

DEVELOPMENT AND APPLICATIONS OF THE LANDFIRE FOREST STRUCTURE LAYERS

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Abstract.—The LANDFIRE program is developing 2010 maps of vegetation and wildland fuel attributes for the United States at 30-meter resolution. Currently available vegetation layers include ca. 2001 and 2008 forest canopy cover and canopy height derived from Landsat and Forest Inventory and Analysis (FIA) plot measurements. The LANDFIRE canopy cover layer for the conterminous United States is the first of its kind developed with FIA tree measurements as the source of ground reference data. The mapping process is based on regression tree models with FIA plot values as the dependent variables (canopy cover, canopy height), using predictor variables derived from reflectance, terrain, and a Shuttle Radar Topography Mission-based height metric. Base vegetation maps are updated beginning with a set of annual disturbance maps that combine extant fire severity mapping with Landsat time-series disturbance and polygon data describing management activities on Federal and state lands. FIA plot data are used in the Forest Vegetation Simulator to model disturbance effects on forest vegetation for each disturbance type and severity class. Updated 2010 products are scheduled for delivery during early 2013. The 2010 products include a new tree list layer in which stand structure is depicted explicitly by approximating a representative list of trees occurring at each 30-m pixel. The tree list layer provides a more detailed characterization of canopy fuel structure than is available with standard LANDFIRE products, facilitating new applications and research in fire behavior and fire effects simulation.

INTRODUCTION

The LANDFIRE program, now in its second update phase, produces more than 20 different 30-meter raster layers of vegetation structure and composition, fire behavior, and fire regimes for all of the major ecosystems in the United States (more information is available at www.landfire.gov). The layers describe vegetation and wildland fuel across all lands, and are designed to facilitate national and regional planning and reporting of fire management activities. This program has collaborated closely with the Forest

Inventory and Analysis (FIA) Program since 2004 and FIA data are a critical component of several vegetation and fuel layers developed by LANDFIRE.

This paper focuses on a subset of LANDFIRE layers depicting forest structure that were based heavily on FIA field measurements. Forest canopy cover is the proportion of the forest floor covered by a vertical projection of the tree crowns. Canopy height is the representative height above ground level of the taller trees composing the upper canopy layer. Canopy cover and height are key variables required for modeling fire behavior spatially (Finney 2004).

The LANDFIRE canopy cover layer for the conterminous United States is the first of its kind developed with FIA tree measurements as the source of ground reference data, and is paired with

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an integrated canopy height layer. Here we give an overview of the mapping process along with current applications in wildland fire management and research. We also describe a new LANDFIRE layer under development in which stand structure is depicted explicitly by approximating a representative list of trees occurring at each 30-m pixel.

FIELD REFERENCE DATA

Tree canopy cover estimates for FIA plots were based on predicted crown dimensions, using stem coordinates recorded by field crews to map the locations of trees within the subplots and microplots (Fig. 1) (Toney et al. 2009). Canopy height was the basal area-weighted average height of the dominant, codominant, and open-grown trees in each plot. Plot records were filtered based on FIA disturbance attributes and location-specific Landsat image dates to obtain canopy cover/canopy height training sites. Some plots were omitted from the training set if they had significant disturbances (such as cutting, fire, or wind) recorded after the most recent location-specific image date in the multi-temporal Landsat mosaics described below.

PRODUCTION MAPPING PROCESS

Canopy Cover and Canopy Height

Forest canopy cover and height were produced using several dates of Landsat imagery and derived layers as predictor variables. Landsat images from leaf-off, leaf-on, and spring (U.S. Geological Survey 2001) were used, along with texture images derived from tasseled-cap images of the three dates. Elevation, slope, and aspect were also used (U.S. Geological Survey 2005). A Shuttle Radar Topography Mission-derived metric (Kelldorfer et al. 2004) was included in the canopy height modeling.

Regression tree models were fit using Cubist software (RuleQuest [n.d.]). Model predictions were applied to all 30-m pixels within the LANDFIRE forest mask. The output layers were visually checked for seam lines and presence of clouds and other artifacts from the imagery. Problem source data were eliminated or localized revisions were made.

