#)

Acknowledgements

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Figure 7: README example showing the Models, Authors and Acknowledgements for the main UC GitHub repository.

With the presentation of these tutorials, it was possible to clearly explain how to publish the models and datasets in an organised manner for all ICAERUS members, being able to communicate the information clearly in a public manner.

2.2.3. JSON files

To facilitate interoperability and data reuse, we have adopted the use of JSON files. These files allow for a clear, machine-readable structure, facilitating integration with different systems and tools. Two types of files have been developed:

- **platform.json**: is defined in each UC repository and contains the models developed for that use case. This same file that globally defines all JSON documents is also found in the DDAL global repository. Figure X shows the template made for this document, which must be updated by each member.

```
□[{
  "title": "the title of the algorithm",
  "creator": "the developer/creator of the algorithm",
  "date": "dd/mm/YYYY",
  "icon": "uri for an image/icon for the algorithm",
  "url": "url to the path of the github repository"
  "icaerus_applications": ["crop-monitoring", "drone-spraying", "livestock-
monitoring", "forestry-and-biodiversity", "rural-logistics"],
  "uses_cases": [1,2,3,4],
  "extra": {
    "key1": "value1",
    "key2": "value2"
  },
  "filters": {
    "content": [
```

```

    "Machine learning",
    "Deep learning",
    "Computer vision",
    "Detection",
    "Tracking",
    "Flight control",
    "Path planning",
    "Simulations",
    "Framework",
    "ROS",
    "BVLOS",
    "Networking"
  ],
  "data-type": [
    "RGB images",
    "RGB videos",
    "Hyperspectral/Multispectral images",
    "Thermal",
    "Orthomosaic",
    "Droplet deposition",
  ],

  "subject": [
    "Vineyards",
    "Drone spraying",
    "Drift",
    "Forestry",
    "Fire fuel",
    "Fire prevention",
    "Wild boars",
    "Cattle",
    "Sheep",
    "Other animals",
  ],

  "location": [
    "Spain",
    "Macedonia",
    "Greece",
    "The Netherlands",
    "Lithuania",
    "France"
  ],
}
]
□

```

It is observed that the characteristics of each model must be specified, including the title, authors, date, image, the link of the model, etc., along with the use of some labels for identification.

The update method follows the following workflow:

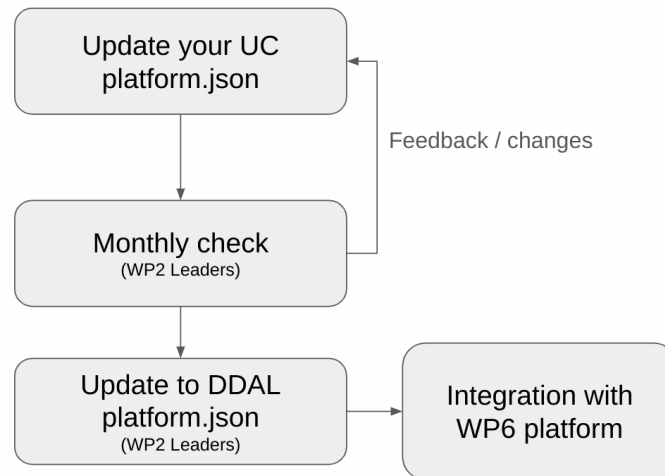


Figure 8: Workflow diagram to update the platform.json file.

- **datasets.json**: in this case, this file is modified in the [Zenodo Datasets GitHub](#) by the WP2 leaders. All datasets are organised according to the following template which adds the information of the datasets separately according to the use cases and the written parts for each one are defined.

```

□{
  "UC1": // Information for each dataset
  [{
    "name": "", // Name of the dataset
    "author": "", // Author of the dataset
    "date": "", // Date when the data was collected
    "link": "", // Link to dataset in Zenodo
    "description": "" // Add description of the dataset
  }],
  "UC2" : [{}],
  "UC3" : [{}],
  "UC4" : [{}],
  "UC5" : [{}]
}
□
    
```

By using these documents, users can easily integrate information with the ICAERUS platform and obtain information in an accessible and organised manner. Updates to the templates are expected, to facilitate a wider set of contributors, such as the ICAERUS OCT and external partners. Changes will allow for more specificity and allow for improved filtering within the Platform.

