The Challenge: Why Stratify?

- ü **Meets Regulatory Requirements:** Carbon Estimation Area (CEA) delineation and Stratification under the 2021 Soil Carbon Method.
- ü ***Improves Statistical Power:*** Enhances detection of real SOC changes by reducing variance.
- ü ***Minimises Credit Penalties:*** Lowers uncertainty to reduce PoE-based discounting.
- ü ***Cuts Sampling Costs:*** Requires fewer samples to achieve precision targets.
- ü **Follows Best Practice:** Consistent with soil science and carbon accounting standards globally.

Our Fantastic Farms (And Farmers!)

Case Study	Farming system	Avg. Rainfall (mm)	CEA No.	CEA Size (ha)	Dominant Texture Class	SOC (%) 0-30 cm	SOC (%) Variance	SOC Sample Size (n)	Sampling Density (ha)
1 (Kendenup)	Mixed (Cattle/Cropping)	814 mm	1	153.07	Sandy Clay	1.1	0.06	21	0.22
2 (Northampton)	Cattle	365 mm	3	624.15	Sand	0.37	0.01	45	0.13
3 (Badgingarra)	Mixed (Sheep/Cropping)	515 mm	2	367.51	Sand	0.56	0.05	60	0.12

What We Did: Defining & Assessing Stratification

Tested two stratification approaches

Unsupervised: Based on composite surface rasters

Supervised: Builds predictive models trained on measured SOC and surface rasters

Key questions:

1. Which one better aligns strata with actual SOC distribution?
2. If the answer isn't obviously "the supervised one!" — why not?
3. Where the supervised approach reduces variance **in some areas but not others** — what's driving that?

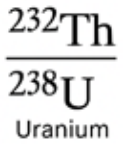
Example Surface Rasters

Texture: Clay/Silt/Sand

Topographical wetness

Vegetation indices (EVI, TSAVI, NDVI)

Topography (Slope, Elevation)



Radiometrics (U, Th, K)

Unsupervised: “Blind to Carbon”

Informed Raster Selection

- Assess covariates
- Weight rasters (ML approach)

Stratification

- K-Means Clustering
- Non-spatially contiguous strata (n=3)

Allocate Random Samples

- Unbiased, random
- How many?

Assumes: *“Pixels that look similar likely have similar SOC”*

We Oversampled On Purpose

This allowed us to:

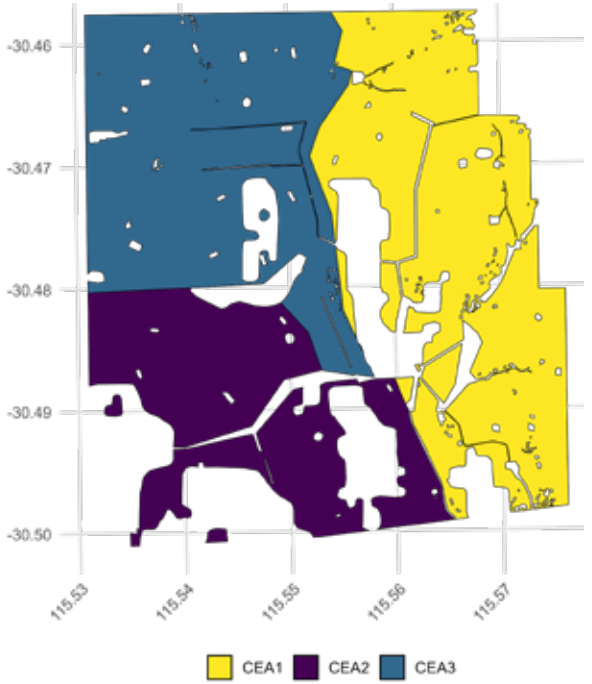
✓ Quantify actual variance within and between strata

