Forest Biomass Change over a Coniferous Forest Landscape Based on Tree-level Analysis from Repeated Lidar Surveys

Sabrina B. Turner[1], David P. Turner[2], Andrew N. Gray[3]

[1]Department of Geography (Master of GIS Program), Penn State University, [2]Department of Forest Ecosystems and Society, Oregon State University, [3]USDA Forest Service, PNW Station

OSU Oregon State University

Background

Changes in forest biomass play a significant role in the global carbon cycle, and are of interest in relation to climate change mitigation. Approaches to quantifying changes in forest biomass include traditional repeated plot-based inventories, but remote sensing offers the opportunity for spatially continuous coverage over large domains. A high-resolution 3D lidar point cloud, from an airborne sensor, provides a clear depiction of the canopy structure, from which biomass can be estimated at the level of individual tress or plots. In this study, we evaluated the potential for estimating forest biomass change at the landscape scale in a conifer forest using repeated lidar surveys and tree-level analysis.

Approach

The study aimed to estimate change in forest biomass at the landscape scale based on two lidar data acquisitions (**Figure 1**, **Figure 2**). Individual trees were delineated based on point cloud clustering. Tree height and crown area provided the basis for estimation of tree-level biomass using allometry. Change in area-wide biomass was based on the difference in total biomass over the interval between lidar acquisitions.

The tree-level reference data used to develop our allometric equation came from the Forest Inventory and Analysis (FIA) National Program of the USDA Forest Service (Woudenberg et al. 2010), specifically the PNW-FIA Integrated Database. A total of 14,709 trees were used and the predicted variable (aboveground biomass) included all above-ground wood plus foliage. RMSE across all trees was 823 kg, with a small positive bias (**Figure 3**).

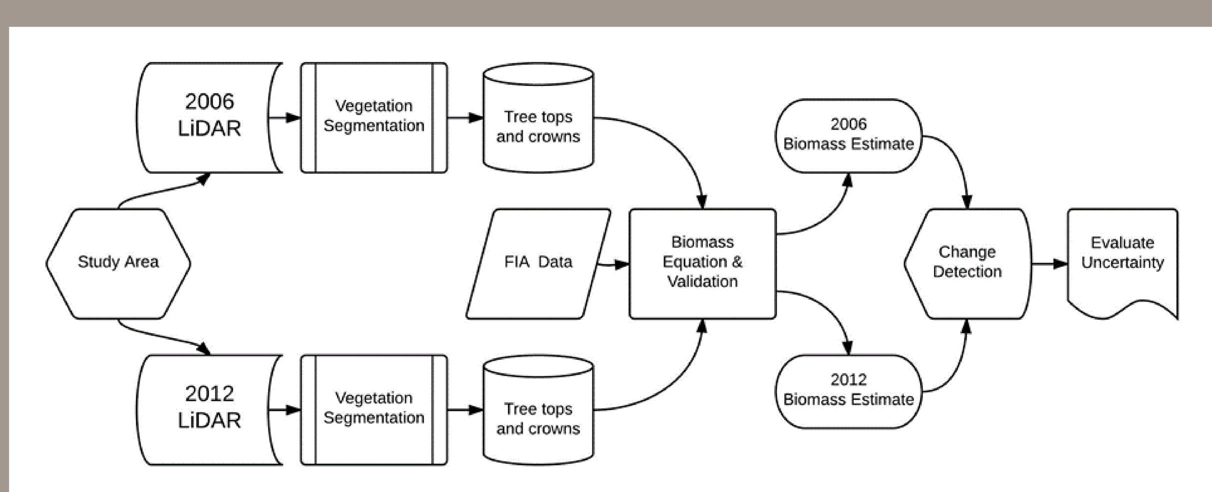

Figure 1. Information flow diagram.

