New Proposal

Using Small Area Estimation and 3D-NAIP/Sentinel-derived Variables for Multivariate Prediction of Stand Attributes

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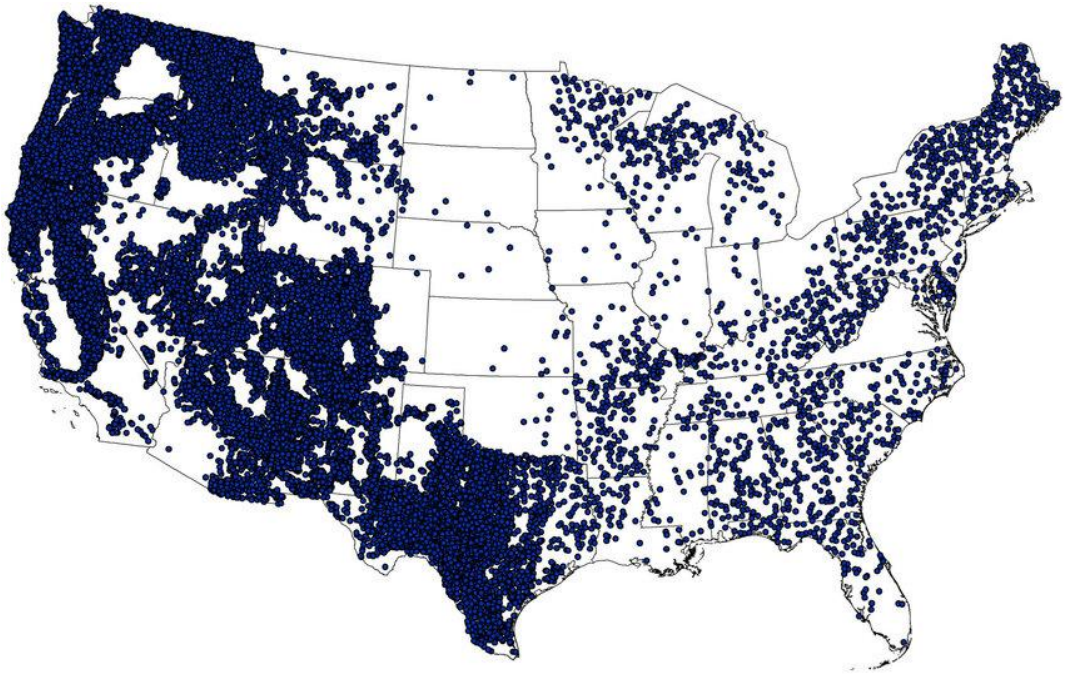
Justification

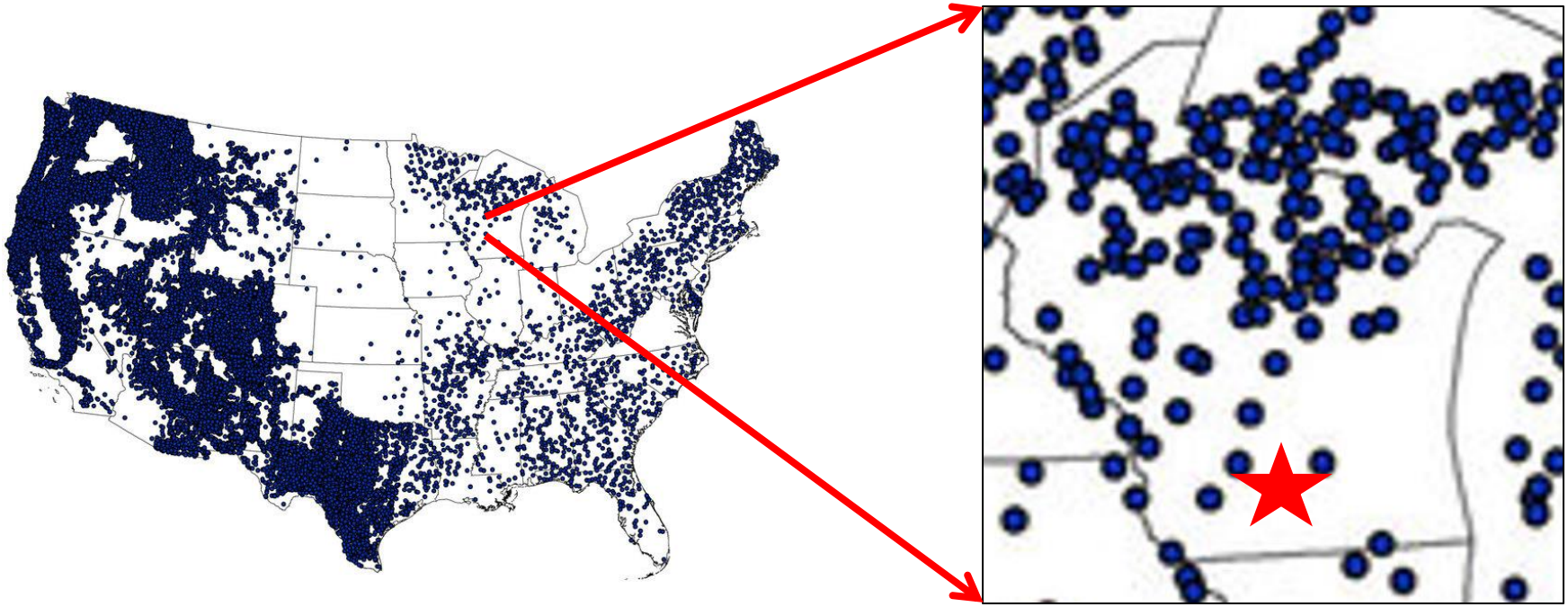
- Forest Inventory and Analysis (FIA) program by the USDA Forest Service provides reliable forest inventory data at national and regional levels.



