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# Creating high-fidelity LULC for smarter carbon project design



2025

# Accurate land classification is crucial for resilient and impactful carbon projects

Designing a robust and high-impact carbon project requires a deep understanding of the land. Land Use and Land Cover (LULC) classification, a process to categorise earth's surface into categories such as forests, croplands, grasslands, and wetlands, is a critical tool in designing credible and effective carbon projects.

By leveraging high-fidelity LULC methods, we gain and provide an accurate picture of the land that significantly improves the accuracy and efficiency of carbon project planning, ensuring interventions are targeted, impactful, and maximise climate benefits.

# Why it matters for carbon projects

Carbon projects depend on precise assessments of where and how much carbon can be sequestered or conserved. Here's how high-fidelity LULC enables smarter carbon project design:

**Accurate and scalable project design:** By mapping the distribution and changes across multiple landcovers, forests, grasslands, croplands, and wetlands, our LULC ensures interventions (e.g., reforestation or agroforestry) align with local conditions. This precision helps focus limited resources on high-value opportunities and supports local biodiversity and community goals.

**Baseline validation:** Additionality requires proof that carbon benefits wouldn't occur without the project. LULC data helps establish the baseline scenario, showing what would likely happen to the land with the ongoing business-as-usual trajectory and without the intervention (e.g., continued degradation or suboptimal land use).

**Reducing non-compliance risk:** By verifying each parcel of land against relevant methodologies or standards (e.g., Verra VM0047), we reduce the risk of non-compliance and ensure credits reflect genuine carbon benefits.

**Enabling operational scalability:** High-fidelity LULC methods scale to large and diverse landscapes, enabling streamlined implementation and verification processes across regions.

**Availability of historical data:** LULC data acts as a first source of actual ground condition for capital partners, landowners, and field organizations throughout the project development lifecycle - critical for design, implementation, monitoring and verification, and risk management.

**Strengthening permanence:** With detailed LULC analysis, we can track vegetation changes over time and detect early signs of land degradation. This safeguards carbon investments by revealing potential risks to permanence and by guiding adaptive management strategies.

**Avoiding leakage:** Projects can unintentionally shift undesirable activities, like deforestation or agricultural expansion, to areas outside the project boundary (known as "leakage"). Historical land-use context informs us about potential displacement risks, helping to mitigate them.

# Key benefits for stakeholders

## For capital partners

**Financial risk reduction:** More accurate project scoping and eligibility assessments lower financial risks associated with overestimating eligible lands and thereby the carbon sequestration potential.

**Operational risk reduction:** Regular interval LULC data provides transparent ongoing monitoring of project progress and impact, improving the project's success.

**Compliance management:** Ensuring compliance with the carbon standard and methodologies like Verra VM0047.

## For landowners

**Maximising revenue potential:** Identifies the most lucrative carbon project opportunities based on land type and eligibility, ensuring landowners can capitalize on high-value projects.

**Optimising land use:** Helps balance carbon projects with existing agricultural or forestry activities, ensuring sustained income streams without compromising productivity.

**Regulatory compliance:** Supports adherence to conservation policies, land-use planning requirements, and sustainability certifications.

## For field organisations

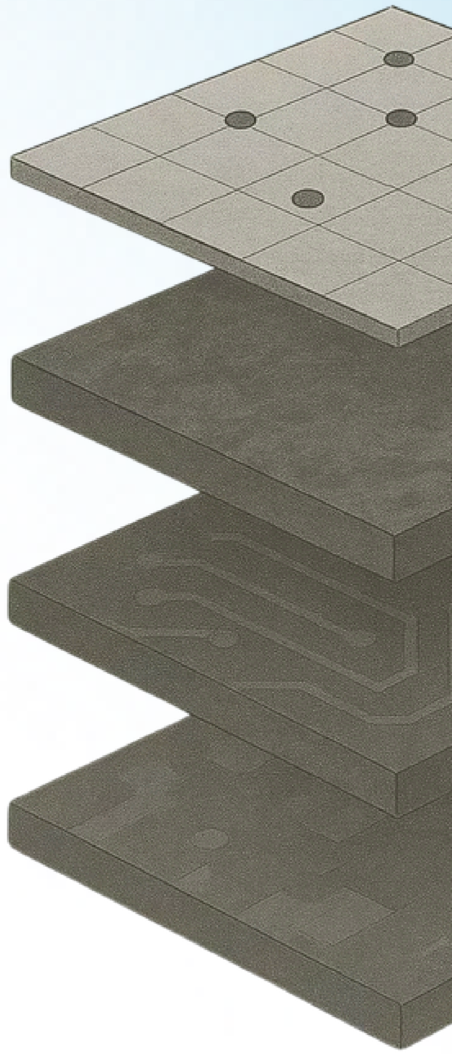
**Precision planning:** Reduces time and resources spent on land eligibility assessments, enabling efficient project rollout. With significantly higher accuracy than conventional methods, this allows for faster, more reliable project execution.

