# Landscape-scale Forest Carbon Estimation in a Northern Forest

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Completion date: May 2017

- LiDAR data are appropriate for describing forest structure and characterizing wildlife habitat
- A simplified method for predicting aboveground biomass did not perform well under Northern Forest conditions

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.
http://www.nsrcforest.org

# Project Summary

Field-based forest inventory is expensive and is being reduced or abandoned by many landowners in the Northern Forest region. However, accurate estimates of forest carbon and habitat structure are critical for sound decision-making, especially at the landscape scale and in relationship to ecosystem services. An emerging approach combines LiDAR, which uses lasers to measure tree heights from aircraft, with field measurements to develop estimates of forest biomass, carbon, and structure. Our goal is to evaluate a combined LiDAR and field based method suggested by Asner et al. (2011) for tropical forests, to see if it can reduce inventory costs and increase accuracy under Northern Forest conditions. Lidar data collected by a commercial vendor was processed to produce a variety of data layers (e.g. canopy height, canopy cover). These structure metrics were combined with standard inventory data collected by field crews that used the field data to test the predictive model developed by Asner et al. Bird surveys were also conducted to develop habitat assessment tools. We found that the moderate resolution LiDAR dataset was adequate for developing a variety of maps and data products useful to managers. However, due to the lack of a relationship between basal area and LiDAR height metrics, the Asner et al. approach performed poorly when estimating live biomass in this forest type. A simple canopy cover metric did perform well in predicting early successional habitat and is undergoing further validation. While a satisfactory approach has not yet been developed for estimating forest biomass from LiDAR data in a way that is operationally feasible for Northern Forest managers, LiDAR data of moderate resolution is still a useful tool for characterizing the Northern Forest and has many applications for managers.

# Background and Justification

- Resource managers need accurate information about forest biomass and carbon across the landscape
- Ground based forest inventory is expensive
- Forest Inventory and Analysis data are often not appropriate for use at stand and landscape scales
  - One FIA plot for every 6000 acres
- Airborne LiDAR (Light Detection And Ranging) technology can provide information about forest structure at the landscape scale
- But...to use this information, field data are still needed

# Background and Justification

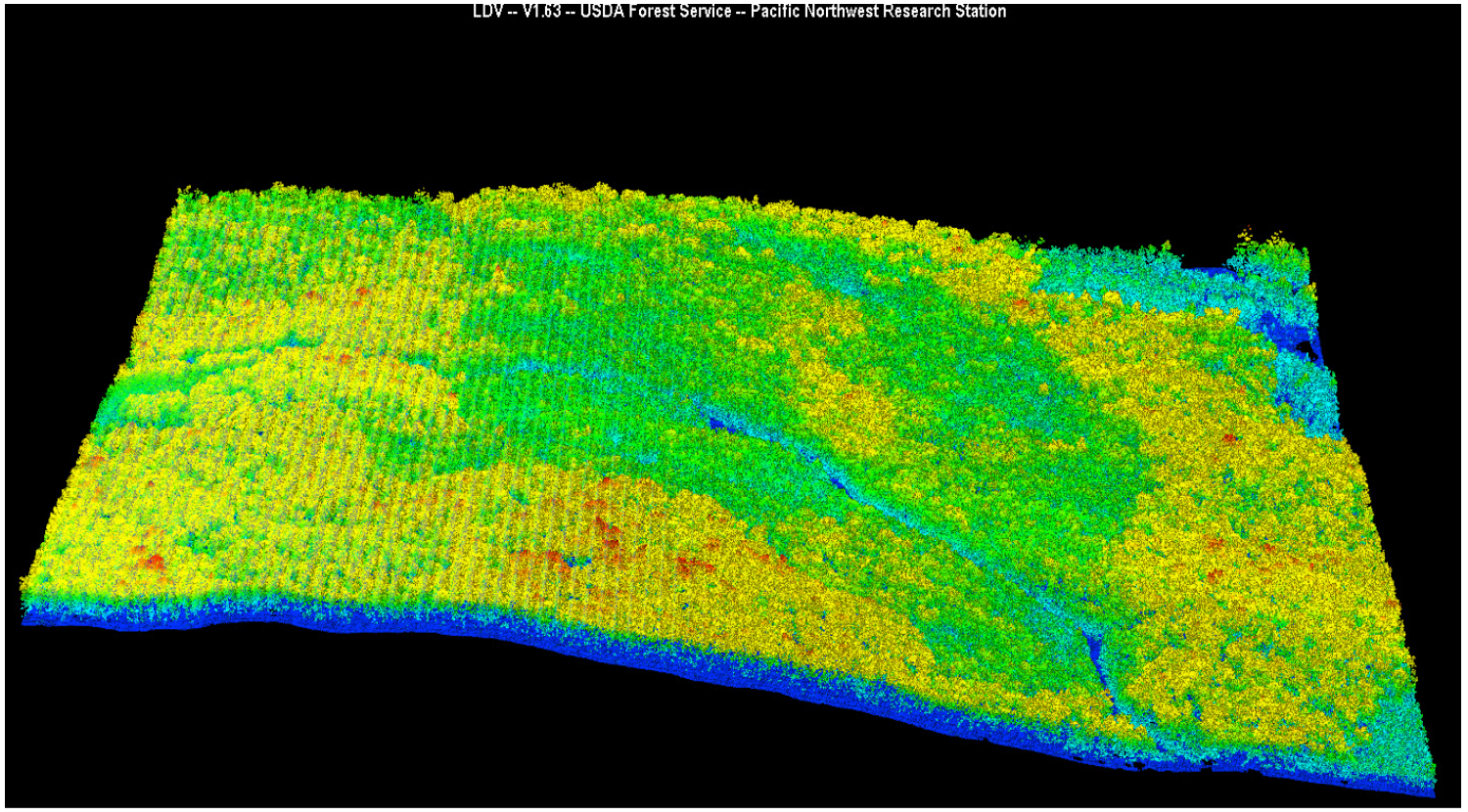
- Asner et al. (2011) developed a streamlined approach to estimating forest biomass from LiDAR data
- Developed and tested in tropical forests
- The model used basal area and average wood density combined with height variables from the LiDAR data to estimate aboveground live biomass
- Approach requires far fewer field measurements, and could be feasible for mangers to use operationally