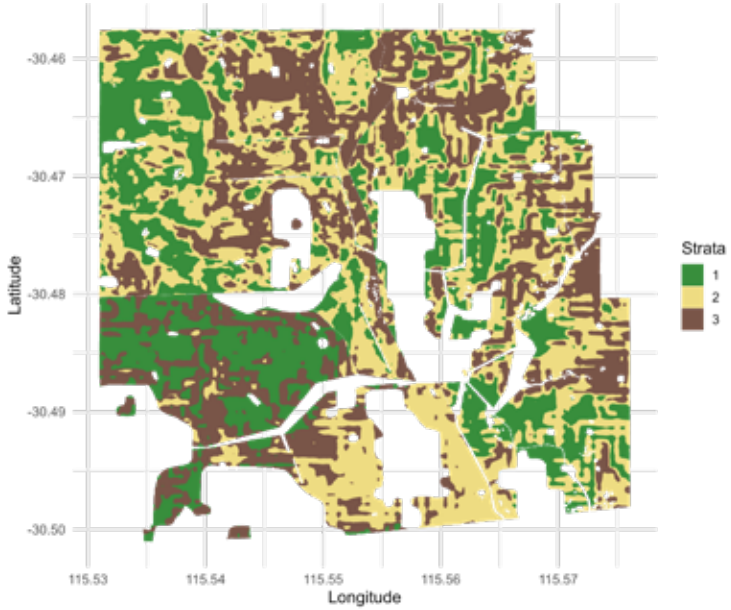
✓ Test if stratification reduced variance

✓ Compare unsupervised *vs* supervised stratification using real SOC data

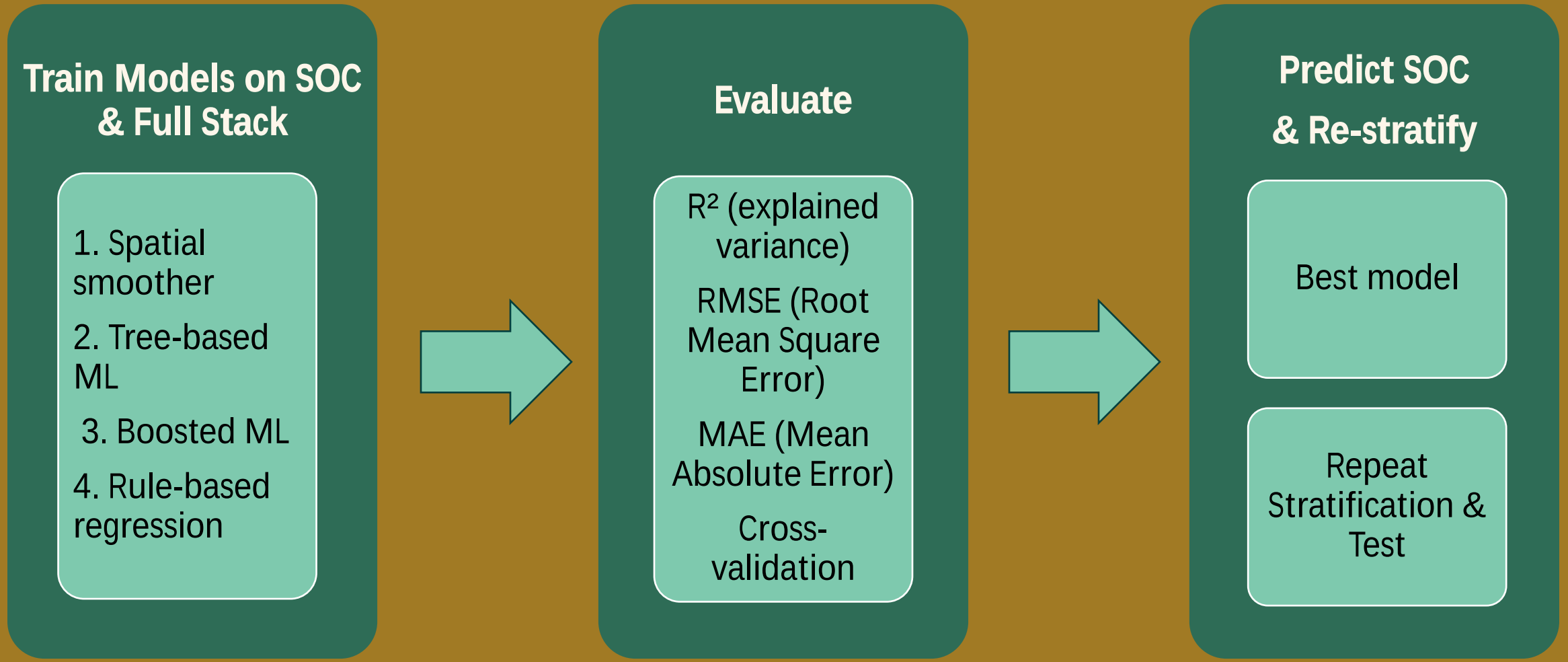
Most developers don't do this — they stop at minimum compliance

