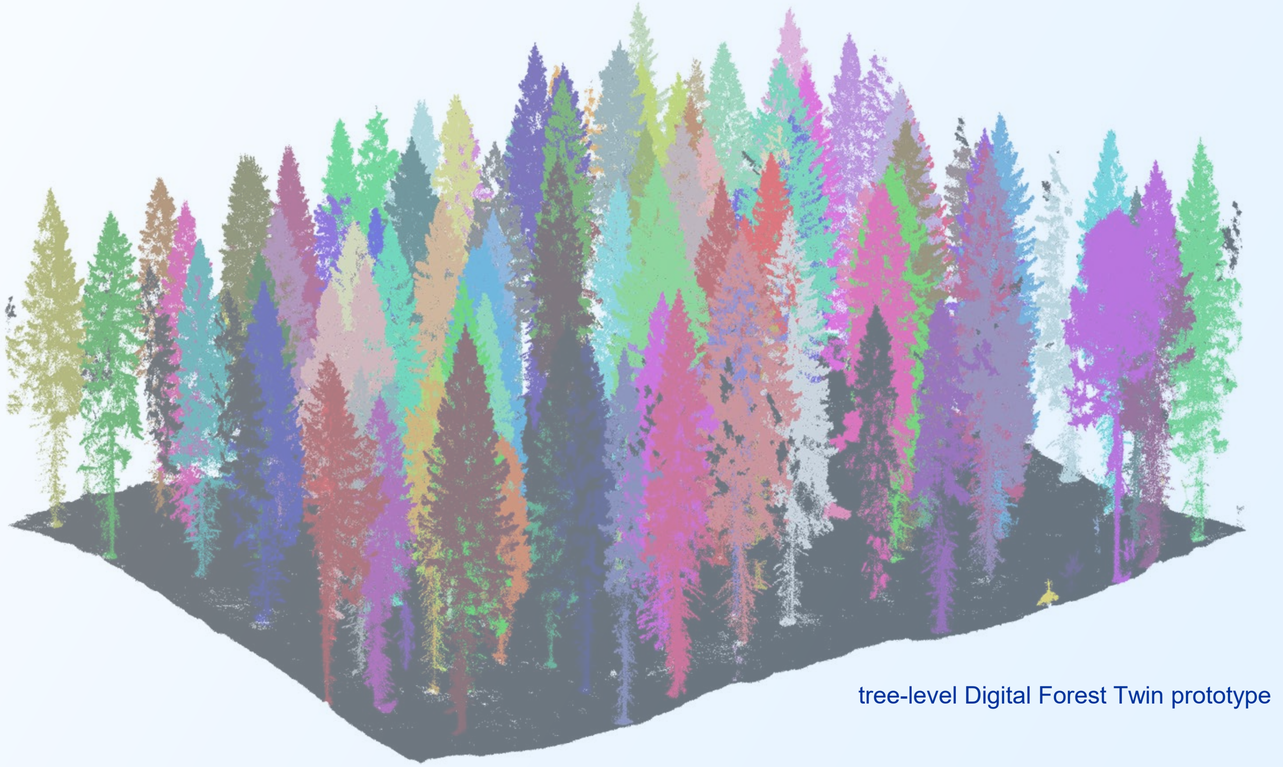
From Forest Carbon Farming to Digital Forest Twins