2.3. Optimisations of models and datasets

The file structures, supporting documents, repositories, and evaluations presented above all serve the purpose of optimising models. The initial results from T2.1. indicated that there is a distinct lack of datasets, openly available models, model weights and codebases to get started with UAV analytics in every ICAERUS Use Case (UC). After the UCs identified relevant models in T2.1. to fit their project, the next step was to develop and adapt these for their own use case. The initial set of models and datasets are presented in the tables in Section 2.3.1. and 2.3.2.

As previously shown, the DDAL is built around GitHub repositories, which can contain codebases, model weights, Python notebooks, descriptions, and best practices, all of which can be a model itself or can be

combined to constitute a model. The other half of the DDAL is datasets on Zenodo, as UAV analytics is built around the various datasets that the flying platform can offer, from hyperspectral imagery in Use Case 4, to the RGB images of cattle in Use Case 3.

All details of these models and datasets can be aimed towards optimisation, as increasing the variability in the dataset is expected to improve its performance accuracy and applicability. This means that after an initial development of models, initial forays can be optimised along various axes: usability, explainability, generalisability, or accuracy. The process developed for the UCs is presented in Section 2.3.3.

Through monthly meetings, the UCs are asked to share their recent work and present their upcoming steps at monthly intervals. These updates are tracked in the Trajectory Dashboard Google Sheet. Both newly developed models and datasets, as well as optimisations to new ones are included in the tracking dashboard (figure 9). This provides all partners with an overview of the current status across all UCs and allows WU as Task leader to get an insight into the timing of various aspects. Finally, beyond the UCs, WU is also a partner with many UAV applications, and research occurring, and could have a contribution from time to time for the DDAL.

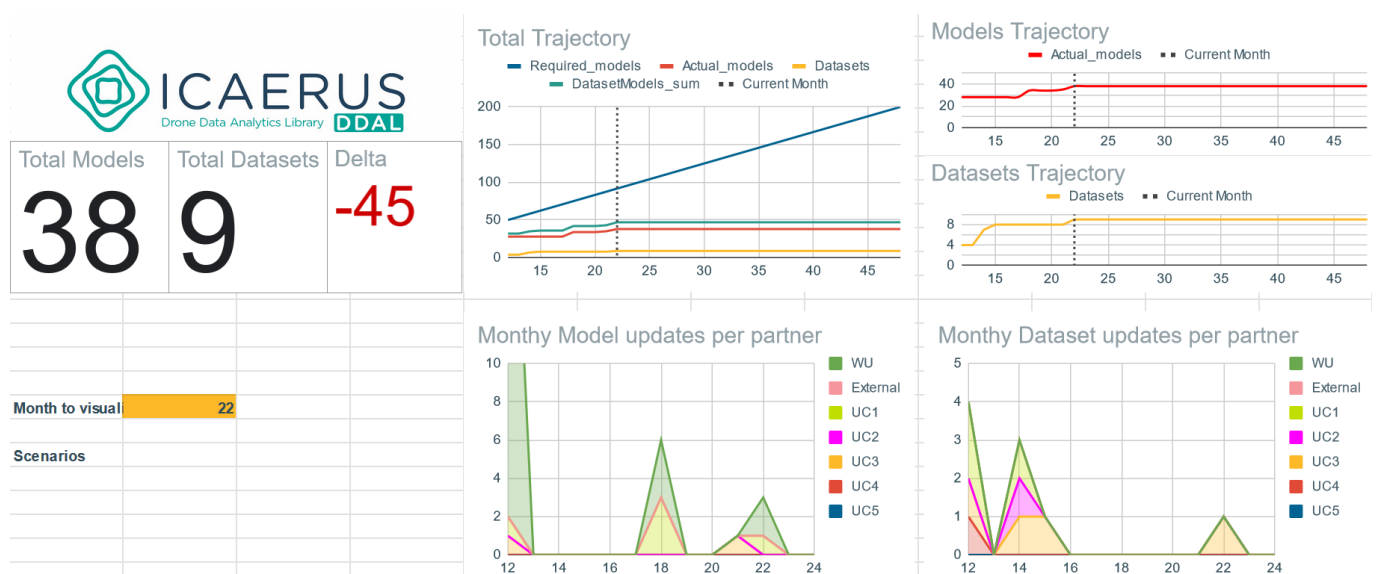


Figure 9: Example of the trajectory dashboard for tracking number of models and datasets.

2.4. Open Drone Analytics Models on GitHub

With the structures and templates in place, the UCs were requested to contribute to the library for the rest of the project following these guidelines. This means that the DDAL is a work-in-progress, with ongoing updates and additions throughout the lifetime of the project. The table (table 2) below shows the available repositories in the library (some repositories may contain multiple models).

