

LF 2012 CLOSE-OUT REPORT

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Department of the Interior
U.S. Geological Survey



LF 2012 PROJECT CLOSE-OUT REPORT



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1 GENERAL PROJECT INFORMATION

	Description
Project Name	LANDFIRE 2012
Project Description	<p>The scope of the LANDFIRE 2012 (LF 2012) project was to deliver a suite of updated LANDFIRE (LF) data products for the conterminous United States (CONUS), Alaska, and Hawaii current as of 2012.</p> <p>Key objectives for LF 2012 included:</p> <ul style="list-style-type: none"> • Update the comprehensive suite of LANDFIRE National (LF National) data products to account for landscape changes and disturbance information for the years 2011 and 2012. Updated data products include: <ul style="list-style-type: none"> ○ Reference: Events Geodatabase ○ Disturbance: Disturbance Grids, Vegetation Disturbance (Vdist), Fuel Disturbance (Fdist), Vegetation Transition Magnitude (VTM) ○ Vegetation: Existing Vegetation Cover (EVC), Existing Vegetation Height (EVH), Existing Vegetation Type (EVT) ○ Fuels: 13 Anderson Fire Behavior Fuel Models (FBFM), 40 Scott and Burgan FBFM, Canadian Forest Fire Danger Rating System (CFFDRS; AK Only), Forest Canopy Base Height (CBH), Forest Canopy Bulk Density (CBD), Forest Canopy Cover (FCC), Forest Canopy Height (FCH) Fuel Characteristic Classification System (FCCS) [Optional, Fuel Loading Models (FLM) [Optional] ○ Fire Regime: Succession Classes (SClass) [Optional] • Focus on relevant and significant landscape changes or disturbances to vegetation, such as those resulting from wildland fire, fuel, and vegetation/silvicultural treatments, insects and disease, storm damage, etc. • Leverage Landsat imagery and point and spatial polygon data for years 2011-2012, and utilize newly available or newly refined institutional data sources, to update data products. • Retain original information for areas that did not experience a vegetation change or disturbance. No changes will be made to insular areas from LF 2010. <p>LF 2012 was scheduled to make updated CONUS data products available via the Data Distribution System (DDS) no later than December 31, 2014. These products consisted of databases readable in relational database format or by geospatial database format, as appropriate. Products for the Alaska and Hawaii were to be available by March 30, 2015.</p>
Project Manager	Steve Zahn
Project Sponsor	USDA Forest Service and Department of the Interior

	Baseline	Actual	Variance	% Variance
Start Date	12/5/2013	12/5/2013	0	0%
Finish Date	3/30/2015	4/27/2015	+20	+5.8%
Work Days	343	363	+20	+5.8%

2 INTRODUCTION

This is the Project Closeout Report (PCR) for LF 2012 (also known as LF 1.4.0). The LF 2012 PCR provides documentation of the overall LF 2012 project scope (objectives), schedule, costs, results, lessons learned, open issues, and closure status and serves as the primary communication vehicle for these items.

While the technical work of LF 2012 was completed in April 2015, it is administratively closed with the publication of this PCR. This report ensures that scope was addressed and accomplished, deliverables were reviewed, accepted and published, project effectiveness was evaluated and documentation was completed.

LF 2012 was a project conducted by the LANDFIRE program. It involved the efforts of a variety of LANDFIRE partners. However it was formally a deliverable for the USGS team. LF 2012 scope, as well as project execution, was the sole responsibility of the USGS. The overwhelming bulk of the work was accomplished at the USGS EROS Center. Support from other partners, while important, was usually limited in time and magnitude. Therefore, this PCR focusses exclusively on the efforts of the USGS EROS LANDFIRE team. It completely captures the expectations for LF 2012 and the subsequent results.

3 MANAGEMENT EFFECTIVENESS

Schedule

The LF 2012 Project Kickoff occurred on January 22, 2014. However, at the time of the kickoff, several production activities were well underway in order to make completion deadlines. A LF 2012 schedule was created in Microsoft Excel for the kickoff and was used to manage subsequent activity. In this schedule, the South Central reference task was assigned a start date of Dec 5, 2013. This became the accepted start date for LF 2012. Beginning in late January 2014, all tasks associated with LF 2012 were formally tracked with the LF 2012 schedule.

There were several opinions concerning the LF 2012 completion date. The LF website and parts of the LF Project Plan listed March 31, 2015 as the completion date. However, the LF 2012 Project Plan suggested April 2015 as the required date for AK/HI products. The LF 2012 Schedule tracked to April 30, 2015. The final delivery of HI was posted on April 27, 2015.

Cost

While LF costs were routinely and carefully tracked, they were done so at the program level only. No separate cost baseline, and thus no independent mechanism to track costs, existed for the LF 2012 Project. All budget data for LF 2012 was estimated only within the known program costs.

