

Advancing forest simulation through individual tree models

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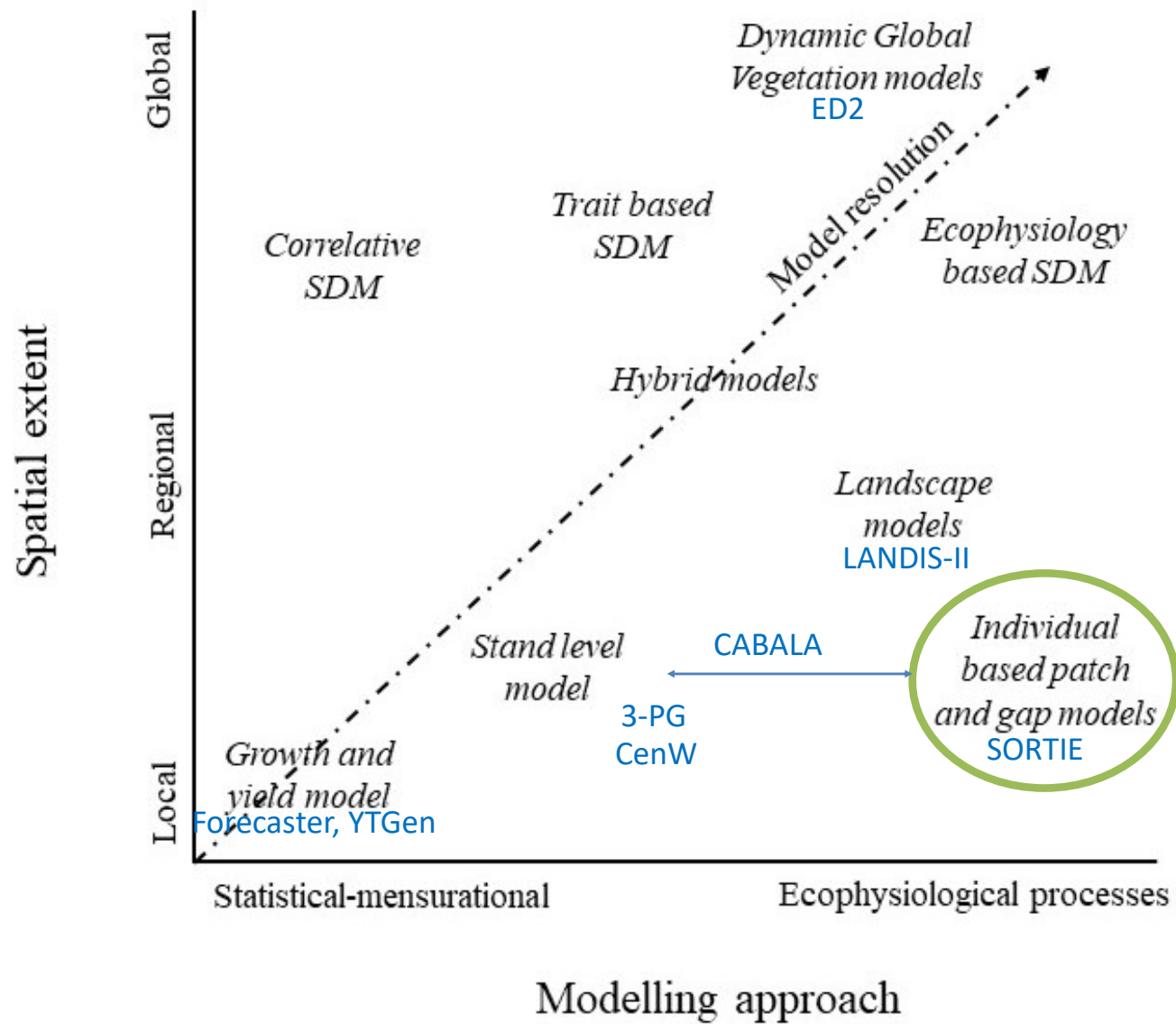
The challenge

- Forest simulation is critical to industry.
- Existing models used by industry tend to be empirical.
 - Based on historical inventory data.
 - Models are getting older.
- Resilience in the face of uncertain future.
 - Novel and potentially complex silviculture.
 - Novel climates on existing soils/topography.



What do we want out of models?

Rank	Topic/Issue
1	Not just growth functions – mortality, breakage, taper and volume as well
2	Distance-dependent individual tree models
3	Silvicultural planning
4	Flexible framework – i.e. can add in carbon wood and properties etc. later
5	Rethink PSPs and model building now we are collecting tree measurements in a different way, e.g. LiDAR
6	Use of models for valuations and estate modelling and day to day production planning
7	Managing variation of a genetic origin within and between species
8	Statistical basis of measurement and modelling
9	What are the variables we want to collect besides stem variables?
10	What platform do you build and distribute the models on?