**Monitoring and adaptive management:** Provides data to track project success, enabling timely interventions to address emerging challenges.

**Community and biodiversity co-benefits:** Helps identify areas where carbon projects can support local communities and ecosystem restoration, maximizing environmental and social co-benefits.

# How we create high-fidelity LULC

Our approach follows four steps:



**01** Creating training datasets

**02** Classification following pixel and object-based approaches

**03** Robust quality assessment and field validation

**04** Eligibility mapping and activity zonation

# 01

# Creating training datasets

## Ground-truth data for precision mapping

Effective classification hinges on solid training data. Global LULC might not provide actual picture because the classifications are not designed for carbon projects and may overlook the nuances to identify the land class.

Rather than relying on these global datasets we build high-quality, project-specific training datasets that provide high fidelity mapping of the land cover in the exact project area we're working in.

Collecting field data for LULC training in North Sulawesi, Indonesia.

# 01

# Creating training datasets

Ground-truth data for precision mapping

### How do we do it:

Combine satellite imagery from various sources such as Landsat, Sentinel, and ALOS with local field data to build training datasets that capture real variations in vegetation and land use, giving our models a strong foundation for accurate classification.

Tailor training datasets to the local ecological and land-use context, ensuring region-specific spectral signatures and land cover types are accurately represented.

Use time-series data to capture seasonal and historical trends, leveraging multi-temporal composites and feature extraction.


Satellite imagery showing manually selected training points for four land cover classes (Tree Cover, Built Up, Barren/Agriculture, and Water) across the project area. These training points will be used to develop a Land Use/Land Cover (LULC) classification model.

## 02

# Classification following pixel and object-based approaches

Captures land cover detail and select meaningful clusters

Classifying land accurately requires more than just analyzing pixels. While traditional pixel-based methods offer high granularity, they often miss the broader context, like how land is grouped and shaped.

That's where object-based methods come in, incorporating segmentation, shape, and texture, to group pixels into meaningful clusters. This helps us to distinguish classes such as croplands and grasslands (a common challenge in carbon project planning) - reducing the risk of misclassification, and improving the reliability of land type detection.

With this robust approach, we identify risks that could impact the project and filter out higher-risk projects, focusing instead on projects with a higher potential for permanence.

### How do we do it:

Use both pixel and object-based approaches, combining per-pixel analysis with object-level classification to improve clarity and reliability.

Combine the above analysis with an ensemble of ML/AI approaches, including Random Forest classification, support vector machines (SVMs), and neural networks.

Segment imagery to identify object-level features like shape and texture. Extract features per pixel and object: spectral, geometric, and contextual.

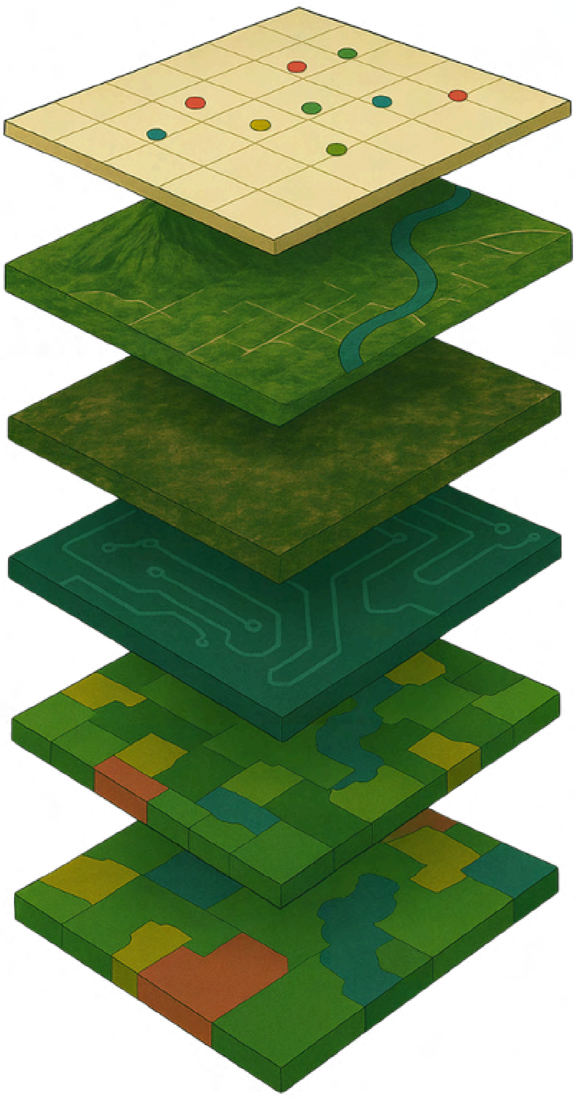
Utilize hyperparameter tuning to find the optimal combination for the machine learning model to maximize its performance.