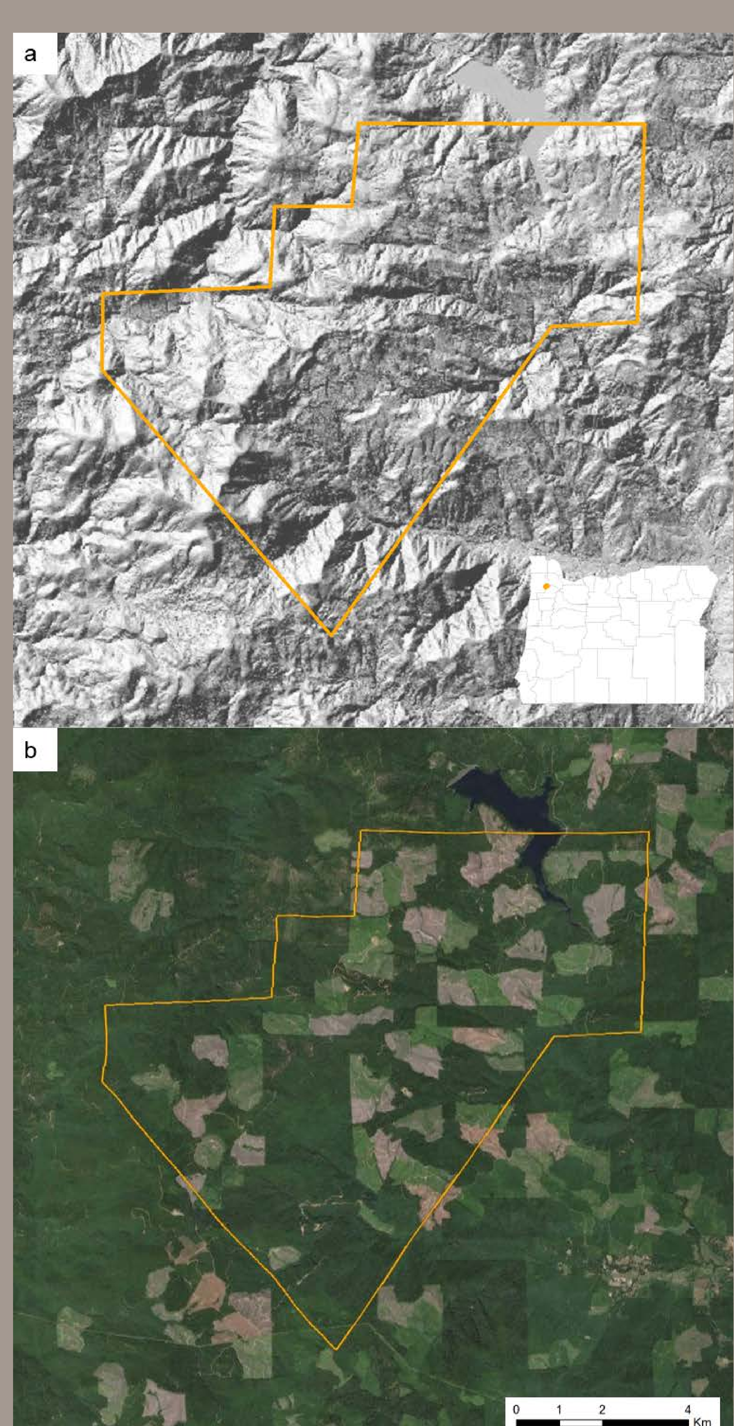

Figure 2. The study area covers 52.76 km^2 of land located in northwest Oregon (USA). It is comprised of actively managed, temperate coniferous forest, and includes 0.44 km^2 of a reservoir. The land is in private ownership. a) Study area polygon over a hillshaded digital elevation model from the Oregon Department of Geology and Mineral Industries. b) study area polygon over a Google Earth image from July 2012.

Results

Above-ground biomass for the study area averaged 43.6 kg m^{-2} in 2006 and 35.2 kg m^{-2} in 2012 (**Figure 4**), indicating an average 1.27 kg m^{-2} reduction per year (6.66 years passed between the two surveys).

Total change in biomass over the study interval was -0.45 Tg (**Figure 5**).

When binned by height, trees of intermediate height (35 – 40 m) showed the largest biomass increase, with an average 381 kg gain per tree over the 6-year period (**Figure 6**). The average height growth per tree between the two surveys was 3.6 meters (**Figure 7**).

Using a threshold biomass loss rate of 4.5 kg m^{-2} yr^{-1} (i.e. a harvest of ≥ 30 kg m^{-2}), approximately 3% of the study area was harvested per year.

Errors in segmenting a lidar point cloud into individual trees take the form of over-segmentation (reporting multiple trees where only one tree exists within the multiple polygons) or under-segmentation (reporting one tree polygon where multiple trees exist within the polygon). Here, visual inspection of 0.56 km^2 indicated an over-segmentation rate of 0.3% and an under-segmentation rate of 2.7%.