(Adapted from Salekin 2019 and Ruiz-Benito et al. 2020)

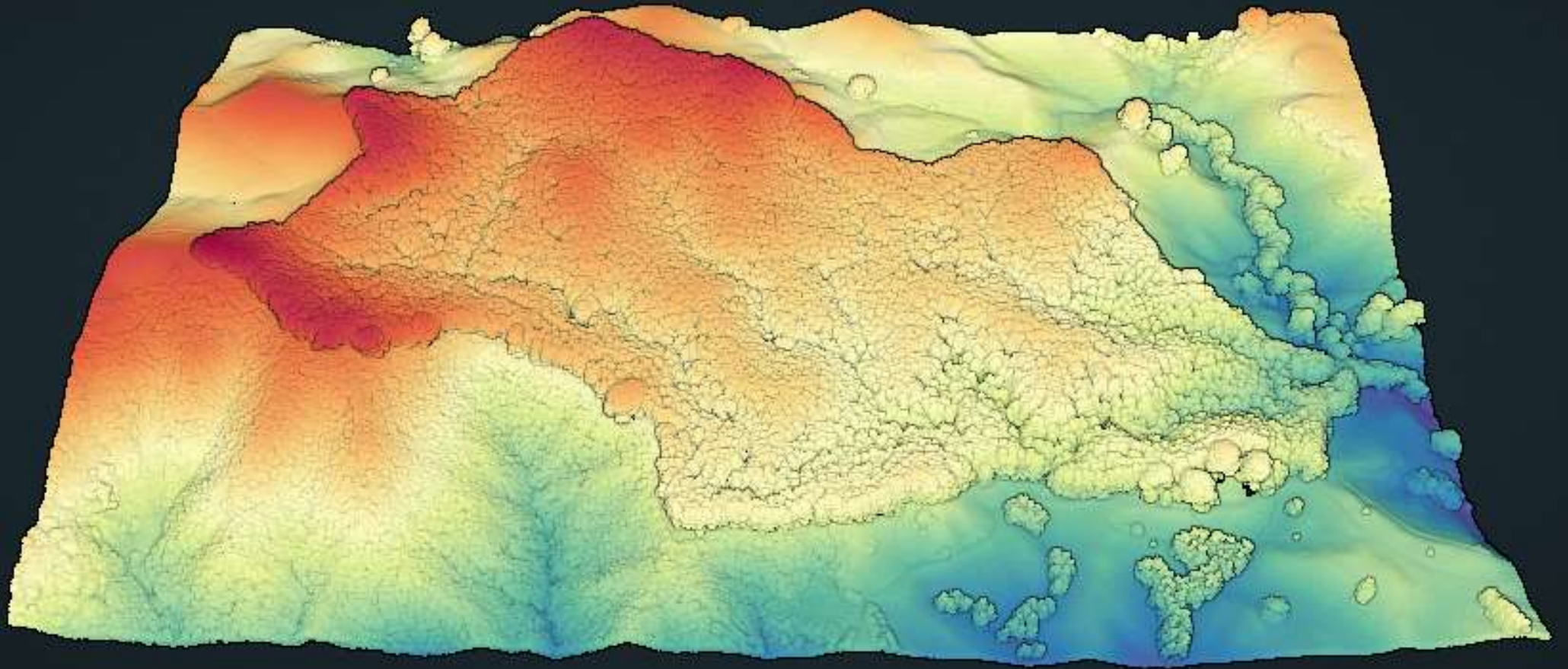
Not a new idea...

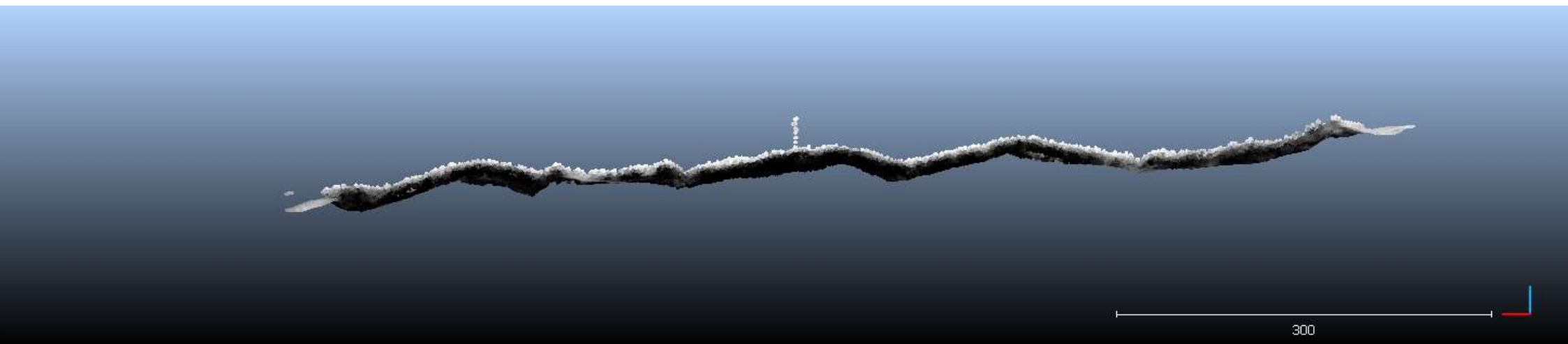
- Tennent (1982)
 - Distant dependent
 - 150 trees sampled over three years
- Individual-Tree Growth Model (ITGM)
 - Gordon and Shula through 1990's & 2000's
 - Distance independent