For validation and accuracy assessment, we use ground datapoints which gives us unbiased accuracy of the model.

**02**

# Classification following pixel and object-based approaches

Captures land cover detail and select meaningful clusters



Training points

↓

Satellite imagery

↓

ML algorithms

↓

Time series LULC

↓

Accuracy assessment

From field and visual training points to satellite imagery and ML algorithms — generating LULC maps for 2014 and 2024.

03

# Robust quality assessment and field validation

## Ensures accurate LULC outputs, building confidence and trust

We ensure high-quality mapping through rigorous field validation and robust accuracy assessments.

This systematic approach ensures accurate LULC outputs, building confidence and trust among investors, certification bodies, and local communities.

Field surveys for LULC validation in North Sulawesi, Indonesia.

# 03

# Robust quality assessment and field validation

Ensures defensible LULC outputs, building confidence and trust

**How do we do it:**

Conduct field visits, interacting with local communities to understand the land use, land cover and historical patterns - this helps us better understand how our map fits with on-the-ground expectations.

Collect GPS coordinates and field photographs from diverse land cover types (forest patches, crop fields, grasslands, etc.) with the help of local field partners within the project region to further calibrate our models.

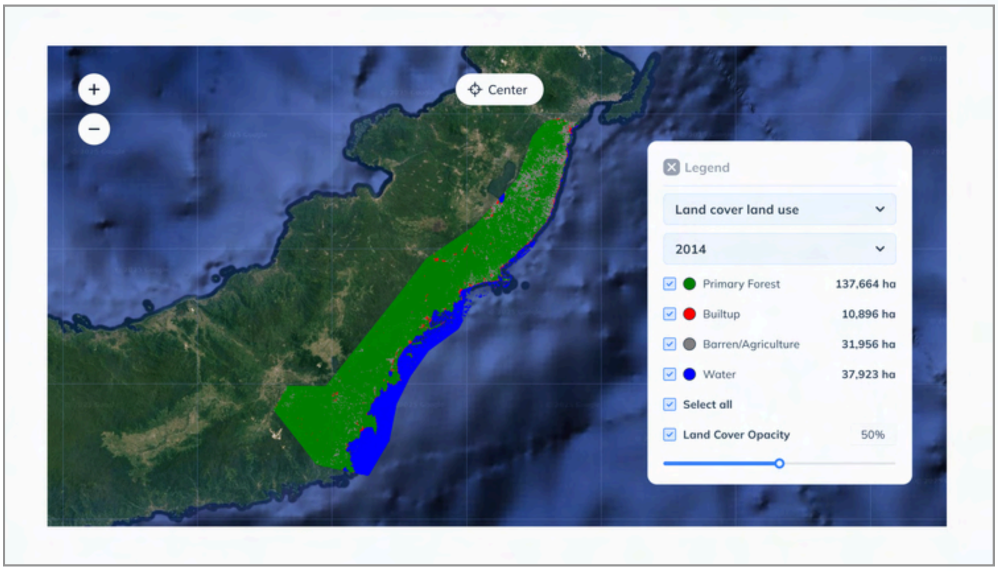
Focus on areas where classification errors are more likely, such as transitional zones between shrubland and open forests, enabling us to delineate difficult-to-map land landcovers better and make our local maps more accurate.

Use established protocols (e.g., confusion matrix, kappa value, omission and commission accuracies) to benchmark classification results against ground-truth data. As of April 2025, our most recent assessments reached an overall accuracy of >90%.

03

# Robust quality assessment and field validation

Ensures defensible LULC outputs, building confidence and trust




Baseline map showing primary forest, built-up areas, agriculture, and water extent in 2014.


Updated land cover classification for 2024, showing changes in forest cover, agriculture, and water bodies.

# 04

# Eligibility mapping and activity zonation

## Mapping eligible zones with accuracy

Accurate eligibility mapping is crucial to align carbon projects with methodologies like Verra's VM0047 for ARR activities. Our process identifies specific land parcels that meet project requirements while providing a clear visualization of eligible zones.

