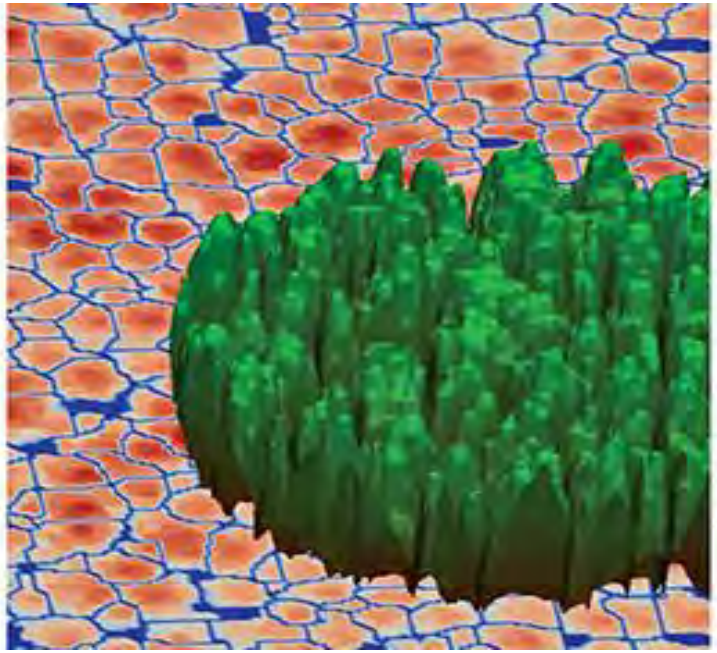
Growing confidence in forestry's future Research Programme

SCION
FORESTS | PRODUCTS | INNOVATION

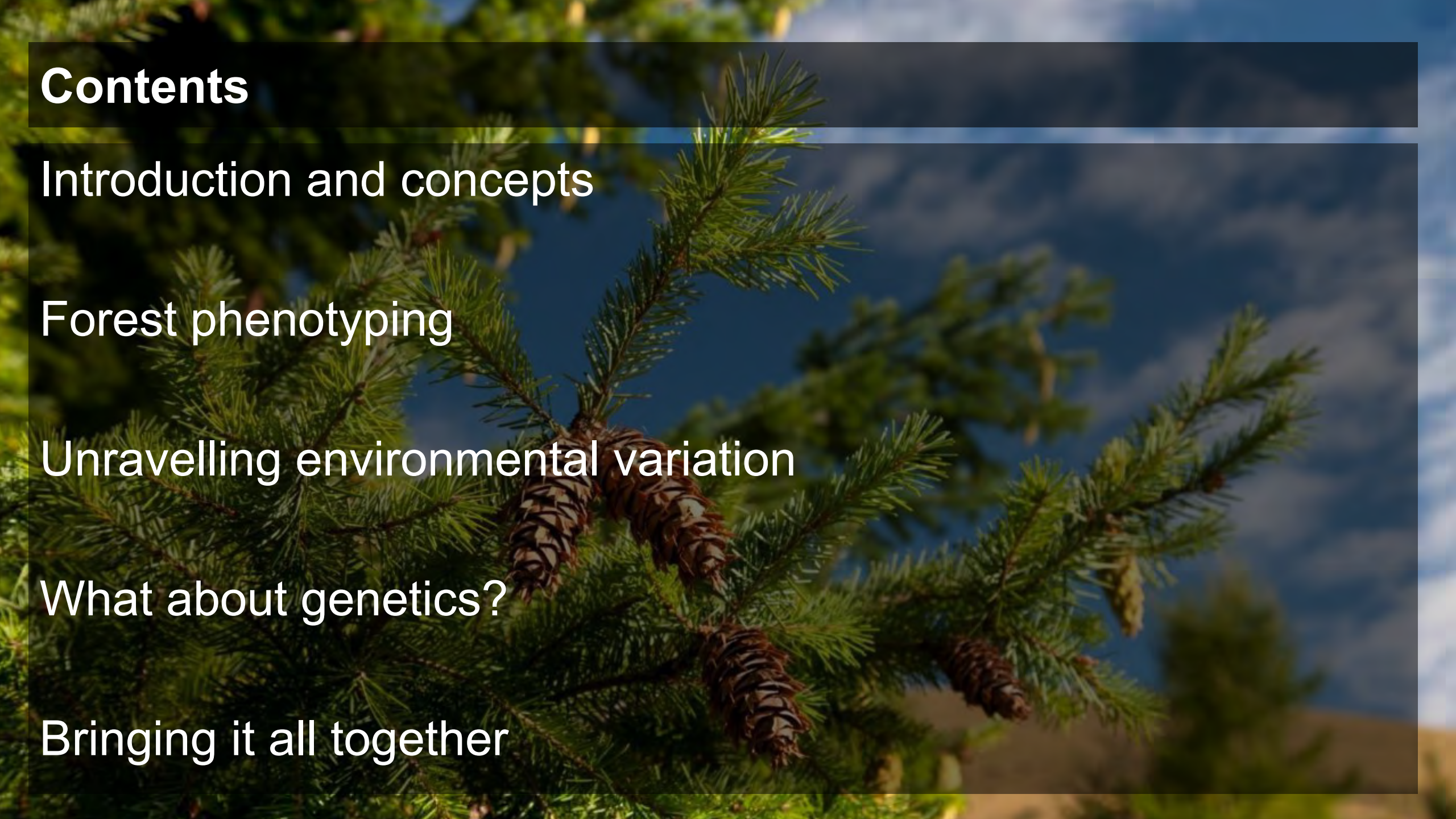
From concept to implementation: the evolution of forest phenotyping


Authors: Jonathan Dash, Heidi Dungey, Emily Telfer, Michael Watt, Peter Clinton, Ben Aves

supported by forestgrowers commodity levy

FOREST GROWERS RESEARCH



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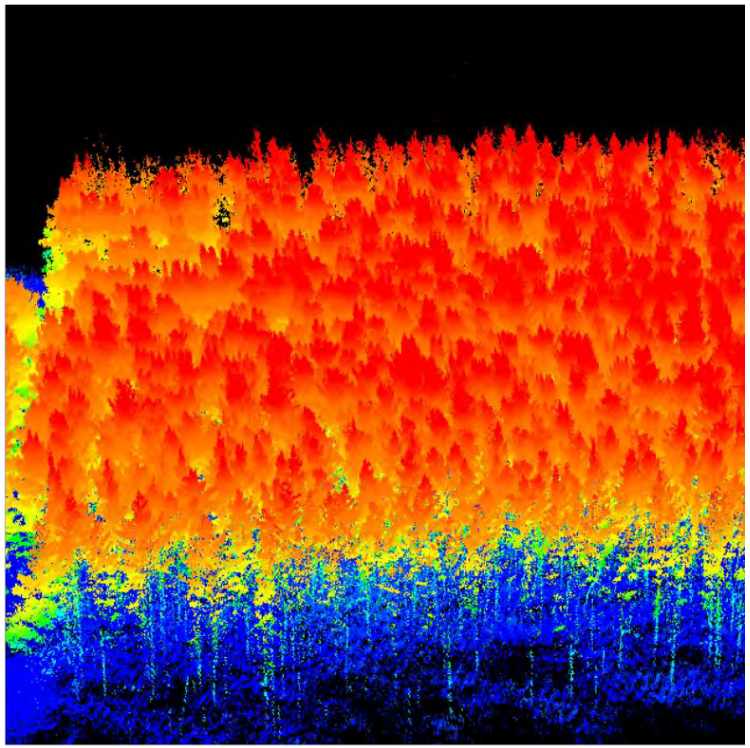
Introduction and concepts



Background

Phenotyping is the detailed quantitative description of plant traits.

In this research a 25 m patch was used.

A phenotyping platform is a framework that integrates phenotypic information with other data to provide useful inference.

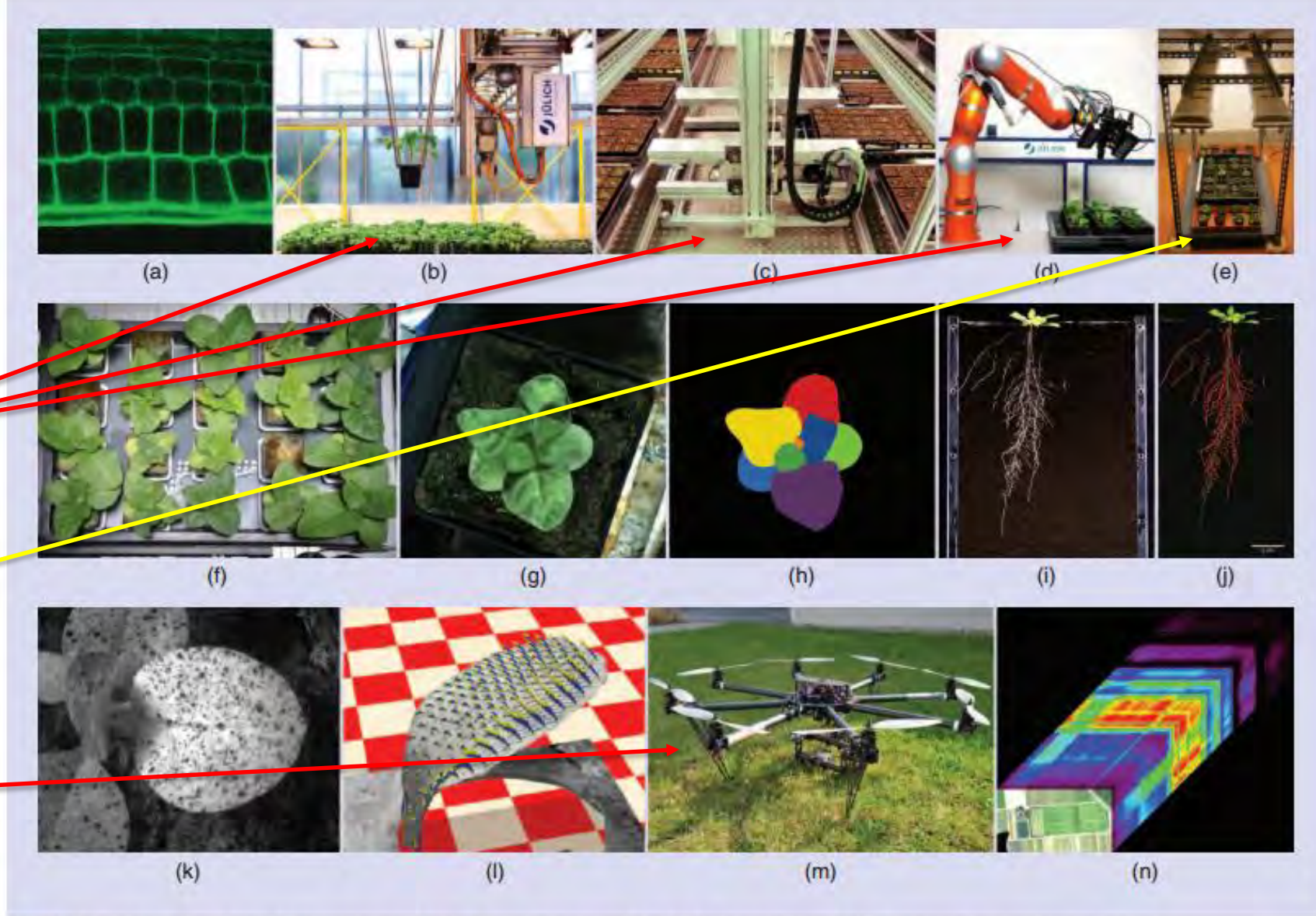
Phenotyping has significantly accelerated gain from genetic research in the agricultural sector.