Making forest carbon farming visible, measurable, and discussable



tree-level Digital Forest Twin prototype

FORESTCARBOVISION Living Lab, Joensuu | 18 May 2026

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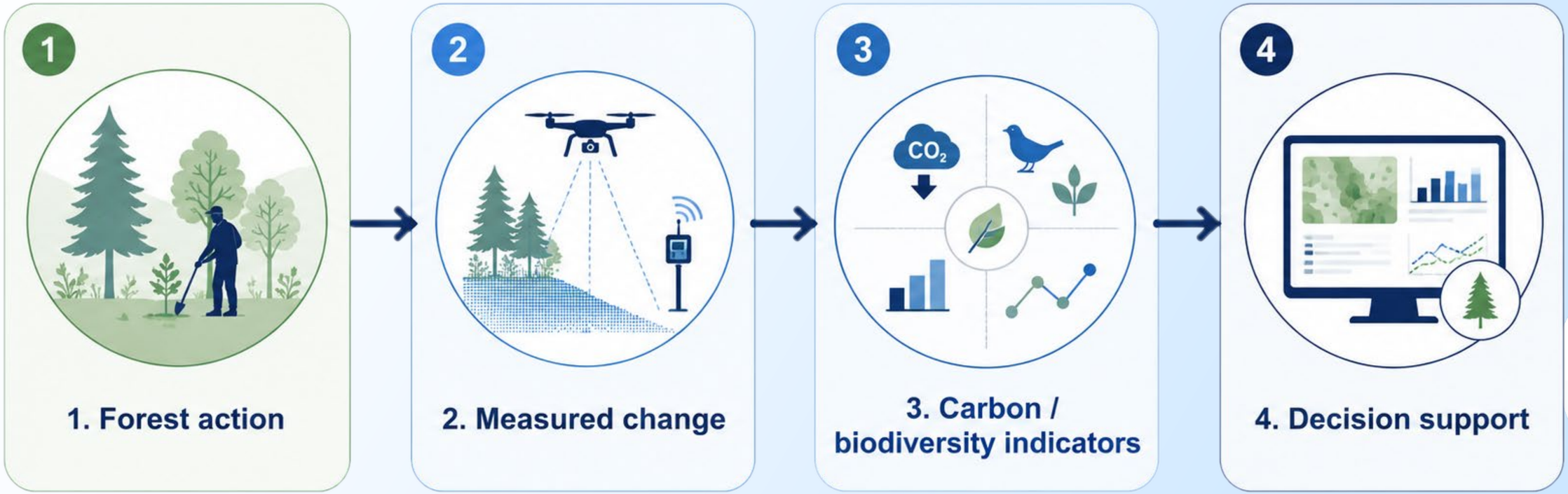
Why forest carbon farming needs a Digital Forest Twin

The key challenge: carbon farming needs trusted evidence

- Carbon farming only works if forest change can be measured and trusted
- MRV must connect field data, remote sensing and management decisions
- Digital Forest Twins turn forest data into decision-ready evidence



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The Digital Forest Twin connects actions, measurements, indicators and decisions.

What we can now demonstrate

From laser data and field measurements to decision-ready forest objects

Today’s working backbone:

