# LANDFIRE Remap: Integrating lidar for Improving Vegetation Structure Mapping


**Jordan Long[1], Birgit Peterson[2], and Kurtis Nelson[2]**

[1]Stinger Ghaffarian Technologies (SGT), contractor to U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS), Sioux Falls, SD. Work performed under USGS contract G15PC000012.

[2]USGS EROS Center, Sioux Falls, SD.


## Introduction

### LANDFIRE Program

LANDFIRE (LF), Landscape Fire and Resource Management Planning Tools, is a joint program between the wildland fire management programs of the U.S. Department of Agriculture (USDA) Forest Service and U.S. Department of the Interior (DOI), with involvement of the United States Geological Survey (USGS), The Nature Conservancy (TNC), USDA Forest Service FireLab, and USDA Forest Service Forest Inventory and Analysis (FIA) program. This multi-partner program produces consistent and comprehensive geospatial data that describe vegetation, wildland fuel, and fire regimes across the United States and insular areas to provide agency leaders and managers with a common 'all-lands' data set of vegetation and wildland fire and fuels information for strategic fire and resource management planning and analysis. Please visit https://landfire.gov for additional information about the LANDFIRE program as well as accessing and downloading LANDFIRE geospatial data.

### LANDFIRE Remap

LF Remap is an innovative vegetation and fuels mapping effort designed to produce current base maps of the LF product suite. Consistent methodologies and processes, including access to the most current satellite imagery, contemporary data sources and software and hardware technologies, are being combined to create updated LF base layers that improve upon the updated versions of legacy LF National. Learn more about the LF Remap by visiting https://landfire.gov/documents/LF_2015_Remap_Final_V2.pdf.

LF Remap efforts have been focused towards advancing LF mapping methodologies in several prototype areas throughout the conterminous United States (Figure 1). LF Remap prototyping spans several topical areas, including: LANDFIRE Reference Database (LFRDB), Satellite Image Compositing, Lifeform modeling, Existing Vegetation Type modeling, and Vegetation Structure modeling (Picotte et al., 2017). This poster focuses on how LF Remap is incorporating lidar (Light Detection and Ranging) data to enhance LF vegetation structure products.

