Diameter and Height Modeling for less abundant tree species in Elliot Research Forest

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2025 Western Mensurationists Conference

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INTRODUCTION

- Exponential increase in use of LiDAR in inventory
- Traditional inventory- the field measurement, modeling height from DBH is less cumbersome
- BUT, (West and Strimbu, 2025), novel approach-predicting DBH from height, so that we could obtain forest metrics, with ONLY aerial lidar data.

Major species including Douglas fir, Red alder, Western, red cedar, Western Hemlock(West and Strimbu,2025)

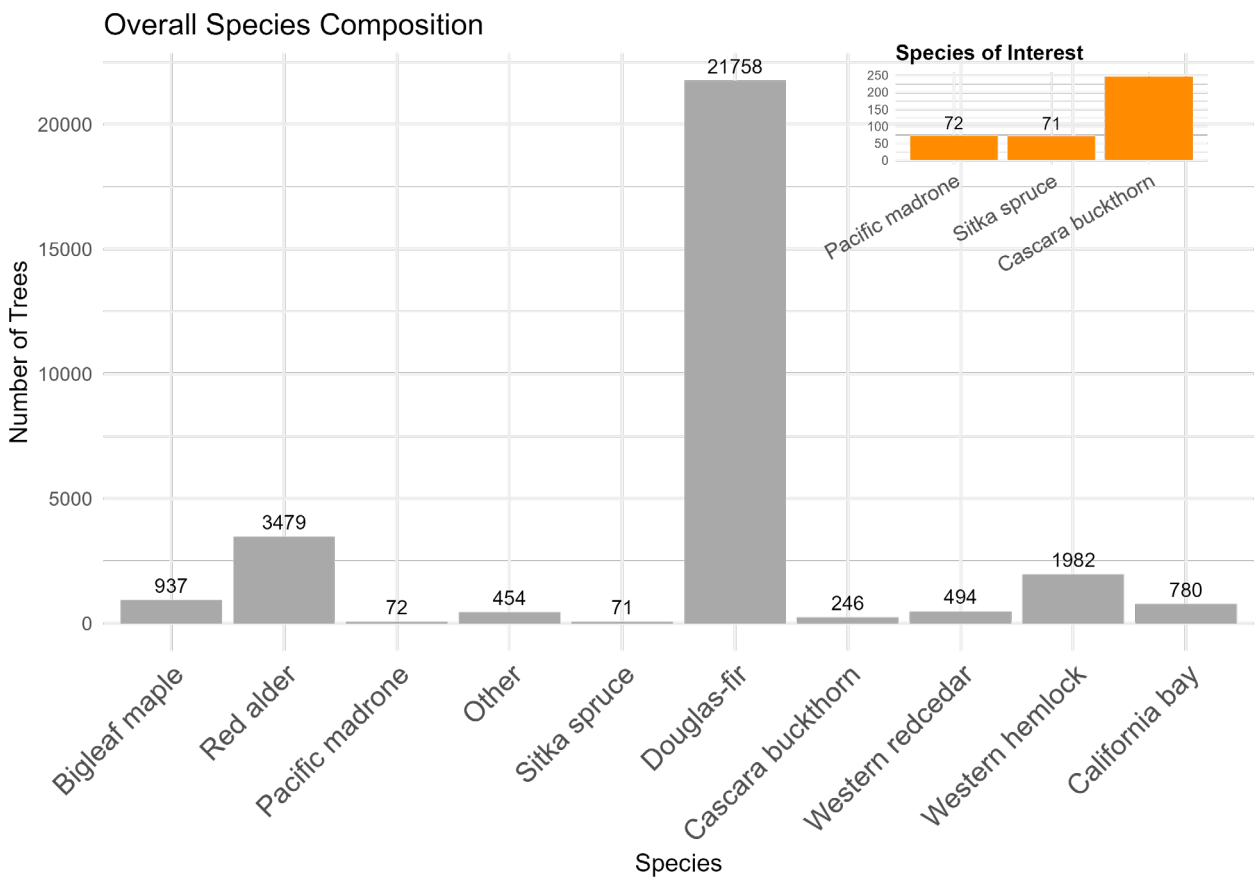
How does these model behave for less abundant species (<1%)--which were previously under 'other' category

