Stand Effects
What Are They and What Can We Do About Them?

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April 5th, 2023

Premise

A few months ago, I wanted to explore *bias* in lidar maps at the stand-level.

Stand exams, in some situations, can provide unbiased estimates of stand-level quantities.

A rich collection of stand exams could be used to evaluate bias in lidar maps…or so I thought.

Join me on this journey as we learn about the differences between stand exams and stand-level lidar estimates.

Outline

Part 1: What is a Stand Effect?

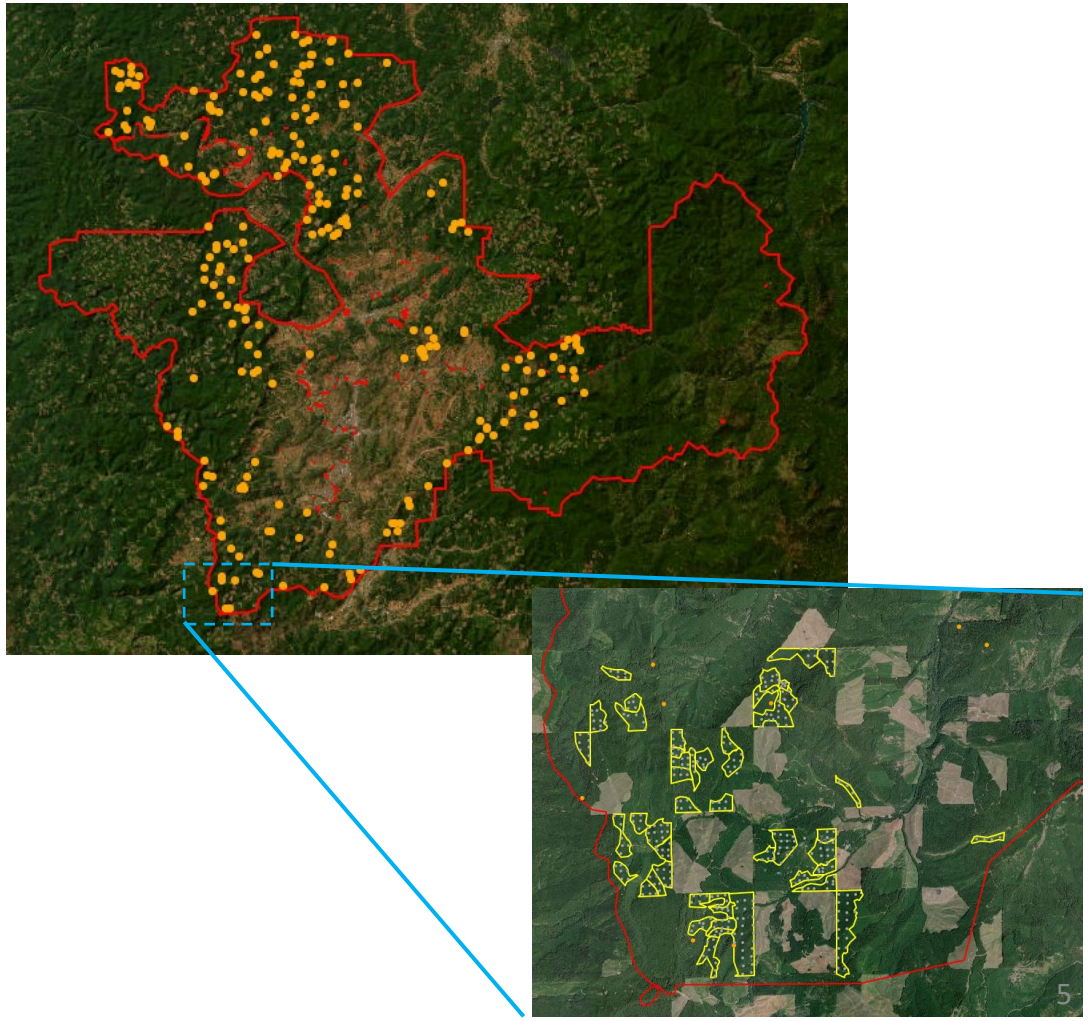
Part 2: Case Study: Roseburg District

What Can We do About Them?

Part 1 – What is a Stand Effect?

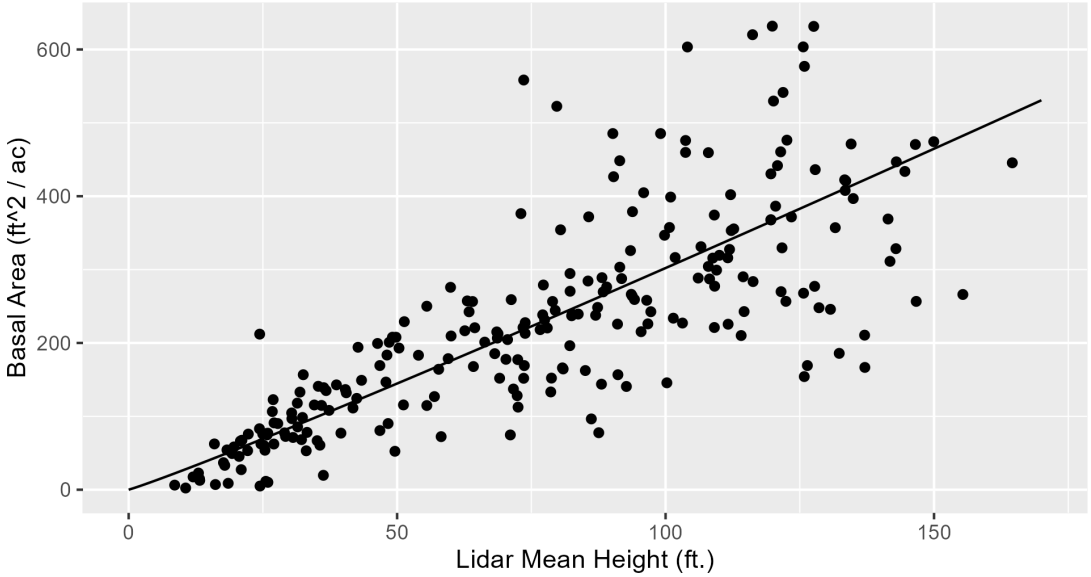
Mappers and Examiners

- Analysis Scenario
  1. A sparse network of field plots
     - Using a *known* sampling design
     - Used to develop lidar inventory maps
  2. A set of stand exams
     - Each exam uses a *known* sampling design
     - Used to estimate stand-level variables
  3. A wall-to-wall lidar acquisition



