# Start Here

# Lidar outperforms radar based (Sexton et al 2009 and Hyde et al 2007)

Cost problem statement: Lidar based biomass models outperform field based \*\* inventories (Naesset), but the financial costs associated with collecting field data to train the models can render it infeasible for estimating forest structure with new lidar acquisitions. When new lidar acquisitions become available, the ability to use relationships developed from existing data to update lidar-based forest inventories can result in substantial savings from reduced field data collection efforts.

The goal of this work is to \*\*\*. No studies have attempted to build and apply a regionally developed model to new lidar acquisitions. We use discrete-return lidar data from similar acquisitions and environmental data to develop a regional lidar model to estimate above-ground biomass in \*\* in Ponderosa pine (*Pinus ponderosa*) and mixed conifer \*\* forests in the Southwest United States. We supplement the lidar based information with environmental data (topography, ecological response units, and seasonal greenness data derived from Landsat images) to explain differences in forest structure due to contrasting environmental conditions, site productivity, and species composition. We evaluate the reliability and transferability of the model derived from regression analysis using data from all sites by comparing it with independent data from each site and two new lidar acquisitions. When new lidar acquisitions become available, the ability to use relationships developed from existing data to update lidar-based forest inventories can result in substantial savings from reduced field data collection efforts.

The overall objective of this study is to model forest AGBM and gV utilizing LiDAR metrics from individual subplots, four clustered subplots (hereafter referred to as a plot), and hectare plots using AGBM and gV estimates for individual subplots and plots calculated from ground-based FIA measurement data and regional allometric equations and subsequently compared to LiDAR-derived height percentile, height bin, and density bin metrics calculated for individual subplots, plots, and hectare plots. Plot AGBM and gV estimates were compared to plot and hectare plot LiDAR metrics as exhaustive tree tallies were not collected for the hectare plots. Since the data collected by ALS systems are capable of describing the three dimensional structure of the forest, they can be used to estimate forest biophysical parameters of interest such as AGBM and gV. Specific study objectives include: (1) development of a methodology to derive area-based airborne LiDAR metrics related to forest biophysical parameters for FIA subplots, plots, and hectare plots; (2) identification of relationships between the LiDAR metric sets and FIA subplot and plot estimates of forest AGBM and gV calculated using regional allometric equations; (3) investigation of the effectiveness of individual and multiple point cloud metrics to predict AGBM and gV within the context of the FIA plot design; and (4) identification of the most appropriate LiDAR metrics and analysis level for estimating AGBM and gV in the conditions present in the western forests in the US. While the remote sensing literature abounds with forestry LiDAR studies, our study brings novel elements that include: (1) development of an ALS-based methodology for estimating AGBM and gV utilizing the national forest inventory in the US, the USFS FIA plot design and ground measurements; (2) investigation of the effectiveness of previously developed point cloud metrics within the context of the FIA plot design; and (3) comparison of AGBM and gV estimates over three analysis scales: individual subplots (*r* = 7.32 m), plots (*n* = 4 subplots, each with *r* = 7.32 m), and hectare plots (*r* = 56.42 m). {Sheridan}

We test this approach using AGB as our pilot metric. In the 10 CFLRP projects now underway, the most common, and often the most urgent, treatment objective is a reduction of fuel densities through mechanical thinning, prescribed fire, harvesting woody biomass, and managing lightning-caused fire (Schultz). Accurate estimates of biomass are important for forest management, diversity conservation, fire planning, and global carbon accounting \cite{Dubayah and Drake 2000, Goodale et al 2002}. Biomass provides information about the growth, health, and forest productivity and sequestration rates; and is a key parameter in estimating carbon stock, timber production, wildlife habitat, fire behavior, fire impact, and ecological modeling.

BIOMASS:

1. Defined as the total dry weight of organic material (flowers, fruits, stems, branches, foliage, bark roots: above and below ground) (definition pulled from Luo intro)

Simulatenously, regional variation \*\*\*? Further regional models have been successful at accurately estimating above ground biomass forest structure using both full waveform data \cite{Lefsky et al 2002 Lefsky 2005} and discrete data from ALS instruments \cite{Nelson 2004, Naesset 2008, Asner 2012}. Airborne laser scanners (ALS) can be broadly grouped into two categories: discrete return and full waveform digitizers. These categories can be further specified by the type of system (profiling or scanning), laser footprint size, and the number of recorded returns for each laser pulse. Little work has been done in forests of relatively low density, such as the ponderosa pine forests \cite{Hall et al 2005, Sherrill, Kim}. Sherrill et al \cite{Sherrill et al 2008} attempted to, but… No study has been conducted for temperate, fire-prone \*\*\* in the Southwest United States.

## Literature

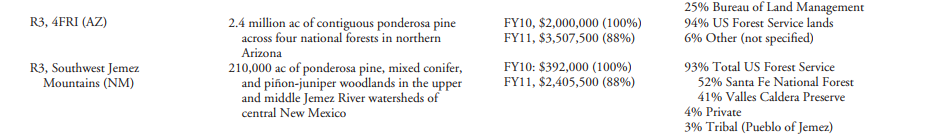
\bibitem{ Mast et al 1999}

Mast, J. N., Fule, P. Z., Moore, M. M., Covington, W. W., & Waltz, A. E. (1999). Restoration of presettlement age structure of an Arizona ponderosa pine forest. *Ecological applications*, *9*(1), 228-239.

\bibitem{ Goodale et al 2002}

Goodale et al 2002

## Study Region Notes



The 4FRI is currently CFLRP contract awarded in May of 2012 and is the largest such contract the US Forest Service has ever offered (US Forest Service 2012a). The Four Forests Restoration Initiative primary goals are to

* restore the ecosystem so that it is more resilient to fire and climate change over time,
* increase native biodiversity,
* reduce the risk to communities of wildfire, and
* promote sustainable wood products industries that can support restoration efforts and strengthen local economies.

