



WP2 Copernicus uptake and spatial data lab

# D2.4: ML based Copernicus data enhancer tool

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## Table of Contents

<b>1</b>	<b><u>AIM OF DELIVERABLE .....</u></b>	<b><u>7</u></b>
<b>2</b>	<b><u>INTRODUCTION .....</u></b>	<b><u>8</u></b>
<b>3</b>	<b><u>SYSTEM OVERVIEW .....</u></b>	<b><u>9</u></b>
<b>3.1</b>	<b>GETTING STARTED.....</b>	<b>9</b>
<b>4</b>	<b><u>WORKFLOW WALKTHROUGH.....</u></b>	<b><u>10</u></b>
<b>5</b>	<b><u>UNDERSTANDING THE OUTPUT.....</u></b>	<b><u>19</u></b>
<b>6</b>	<b><u>CONCLUSION .....</u></b>	<b><u>20</u></b>

### Table of figures

Figure 1	Click the blue 'Create new project' button to start a new mapping workflow.....	10
Figure 2	Select your Region of interest .....	10
Figure 3	Select your year of interest .....	11
Figure 4	Select your month of interest .....	11
Figure 5	Click the blue 'Create project' button to initiate preprocessing.....	12
Figure 6	Track the progress of your new project creation on the main panel and click the actions button to enter the newly created project.....	13
Figure 7	Activating the super resolution output by clicking the eye icon on .....	14
Figure 8	Activating the basemap land cover output by clicking the eye icon on the right hand panel .....	15
Figure 9	Toggling on and off the auxiliary datasets.....	15
Figure 10	Add training data by clicking one of the 7 land cover categories and draw training polygons directly on the map .....	16
Figure 11	Activating the user tuned land cover output by clicking the eye icon on the right hand panel.....	17
Figure 12	By clicking the download icon, the user can download the results and associated datasets for both the base map and user refined products .....	18

## Executive Summary

This manual introduces the FRAME (Fine-Resolution AI Mapping for Urban Environments) portal (<https://frame.dhigroup.com/>) —an innovative web-based platform developed by DHI as part of the Horizon Europe 100KTREES project. FRAME empowers users to create detailed urban land cover classifications using AI-enhanced Sentinel-2 satellite imagery, offering 5-meter resolution outputs suitable for city-scale analysis.

The portal guides users through a streamlined workflow: selecting a region and time period, launching automated preprocessing, visualizing classified results, refining outputs with user-generated training data, and downloading the final deliverables. The system includes access to auxiliary reference layers, such as Urban Atlas 2018 and Copernicus High Resolution Layers, to support interpretation and validation.

FRAME is designed to support a wide range of users—from urban planners and environmental researchers to policymakers—enabling scalable, repeatable, and cost-effective urban mapping for nature-based solutions, climate resilience, and sustainable city development. While the tool is optimized for large-area applications, users are encouraged to consider integrating local datasets for enhanced accuracy in site-specific studies.

This manual serves as a practical guide for navigating the portal and understanding the strengths and limitations of its outputs, helping users maximize the value of this advanced satellite-based mapping tool.

For more information about the FRAME portal or to request access, please reach out to **Mads Christensen (DHI A/S)** at [madc@dhigroup.com](mailto:madc@dhigroup.com). We welcome collaboration and feedback to help improve and expand the platform's capabilities.

## 1 Aim of deliverable

This manual serves as a comprehensive guide for stakeholders, developers, and end-users of the Fine-Resolution AI Mapping for Urban Environments (FRAME) urban mapping portal.

The aim is to:

- Demonstrate the core functionalities of the platform through a high-level walkthrough.
- Provide clarity on the data processing and AI classification workflow.
- Support onboarding of new users through structured explanations and annotated screenshots.
- Ensure that users understand how to interpret, refine, and apply the land cover results for urban environmental analysis, planning, and decision-making.
- Communicate the technical and functional value of the portal as part of the 100KTREES initiative.

## 2 Introduction

The Fine-Resolution AI Mapping for Urban Environments (FRAME) portal (<https://frame.dhigroup.com/>) is an AI-powered toolbox for mapping urban land cover using freely available Sentinel-2 satellite imagery. Developed by DHI as part of the HORIZON Europe-funded 100KTREES project, it enhances conventional remote sensing approaches with machine learning and super-resolution to provide a detailed, up-to-date picture of urban landscapes.

By classifying land into seven urban land cover categories and delivering 5-meter resolution outputs, FRAME supports data-driven decisions for biodiversity, air quality, and green infrastructure planning.

This demonstration manual provides a step-by-step guide to using the FRAME portal, which enables users to generate high-resolution urban land cover classifications using super-resolved Sentinel-2 imagery and artificial intelligence.

Through a simple and intuitive interface, users can define areas of interest, select relevant time periods, initiate processing workflows, visualize outputs, and iteratively refine results using their own training data. The platform also offers access to a set of auxiliary reference layers and supports exporting results in standardized formats for further use in GIS environments.