Mappers and Examiners

- Mappers fit models using the mapping plots
  - $\hat{y}_{ij} = f(\boldsymbol{x}_{ij}, \widehat{\boldsymbol{\beta}})$
- Fit the model, predict all the pixels in the stand, and take their mean
  - $\hat{y}_{i,m} = \frac{1}{N_i} \sum \hat{y}_{ij}$



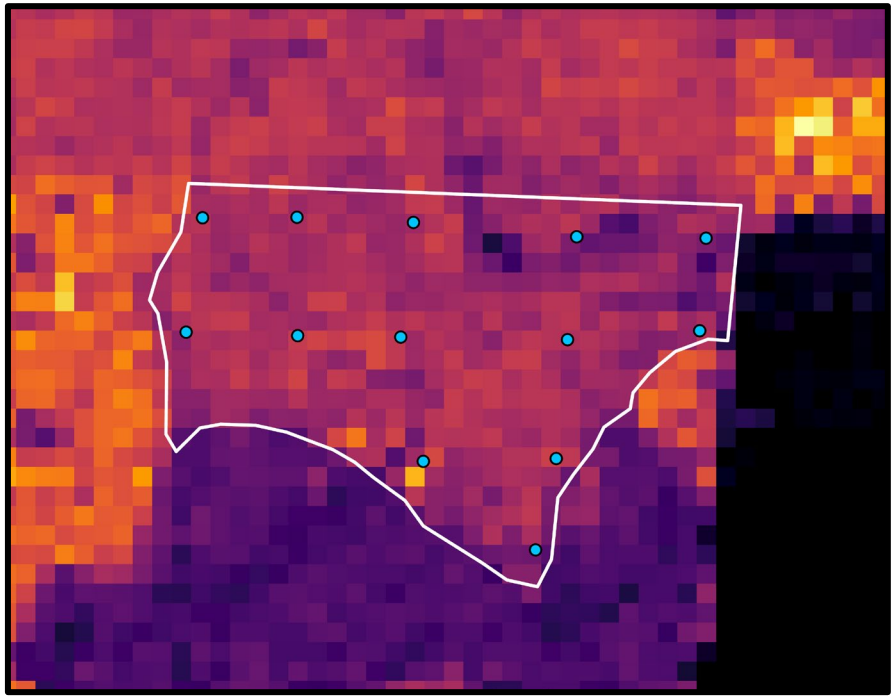
Mappers and Examiners

- Examiners estimate the stand-level mean using a sample of field plots collected with uniform intensity inside the stand
  - $\hat{y}_{i,e} = \frac{1}{n_i} \sum y_{ij}$

Mappers and Examiners

- Two competing estimators
  - Mapper's estimator: $\hat{y}_{i,m}$
  - Examiner's estimator: $\hat{y}_{i,e}$
- What can we learn from these two estimators?

