Modelling site productivity for forest management using eco-physiology

Euan G. Mason

Tuesday, 10th July 2018

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Quantifying and understanding factors limiting productivity across forest estates

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Overview

- What are we doing?
- How is it useful?
- How is it different?
- Estimating productivity
- Philosophy of science
- Hybrid growth and yield models

What are we doing?

Finding ways to bring eco-physiology into a mensurational context

- Constraints on radiation use
  - Temperature, Soil moisture, Vapour pressure deficit, Nutrition
- Substituting cumulative potential radiation use for time

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Estimates of productivity: Hybrid physiological/mensurational modelling

- ***Distinguish site influences*** **from silvicultural and genetic effects on productivity**
- **Show which *site factors are limiting growth***
- **Provide estimates of current *and future* crop dimensions**
- **Represent impacts of *climate change***
- ***Represent impacts of site preparation*** **on final crop dimensions**

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How do our methods differ from other hybrid modelling methods?

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Hybrid modelling approaches

- **Some teams run pure eco-physiological models**
  - **3-PG, Cabala, CenW**
- **Others run eco-physiological models in parallel with growth & yield models**
  - **Use physiology to adjust coefficients**
- **We use eco-physiology to predict productivity indices**
  - **Then run mensurational models**
- ***We are moving to fully integrated growth and yield hybrid models***
  - **Retain desirable mensurational attributes**
  - **Minimise errors**

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How do we do it?

- Assemble and localise topographic, climatic, soils inputs
- Run eco-physiological model at points in landscapes to predict productivity
- Test predictions with PSP estimates of productivity indices
- Deliver high resolution GIS rasters
  - Productivity estimates
  - Factors constraining productivity
- Deliver hybrid growth and yield models
  - Substitute cumulative potential radiation use for time

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Localising inputs

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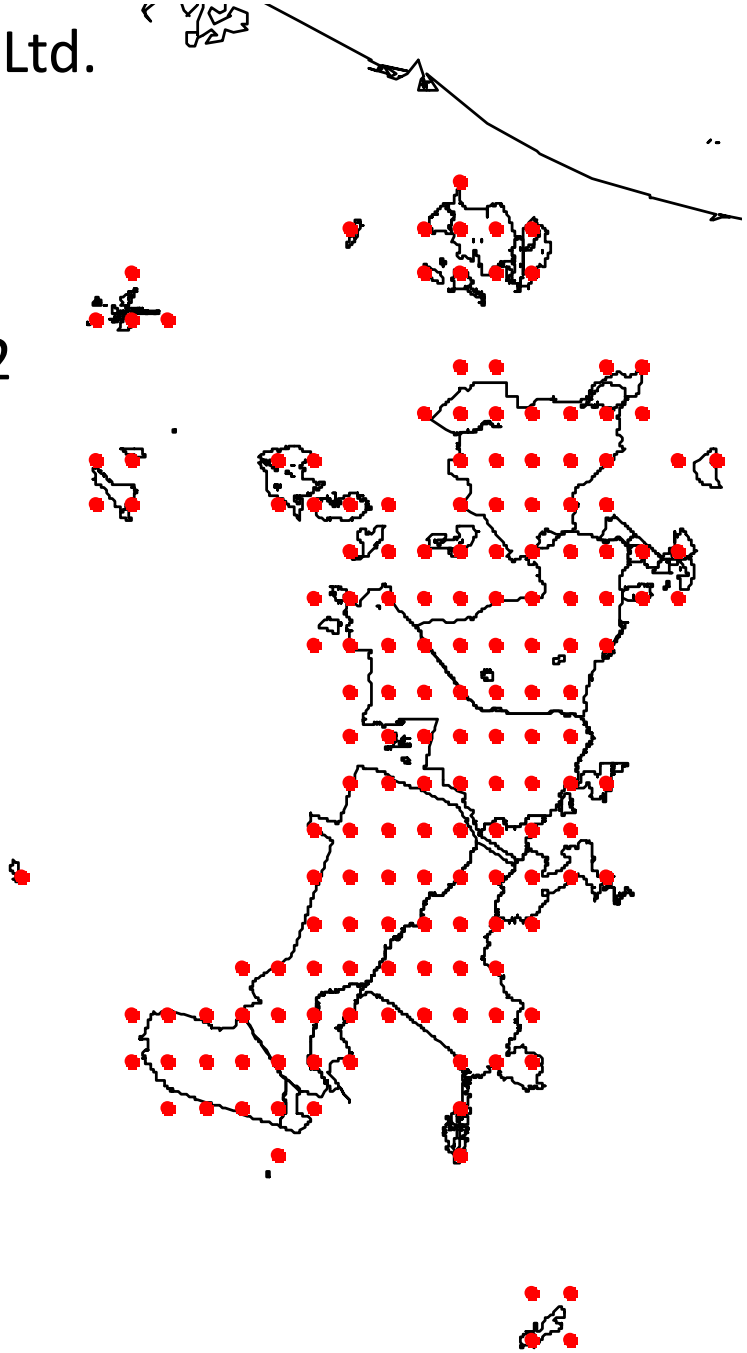
KaingaroaTimberlands Ltd.

166 VCSN points for monthly weather data across years since 1972



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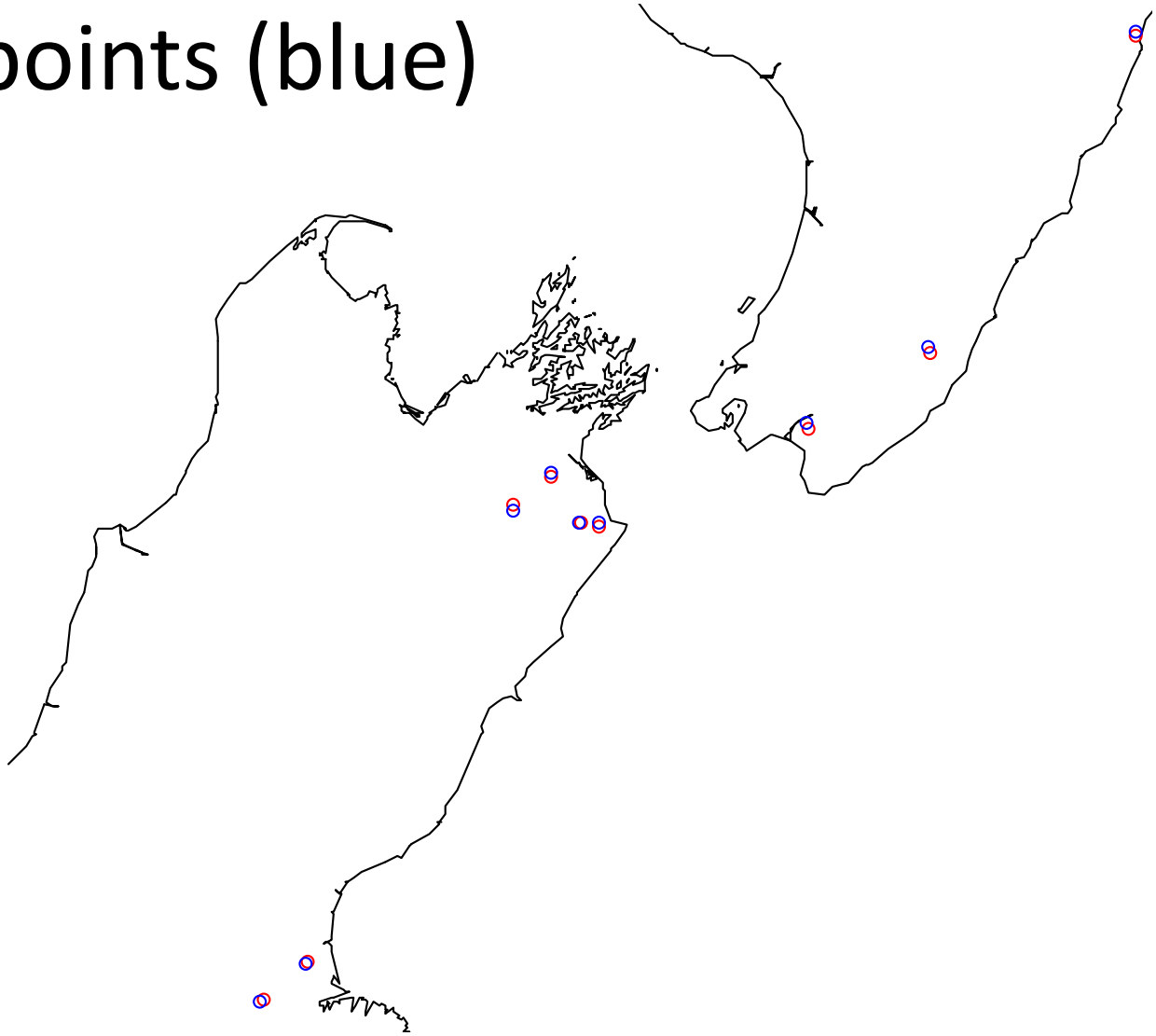
Our stations (red)
VCSN points (blue)