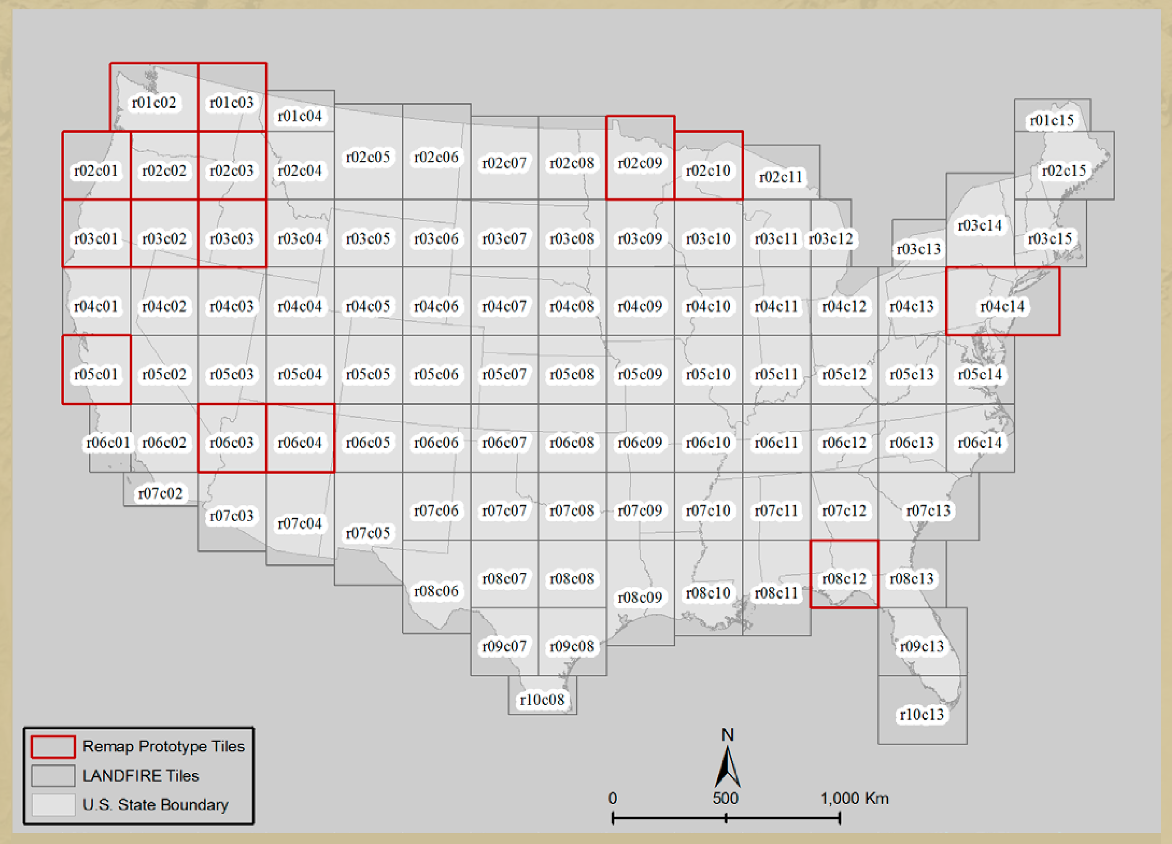


**Figure 1.** LF production tiles (gray) overlain with LF Remap prototype areas highlighted in red.

### Vegetation Structure Mapping

LF vegetation structure layers include Existing Vegetation Cover (EVC) and Existing Vegetation Height (EVH) for dominant vegetation lifeforms (i.e., herbaceous, shrub, and tree). In LF National and previous LF updates to vegetation structure products, EVC values were binned into discrete classes (Figure 2). For Remap, LF is amending the EVH and EVC legends for the conterminous U.S. to represent continuous percent cover and height to represent the landscape structure characteristics and variability at a finer thematic resolution, which fire fuel modeling is greatly dependent. These structure enhancements are possible by enhancing reference data through incorporating lidar data in combination with the LANDFIRE Reference Database (LFRDB). The LFRDB consists of field validated plot reference data covering the United States. Reference plot data are collected from a variety of contributors including federal, state, local, and tribal government agencies, universities, non-governmental organizations, and private groups. Plot information includes observed vegetation characteristics of lifeform, EVC, EVH, and Existing Vegetation Type (EVT). Although there are tens of thousands of LFRDB plots across the United States, structure data gaps remain in several regions. Incorporating lidar observations will increase reference data and reduce vegetation structure data gaps.

| Legacy EVC Legend | | Remap EVC Legend | | Legacy EVH Legend | | Remap EVH Legend | |
|---|---|---|---|---|---|---|---|
| Class | Description | Class | Description | Class | Description | Class | Description |
| 100 | Sparse Vegetation Canopy | 100 | Sparse Vegetation Canopy | 100 | Sparse Vegetation Height | 100 | Sparse Vegetation Height |
| 101 | Tree Cover >= 10 and < 20% | 110-200 | Tree Cover 10-100% | 101 | Herb Height 0 to 0.5 meters | 101-199 | Tree Height 1-99 meters |
| 102 | Tree Cover >= 20 and < 30% | 210-300 | Shrub Cover 10-100% | 102 | Herb Height 0.5 to 1.0 meters | 201-299 | Shrub Height 1-99 decimeters |
| 103 | Tree Cover >= 30 and < 40% | 310-400 | Herb Cover 10-100% | 103 | Herb Height > 1.0 meter | 301-399 | Herb Height 1-99 decimeters |
| 104 | Tree Cover >= 40 and < 50% | | | 104 | Shrub Height 0 to 0.5 meters | | |
| 105 | Tree Cover >= 50 and < 60% | | | 105 | Shrub Height 0.5 to 1.0 meter | | |
| 106 | Tree Cover >= 60 and < 70% | | | 106 | Shrub Height 1.0 to 3.0 meters | | |
| 107 | Tree Cover >= 70 and < 80% | | | 107 | Shrub Height > 3.0 meters | | |
| 108 | Tree Cover >= 80 and < 90% | | | 108 | Forest Height 0 to 5 meters | | |
| 109 | Tree Cover >= 90 and <= 100% | | | 109 | Forest Height 5 to 10 meters | | |
| 111 | Shrub Cover >= 10 and < 20% | | | 110 | Forest Height 10 to 25 meters | | |
| 112 | Shrub Cover >= 20 and < 30% | | | 111 | Forest Height 25 to 50 meters | | |
| 113 | Shrub Cover >= 30 and < 40% | | | 112 | Forest Height > 50 meters | | |
| 114 | Shrub Cover >= 40 and < 50% | | | | | | |
| 115 | Shrub Cover >= 50 and < 60% | | | | | | |
| 116 | Shrub Cover >= 60 and < 70% | | | | | | |
| 117 | Shrub Cover >= 70 and < 80% | | | | | | |
| 118 | Shrub Cover >= 80 and < 90% | | | | | | |
| 119 | Shrub Cover >= 90 and <= 100% | | | | | | |
| 121 | Herb Cover >= 10 and < 20% | | | | | | |
| 122 | Herb Cover >= 20 and < 30% | | | | | | |
| 123 | Herb Cover >= 30 and < 40% | | | | | | |
| 124 | Herb Cover >= 40 and < 50% | | | | | | |
| 125 | Herb Cover >= 50 and < 60% | | | | | | |
| 126 | Herb Cover >= 60 and < 70% | | | | | | |
| 127 | Herb Cover >= 70 and < 80% | | | | | | |
| 128 | Herb Cover >= 80 and < 90% | | | | | | |
| 129 | Herb Cover >= 90 and <= 100% | | | | | | |