Stand 32273

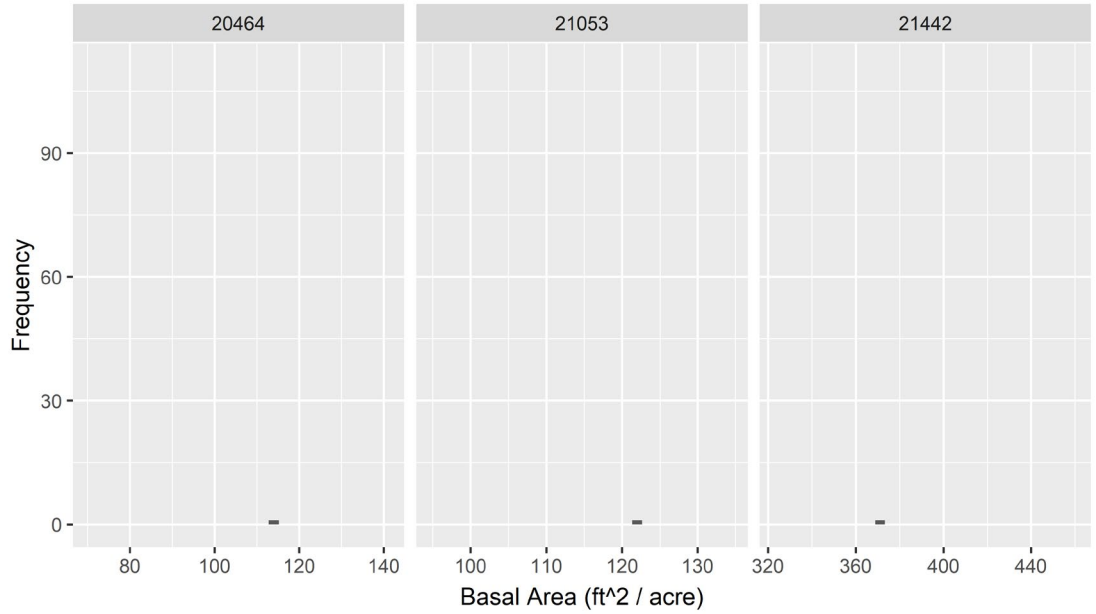


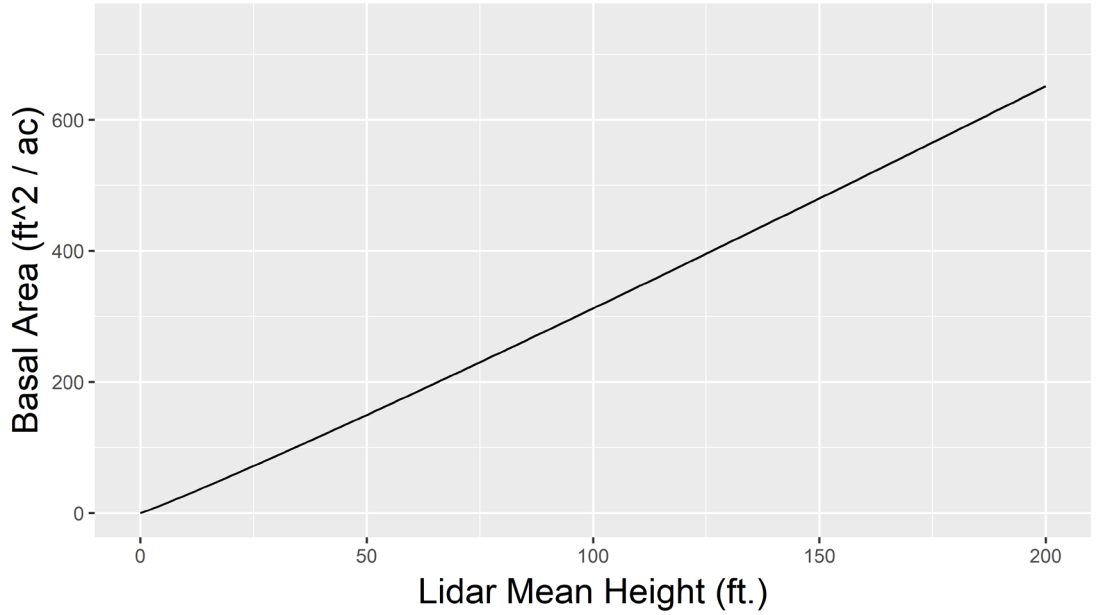
$$\hat{y}_{i,e} = 191\ ft^2 ac^{-1}$$

$$\hat{y}_{i,m} = 187\ ft^2 ac^{-1}$$

Stand Effects

- Estimators can be evaluated using their sampling distributions
  - Variance, expected value (mean)
- Stand Exams
  - Reallocate exam sample, estimate the mean
- Mappers
  - Reallocate mapping sample, estimate the model parameters (and predict)



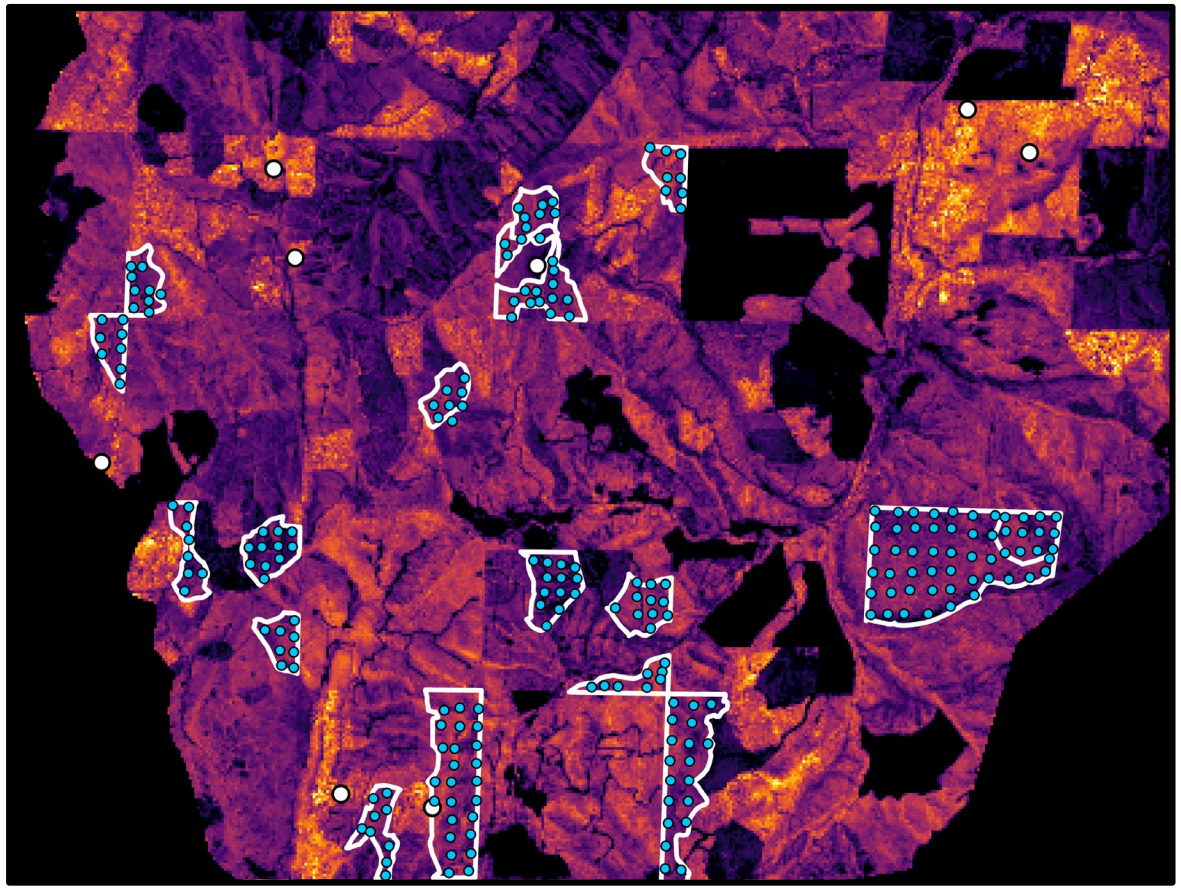


Stand Effects

- We are interested in the *expected difference* between our two estimators
  - $D_i = E(\hat{y}_{i,e}) - E(\hat{y}_{i,m})$
- We will refer to D_i as the stand effect
- The stand effect is practically unknowable
  - We must estimate it from the data
  - We *should* test for significance

Estimating Stand Effects

- If you have the right data, you can *estimate and test* the stand effect
  - Stand exams + design
  - Lidar plots + design
  - Not everyone has this type of data on hand
- The estimate for the stand effect is
  - $\widehat{D_i} = \hat{y}_{i,e} - \hat{y}_{i,m}$
  - It is just the examiner's estimate minus the mapper's estimate