Table 2: Open and available models

| Open and Available Models on GitHub | | | |
|-------------------------------------|-------------|---|--|
| Model name | Contributor | URL | Description |
| Plant disease detection | UC1-NMN | https://github.com/ICAE-RUS-EU/UC1_Crop_Monitoring/tree/main/models/01_plant_disease_detection_yolov8_v1 | Row-view disease detection model with YOLOv8 |

| | | | |
|--------------------------------------|-----------|--|---|
| | | | |
| Plant locator | UC1-NMN | https://github.com/ICAERUS-EU/UC1_Crop_Monitoring/tree/main/models/02_plant_locator_v1 | This algorithm contains the complete workflow from detecting a plant in an image to locate this plant in the global-view orthomosaic to visualise its health status. It also locates drone position. |
| Cow detection V1 Cow detection V2 | UC3-IDELE | https://github.com/ICAERUS-EU/UC3_Livestock_Monitoring/tree/main/Models/01_cow_detection_v1 https://github.com/ICAERUS-EU/UC3_Livestock_Monitoring/tree/main/Models/01_cow_detection_v2 | This repository contains code for a cow detection model using PyTorch and YOLO. The key difference between the first version of the cow detection model and the current one is the preprocessing of images before training. Specifically, we resize large images to smaller ones with dimensions of 640 x 640 pixel. |
| specim library | UC4-ART21 | https://github.com/ICAERUS-EU/UC4_Forestry_and_Biodiversity/tree/main/hyperspectral-lib/specim-lib | Hyperspectral preprocessing and calibration in Python. |
| sentinel tools | UC4-ART21 | https://github.com/ICAERUS-EU/UC4_Forestry_and_Biodiversity/tree/main/sentinel-tools-lib | Sentinel satellite data analysis code to identify most suitable regions for uav flight. |
| uavgeo | WU | https://github.com/icaerus-eu/uavgeo | Orthomosaic processing toolbox for Python, built on xarray and geopandas. |
| p2p_ros | WU | https://github.com/jurriandoornbos/p2p_ros | ROS Pix2Pix node, for image conversion using Pix2Pix inside the ROS ecosystem. Adapted from the original junyanz Pix2Pix repository. |
| Botrytis bunch rot mapping Canyelles | WU | https://github.com/jurriandoornbos/BBR_canyelles | Mapping Botrytis Bunch Rot in Canyelles vineyard using implementation from Ariza et al. (2023). |

| | | | |
|--|----|---|---|
| RGBtoNDVI conversion | WU | https://github.com/jurriandoornbos/RGBtoNDVIconversion | Using Deep Learning to convert RGB to NDVI images in vineyard orthomosaics. |
| Post Cowtization | WU | https://github.com/jurriandoornbos/post_cowtization | Code for ICAERUS blogpost on Deep Learning quantisation using a trained cow detection model. |
| Weeds detections using Transfer Learning | WU | https://github.com/jurriandoornbos/crop-weed-detection-yolov7 | Evaluating Pretraining effects of MEGAWEEDES vs standard COCO in Precision Agricultural activities. |

2.4.1. Optimisation plan of selected models:

There are multiple dimensions at play for optimising UAV analytical models. Whilst the list below is not exhaustive, it is deemed as a guideline for the optimisation of the essential models developed by the UCs. The relevant dimensions in Drone Analytics are usability, explainability, generalisability, and accuracy (Doornbos et al., 2024).

Usability

Usability refers to how easy it is for end-users to deploy and interact with the model. This includes aspects like:

- **User Interface (UI):** A well-designed UI makes it easier for users to input data and interpret results.
- **Integration:** The model should be easily integrable to existing systems and workflows.
- **Documentation:** Comprehensive documentation and user guides help users understand how to use the model.

Optimising for usability ensures that the model can be effectively used by its intended audience without requiring extensive technical expertise. Steps to improve usability can include but not be limited to providing more documentation, more accessible installations through Google Colab, and/or a front-end interface for the user to interact with.

Explainability

Explainability involves making the model's workings and outputs understandable to humans. This includes:

- **Transparency:** The model should be transparent about how it makes decisions. For example, linear regression models are generally more explainable than complex deep learning models.
- **Interpretability:** It should be possible to interpret the results in a way that makes sense to users. Techniques like SHAP values and LIME can help with interpreting complex models.
- **Accountability:** Explainable models allow for better accountability and trust, as users can understand the reasoning behind predictions.