Scope

LF 2012 Scope was largely defined as the creation and delivery of updated data products. For LF 2012 this list consisted of:

Reference – Events Geodatabase

Disturbance - Disturbance Grids, Vdist, Fdist, VTM

Vegetation - EVC, EVH, EVT

Fuels - 13 Anderson FBFM, 40 Scott and Burgan FBFM, CFFDRS (AK Only), CBH, CBD, FCC, FCH

Additional production objectives for LF 2012 included:

1. Using Remote Sensing of Landscape Change (RSLC) methods to map disturbance in Hawaii
2. Provide Gap Fill to correct scan line issues in select Monitoring Trends in Burn Severity (MTBS), and Rapid Assessment of Vegetation Condition after Wildfire (RAVG) disturbance products.
3. Methodological adjustment of the EVC and EVH mapping procedure from LF 2001/2008 to LF 2010.
4. Creation of the Vegetation Transition Rules database.

5. Adding CBH Regression Tree Analysis (RTA) capability to the LF Total Fuel Change (LFTFC) tool.

The following products were listed as in scope for LF 2012 but to be accomplished by alternative teams who were never identified. These products were not included as scope during the execution of LF 2012.

Fuels – Fuel Characteristic Classification System fuelbeds, Fuel Loading Models

Fire Regime – Succession Class 2012

Document - CONUS; AK; HI; Final Report

During the course of the project a decision was made to complete a scaled down final report and this Close-out report represents that decision.

Baseline Changes

The current baseline plan is dated January 22, 2014. No baseline changes occurred for LF 2012.

Quality

As part of the LF 2012 Project Kickoff, a challenge was initiated to formalize the final review of Geographic Area (GeoArea) products prior to release to the general public. This challenge was met through the creation of GeoArea Product Acceptance reports. Each report addressed key quality items related to internal and external checks. Internal checks provided validation evidence for projections, spatial extents, pixel counts and pixel framing (quantitative metrics) summarized by an analysis of overall performance (qualitative review) all aimed at answering the question “do these results meet our expectations?” External checks demonstrated independent validation for technical integrity and a confirmation that the processes/data performed as expected.

In March 2015, the production team discovered that Landsat change detection data from 2012 were omitted from the disturbance layers for portions of the Northwest GeoArea. During the original Northwest GeoArea Quality Assurance (QA) process, a geometry shapefile issue was corrected. Unfortunately, as a result of that correction, some RSLC sourced disturbances were inadvertently omitted from the final disturbance product. However, disturbances identified by fire program mapping efforts (e.g. MTBS), and those included in the LF Events Geodatabase were not omitted. The disturbance product for 2011 was not affected. In the originally published disturbance layer, 7,326,354 acres were mapped as disturbed, and in the corrected version 7,909,424 acres were mapped as disturbed. The differences between versions affect 0.18% of the NW GeoArea.

Both the final product assembly and QA processes have been amended to add a combine operation of each piece individually to the original mosaic to ensure the correct data mosaicking. Then another combine operation was added after any GeoArea fixes were addressed to ensure only the pixels intended to be changed were changed in the final product from the original mosaic.

Risk

Risks were not formally managed in LF 2012. However, prior to project kickoff, a list of risks were identified to assist in final scope and schedule development. These risks were updated, dispositioned and ultimately presented to the entire team during a LF team meeting in May 2014.

These were the risks to LF 2012 along with their final disposition.

1. Distractions (BLG requests, user support, etc.) impact the production schedule.
Final Status: This risk did not fully materialize during the execution of LF 2012 except in isolated situations.
2. Time requirements for supporting previous versions (e.g., LF 2008, LF 2010) or for special teams are greater than expected.
Final Status: This risk became an issue during the NW GeoArea Disturbance correction activity. However, the impact of previous versions was not wide spread and had little overall impact.
3. Project transition of role assignments and expectations is not concluded as timely as expected, resulting in potential confusion on production roles and responsibilities.
Final Status: This risk was accepted in May 2014 and did not result in any issues.
4. More Events data are submitted than expected.
Final Status: This risk was accepted in May 2014 and did not result in any issues.
5. New, different, or inconsistent types of Events data are submitted and must be processed.
Final Status: This risk was accepted in May 2014 and did not result in any issues.
6. Reference data team is distracted from production.
Final Status: This risk did not fully materialize during the execution of LF 2012.
7. New products (e.g. VTM) will take some production time unless delayed until Events data delivery is complete.
Final Status: This risk was accepted in May 2014 and did not result in any issues.
8. Support for current LF products requires more effort than expected.
Final Status: This risk was accepted in May 2014 and did not result in any issues.
9. Schedule presented is for the mapping component. The front-end processing component extends beyond February 2014.
Final Status: This risk was accepted in May 2014 and did not result in any issues. The image processing (composite generation, change detection) was not a limiting factor.