Beyond identifying eligible land, we conduct detailed activity zonation. For instance, zones with a history of agricultural use may be designated for agroforestry, while areas confirmed as historically forested (e.g., deforested more than 10 years prior) are prioritized for reforestation.

An eligible field plot identified through our analysis as observed on the ground.

# 04

# Eligibility mapping and activity zonation

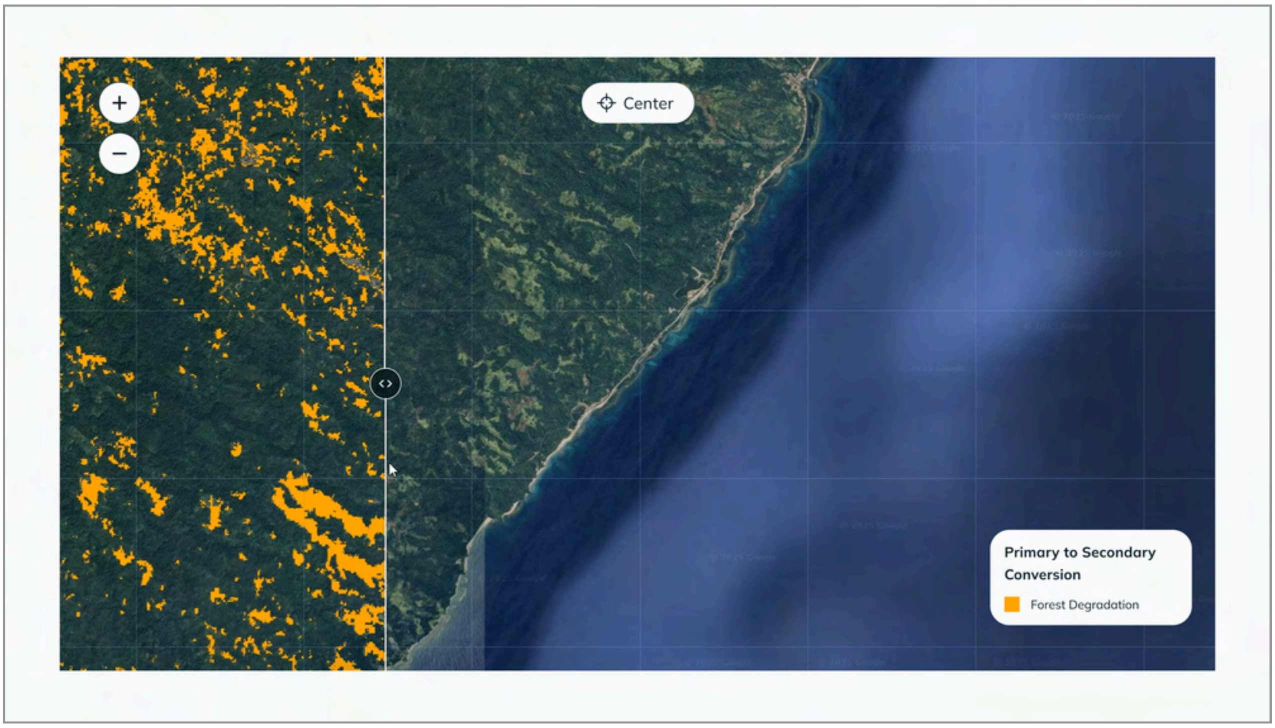
Mapping eligible zones with accuracy

### How do we do it:

Validate eligibility with multi-temporal analysis and ensure alignment with methodology requirements.

Assign land cover types to interventions (e.g. agroforestry on current cropland) to get the total eligible area per activity and accurately calculate carbon sequestration.

Integrate high-resolution satellite imagery and additional datasets (e.g., soil data) to refine zonation and support planning decisions.




Detecting eligible areas by identifying persistent non-forest cover (barren,grassland and cropland) between 2014 and 2024.

# The future of carbon projects

High-fidelity LULC mapping enables smarter carbon project design by ensuring additionality, permanence, and leakage mitigation.

By leveraging project-specific training datasets, advanced classification techniques, and detailed eligibility mapping, we create more reliable and actionable insights for carbon project development.

This approach not only enhances project efficiency but also strengthens the integrity of carbon credit generation, ensuring measurable climate impact while maximizing financial returns for investors and landowners.

**To learn more about our approach, visit www.thryve.earth.**

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Thryve develops high-quality Nature-based Solutions (NbS) carbon projects that regenerate ecology.

By combining a locally grounded and tech-enabled approach with rigorous project management and strong governance, we create resilient returns and lasting value for capital partners, landowners, and communities.

## Interested in learning more?

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