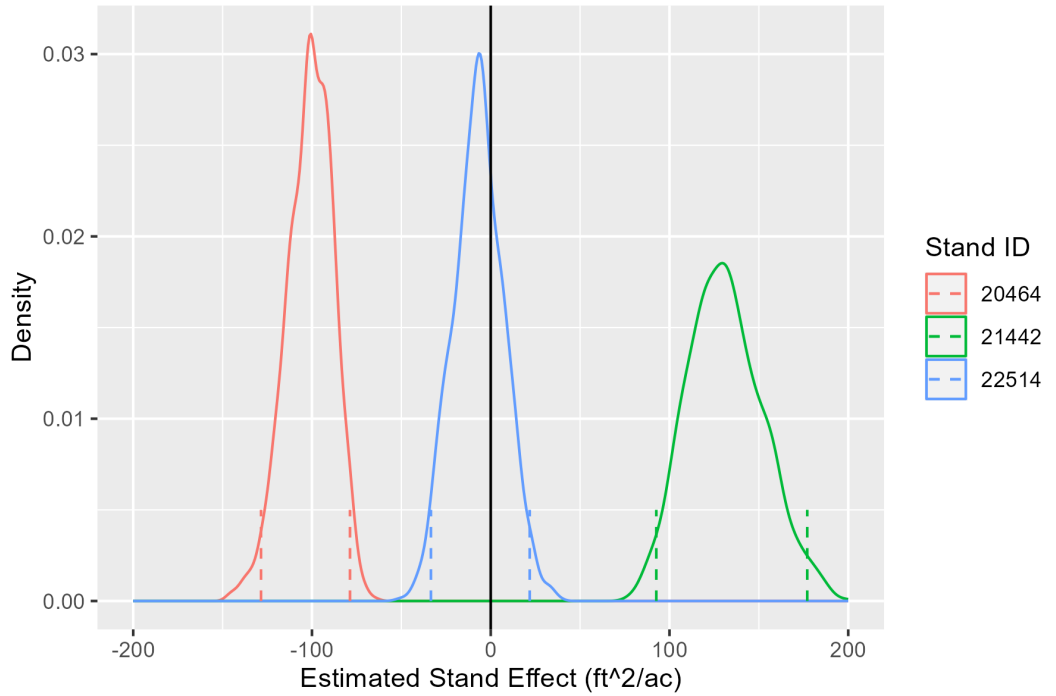


Estimating Stand Effects

- $\widehat{D}_i = \hat{y}_{i,e} - \hat{y}_{i,m}$ is boring
- What is more interesting is its statistical significance
  - $\hat{y}_{i,e}$ and $\hat{y}_{i,m}$ are random (remember our sampling designs)
  - Therefore the estimate of the stand effect is uncertain!
- If $\widehat{D}_i \neq 0$ *it does not imply the existence of a stand effect*
  - Estimates of stand effects are uncertain, so we will test their significance given the data
  - In practice: "my estimate differs from your map" is not good enough to discredit the map's estimate for a given stand, and vice versa for stand xams

Bootstrapping

- Bootstrapping approximates the sampling distribution
  - Examiner: Resample exam plots with replacement *M* times
  - Mapper: resample mapping plots with replacement *M* times
- Test of significance using the 95% confidence interval of $\widehat{D}_i$