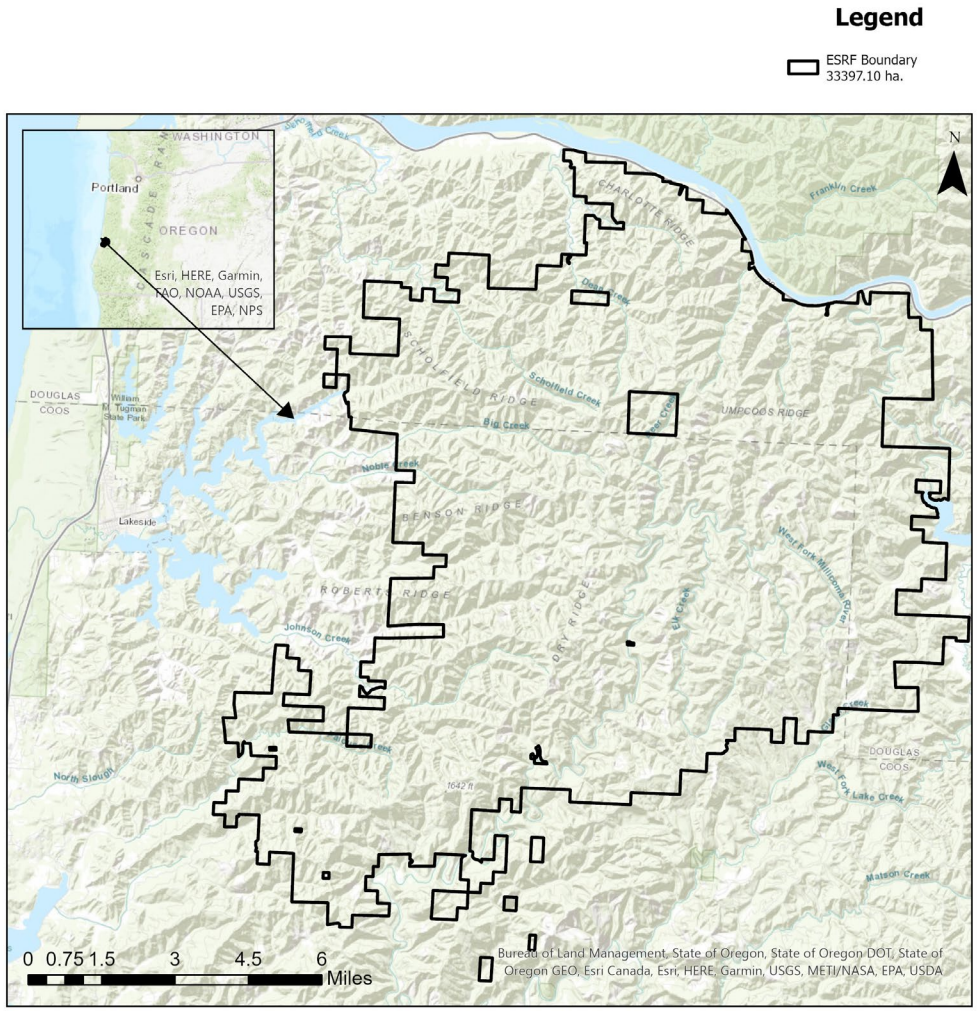
OBJECTIVE

Evaluate Non-linear and GAMs for predicting height and DBH of 3 less abundant species

Assess the importance of physiographic variables and stand type in the prediction

METHODS: STUDY AREA

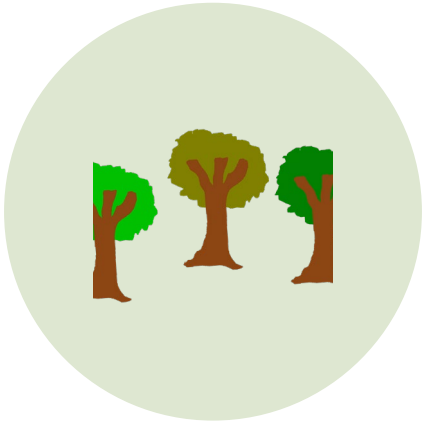




METHODS: DATA

- 2015/16, 10,036 plots in 738 stands cruised
- VRP and FRP measurement (West & Strimbu, 2024)