This manual walks you through each step of the workflow, from region selection to output download, ensuring a smooth onboarding experience for first-time users and stakeholders engaged in urban planning, environmental assessment, or nature-based solution design.

### 3 System overview

The FRAME portal allows users to:

- Select a temporal window (year and month)
- Trigger an automated preprocessing pipeline
- Visualize enhanced super-resolution imagery and model-generated basemaps
- Fine-tune classification results using user-provided training data
- Iteratively improve map accuracy and contextual relevance

Outputs are provided in georeferenced GeoTIFF format, compatible with GIS software such as QGIS.

#### 3.1 Getting Started

##### **Accessing the Portal**

- Navigate to the FRAME portal via [insert portal URL].
- Log in using your institutional credentials (if applicable).
- New users can request access by contacting DHI (see Section 10).

##### **System Requirements**

- Recommended browser: Chrome, Firefox, or Edge (latest versions)
- Internet connection:  $\geq 10$  Mbps for smooth image rendering
- Supported platforms: Windows, macOS, Linux

## 4 Workflow walkthrough

This section outlines each step in the FRAME portal workflow, with screenshots recommended at each stage.

### Step 1: Create a new project

Start a new project by clicking the blue 'Create new project' button in your lefthand panel

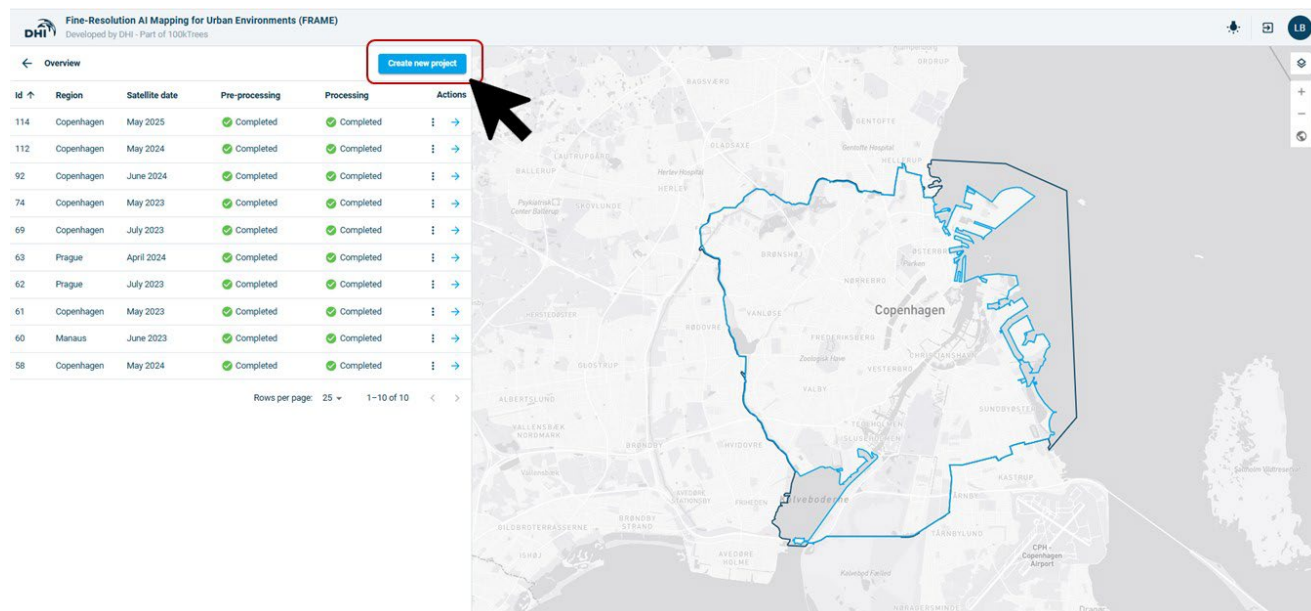


Figure 1 Click the blue 'Create new project' button to start a new mapping workflow

### Step 2: Select your region

Under item 1 (Select region) in the lefthand panel, select your Region from the list or click your Region of interest on the map to select.