Statistical Science
2003, Vol. 18, No. 2, 191–198

Impact of the Bootstrap on Sample Surveys

Jun Shao

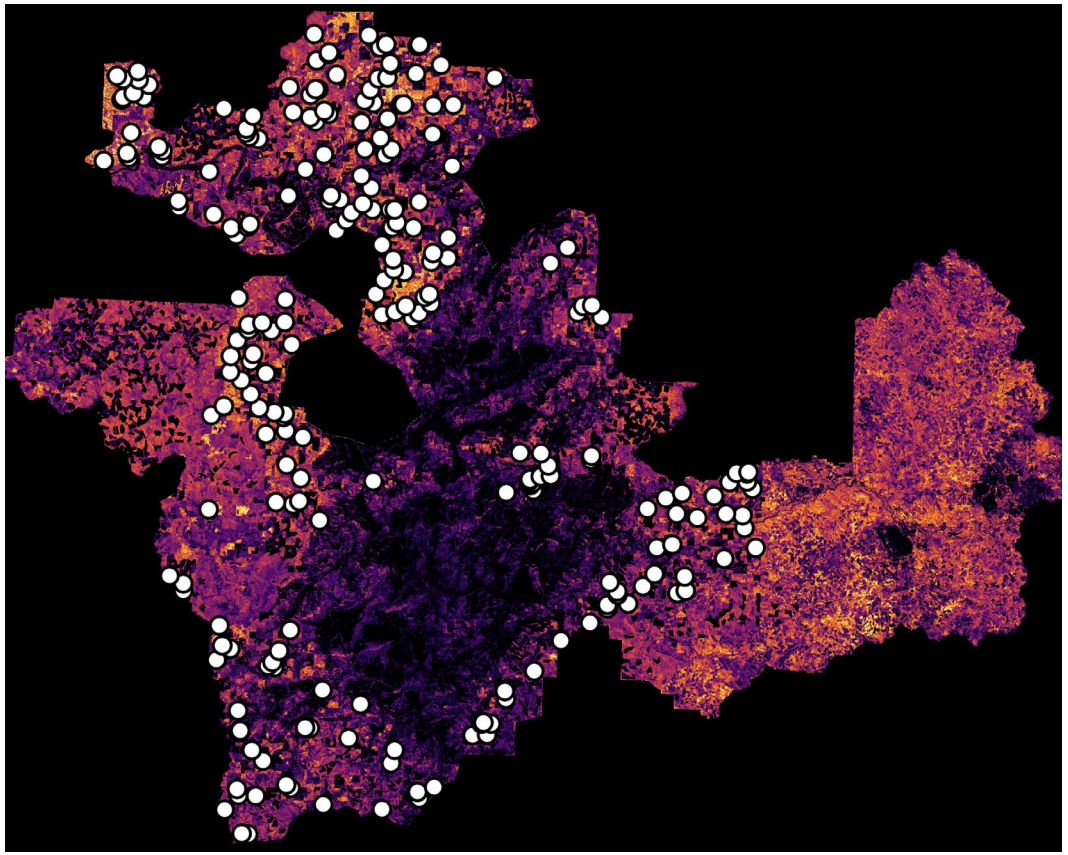
Part 2 - Case Study: Roseburg District

Data

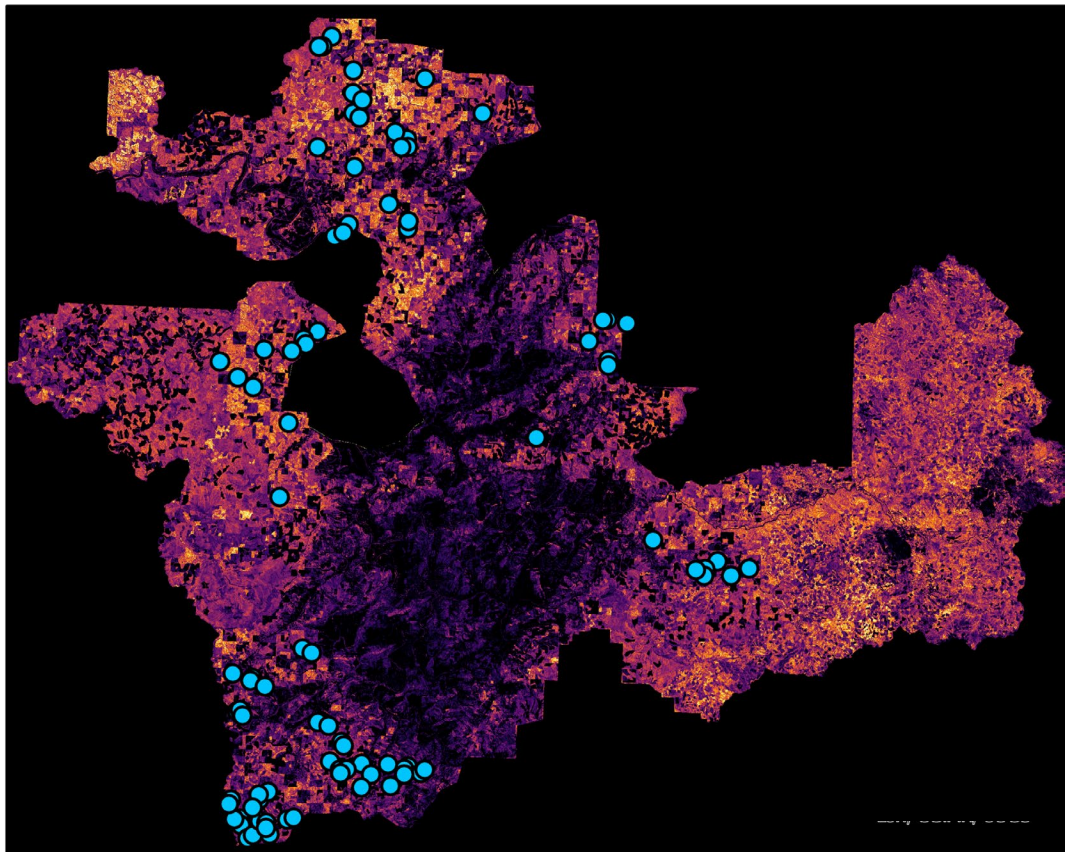
- Acquisition
  - Upper Umpqua 2015 Acquisition
  - ~1.4 million acres
  - February 2015 to November 2015
- Number of mapping plots: 240
- Number of stand exams: 80
  - $n_i \geq 7$
  - 2013 – 2017
  - Median size: 41 acres

Mappers and Examiners

Mapping Plots



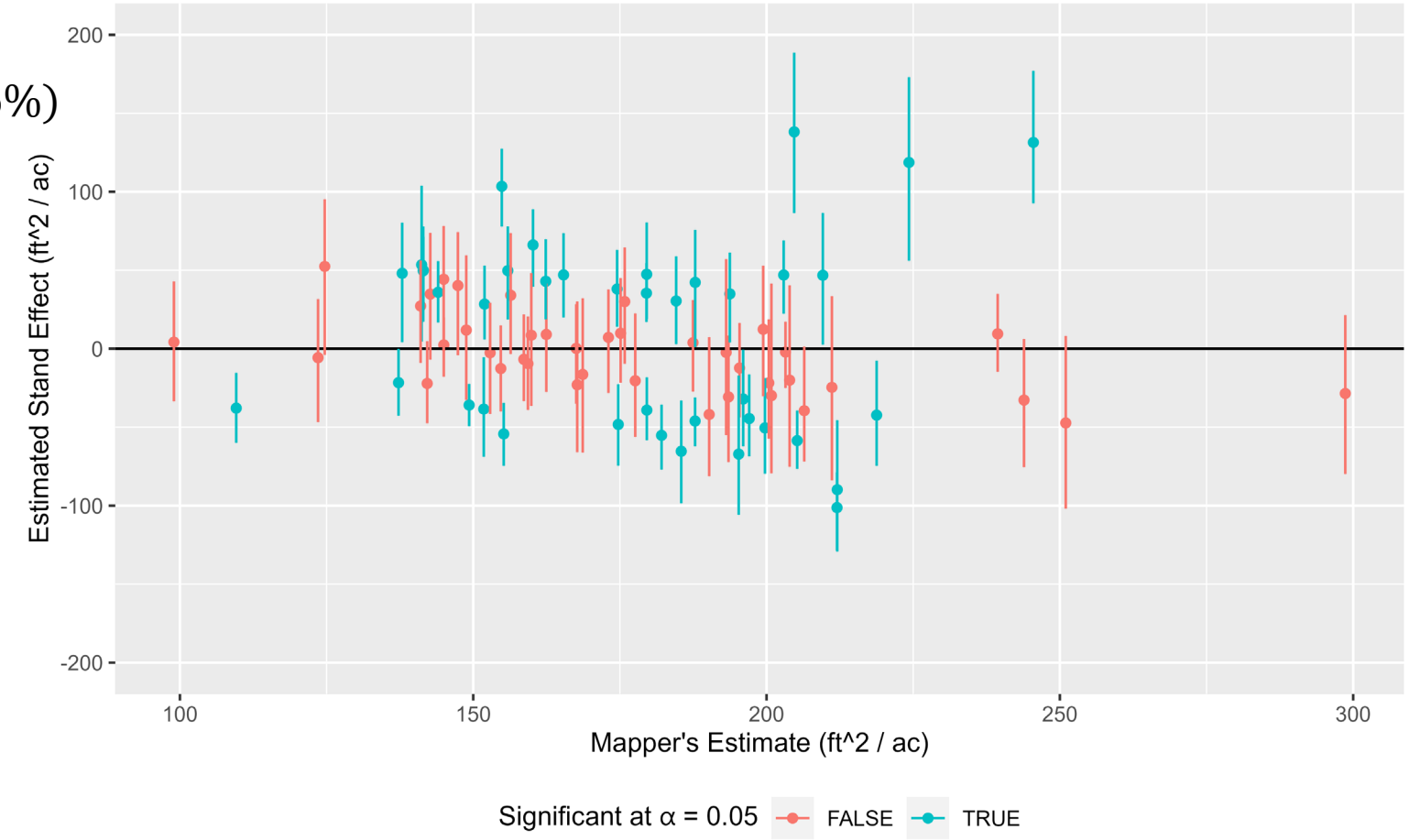
Stand Exams (Centroids)



How Large are Stand Effects?