TREE LEVEL: DBH, TOTAL HEIGHT

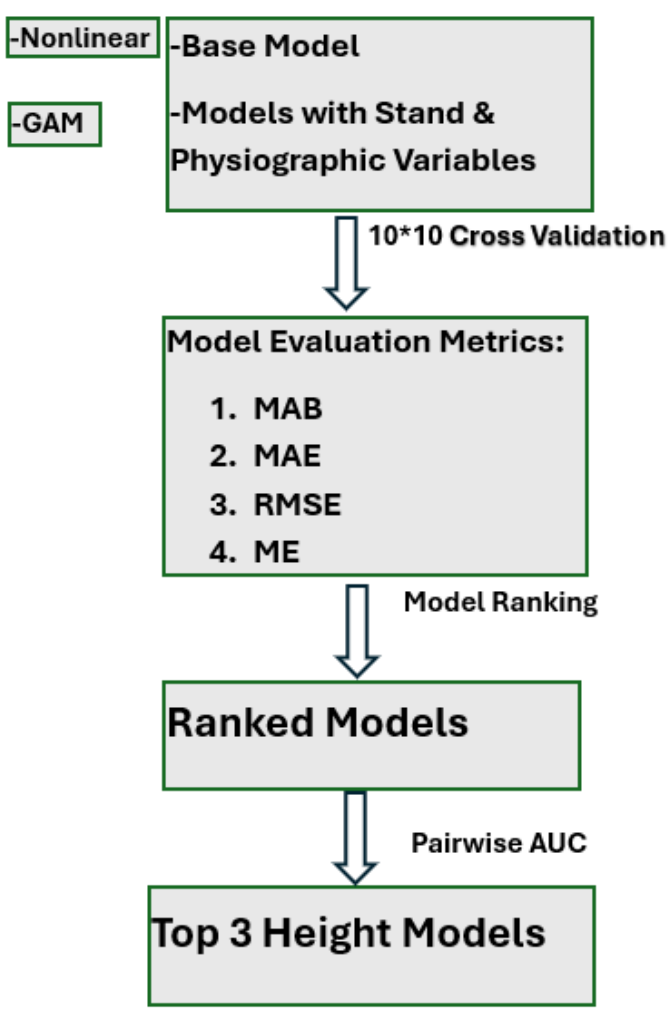


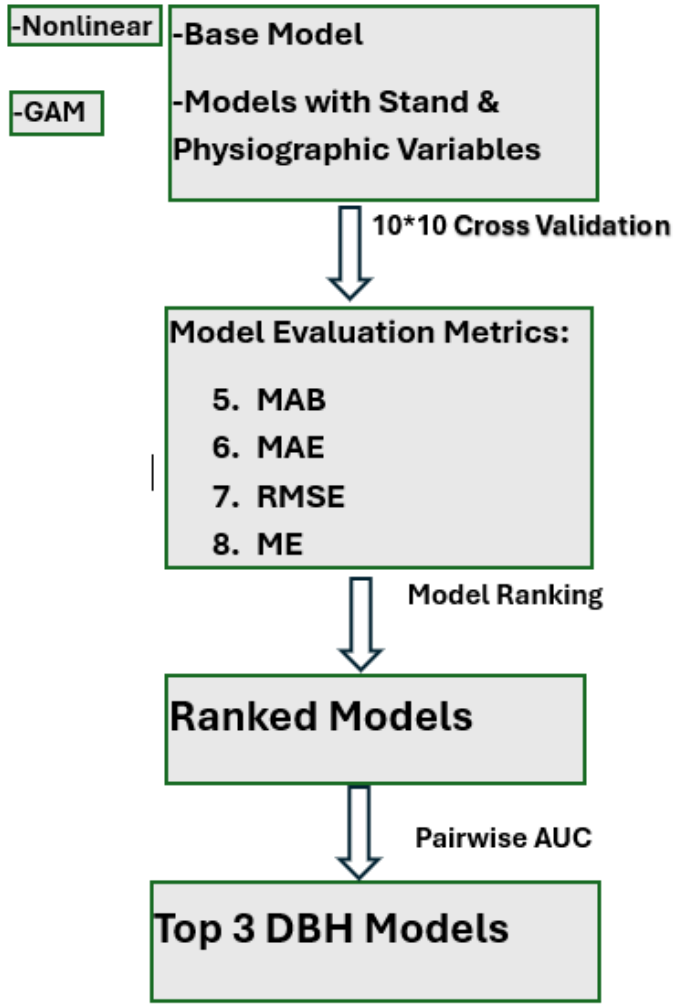
STAND LEVEL: BA (M^2/HA), BALARGER (M^2/HA), QMD, RELATIVE DBH, RELATIVE HEIGHT

PHYSIOGRAPHIC: