

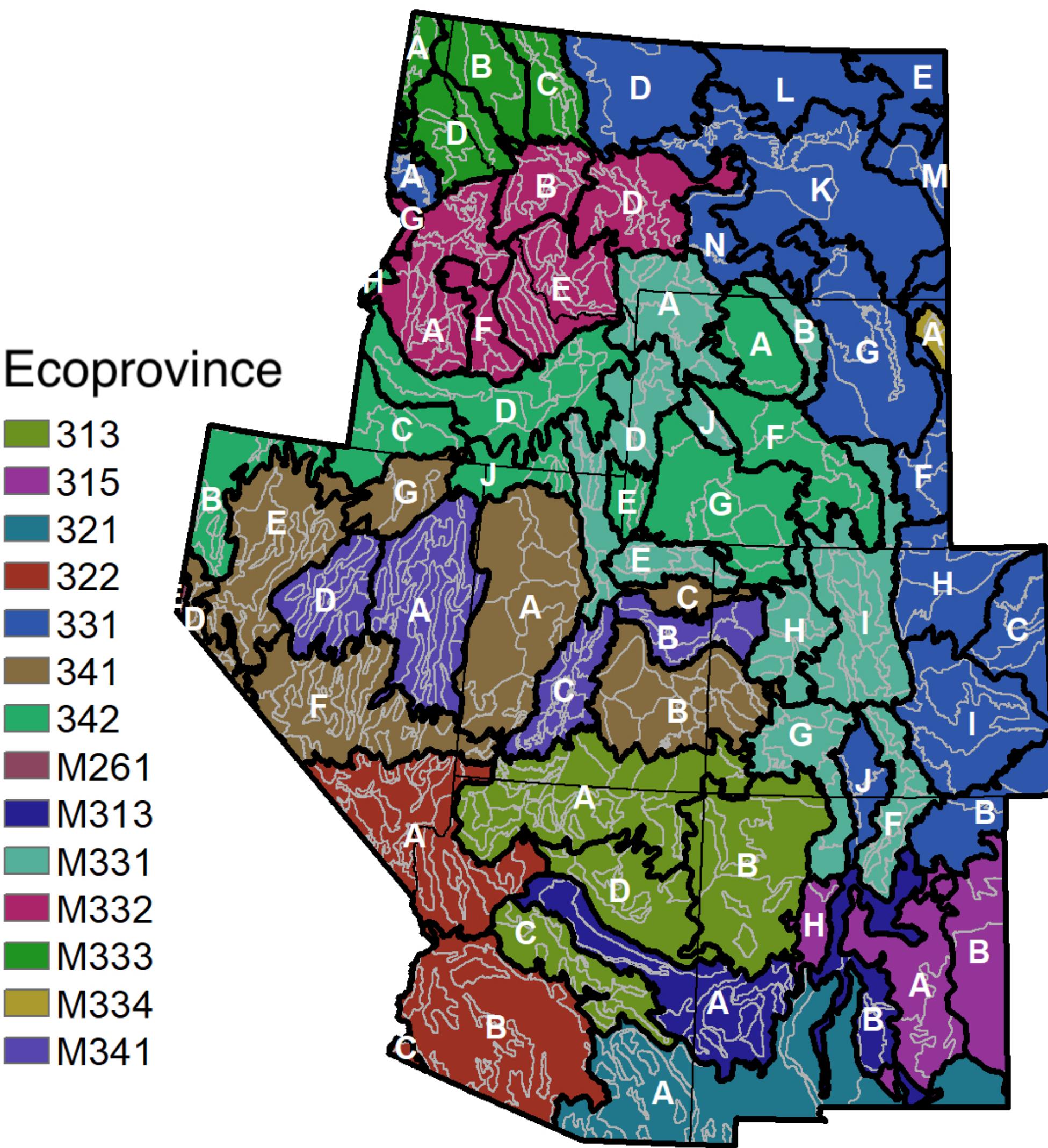
# Improving Forest Inventory Small Area Estimates through Ecological Borrowing and Hierarchical Bayesian Methods

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Gretchen Moisen<sup>3</sup>, Tracey Frescino<sup>3</sup>

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# The Big Idea: Improving Estimation

- Combine FIA and auxiliary data to fit Fay-Herriot models to **estimate means** of four FIA variables **within ecosubsections**.
- Borrow strength from different levels of hierarchy in these ecological regions: models that **borrow out to the ecosection level** and models that **borrow out to the ecoprovience level**.
- Assess both borrowing strategies for hierarchical Bayesian models and for EBLUPs.
- Compare estimator performance between models and with a post-stratified estimator.