Generalisability

Generalisability refers to the model's ability to perform well on new, unseen data. This includes:

- **Training and Test Balance:** The model should not be overfitted to the training data; it should generalise to new data (Barbedo et al., 2019)

- **Cross-Validation:** Techniques like cross-validation are used to ensure that the model performs well across different subsets of the data.
- **Robustness:** The model should be robust to variations in data, such as different distributions or slight variations in input features.

Optimising for generalisability ensures that the model is not just tailored to the training data but can be reliably used in real-world scenarios. Especially testing for generalisation is the first step to ensure usable models, going beyond the training data and finding different scenarios for models to be tested in. Additionally, it is the use of simpler, less overfitting models, as well as unsupervised modelling approaches that can increase the generalisation (Caron et al.,2021).

Accuracy

Accuracy refers to how well the model’s predictions match the actual outcomes. This includes:

- **Precision:** The proportion of true positive predictions among all positive predictions.
- **Recall:** The proportion of true positive predictions among all actual positives.
- **F1 Score:** The harmonic mean of precision and recall, providing a single metric that balances both.
- **Other Metrics:** Depending on the task, other metrics like mean squared error (for regression) or area under the ROC curve (for classification) might be used.

Optimising for accuracy ensures that the model makes correct predictions as often as possible, which is often the primary goal of building a model. However, a deep focus on accuracy can miss other optimisations required for the adoption of the model in rural and agricultural areas.

The first step in applying optimisations is directing the UCs towards which optimisation-step is required, and how this will be implemented in a stepwise manner. The optimisations are planned for discussion in the following Project Management Board in June, and the recurring WP2 meetings.

2.5. Open Drone Analytics Datasets on Zenodo

Data analytics for the ICAERUS DDAL consists of two parts: i) Models, as described in the previous section, and ii) Datasets.

Datasets within UAV analytics can be information from the UAV during flight, such as location or path taken, or datasets can be information the UAV has measured, such as digital images, multispectral observations or sound measurements. These data are often denoted as ‘raw data’, and can have many processing steps before they can be practically used in the field. Processing steps such as calculating an orthomosaic or an elevation model. Such sets of imagery, resulting products, or raw logs can be developed into a complete dataset. With additional documentation on how the dataset came to be, what flight settings and processing parameters were chosen.

Furthermore, the availability of ground truth, such as ground truth measurements, human-created labels of objects, and ground control points is often essential in bridging the gap from raw data created by the UAV to usable application.

Finally, datasets are essential for model development as they are either in- and/or output of analytical models and serve to validate the models. Whilst sometimes being valuable in themselves, in the form of maps.

The currently included datasets in the library are presented in the table below.

Table 3: Open and available datasets

| Open and Available Datasets on Zenodo | | | |
|---------------------------------------|-------------|-----|-------------|
| Dataset name | Contributor | URL | Description |

| | | | |
|--|-----------|---|---|
| UAV Canyelles Vineyard Dataset 2023-06-09 | UC1-NMN | https://zenodo.org/records/10171243 | Crop monitoring dataset that contains RGB images, NIR images, point cloud data, RGB and NDVI orthomosaic images, DEM and the shape that defines the total vineyard terrain. |
| UAV Canyelles Vineyard Dataset 2023-04-21 | UC1-NMN | https://zenodo.org/records/8123870 | Crop monitoring dataset that contains RGB images, point cloud data, an orthomosaic image and the DEM. |
| UAV Spraying Parameters-Coverage in Vineyards | UC2-AUA | https://zenodo.org/records/10276149 | A set of UAV spraying data collected using WSPs, across different parameter configurations. |
| Drone raw images of cattle in french grazing areas | UC3-IDELE | https://zenodo.org/records/8234156 | The dataset encompasses around 900 raw .jpeg drone images of grazing areas where cattle graze collected between June and August 2023. |
| Drone images and their annotations of grazing cows | UC3-IDELE | https://zenodo.org/records/10245396 | The dataset encompasses around 1100 raw .jpeg images from drone (DJI mavic 3 Enterprise and Thermal) of grazing areas where cattle graze collected between June and October 2023. |
| Sheep videos taken from drone at low altitude | UC3-IDELE | https://zenodo.org/records/10400302 | The dataset encompasses 16 .MP4 videos from drone (DJI mavic 3 Enterprise and Thermal) of around 50 sheep crossing a gate. |
| Drone images and their annotations of grazing cows | UC3-IDELE | https://zenodo.org/records/11048412 | It contains 1385 images and 4941 bounding boxes of cows taken with a DJI Pilot 2 drone. This dataset is a major contribution for public and research stakeholders to develop cow detection and counting models. |

2.5.1. Optimisation plan of selected datasets:

The same axes of improvement can also be applied to the datasets. Especially the variety of data, to improve generalisation, and inclusion of further ground-truth labels to test and evaluate on new and unseen activities. Finally, further precision on sharing what kind of data is shared is essential: which exact spectral bands the sensor has, which flight parameters, overlap, etc. is all information that needs to be shared (Doornbos et al., 2024).