ELEVATION, SLOPE, SIN/COS(ASPECT), TOPOGRAPHIC SHELTER INDEX

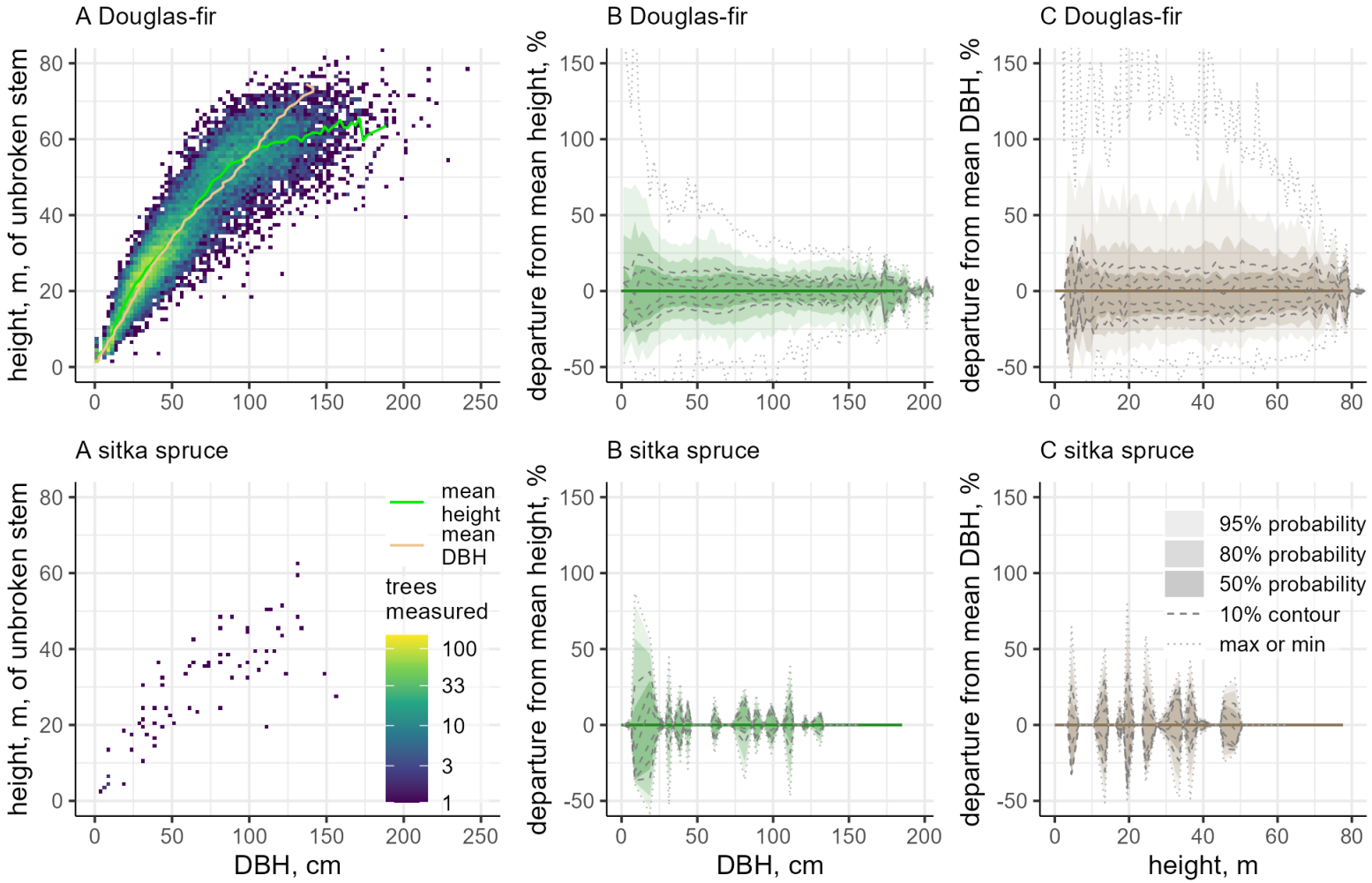
METHODS: WORKFLOW

- **Base model**: model with only DBH or height
- **Model Assessment:** Area Under The Curve (AUC) for Model Evaluation metrics:

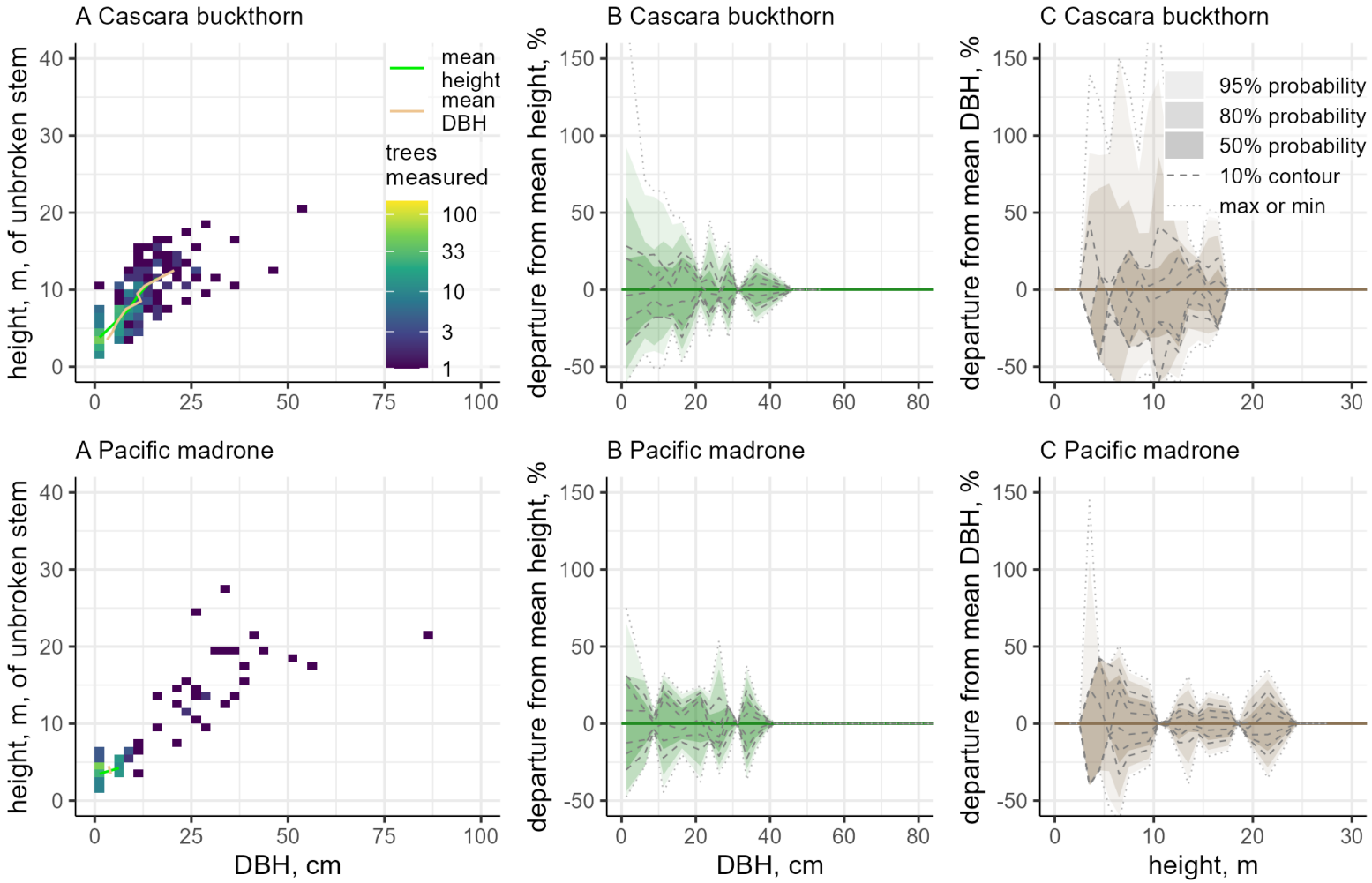




METHODS: EXPLORATORY ANALYSIS



METHODS: EXPLORATORY PLOTS



METHODS: HEIGHT REGRESSION FORMS

- Nonlinear forms
  - Chapman-Richards:
    - $TotalHt = 1.37 + a_1{*}(1 - e^{(b_1 * DBH)})^{2} + \varepsilon$
  - Chapman-Richards BA+L physio:
    - $TotalHt = 1.37 + (a_1 + a_1 p * isPlantation + (a_2 + a_2 p * isPlantation) * \boldsymbol{basalAreaLarger} + a_8 * \boldsymbol{topograpicShelterIndex}) * (1 - e^{(b_1 + b_1 p * isPlantation) DBH})^{2} + \varepsilon$

- Generalized additive models (GAMs)
  - REML GAM RelDbh physio:
    - $TotalHt = a_0 + s_1(DBH) + s_2(elevation) + s_3(slope) + s_4(topographicShelterIndex) + s_5(relativeDiameter) + \varepsilon$
- Linear & parabolic as controls:
  - $TotalHt = a_1 \times DBH + \varepsilon$
  - $TotalHt \sim a_1 \times DBH + a_2 DBH^2 + \varepsilon$

METHODS: DIAMETER REGRESSION FORMS

- Inverse & "replace" forms of existing height models
  - Chapman-Richards replace:
    - $\text{DBH} \sim a_1 * e^{(b_1 * (TotalHt - 1.37) - 1)^{b_2}} + \varepsilon$
  - Chapman-Richards inverse:
    - DBH ~ a1∗log(1 − pmin($(b_1 * (TotalHt - 1.37))^{b_2}$, 0.9999) + ε
    - pmin to avoid the value of log being 0 or negative.
  - Linear & parabolic as controls:
    - DBH = a_1 × (TotalHt − 1.37) + ε
    - DBH =a_1(TotalHt − 1.37) +a_2(isPlantation∗(TotalHt − 1.37))+a_3(isPlantation ∗(TotalHt − 1.37)^2)+ ε

RESULTS

Cross validated Models

- Cross validation and model evaluation comparable for DBH
- But not for height
- Height models more sensitive to no. of observation.