Root mean square error: $47\ ft^2 ac^{-1} (26\%)$
Range: $(-101, 138)\ ft^2 ac^{-1}$

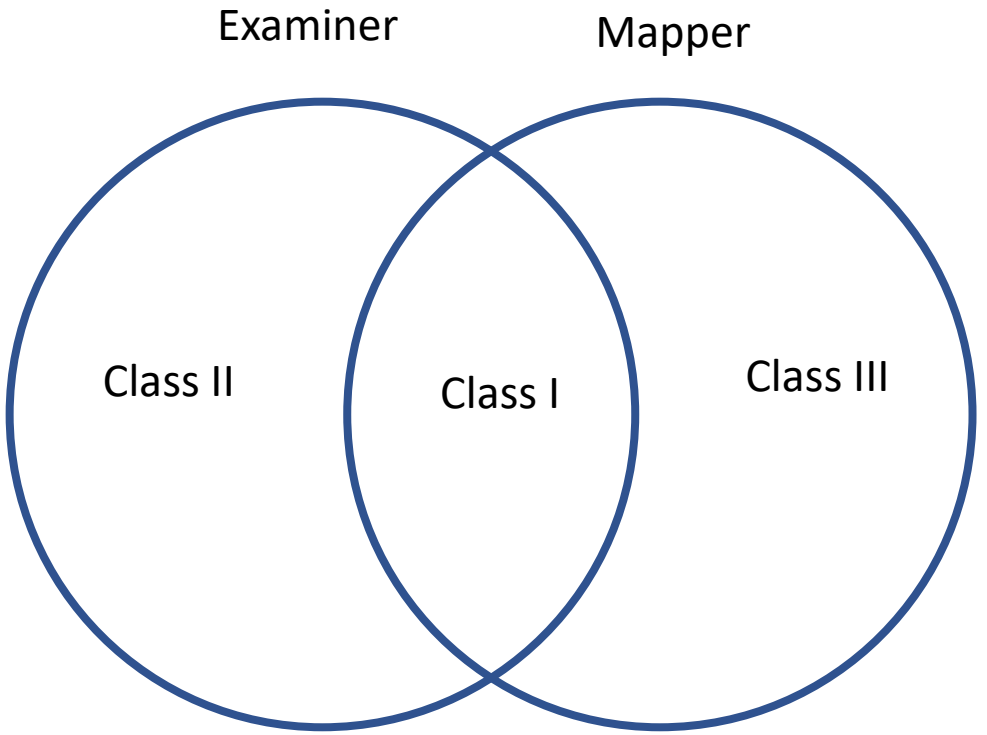
50% of stands have significant effects



Where Might they Come From?

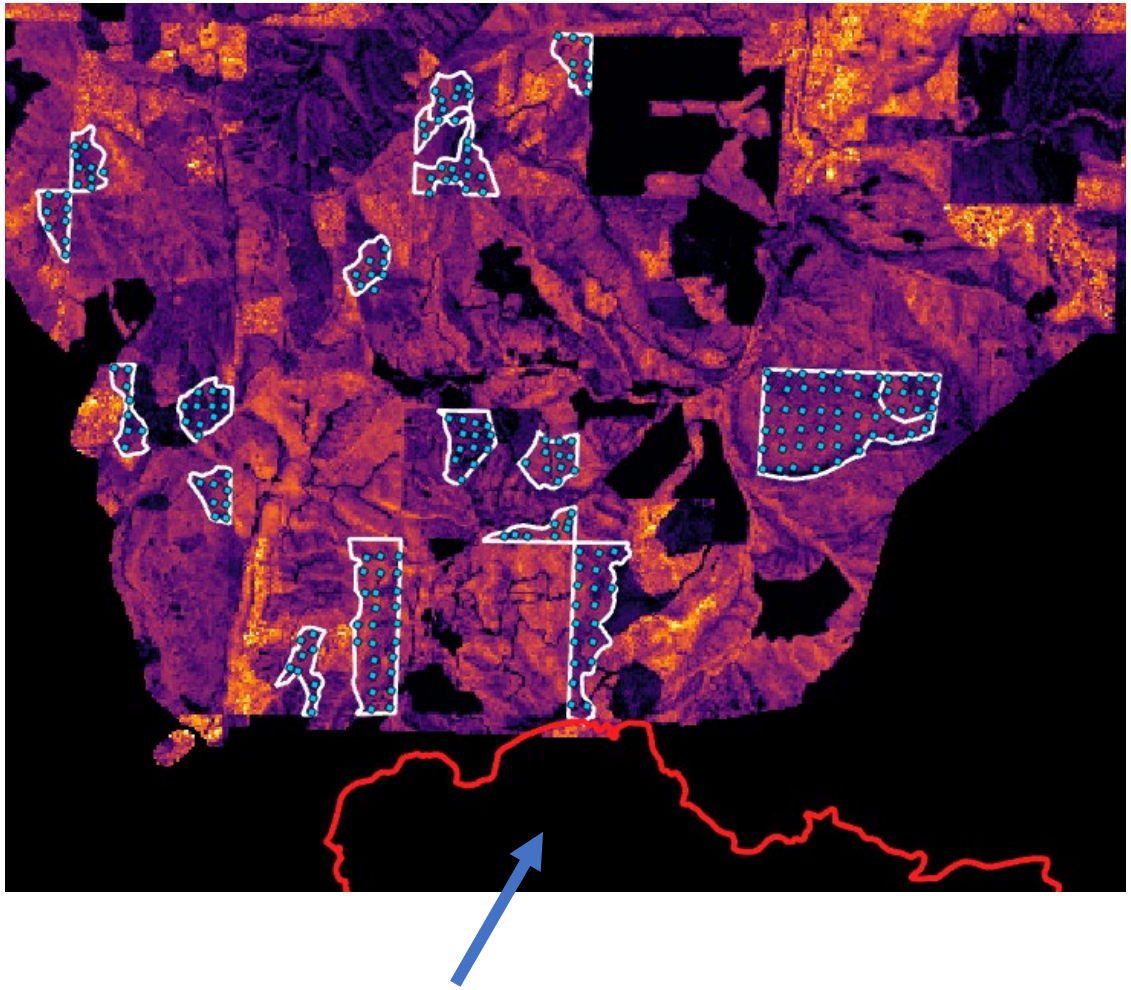
Let's assign blame…

1. Class I Effects: Shared issues
   - **Changes in forest structure between estimates**
   - **Differences in attribute estimated**
2. Class II Effects: Issues with examiner
   - Quality issues on exam plots
3. Class III Effects: Issues with mapper
   - Quality issues on mapping plots
   - Quality issues with lidar
   - **Model mis-specification**