Many sensors and platforms have been developed for plant phenotyping

Movable imaging setups

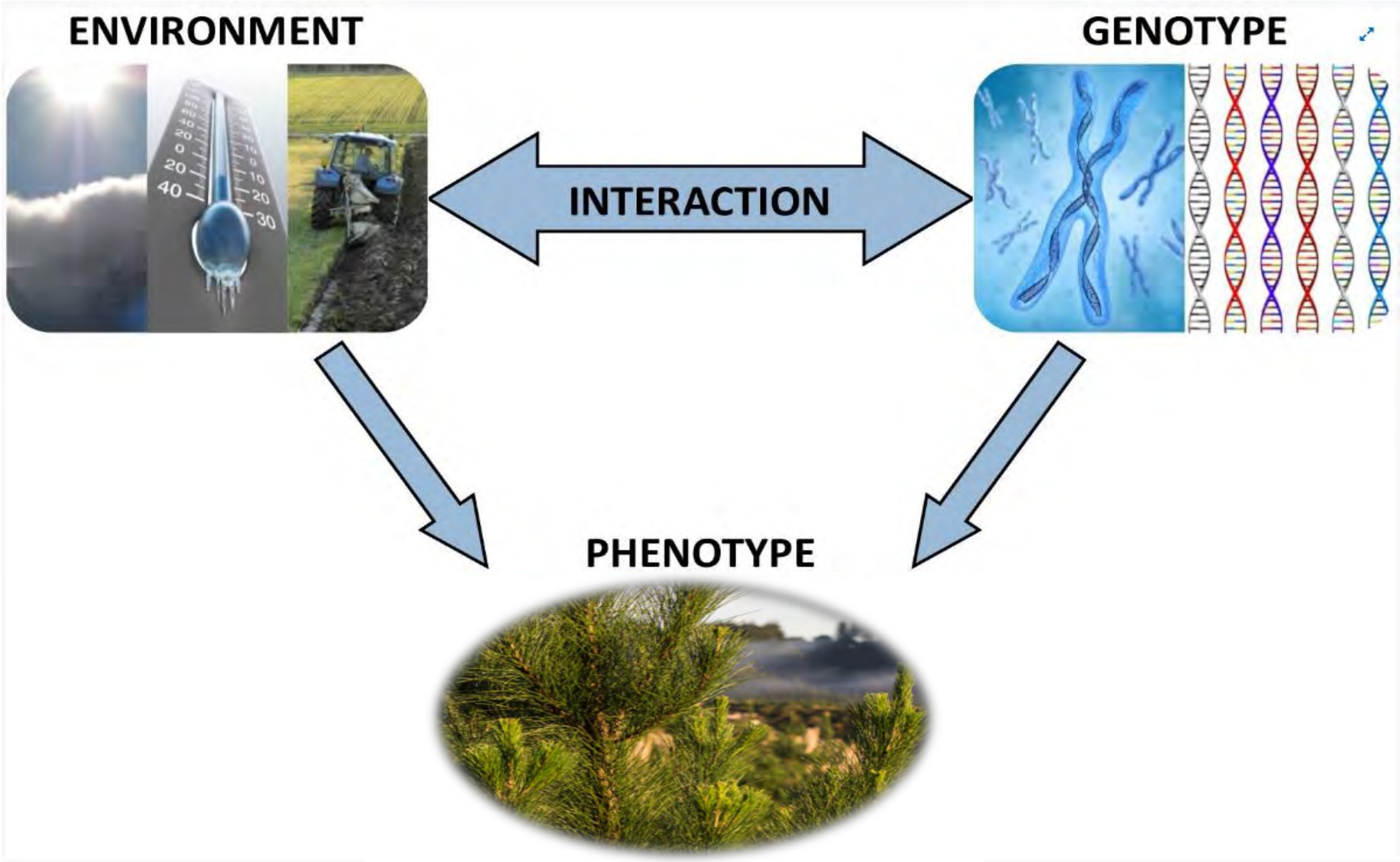
Single overview camera

UAV

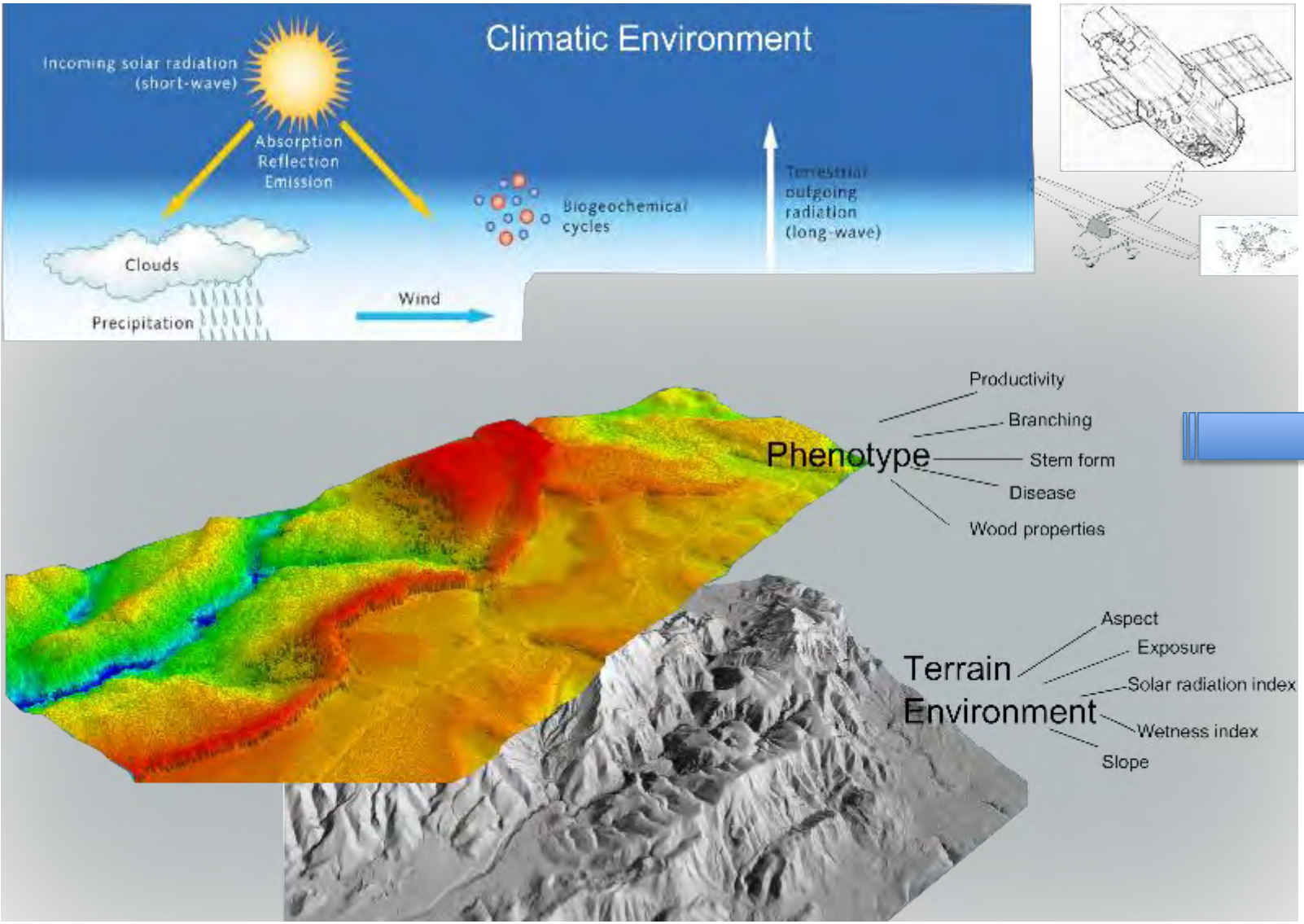


[FIG1] An example of plant phenotyping setups and images. (a) At the smallest scale, microscopy can image cells. (b)–(d) Movable imaging setups [15] or a (e) single overview camera setup can be used to image (f) many plants or (g) single plants, where (h) leaf segmentation is a sought-after outcome yielding growth measurements. Roots can be imaged in (i) rhizotrons [15], requiring (j) delineation. (k)–(l) Optical flow tracking [15] can measure finer leaf level growth. Airborne vehicles, e.g., (m) drones, can provide information on fields, e.g., (n) hyperspectral images [15]. [(a) is adapted from [7] and reproduced by permission of Elsevier. (b), (c), and (m) are courtesy of Alexander Putz, (i) and (j) are courtesy of Kerstin Nagel, and (n) is courtesy of Uwe Rascher.]