2.6. Planned contributions coming period from the UCs

As the UCs are expected to both update and contribute new models and datasets to the library, WU quarterly requests them to update their planning on proposed models and datasets. These updates are based on their earlier steps of analysis and implementation. Below are the proposed updates to the DDAL from the UCs in the coming period.

Table 4: Planned models

| Planned models from existing planning | | |
|---------------------------------------|-------------|--|
| Model name | Contributor | Description |
| Heatmap of diseased plants | UC1-NMN | NEW: Heatmap method and visualisation of diseased plants in the vineyard |
| Plant disease detection v2 and v3 | UC1-NMN | OPTIMISATION: YOLOv8 additionally trained with newly labelled data |
| Crop spraying parameters and model | UC2-AUA | NEW: Impact of various aspects in spraying, from nozzle sizes, wind effects, and flight height on spraying coverage. Usable as an online tool. |
| Sheep detection model | UC3-IDELE | NEW: Deep Learning trained model on sheep videos to detect sheep and count them. |
| Cattle counting model | UC3-IDELE | NEW: New layer for the cattle detection model is to count the output of the detector. |
| Sheep tracking model | UC3-IDELE | NEW: Deep Learning trained model to detect sheep moving and track them in the frame for a UAV specific method for sheep counting. |
| Benchmark YOLO | UC3-IDELE | NEW: Identifying for the UC3 datasets, which YOLO models (both size and generation) are best for UC3. |
| Sentinel health classification | UC4-ART21 | UPDATE: Healthy areas classification for the new year. |
| Thermal boar detection | UC4-ART21 | NEW: Implementation to detect wild boar in thermal imagery from UAVs using computer vision. |

| | | |
|------------------------------------|-----------|--|
| Thermal boar tracking | UC4-ART21 | NEW: Implementation to track wild boar in thermal imagery from UAVs using computer vision. |
| Hyperspectral forest fuel analysis | UC4-ART21 | NEW: Forest fuel analysis from hyperspectral imagery. |

Table 5: Planned Datasets

| Planned Datasets | | |
|--|-------------|---|
| Dataset name | Contributor | Description |
| Canyelles field data 2024 | UC1-NMN | NEW: Both local low-altitude video flights, multispectral orthomosaics and labelled field-data. Expected to be multiple datasets and uploads. |
| Spraying data field trials 2023 | UC2-AUA | NEW: various outputs from the analysis performed by AUA, that is relevant to a wider audience concerned with crop spraying using UAVs. |
| Dataset sheep videos | UC3-IDELE | NEW: More videos on sheep moving in various set-ups as taken from a UAV, with ground truth labels on where sheep are. |
| Thermal wild boar detection and tracking | UC4-ART21 | NEW: Thermal videos and snapshots of boars in forested areas in Lithuania. and their annotated masks and/or labels in the frames. |
| Hyperspectral forest fuel | UC4-ART21 | NEW: Hyperspectral dataset and ground truth labels of forests |

3. Scale-up and Expansion of the ICAERUS Drone Data Analytics Library (T2.3)

In the ICAERUS project, the scale-up and expansion strategy focuses on maximising accessibility and dissemination of knowledge. This is achieved by sharing information as widely as possible and ensuring comprehensive documentation is readily available. By creating detailed and accessible documentation, the project aims to facilitate the replication and adaptation of its innovations and methodologies across different contexts and regions. This approach not only promotes transparency but also empowers stakeholders and partners to implement and benefit from the project's outcomes, thereby driving broader impact and sustainability. Through this strategy, ICAERUS ensures that the tools, insights, and advancements developed within the project are effectively communicated and utilised to their fullest potential.

3.1. Documents prepared and shared

The following table provides an overview of all the documentation and shareables that have been prepared as part of the ICAERUS project. Each entry includes the document name, a summary of its contents, and additional information to aid in understanding and utilising the materials. This comprehensive collection is designed to facilitate the dissemination of knowledge and resources developed during the project, ensuring that all relevant data, methodologies, and findings are accessible to stakeholders and the broader community.