Stratification is **only useful if tested** — and that takes data.





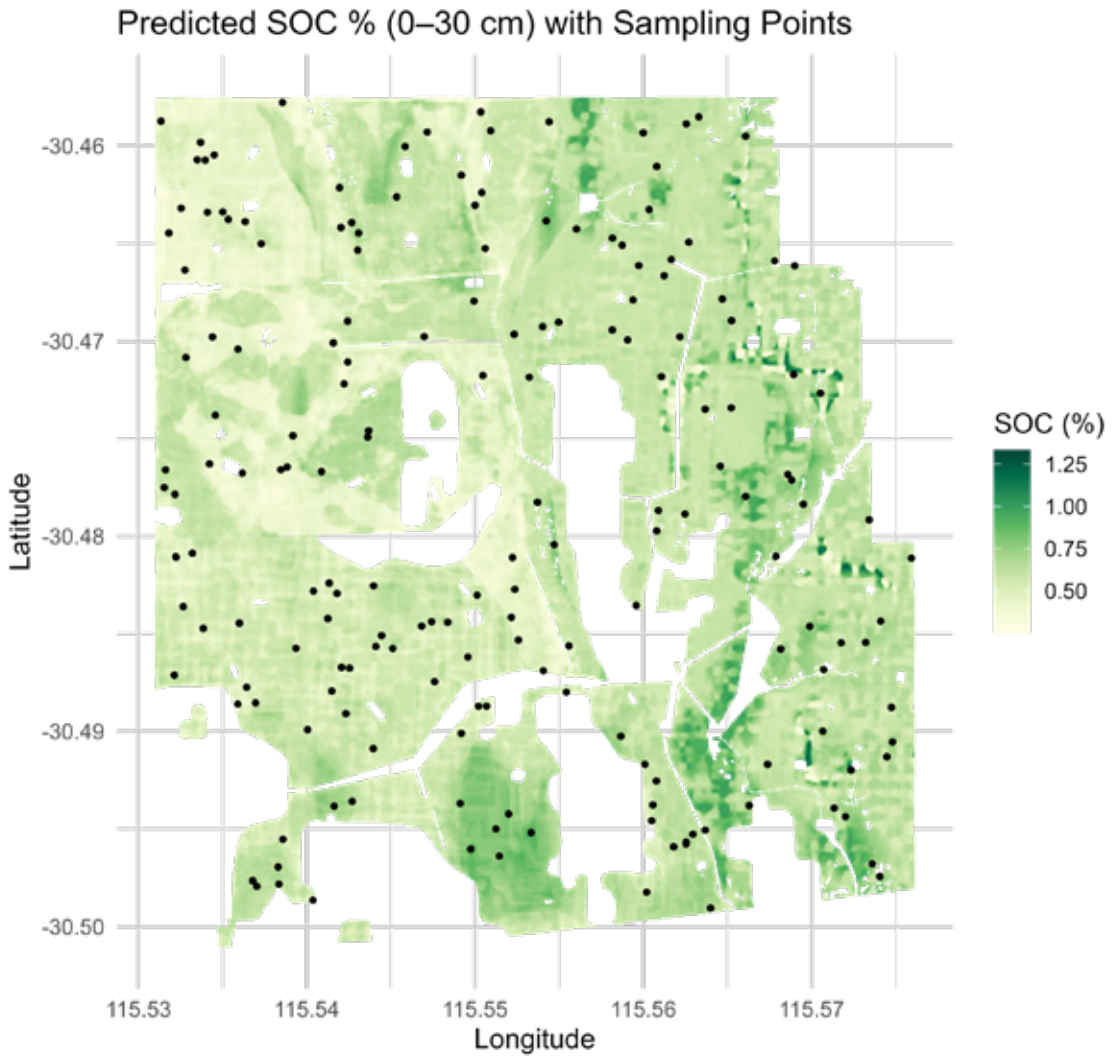
Supervised: Trained on SOC



"Which pixel patterns actually predict SOC — and which don't."

Final Model SOC Prediction

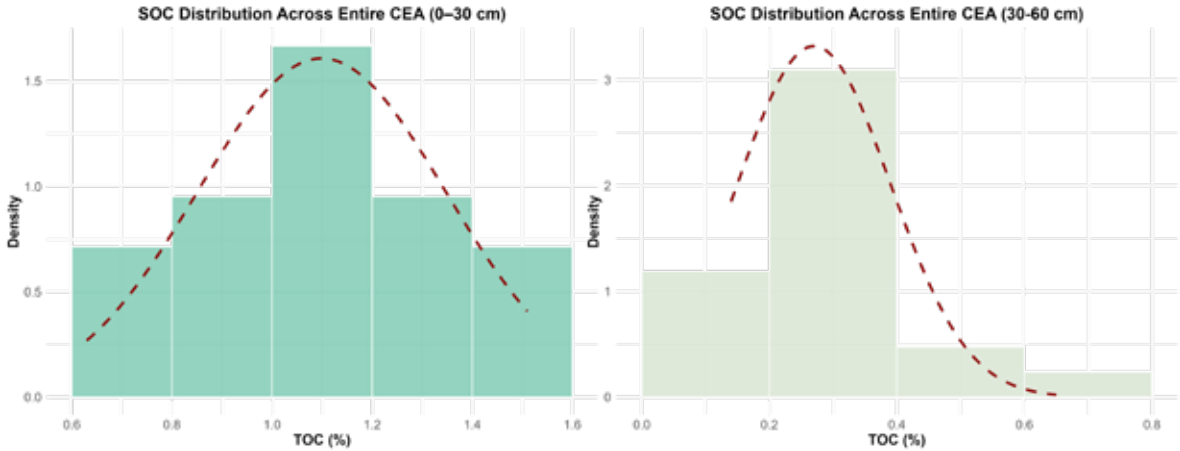
- ü Predicted SOC % (0–30 cm) across the full landscape
- ü Based on best-performing model or ensemble
- ü Used as the foundation for supervised stratification



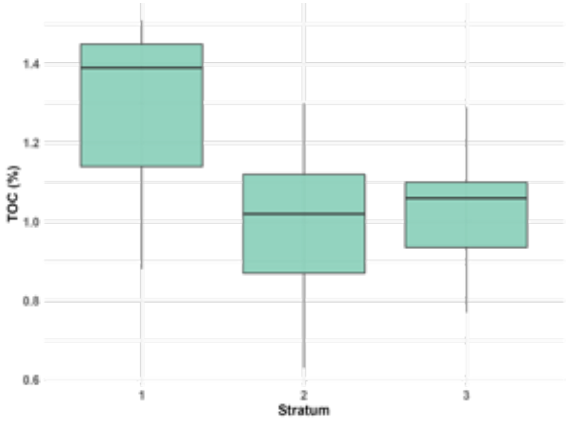
Results: Unsupervised *vs* supervised stratification