In-forest phenotyping platform will provide information on all there of these – A new concept for plantation forestry



We have built a prototype for a landscape scale phenotyping platform



Genotype

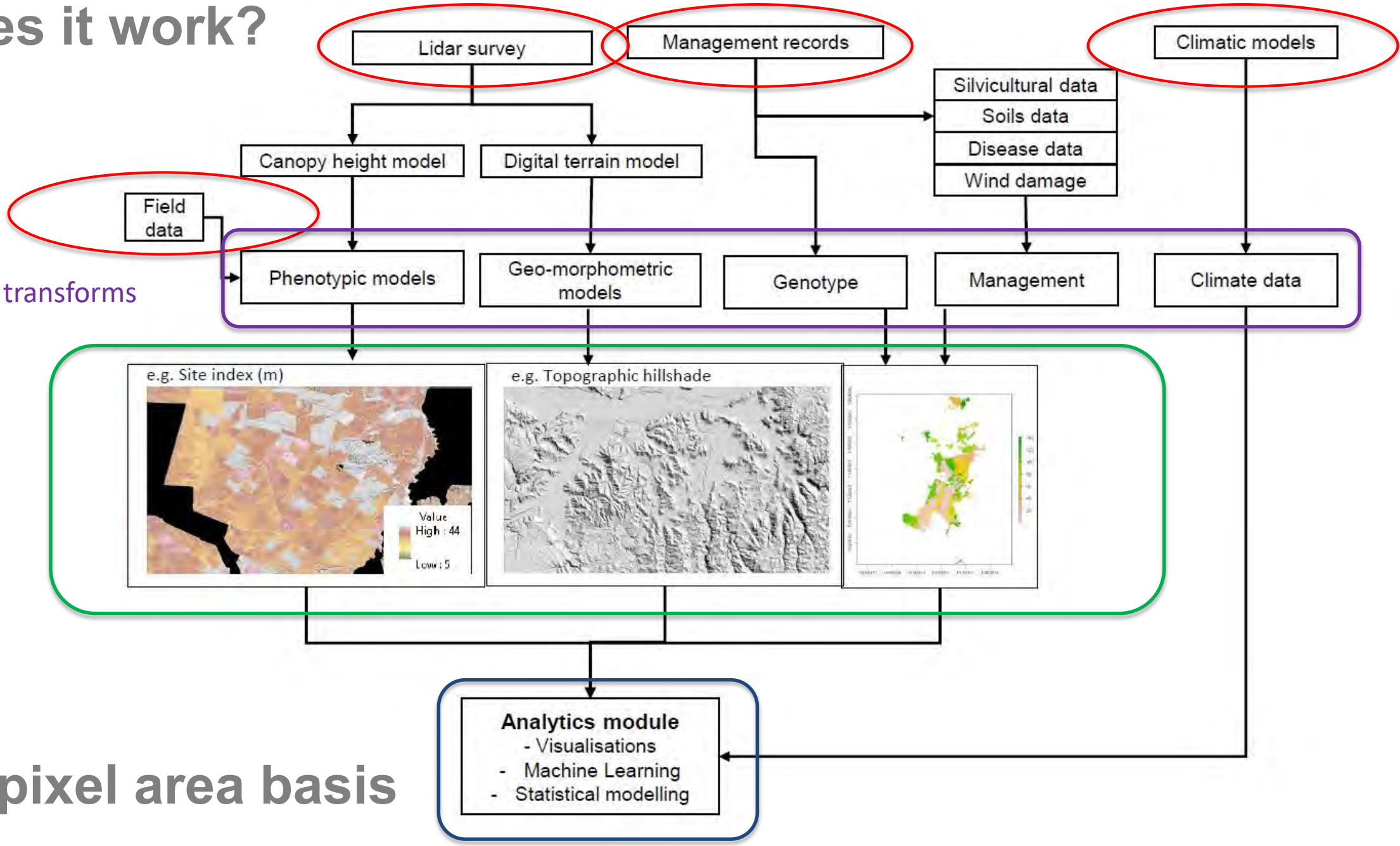
Analysis Platform

How does it work?

Inputs

Modelling and transforms

Extraction layer



A 25 m pixel area basis

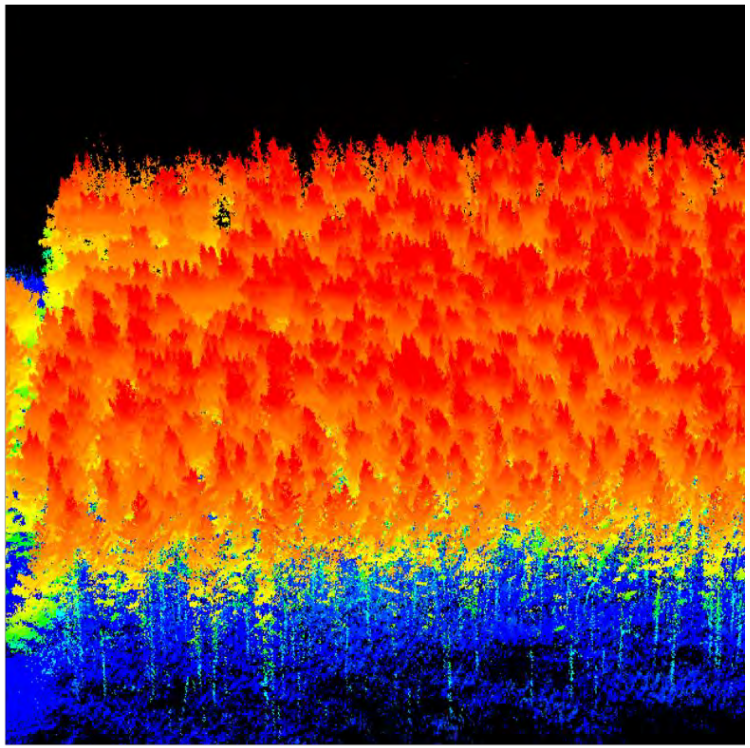

Kaingaroa
Rotoaira
Lake Taupo

Phenotyping for plantation forestry is being enabled by emerging technologies

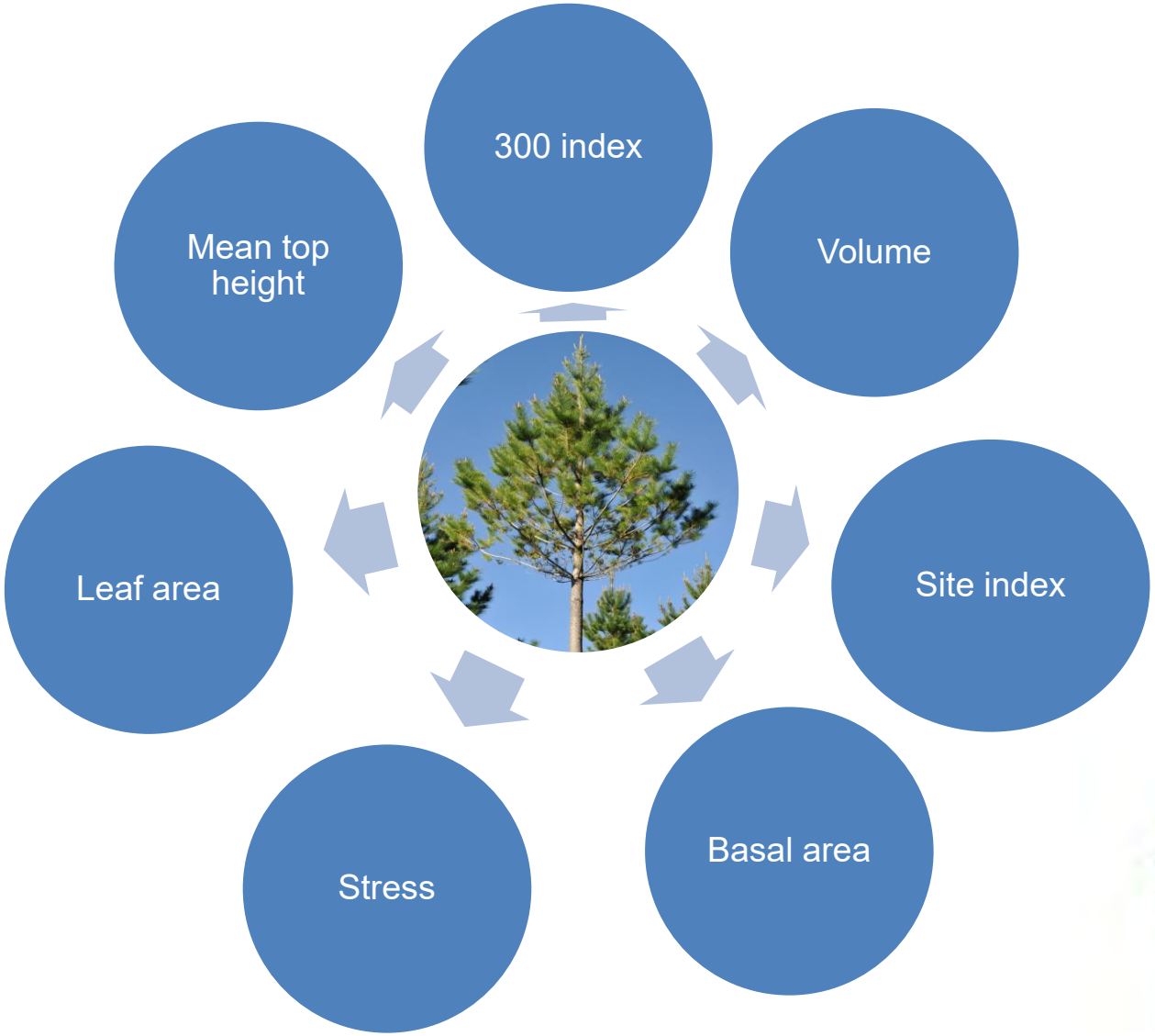
- Advances in remote sensing,
- Emergence of the field of data science, HPC, and good quality algorithms,
- Detailed spatial stand record keeping,
- Tree breeding programmes.