Table 6: Documentation and shareables of the ICAERUS platform.

| Documentation and shareables of the ICAERUS platform. | | |
|--|--|---|
| Name of document | Summary | Additional information contained |
| General slides | Introduction to the Drone Data Analytics Library | Models, datasets, and contributions |
| Hoverview- Blog A: What is currently available//uavgeo | Blog post for the 'uavgeo' python library usage and orthomosaic analysis | Tutorial on how to use the python the 'uavgeo' python library and orthomosaic analysis model from scratch |
| Hoverview Blog B: Overview/Public release of Library | Overview of the Drone Data Analytics Library | Information for users and for contributors |
| Hoverview Blog C: Deep Learning Quantization tutorial | Blog post for real-time cow detection with Deep Neural Networks | Tutorial on how to use the cow detection model from scratch |
| Spotlights (5days of DDAL) | Explanation of the 3 use case scenarios | Further information on the orthomosaic analysis, cow |

| | | |
|--------------|---|--|
| | | detection, and vineyard analysis |
| Website text | Overview of the ICAERUS website description of the Drone Data Analytics Library | General information of the Drone Data Analytics Library |
| Invitation | Invitation to collaborate on the ICAERUS Drone Data Analytics Library | Explanation of the repository and its contribution possibilities |
| Brochure | Invitation to explore the Drone Data Analytics Library | What is and why to use it, its focus, usage possibilities, contribution to the library, origin of data |

3.2. DDAL Week

DDAL Week (May 13-17, 2024) was a promotional campaign aimed at announcing the public launch of the DDAL and highlighting various aspects, including specific models and datasets. It also equipped partners with resources to start promoting the DDAL. The files that were shared during this week were the following:

- 1) A new bifold brochure was created for the DDAL, detailing its objectives, reasons to contribute, and QR codes linking to GitHub and Zenodo. This brochure was translated into Dutch, Greek, North Macedonian, French, Spanish, Catalan, and Lithuanian.
- 2) An invitation template was created for partners to share with other projects or stakeholders, explaining the DDAL and inviting contributions.
- 3) A press release was prepared to announce the launch of the DDAL and translated into the aforementioned languages.
- 4) PPT update: Additional slides about the DDAL were added to the ICAERUS general presentation, allowing partners to present it at various events.

DDAL Week began with an email to partners explaining the campaign and included all the above files and links to the social media post marking the kick-off.

The following table includes a summary of the activities carried out each day during DDAL Week, detailing the social media posts made. It provides an overview of the announcements, featured datasets, models, and blog posts shared to promote the DDAL and engage the community.

Table 7: Outreach activities done in DDAL week

| Outreach activities done in DDAL week | | |
|---------------------------------------|--|-------------------------------------|
| Day | Social Media Post | Impressions |
| Monday 13 May | Announced the DDAL with links to the blog, DDAL page of the ICAERUS website, and GitHub. Tagged all use case partners. Link here . | LinkedIn: 1299; X: 92; Facebook: 55 |

| | | |
|------------------|---|-------------------------------------|
| Tuesday 14 May | Spotlight on IDELE's Annotated-cow datasets with a link to access them on Zenodo. | LinkedIn: 1033; X: 13; Facebook: 79 |
| Wednesday 15 May | Post with a link to another blog post and GitHub. Link here . | LinkedIn: 555; X: 66; Facebook: 49 |
| Thursday 16 May | Spotlight on RGBtoNDVI conversion model from WU with a link to GitHub. | LinkedIn: 1127; X: 57; Facebook: 72 |
| Friday 17 May | Spotlight on NMN's row-view to top-view vineyard analytics with a link to GitHub. Link here . | LinkedIn: 715; X: 49; Facebook: 30 |

Checking the metrics of all activities carried out during this DDAL week across various social media platforms, including LinkedIn, Facebook, X, and the ICAERUS webpage, it can be observed that the highest impressions and reactions were achieved by the post on May 14, which featured the cow detection dataset. This post was particularly well-received. This trend is consistent across social media, with the highest impressions and engagement seen for cattle counting: LinkedIn recorded 1310 impressions with 671 unique impressions and 37 clicks, while Facebook saw 79 impressions and 24 engagements. The organic nature of these posts, with no sponsored content, underscores the importance of high-quality content in driving organic engagement. Overall, the engagement rates suggest a positive trend, with organic clicks and reactions playing a crucial role in audience interaction. On the other hand, the top post on X was on May 13, announcing the DDAL week, which gathered 92 impressions and 25 engagements. Regarding the webpage, news about ICAERUS was the most viewed content during the week. LinkedIn is the most successful platform to share DDAL related content.