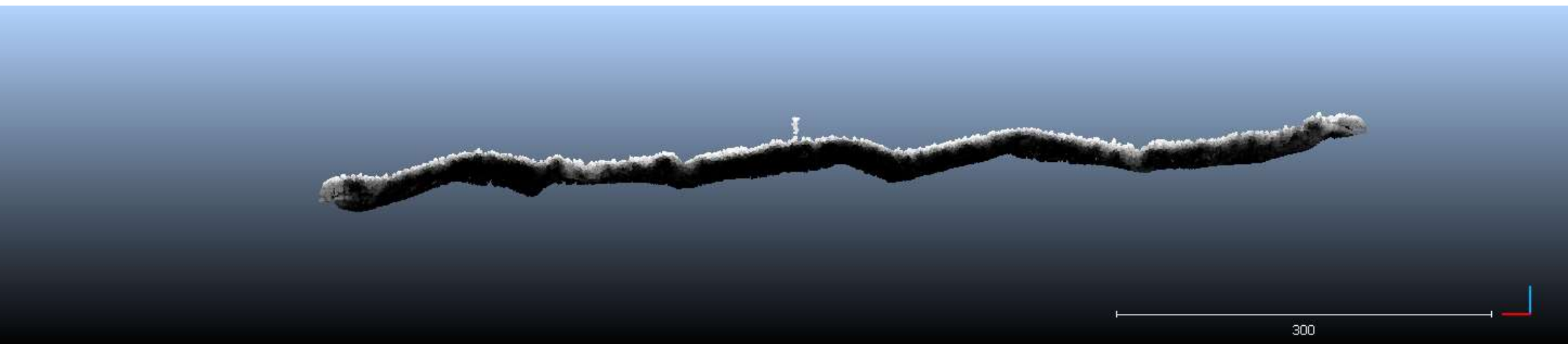
Proof of concept prototype – Even-aged *Pinus radiata* in Puruki Experimental Forest

- A relatively simple scenario to start
 - One species
 - One age-class
 - One site
 - One time period