# The Data



Washington Highway 410, edge of Mt. Rainier National Park

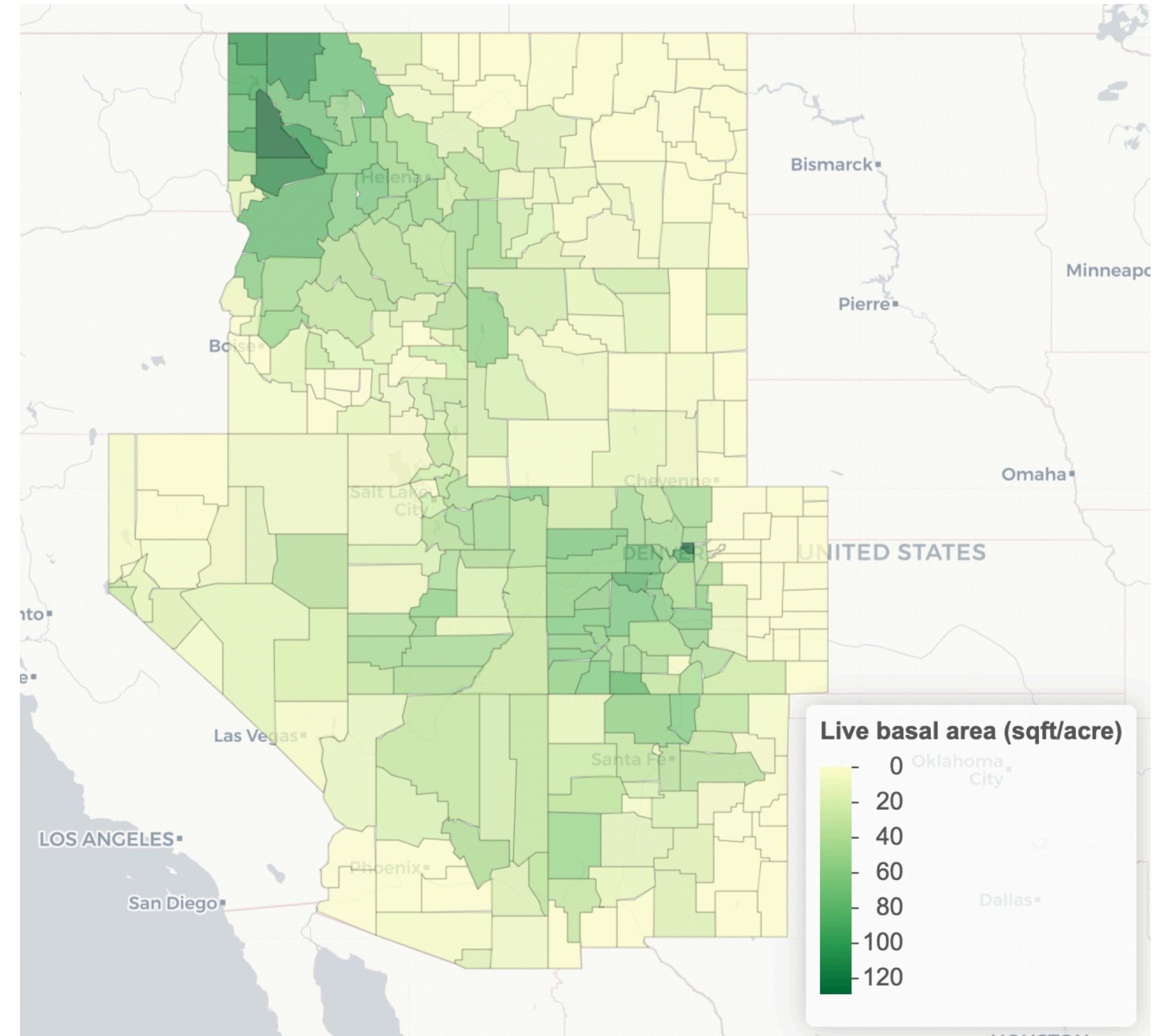
# Data Acquisition

- We used FIESTA to retrieve a FIA evaluation of data from the Interior Western region of the United States from 2007 to 2017, which included 86,065 plots.
- FIESTA is FIA's custom estimation tool which allows for easy access to FIA data and many estimators, all in R.
- Available on CRAN.



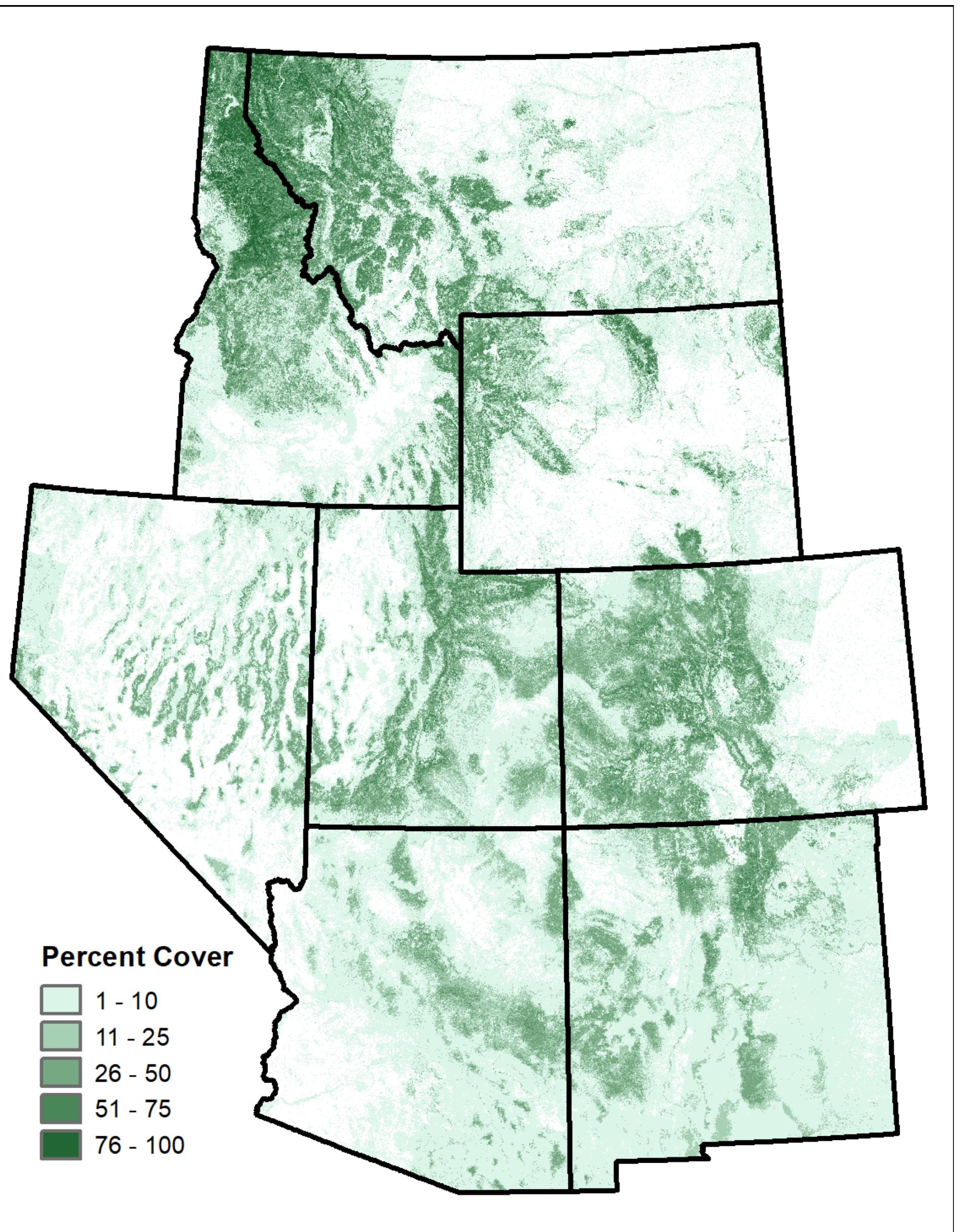
# Response Data Overview

- Four FIA variables of interest: basal area, biomass, trees per acre, and net volume.
- This data is available at the **plot level**, but we have aggregated it to the **area level**.



# Auxiliary Data Overview

- Remotely-sensed explanatory variable at pixel level: tree canopy cover.
- Forest/non-forest strata indicator variable for each sampled plot.