Use mechanical thinning on approximately 50,000 acs/year to allow for increased use of both planned and unplanned fires to meet restoration objectives, ultimately mechanically treating roughly 1 million ac over 20 years; ramp up to an additional 30,000 ac of treatment per year, over and above the forests’ current program of work. Analyzing approximately 750,000 ac to identify roughly 300,000 ac of treatment for 10 years of work.

Community Forest Restoration Act of 2000, which created the Community Forest Restoration Program (CFRP) under legislation introduced by Senator Bingaman (D-NM) as part of the Secure Rural Schools and Community Self-Determination Act. In many ways CFRP is a state level version of the CFLRP. It allows for the appropriation of $5,000,000 annually for community-based restoration projects, selected through a competitive process, on any combination of federal, tribal, state, county, or municipal forestland in New Mexico. The CFRP provides federal grants of up to $360,000 over 4 years. Grantees are required to complete a multiparty assessment to report on the positive or negative impact and effectiveness of the project, including improvements in local management skills and on-the-ground results.

What is CFLRP (planning at larger scales and across jurisdictional boundaries, and the use of monitoring and adaptive management to address uncertainty (Grumbine 1994, Yaffee 1999, Butler and Koontz 2005), created to address concerns $40 million and require a 50% match by the region- Competitive funding – awarded based on ability to meet CFLRP Objectives: promote ecological, economic, and social sustainability; leverage local resources to accomplish these goals; reduce fire management costs through the reestablishment of natural fire regimes and reduction of the risk of uncharacteristically severe fires; demonstrate the degree to which restoration activities achieve ecological/watershed objectives and affect fire activity and its associated costs; and show how capturing the value of forest restoration byproducts can reduce treatment costs and support local economies.

The CFLRP requires multiparty monitoring, collaboration, planning and prioritization at landscape scales, and the competitive allocation of funding to a limited number of projects, it represents the beginning of a potential paradigm shift in forest policy in the United States. The Act is meant to encourage landscape-scale projects across multiple land ownerships, in line with the Secretary of Agriculture’s call for an “all lands” approach to land management (US Forest Service 2009), by supporting projects developed and implemented through a collaborative process that leverages local, private, and other federal resources with CFLRP funding awarded for work on National Forest System lands.

The legislation anticipates that fire suppression costs should decrease over time as a result of these projects, as should restoration treatment costs, because of improvements in efficiency and capacity of both industry and local US Forest Service units. The CFLRP also promotes a model of adaptive planning and management based on multiparty monitoring and learning. Act requires all projects to monitor social, ecological, and economic outcomes for at least 15 years after implementation begins, with this information ideally informing future decisions in an adaptive planning cycle. One of the stated purposes of the Act is to encourage a process that shows the degree to which restoration activities successfully achieve ecological objectives, reduce fire activity and management costs, and benefit local economies, while offsetting the costs to the agency of implementing treatments. [5] Thus, knowledge generation and learning are central components of the program.

Historical reference conditions have long been used to guide the restoration of degraded ecosystems. However, a rapidly changing climate and altered disturbance regimes are calling into question the usefulness of this approach. As a consequence, restoration goals are increasingly focused on creating communities that are resilient to novel environmental stressors and emphasis is being placed on defining functional targets through the use of plant traits. While changes in forest structure and composition have received much attention, long-term changes in stand-level functional traits are not well understood. Strahan (2016) argue that a focus on restoring optimal functional trait combinations may be as important as managing ecosystem structure for restoring resilient ecosystems. Silvicultural treatments such as thinning and prescribed burning aim to reduce overall tree densities, \*\*\*.

challenges:

* build trust - as fire suppression costs continued to rise, money that had been allocated to community-supported fuels reduction projects, under both Healthy Forests Restoration Act (HFRA) in 2003 and non-HFRA authorities, was redirected to pay for fire suppression and never replenished, eroding trust with stakeholders and frustrating restoration efforts (Cromley 2005)).
* Multiparty monitoring, a key oversight mechanism for the contracts, was originally required for projects, but under the extended authority, only programmatic monitoring is required. The inclusion of a project-level monitoring requirement in the CFLRP reintroduces this as an oversight mechanism for funded projects, whether or not stewardship contracts are used. Demonstrate forest restoration is conducted with partners at scales that can meaningfully influence fire behavior and accomplish restoration goals.

Restoration treatments are based largely on applying the concept of reference conditions and the natural range of variability, defining targets based on historical forest structure and composition (Roccaforte et al 2015). Synergistic effects of climate change, altered fire regimes, and land use are also likely to alter the regime of other forest disturbances, such as insect and disease outbreaks \cite{Seidl 2017}. Forests are expected to experience conditions outside of their natural range of variability, resulting in the emergence of novel combinations of environmental conditions and disturbances \cite{ Hobbs et al 2006, Hobbs et al 2009}. further \*\* needs for monitoring ecological responses and assessing efficacy of restoration treatments under new processes and \*\* \cite{ Hobbs et al 2006, Hobbs et al 2009}.Need for monitoring to evaluate ecological conditions and guide management prescriptions, assess effectiveness of treatments and adapt restoration treatments and hazardous fuels mitigation strategies, inform land use planning, stakeholder discussions.

In the 10 projects now underway, the most common, and often the most urgent, treatment objective is a reduction of fuel densities through mechanical thinning, prescribed fire, harvesting woody biomass, and managing lightning-caused fire (Schultz). In the 4FRI -- stakeholders, with financial support from the US Forest Service, completed an assessment of small-diameter wood supply in 2008, both to assess volume and to find social agreement around harvesting parameters.