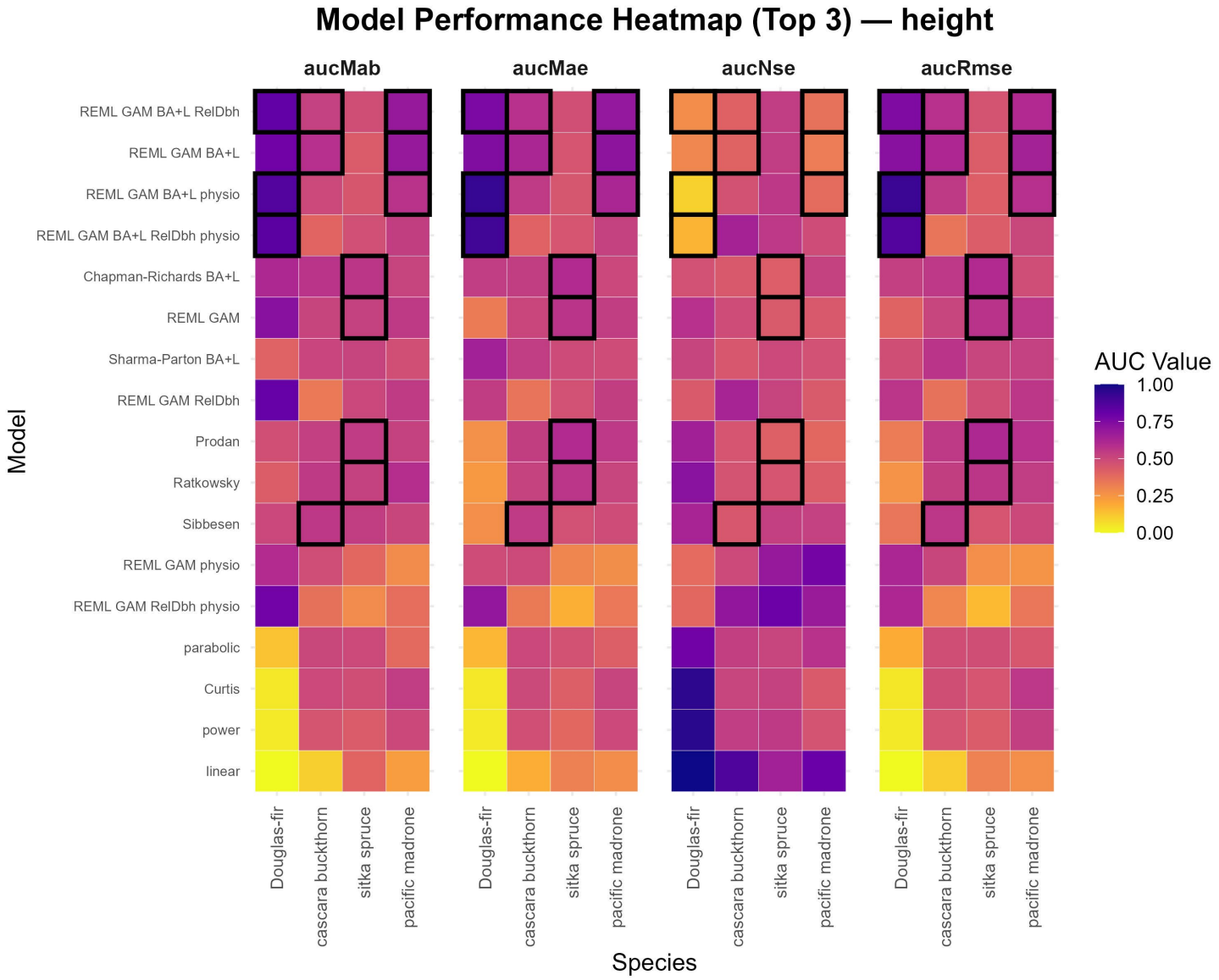
Table: Cross Validation Information

	No. of Cross validated models for …	
Species	DBH	height
Douglas-fir	38	39
Cascara Buckthorn	35	29
Sitka Spruce	35	36
Pacific Madrone	35	17

RESULTS

- Height
  - Base model of Chapman Richards better for prediction of cascara buckthorn and sitka spruce, after GAMs.
  - No convergence issue for Doug fir, but other three species, model relevance dropped quickly
- DBH
  - Douglas Fir
  - DBH = $(a_1 + a_9 \times \text{relativeHeight}) \times \log(1 - \min[b_1 \times (TotalHt - 1.37)^{b_2}, 0.9999]) + \varepsilon$
  - DBH = $(a_1 + a_2 \times \text{tallerApproxBasalArea} + (a_9 + a_9p \times \text{isPlantation}) \times \text{relativeHeight}) \times (\text{TotalHt} - 1.37)^{b_1} \times (\text{TotalHt} - 1.37)^{b_2} + \varepsilon$
  - Across all other species, Chapman Richards, Sibbesen replace, and Ruark, did not improve model prediction significantly by addition of physiographic and stand level variables to base models.
- Selection of “top" model
  - Preference given to AUC for each metric.

RESULTS: HEIGHT MODELS



RESULTS

Chapman Richards

$$\text{TotalHt} = 1.37 + (a_1 + a_{1p} \cdot \text{isPlantation}) \cdot \left(1 - e^{b_1 \cdot \text{DBH}}\right)^{(b_2 + b_{2p} \cdot \text{isPlantation})}$$

REML GAM BA+L

$$\text{TotalHt} = \alpha + f_{\text{plantation}}(\text{DBH},\ \text{standBasalAreaPerHectare},\ \text{basalAreaLarger}) + \varepsilon$$