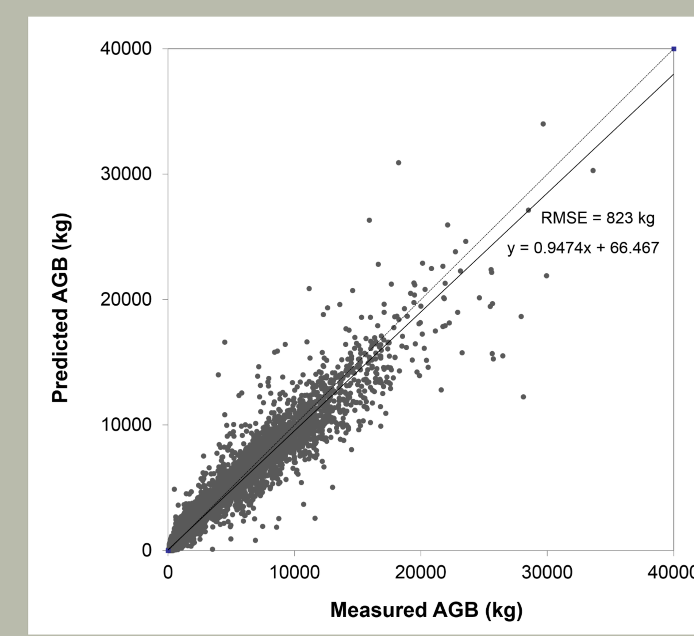

Figure 3. Scatter plot of measured vs. predicted tree biomass for all trees used to develop the Above-ground Biomass (AGB) prediction model (N = 14,709 trees).

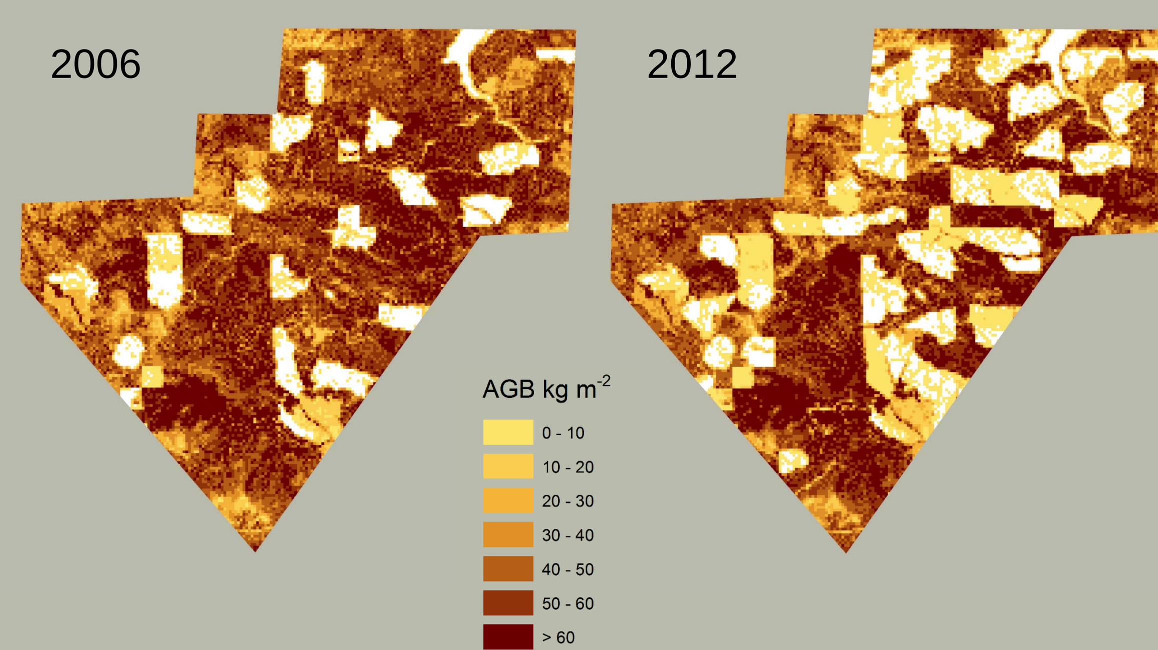

Figure 4. Biomass estimates for 2006 and 2012. White represents areas where no trees were detected.

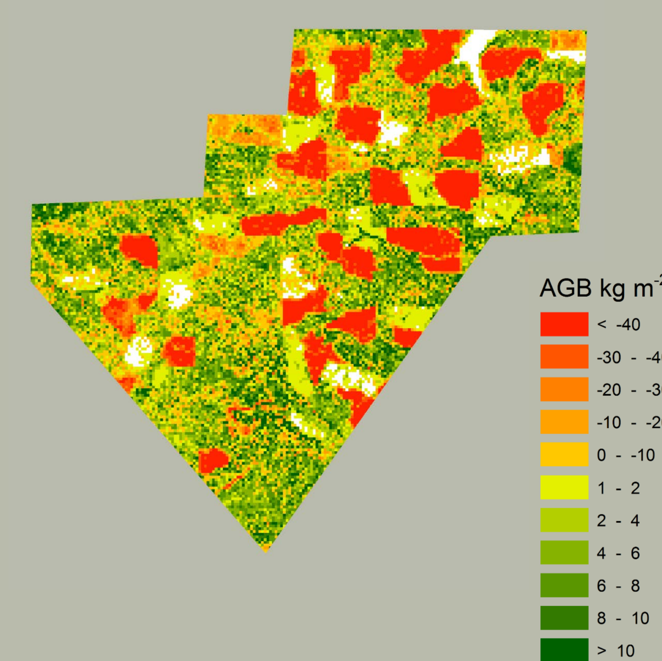

Figure 5. Calculated change in biomass over the 6-year period. White represents areas with no detected change in biomass.