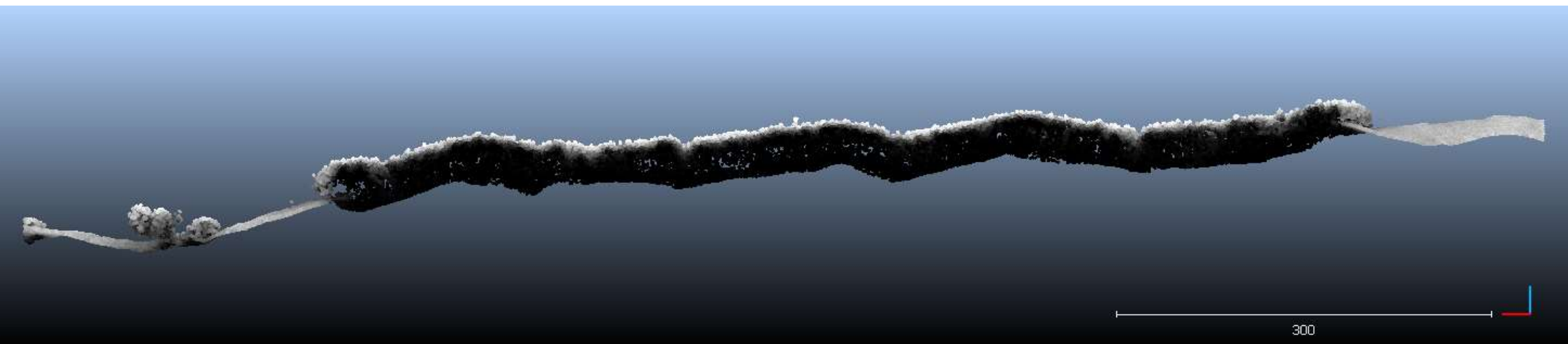




2006



2010















2019

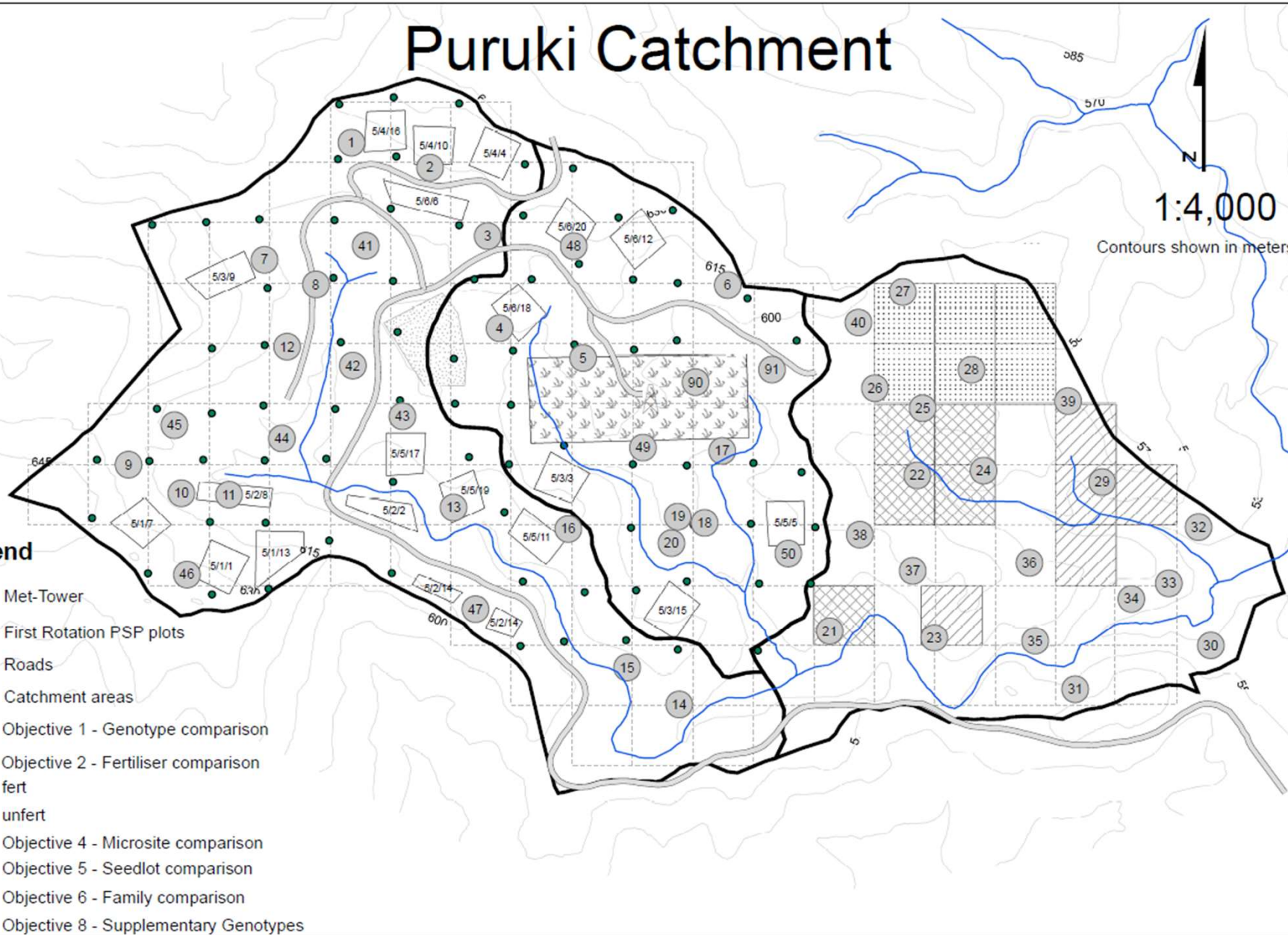
Puruki Catchment

1:4,000

Contours shown in meters

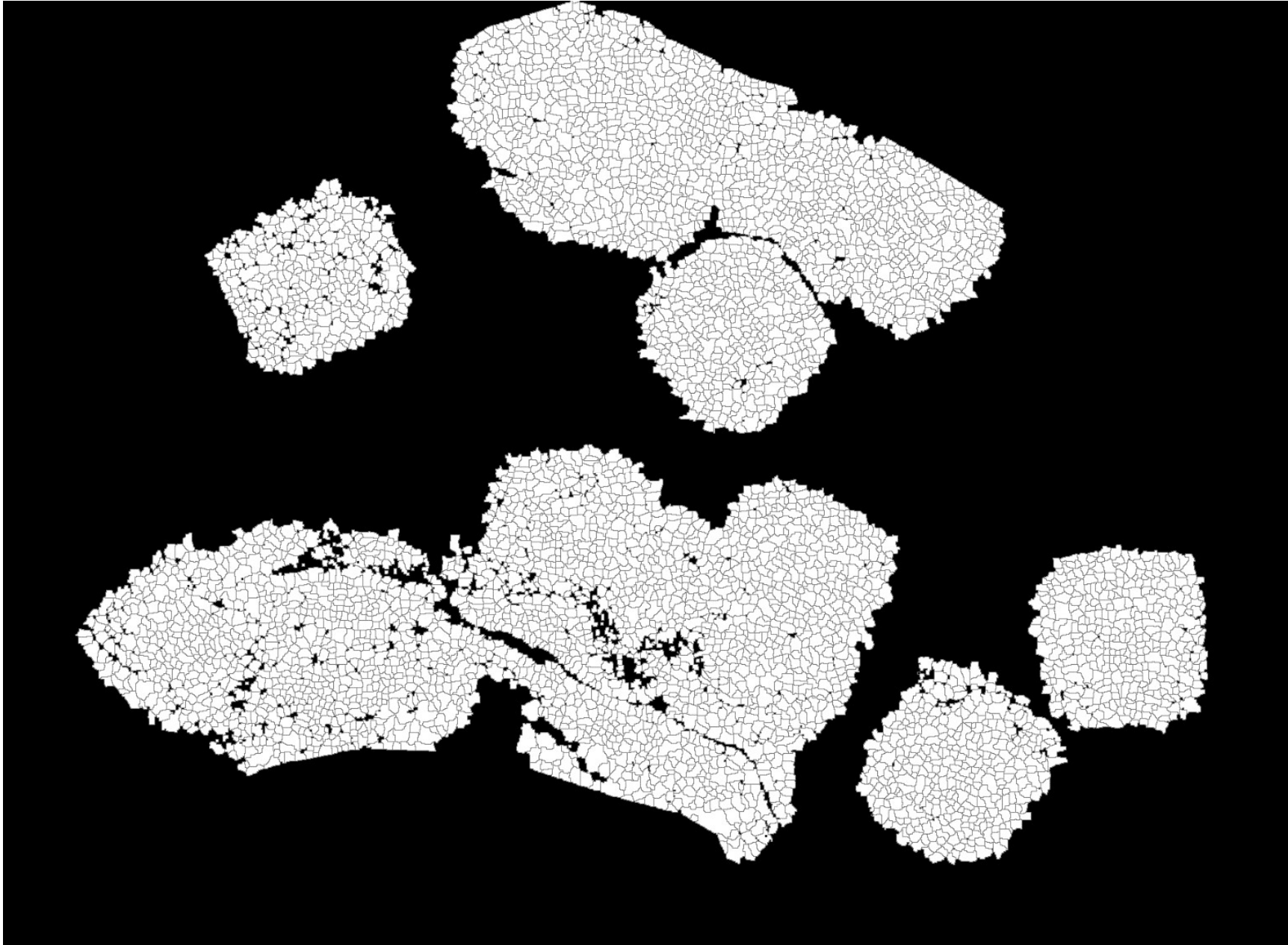
Legend

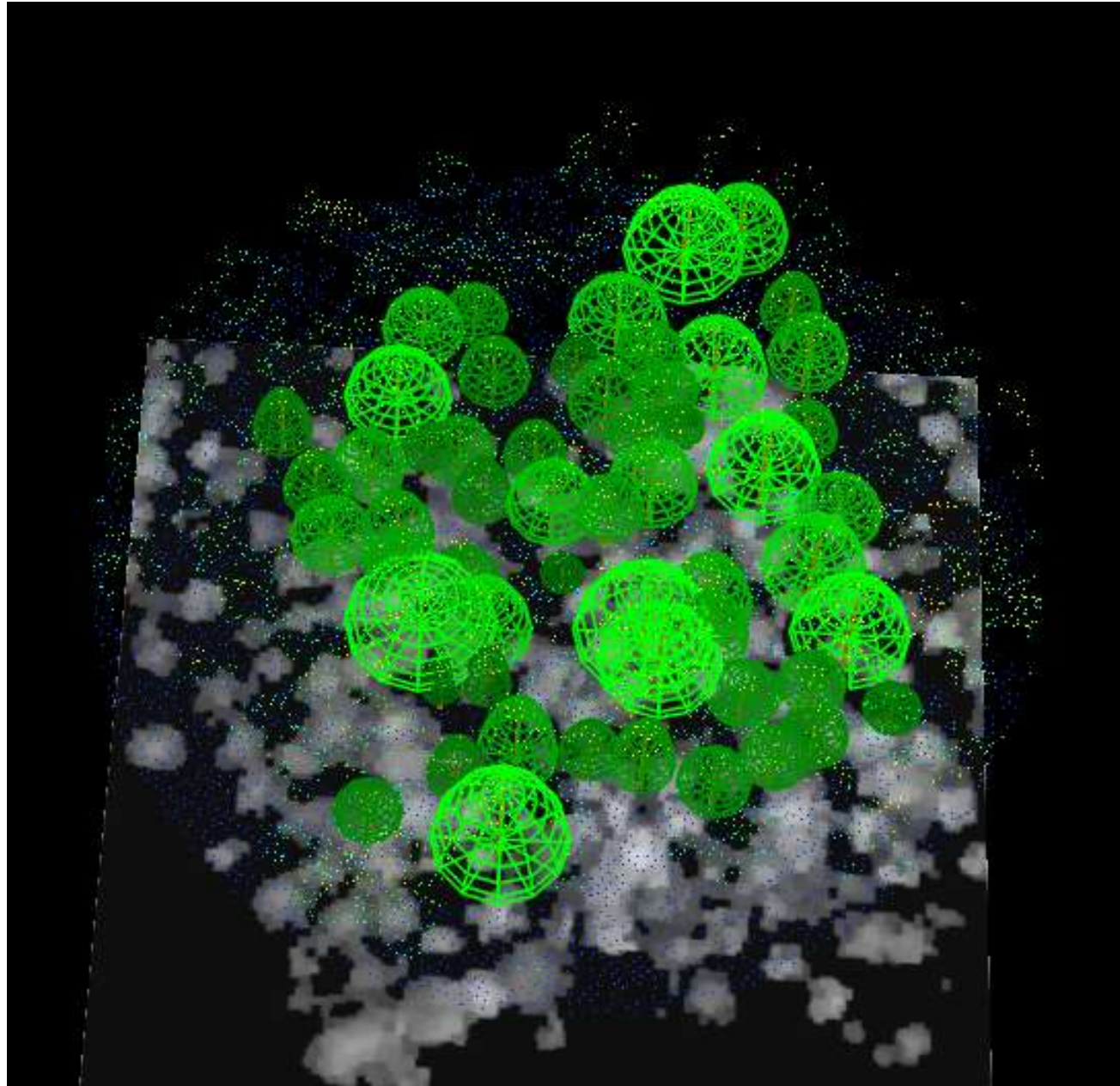
-  Met-Tower
-  First Rotation PSP plots
-  Roads
-  Catchment areas
-  Objective 1 - Genotype comparison
-  Objective 2 - Fertiliser comparison
-  fert
-  unfert
-  Objective 4 - Microsite comparison
-  Objective 5 - Seedlot comparison
-  Objective 6 - Family comparison
-  Objective 8 - Supplementary Genotypes



31 CITY/9808 photo.tif
1 shape, Total area 12.79ha, 157 plots use 65, 17 edge plots 17 used.
65 plots 12.32 plots per ha, 9.52 percent area sampled.
65 plots 5.18 plots per ha, 9.52 percent area sampled.