10. More images processed, and approach is different (tiles versus individual scenes).
Final Status: This risk was accepted in May 2014 and did not result in any issues. More images were processed than in LF 2010 (nearly 20,500 for LF 2012 vs. 4,380 for LF 2010), however our external processing systems were able to provide disturbance data ahead of the mapping team's schedule.
11. RSLC Processing for HI.
Final Status: This risk was realized. RSLC processing was more complicated than previous disturbance identification methods used in Hawaii. The disturbance activity took several weeks longer than planned. Had risk management been in place on LF, this risk would have been a candidate for mitigation.
12. Potential Circa 2011 herbaceous and shrub cover layer may not be available from the National Land Cover Database (NLCD). Transition process is a fall back. Good chance to have the data in hand by January.
Final Status: This risk was accepted in May 2014 and did not result in any issues.
13. Urban cover may also be available, similar uncertainty with the NLCD delivery.
Final Status: This risk was accepted in May 2014 and did not result in any issues. NLCD 2011 imperviousness had been released.
14. Alaska: Slope areas relating to EVC and EVH, more resolution may amplify scan lines. EVC enhancement.
Final Status: Final Status: This risk was listed as a watch item in May 2014 but did not appear to result in any issues.
15. Hawaii: RSLC disturbance.
Final Status: See Risk #11.
16. Vetting of the National Agricultural Statistics Survey (NASS) Cropland Data Layer (CDL).
Final Status: This risk was accepted in May 2014 and did not result in any issues. Completed and being used in LF 2012.
17. EVC/EVH infusion (Veg/Fuels prototyping in progress) does not resolve the underlying issue.
Final Status: This risk was listed as a watch item. The EVC/EVH solution was implemented. It is unknown at this time as to whether the solution was successful.
18. Fuels Team needs clear expectations about a user review/calibration process.
Final Status: This risk was listed as a watch item in May 2014 but did not appear to result in any issues.

19. IF delivery of input layers to the Fuels Team is delayed, THEN the delivery schedule is thus compressed—provides less time to evaluate the final products.
Final Status: This risk was listed as a watch item in May 2014. Occasional delays occurred but did not adversely affect overall schedule.
20. Role of National Interagency Fuels Technology Transfer team is currently unknown—available to help as in the past. [Need confirmation]
Final Status: This risk was accepted in May 2014 and did not result in any issues.
21. Unexpected changes in the codes/input data sets occur.
Final Status: This risk was listed as a watch item in May 2014 and did not result in any issues.
22. Complication with the constrained vegetation mapping using LF 2001/08 methods extends duration of Vegetation/Transition tasks beyond planning estimates.
Final Status: This risk was listed for mitigation in May 2014. A successful plan was developed and implemented to revert back to LF2001/08 products.
23. Revised vegetation mapping considered a risk exposure in stakeholder management regarding potential product consistency concerns between LF 2010 and LF 2012. Potential for significant increases in support demands placed on the LF team in assisting customers with the LF 2012 product, due to differences vice LF 2010.
Final Status: Not a LF 2012 Project Risk but an operational risk. Closed.
24. The last team in the production process often receives products later than expected as all delays flow downstream, making the specific delivery dates imprecise.
Final Status: This risk was listed as a watch item in May 2014 but did not result in any issues.
25. The actual products to be processed and evaluated are unknown at this time, reducing precision in the duration estimates (it could take significantly more or less time depending on what is delivered).
Final Status: This risk was accepted in May 2014 and did not result in any issues.
26. Upgrade to DDS could create a delay—no data processing during conversion.
Final Status: This risk was accepted in May 2014 and did not result in any issues.
27. Requests to assist other production teams and/or non-production activities.

Final Status: This risk was accepted in May 2014 and did not result in any issues.

28. Delays in authorization to conduct project activity due to contractual complications or federal government budget delays.

Final Status: This risk was listed as a watch item in May 2014 but did not result in any issues. Funds were sufficient.

29. Coordination activities to incorporate enhanced mapping processes in AK and HI GeoAreas result in unpredicted challenges when taken into the Fuels and Datahub segments of the production lifecycle.

Final Status: This risk was listed as a watch item in May 2014 but did not result in any issues.

Change Management

Formal change management was not applied to activities associated with LF 2012. However, a prototype change management system has been adopted for activity related to the LF website. This includes the addition of LF 2012 data products to the website and other information and status related to LF 2012. Since inception LF has processed over 100 change requests to the LF Website.

Communications

Several new communication methods were added to existing LF 2012 communication mechanisms. LF 2012 communication was conducted using:

1. LF 2012 Project Kickoff. This was presented on January 22, 2014.
2. LF 2012 Team Meeting. This was a one-time only, all hands discussion, to share and discuss current status on the project. It was held in May 2014.
3. LF 2012 After Action Report. This was a one-time only, all hands discussion, to share and document the completion of LF 2012 activity. It was held in December 2014.
4. LF 2012 Project Close-out. This was a one-time only final report that describes and defines new processes and results.
5. LF Program Status Meeting. This was the regularly scheduled status meeting for LF 2012. The purpose of this meeting was to provide schedule status and discuss and share scope and other technical issues of interest to the entire team. This meeting transitioned into the LF Technical Leadership Group in the spring of 2015.
6. LF Support Meeting. This was the regularly scheduled LF Operations meeting. The purpose of this meeting was to focus on operational activity of LF including website maintenance, infrastructure, and customer support. Specific to LF 2012, all final products and final product acceptance reports were dispositioned by this group.