3.2.1. Coming up/planned

The upcoming and planned activities for the DDAL include writing one spotlight every month on contributions from the UCs, OCTs, or WU. Additionally, around three more blogs are anticipated to be written over the next two years, providing in-depth insights and updates on various aspects of the DDAL. These efforts aim to continuously highlight and promote the diverse contributions to the library, fostering ongoing engagement and collaboration within the community.

Presentations within the Wageningen University, to acquire more models and datasets are planned with the Unmanned Aerial Remote Sensing Facility (UARSF), and Vision+Robotics.

3.3. OCT contributions to the DDAL

The expected outputs for the ICAERUS Drone Data Analytics Library from each Open Call Trial (OCT) are outlined in the T23_OCT_DDAL_Contribution_overview document. It covers both Push and Pull contributions, and is designed to be a living document, updated regularly. Each OCT contributes models and datasets to GitHub or Zenodo, adhering to FAIR Principles: Findable, Accessible, Interoperable, and Reusable. Proper documentation and metadata are essential for every contribution.

Table 8: Contributions for the coming period.

| Contributions for the coming period. | | | |
|--------------------------------------|----|---------------------|------------------------|
| OCT | By | Project Description | Proposed Contributions |
| | | | |

| | | | |
|------|---|--|---|
| OCT1 | Agrobit s.r.l. | Agrotwin: Developing analysis methods and datasets for vineyard analysis using affordable RGB sensors. | <ol style="list-style-type: none"> 1. GitHub Model: Codebase of 3D-Point cloud analysis of vineyard 2. GitHub Model: Sensitivity Analysis documentation 3. Zenodo Dataset: Raw image data from flights 4. Zenodo Dataset: Reconstructed Point Cloud 5. Zenodo Dataset: Ground-truth biophysical observations |
| OCT2 | Schweitzer Ingenieur-gesellschaft GmbH | AIM Gas sensor: AI-enhanced methane gas leak detection. | No specific analytical models required. |
| OCT3 | TAAL s.r.l. | Sensor 2.0: Developing a recognition system for olive trees and Xylella fastidiosa detection using RGB and deep learning. | <ol style="list-style-type: none"> 1. Zenodo Dataset: Raw Drone Sensing Data 2. Zenodo Dataset: GIS Data from the Sites 3. Zenodo Dataset: Ground truth data 4. Zenodo Dataset: Plant Health Status 5. GitHub Model: Olive Tree Recognition 6. GitHub Model: Xylella Fastidiosa Detection |
| OCT4 | Virtual Angle B.V. | SHIELD: High-integrity RTK drone system for precision agriculture using Galileo OSNMA. | <ol style="list-style-type: none"> 1. Zenodo Dataset: NMEA sentence dataset - landing operations 2. Zenodo Dataset: NMEA sentence dataset - agriculture/security path-following 3. GitHub Model: Integration of Galileo OSNMA in the drone system 4. GitHub Model: Process EGNSS data for accurate positioning |

| | | | |
|------|------------------|--|---|
| OCT5 | Agricloud | SKYFAR Academy: Not sure if applicable. Training Indicative contributions: drone sensing data, GIS data, weather data, ground truth data, and metadata. | Indicative contributions: <ul style="list-style-type: none"> - Drone sensing data - GIS data - Weather data - Ground truth data - Metadata |
|------|------------------|--|---|

For example, the Agrobot – Agrotwin project already agreed on contributions to the library. These follow the provided template, as well as the suggested contributions. The contributions contain:

1. GitHub Model: Codebase of 3D-Point cloud analysis of vineyard
 - Files: Various scripts for data loading, processing, and analysis
 - Documentation: Readme.md and platform.json templates
2. GitHub Model: Sensitivity Analysis documentation
 - Files: Images and scripts for analysis
 - Documentation: Readme.md and platform.json templates
3. Zenodo Dataset: Raw image data from flights
 - Files: Raw images and other relevant data
 - Documentation: Zenodo Description template
4. Zenodo Dataset: Reconstructed Point Cloud
 - Files: Various point cloud and orthoimagery files
 - Documentation: Zenodo Description template
5. Zenodo Dataset: Ground-truth biophysical observations
 - Files: Biophysical data in CSV and other formats
 - Documentation: Zenodo Description template