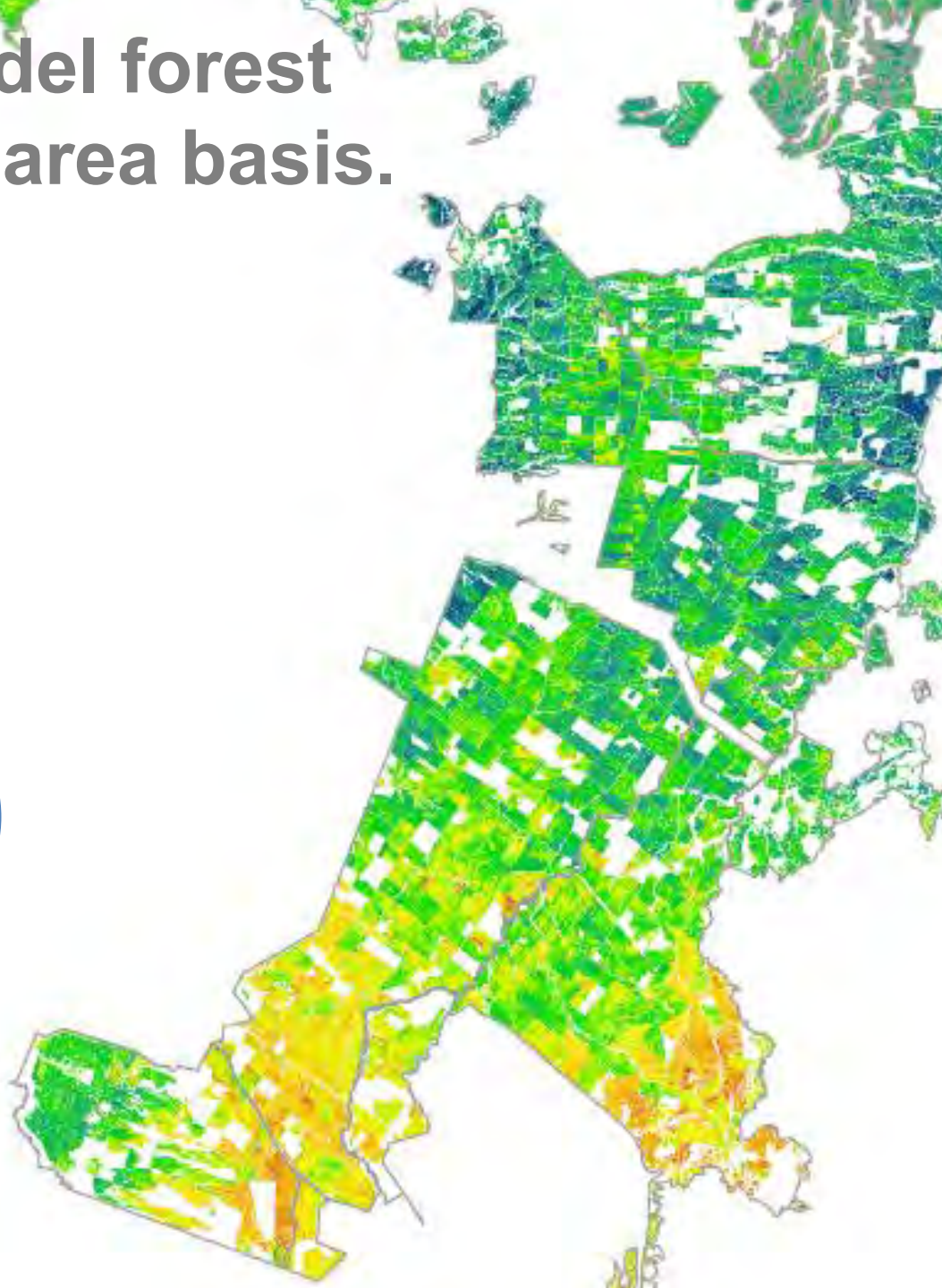
A landscape scale sensor-to-plant phenotyping platform is a possibility for plantation forests.

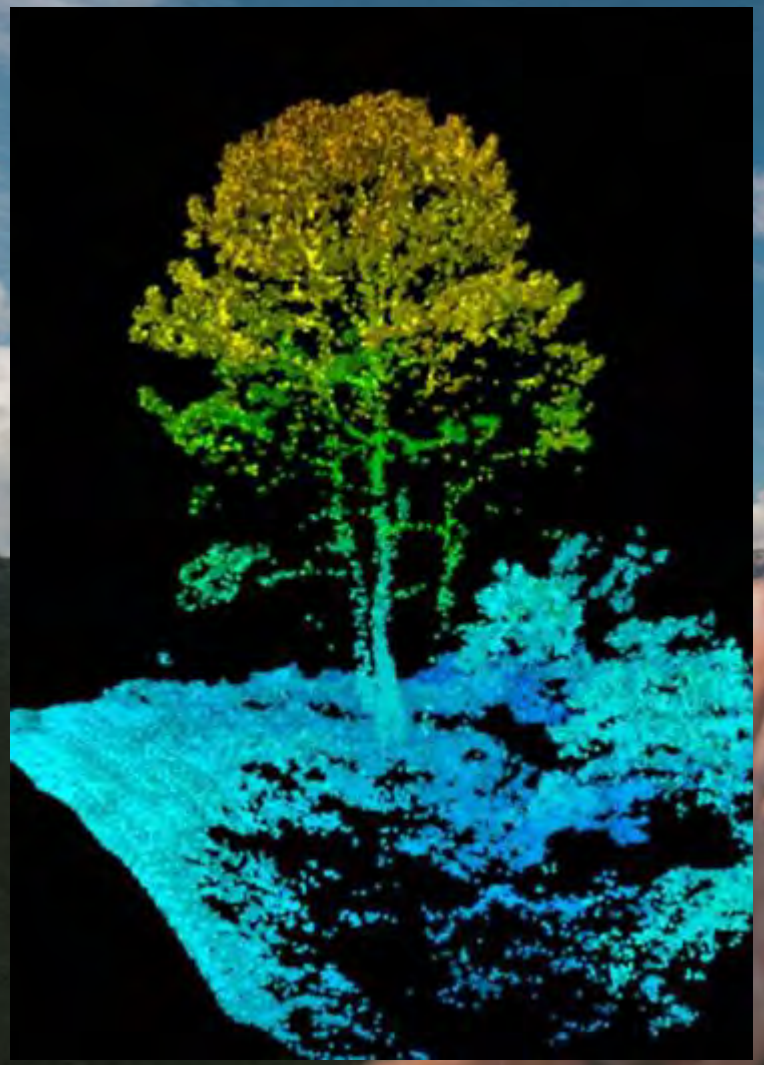
Forest phenotyping



We have used remote sensing to model forest phenotype across landscapes on an area basis.

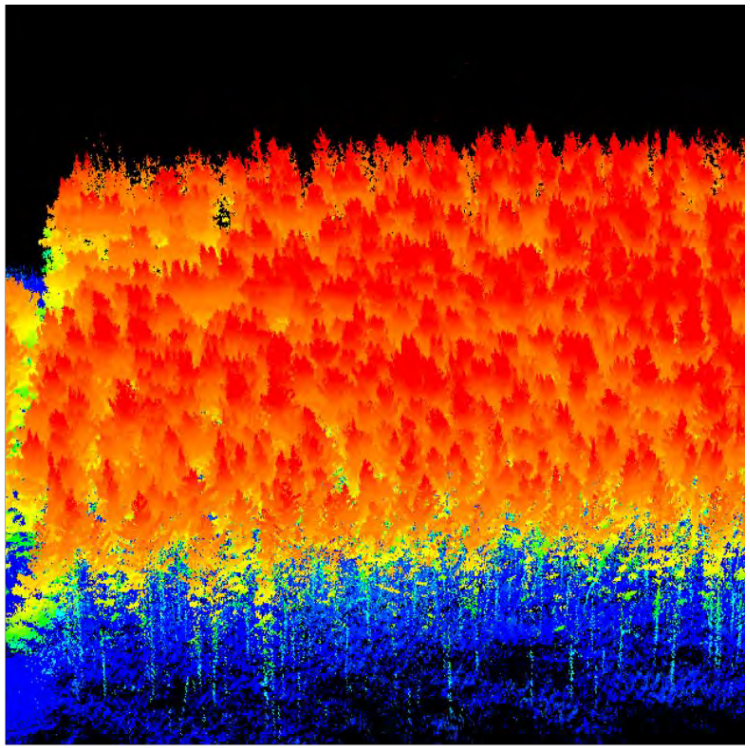


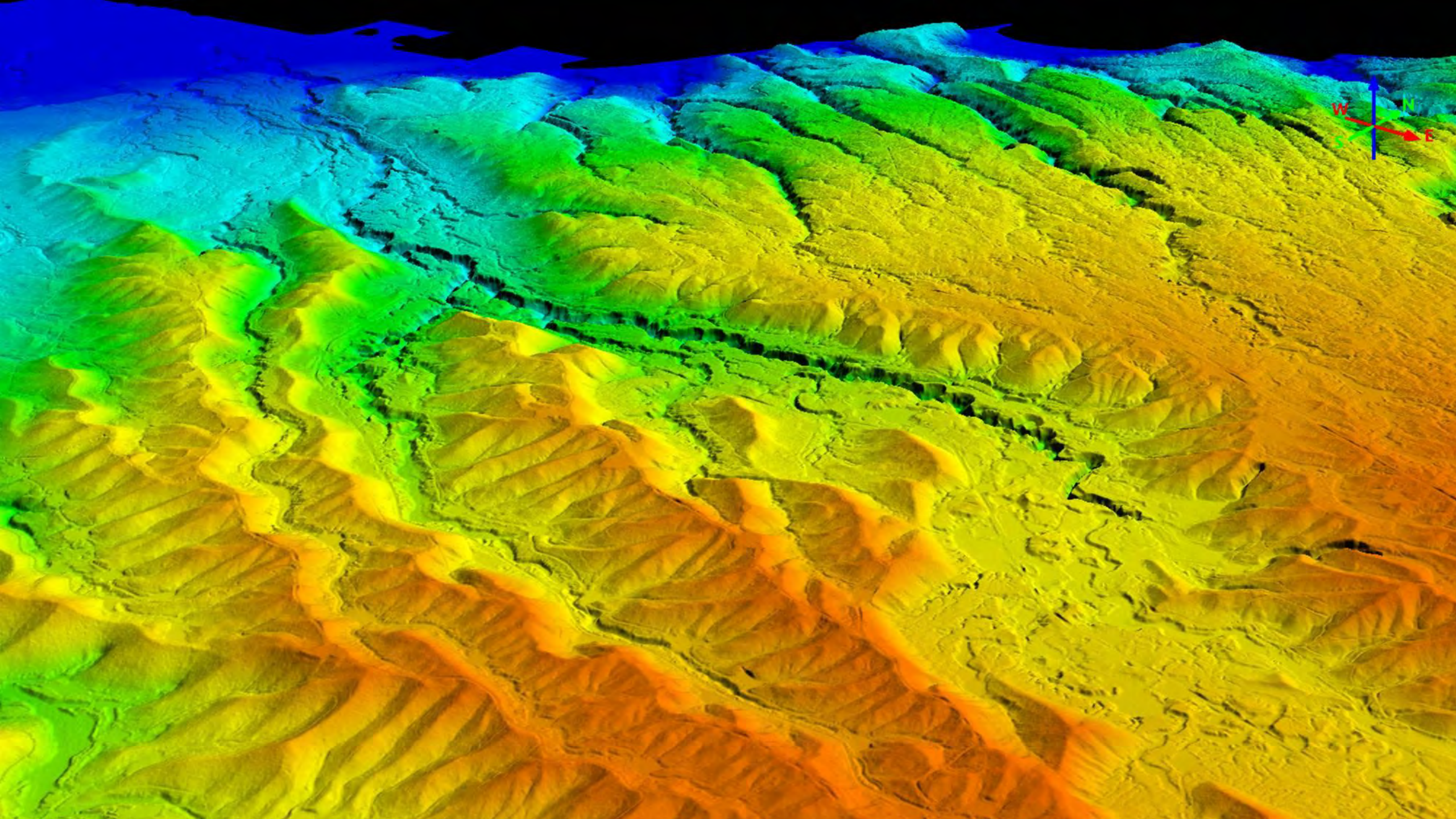




By fusing multiple datasets we can provide descriptions that are richer cover larger areas.