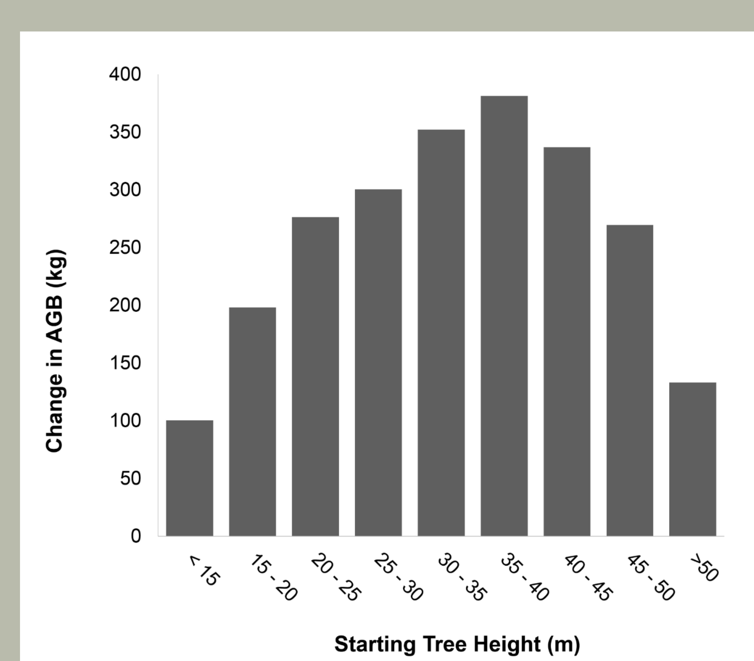

Figure 6. Change in Above-ground Biomass (AGB) between 2006 and 2012 for trees that were not harvested (N = 499,411 trees).

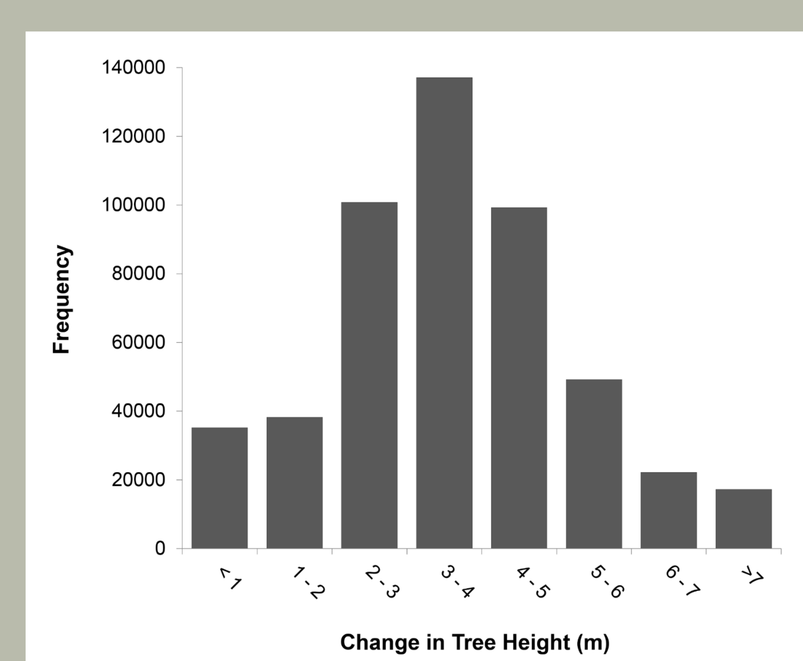

Figure 7. Change in tree height between 2006 and 2012 for the trees that were not harvested (N = 499,411 trees).

Conclusions

In this study of a managed conifer forest in the temperate zone, an interval of 6 years was sufficient to detect significant changes in tree height and biomass. The study area lost carbon, associated with a harvest rate of 3% per year. The tree-level approach to characterizing forest structure and growth has a wide array of potential applications.

References

Li, W., Guo, Q., Jakubowski, M.K., Kelly, M. 2012. A new method for segmenting individual trees from the lidar point cloud. Photogrammetric Engineering & Remote Sensing. 78(1), 76-84.

Woudenberg, S.W., et al. 2010. The Forest Inventory and Analysis database. USDA Forest Service General Technical Report RMRS-GTR-245. 336p.