

**Project Report:** Applications of Small Area Estimation over the Contiguous United States: Testing and Development of Alternative Methods

**Reporting Period:** January 1, 2025 through July 31, 2025

**Project Personnel:**

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**Work Completed:**

The manuscript titled “Comparing canopy height models from regional-scale aerial photogrammetry with global spaceborne lidar-derived data for estimating forest volume and biomass” was published this reporting period, and is listed under “Publications” below as Cao et al. (2025).

During this reporting period we revisited some details of work reported in January 2025 as completed, mainly as we continued to work on manuscripts for publication and noted where additional testing or updating of results was warranted. Details are presented under the next section “Work Updated or in Progress”

**Work Updated or in Progress:**

1. CONUS wide county-level biomass SAE

We updated this work with FIA direct estimates better suited to the time period during which auxiliary data were acquired. The earlier version of this work and manuscript in preparation did not include all states having county-level FIA biomass estimates because it had been prepared before 2019 statewide evaluations were available CONUS-wide. In general, the results did not change appreciably, but there were minor differences in details such as which predictors were deemed “best” by variable selection procedures. The number and which states showed zero random-effects variances changed slightly, but the conclusions of the work did not change

appreciably. We expect to circulate a draft of the manuscript to PSAE co-authors for comments prior to submission by September 1, 2025.

## 2. Unit level SAE using aerial lidar as auxiliary data in Coastal Georgia pine plantations

We updated this work to address two additional goals that were not completed at the time former graduate research assistant Bipana Subedi completed her M.S. at Virginia Tech (December 2024). One is an examination and improvement of predictors for the unit-level Battese, Harter, Fuller (BHF; Battese et al., 1988) model used to produce plantation level estimates of volume and biomass attributes with increased precision. The other was the implementation of a simulation for evaluating the effects of very small sample sizes in field plots and effects of biased, non-random field sampling on EBLUPS. A presentation on the updated predictors was delivered at the June, 2025 PSAE meeting in Missoula, Montana (Subedi et al. 2025).

## 3. Collaboration on PSAE project “Integrating SAE methods with stand-level forest inventory for southern pine plantations”

To facilitate progress on the University of Georgia’s PSAE project led by Dr. Sheng-I Yang, we assisted with computer code and data preparation for a unit-level analysis of plantation-level estimates using auxiliary data from aerial laser scanning (LAS). Contributions and progress were presented at the June, 2025 PSAE meeting in Missoula, Montana (Yang et al. 2025).

### **Next Period Plans:**

Work to-date has involved model-based SAE methods including Fay and Herriot (1979) and Battese, Harter, and Fuller (1988). We recently engaged Dr. Ray Cziaplewski, retired, USDA Forest Service, to make comparisons of these model-based approaches with a model-assisted method he has pioneered known as the Generalized Multivariate Difference estimator (GMDe). We will pursue the comparisons involving GMDe in addition to continuing and completing work that uses models based methods, and the quasi unit level SAE approach that uses field heights as proxies for aerial remote sensing canopy heights.

### **Publications and Presentations:**

Cao Q, Radtke PJ, Coulston JW, Thomas VA, Wynne RH, Walker DM. 2025. Comparing canopy height models from regional-scale aerial photogrammetry with global spaceborne lidar-derived data for estimating forest volume and biomass. *Forest Science*. 10.1007/s44391-025-00021-z.

Cao Q, Radtke P. 2025. Accounting for highly influential domains in county-level Fay-Harriot SAE: An application with two random-effect variances. Presentation at the summer Meeting of the Partnership for Small Area Estimation, June 2025, Missoula, MT.

Subedi B, Radtke P, Cao Q, Coulston J, Montes C, Fox T. 2025 Simulation for testing Battese, Harter, Fuller unit-level SAE in planted pine stands. Presentation at the summer Meeting of the Partnership for Small Area Estimation, June 2025, Missoula, MT.

Yang S, Cao Q, Radtke P, Bullock B, et al. 2025. Integrating SAE methods with stand-level forest inventory for southern pine plantations. Presentation at the summer Meeting of the Partnership for Small Area Estimation, June 2025, Missoula, MT.

**Publications in preparation:**

Cao Q, Radtke PJ, Coulston JW. 2025. Testing Fay-Herriot inferences from U.S. national forest inventory of county-level biomass. *Manuscript in preparation*.

Cao Q, Radtke PJ, Sapkota A. 2025. Bivariate Fay-Herriot small area estimation of county-level forest biomass and volume. *Manuscript in preparation*.

Cao Q, Radtke PJ, Coulston JW. 2025. Two-group random effect variances in Fay-Herriot of county-level biomass. *Manuscript in preparation*.

Subedi B, Radtke P, Coulston J. 2025. Improving precision in forest inventory through small area estimation for loblolly pine plantations in coastal Georgia. *Manuscript in preparation*.

**Literature Cited:**

Battese GE, Harter RM, Fuller WA, 1988. An Error-Components Model for Prediction of County Crop Areas Using Survey and Satellite Data. *Journal of the American Statistical Association* 83(401):28-36.

Fay RE, Herriot RA. 1979. Estimates of Income for Small Places: An Application of James-Stein Procedures to Census Data. *Journal of the American Statistical Association* 74(366):269-277.