Justification

- When estimating at fine spatial resolution, such as geographic units, industrial land ownerships, or county levels, the accuracy decreases due to increased sampling errors caused by limited sample sizes.

Justification



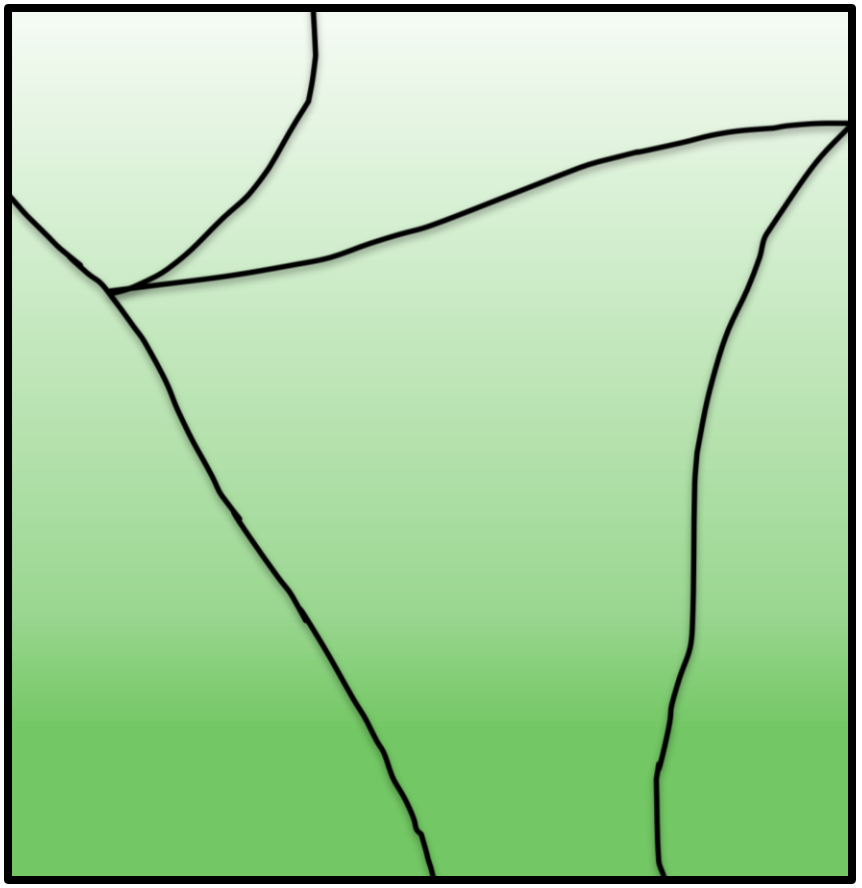
Justification

- When estimating at fine spatial resolution, such as geographic units, industrial land ownerships, or county levels, the accuracy decreases due to increased sampling errors caused by limited sample sizes.

- Small area estimation (SAE) techniques have been proven effective in forest inventories for generating reliable estimates in areas with limited data (i.e., small areas).

Justification

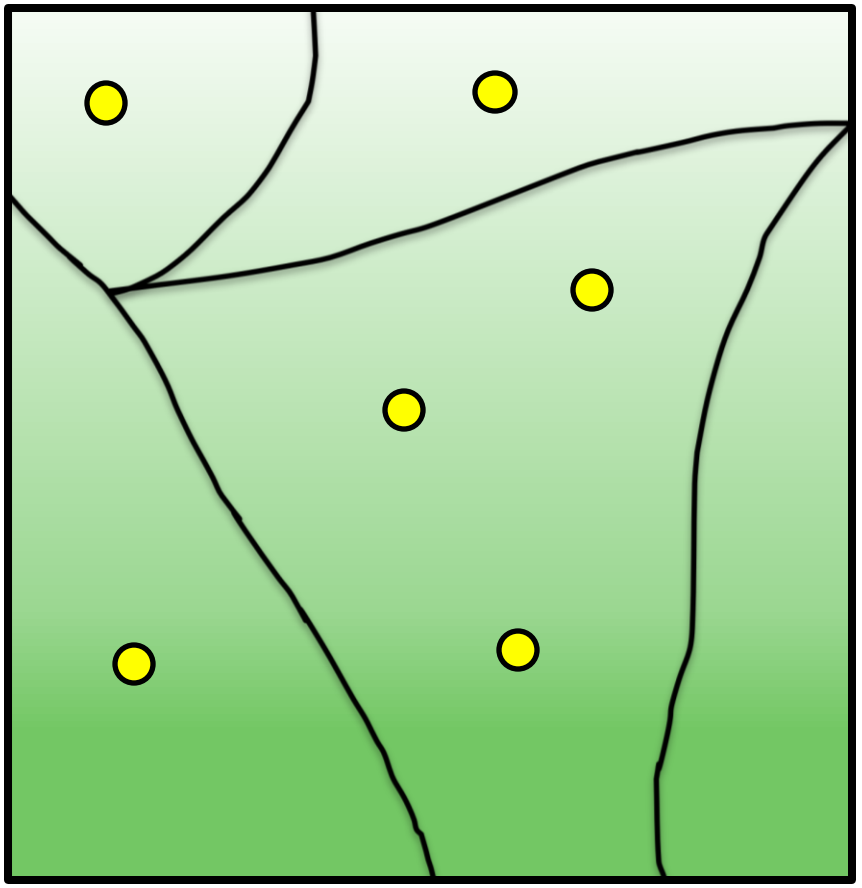
Forest inventory polygons (black line)