1. **Capture**

Laser scanning + UAV data → forest structure data

2. **Structure**

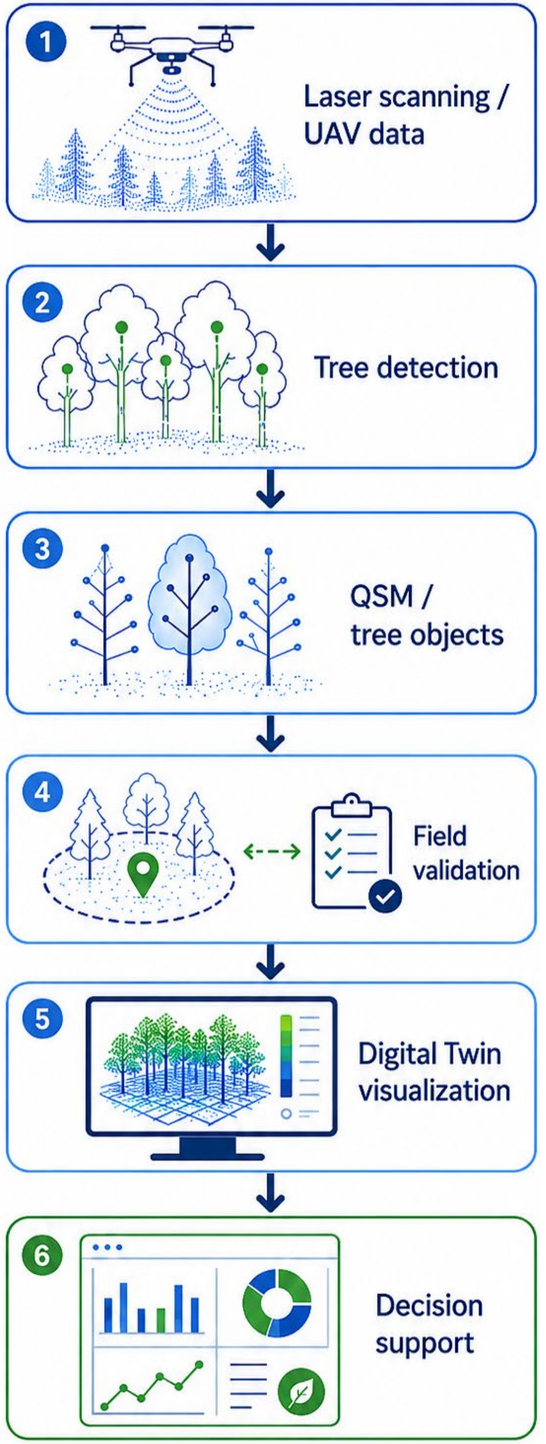
Tree detection + QSM → digital trees

3. **Validate**

Field measurements → linked and validated tree objects

4. **Apply**

Carbon, biodiversity and management indicators → decision support



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Analytical backbone: data → digital trees → indicators → decisions

DIGITAL FOREST TWIN – ANALYTICAL PIPELINE

From raw UAV LiDAR data to actionable forest intelligence

1 Raw UAV LiDAR

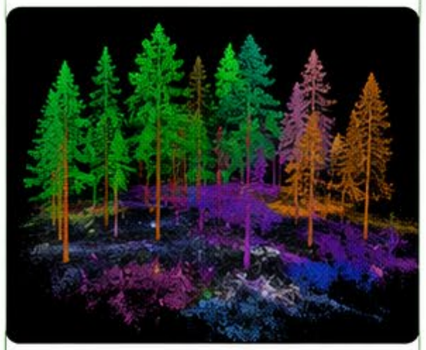
High-resolution LiDAR point cloud

OUTPUT

- Raw point cloud (.las / .laz)

2 Point Cloud Classification

AI-based classification of forest elements



OUTPUT

- Vegetation
- Stems
- Ground
- Other / Noise

3 Stem and Crown Segmentation

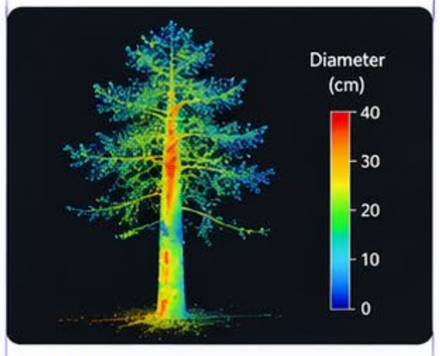
Individual tree detection and component segmentation

OUTPUT

- Tree objects (ID)
- Stem & crown segments

4 QSM Reconstruction

Quantitative Structure Model reconstruction

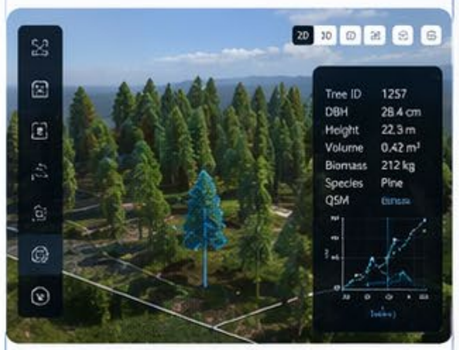


OUTPUT

- QSM models (.ply)
- Tree metrics (DBH, H, V, ...)