Unravelling environmental variation




W
N
S
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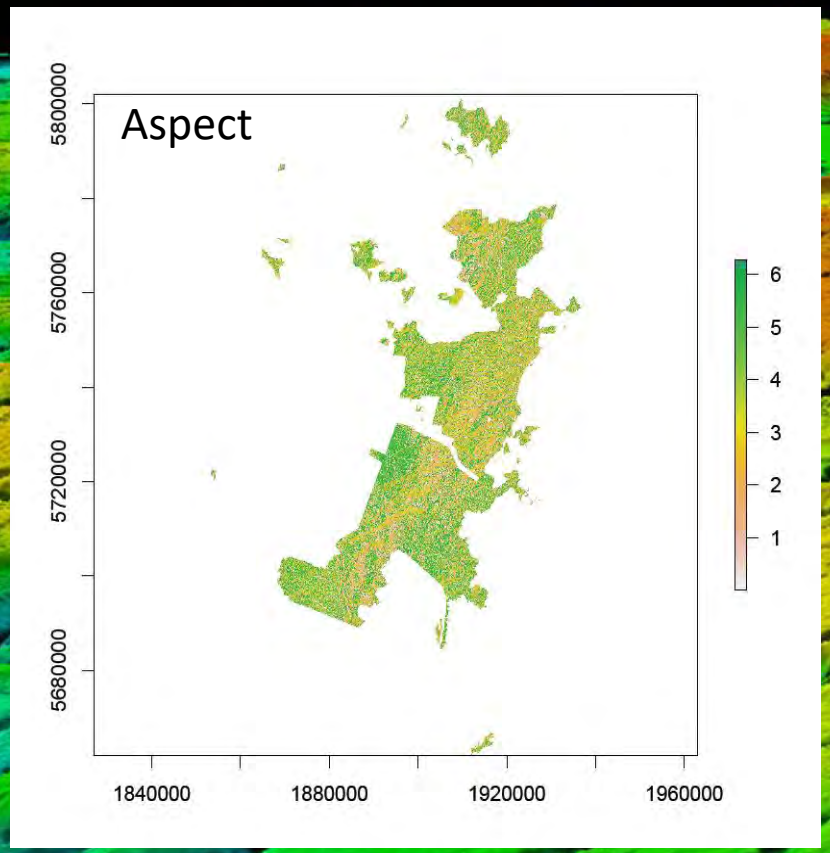
Aspect
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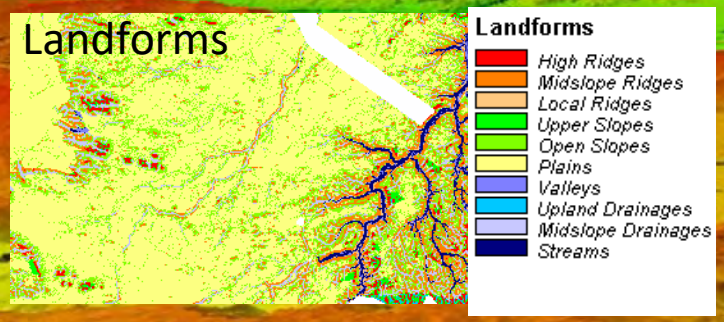
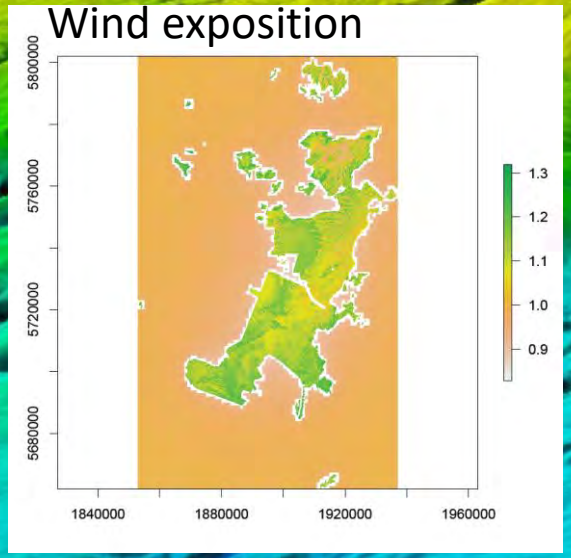
1960000
6
5
4
3
2
1


Landforms
Landforms
High Ridges
Midslope Ridges
Local Ridges
Upper Slopes
Open Slopes
Plains
Valleys
Upland Drainages
Midslope Drainages
Streams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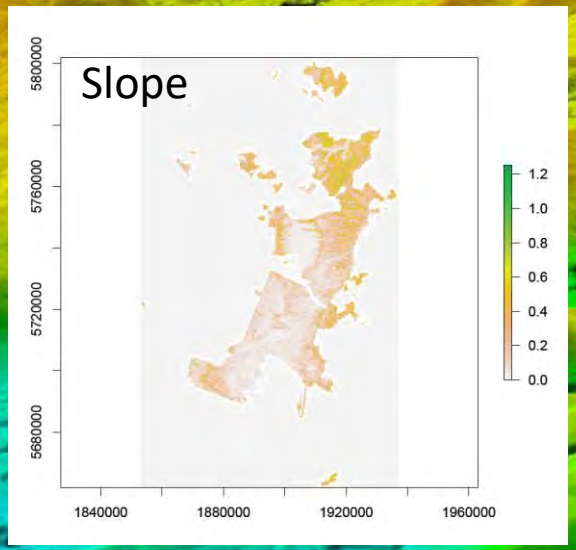
Slope
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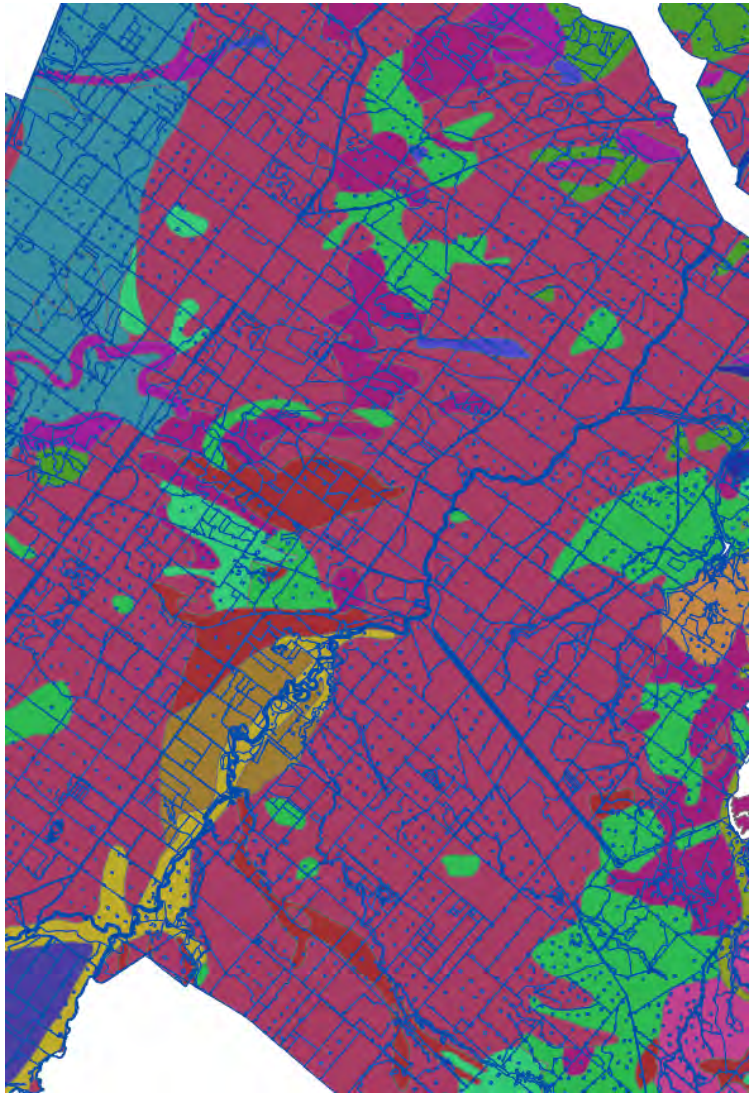
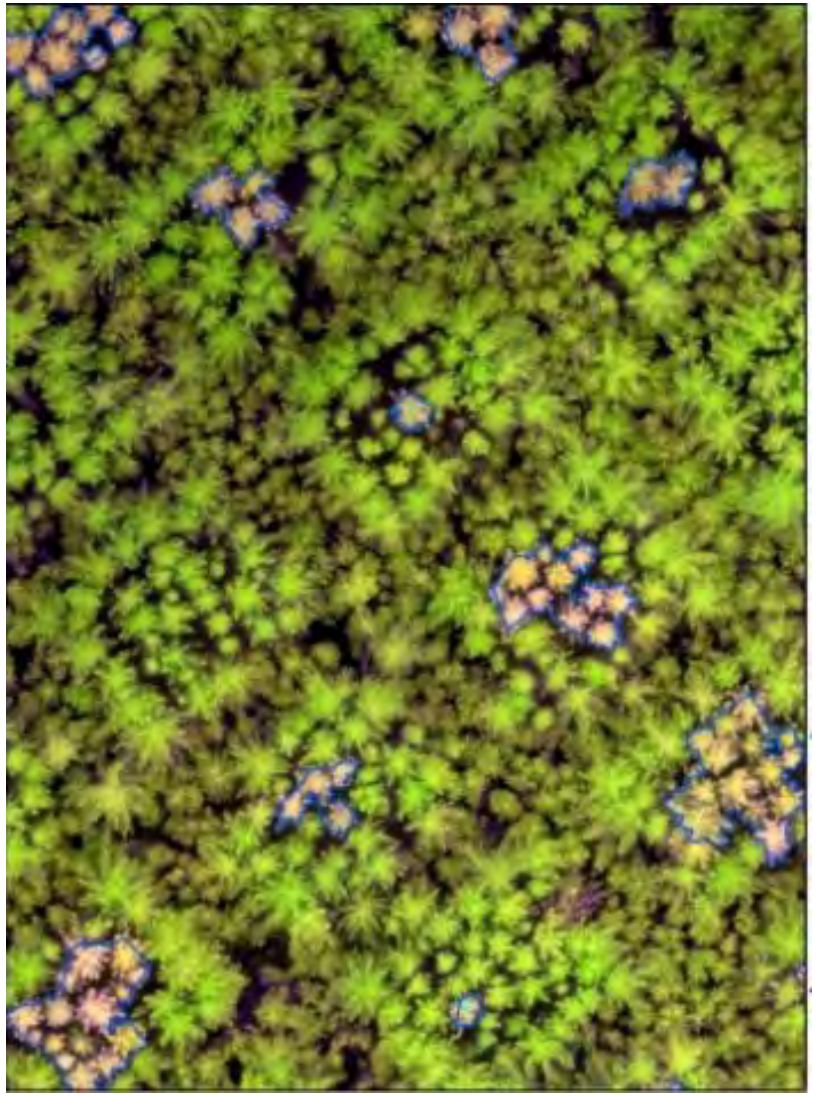
5760000
5720000
5680000
1840000
1880000
1920000
1960000
1.2
1.0
0.8
0.6
0.4
0.2
0.0