# Methods



Orcas Island, Washington

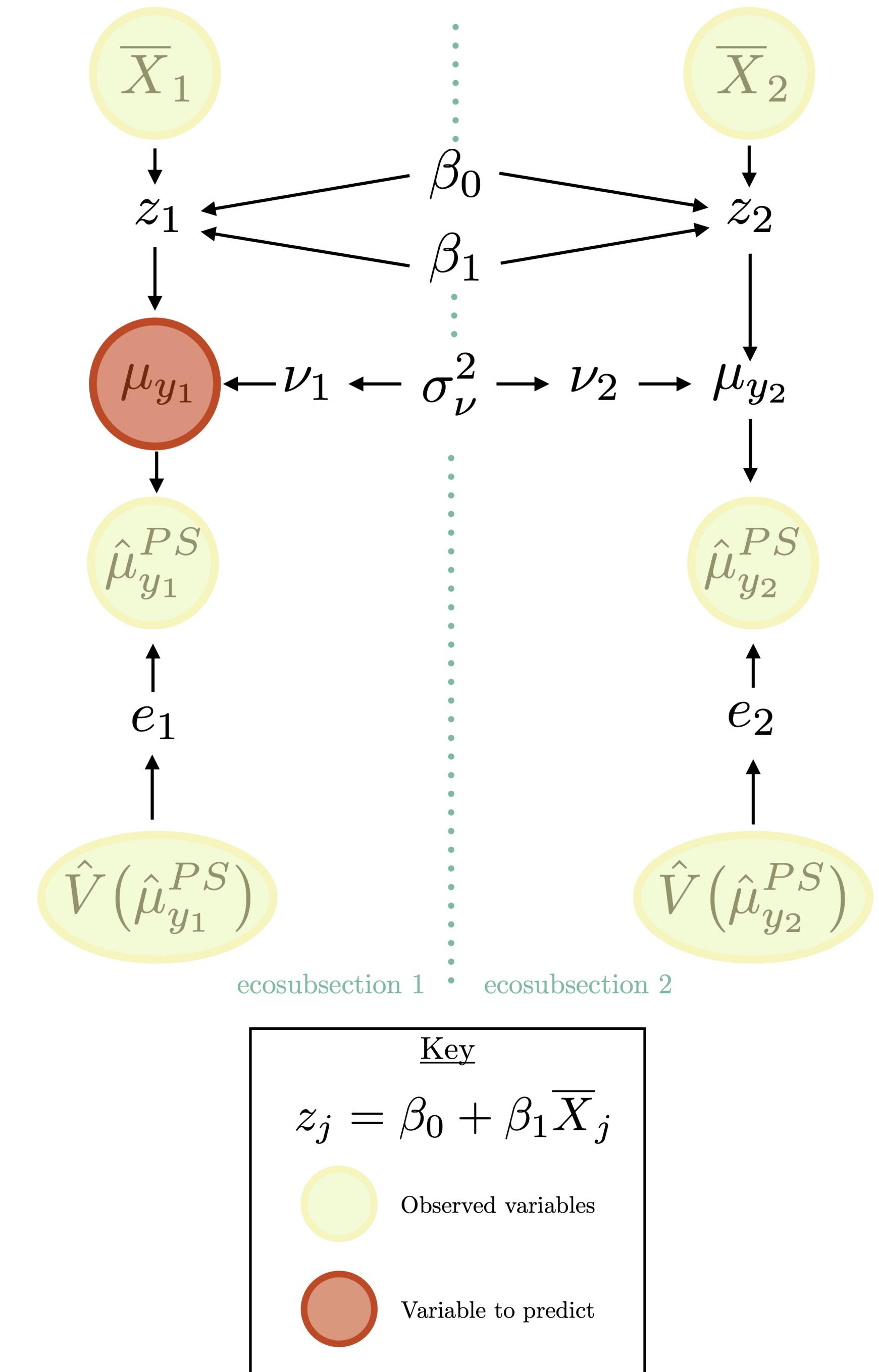


Lansing, Michigan

# Our Estimators

- The post-stratified estimator and six variations of the Fay-Herriot model.