5 Web Visualization / Digital Twin Layer

Interactive visualization and analysis in web environment



OUTPUT

- Web map / 3D viewer
- Tree-level analytics & insights

Tree-level understanding
individual trees and structure

Scalable & repeatable
from plot to landscape

Supports decisions
carbon, management, biodiversity

Transparent & auditable
data-driven MRV

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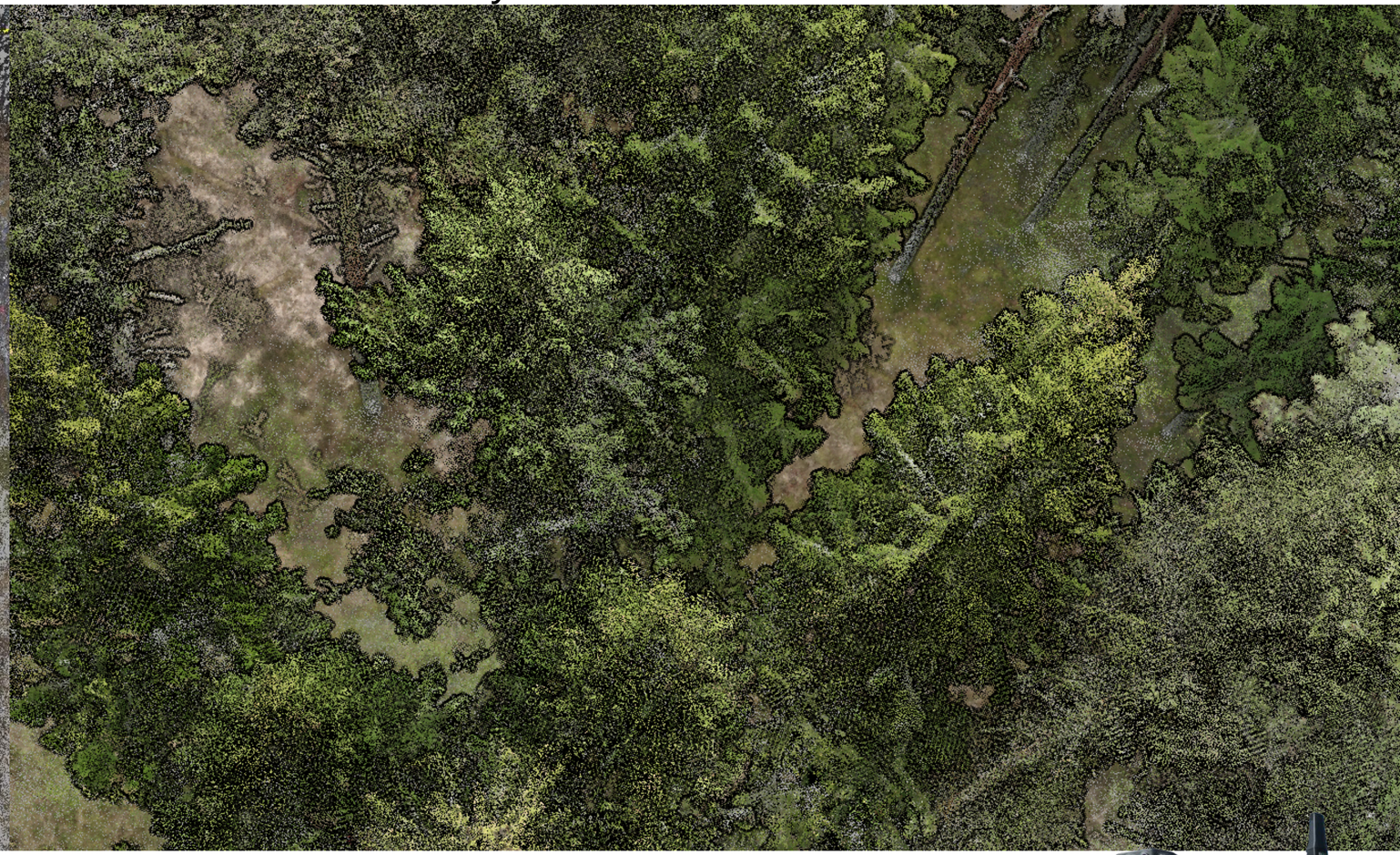
The key step is moving from forest data to validated digital tree objects.

Joensuu Living Lab: multi-source forest data

Linking laser scanning, UAV data and field measurements on the same City of Joensuu forest site

Ground laser scanning



UAV canopy view

- Laser scanning → stem and lower-canopy structure
- UAV data → canopy view and spatial context
- Field measurements → calibration and validation

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Same site, three perspectives: stem structure, canopy context and field validation

From point clouds to measurable tree objects

QSM transforms 3D observations into measurable tree structure for volume, biomass and carbon estimation

QSM = Quantitative Structure Model

- Point clouds are observations
- QSM creates measurable digital trees
- Measurable trees can support carbon, biodiversity and management indicators