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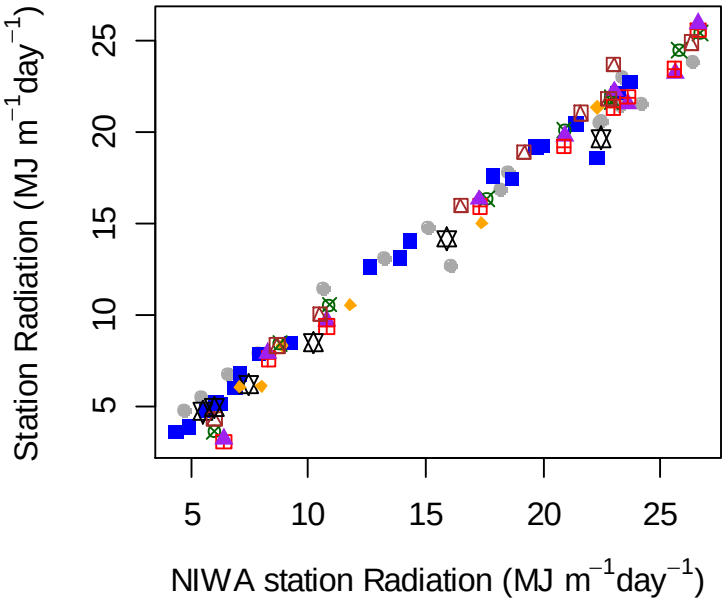

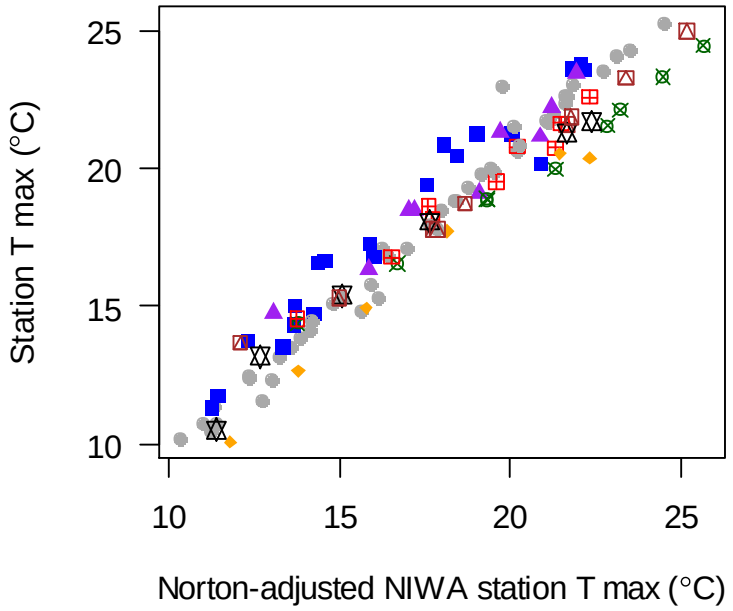

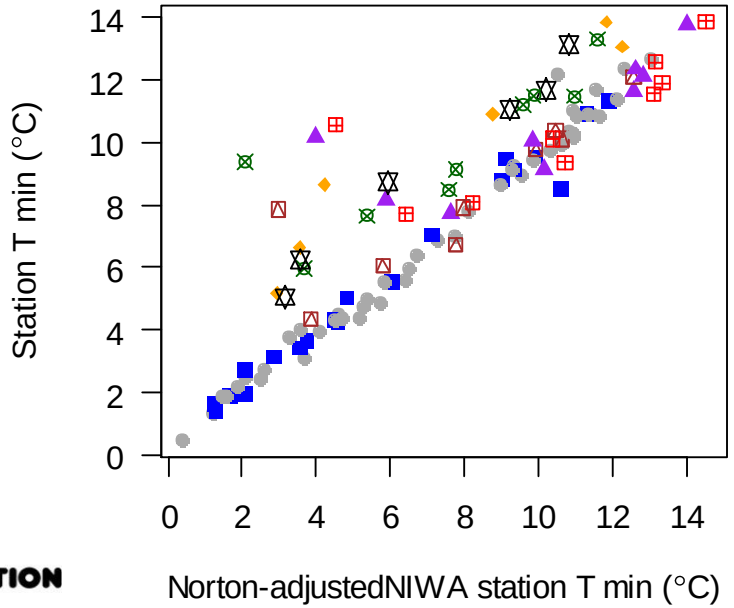

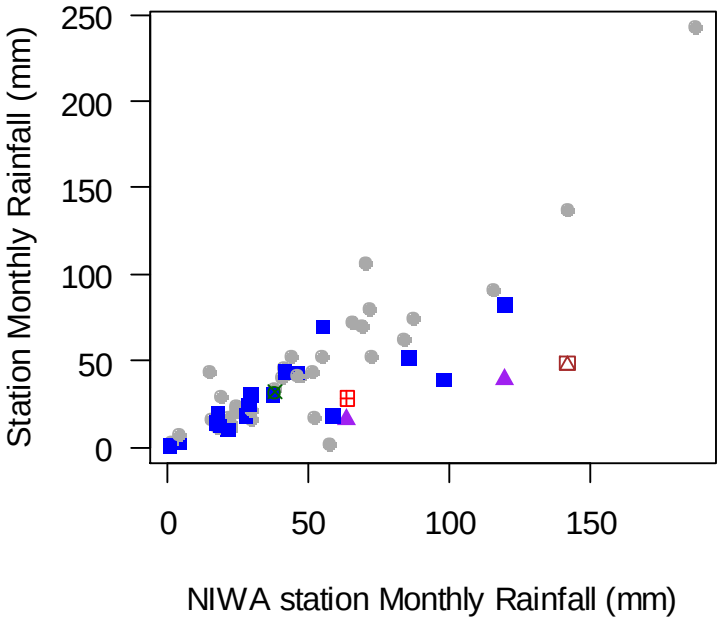

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Estimating productivity indices

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Hybrid model estimates of site index in Kaingaroa Timberlands' estate

- **Radiation-use efficiency model runs**
  - **Potentially useable radiation sum since time of planting**
  - **LiDAR DEM**
  - **Adjusted VCSN climate**
  - **Fundamental soil layer**
- **Test different physiological model forms**
  - **Productivity indices from PSPs planted after 1972 with measurements > age 15**
- **Implement estimates of productivity across landscapes at high resolution**

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Best hybrid model prediction of site index in Kaingaroa Timberlands' estate

- **Independent variables**
  - **Temperature and VPD modified radiation sums**
  - **Slope (highly curvilinear, small slopes most important)**
  - **Fertility estimated as pH & C:N**
- **Soil water balance unhelpful**
- **Standard error = 1.68 m**
- **Lidar tree height estimates of SI (Watt et al. 2015)**
  - **standard error = 1.38 m**

