Tree-centric mapping of forest carbon density from airborne LiDAR and hyperspectral data

David A. Coomes[1], Xiaohao Cai[1,3], Michele Dalponte[1,2], Juheon Lee[1,3], Carola Schönlieb[3]

Author's affiliations. 1 Department of Plant Sciences, University of Cambridge, UK; 2 Department of Sustainable Agro-ecosystems and Bioresources, Fondazione E. Mach, Trento, Italy; 3 Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK

Highlights: A tree-centric approach to carbon mapping is described, based on measuring the dimensions of individual tree crowns (ITCs) from LiDAR data, and species from hyperspectral data, from which individual-tree carbon stocks are calculated. We should tree-centric approaches deliver highly precise and accurate carbon maps.

Key words: *individual tree crown delineation, graph cut, hyperspectral, carbon mapping.*

Introduction

Forests are a major component in the global carbon cycle, and accurate estimation of forest carbon stocks and fluxes is important in the context of anthropogenic global change. Airborne LiDAR is increasingly recognized as outstanding data source for high-fidelity mapping of carbon stocks at regional scales. Most LiDAR-based approaches to carbon mapping work with summary statistics derived from the point cloud within pixels, which are calibrated with field-plot data. We develop a tree-centric approach to carbon mapping, based on identifying individual tree crowns (ITCs) and species from airborne remote sensing data, from which individual-tree carbon stocks are calculated.

Content

The first analysis we present uses airborne surveys of a 32 km^2 area of the Italian Alps, which is dominated by conifer species. The average LiDAR point density was high, at 48 pts/m^2 and accompanied by hyperspectral data (AISA Eagle II). ITCs we identified from the laser-scanning point cloud using a region-growing algorithm and identifying species from airborne hyperspectral data by machine learning. For each detected tree, we predicted stem diameter from its height and crown-width estimate. From that point on, we use well-established approaches developed for field-based inventories: aboveground biomasses of trees are estimated using published allometries and summed within plots to estimate carbon density. We show this approach is highly reliable: tests in the Italian Alps demonstrated a close relationship between field- and ALS-based estimates of (a) tree biomasses (r^2 = 0.65) and (b) carbon stocks (r^2 = 0.98) (Figure 1).

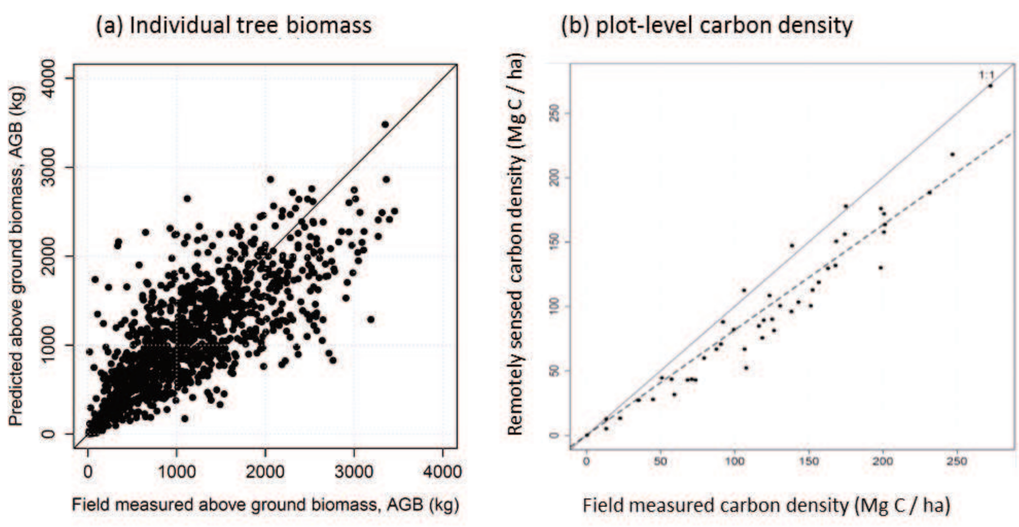

Figure 1: (a) biomasses and (b) carbon densities estimated from airborne imagery using tree-centric methods

Small trees were invisible from the air, meaning that 23% of biomass was not sensed (dotted regression line vs solid 1:1 line in Figure 1), so a correction factor is required to accommodate this effect.

The second illustration of the tree-centric approach uses an airborne survey of lowland tropical forests in Borneo, which is dominated by numerous dipterocarp species. Here the ITCs were identified using a new approach which utilizes the entire point cloud, based on graph cut methods, which allows understory trees to be detected as well as the canopy giants. Despite the complexity of these forests, species detection from hyperspectral imagery (AISA Fenix) was reasonably successful, and tree biomasses estimates were unbiased.

An advantage of the tree-centric approach over existing plot-level methods is that it can produce maps at any scale, and is fundamentally based on field-based inventory methods, making it intuitive and transparent. Airborne laser scanning, hyperspectral sensing and computational power are all advancing rapidly, making it increasingly feasible to use ITC approaches for effective mapping of forest carbon density.