4 PROJECT ANALYSIS

4.1 REFERENCE

Product Description

The Reference data product suite includes spatial databases containing field referenced point and polygon data describing vegetation, fuel conditions, and landscape change events (natural and anthropogenic disturbances). The vegetation and fuel plot data in the LF Reference Database (LFRDB) support vegetation transition modeling to develop rulesets for modifying vegetation attributes based on disturbance and succession. The Events Geodatabase supports disturbance detection and attribution of disturbance causality. A subset of the LFRDB and Events databases are published for public use. Proprietary or otherwise sensitive data that LF does not have explicit permission to share are removed from the public databases prior to dissemination.

Update Process

LF 2012 used the existing LFRDB. The Events Geodatabase was built from data that were both acquired from national databases and contributed to LF from various land management groups including federal, state, tribal, and local agencies, along with private and non-profit organizations. These data were initially combined into a spatial layer containing all available features. This layer was further processed through a series of steps to identify overlapping features, reduce them through a hierarchical topology process, and sort multiple disturbance types in the same year by the relative impact of the various types. The result was a model-ready spatial layer that contained at most one disturbance per year per location. Where multiple disturbances for one location were reported the disturbance type with the most impact on vegetation and fuels was retained. For each event, the type, location, and year of disturbance were recorded. Additional attributes, including the magnitude or severity of the event and date of occurrence, were captured if available.

Results

A total of 159,191 raw events were added to the Events Geodatabase for LF 2012 occurring between 2011 and 2012, which were reduced (using the process described above) to 98,039 model-ready events. Events data acquired by LF staff from public clearinghouses or data sharing agreements accounted for 65% of the total events, while 35% of the total events were contributed by LF data users. The LF 2012 break down of events included the following: 34.8% were mechanical and harvest activities (20% mechanical and 14.8% harvest); 22.5% were fire; 22.5% were chemical or biological treatments; and 9.9% were insects or disease events. Remaining events included weather, reforestation, and development. About 60% of the LF 2012 events were acquired or contributed by U.S. Forest Service (USFS) sources, while the Bureau of Land Management (BLM), multi-agency groups, and state agencies each contributed over 10%. See Table 1 and 2 for more information on event data types and contributors.

Table 1. Break down of LF 2012 event types by percentage

LF 2012 Event Type	Total Percentage (%)
Mechanical and Harvest Activities	34.8%
Fire	22.5%
Chemical or Biological Treatments	22.5%
Insects or Disease Events	9.9%
Weather	5.5%
Reforestation	4.8%
Development	0.1%

Table 2. Break down of LF 2012 event sources by percentage.

LF 2012 Event Agencies	Total Percentage (%)
U.S. Forest Service	57.2%
Bureau of Land Management	13.8%
Multi-Agency	13.3%
State	10.9%
Tribal	1.8%
National Park Service	1.5%
U.S. Fish & Wildlife Service	0.9%
Miscellaneous	0.6%

4.2 DISTURBANCE

Product Description

Disturbance products are developed to reflect change on the landscape caused by management activities and natural disturbance, and are necessary for updating LF vegetation and fuel products. They are produced by processing and analyzing data from many sources, including: Landsat satellite imagery, operational fire mapping programs, including MTBS, Burned Area Emergency Response (BAER) and RAVG, the LF Events Geodatabase, and other ancillary sources such as NLCD, NASS CDL, and the U.S. Geological Survey (USGS) Gap Analysis Program (GAP) Protected Area Database (PAD-US). The final products are annual disturbance layers attributed with disturbance type, disturbance severity, confidence in the type and severity, and the source(s) of disturbance information. Subsequently,

composite disturbance layers depicting the disturbance type, severity, and time since disturbance are provided for the years 2003-2012.

Update Process: CONUS

Disturbance mapping is multifaceted and involves the processing of several data sources, script writing, management and execution, and manual interpretation. The complete process for updating LF products is detailed in the USGS Open File Report: *LANDFIRE 2010: updates to the national dataset to support improved fire and natural resource management* (Nelson, et. al., in process). LF 2012 presented new challenges, most of which involved the unprecedented reliance on Landsat 7 Scan Line Corrector (SLC)-off imagery due to the decommissioning of Landsat 5. Landsat 7 SLC-off imagery became the sole source of image data for the 2012 growing season. The prevalence of data gaps in the imagery led to research and development of methods for filling the scan gaps with quality data, and within the scope of the production schedule. The result was to use a best-pixel compositing approach within a tiled framework (Nelson and Steinwand 2015). The benefits were twofold: 1) the tiling approach proved more efficient by removing scene overlap, which is prevalent if mapping by individual scenes (i.e., LF_2008-2010); and 2) the best-pixel approach, although not perfect, removed the majority of no data areas caused by Landsat 7 scan gaps, as well as those caused by clouds and cloud shadows.