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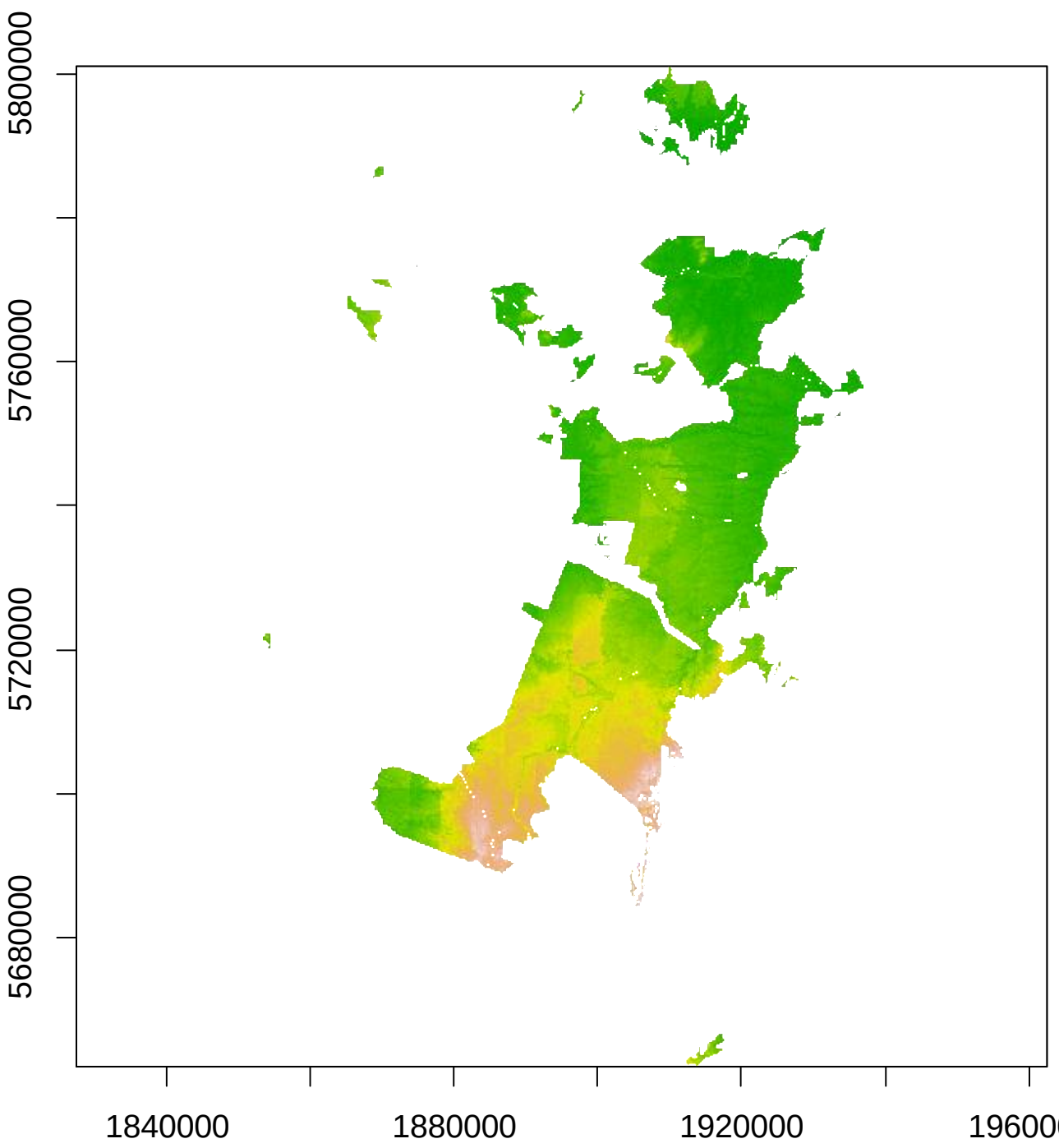

Site index 2010

220,000 ha
Pixels @ 15 m
9,800,000
points

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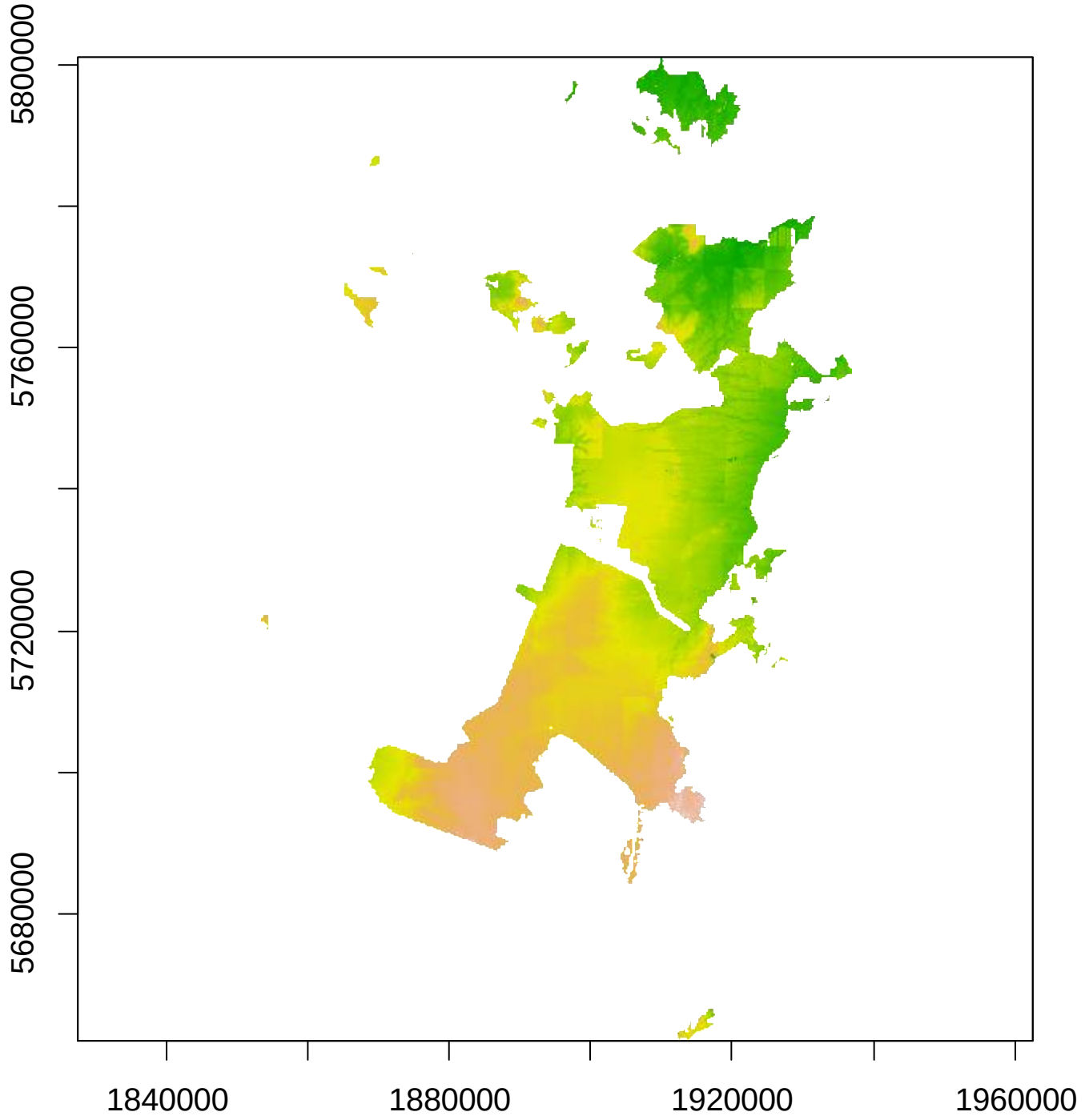

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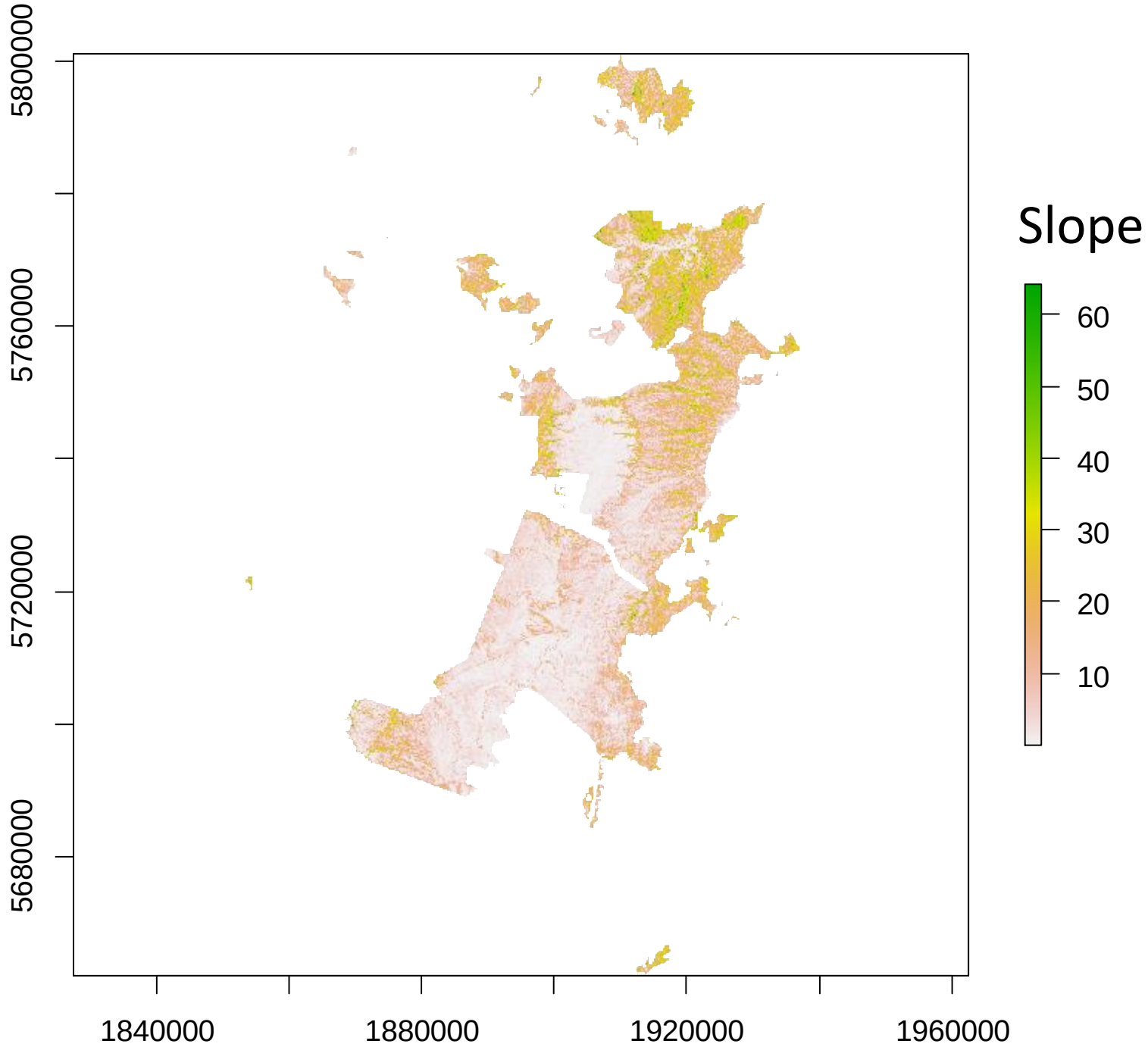