**Figure 2.** LF legacy EVC legend (left); LF Remap EVC legend (center left); LF legacy EVH legend (center right); LF Remap EVH legend (right).

## Mapping Methods

For Remap, lidar observations are used in combination with reference plots as dependent variables (i.e., training data) to model EVC and EVH structure characteristics at regional scale (Figure 3). First, an inventory of lidar data is performed to access lidar availability from open source resources such as EarthExplorer (https://earthexplorer.usgs.gov) and OpenTopography (www.opentopography.org), as well as state distribution sites. Next, a sampling design selects the most current lidar datasets that represent a variety of lifeform cover and heights per LF tile. Lidar datasets are then downloaded and processed from point clouds (.las or .laz format) to 30 meter canopy cover and height raster images (.tif format) using LAStools software (http://rapidlasso.com). Next, independent variables, including Landsat composites (circa 2016), vegetation spectral indices, LF disturbance products, and topography composites, are extracted against LFRDB plots and lidar data to create modeling files required for decision tree classifiers. Lidar and reference plots that fall within recently disturbed areas are discarded from training dataset. Finally decision tree models are then used to create EVC and EVH products (Figure 3).

## Results

We found that incorporating lidar data increased the amount of EVC reference data by 310% in the Grand Canyon prototype area (LF tiles r06c03 and r06c04 – Figure 2) and EVC reference data by 79% in the Northwest prototype area (LF tiles r01c02, r01c03, r02c01, r02c02, r02c03, r03c01, r03c02, and r03c03 – Figure 2). The addition of lidar data increased reference data in areas that are under-represented by the reference plots alone; for example, tree cover ranging from 10 to 15 percent had very few plots in the Northwest (figure 4, left) and Grand Canyon (figure 5, left) reference plots, but including lidar considerably increased plots in this range as well as most other percent covers (figure 4, right and figure 5, right).

A comparison of lidar tree cover and height derivatives with FIA reference plot observations show a general agreement between lidar observations and field observations with height being slightly more correlated than cover (figure 6). Yebra et al., 2015 reported similar findings that lidar derived tree canopy height corresponds very well with traditional field observations of canopy height.