Image Composites

A tiled grid of 10,000 x 10,000 30-m pixels was defined for CONUS based on the Albers Equal Area Conic projection. Some tiles were adjusted to eliminate those of relatively small size, such as along national borders and coastlines. Ultimately, 98 non-overlapping tiles covered CONUS. The efficiencies gained in moving from individual scenes to tiled image processing and mapping are demonstrated below in Figure 1. Additionally, Figure 2 shows the tile identifier and its location in relation to the six GeoAreas (Northwest (NW), Southwest (SW), North Central (NC), South Central (SC), Northeast (NE), and Southeast (SE)).

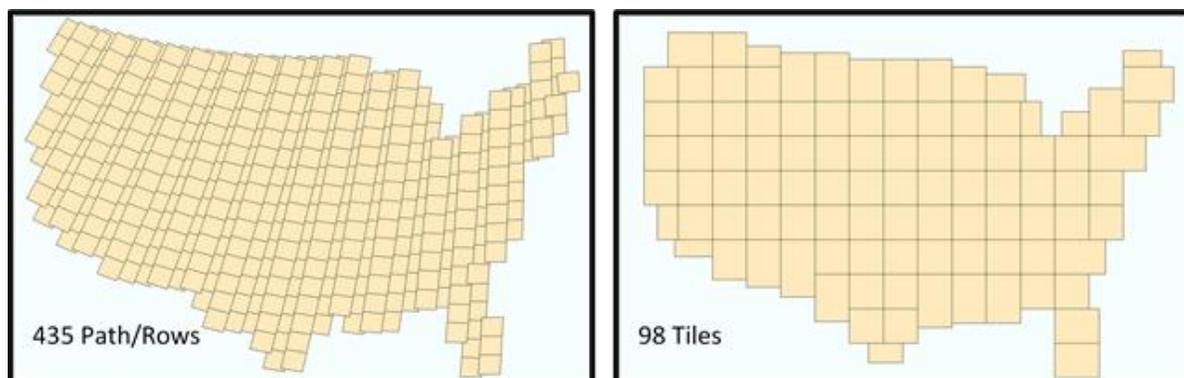


Figure 1. A comparison between the 435 individual scene mapping system to the 98 tile-grid mapping system.

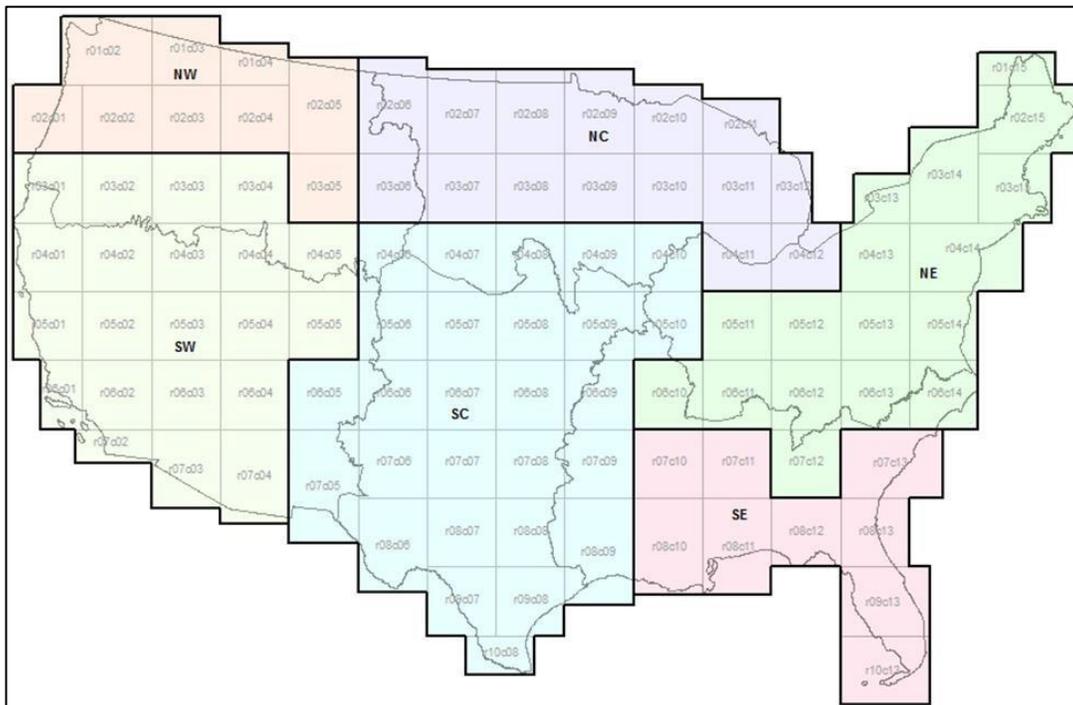


Figure 2. LF 2012 tile layout by GeoArea.