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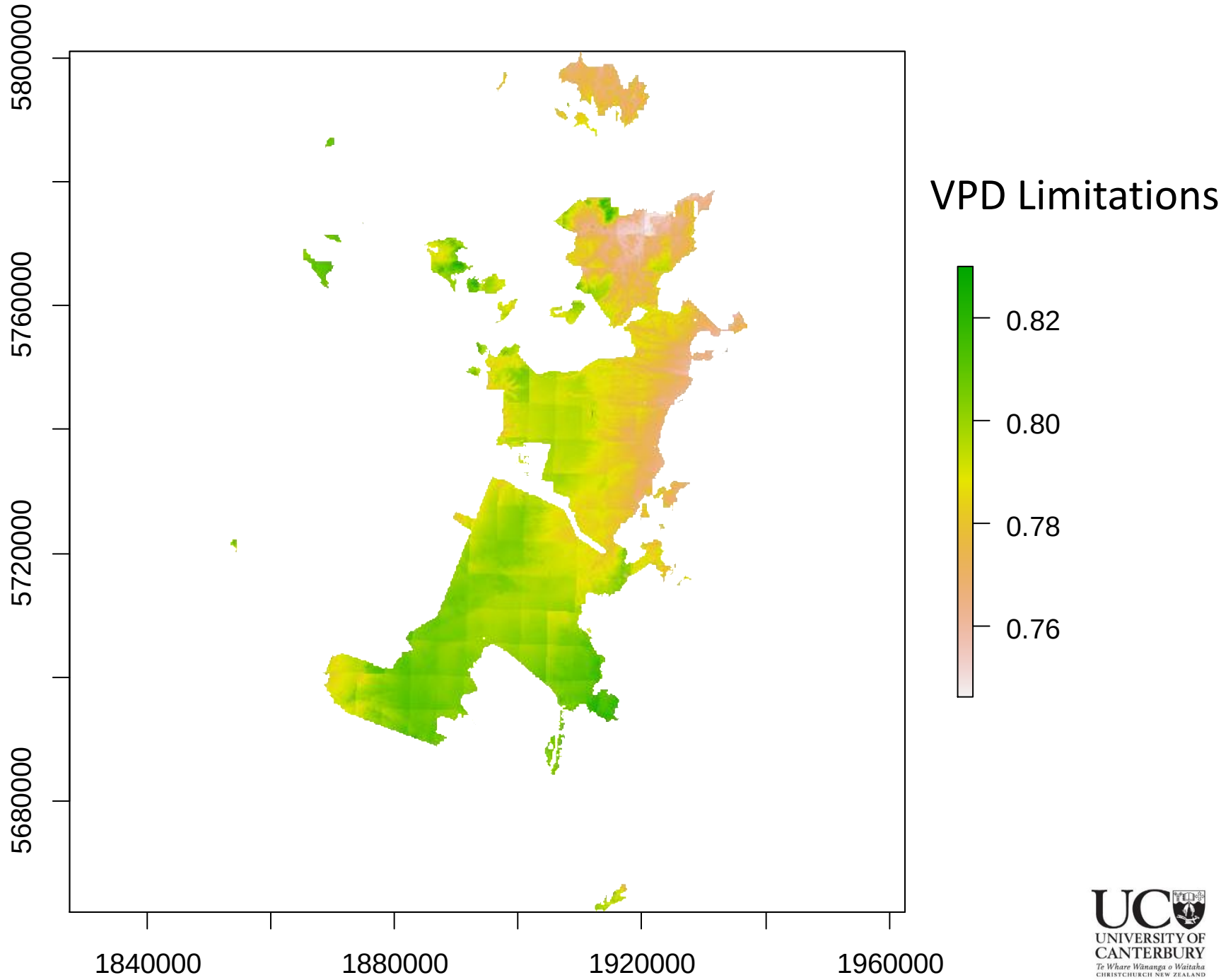

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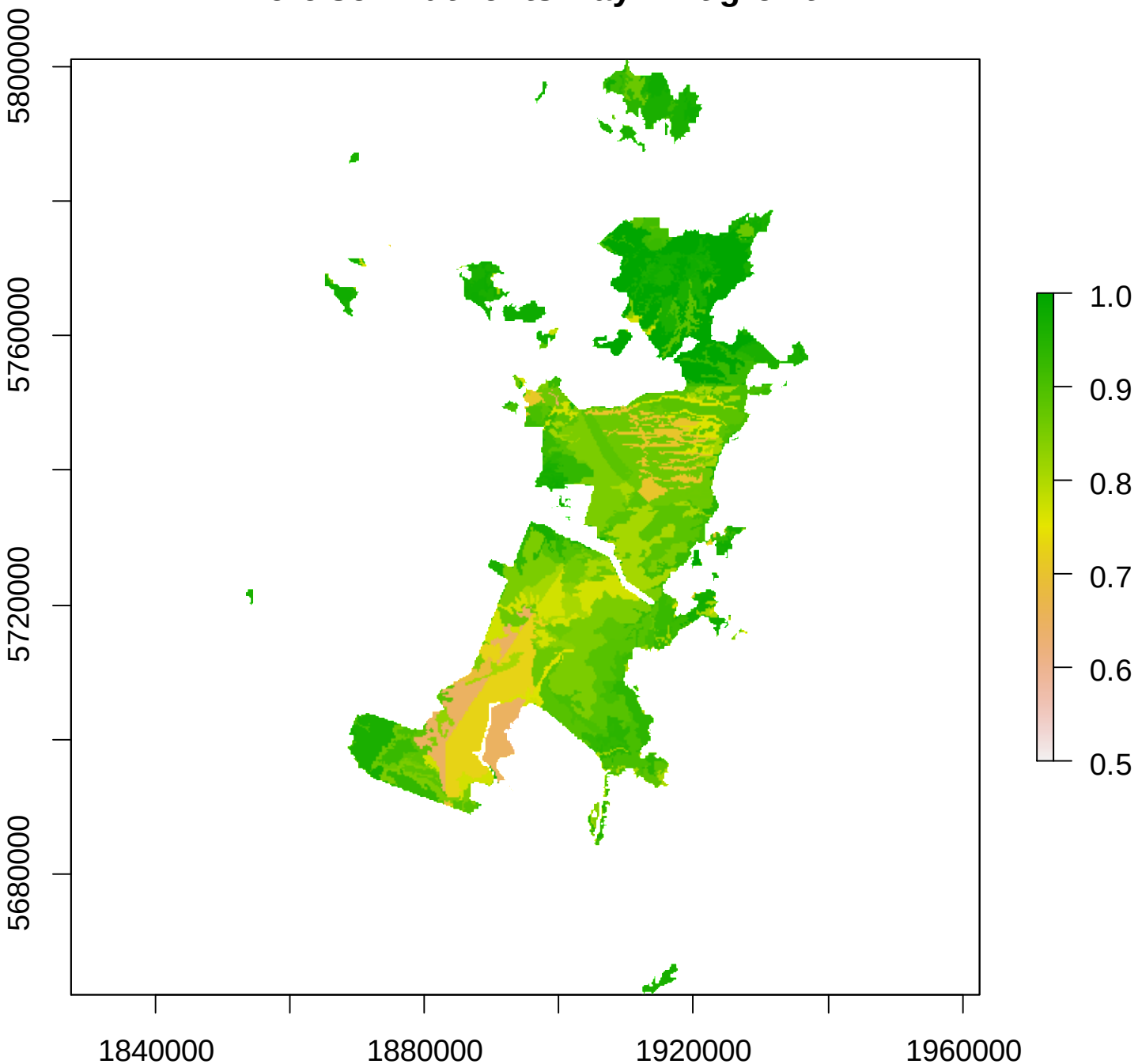
Where soil nutrients may limit growth