Justification

Forest inventory polygons (black line)

Field plots (yellow)

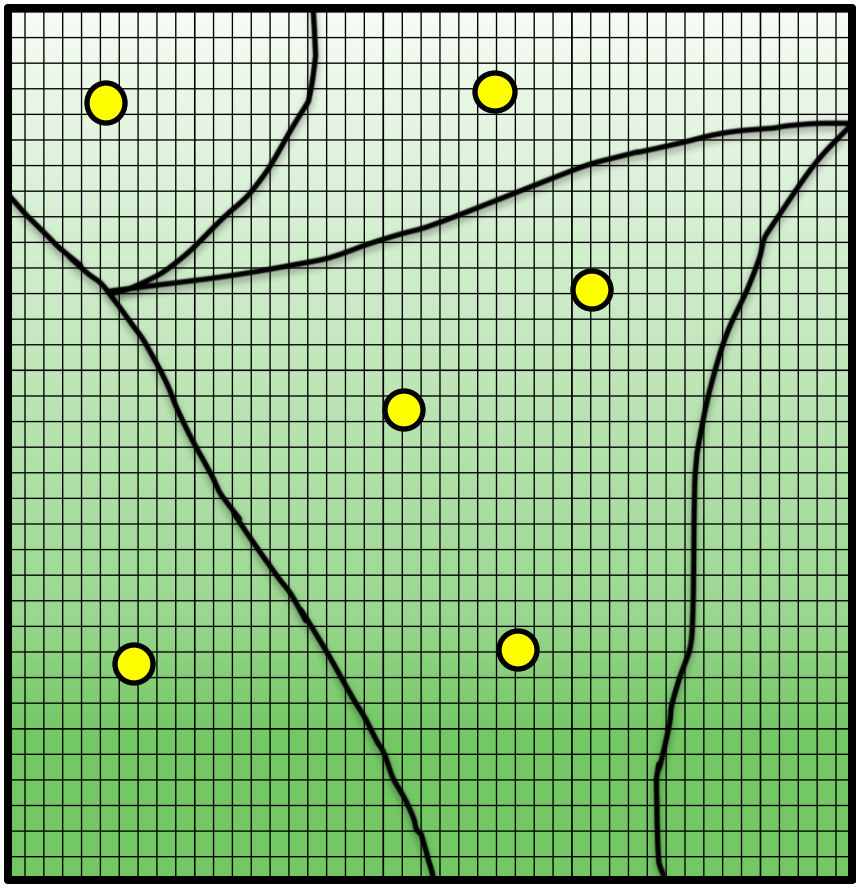


Justification

Forest inventory polygons (black line)

Field plots (yellow)

Auxiliary variables (grid)



Justification

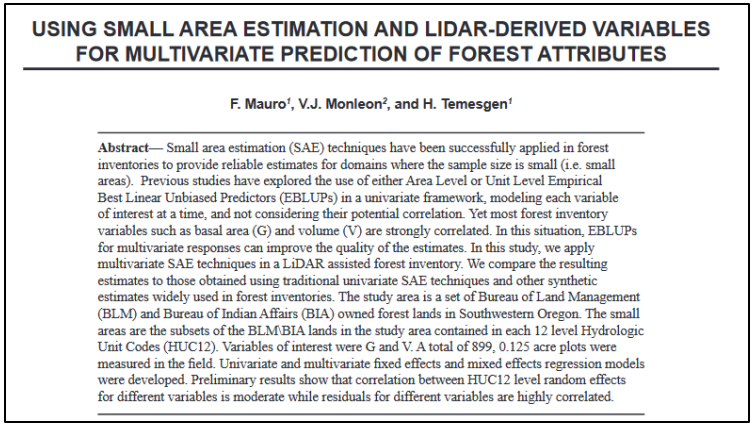
- Previous research has focused on using area- or unit-level predictors within a univariate framework, analyzing each variable independently without accounting for their correlations.

- Many forest inventory variables exhibit strong correlations, such as basal area, stand volume, and trees per acre.

- In such cases, employing multivariate responses can enhance the accuracy of the estimates.