Asner, GP et al., 2011. A universal airborne LiDAR approach for tropical forest carbon mapping. Oecologia (online first; DOI 10.1007/s00442-011-2165-z).

# Methods

- Study site: 17,000 acre watershed on the Ammonoosuc River on the White Mountain National Forest
- Northern hardwood forest with a conifer component
- LiDAR data acquired as part of a landscape typing project
- LiDAR data processed with FUSION software to product a variety of data layers describing the forest
  - e.g. canopy height, canopy cover
- These are used in the modeling process

# Methods




Example of LiDAR point cloud from study area.  Color indicates height.

# Methods

- 176 field plots were established
- Plot locations were recorded with a high-precision GPS unit (to link the same areas to the LiDAR point cloud)
- Basic forest measurements were taken, including:
  - Species and diameter of live and dead trees
  - Height of a subset of trees on plot
  - Basal area
- These plot-level variables were used with the corresponding LiDAR variables for the plots to test the Asner et al. (2011) model

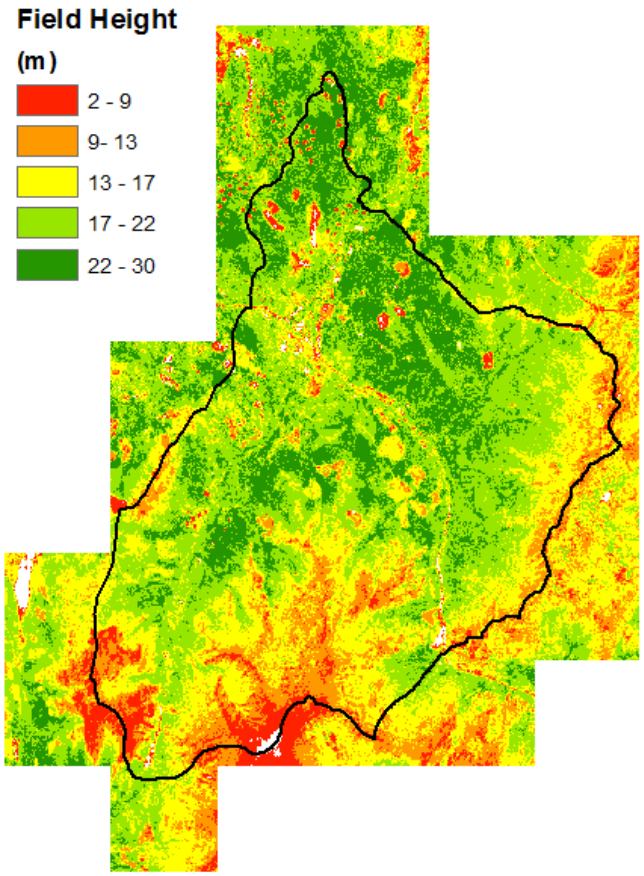
# Results/Project outcomes

## Summary of mean plot values

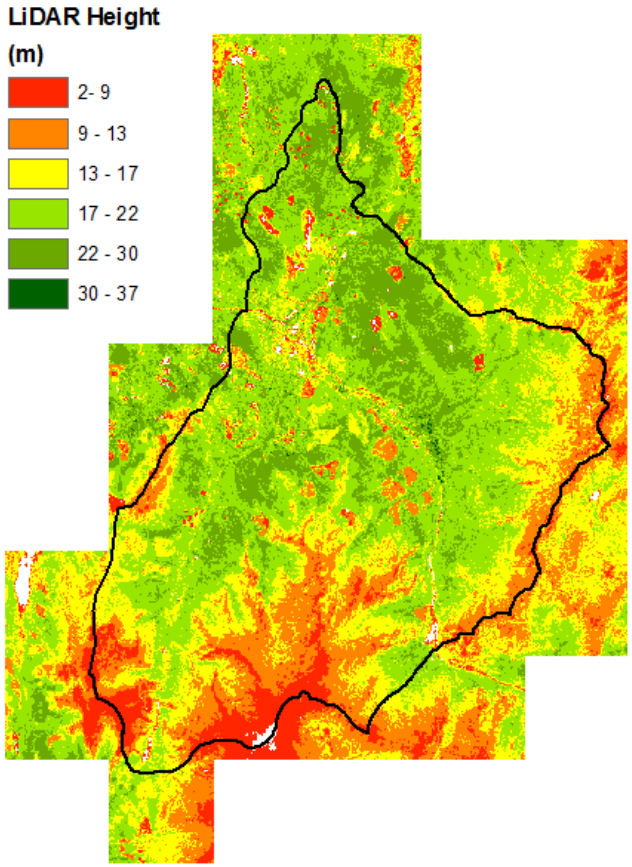
| Variable | Minimum | Median | Mean | Maximum | Std. Dev. |
|---|---|---|---|---|---|
| Trees/ha | 223 | 1805 | 2452 | 17880 | 2328 |
| Basal Area ($m^2$/ha) | 1.0 | 34.4 | 34.5 | 68.6 | 11.7 |
| Quadratic Mean DBH (cm) | 4.3 | 14.9 | 15.8 | 33.2 | 5.8 |
| Relative Density | 0.03 | 0.93 | 0.95 | 1.90 | 0.30 |
| Lorey's Height (m) | 5.9 | 18.0 | 17.4 | 27.4 | 5.5 |
| Top Height (m) | 7.0 | 20.9 | 20.4 | 30.3 | 5.3 |
| Live Tree Aboveground Biomass (Mg/ha) | 3.0 | 200.5 | 200.4 | 418.8 | 78.2 |
| Conifer Fraction | 0.00 | 0.08 | 0.23 | 1.00 | 0.28 |
| Basal Area-weighted Wood Specific Gravity | 0.35 | 0.56 | 0.54 | 0.64 | 0.08 |