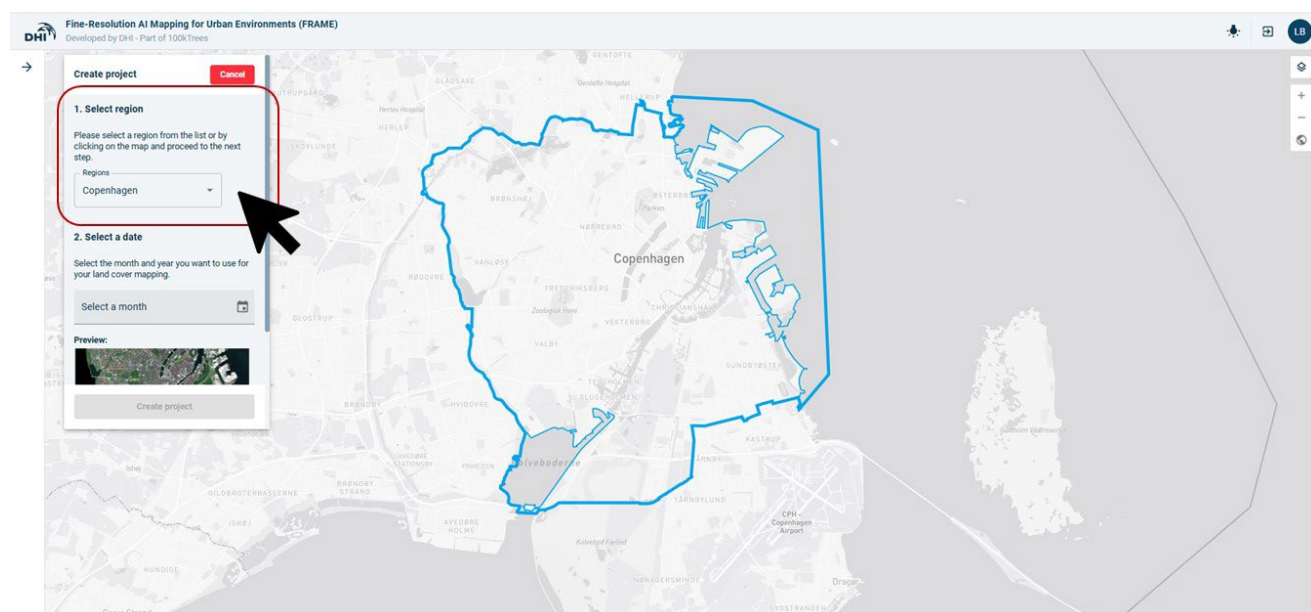


Figure 2 Select your Region of interest

### Step 3: Select Year and Month

Once your AOI is defined, select the year and month for which you want to generate the land cover classification. This determines the Sentinel-2 image collection used for the analysis.

① *Tip: Choose months with minimal cloud cover (e.g. May–September in temperate regions).*