Justification

- Improved estimates due to the correlation of random effects and/or residuals



USING SMALL AREA ESTIMATION AND LIDAR-DERIVED VARIABLES FOR MULTIVARIATE PREDICTION OF FOREST ATTRIBUTES

F. Mauro[1], V.J. Monleon[2], and H. Temesgen[1]

Abstract— Small area estimation (SAE) techniques have been successfully applied in forest inventories to provide reliable estimates for domains where the sample size is small (i.e. small areas). Previous studies have explored the use of either Area Level or Unit Level Empirical Best Linear Unbiased Predictors (EBLUPs) in a univariate framework, modeling each variable of interest at a time, and not considering their potential correlation. Yet most forest inventory variables such as basal area (G) and volume (V) are strongly correlated. In this situation, EBLUPs for multivariate responses can improve the quality of the estimates. In this study, we apply multivariate SAE techniques in a LiDAR assisted forest inventory. We compare the resulting estimates to those obtained using traditional univariate SAE techniques and other synthetic estimates widely used in forest inventories. The study area is a set of Bureau of Land Management (BLM) and Bureau of Indian Affairs (BIA) owned forest lands in Southwestern Oregon. The small areas are the subsets of the BLM\BIA lands in the study area contained in each 12 level Hydrologic Unit Codes (HUC12). Variables of interest were G and V. A total of 899, 0.125 acre plots were measured in the field. Univariate and multivariate fixed effects and mixed effects regression models were developed. Preliminary results show that correlation between HUC12 level random effects for different variables is moderate while residuals for different variables are highly correlated.

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Multivariate inference for forest inventories using auxiliary airborne laser scanning data

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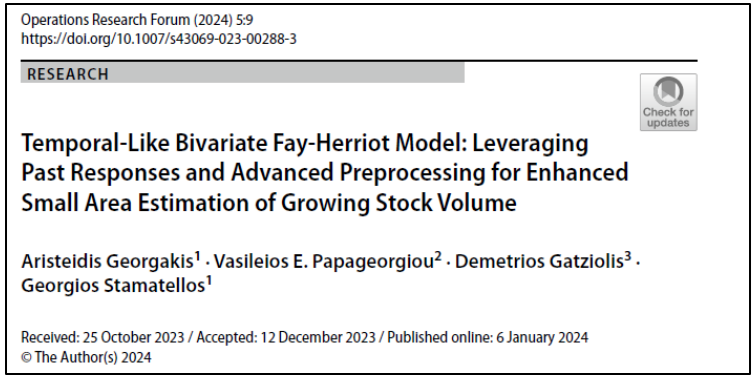

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RESEARCH

Temporal-Like Bivariate Fay-Herriot Model: Leveraging Past Responses and Advanced Preprocessing for Enhanced Small Area Estimation of Growing Stock Volume

Aristeidis Georgakis[1] · Vasileios E. Papageorgiou[2] · Demetrios Gatziolis[3] · Georgios Stamatellos[1]

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Objectives

- Provide current stand-level attributes across various spatial resolutions.
  - Volume, basal area, and trees per acre
- Create detailed multivariate models integrating FIA, 3D-NAIP, and Sentinel data with non-FIA private industry and climate data.
- This study will focus on forests within the Pacific Northwest, Inland Northwest, and Southeast United States.

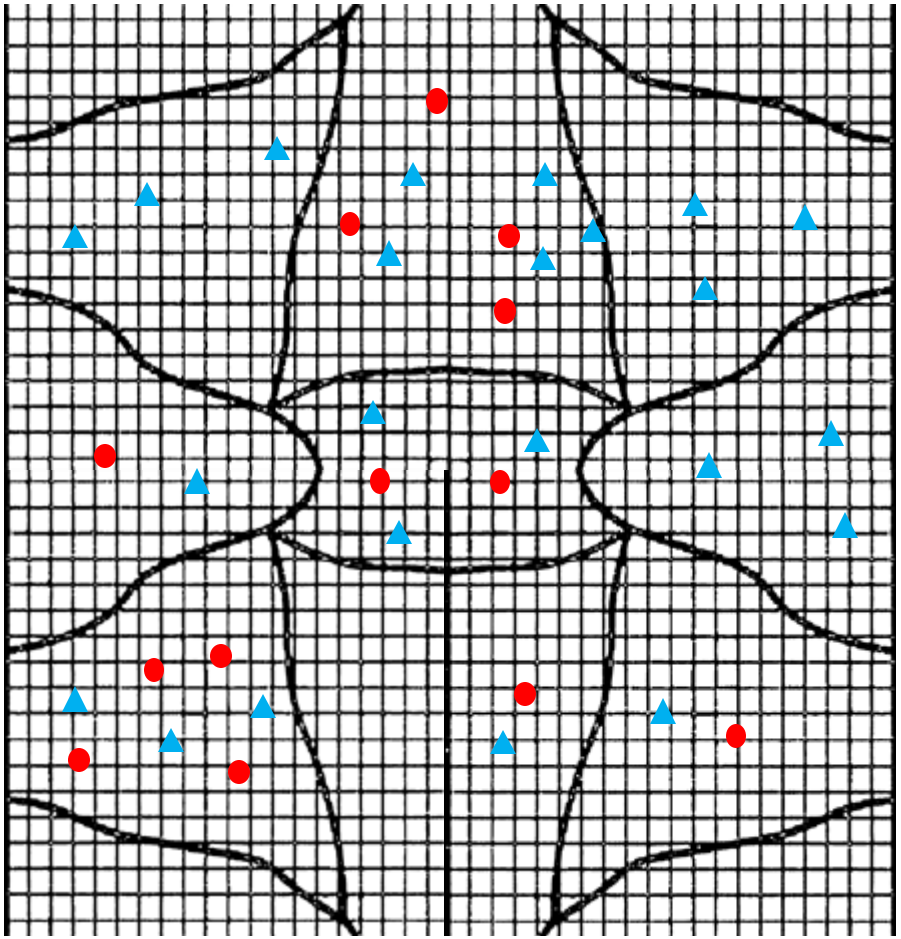
Methods

Phase 1: Model development

- Develop candidate multivariate models
- Data integration: FIA with remote sensing and climate data
- Consider the impact of climate data noise.

