Opportunities and Challenges of Using FIA Data to Validate Biomass Maps from LiDAR: Results from a Case Study in Maryland

Kristofer Johnson, Craig Wayson, Jason Cole, Richard Birdsey, Yude Pan

USDA Forest Service

Introduction

This study contributes to NASA's local scale Carbon Monitoring System (CMS) biomass pilot study. Major objectives of the CMS project include quantifying aboveground carbon stocks and assessing uncertainties in biomass maps. Forest Inventory and Analysis (FIA) data provide independent field-based estimations that are a logical choice for comparison to LiDAR-based biomass maps. FIA plots consistently measure aboveground biomass with well documented methods, are spatially unbiased at large scales, and are straightforward to replicate for augmenting sample sizes. Further, although FIA data is primarily designed to represent forests at broad geographic scales (e.g. counties), there is potential to use FIA plots to compare biomass at the plot/pixel scale. Finally, in addition to providing independent estimates of biomass at different scales, FIA data may also be used to identify and improve uncertainties in remote sensing-based biomass maps.

Despite the advantages of using FIA data for biomass map comparisons, there are challenges related to both uncertainties in the measurement data and in matching plots to pixels. For example, there are errors associated with allometric models and decisions about which models to use. Additionally, FIA plot coordinates have GPS registration errors as much as 20 meters. Finally, there is lack of representation of "non-forest" biomass, since FIA does not routinely measure these areas.

LiDAR-based biomass maps were created for two counties in Maryland, Howard and Anne Arundel, by a NASA CMS team (Fig.1). The map used for comparison in this study was made with a Bayesian Model Averaging method. In order to compare the map with FIA data we addressed the above uncertainties with several approaches: 1) we applied multiple allometric models and propagated allometric model error, 2) we intensified the sampling of biomass with plots designed after FIA protocol ("FIA-like" plots), 3) we matched FIA-like plot biomass to a range of biomass map pixels, and 4) we included estimates of non-forest biomass from a previous study (Riemann et al., 2003).

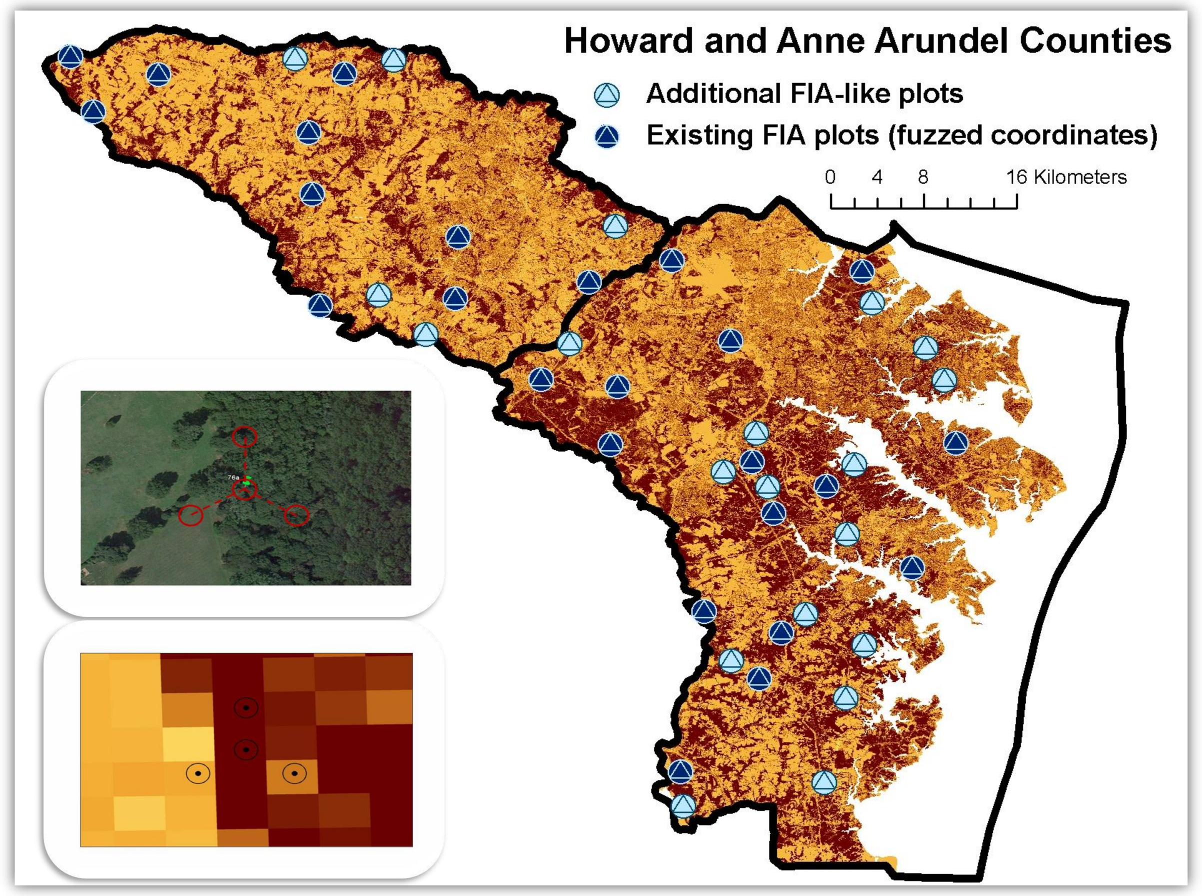

Figure 1. FIA (n = 25) and FIA-like plots (n = 20) used for comparison. LiDAR-based biomass map is 30m resolution and was provided by Jaun Suarez of the NASA CMS biomass pilot team.