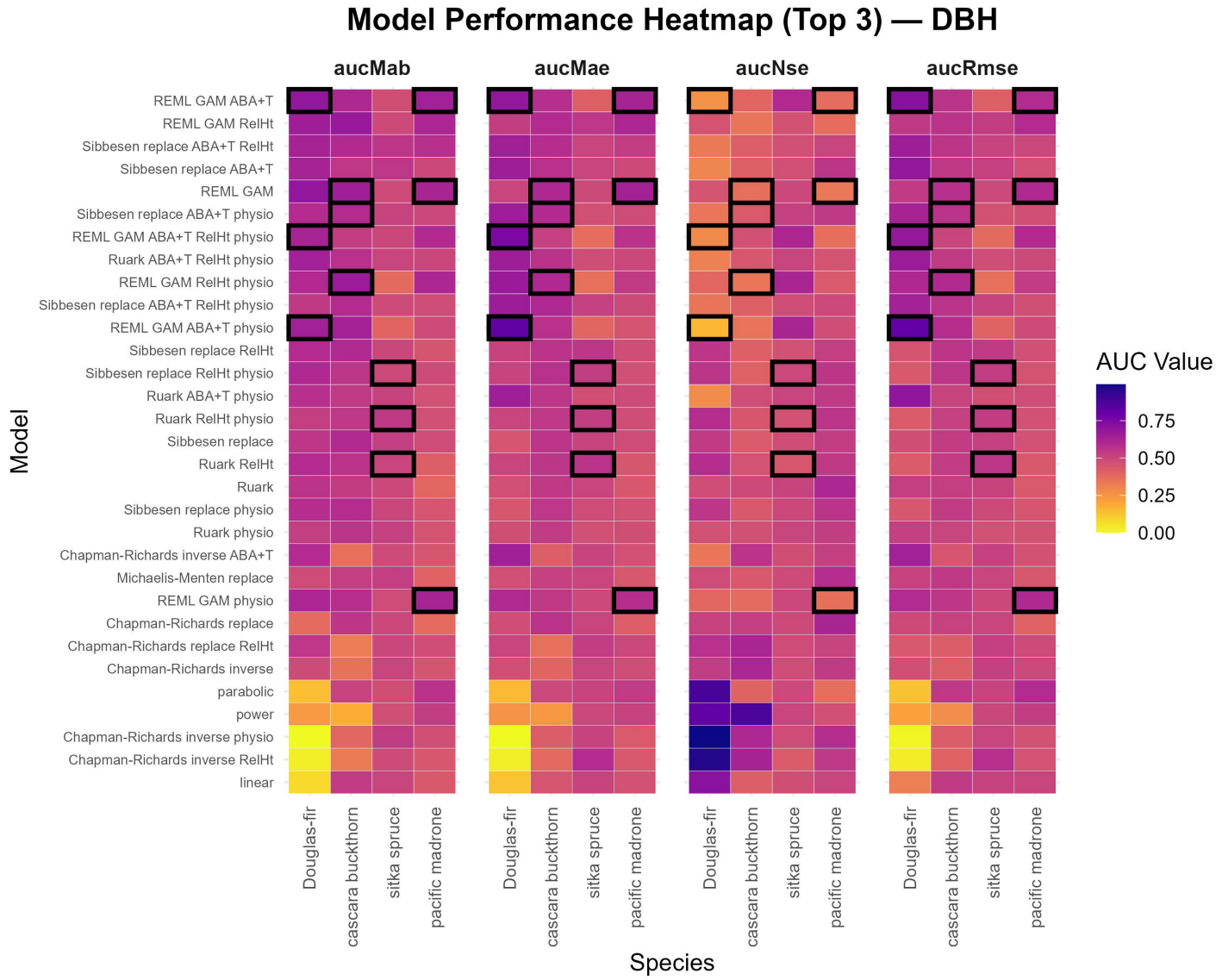
Sibbesen

$$\text{TotalHt} = 1.37 + (a_1 + a_{1p} \cdot \text{Plantation}) \cdot \text{DBH}^{(b_1 + b_{1p} \cdot \text{Plantation}) \cdot \text{DBH}^{(b_2 + b_{2p} \cdot \text{Plantation})}} + \varepsilon$$

Prodan

$$\text{TotalHt} = 1.37 + \frac{\text{DBH}^2}{a_1 \cdot \text{DBH}^2 + (a_2 + a_{2p} \cdot \text{Plantation}) \cdot \text{DBH} + (a_3 + a_{3p} \cdot \text{Plantation})} + \varepsilon$$

METHODS: DIAMETER MODELS



RESULTS

REML GAM
ABA+T

$$\mathrm{DBH} = f_{\mathrm{Plantation}}\left(\mathrm{TotalHt},\ \mathrm{tallerApproxBasalArea},\ \mathrm{standBasalAreaApprox}\right) + \varepsilon$$

Sibbesen replace ABA+T

$$\mathrm{DBH} = \left(a_1 + a_{1p} \cdot \mathrm{Plantation} + a_6 \cdot \cos\left(\frac{\pi}{180} \cdot \mathrm{aspect}\right) + a_9 \cdot \mathrm{relativeHeight}\right) \cdot (\mathrm{TotalHt} - 1.37)^{b_1 \cdot (\mathrm{TotalHt} - 1.37)^{b_2}} + \varepsilon$$

RESULTS

Almost 50% of nonlinear models for Pacific madrone don't converge because relative height close to 0.