Climatic data

- Seasonal and annual rainfall
- Seasonal and annual wind speeds
- Seasonal and annual temperatures
- Seasonal and annual sunshine hours
- Seasonal and annual global radiation

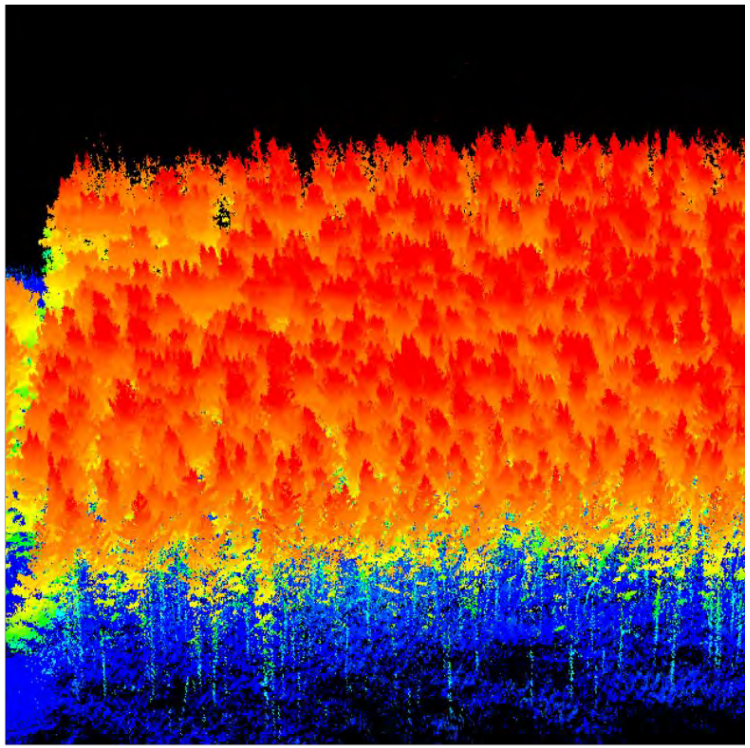
Soils data, silvicultural treatment, disease control



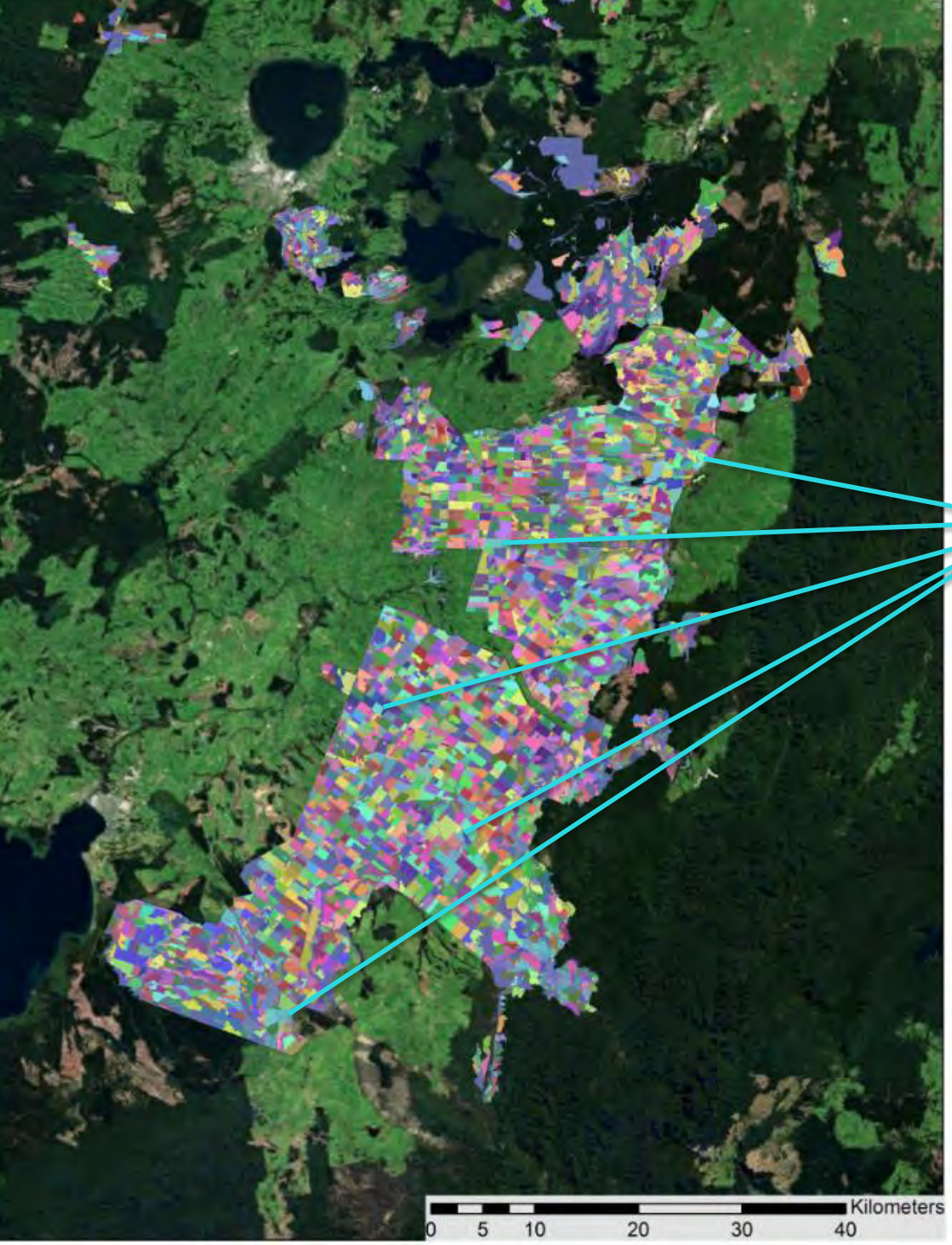


Kindly provided by the forest managers

What about genetics



Seedlot information provides us with a useful starting point




GF Plus™ SEED CERTIFICATE

Trait ratings

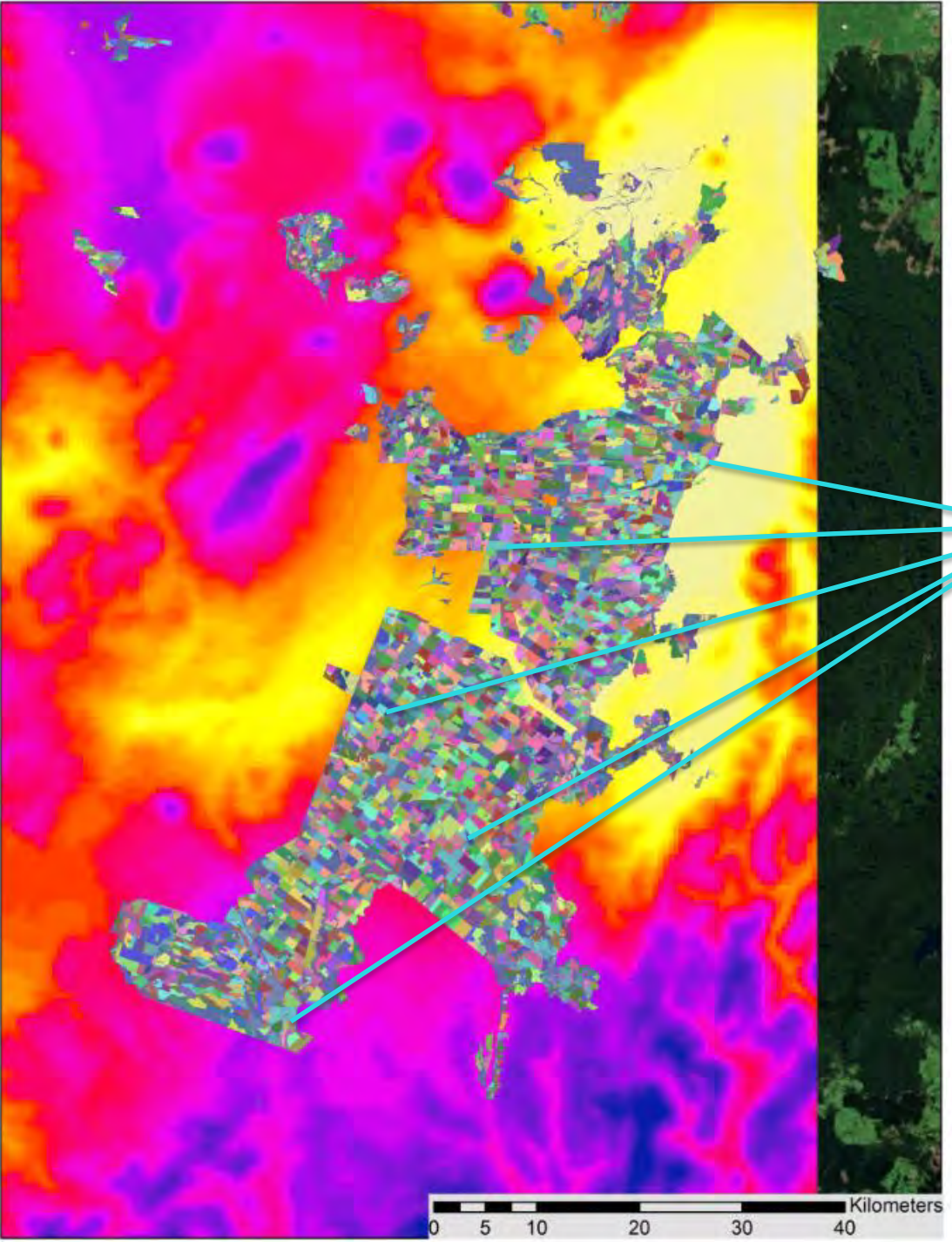
Growth	Straight	Branch
22	21	23

List of parents

APPENDIX I
Seedlot Crosses

No. of Crosses: 40

Parents		% of
Female	Male	seedlot
268.005	268.532	0.8%
268.005	875.220	0.3%
268.007	268.054	4.1%
268.007	268.228	2.1%
268.007	875.220	1.3%
268.054	268.262	1.7%
268.054	268.532	1.9%
268.054	875.066	3.4%
268.123	268.248	1.9%
268.228	268.609	1.3%
268.228	875.076	2.4%