Tree structure → volume → biomass → carbon

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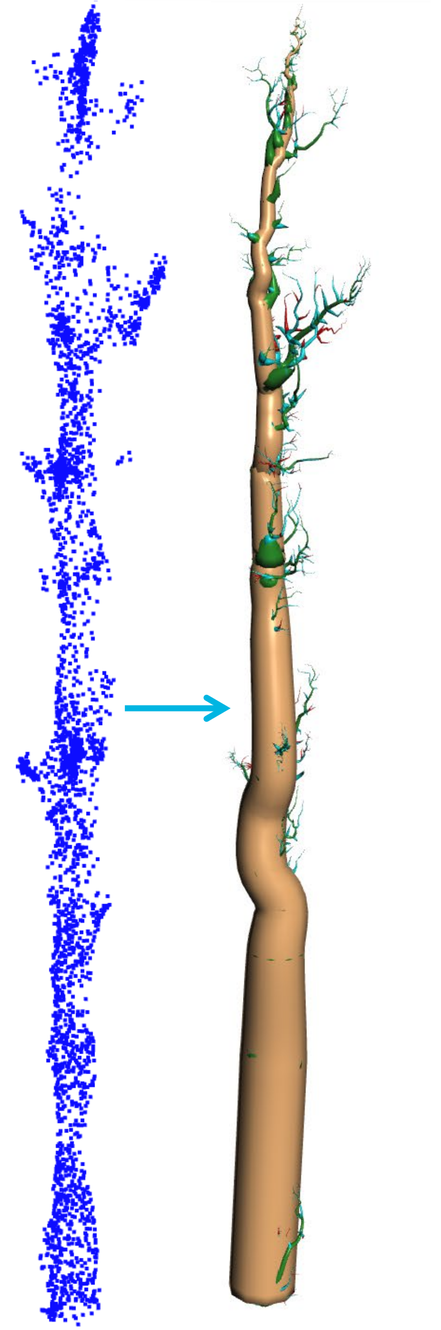
QSM is the bridge between forest visualization and forest measurement.



Point cloud raw 3D observations

QSM measurable tree structure

Live Demo: Digital Forest Twin Prototype

- Forest area visualization
- Tree-level objects
- Field measurement points
- Matching between measured and digital trees
- First step toward carbon and management indicators
- **Prototype focus today: workflow demonstration, not final carbon verification.**

Demo order

1. Open prototype
2. Show forest area Show tree objects / QSM
3. Show field points
4. Show matched examples
5. Show how this could become decision support

DIGITAL FOREST TWIN CORE

Integrated data, models and analytics

3D FOREST VIEW

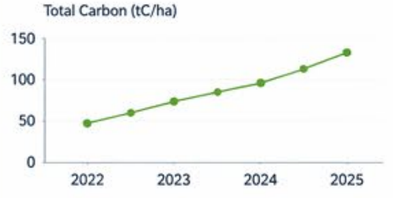
TREE ATTRIBUTES TABLE

Tree ID	Species	DBH (cm)	Height (m)	Volume (m³)	Biomass (kg)	Carbon (kg)	Status
T_0001	Pine	32.4	24.1	0.81	402	201	Live
T_0002	Pine	28.7	22.3	0.62	310	155	Live
T_0003	Spruce	26.1	20.8	0.48	240	120	Live
T_0004	Pine	35.6	26.7	1.05	520	260	Live
T_0005	Birch	18.3	16.4	0.23	110	55	Live
...	...	...	...	...	...	...	...

Total trees: 1,248 Total biomass: 512,430 kg Total carbon: 256,215 kg

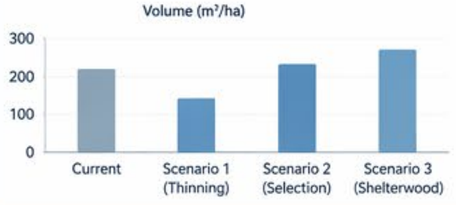
CARBON MRV

- Tree-level biomass & carbon
- Scalable monitoring
- Audit-ready reporting



FOREST MANAGEMENT SCENARIOS

- Thinning & harvesting scenarios
- Growth and yield projections
- Impact assessment