Landsat 5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper (ETM)+, and Landsat 8 Operational Land Imager scenes were selected using automated metadata searching scripts. Once selected, imagery were reprojected to the tile extents, masked to remove clouds, cloud shadows, water, and snow/ice, then composited. Tile compositing was based on a best-pixel cosine similarity approach. Simply put, the pixels used in the composite images were selected through automated processes which compare stacked pixels by spectral similarity (i.e., cosine similarity), followed by pixel proximity to the defined center date. The logic behind the compositing process is graphically represented in Figure 3, below. The best-pixel algorithm requires user-specified start, center or target and end dates. The target date defines the optimal date from which a pixel should be selected if unmasked. The start and end dates define the window from which imagery can be used. Any image outside of the defined date range is not considered. For LF 2012, every CONUS tile used the following date definitions in order of early, target, and late dates (note: dates shown are for non-leap years):

Early Season: Day 100 (April 10); Day 175 (June, 24); Day 199 (July 18)

Late Season: Day 200 (July 19); Day 250 (September, 7); Day 299 (October 26)

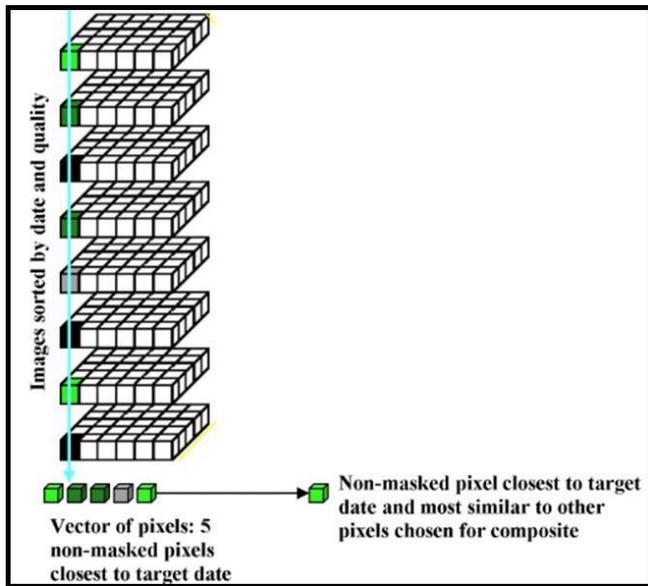


Figure 3. A graphical representation of the best pixel compositing approach (Nelson and Steinwand 2015).

The best pixel algorithm analyzes all of the non-masked pixels in a stack. Of the non-masked pixels the one most similar (spectrally) to the other pixels and closest to the target date is applied to that pixel space in the composite output. Figure 4 demonstrates how the best-pixel compositing method eliminates data gaps and clouds in a Landsat 7 SLC-off image. Subtle artifacts from the compositing process are visible in the composite scene, though the overall data are improved.

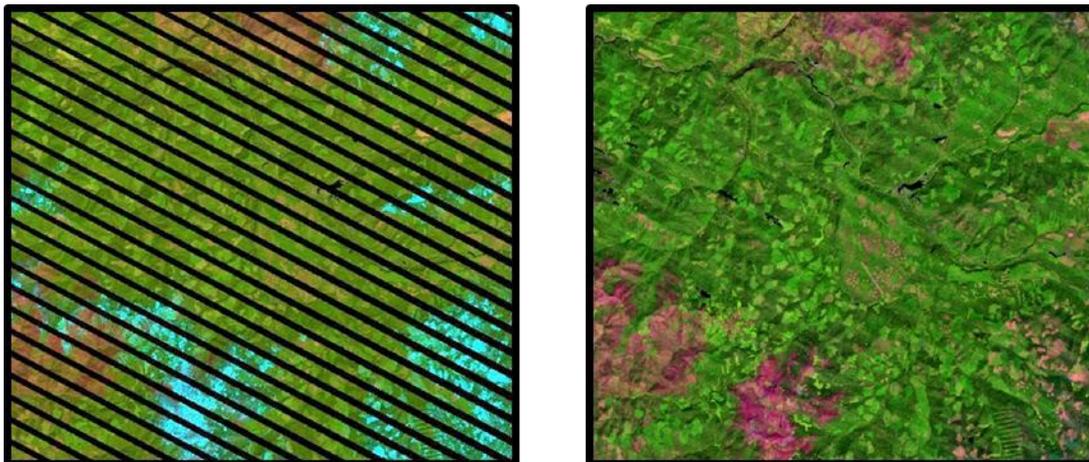


Figure 4. Landsat 7 data shown before and after best-pixel compositing.

MTBS Gap Filling

Two national fire mapping program datasets that were used to locate and characterize large wildfires - MTBS and RAVG- contained a large number of no data areas due to the use of Landsat 7 SLC-off imagery in 2011 and 2012. These fire mapping programs do not employ methods to fill in the no-data pixels with alternate data. Left “as is” no-data pixels would remain in the disturbance data product and affect subsequent LF products (e.g. fuel models). In order to mitigate the no-data issues, decision tree modeling, using best-pixel composite imagery (or occasionally, other available imagery), or majority focal filling techniques were employed. The flow chart (see Figure 5) demonstrates the logic used to select the appropriate filling method for MTBS or RAVG datasets.