Class I – Shared Issues

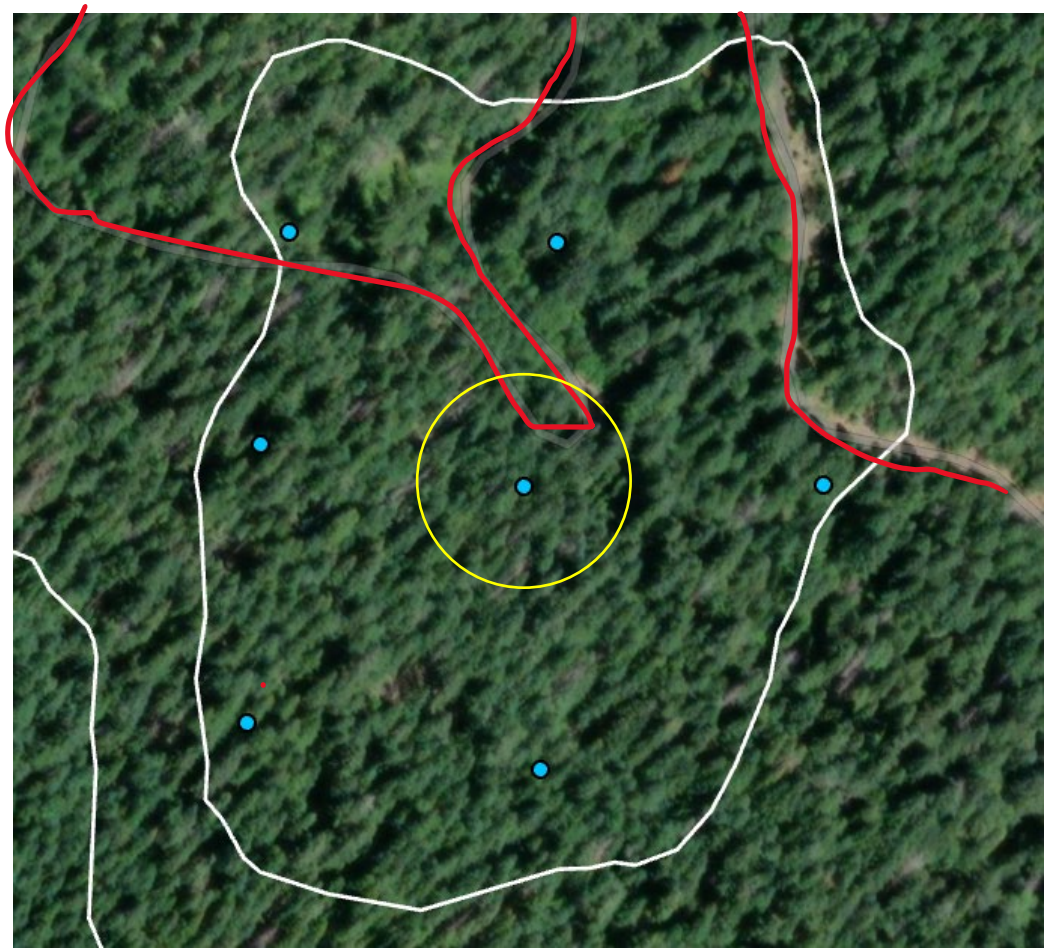
- *Changes in forest structure? e.g., wildfire, thinnings, other disturbances?*
- Unlikely, corporate database does not indicate large fires or treatments
- Manual checking with aerial images reveals the same



Horse Prairie Fire (2017)