Methods

Allometric Models and Error Propagation

We included three approaches to estimate plot biomass: 1) general equations developed by Jenkins et al., (2003), 2) equations specific to major species in the area of interest, and 3) the Component Ratio Method used by the FIA (CRM, Heath et al., 2009).

To address allometric model error, the standard error of the allometric equation was simulated by systematically and iteratively adding many points around an equation until the original R2 was approximated (Wayson, in prep) (Fig.2). The resulting standard error structure is iteratively applied to every DBH of every tree simultaneously, say 100 times, producing a distribution of biomass estimates at the plot and subplot level (Yanai et al., 2010).

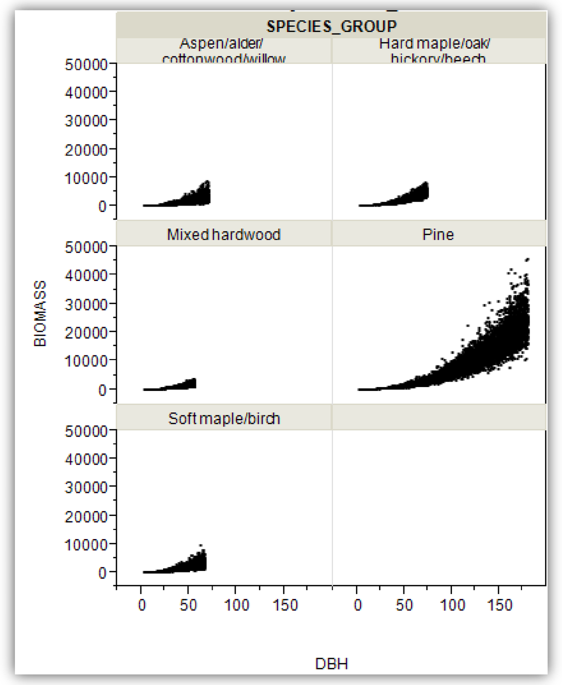

Figure 2. Pseudo replication of standard errors from the allometric prediction model

GPS Error

To address known GPS error, a range of GIS data within 17-m from the plot center were extracted instead of just one value. The 17-m distance accounts for the average GPS error observed under heavy canopy in the NE region.

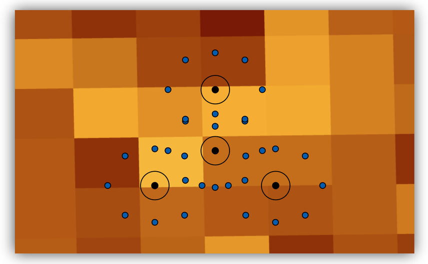

Figure 3. FIA plot design. The blue dots represent all the biomass values extracted to account for GPS error.

Results

Allometric model comparisons (Fig. 4a,b)

- •Mean biomass from Jenkins equations was about 17% higher than the Component Ration Method (CRM)
- •Species Specific was about 30% higher than CRM
- •However, none of the estimates were significantly different from each other
- •The variability due to using different allometric models was similar the variability from biomass values of the surrounding pixels

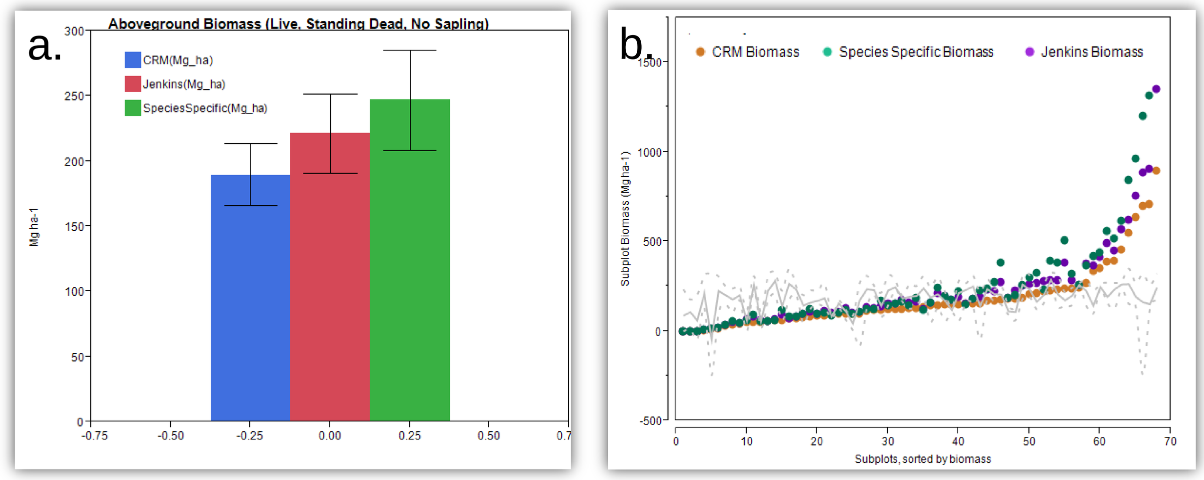

Figure 4. a) Mean Biomass using three different allometric model approaches. b) Variability of subplot biomass