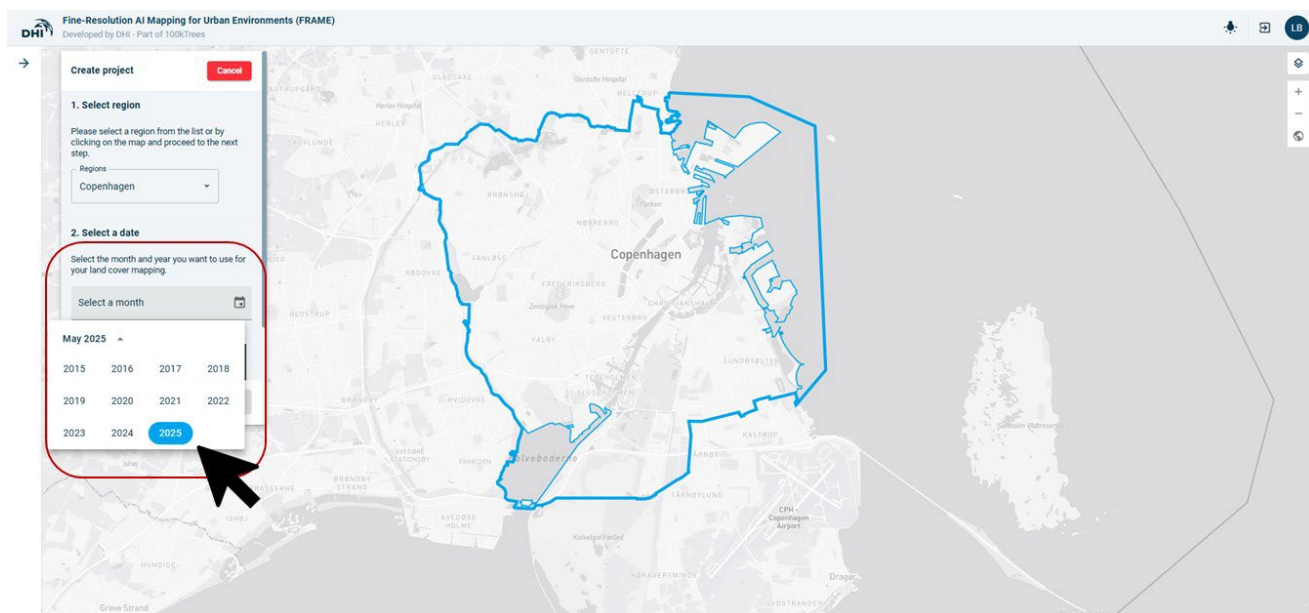


Figure 3 Select your year of interest

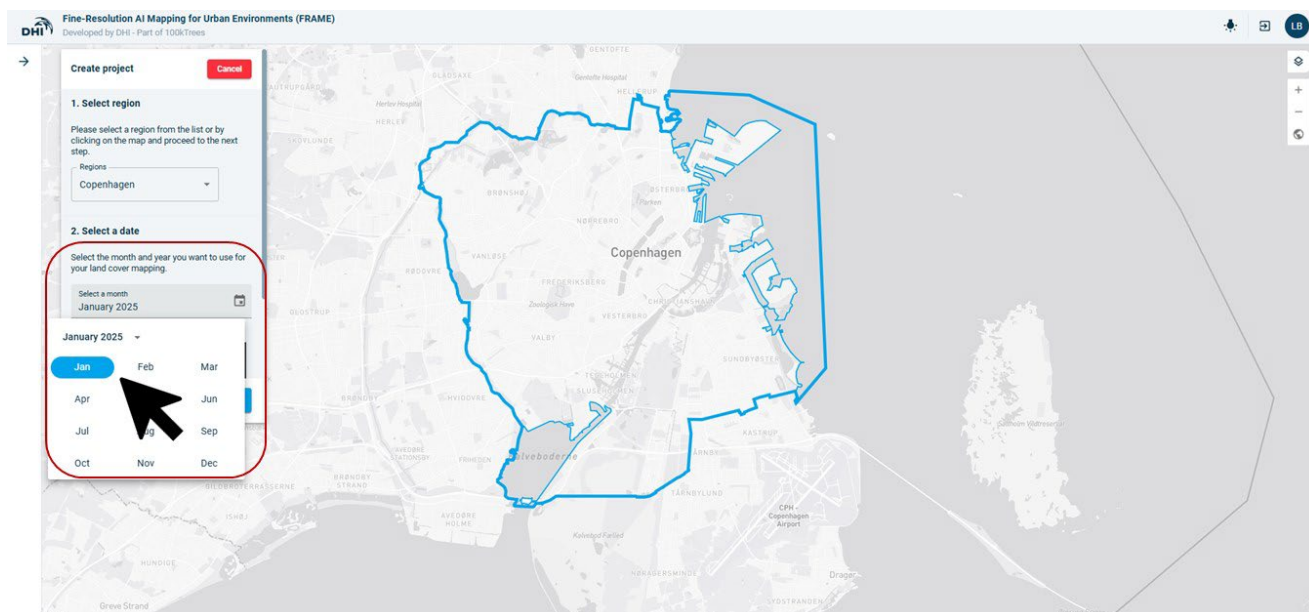


Figure 4 Select your month of interest

### Step 4: Initiate Preprocessing

Click the blue “Create project” button to trigger cloud masking, mosaicking, super-resolution development and basemap land cover production workflow. This step may take several minutes.

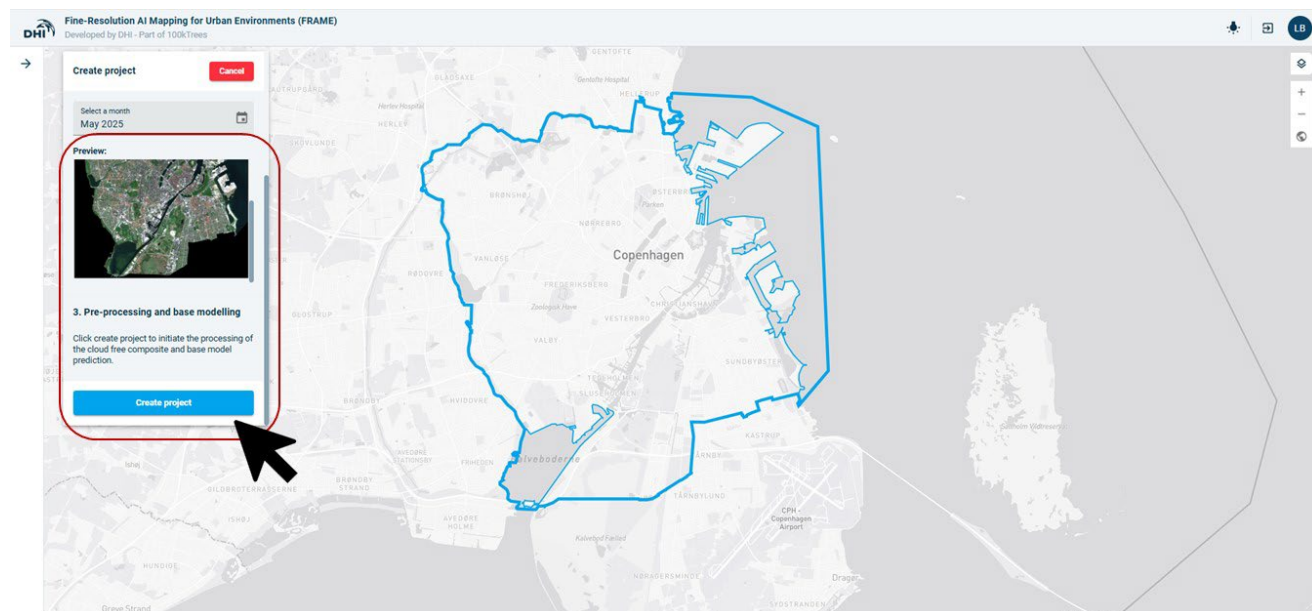


Figure 5 Click the blue 'Create project' button to initiate preprocessing

### Step 5: Track progress on your new project

After initiating preprocessing and returning to the main panel, users can monitor the full processing workflow of their selected project in real time. The project will appear in the project list, displaying its number, region, satellite data selection and current status.