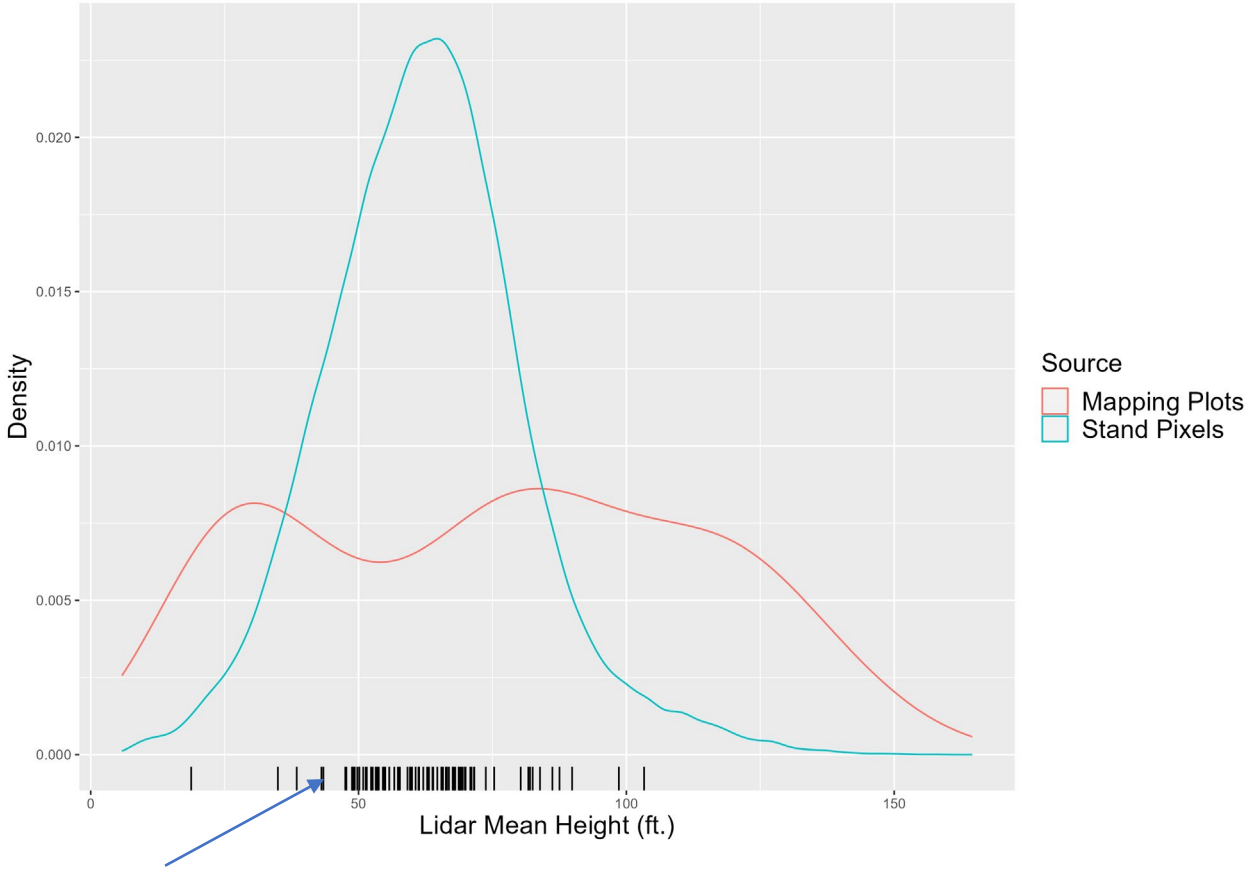
Class I – Shared Issues

- *Differences in attribute estimated?*
  - Differences in condition of interested (e.g., road plots)
  - Differences in the target attribute itself (e.g., lower diameter threshold, gross vs. merch. volume)
- Examiners were encouraged to move “road plots” 50’ into the stand
- Target attribute appears to be aligned



Class III – Mapper's Issues

- *Model Mis-specification*
  - Occurs when the model form is incorrect *for the stand*
- Poor model fit
- Stand types not represented in mapping plots
- Extrapolation may be cause for concern (but not in our case study)

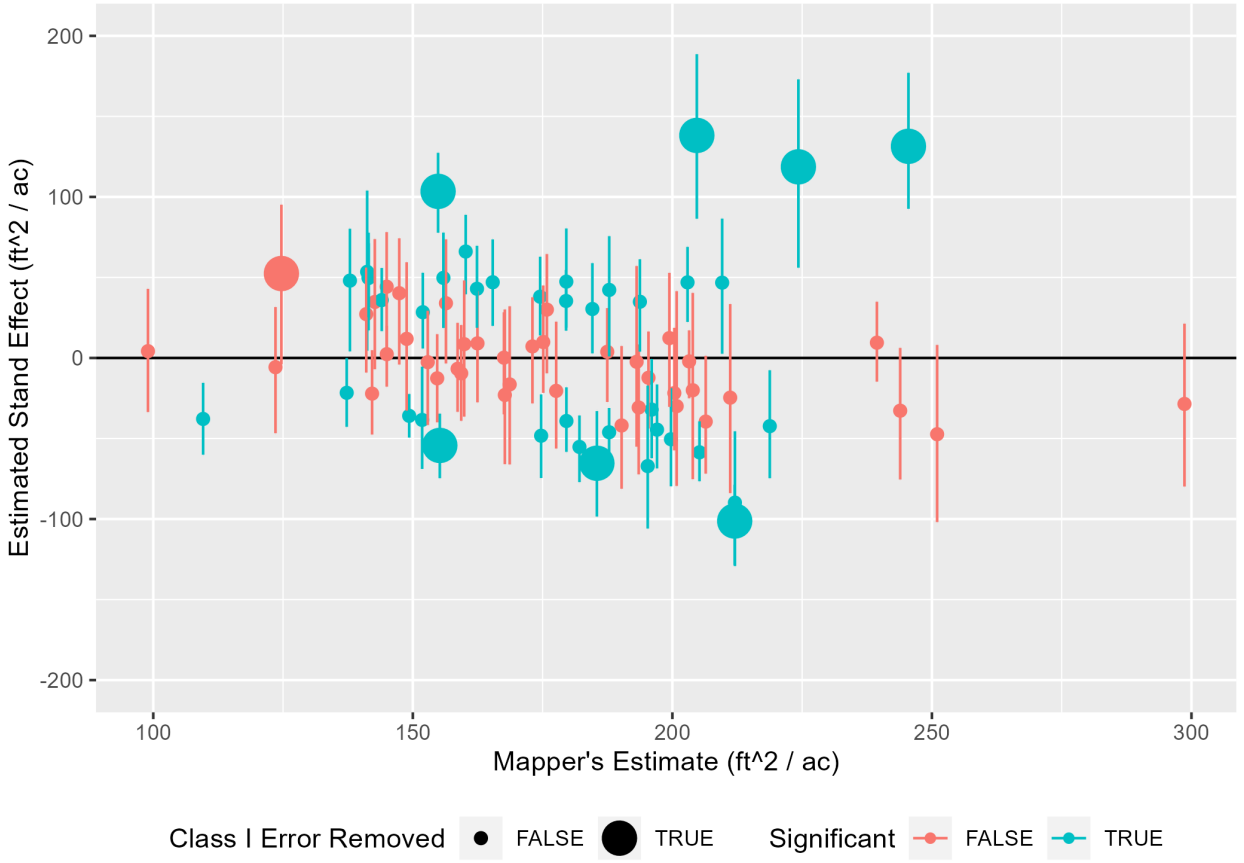


What Happened to Bias…?

- In some world where only Class III errors exist…
- We could claim that
  1. The mapper and examiner *agree* on what is to be estimated
  2. The examiner's estimate for this quantity is unbiased
  3. The estimated stand effect $\widehat{D}_i$ is an estimate of the mapper's bias!
- This would allow a very clean assessment of stand-level bias in lidar maps

What Happened to Bias…?

- Even still, 33/72 stands that did not exhibit obvious Class I errors had significant effects
  - 8 removed for large road presence, pull outs, etc.
- It appears there is evidence for bias from the mapper in the remaining stands



Root mean square error: $47\frac{ft^2}{ac}$ =>$36\frac{ft^2}{ac}$

$26\% \Rightarrow 20\%$

What Can We Do About Stand Effects?

- Stand effects should be resolved using a holistic approach
- Class I: Shared
  - Minimize temporal lag when comparing estimates
  - Check for disturbances
  - Ensure agreement between attribute estimated
    - ***Has anyone tackled the roads issue yet?***
- Class II: Examiner
  - Quality assurance and control of field plots
- Class III: Mapper
  - Quality assurance and control of field plots
  - Ensure subpopulations of interest are represented in sample
  - Ensure sample minimizes extrapolation
  - Quantify possible biases due to mis-specification

Thank You

- Questions or comments?