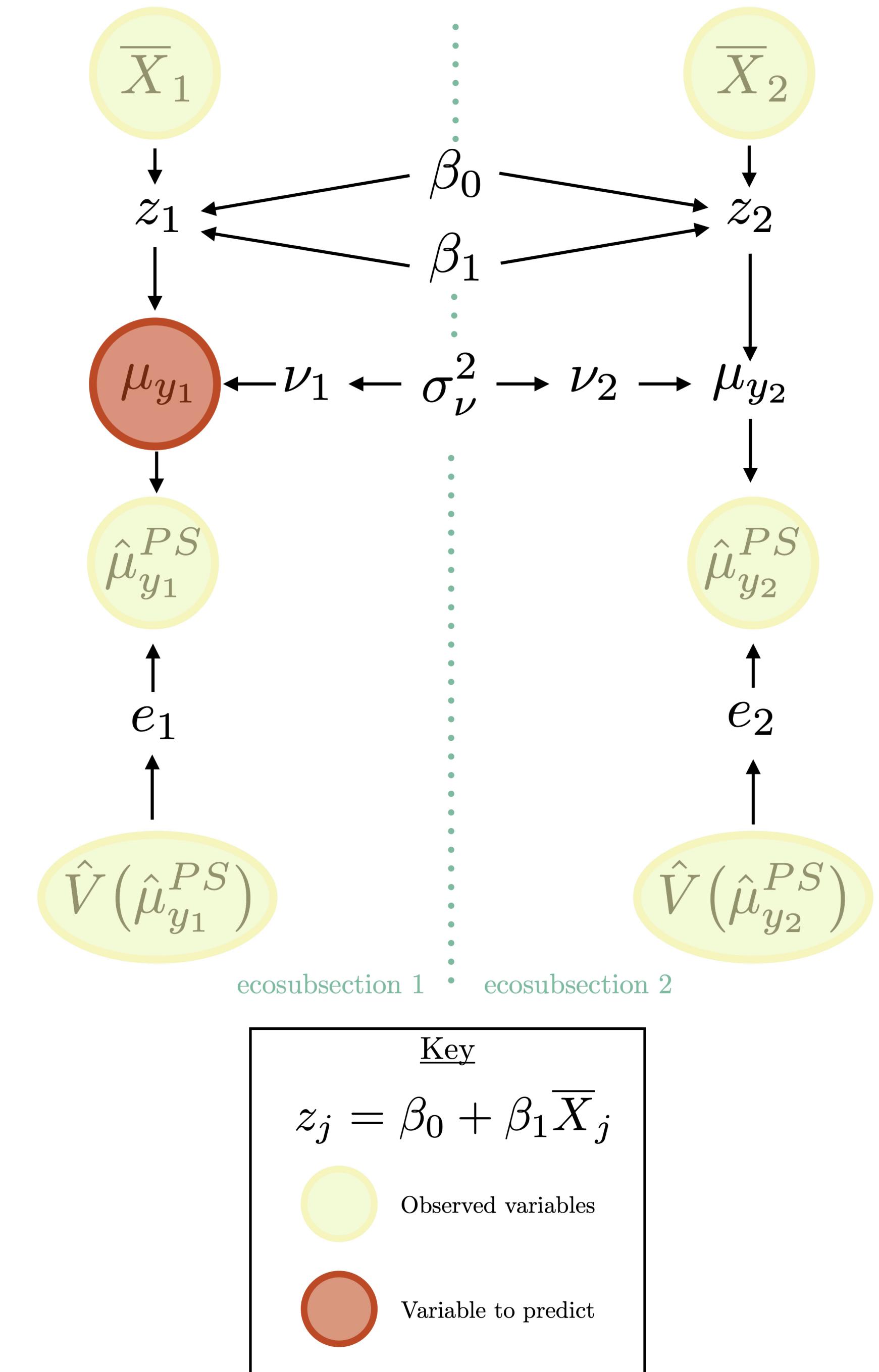
Short Name	Fitting Method	Borrow Strength to...	Prior on $\sigma_\nu^2$
Post-Strat	Analytical	NA	NA
EBLUP Section	REML	Section	NA
EBLUP Province	REML	Province	NA
HB Section Flat Prior	MCMC	Section	$f(\sigma_\nu^2) \propto 1$
HB Province Flat Prior	MCMC	Province	$f(\sigma_\nu^2) \propto 1$
HB Section half Cauchy Prior	MCMC	Section	$\sigma_\nu \sim \text{half-Cauchy}(\text{scale} = 1)$