A design requirement for the canopy cover layer was to map a statistical distribution of cover values consistent with the distribution expected for spatial fire

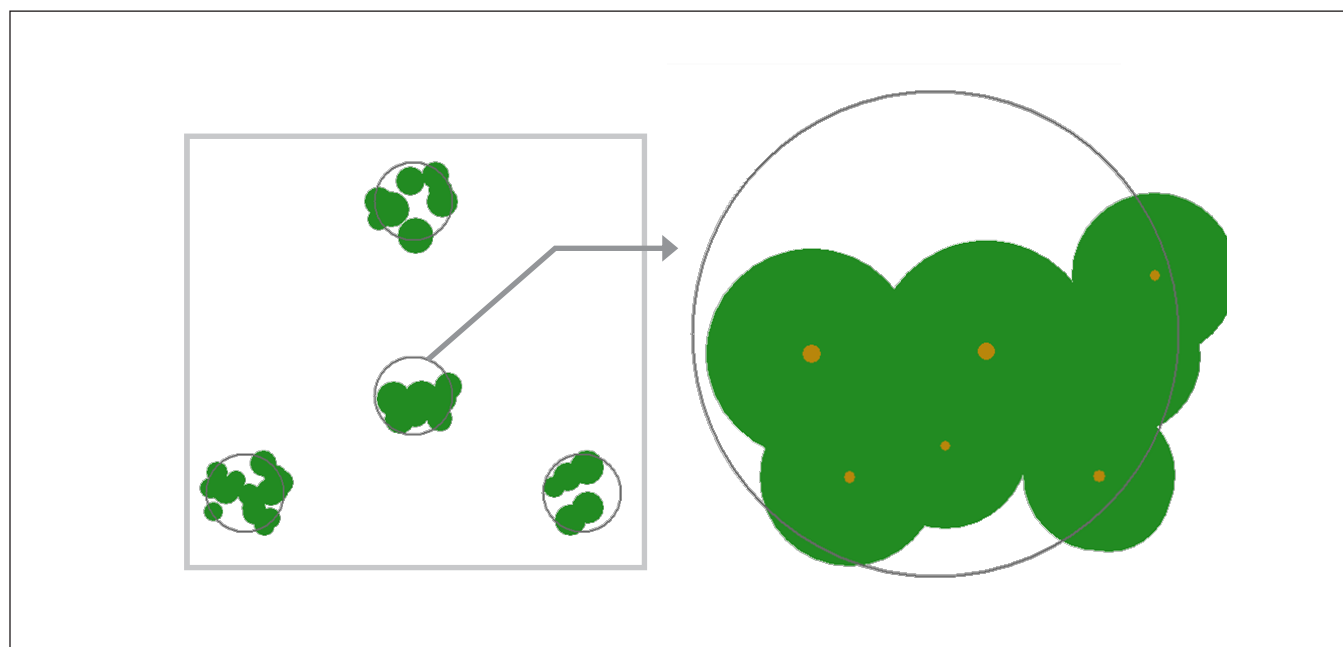


Figure 1.—Example of mapping the modeled crowns of trees in an FIA plot using stem coordinates recorded by field crews.

modeling. Canopy cover rarely exceeds 70 percent in western U.S. forest types (Scott and Reinhardt 2005, Stratton 2006) but is higher in multi-storied forests of the eastern United States. The distribution of stem-mapped FIA canopy cover was consistent with the distribution as evaluated in fire behavior models.

Updating from the 2001 base vegetation maps (Vogelmann et al. 2011) begins with a set of annual disturbance maps that combine fire severity mapping with Landsat time-series disturbance (Huang et al. 2010) and polygon data describing management activities on Federal and state lands. Products available for fire severity mapping include Monitoring Trends in Burn Severity (MTBS) (U.S. Forest Service and U.S. Geological Survey 2012), Rapid Assessment of Vegetation Condition after Wildfire (U.S. Forest Service 2011), and Burned Area Reflectance Classification (U.S. Forest Service and U.S. Geological Survey [n.d.]). Disturbance effects on forest vegetation are modeled for each disturbance type and severity class using FIA plot data in the Forest Vegetation Simulator.

Tree List Layer

The tree list layer is composed of a thematic raster map in which each 30-meter pixel is assigned a tree list identifier, along with a lookup table of tree data for each identifier. The tree list information includes species, size, status, and density from the FIA plot records. Production of the tree list layer involves post-processing the existing classified Landsat (LANDFIRE vegetation type, canopy cover, canopy height) by nearest neighbor imputation within specific landscape strata. The vegetation-based stratification defines subsets of plots eligible for imputation to pixels within each stratum on the map. At each pixel, a nearest neighbor search of the eligible plots is done in a normalized Euclidean space of variables describing geography (x, y coordinates), terrain (elevation, slope, transformed aspect), and vegetation (continuous canopy cover, canopy height). The tree list approach provides much greater detail characterizing forest structure attributes (cf. Wilson et al. 2012). For example, rather than a single canopy height value, a

distribution of tree heights is presented, facilitating use of these layers as inputs to specialized models or more in-depth analysis.