Property	CEA	Depth	Method	CEA-level Variance	Stratified Variance	Variance Reduction (%)
Kendenup	1	0-30 cm	Unsupervised	0.06	0.05	20.38
Kendenup	1	30-60 cm	Unsupervised	0.01	0.01	3.96
Kendenup	1	0-30 cm	Supervised	0.06	0.01	78.91
Kendenup	1	30-60 cm	Supervised	0.01	0.01	2.76
Northampton	3	0-30 cm	Unsupervised	0.01	0.01	18.58
Northampton	3	30-60 cm	Unsupervised	0.00	0.00	4.14
Northampton	3	0-30 cm	Supervised	0.01	0.01	51.75
Northampton	3	30-60 cm	Supervised	0.00	0.00	18.87
Badgingarra	3	0-30 cm	Unsupervised	0.05	0.04	17.84
Badgingarra	3	30-60 cm	Unsupervised	0.01	0.01	-2.19
Badgingarra	3	0-30 cm	Supervised	0.05	0.02	62.65
Badgingarra	3	30-60 cm	Supervised	0.00	0.00	-2.06

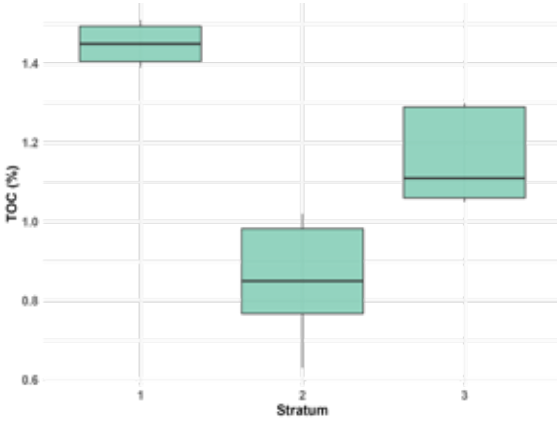
Kendenup (CEA1)



Unsupervised



Supervised



Sandy Soils Are Hard to Stratify: Here's What Worked

Factor	Kendenup	Northampton	Badgingarra
Inherent SOC variance	🟢 High	🔴 Low	🟡 Moderate
SOC–covariate alignment	🟢 Strong (Moisture-driven)	🟡 Moderate (Terrain/gamma)	🔴 Latent/complex (not visible to clustering, but modelled well)
Landscape heterogeneity	🟡 Moderate	🟢 High	🔴 Low
Unsupervised effectiveness	🟢 Moderate	🟢 Moderate	🟡 Partial
Supervised gain	🟢 +58.5%	🟡 +33.2%	🟢 +44.8%

⚠ Caveat: Results depend on the accuracy of input rasters.

If rasters poorly reflect real conditions, stratification and model performance may be misleading — especially for unsupervised methods.

Key takeaways for sandy soils

Low SOC ≠ low potential

- Small changes are proportionally meaningful
- But they’re hard to detect without good design

Stratification is harder — but arguably more important

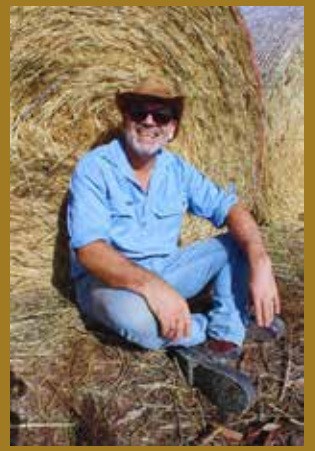
- Weak surface signals in sandy soils
- Unsupervised often fails
- Supervised methods can recover subtle patterns

This is where the method gets tested

- Sandy, uniform soils may dominate future project areas
- Stratification needs to be high-resolution, data-informed, and defensible

CARBON SYNC Thanks You!!

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