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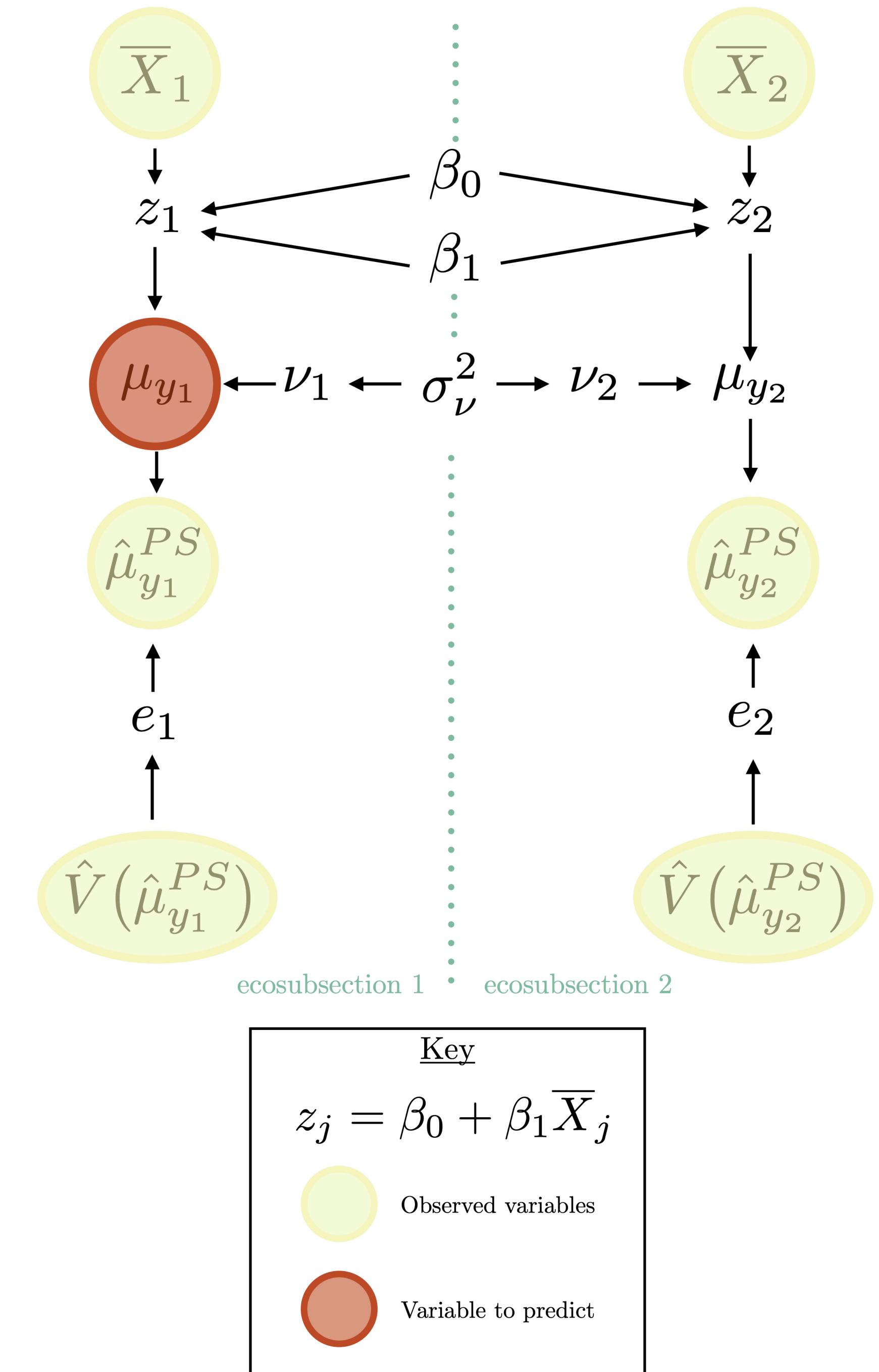
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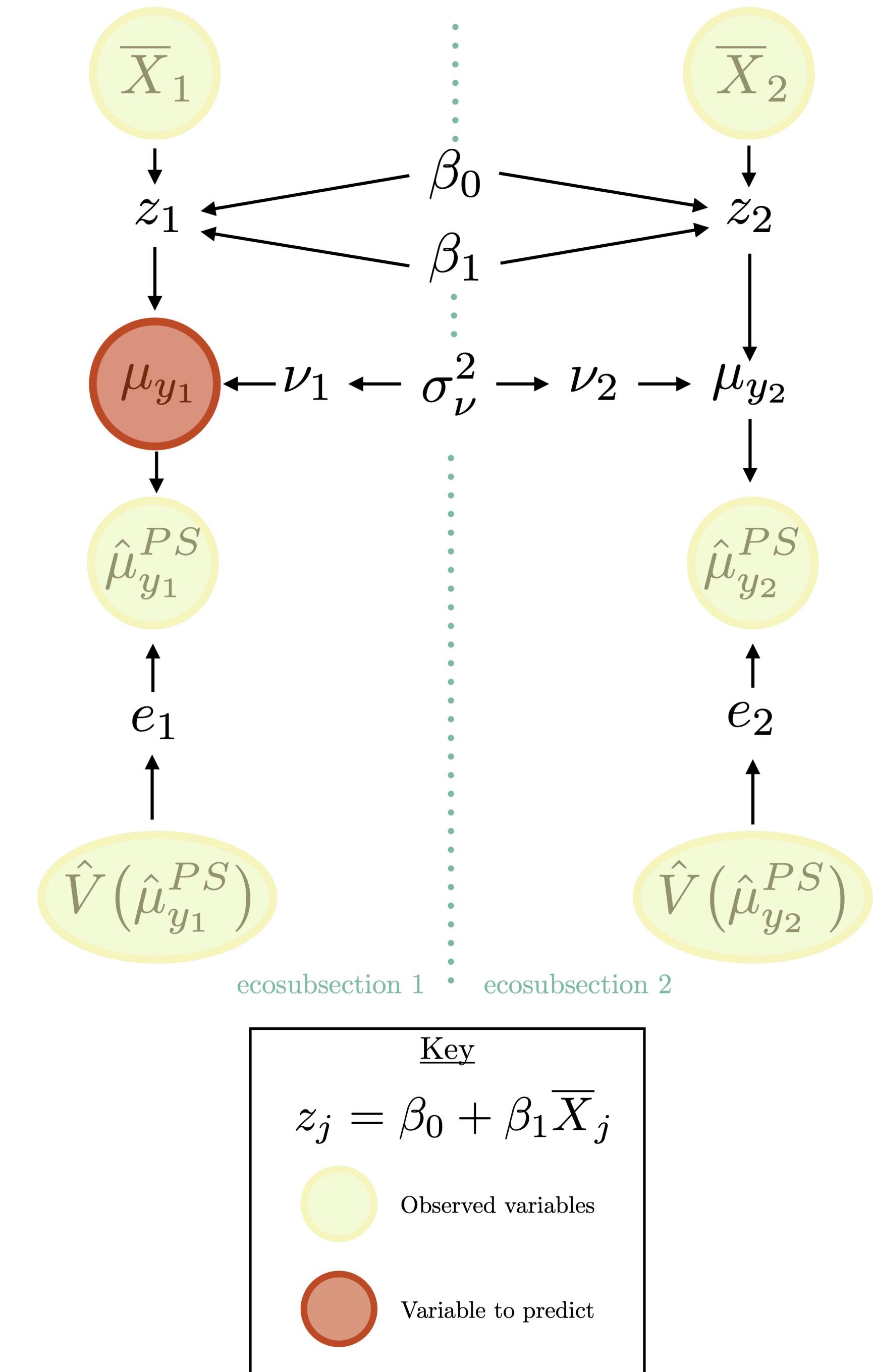
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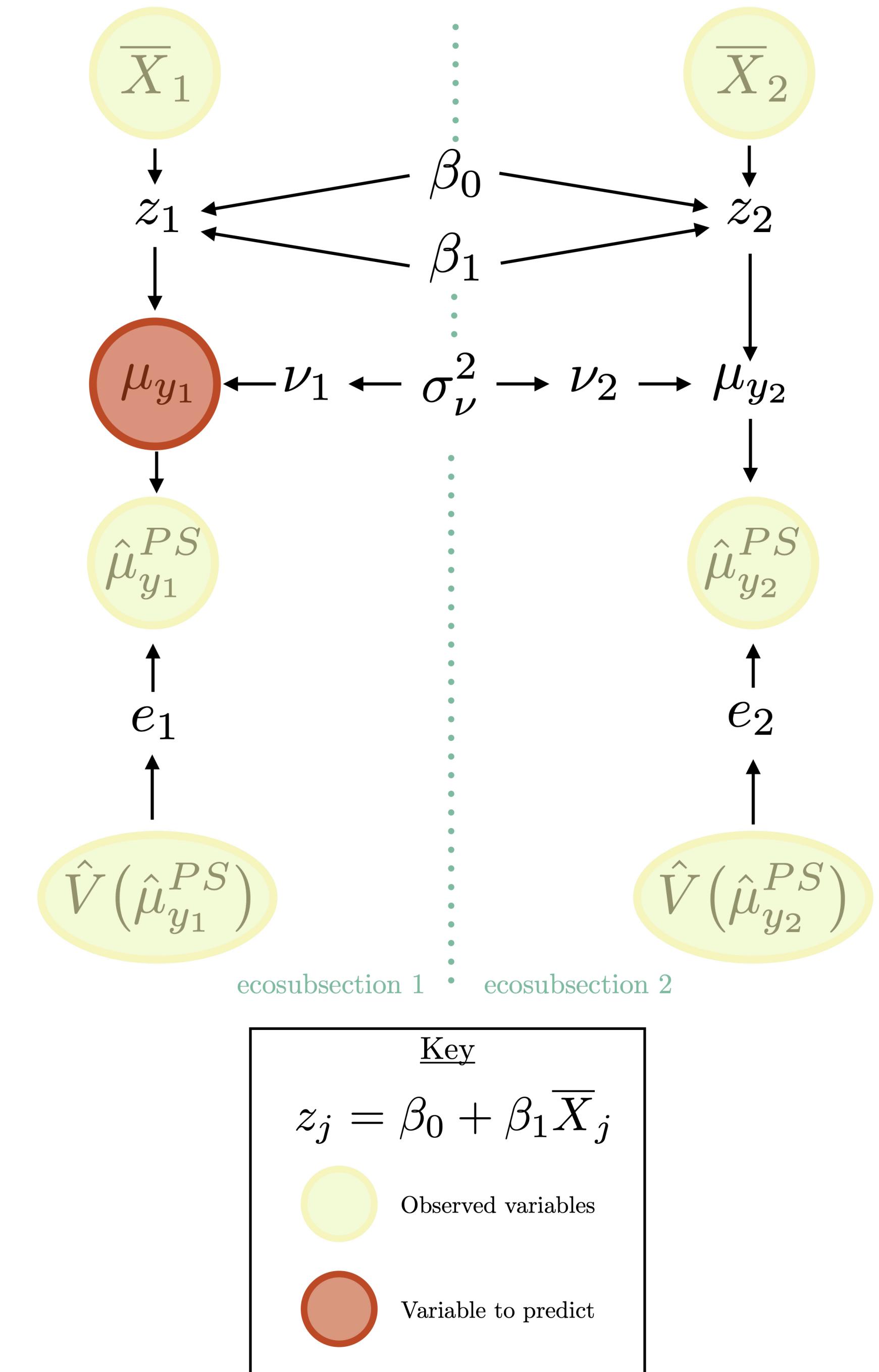
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# Results