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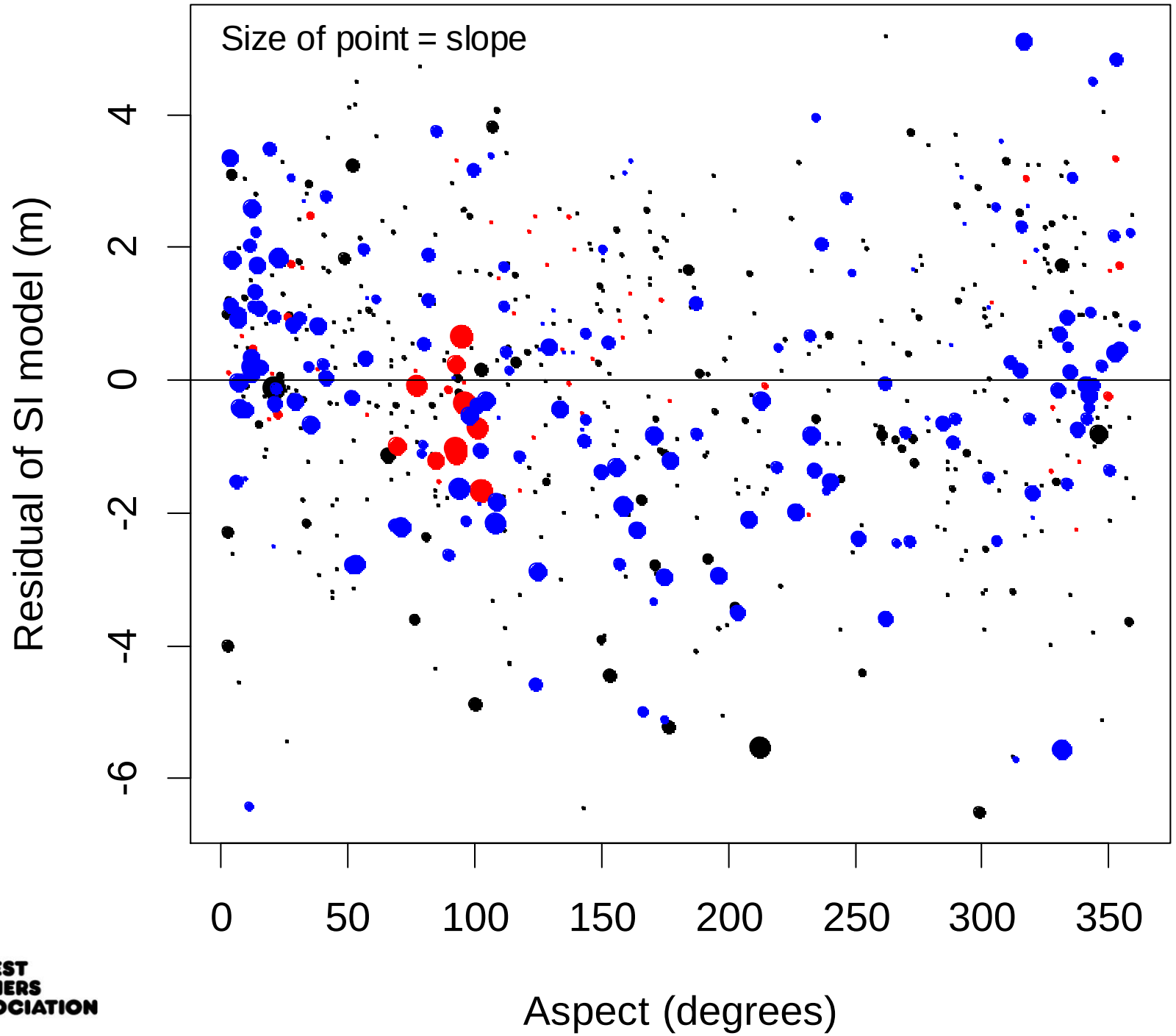

Residuals of model without slope and aspect

Colours = different companies

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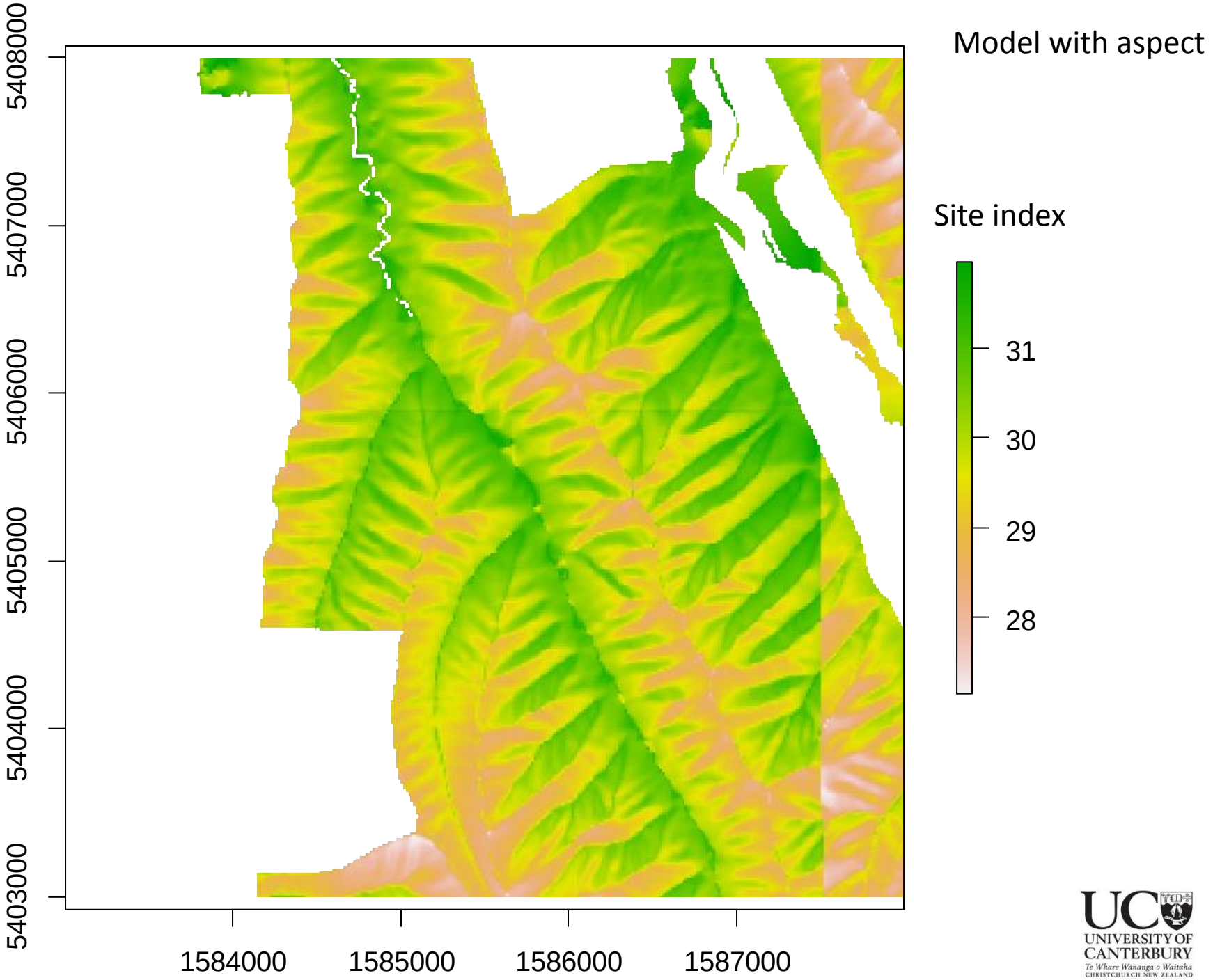