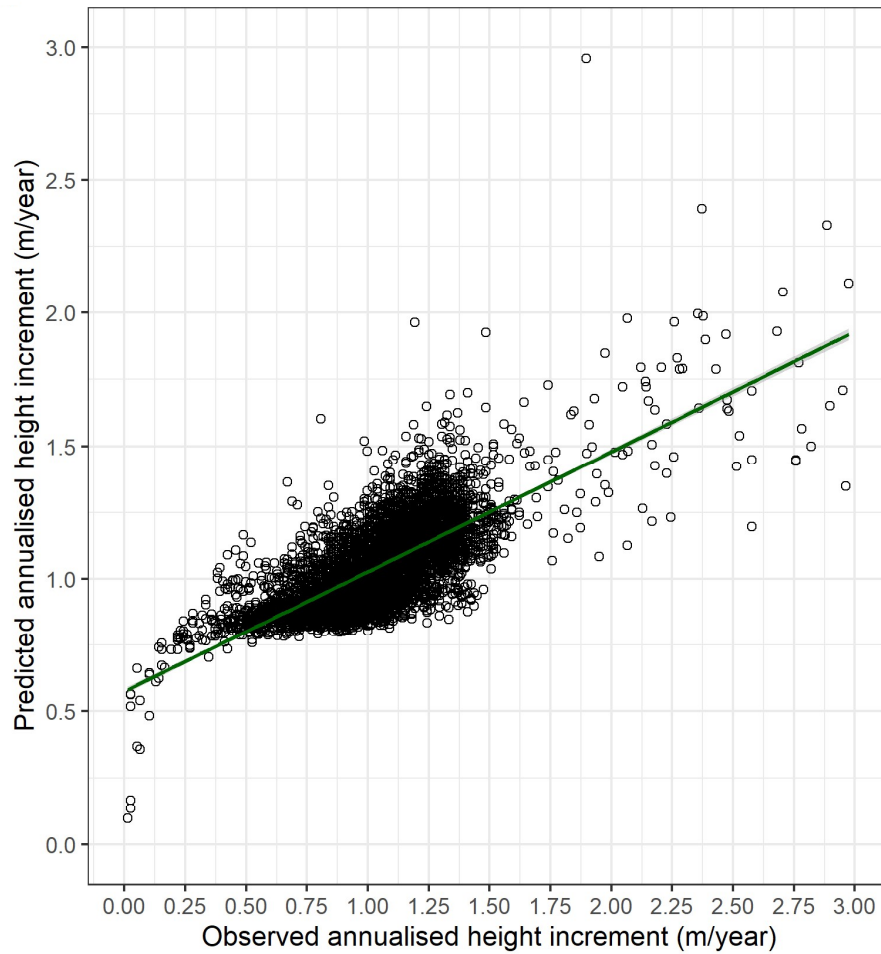






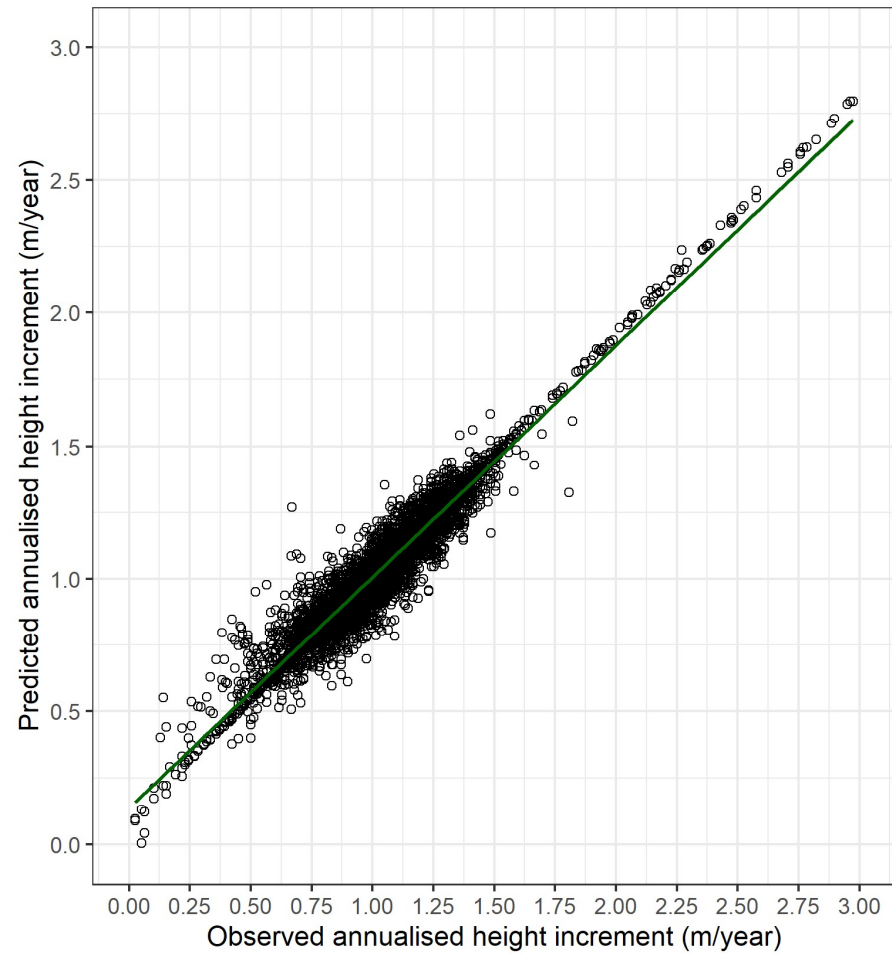
Augmented two parameter Shumacher model

$$\Delta H = e^{(\alpha_0 + \alpha_1 \times CI + \alpha_2 \times CPA_2) - \frac{(\beta_0 + \beta_1 \times NI_1)}{T}}$$