Each stage of the processing pipeline (preprocessing and processing) is individually tracked and visually marked with intuitive status icons:

- **Yellow “i” icon** indicates that the process is currently running.
- ✓ **Green checkmark** confirms successful completion of the step.
- ✗ **Red error icon** signals that an error has occurred and requires user attention.

To view detailed logs or troubleshoot an issue, click the **“Actions”** button at the end of the row for your project.

① *Tip: If a workflow step fails, review the message log or download the error report to share with the support team.*

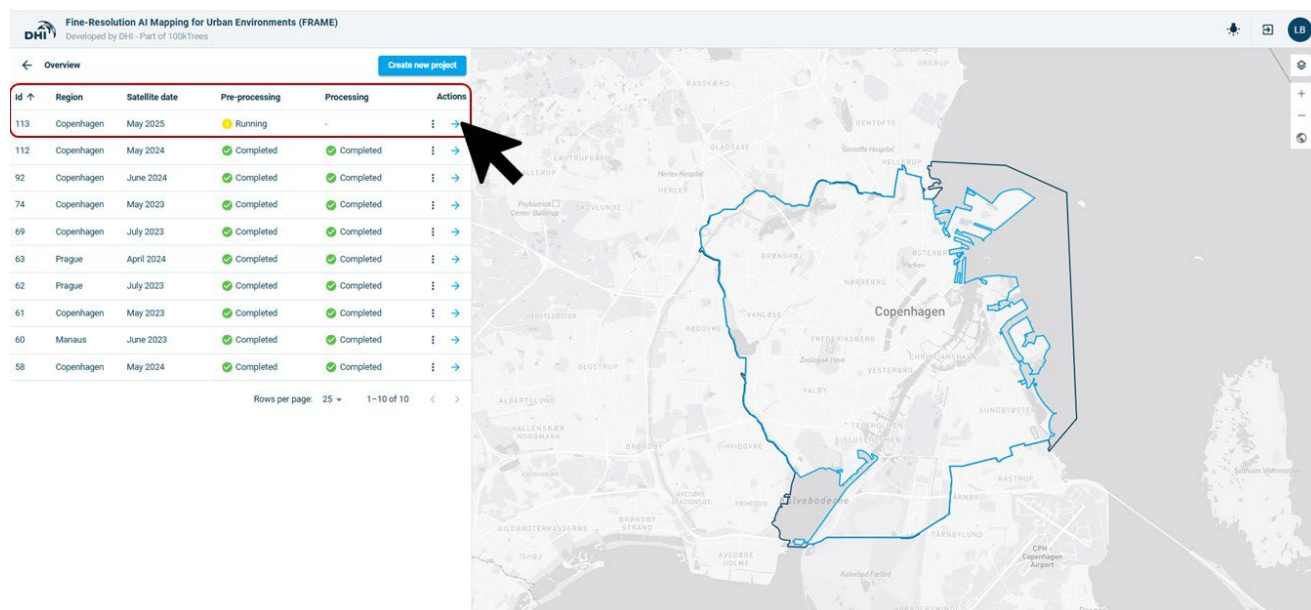





Figure 6 Track the progress of your new project creation on the main panel and click the actions button to enter the newly created project

### Step 6: Visualize Super-Resolution and Basemap

Once the processing workflow has successfully completed, you can explore the output directly in the map viewer. The Layer Panel allows you to toggle between the available visual outputs:

- 
**Super-Resolved Imagery (5-meter resolution):**  
 This enhanced version of Sentinel-2 imagery has been processed using advanced AI-based super-resolution techniques. It provides significantly more spatial detail than the native 10-meter resolution, making it easier to distinguish fine-scale features such as narrow roads, small buildings, and patches of vegetation.
- 
**Classified Basemap (Urban Land Cover):**  
 This layer displays the initial based model-generated land cover classification, where each pixel has been assigned to one of seven urban land cover categories: *Bare Soil, Buildings, Coniferous Trees, Deciduous Trees, Grass, Impervious, and Water*. Each class is represented with a distinct color legend, which is accessible from the legend tab.
- 
**Auxiliary Layers (Reference and Contextual Data):**  
 To support better interpretation, comparison, and validation of the classification results, the portal includes a set of auxiliary layers that can be activated through the layer panel. These layers provide independent reference data drawn from well-established sources. The **Urban Atlas 2018** dataset offers a detailed picture of functional urban land use zones, which is particularly helpful for validating large-scale classifications or understanding general zoning patterns. Additionally, a suite of **Copernicus High Resolution Layers** is included: these layers show imperviousness density, grassland extent, tree cover density, and water and wetness presence. These thematic layers are derived from consistent pan-European methodologies and provide a valuable external benchmark to assess the FRAME model outputs,

particularly for features such as vegetation cover and artificial surfaces. Finally, a **region outline layer** delineates the boundary of the selected area of interest, helping users visually anchor the analysis and isolate their project extent during review. These auxiliary datasets serve as a contextual frame to enrich interpretation, identify discrepancies, or guide refinement in subsequent iterations of user-led training.