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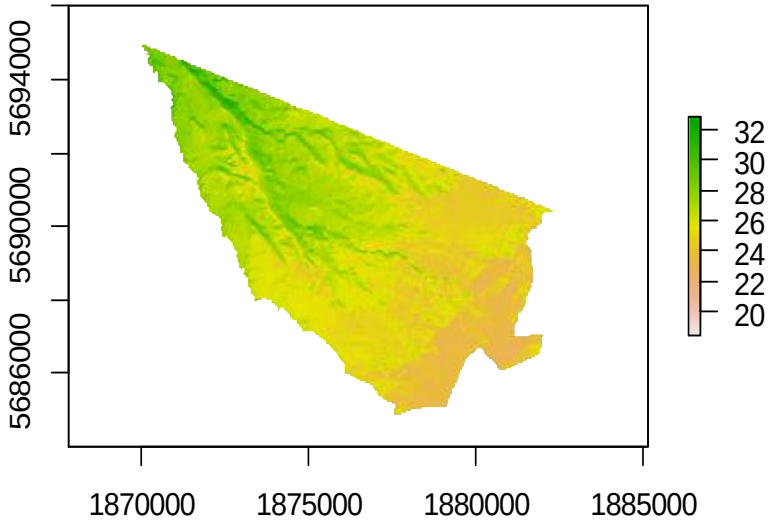

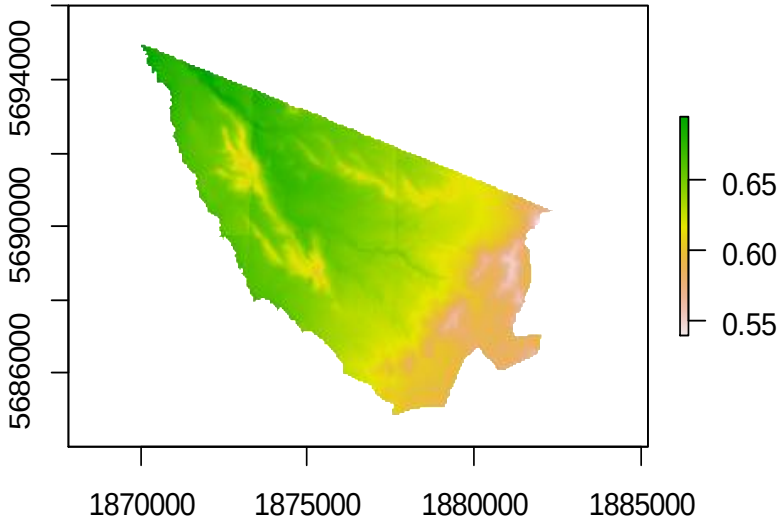

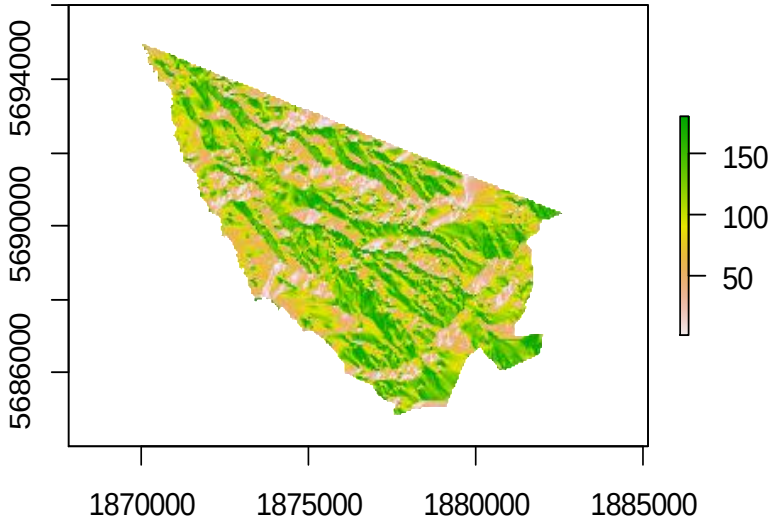

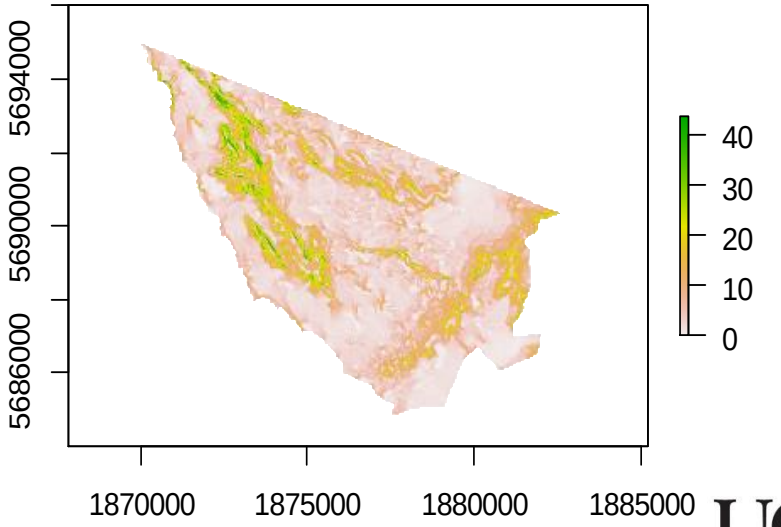

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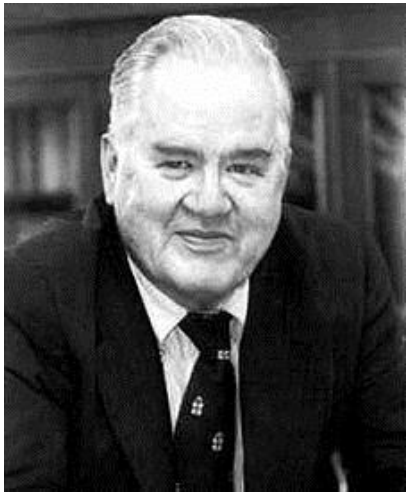
N.B.: *No tree growth data* employed to estimate productivity and site limitations

- **Popperian philosophy of science**

Hypothesis → Model → Data collection → Analysis → Conclusion

- **Traditional growth and yield modelling**
  - **Begins with data**
  - **Exploratory data analysis (Tukey 1977)**

Data collection → Analysis → Model → Conclusion



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Hybrid growth and yield models

Blending physiology with growth and yield modelling

- **Use physiology to predict index values, then run index-based models**
  - **Overall error:**
    - **physiology error + index model error + growth & yield model error + measurement error**
- **Use modified light sum instead of time in equations**
  - **Overall error:**
    - **physiology error + growth & yield model error + measurement error**

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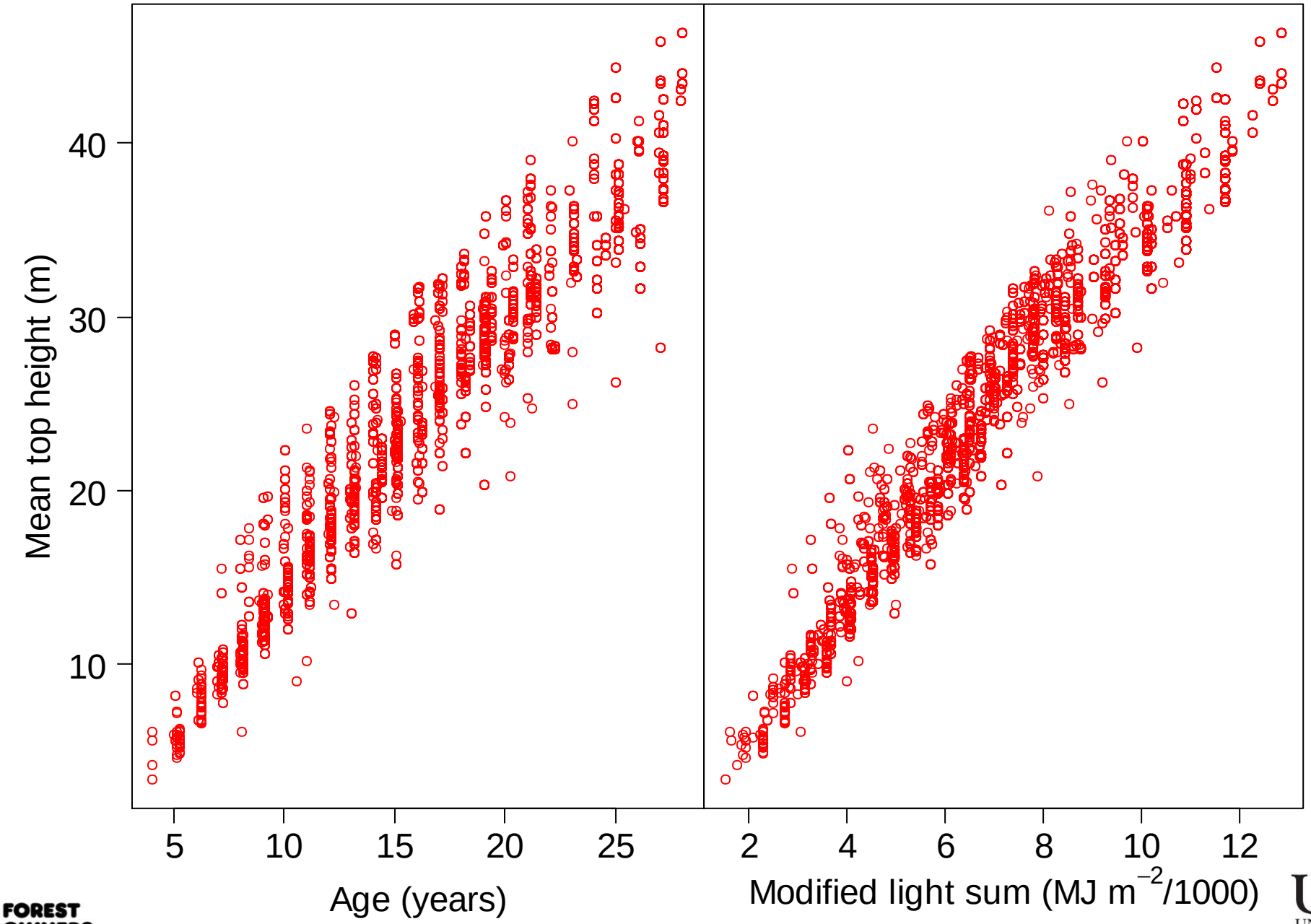