Relative ht = TotalHt/topHeight

Pacific Madrone → high variability, and problem in convergence

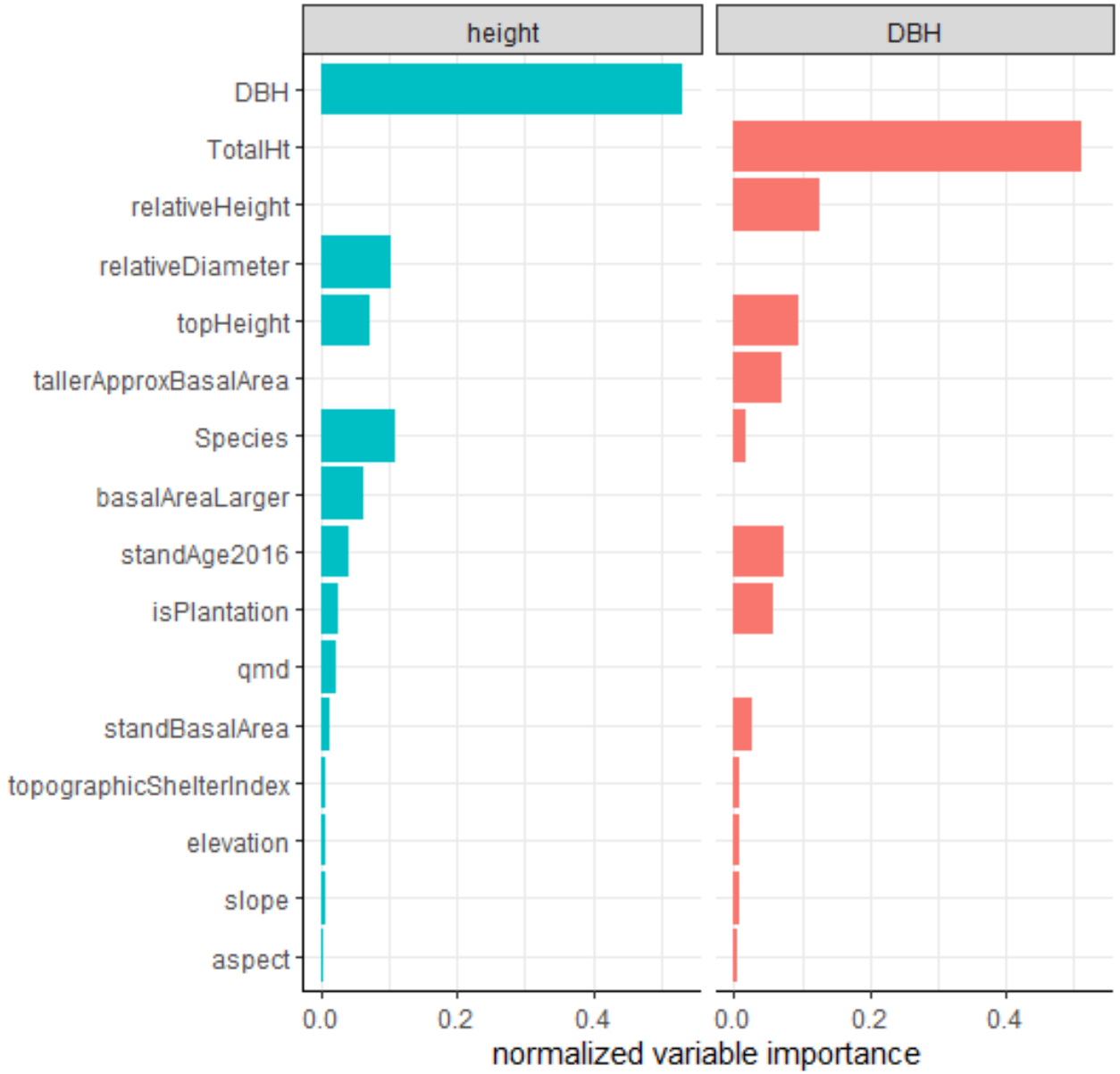
Cascara buckthorn→ model discrimination not so much

Sitka spruce → better than pacific madrone and cascara buckthorn

Variable importance

- Major predictors were height for diameter and vice versa
- Species improved the prediction ability of height better than diameter
- Physiographic variables marginally improved the performance of both height and diameter prediction.

- Note: less text for whole presentation as well, re-run the vi for three species



NEXT?

- Is it really due to less observation?
- Confidence Intervals?
- Nonlinear mixed effect models?
- Nonlinear robust models?
- A summary metric combining all the metrics?--weighted?

ACKNOWLEDGEMENTS

- Bogdan Strimbu, Ph.D -- Supervisor
- Todd West, Ph.D--Mentor
- Research funded from the AFRI grant
- Ellitt State Research Forest

REFERENCES

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QUESTIONS/SUGGESTIONS/COMMENTS