PRODUCT AVAILABILITY

Canopy cover (Fig. 2) and canopy height products from LANDFIRE for 2001 and 2008 are currently available for download at www.landfire.gov. Canopy cover and height for 2010 are scheduled for delivery during early 2013. The tree list product for 2010 is also scheduled for early 2013, but availability is by request with an FIA confidentiality agreement.

APPLICATIONS

The LANDFIRE vegetation structure layers have been widely used since 2005 in fire modeling for incident support as well as planning. The layers are used for simulations in the Wildland Fire Decision Support System (<http://wfdss.usgs.gov>) and the Fire Program Analysis System (<http://www.fpa.nifc.gov>). Nonfire land management applications are also a major use (e.g., <http://www.conservationgateway.org/topic/applications>).

The LANDFIRE tree list layer represents a new approach for fuel mapping, providing detail similar to what might be achieved with Light Detection and Ranging mapping, but with the benefit of wall-to-wall coverage consistent with the other LANDFIRE layers. This approach has significant potential for new applications and analysis. For example, the tree list layer can be used to provide realistic inputs to new, physics-based 3D fire behavior models (e.g., FIRETEC), in which canopy fuels can be represented as discrete entities such as individual trees (Linn et al. 2005) (Fig. 3).

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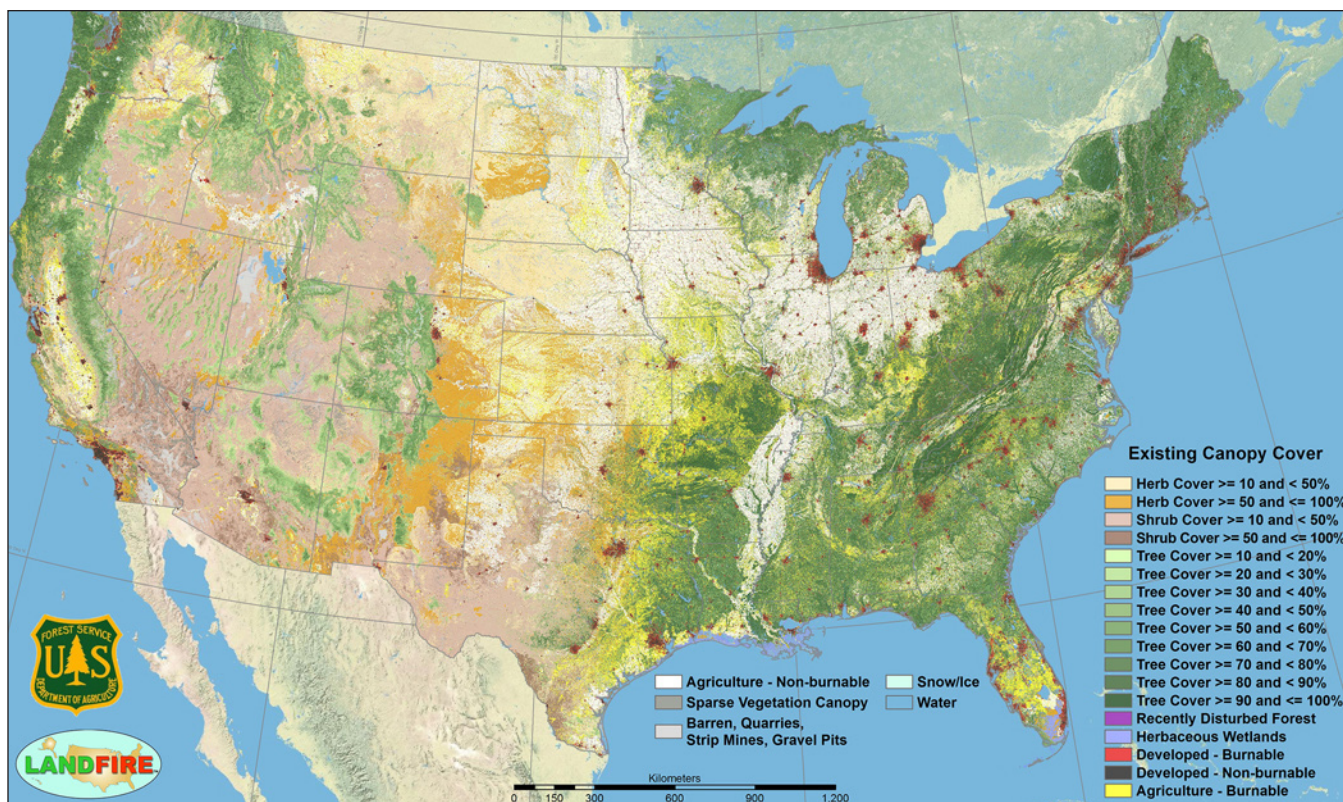