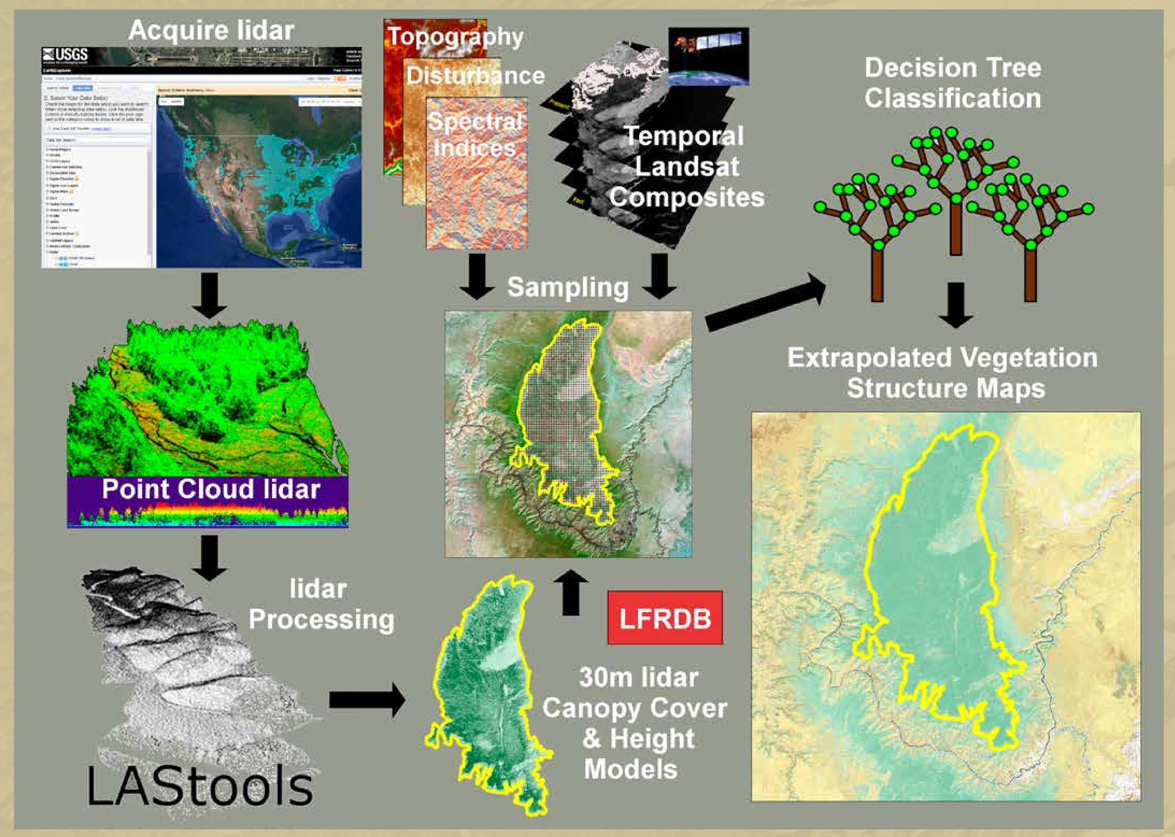


**Figure 3.** LF Remap EVC and EVH modelling processing steps.

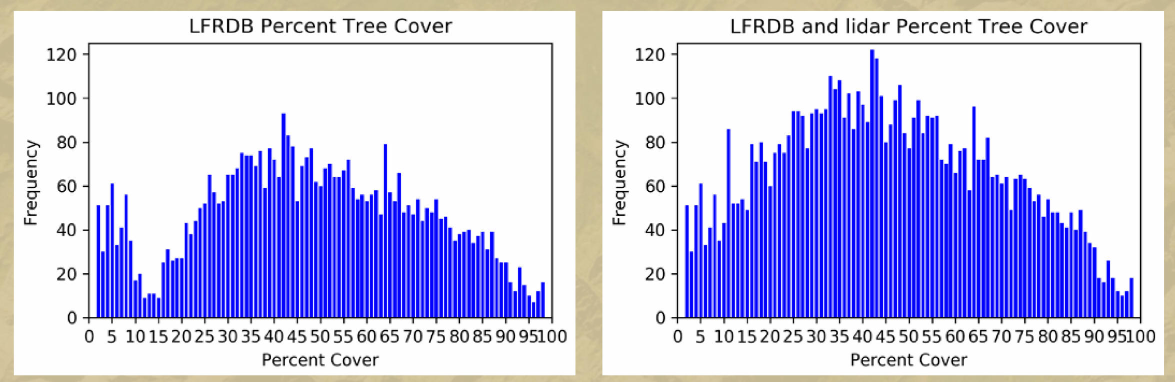


**Figure 4.** Northwest prototype vegetation cover plots from reference plots only (left) and combined reference and lidar plots (right).