# Canopy Height

## Field measurements

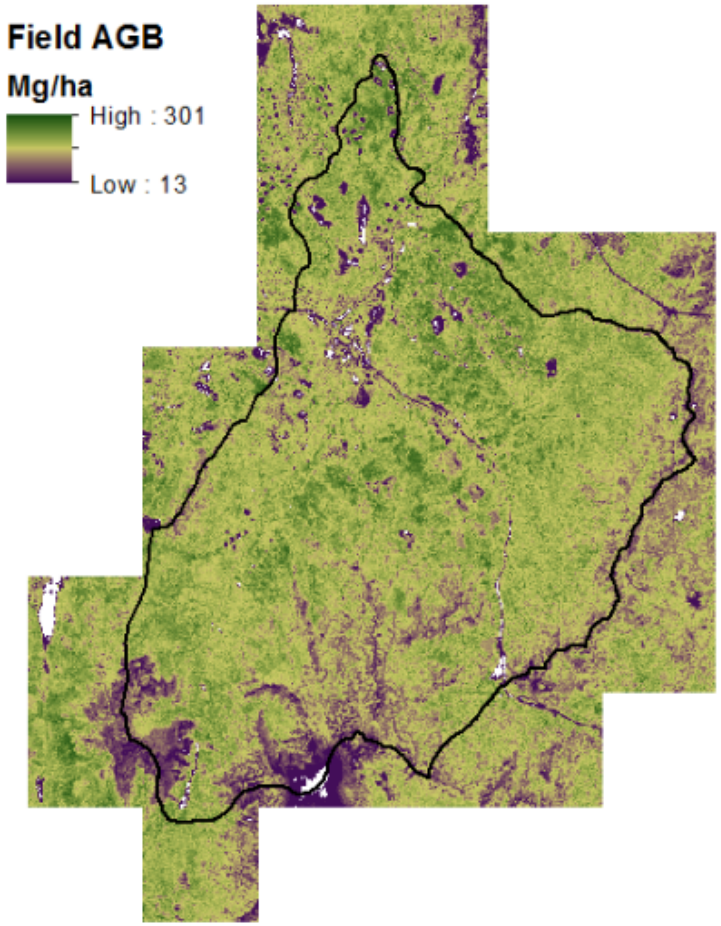



## LiDAR data

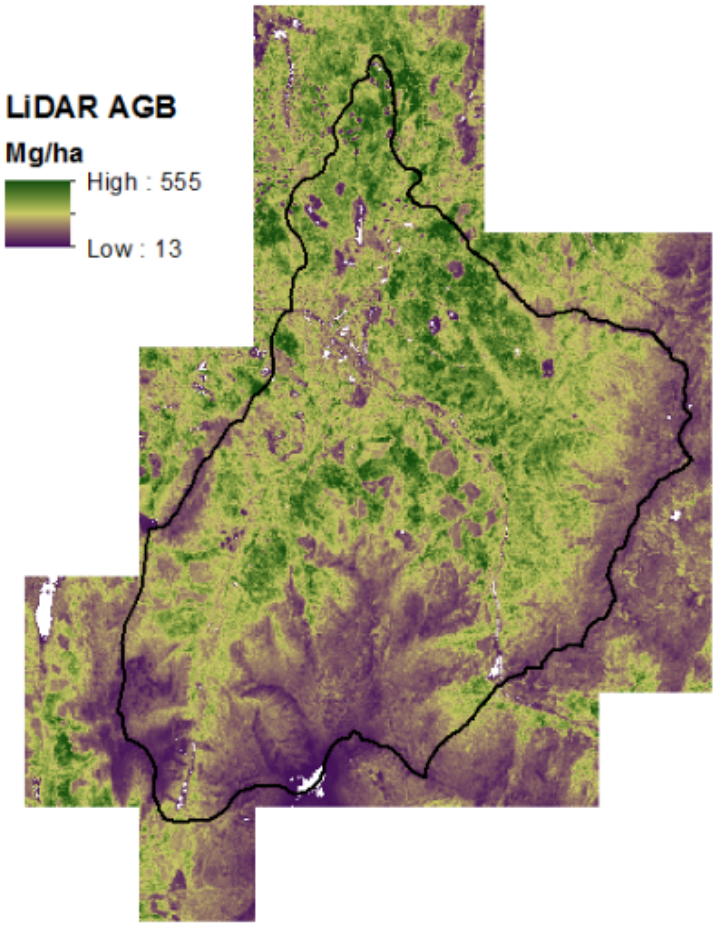


# Live Aboveground Biomass

## Field measurements

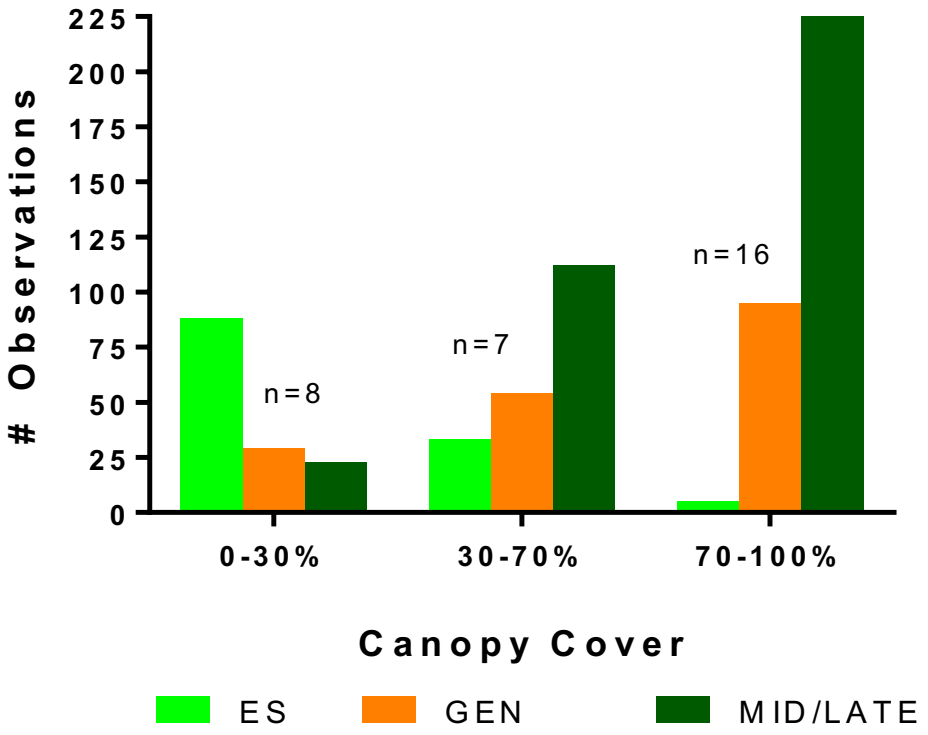



## Predicted w/ Asner model



# Canopy Cover: Bird Community

- Bird surveys were done on some plots at different successional stages
- Data showed that a simple canopy cover metric might predict if early successional birds were present
- We tested this with data from another field site and found that the metric performed well



# Summary

- Moderate-resolution leaf-off LiDAR data were appropriate for describing forest structure
- The LiDAR and field canopy height data were generally a good match
- The Asner approach performed poorly compared to field data when predicting live aboveground biomass
  - Lack of a statistical relationship between measured basal area and LiDAR metrics
- LiDAR canopy cover metric was good predictor of bird community composition

# Outreach Activities

- Overview of project and uses of LiDAR data in forest management presented to NH Congressional staff
- Bird habitat initial results presented at Ecological Society of America annual meeting
- Overview of project and results presented to White Mountain NF and NH Fish and Game staff
- Biomass modeling paper in preparation
  - Will be submitted to Ecological Applications
- Final validation work in progress on avian habitat mapping; manuscript to follow

# Implications and applications in the Northern Forest region

- Moderate resolution LiDAR data is a useful tool for mangers of Northern Forests
  - Canopy height model shows management treatments and disturbances
  - Cover and height metrics have several applications