Methods

Phase 2: Validate multivariate models with cruise/stand exam data

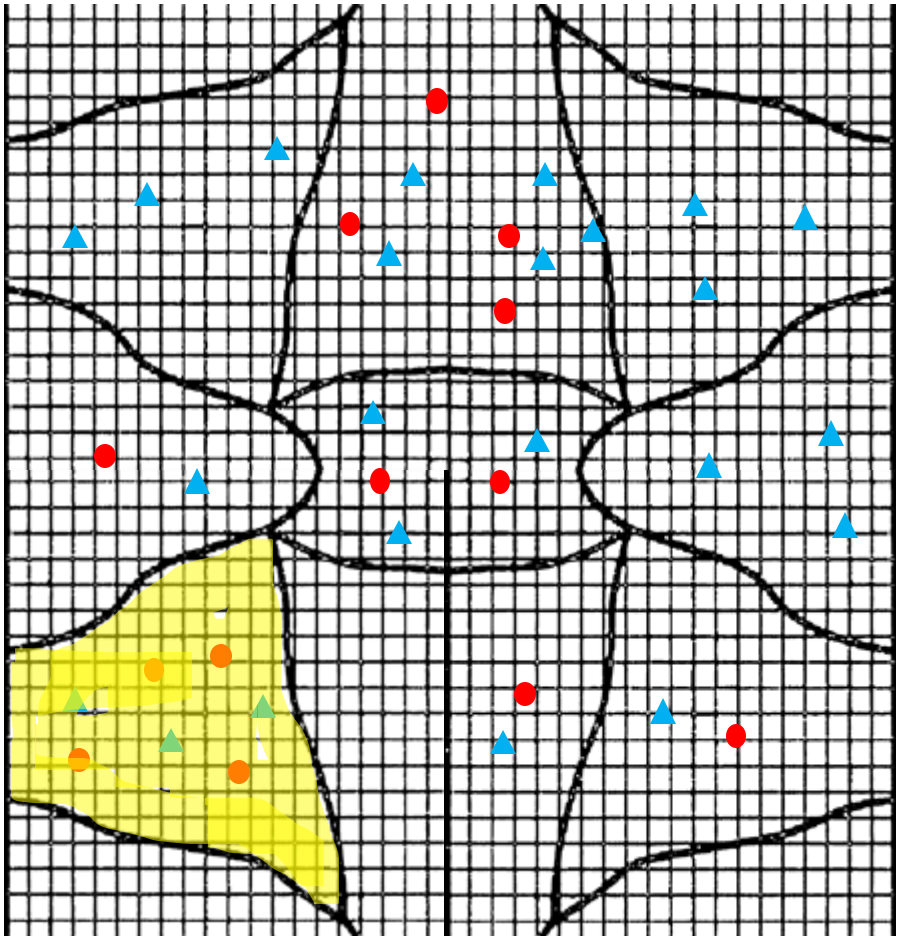


●: FIA plots

▲: Cruise/stand exam plots

Methods

Phase 2: Validate multivariate models with cruise/stand exam data



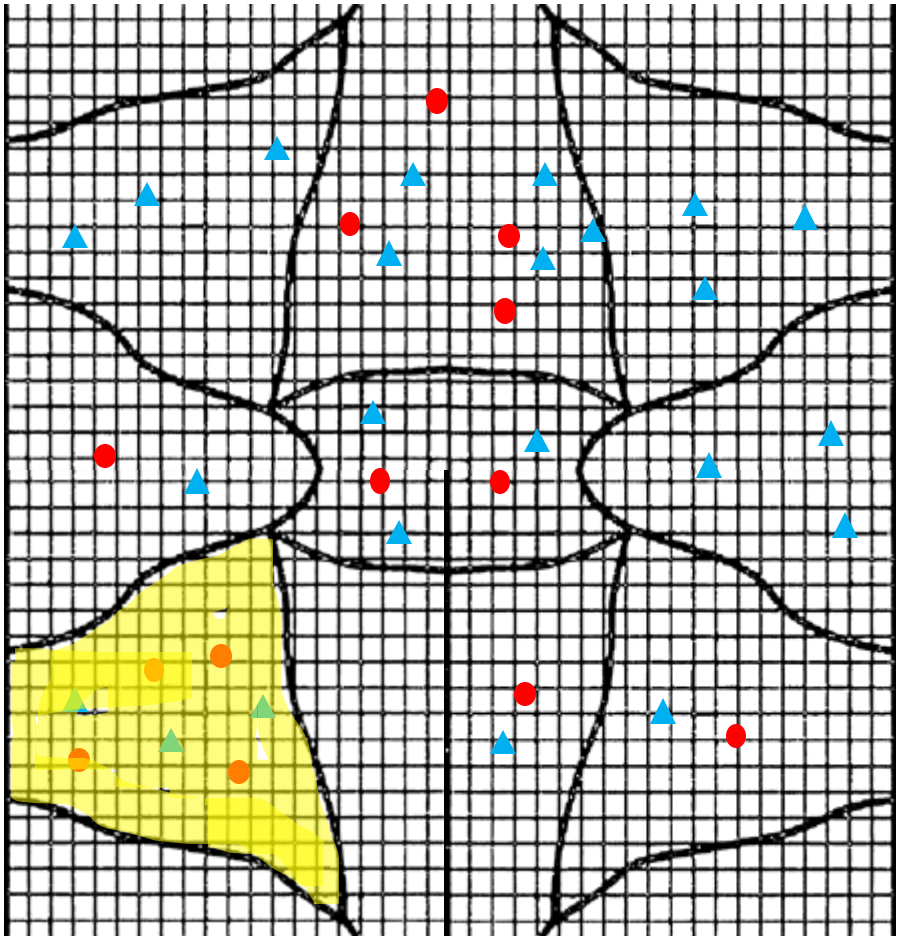
●: FIA plots

▲: Cruise/stand exam plots

Methods

Phase 3: Incorporate cruise/stand exam data