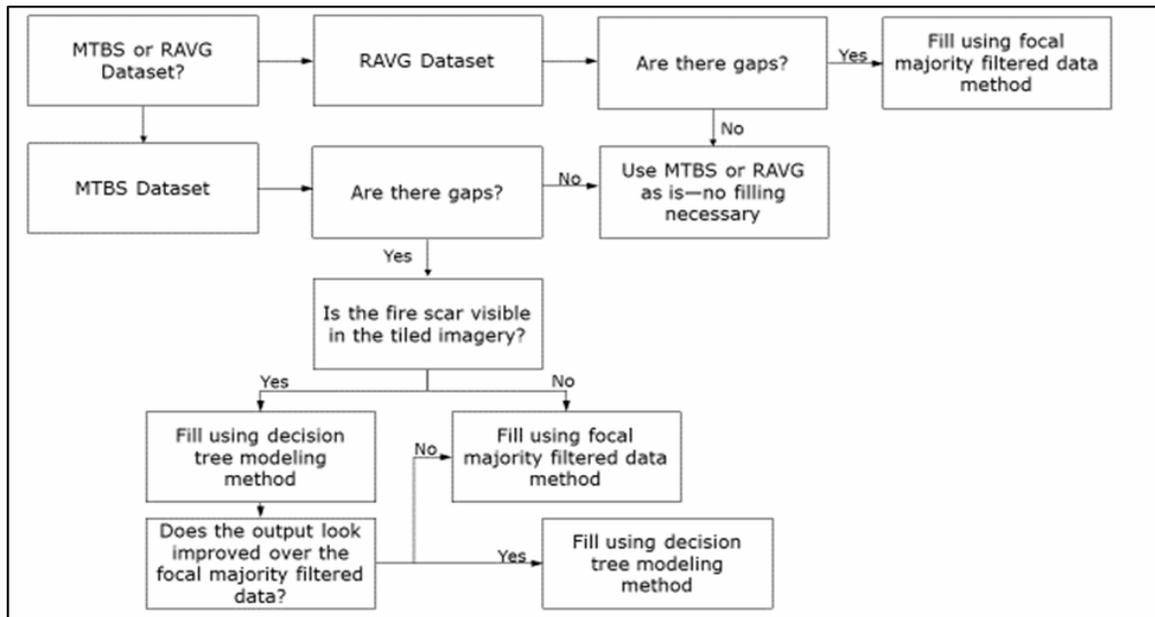


Figure 5. Flow chart to determine methods for filling no data areas within MTBS and RAVG datasets.

The decision tree modeling approach required significantly more time and effort than automated techniques; however, testing showed qualitative improvement over automation in almost all cases. The modeling approach proved most valuable in larger fires containing a wide range of severity levels with varied elevations and fuel conditions. Decision tree modeling, therefore became the preferred method for filling MTBS data gaps when applicable. In all, nearly 600 MTBS fires were modeled across CONUS for 2011 and 2012. The following graphics below show before-and-after no-data filling using the modeling approach (Figure 6).

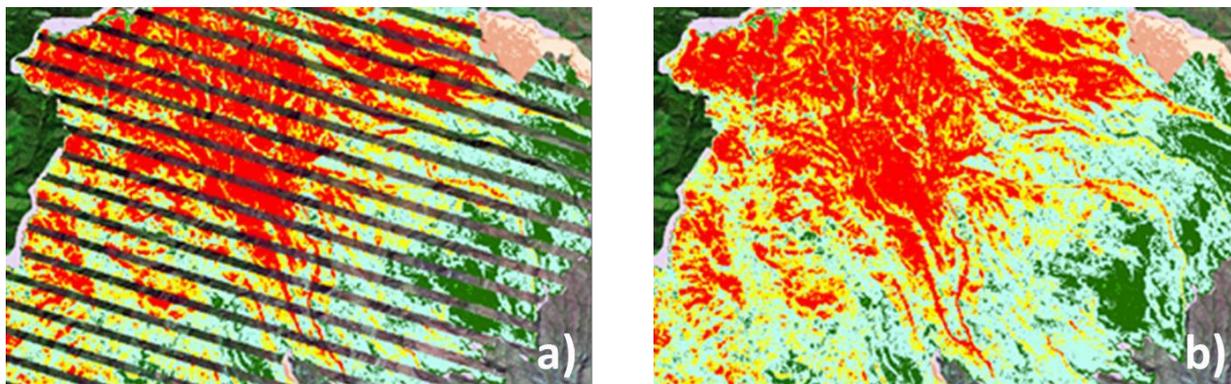


Figure 6. Example of a large multi-severity burn that was mapped with a) no-data gaps and b) with decision tree-modeled data applied.