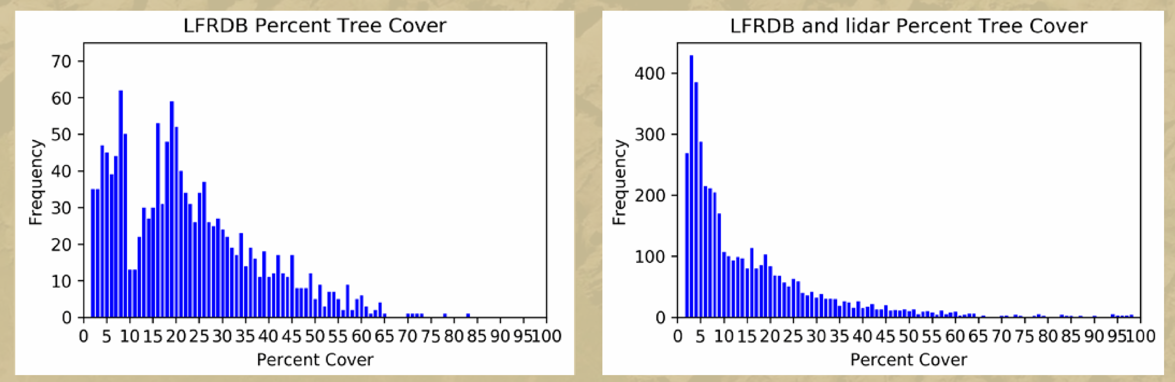


**Figure 5.** Grand Canyon prototype vegetation cover plots from LFRDB only (left) and combined LFRDB and lidar plots (right).

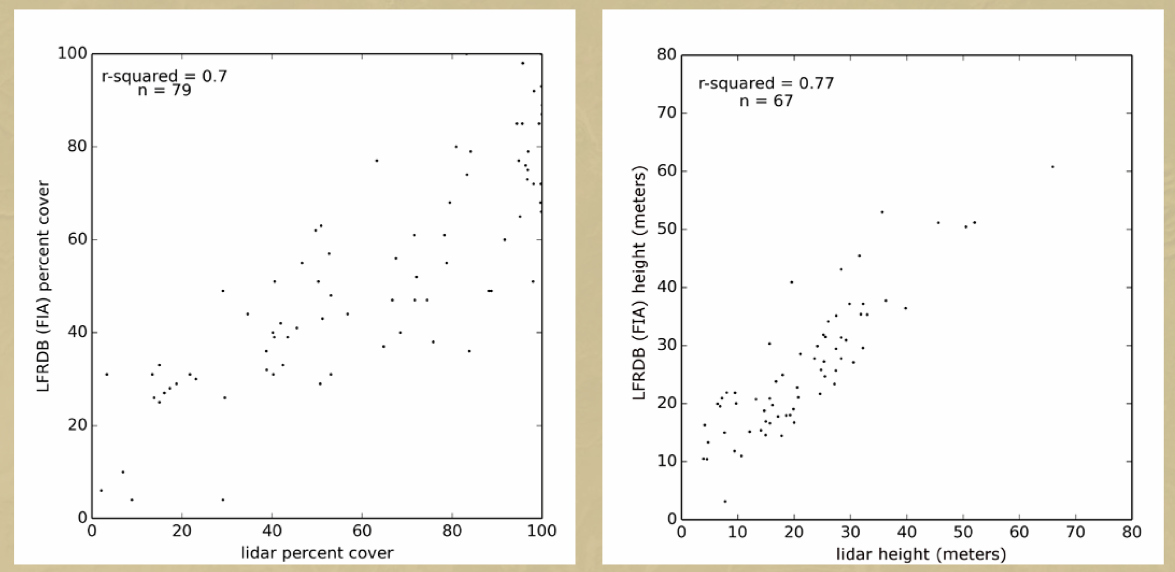


**Figure 6.** Lidar derived cover (left) and height (right) compared with FIA reference plots.

Additionally, we compared a series of regression tree model classifications for the Grand Canyon prototype area with FIA field reference data that were reserved from model development for validation. The EVC model outputs that incorporated lidar (Figure 7, center and right) had a higher correlation with validation plots than using reference plots alone (Figure 7, left), and combining lidar data with LFRDB plots produced the highest correlation results in EVC (Figure 7, right). For EVH, using reference plots alone for training the model produced a very low correlation with validation plots (Figure 8, left), using lidar training data alone produced the highest correlation results for EVH (Figure 8, right) and combining lidar and reference plots produced similar but slightly lower correlation results than lidar alone (Figure 8, center).