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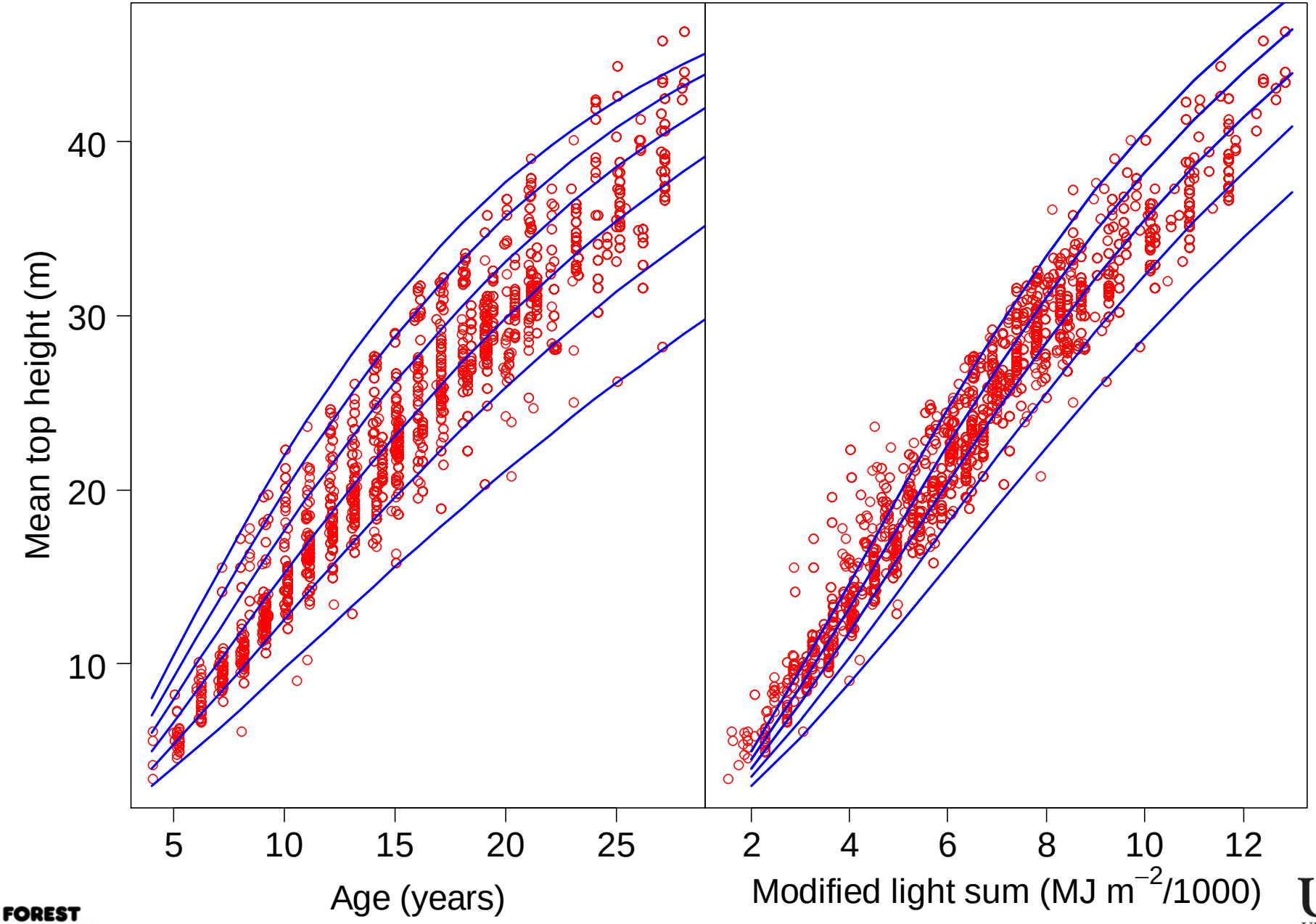

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RESULTS

PRECISION

Percentage precision gain with respect to the least precise approach (based on SE)

	P. taeda			*E. grandis*		
	Base	Augmented	PULSE*	Base	Augmented	PULSE
h_{dom} (m)	2.0	**3.4**	0	0	1.8	**10**
G (m²/ha)	0	2.5	**6.9**	0	4.0	**14.3**
d_{max} (cm)	0	1.4	**9.1**	0	1.8	**9.5**
SD_d (cm)	0	**2.1**	**2.1**	0	0	**8.9**
Average	**0.5**	**2.4**	**4.5**	**0**	**2.0**	**10.7**

*Calculated using a validation dataset

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Casnati (2016)

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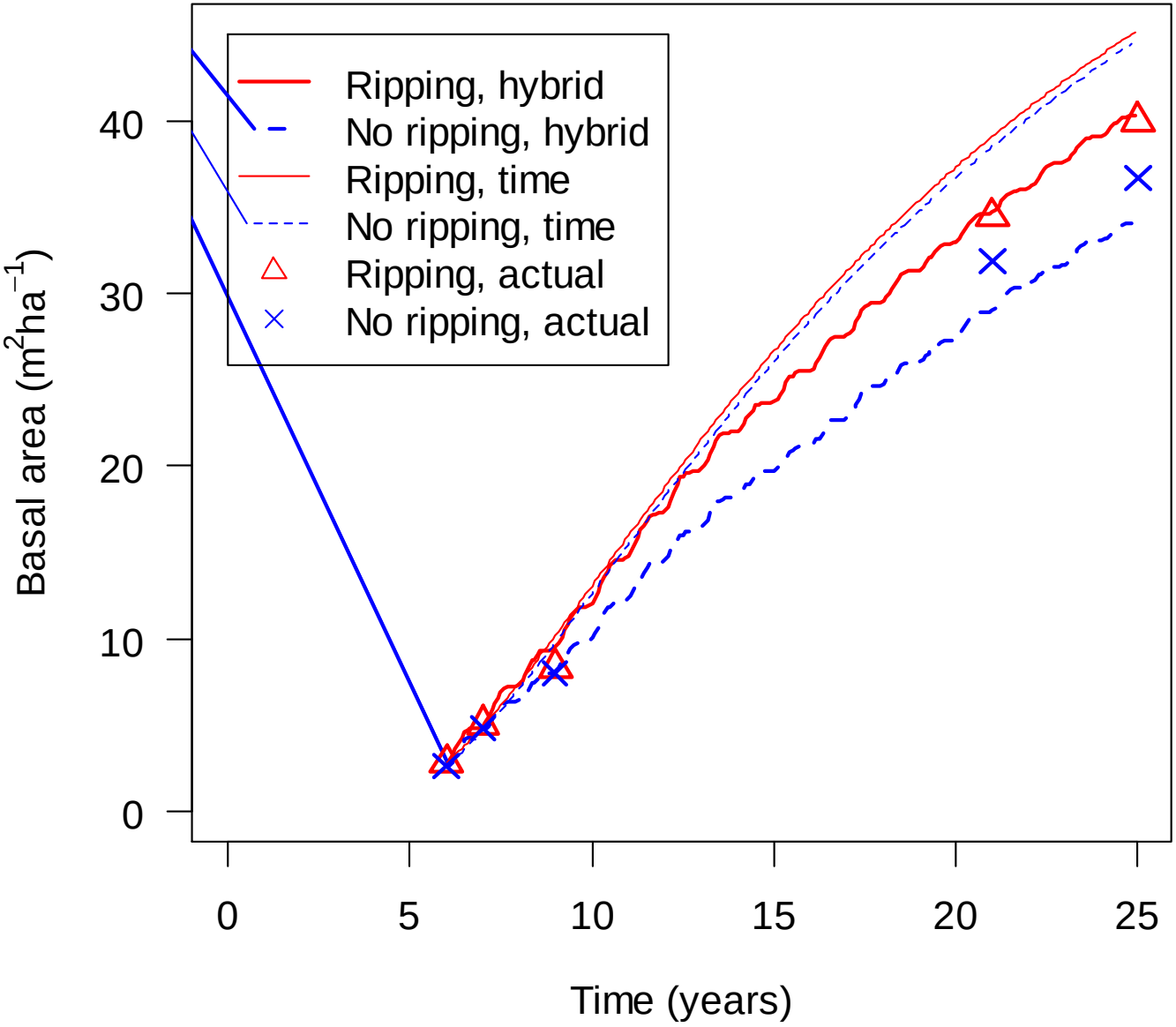
Hybrid model: Effects of site preparation