Once we overlay climatic data we can see we have many different sites across the landscape

GF Plus™ SEED CERTIFICATE

SCION SEED CERTIFICATION SERVICE

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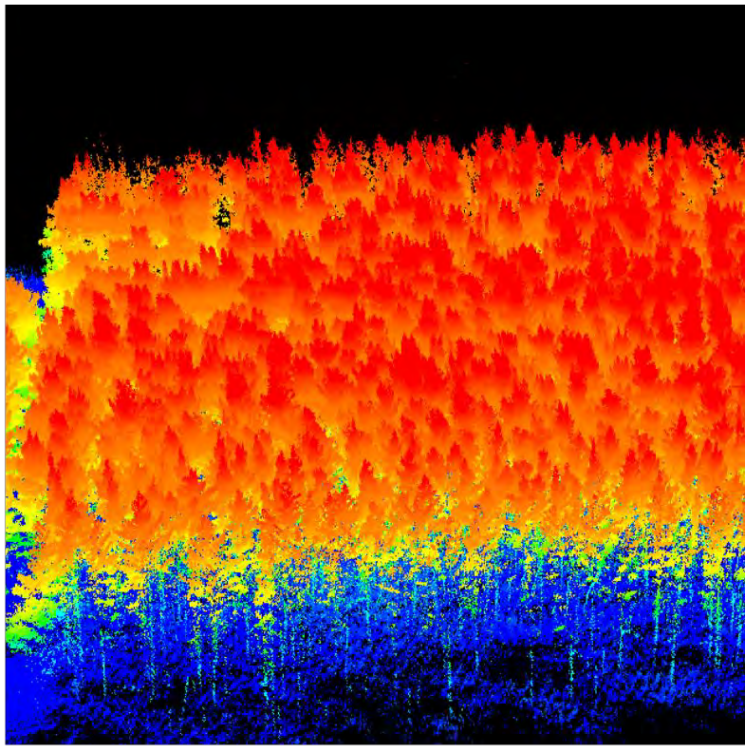
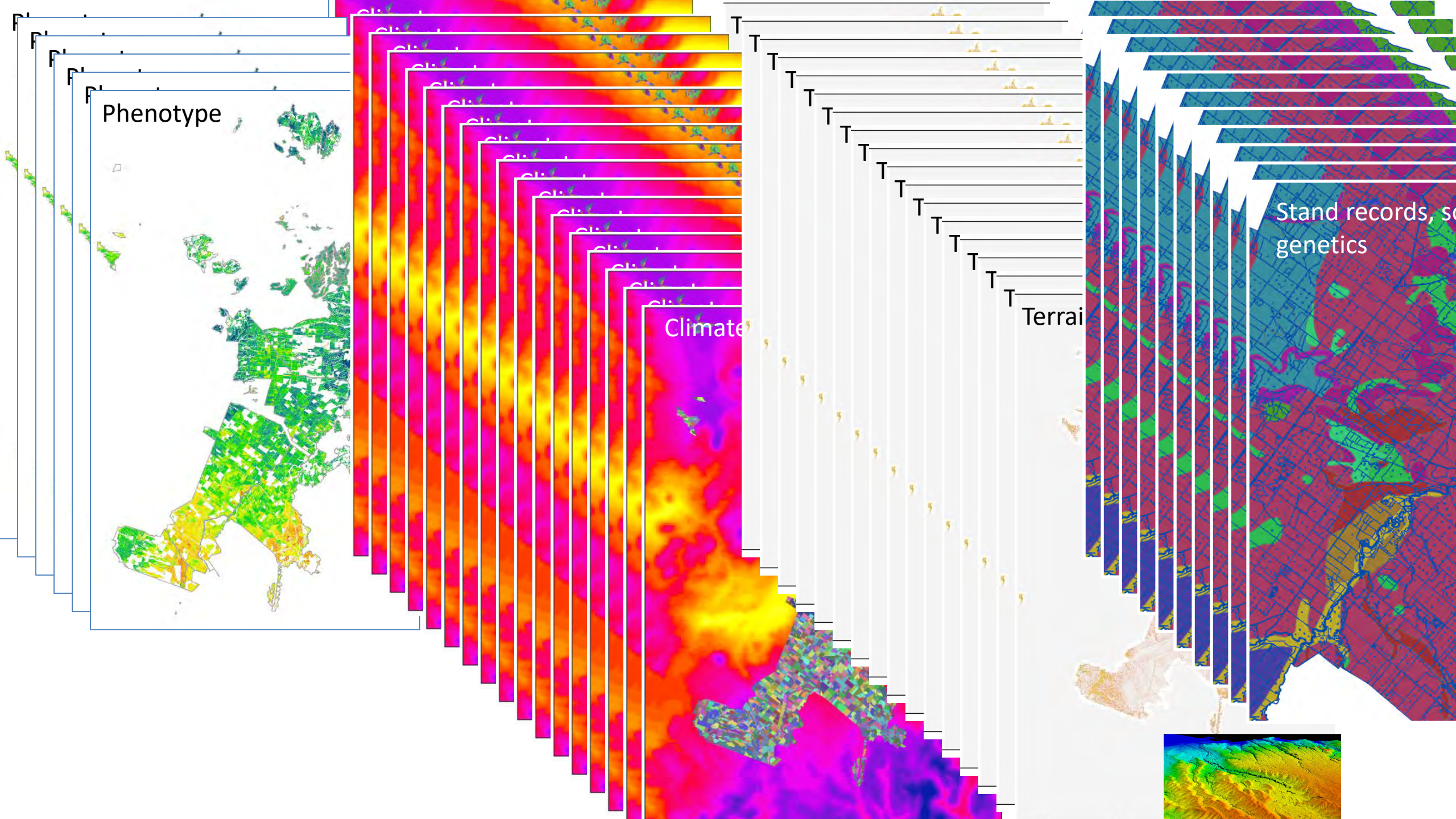
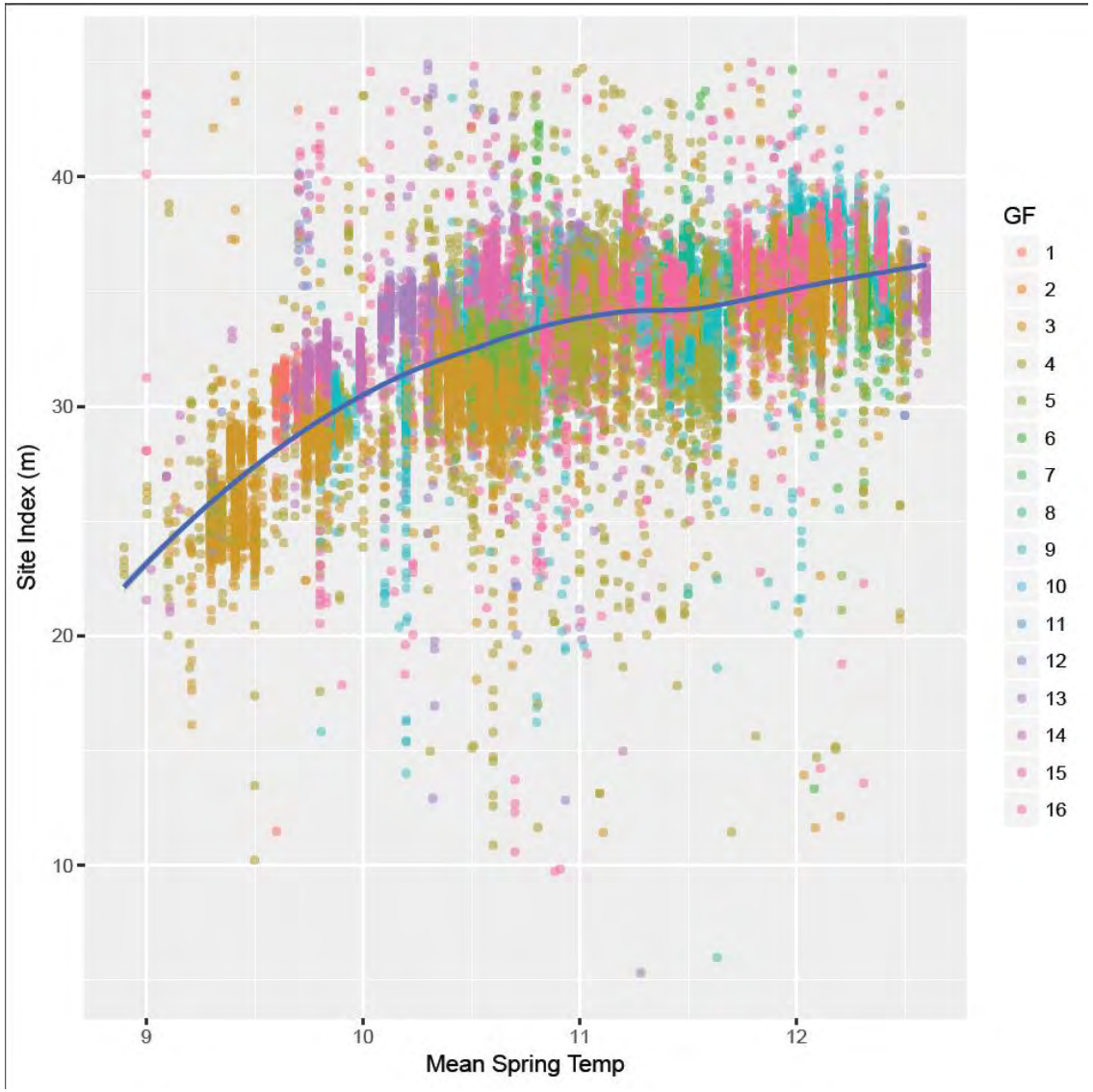
The forest phenotyping platform allows us to study this.