- Cover metrics provide a way for managers to identify potential early successional wildlife habitat at the landscape level
- Lack of a relationship of basal area to LiDAR height metrics resulted in a failure of the Asner approach in this forest type
  - Follow-up work needed to identify other feasible ways to estimate biomass from LiDAR metrics

# Future directions

- Additional development of wildlife habitat assessment metrics
- Application of habitat metrics to other available LiDAR datasets
- Comparison of terrestrial LiDAR (collected at study site) and airborne LiDAR data for describing forest structure
- Additional exploration of ways to use LiDAR data in an operationally feasible way

# List of products

- Ducey, M. J., Colter, R. A., Hoover, C. M., and Yamasaki, M. 2014. Measuring forest vertical structure with inexpensive handheld laser. ECANUSA Forest Science Conference, Rimouski, Quebec, Canada, 18 October 2014.
- Hoover, C. M., Yamasaki, M., Costello, C. 2016. Habitat classification in a northern hardwood forest using moderate return density LiDAR. Annual Meeting of the Ecological Society of America, August 2016, Fort Lauderdale, FL.

- Hoover, C. M. and Yamasaki, M. 2016. Briefing on project and benefits of LiDAR data for NH forest managers to members of Senator Ayotte and Senator Shaheen's staff.
- Yamasaki, M. 2017. Update on project, use of LiDAR data, and LiDAR habitat classification work to members of the White Mountain National Forest and NH Fish and Game biology staff.

- Hoover, C. M., Ducey, M. J. and Yamasaki, M. *In preparation.* Landscape-scale Forest Carbon Estimation in a Northern Forest. Expected submission date: August 2017.
- Hoover, C. M., Yamasaki, M., Costello, C. *In preparation.* Habitat classification in a northern hardwood forest using moderate return density LiDAR. Expected submission date: December 2017.