Regarding the future steps to be taken with the collaborations, they can be summarised as follows. The OCT will initiate the process by drafting the OCT-plan (WP5/FSH+OCT). Afterwards, WU will adapt the data and algorithm-related content with the OCT-plan to reflect their proposed contributions and prepare a presentation of the DDAL. Subsequent steps are that the OCT reviews these proposed contributions, making necessary adaptations. Together, OCT and WU will create a timeline that considers existing OCT activities. WU will provide support to OCT in implementing these contributions into the library, which includes structuring files, creating a repository, documenting code or datasets, and integrating these elements into the ICAERUS platform. Figure 10 below is how these steps fit in the larger scheme of the OCT planning.

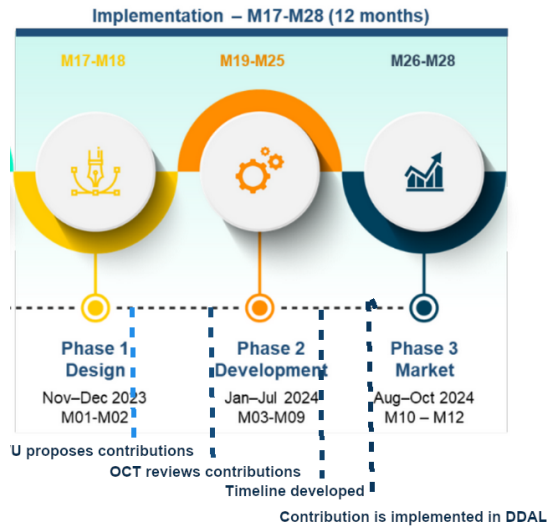


Figure 10: DDAL contributions from OCT planning

4. Conclusion

The "D2.4 Scale Up and Expansion Report" encapsulates the concerted efforts undertaken in Tasks 2.2 and 2.3 to refine and expand the ICAERUS Drone Data Analytics Library. By optimising drone analytics models and tailoring them to the needs of end-users and specific use cases, this deliverable highlights the project's advancements in drone-based data modelling.

Task 2.2's focus on identifying user needs, selecting appropriate models, and optimising these models and datasets ensures that the library is robust, accessible, and standardised. The publication of these models on platforms like GitHub and Zenodo facilitates widespread dissemination and use. Furthermore, Task 2.3 emphasises the scaling-up process and the expansion of the library, supported by a range of publicity events and contributions from external parties. These efforts are crucial in positioning ICAERUS as a comprehensive, EU-wide platform that effectively addresses diverse stakeholder needs. By documenting these activities, the report not only showcases the progress made but also underscores the participatory and collaborative approach of the ICAERUS project.

The next steps can be divided into the same tasks as ongoing work: T2.2. to focus on optimisation and T2.3. to focus on outreach. In the report, various planned activities were presented in section 2.6., these are planned to be implemented in the coming months. Additionally, the alignment of OCT contributions will require some further ongoing contact and collaboration. However, as ICAERUS activities continues more ambitious plans are in development, in line with T2.2. and T2.3. these initial forays are presented below.

For Task 2.2. we propose to identify which models require which type of optimisation, according to the previously presented four dimensions (generalisation, accuracy, explainability and usability). For models requiring generalisation, deepening and widening the datasets is essential, as well as developing models that are pretrained on larger datasets, as well as the use of foundation models. Accuracy should first be explored through selection of relevant and a wide range of metrics. Afterwards, newer architectures or more complex models can be evaluated. Explainability is an increasingly important subject, often solved by deploying simpler machine learning models (Random Forest or Support Vector), which can be beneficial for generalisation as well. Usability is for most of the Use Cases the next step, in which the developed models will be expanded for various platforms, from deploying on Google Colab to increasing the documentation and possibilities for adaptation. As well as avoiding large Deep Learning models (Udumaro et al., 2024), and developing specific applications that fit into existing workflows, such as analytics within OpenDroneMap and Agisoft Metashape.

For Task 2.3. further outreach activities are planned, both to increase the audience of the library as well as the contributors. First and foremost are implementing the contributions from the OCTs. From the existing implementations on the library, standard templates and formats have been developed, as well as new ones that will arise. These templates will serve to support contributions from outside partners, such as the Unmanned Aerial Remote Sensing Facility at Wageningen University. Finally, new outreach material, such as tutorial videos, online workshops and short highlights that fit the online format could be developed to grow the DDAL audience.

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