The layers can be viewed individually or stacked together using transparency sliders to visually compare the input imagery with the model output.

**Additional Features:**

- Zoom and pan to explore different areas within your AOI
- Use the legend to interpret classification categories
- Toggle on/off individual layers using the eye icons
- Adjust opacity to compare super-resolved imagery and classification

*Tip: Use side-by-side or swipe comparison mode (if available) for more effective visual inspection of changes or model accuracy.*



Figure 7 Activating the super resolution output by clicking the eye icon on

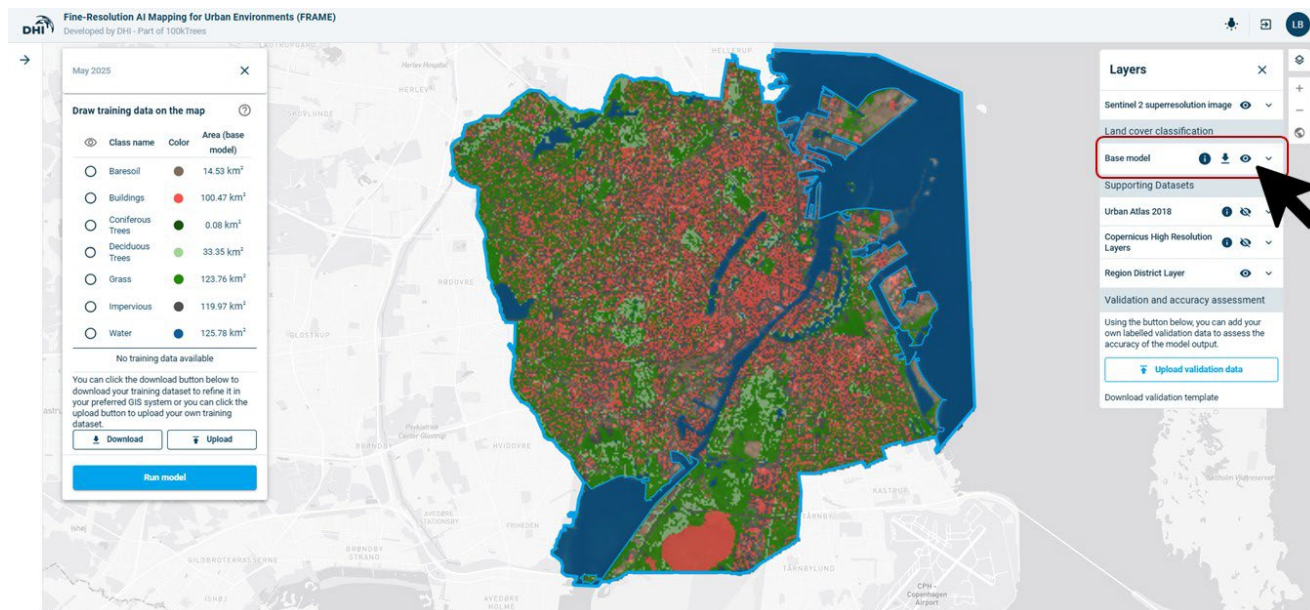


Figure 8 Activating the basemap land cover output by clicking the eye icon on the right hand panel