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Climate change: NIWA prediction for Bay of Plenty, 1990 to 2040

- **+1 degree C to summer and autumn temperatures**
- **+0.9 degrees C to winter temperatures**
- **+0.8 degrees C to spring temperatures**

Source: Ministry for the Environment (2008)

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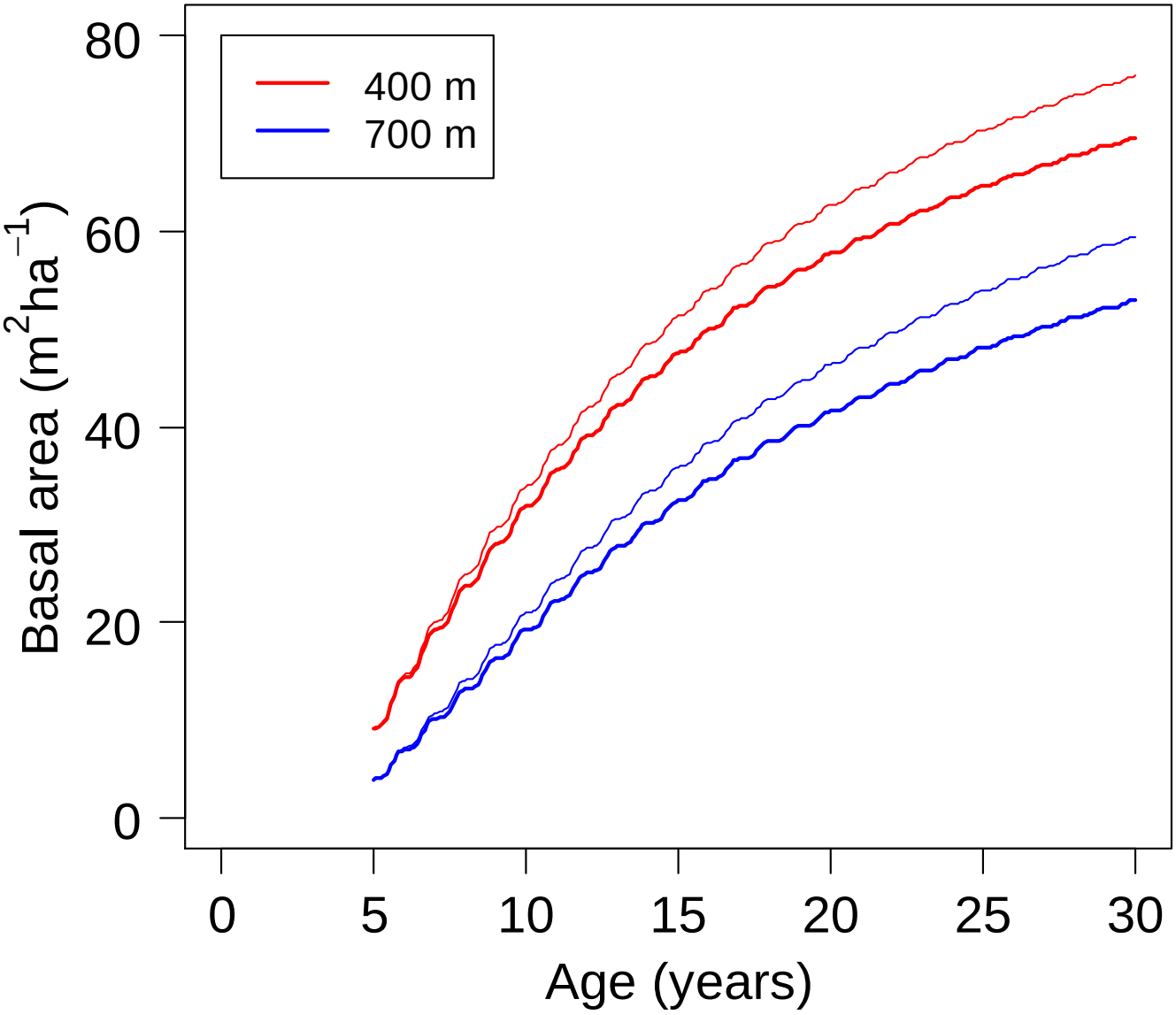
Thick lines = 1990
Thin lines = 2040



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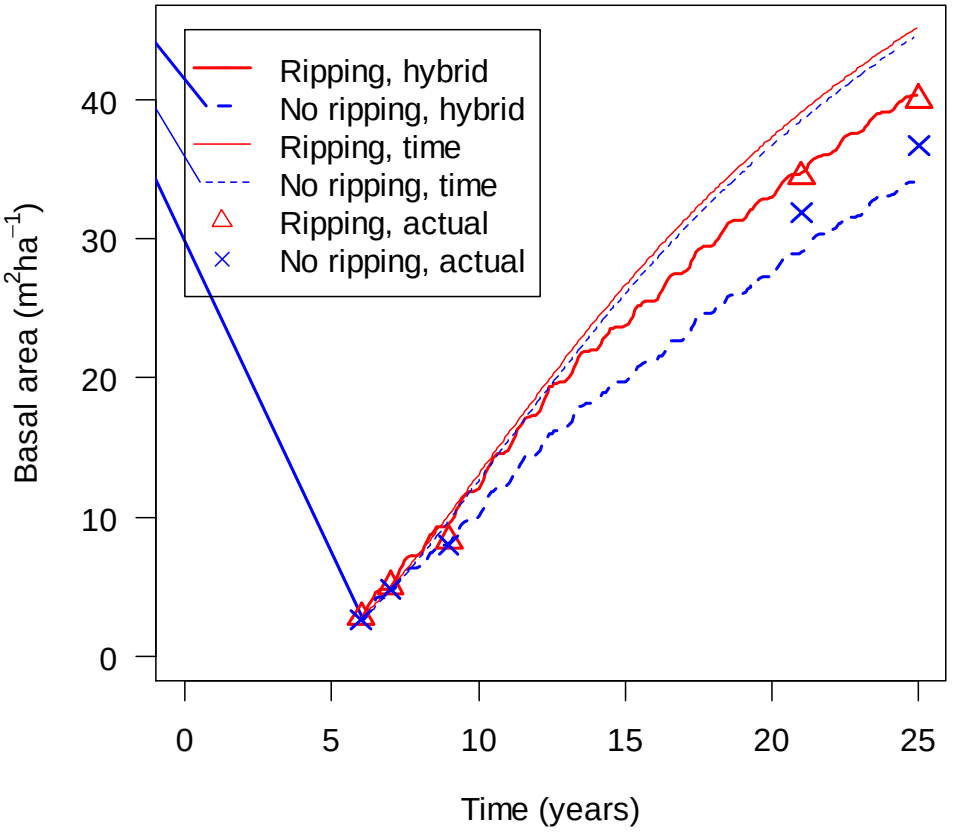
Summary: Hybrid physiological/mensurational modelling

- ***Collaboration between researchers and managers***
- ***Combine the best of physiology & mensuration***
- ***More useful models***
- ***Our methods are different***
  - ***Retain mensurational features***
  - ***Minimise errors***



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