BIODIVERSITY / STRUCTURE INDICATORS

- Species diversity
- Vertical structure
- Habitat quality metrics

ECONOMIC & OPERATIONAL DECISION SUPPORT

- Timber value estimation
- Cost and revenue analysis
- Operational planning

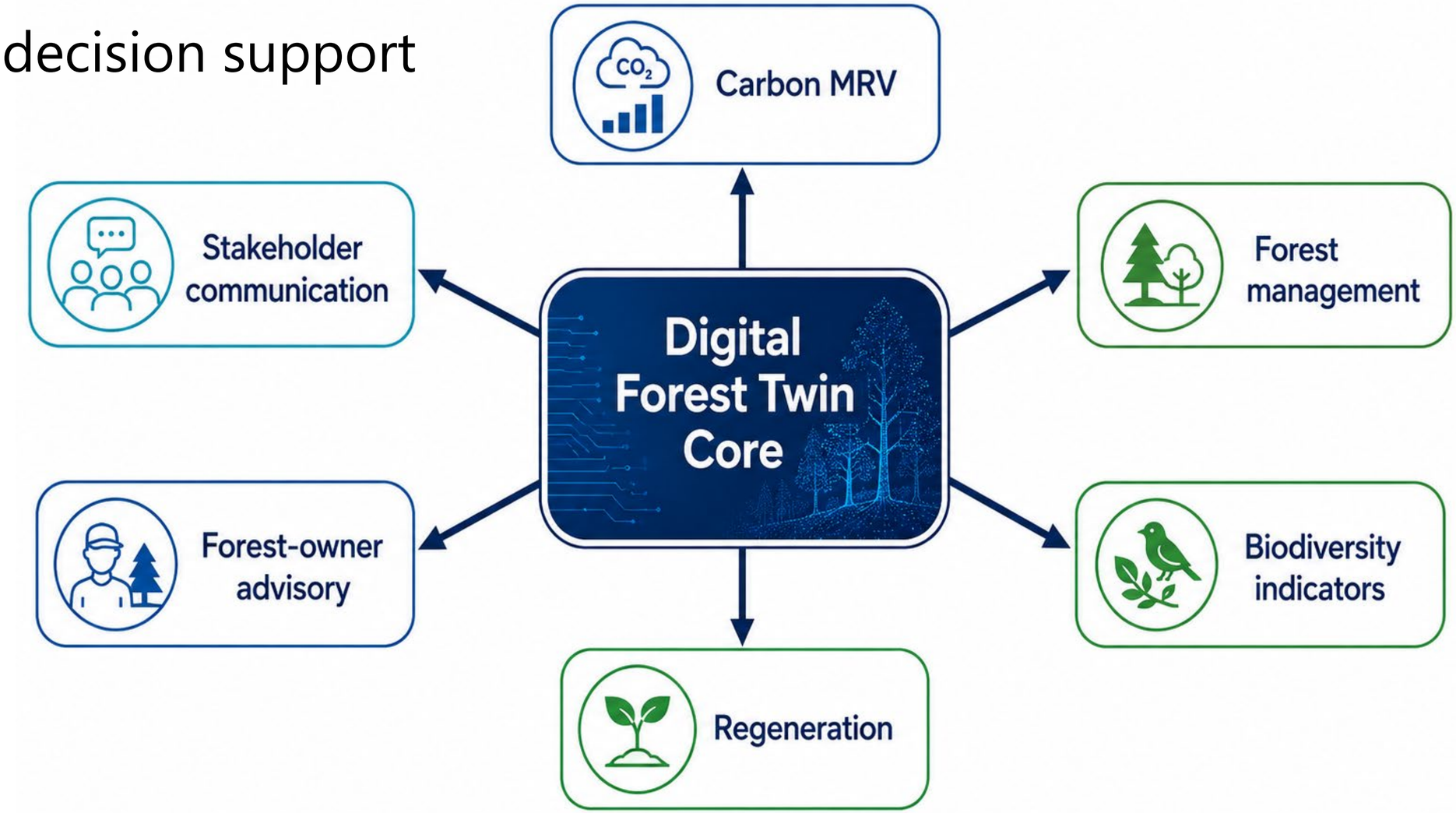
This is not only a nice 3D model — it is a decision system.

What Digital Forest Twins enable for forest carbon farming

From visualization to decision support

Digital Forest Twins can support:

- Monitoring: carbon MRV, regeneration, biodiversity and deadwood
- Management: thinning scenarios and forest-owner advisory
- Communication: transparent outputs for stakeholders and decision-makers



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This is not just a 3D model — it is a decision-support system in development.