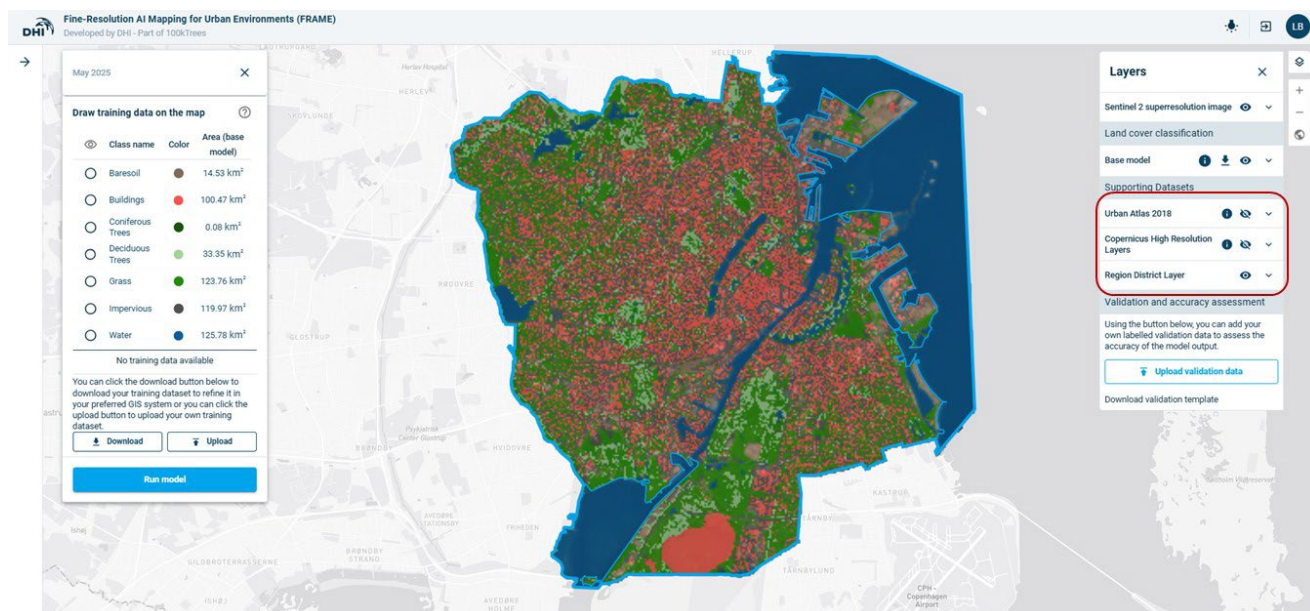


Figure 9 Toggling on and off the auxiliary datasets

### Step 7: Fine-Tune Results with Training Data

Once you've reviewed the initial basemap classification output, you can iteratively improve the accuracy of the map by incorporating your own training data. This step enables you to adapt the model to local characteristics, correct misclassifications, or emphasize specific land cover types relevant to your project.

Using the **Draw training data on the map panel**, you can manually draw training polygons directly on the map by clicking the land cover class on the list below. Each polygon must be labeled with the correct land cover class based on the seven predefined FRAME categories: *bare soil*, *buildings*, *coniferous trees*, *deciduous trees*, *grass*, *impervious surfaces*, and *water*.

As you are adding polygons to the training dataset, they will appear in the list under **User-Defined Training Data** where they can be selected and deleted individually. You can also

upload pre-existing training datasets in supported formats (e.g. GeoJSON) by clicking the **upload button** at the bottom. By clicking the download button, you can download the training dataset created to store locally.

After your training data is uploaded or created, you can launch a new classification run using the **Run Model** button. The system incorporates your training data into the existing model, refining its understanding of local spectral signatures and improving its ability to distinguish between visually similar features—such as between coniferous and deciduous trees vs grass, or buildings vs. impervious roads.

① *Tip: Start with a small, representative set of training polygons before scaling up, and aim to include diverse examples of each land cover class to avoid class imbalance.*

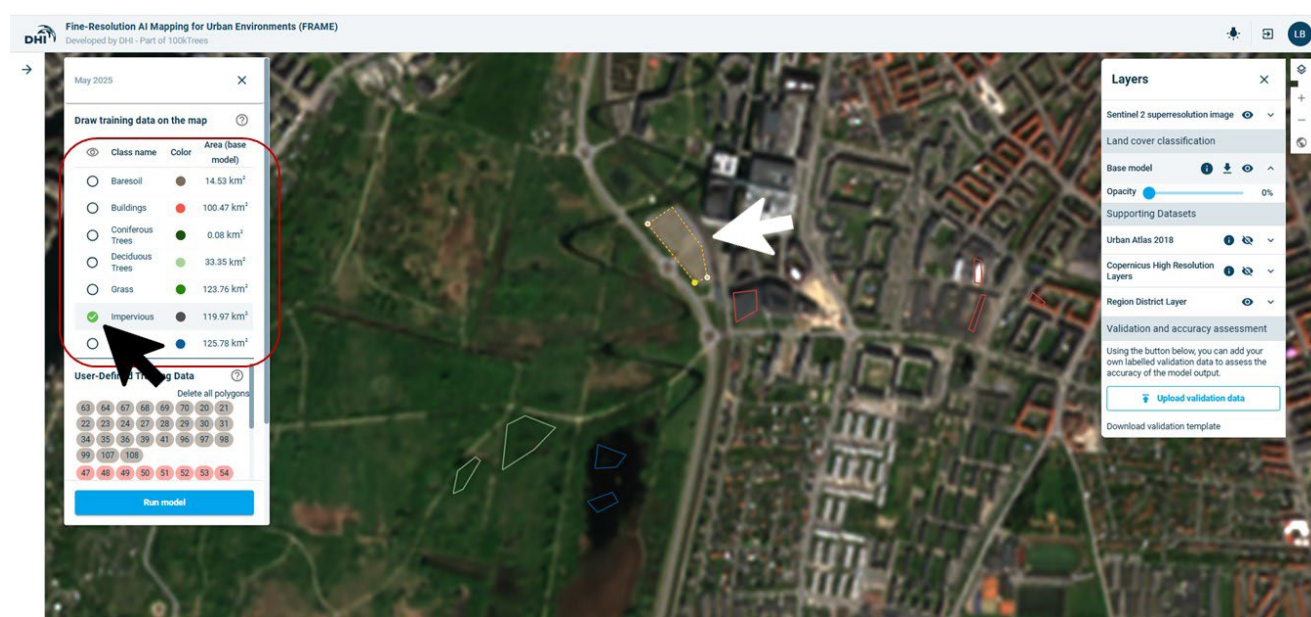


Figure 10 Add training data by clicking one of the 7 land cover categories and draw training polygons directly on the map

### Step 8: Iterate for Improved Results

Once the user refined model has finished, the new product can be found on the right hand panel, labeled **'User tuned model'**.