- Refine model predictions by incorporating cruise/stand exam data

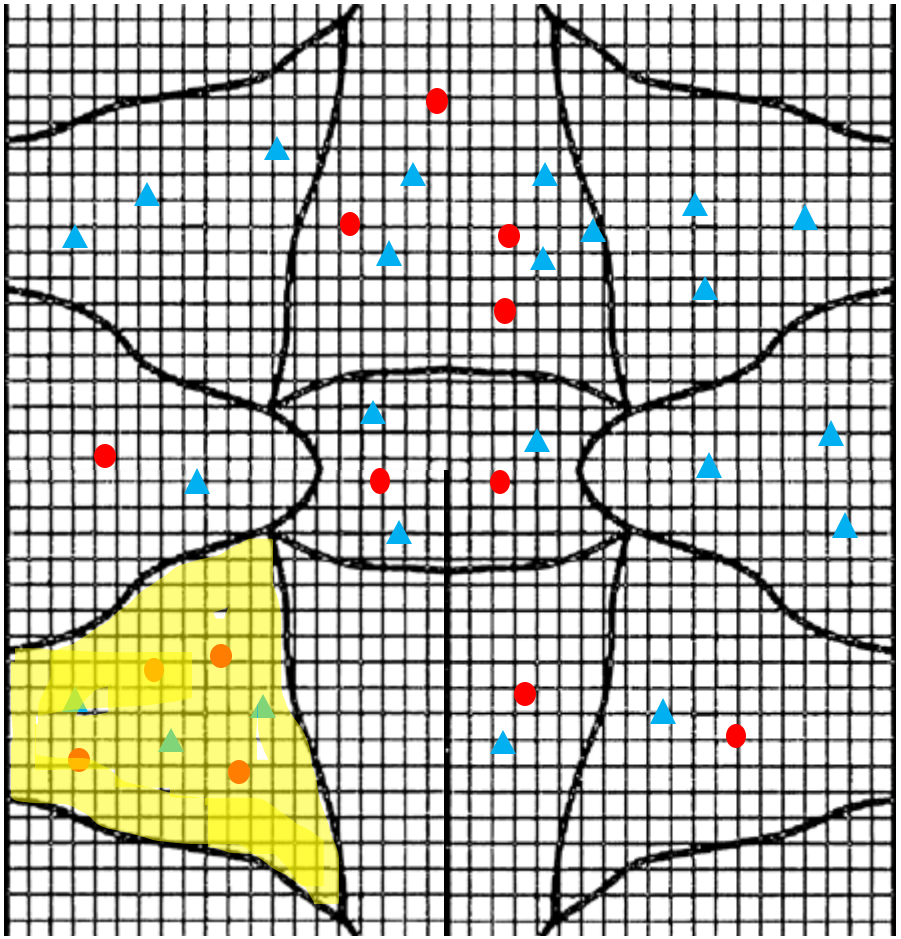


●: FIA plots

▲: Cruise/stand exam plots

Phase 4: Application

- Apply refined models to generate estimates for broader spatial scales



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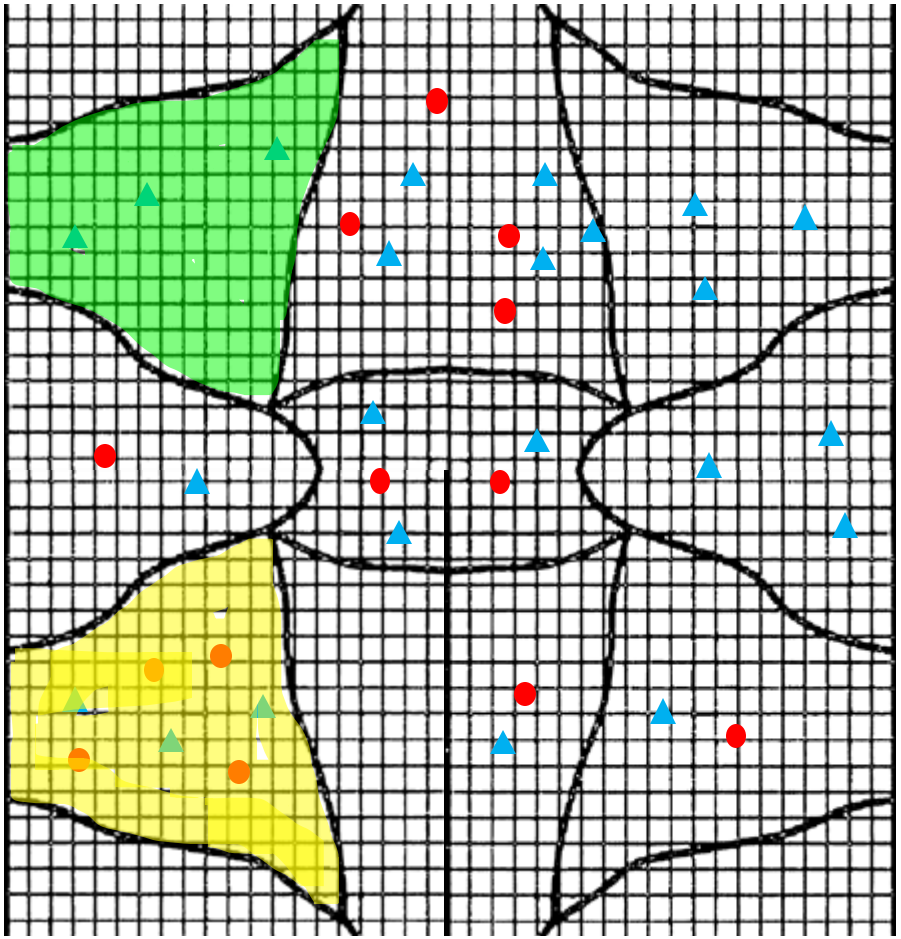