From measured forest change to trusted carbon evidence

Laser scanning

Data Processing

Digital Twin & Carbon Calculation

Precision Growth Maximizer

Blockchain Storage

Marketplace Sale

Luke

Why This Matters for Stakeholders

Different users need different decisions — but the same trusted evidence

- Forest owners — compare management options
- Metsäkeskus — support advisory and planning
- SYKE — improve monitoring and indicators
- City of Joensuu — communicate urban and peri-urban forest values
- Project partners — transfer the workflow to other Living Labs

Stakeholders and project partners

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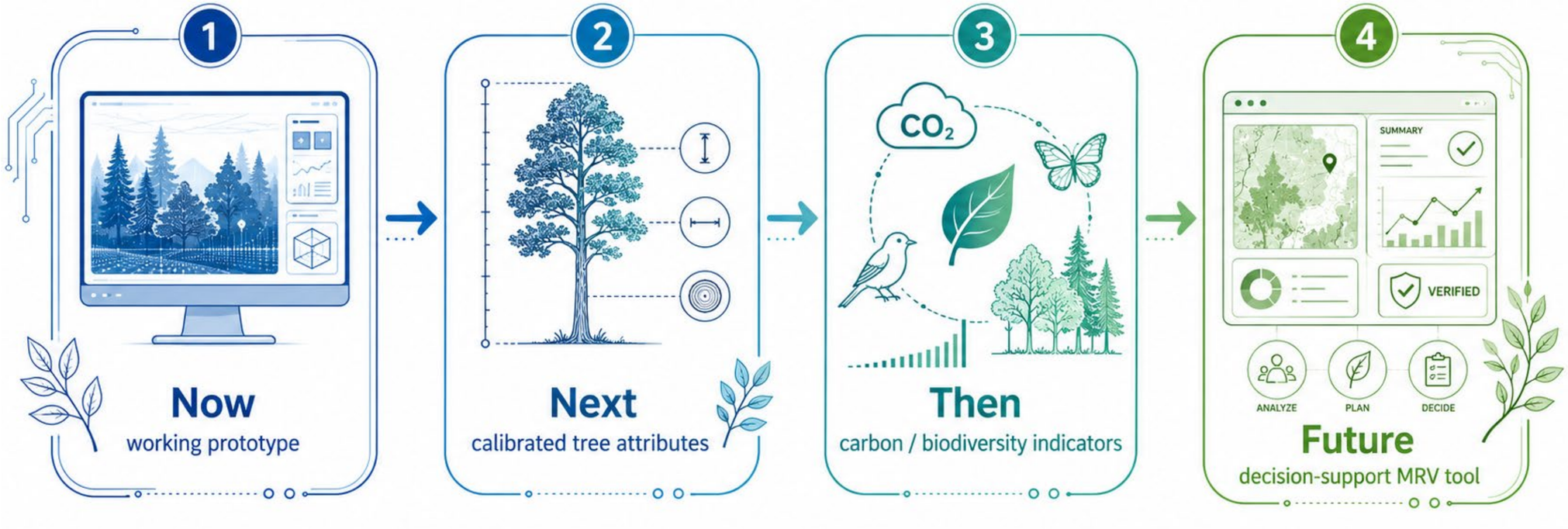
Digital Forest Twin = shared visual evidence layer for carbon farming decisions

From prototype to validated MRV workflow

What we need to improve next

- Full processing of available datasets
- Improved matching between field trees and digital trees
- Calibration of tree attributes with field measurements
- Carbon and biodiversity indicators
- More user-friendly decision-support views



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Today we show the working backbone. The next step is validation and calibration.

Living Lab Question

What should we build first?

The Living Lab helps us decide:

- Which decisions matter most?
- Which indicators are most useful?
- Which outputs are understandable?
- What would increase trust?
- What should be tested next?