Note: All results shown are for the basal area response variable

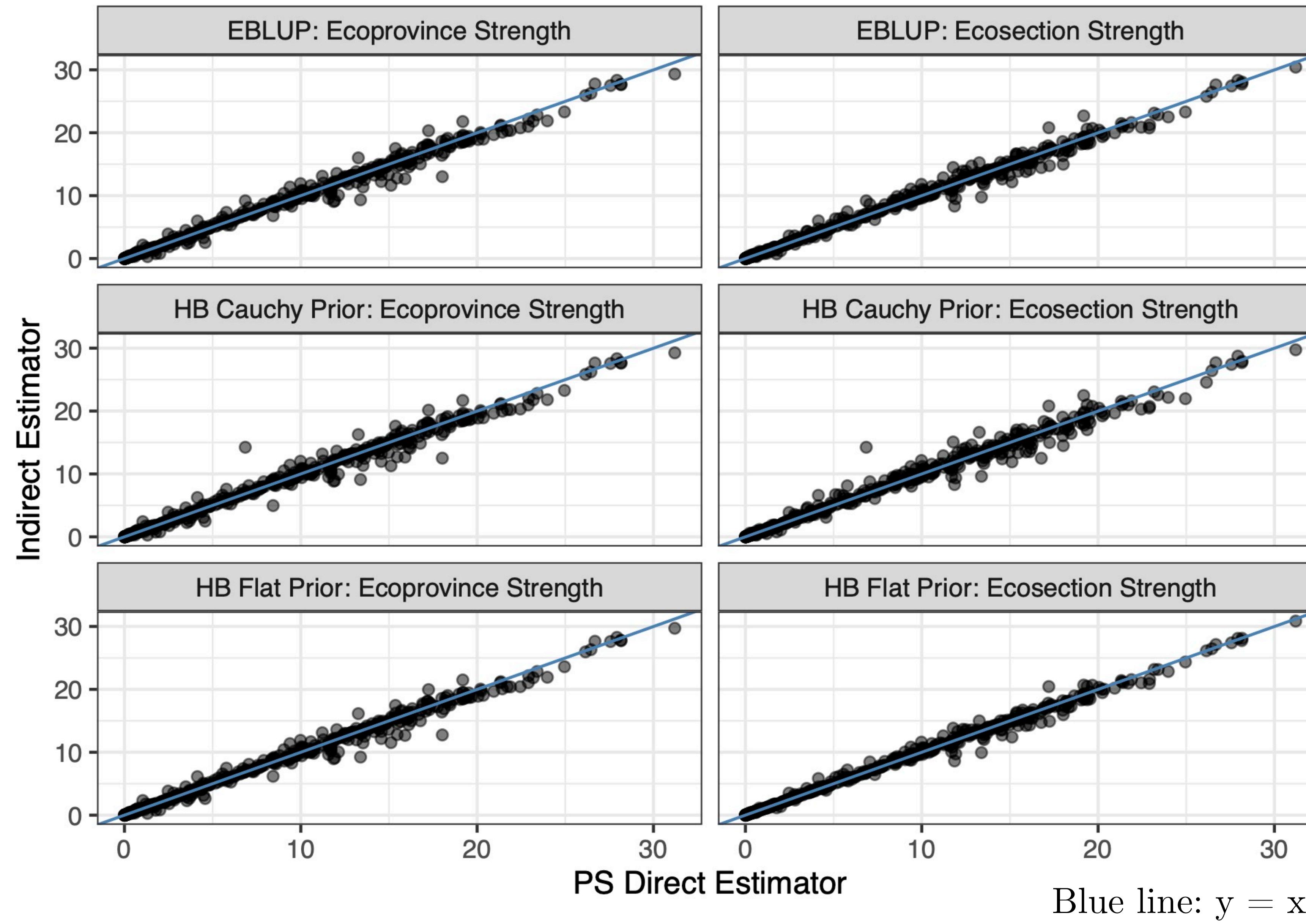


Mt. Hood, Oregon

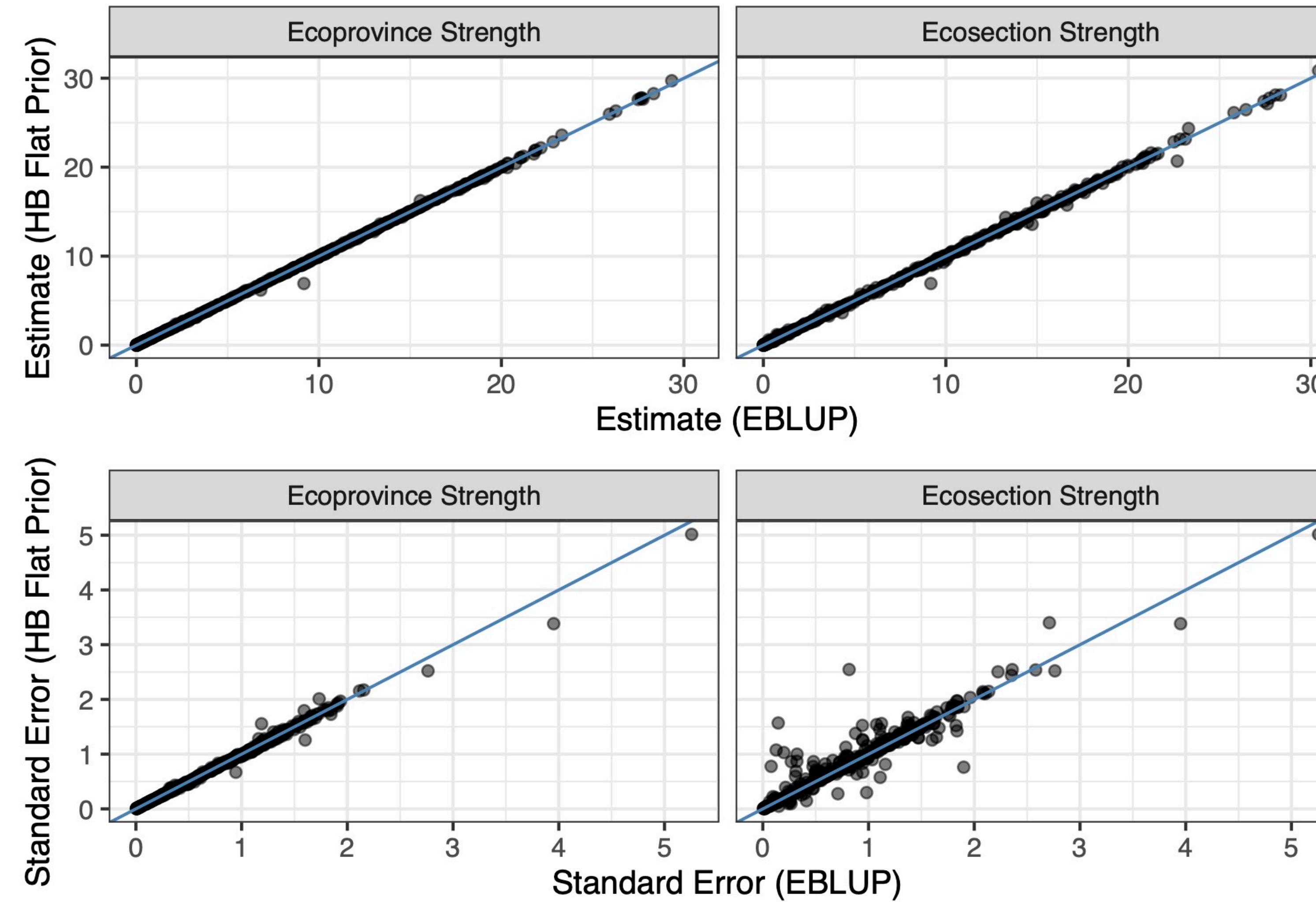


Valley of the Giants, Oregon