●: FIA plots

▲: Cruise/stand exam plots

Deliverables

- **Short-term:**
  - Development of initial multivariate models and validation report on model accuracy and scalability.

- **Long-term:**
  - Demonstrate the capability to generate reliable estimates and quantify uncertainties, even in areas without direct ground data.

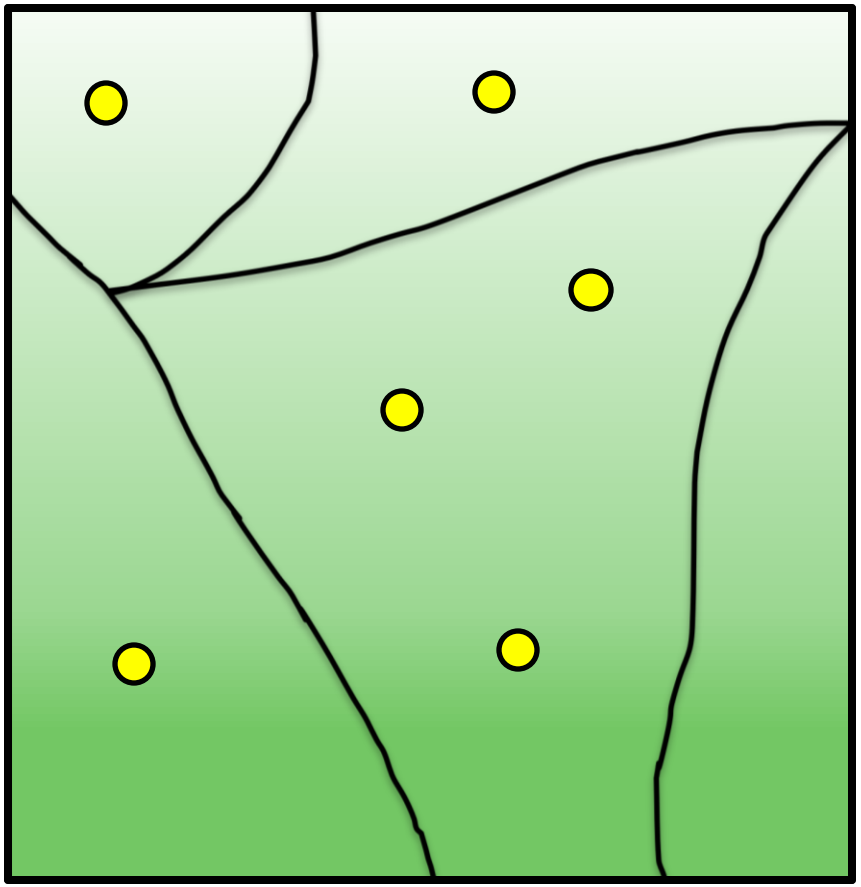
  - Provide enhanced accuracy in forest inventory estimates, leading to more informed management decisions.

  - Publications in peer-reviewed literature.

  - Summary report for member companies.

Company Benefits

- Cost savings through reduced need for extensive ground-based sampling to estimate stand attributes, such as gross and net merchantable volume.