Bringing it all together




Phenotype
Climate
Terrai
Stand records, s
genetics

How do you manage and analyse this data – Analytics Module



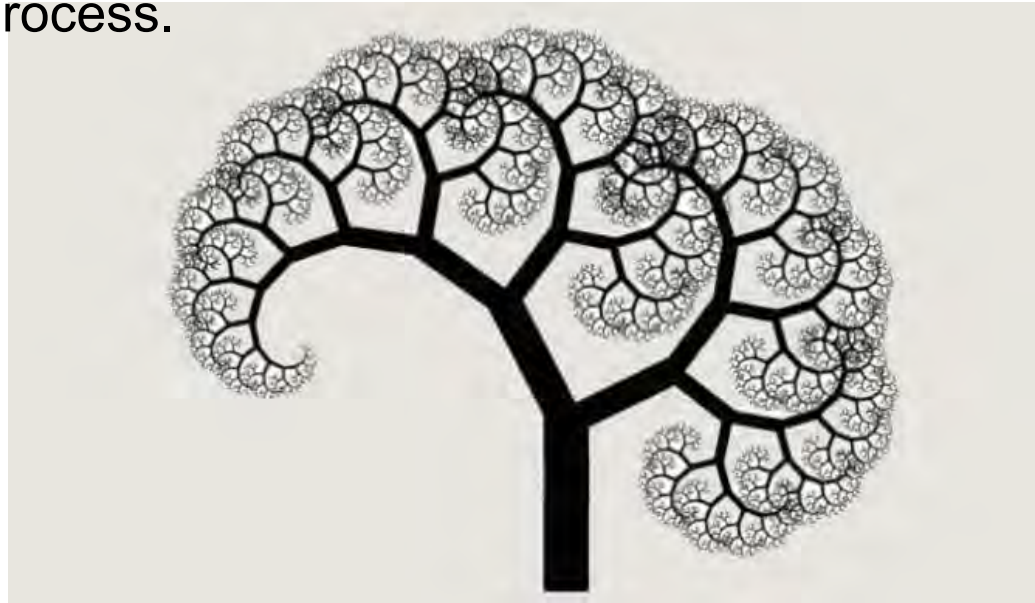
- The dataset is large and noisy.
- The relationships are complex, non-linear, and the predictor variables are inter-correlated.
- *A good candidate for some form of statistical learning approach.*

How do you manage and analyse this data – Analytics Module

Gradient Boosting Machines (GBM) are a set of machine learning algorithms that construct ensembles of initially weak decision tree learners. Model bias is sequentially reduced and precision improved as each subsequent model learns from its predecessor (boosting).

Key Advantages

- Automatically interprets non-linear interactions, tolerate outliers and missing data.
- No knowledge or assumptions about the underlying model required.
- Feature selection inherently performed during the learning process.
- Not effected by collinearity amongst predictors.
- Can handle categorical and continuous predictors.
- Easy to interpret.



Some early example results

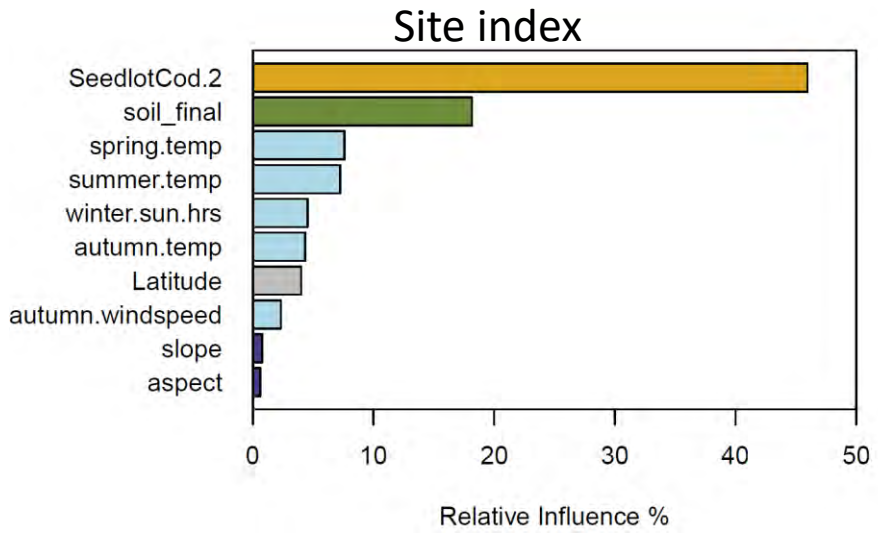
Initial models account for ~ 70 % of the variance in forest productivity across the forest.

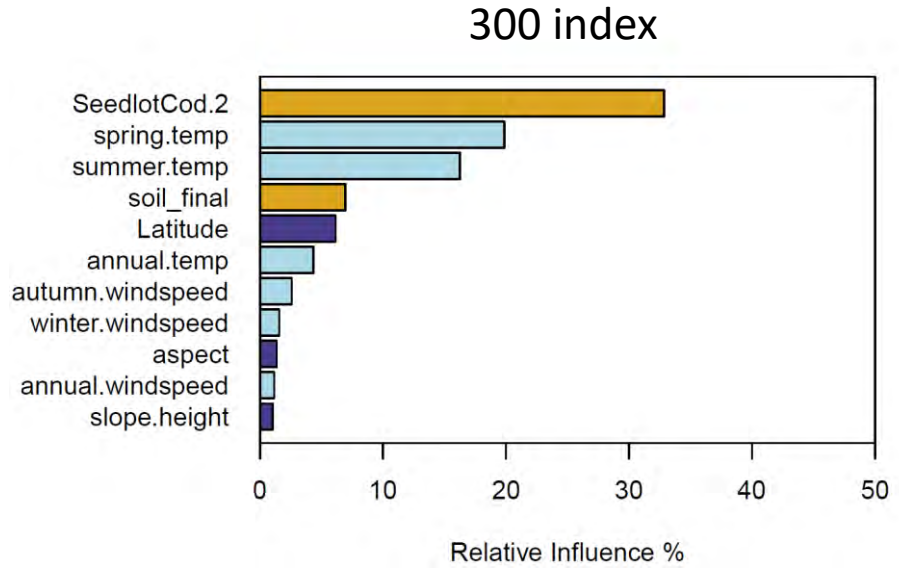
The relative importance of the drivers of forest productivity can be identified.

Seedlot and site attributes are consistently the most important highlighting the importance of matching seedlot to site.

We can use the GBM outputs to examine the interaction between genetic and site factors.

Future analysis will indicate where best to locate specific seedlots.





Can this be used to create impact for forest growers?

What are the worst / best performing seedlots in the forest? Once identified we can cut them out or plant more?

Are there specific areas where certain seedlots perform best?

Are there sites we should be managing differently?

Answering these questions should help improve the productivity and uniformity of the resource?

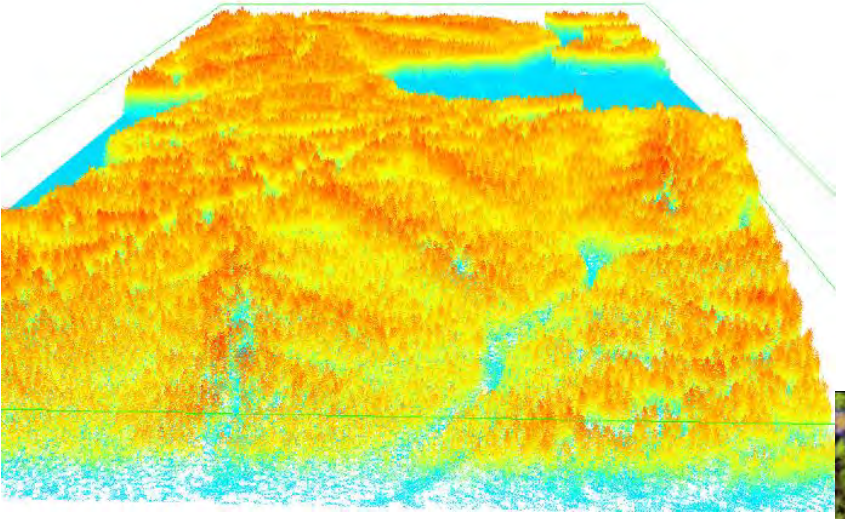
Conclusions

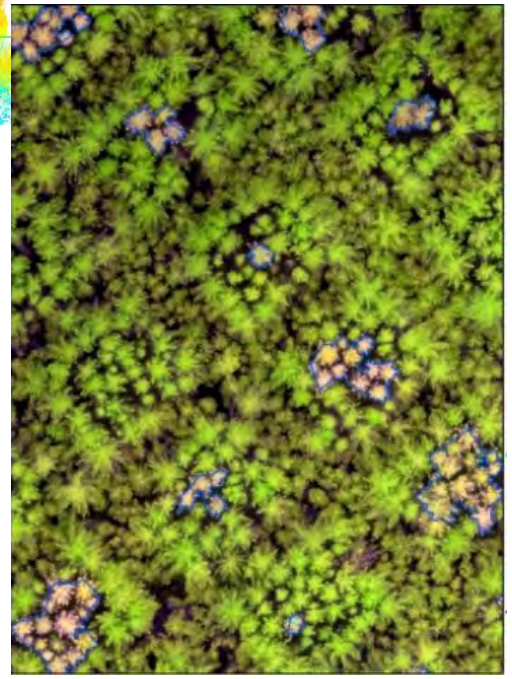
For the first time the concepts of high-throughput plant phenotyping have been extended to plantation forestry.

We have developed a prototype implementation across major forests.

Our research has delivered an integrated remote sensing platform for forest phenotyping and assessing environmental variation to support this.

Thank you…





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