The fine-tuning process can be repeated iteratively: after each run, review the output, identify remaining errors or ambiguous areas, and provide additional training samples to guide the model toward better accuracy. Over time, this adaptive learning cycle allows you to create a highly tailored land cover map that reflects on-the-ground conditions more closely than a generic model could.





After adding additional training data, retrain the model by once again clicking **"Run Model."** Repeat this process until results meet your expectations.



Figure 11 Activating the user tuned land cover output by clicking the eye icon on the right hand panel

### Step 9: Download the results

After finalizing your classification, you can download all outputs for local use and integration into your GIS workflows. By clicking the  icon in the right hand panel, the system will package your mapping results into a structured folder containing the following key components:

-  **Summary Statistics (summary.txt)**  
 A simple text file with basic statistics from your project, including the total area mapped, the percentage coverage of each land cover class, and the resolution used for processing.
-  **Classified Output (classification.tif)**  
 A GeoTIFF file containing the final land cover map. This raster file can be directly imported into GIS software for visualization, further analysis, or integration with other datasets.
-  **Metadata File (metadata.pdf)**  
 A comprehensive PDF containing background information about the FRAME platform, details on how the classification was produced, and a technical description of the input data and output specifications. It includes spatial reference system, resolution, class definitions, usage guidelines, and legal considerations. This document is essential for understanding the capabilities and limitations of the data, ensuring proper usage, and supporting reproducibility and reporting.
-  **QGIS Style File (classification.qml)**  
 A ready-to-use QML style file for visualizing the classification in QGIS. Applying this style will automatically assign appropriate colors and labels to each land cover class, ensuring consistent and meaningful presentation of the map.

These outputs allow you to easily share, visualize, and work further with your results, whether for planning, reporting, or academic use.



Figure 12 By clicking the download icon, the user can download the results and associated datasets for both the base map and user refined products

## 5 Understanding the output

The outputs generated through the FRAME toolbox offer an accessible, cost-effective, and scalable solution for urban land cover mapping. By combining AI-based classification with super-resolved Sentinel-2 data, the system provides detailed urban landscape insights at a 5-meter resolution—making it ideal for city-wide assessments, strategic planning, green infrastructure analysis, and nature-based solutions.

One of the key benefits of the FRAME output is its **broad coverage** and **consistency**, allowing cities or regions to obtain harmonized land cover data across large areas without the cost of commercial satellite imagery. The use of predefined habitat classes—such as buildings, grass, trees, water, and impervious surfaces—makes the results immediately applicable for urban planning, climate risk assessments, biodiversity reporting, and sustainability monitoring.

However, it's important to understand the **limitations** of this output:

- **Mixed Pixels:** At 5-meter resolution, many urban pixels contain a combination of materials (e.g., roads beneath tree cover). The classification assigns a dominant land cover class per pixel based on spectral properties, which can sometimes misrepresent small features or transitional zones.
- **Generalized Classes:** The land cover categories are designed for broad-scale urban analysis and may not capture very specific local features, such as individual tree species, rooftop types, or narrow green corridors.
- **Model Dependency:** While the AI model is trained on large urban datasets, its accuracy can vary depending on local urban form, seasonal imagery, and scene complexity. Fine-tuning with local training data (see Step 7) can significantly improve accuracy for targeted applications.
- **Resolution Trade-Off:** Though super-resolution techniques enhance spatial detail, the data is still derived from 10-meter Sentinel-2 inputs. Users requiring very fine spatial detail for neighborhood-level studies or infrastructure mapping may benefit from higher-resolution commercial or aerial imagery.

By understanding both the strengths and limitations of the output, users can make informed decisions about how best to apply FRAME results in their specific context. Whether used as a stand-alone layer or integrated with auxiliary datasets such as Urban Atlas or field observations, the classified output offers a strong foundation for data-driven urban decision-making.

## 6 Conclusion

The FRAME toolbox represents a new generation of AI-driven Earth Observation tools, bridging the gap between accessible satellite data and actionable insights for urban environments. By combining automated super-resolution processing with user-directed classification and refinement, it provides a powerful yet user-friendly platform for generating detailed urban land cover maps.

This manual has outlined the key steps to successfully navigate and apply the FRAME portal—from initial project setup to downloading results enriched with metadata and styling options. While the outputs offer significant advantages for large-scale assessments and planning, users are encouraged to remain aware of inherent limitations and to supplement the results with local data or field validation when necessary.

Whether used for tree planting strategies, climate adaptation planning, or long-term land cover monitoring, FRAME offers a scalable, open-data-based solution that supports cities and organizations in making data-informed decisions for a more resilient and greener future.

For more information about the FRAME portal or to request access, please reach out to **Mads Christensen (DHI A/S)** at [madc@dhigroup.com](mailto:madc@dhigroup.com). We welcome collaboration and feedback to help improve and expand the platform's capabilities.