Subplot, Plot and Pixel Matching and Error Propagation (Fig. 5a,b)

- •Some FIA-like subplots (168 m2) had much higher biomass estimates than LiDAR model predictions at the pixel level (900 m2).
- •Allometric error was lower at the plot level compared to the subplot level.
- •Plot level estimates were more comparable to the biomass map than subplot estimates

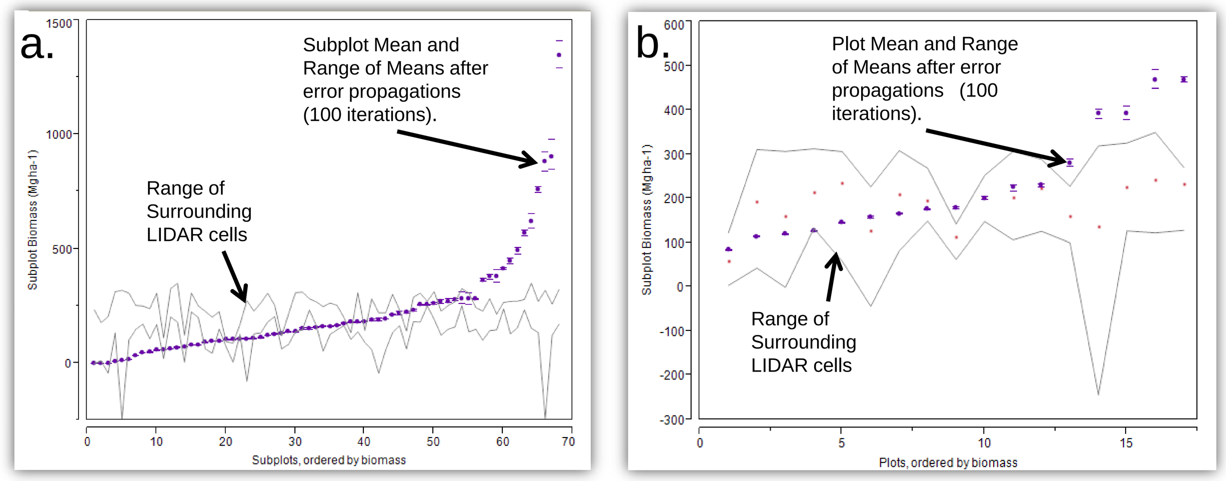

Figure 5. a) Subplot and b) Plot variability of biomass compared to their surrounding LiDAR-based values

County Level Comparisons, Including Nonforest Biomass (Table 1)

- •About 57% of the two counties were covered by nonforest, but overall nonforest biomass was much lower than the forest biomass.
- •Forest biomass estimated by FIA was higher than the LiDAR-based biomass map.

Results (cont)

Table 1. Biomass results for Howard and Anne Arundel counties, both forest and nonforest. Only Jenkins allometric model results are presented.

Aboveground Biomass (Live, Standing Dead, No Sapling)

Method	n	Mean (Mg/ha)	Conf. (Low,Up)‡	Sampling Error (%)	Area (ha)*	Total Biomass (Tg)
Forest - FIA and FIA-like	45	222	(189,252)	7	74820	16.6
Nonforest - Riemann et al., (2003)**	46	21			99080	2.1
Total	91				173900	18.7
Forest - BMA LIDAR		171			74820	12.8
Nonforest - BMA LIDAR		38			99080	3.7
Total					173900	16.5

*from 2008 NLCD landcover
‡95% Confidence Interval for mean biomass after error propagation
**figure doesn't include water plots or missed plots due to inaccesibility; plots were measured in 1999; n = 46 where 14 had trees, 32 had no trees; based on 1/10 acre sampling centered on FIA center subplot

Conclusions

When field measurements are compared to remote sensing based biomass at the plot/pixel scale, differences between allometric models, and their associated errors, will affect interpretations of uncertainties in the map. Further, it helps if the training data used for deriving LiDAR-based maps use the same allometric models.

For plot/pixel comparisons where the pixel is larger than the subplot, it is more comparable to use FIA plots rather than subplots. The small size of subplots sometimes results in inflated values on a per hectare basis because of the influence of a few very large trees.

FIA data is valuable as an independent estimate of county level biomass stock estimate, but it does not represent spatial heterogeneity of biomass as well as LiDAR-based methods. Intensifying the sample number as was done in this study will improve comparison results.

References

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