Linear mixed-effect model

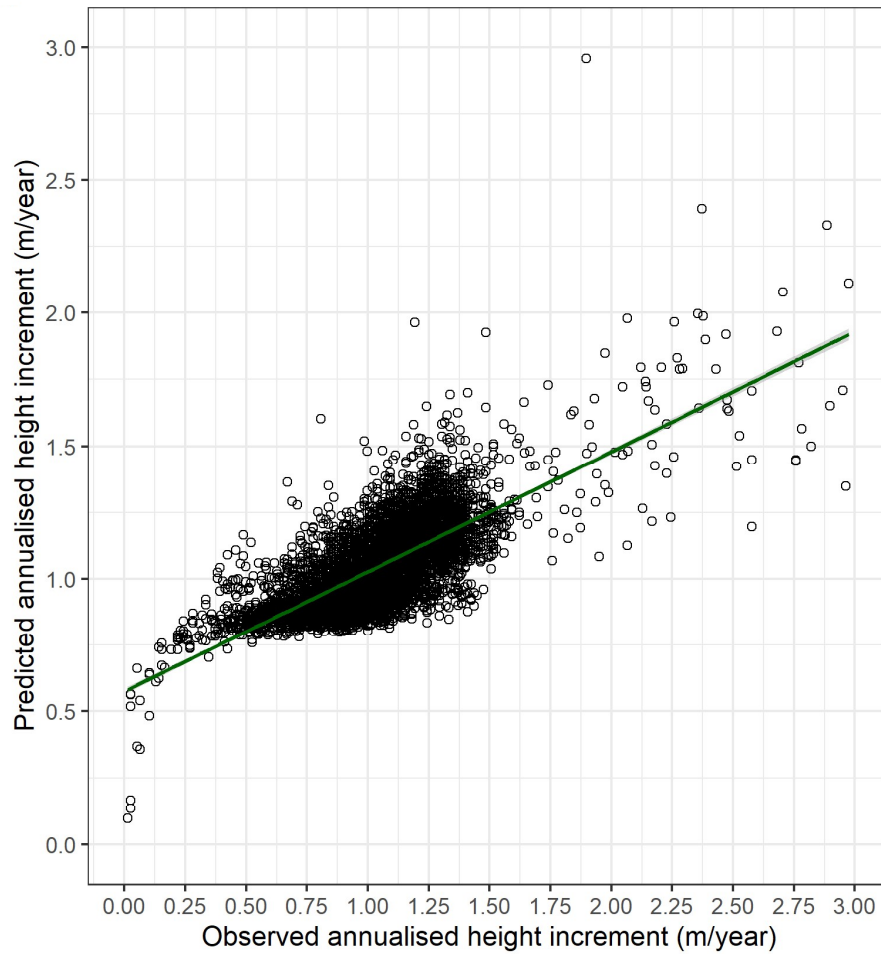
$$\Delta H = \beta_1 \times CI + \beta_2 \times CPA + Z \times NI + \varepsilon$$



CI = Competition Index; CPA = Crown area of individual tree; NI = Neighbourhood stocking; Z = Random effect