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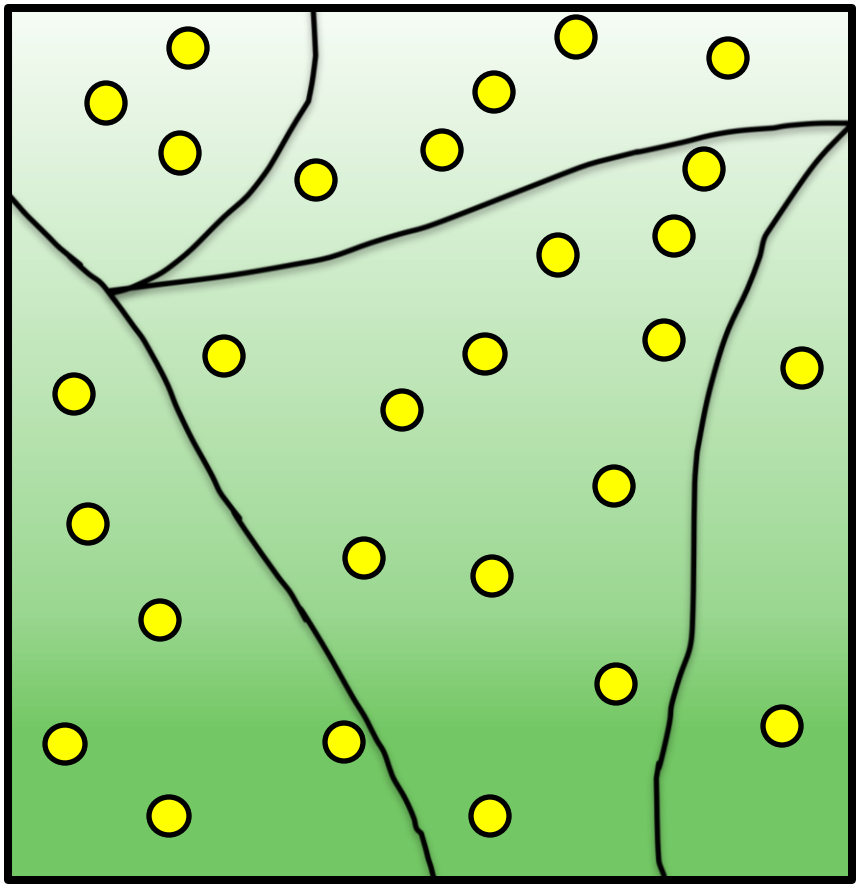

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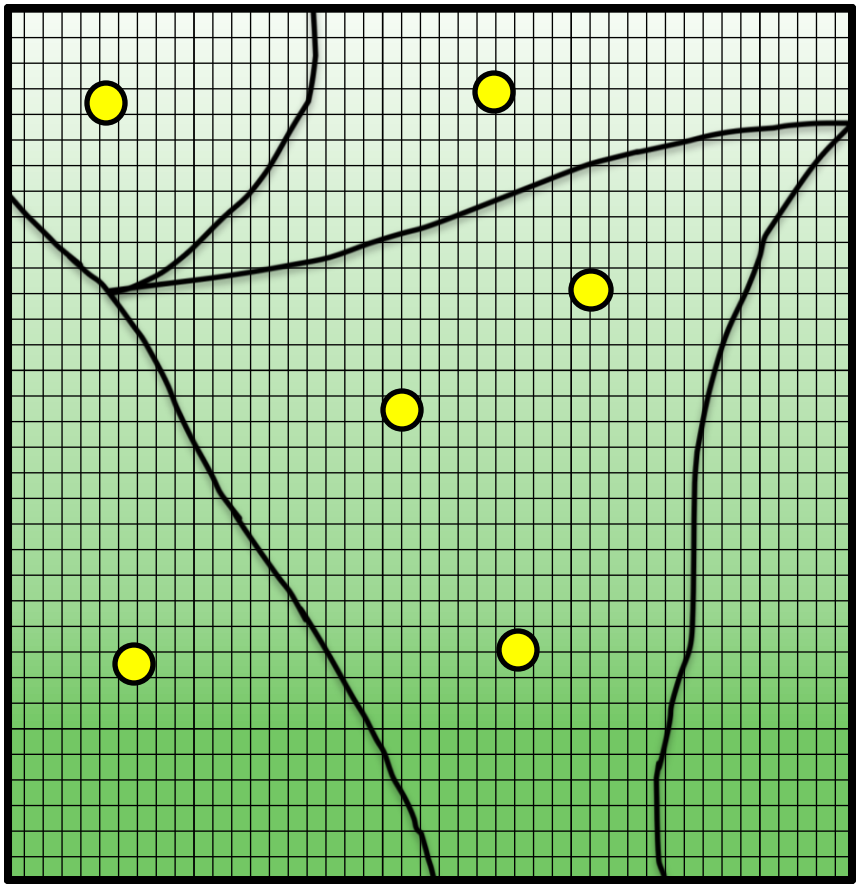

Company Benefits

- Cost savings through reduced need for extensive ground-based sampling to estimate stand attributes, such as gross and net merchantable volume.

- The project will demonstrate methods for integrating small area estimation multivariate models into operational forest inventories, particularly in diverse and complex forest types.

- Members will gain protocols that leverage remotely sensed data and additional information to enhance the precision of predicting key stand attributes (e.g., trees per acre, basal area, volume estimates), thereby reducing uncertainty in these predictions.

Summary

- Many forest inventory variables, such as basal area, stand volume, and trees per acre, exhibit strong correlations.
- This necessitates the development of multivariate models to leverage these correlations and enhance the accuracy and scalability of forest attribute predictions.
- This project will integrate data from the Forest Inventory and Analysis (FIA) program, 3D-NAIP imagery, and Sentinel satellites, and private industry data.
- This study will focus on forests within the Pacific Northwest, Inland Northwest, and Southeast United States, addressing the diverse ecological characteristics and management challenges of these regions.

Appendix

- Multivariate regression methods typically require multivariate normally distributed response variables, a condition that is seldom satisfied for forest inventory variables.

- Linearity
  - The relationship between the response variable and the predictors is assumed to be linear.

- Copula models
  - Links univariate marginal distribution functions to a multivariate distribution function.
  - This approach allows for the modeling of complex dependencies between variables without assuming a specific type of distribution for each variable.

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Unit level small area estimation with copulas

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Key words and phrases: Archimedean copulas; best linear unbiased predictor; Kendall's tau; linear mixed models; normal copula; unit level small area estimation.

MSC 2010: Primary 62D05; secondary 62H12