# Assessing Bias via Agreement With Post-Stratified Estimator

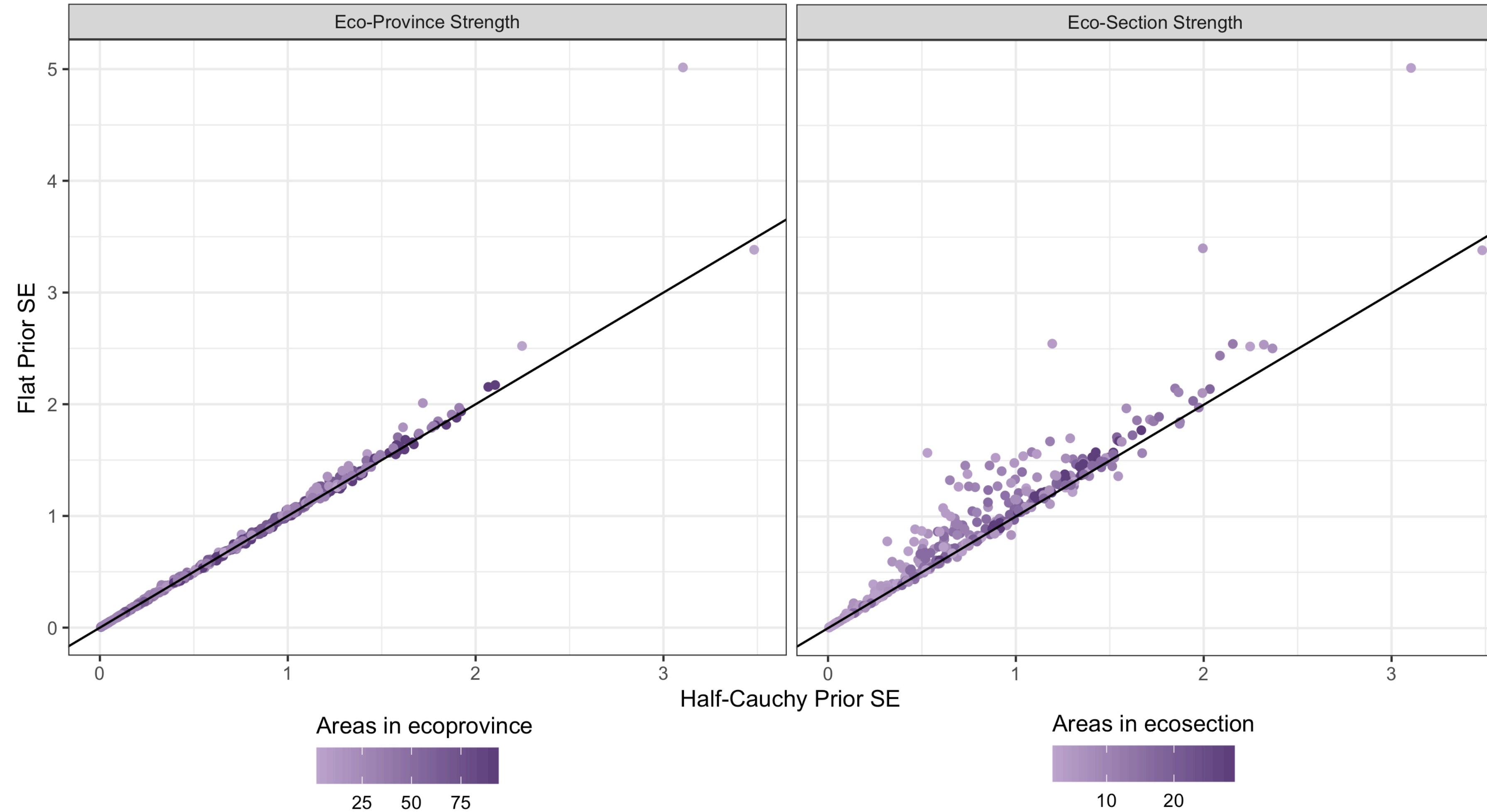


# Comparing the HB Flat Prior and EBLUP Estimates (top) and Standard Errors (bottom)



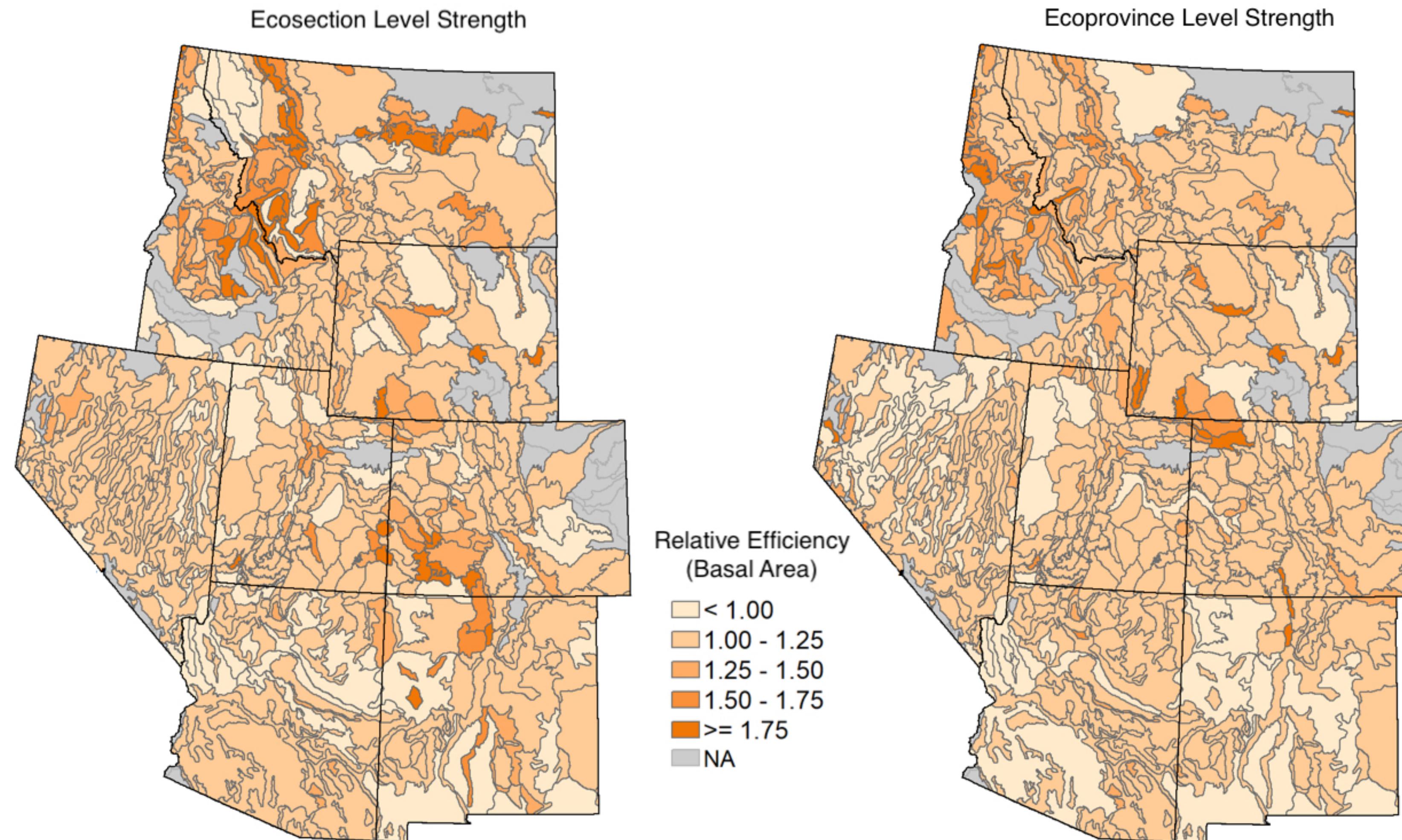
Blue line:  $y = x$ .