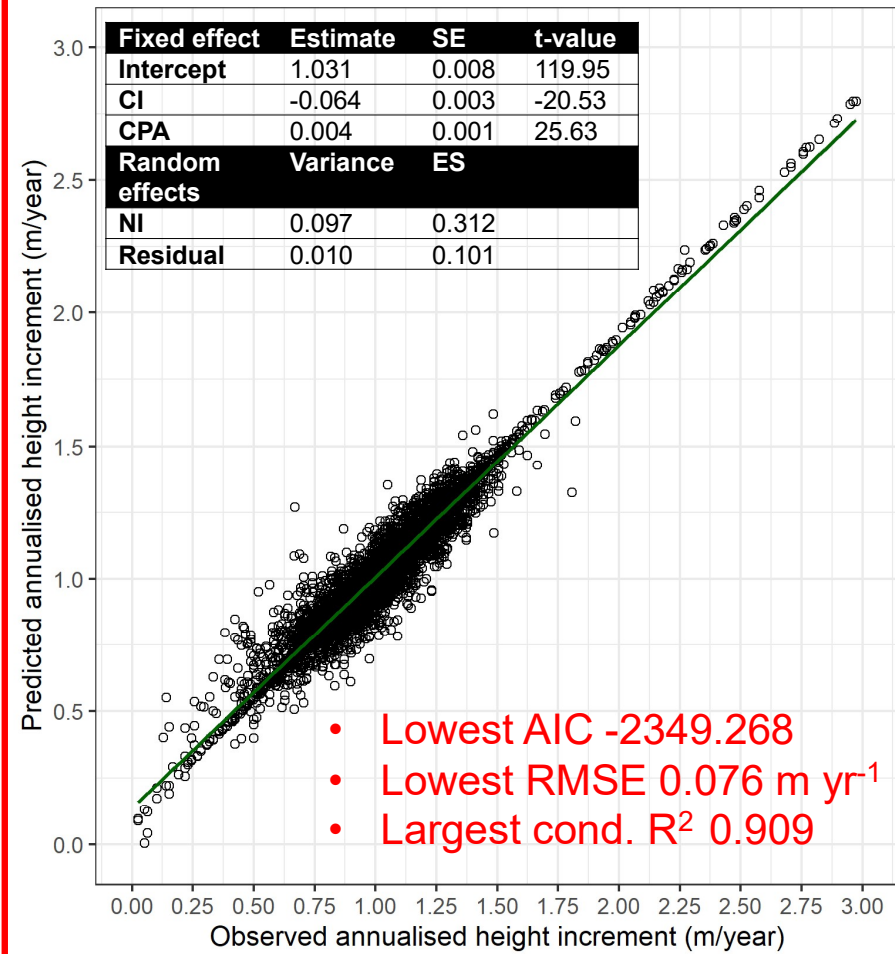
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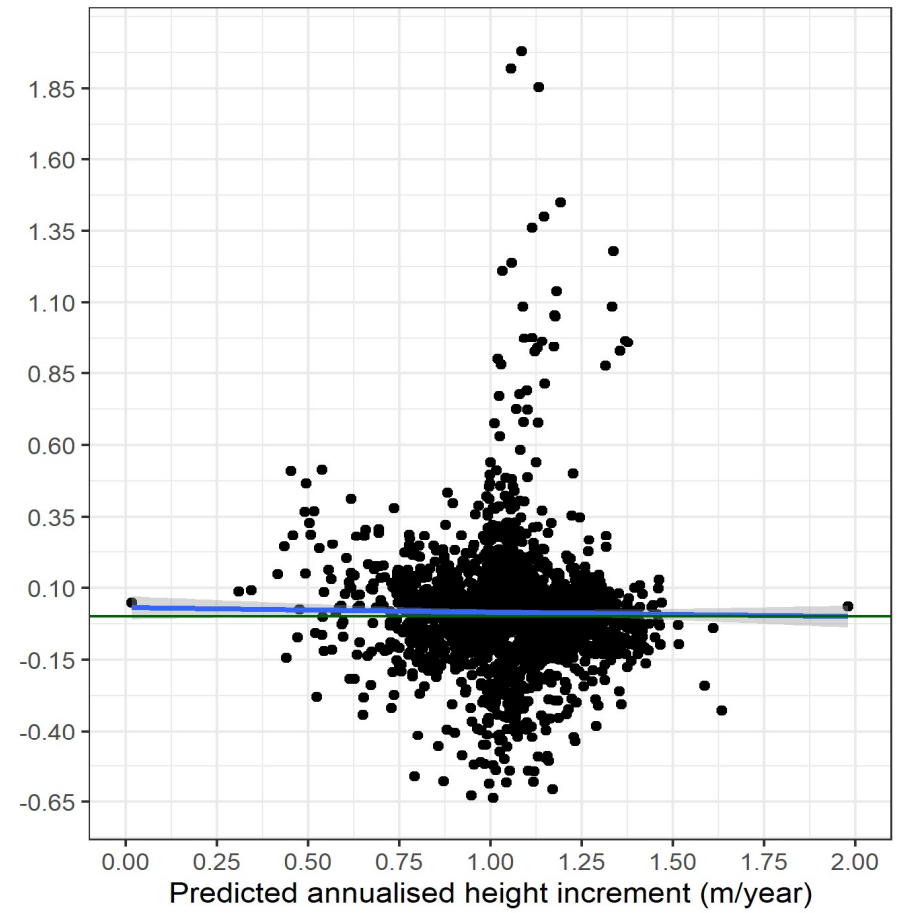
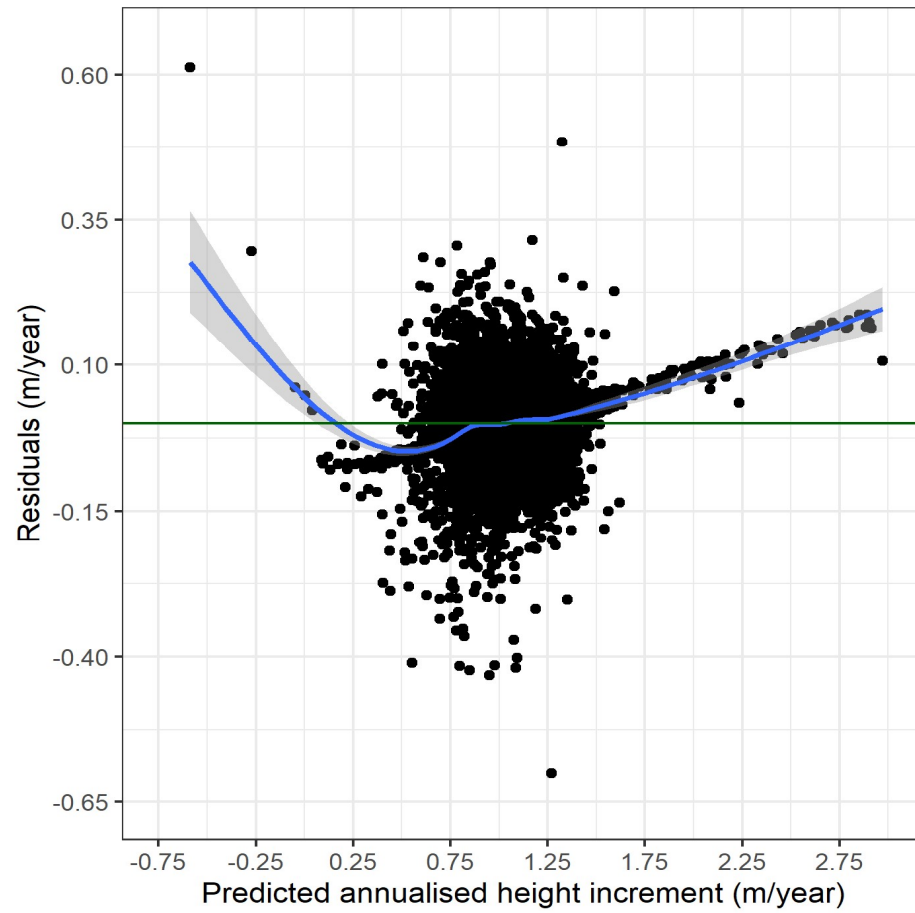
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Trained model		Test model	
RMSE	R ²	RMSE	R ²
0.076	0.909	0.226	0.89



Conclusions and next steps

- Successful prototype, but this is just step with much more development needed
- Refine model
 - Expand beyond Puruki Experimental Forest
 - Expand across rotation
 - Expand factors: climate, silviculture and fertilization, disease, other species and silvicultural systems
 - User interface
- Forest Simulation Interest Group (FSIG)



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