Figure 2.—LANDFIRE 2008 tree canopy cover mapped from FIA plot data and Landsat.

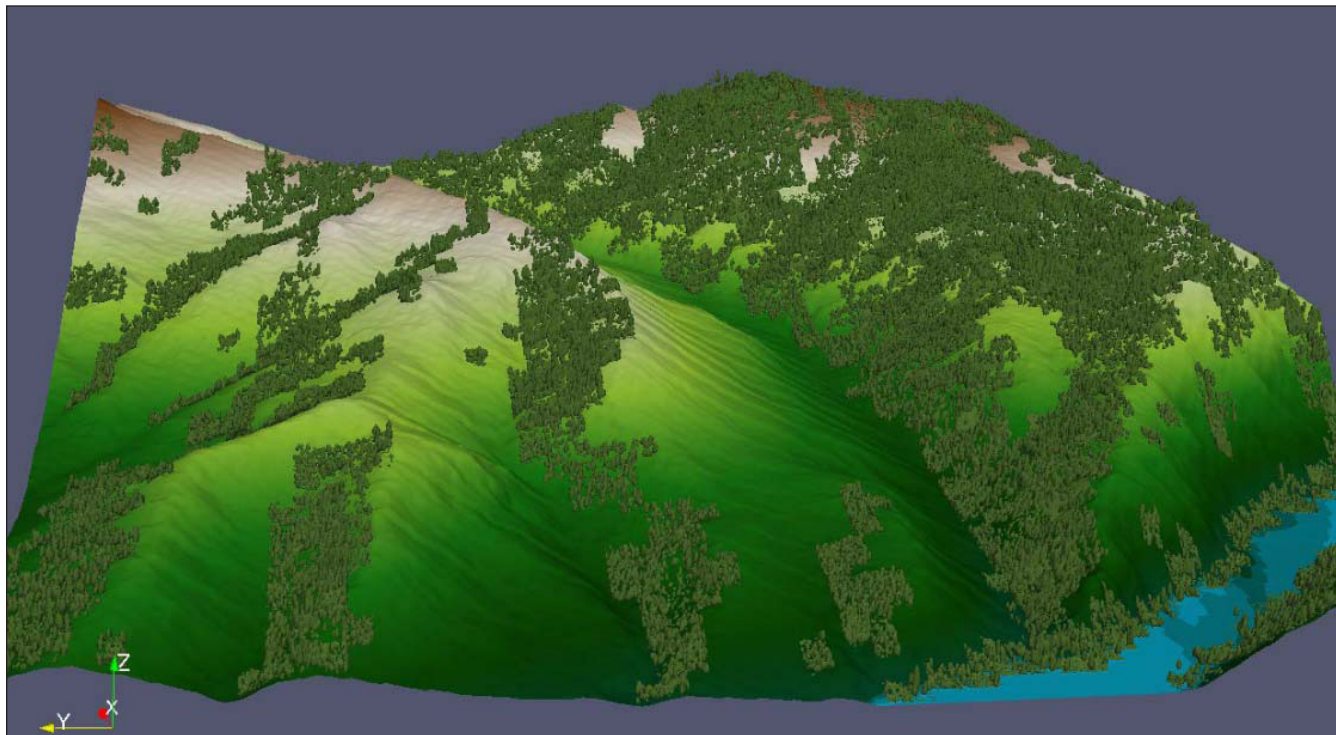


Figure 3.—Application of the LANDFIRE tree list layer as fuels input to the dynamic 3D fire model, FIRETEC. At each forested pixel, tree data from the tree list layer look-up table were expanded to the pixel scale and draped over the LANDFIRE elevation layer. The simulation area is 1 km², centered on Mann Gulch in the Helena National Forest, about 25 miles north-northeast of Helena, MT.

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