# Standard Error Differences in HB Models



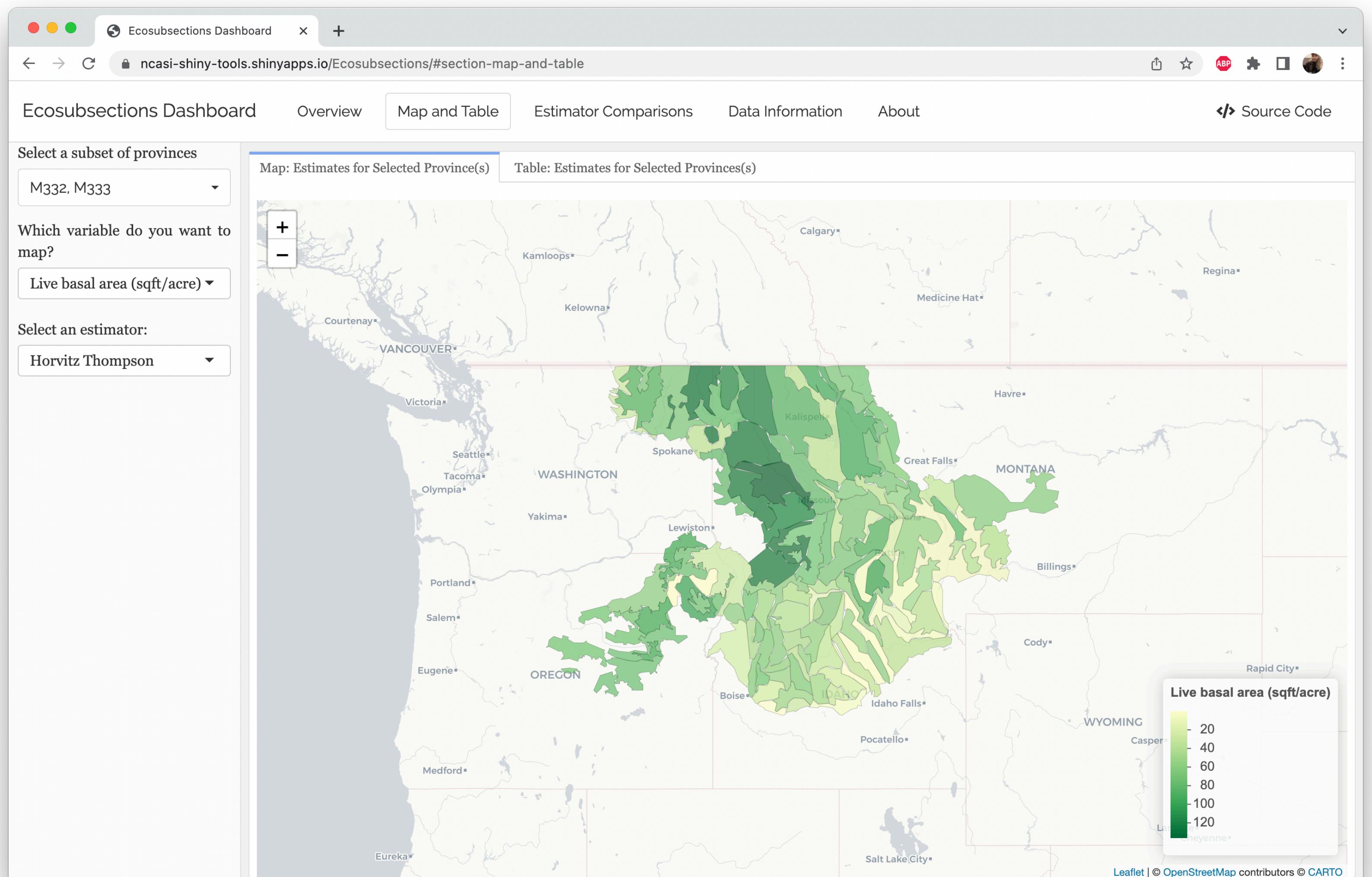
- Black line:  $y = x$ .
- Purple hue:  
amount of areas  
strength is  
borrowed from.

# Relative Efficiency of HB Half Cauchy Prior Estimators and Post-Stratified Estimator



# Impact

- These hierarchical Bayesian small area models have been added to FIESTA, for more wide use in FIA.
- The models are now part of a national portfolio of estimates available via shiny dashboards.



# Future Work



Death Valley, California

- Unit-level small area models: zero-inflated models.
- A simulation study to understand potential bias.
- Further explorations of prior distributions on between-area variation.
- Multivariate small area models for many FIA variables of interest.

# Thank you!

## Relevant References:

White GW, McConville KS, Moisen GG and Frescino TS (2021) Hierarchical Bayesian Small Area Estimation Using Weakly Informative Priors in Ecologically Homogeneous Areas of the Interior Western Forests. *Front. For. Glob. Change* 4:752911. doi: 10.3389/ffgc.2021.752911.

Frescino TS, McConville KS, White GW, Toney JC and Moisen GG (2022) Small area estimates for national applications: A database to dashboard strategy for FIA using FIESTA. *Front. For. Glob. Change*. doi: 10.3389/ffgc.2022.779446.

Frescino TS, Moisen GG, Paterson PL, Toney JC and White GW (In Review) FIESTA: A Forest Inventory Estimation and Analysis R Package. *Ecography*.

## Get in touch:

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Slides/other work available: [www.github.com/graysonwhite](https://www.github.com/graysonwhite)