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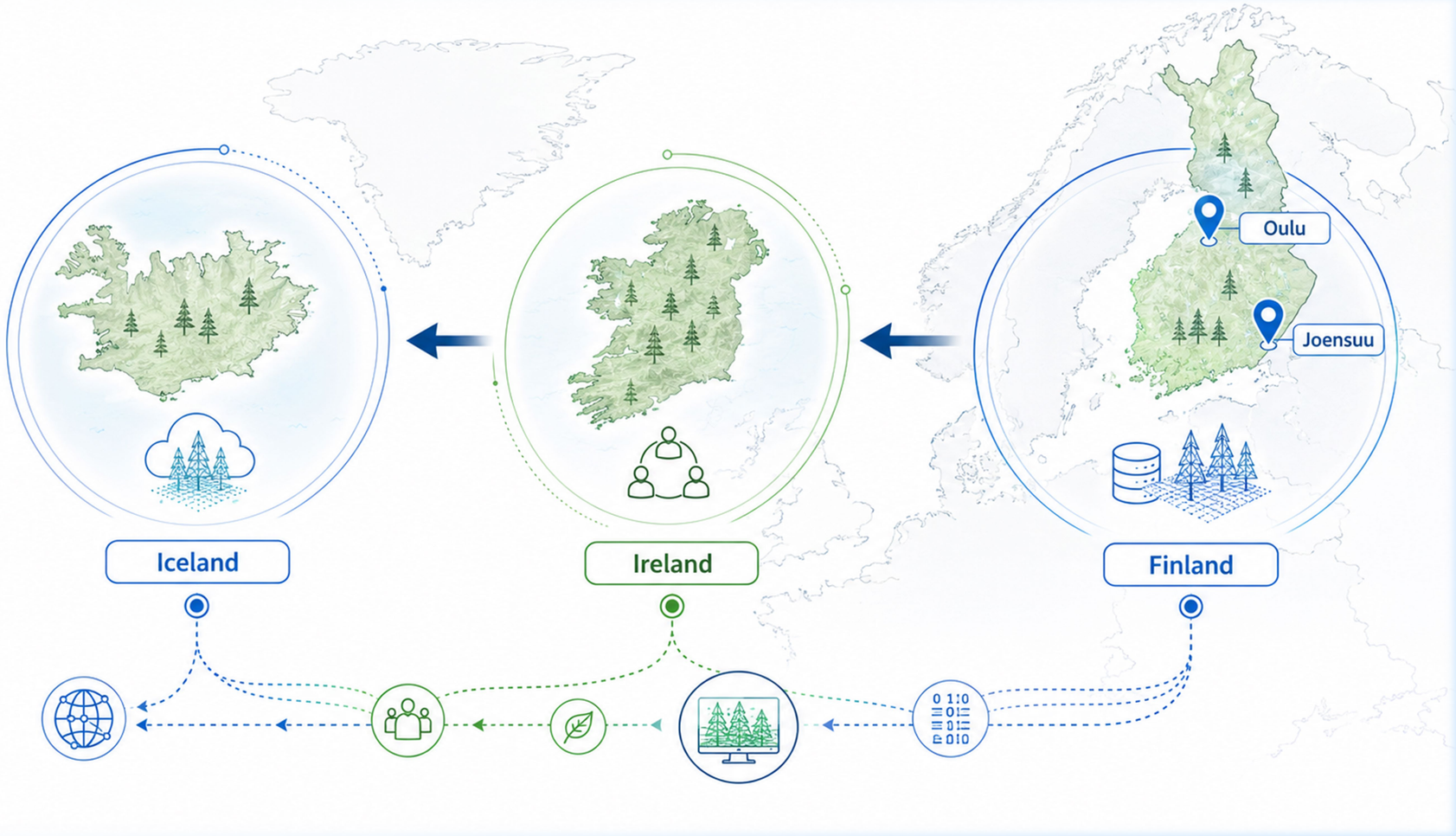
Next Steps

From Joensuu demonstration to transferable FORESTCARBOVISION workflow



- Improve Digital Forest Twin prototype
- Validate tree-level attributes with field data
- Develop carbon / biodiversity / management indicators
- Test with forest owners and stakeholders
- Transfer lessons to Finland, Ireland and Iceland Living Labs

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Key Takeaway

Digital Forest Twins can make forest carbon farming visible, measurable and discussable

1. We now have a working data-to-digital-tree pipeline
2. Field measurements and remote sensing can be connected
3. The prototype opens a path toward transparent MRV
4. Living Labs help define useful decisions and trusted outputs

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From forest data to stakeholder-ready carbon farming evidence.