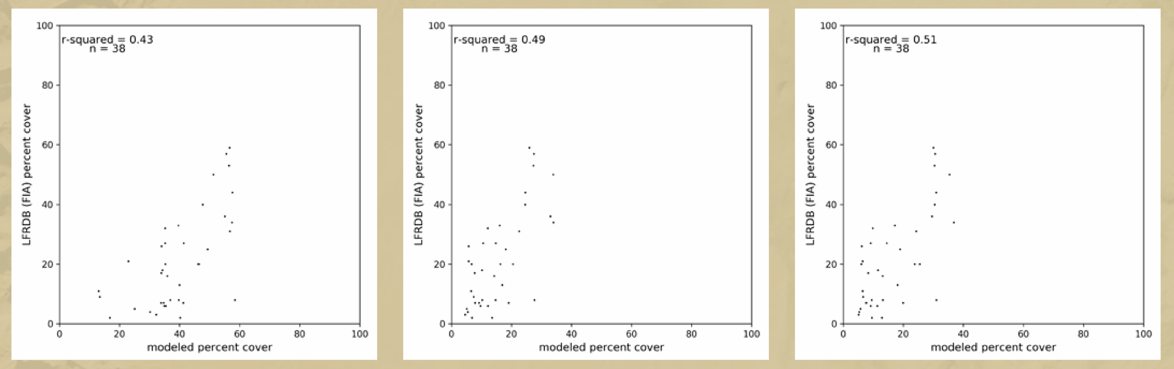


**Figure 7.** Comparisons between FIA validation plots and modeled percent cover using reference plots only (left), lidar plots only (center), and combined reference and lidar plots (right) as model training data.

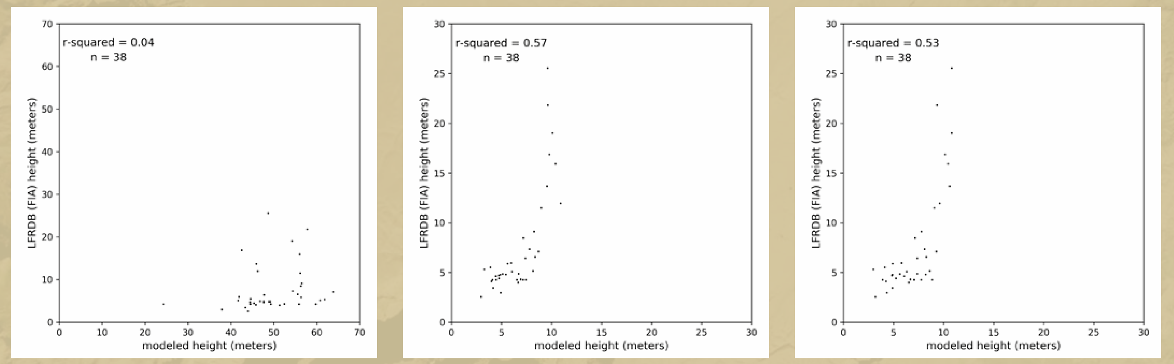


**Figure 8.** Comparisons between FIA validation plots and modeled percent height using reference plots only (left), lidar plots only (center), and combined reference and lidar plots (right) as model training data

## Conclusions

Results of LF Remap prototyping in the Grand Canyon and Northwest study areas confirmed that incorporating lidar-derived plots increases reference data considerably, resulting in a more comprehensive reference database that better represents the continuous nature of vegetation structure characteristics than using reference plots alone. Furthermore, including lidar reference plots resulted in higher correlations with validation plots for both EVC and EVH, indicating the inclusion of lidar reference data increases vegetation structure model accuracies. Our improved vegetation modeling procedures will permit the enhancement of LF EVH and EVC products from binned ranges to continuous field heights and covers. As LF Remap transitions from prototyping to production, LF will continue to leverage lidar to enhance vegetation structure mapping for the conterminous United States, Alaska, and insular areas.

## References


Picotte, J., Long, J., Peterson, B., and Nelson, K., 2017. "LANDFIRE 2015 Remap–Utilization of Remotely Sensed Data to Classify Existing Vegetation Type and Structure to Support Strategic Planning and Tactical Response." earthzine

Yebra, M., Marselis, S., Van Dijk, A., Cary, G. and Chen, Y., 2015. "Using LiDAR for forest and fuel structure mapping: options, benefits, requirements and costs." Bushfire & Natural Hazards CRC, Australia