Majority focal filling is an automated image processing technique that assigns pixel values to areas of no data. Although this technique was not the preferred choice for no-data filling, it offered a practical alternative if the modeling approach was not possible, or results appeared spatially inequitable to surrounding data. RAVG datasets were filled exclusively with this method, whereas it was only occasionally used on MTBS datasets. Majority focal filling was originally developed by the BAER mapping team and slightly modified for LF purposes. The focal-majority filter uses a 12-pixel by 12-pixel moving window to compute the maximum pixel value within the window frame, then applies that value to the center pixel, if the center pixel contains no data. In most cases, fires that were focal filled only contained two or three classes (unburned through low severity). The graphics below show before-and-after comparisons using a focal-majority filled product (figure 7). In figure 7, the blue colors represent low-severity burned areas, and the orange color represents areas of no-burn to low-severity burns.

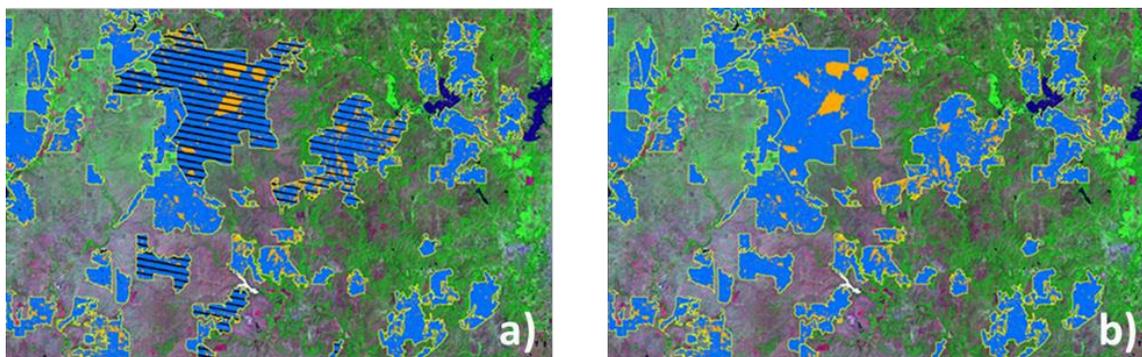


Figure 7. Example of low-severity burn scars a) with no-data gaps, and then b) with focal-majority filling.

Contributing Datasets

In addition to fire program and satellite-derived (RSLC) data, LF disturbance layers include updated Forest Inventory and Analysis (FIA) data from the USFS, land management groups, as well as non-profit and private organizations. These data

are provided voluntarily or through solicitation via the LF website, cataloged in the LFRDB and processed into a model-ready spatial layer depicting one disturbance per year per geographic location. Other spatial data contributing to the update process include NLCD, NASS CDL, PAD-US, and USFS SMARTFire system.

Product Development

In LF 2010, the RSLC process included a new change detection algorithm (Nelson and others, 2013). The Multi-Index Integrated Change Analysis (MIICA) process was developed for the NLCD project (Jin and others, 2013) and was adopted for LF RSLC. MIICA uses image pairs and associated spectral indices to identify changes in vegetation. MIICA was run following image tile production using image pairs of the same time periods from consecutive years (e.g., 2010 early season and 2011 early season). The MIICA outputs for each year were then combined and filtered by LF analysts, using a combination of automated routines with manual interpretation and editing, to remove “false-positive” disturbances. Since MIICA outputs do not assign causality to disturbances, polygons from the LF Events geodatabase were buffered to a distance of 500 m, and then used to assign disturbance types. Other data sets used to assign disturbance types were the PAD-US and the USFS SMARTFire system. The PAD-US GAP Status provides an indication of land use and management characteristics, while USFS SMARTFire provides ignition points indicating active fire detections, which are subsequently buffered. If a RSLC detected disturbance did not intersect with any of these data sets, it was labeled an unknown disturbance type. Disturbance severity was determined from the source data, in the case of wildfire mapping program and Events data that had severity information available, or from the RSLC data for all other cases. In the RSLC case, the differenced Normalized Burn Ratio was computed from the Landsat imagery. Thresholds were automatically derived and used to separate the data into low, medium, and high severity classes, and assigned accordingly. Confidence levels of the disturbance type and severity attributes were recorded based on the source of the data used to develop those attributes. Data that were created at least in part by analysts (e.g. MTBS) were considered to have higher confidence than data that were generated automatically (e.g. SMARTFire). Once the annual disturbance products were completed, the previous and new layers from 2003 through 2012 were combined and summarized to produce the composite vegetation and fuel disturbance layers.

Update Process: Alaska

In Alaska, the disturbance mapping process only combined data from the national wildfire mapping programs and the LF Events Geodatabase. RSLC data products were not used in the Alaska disturbance mapping process due to time constraints and image availability. Similar to CONUS, MTBS data containing no-data were filled with decision tree modeling or majority focal-filling techniques. The same suite of attributed disturbance layers created for CONUS were also created for Alaska, including annual and composite layers depicting all disturbances from 2003 through 2012.

Update Process: Hawaii

Hawaii disturbance mapping for LF 2012 expanded the level of effort from previous years. Image composites, RSLC/MIICA processing, and MTBS no-data filling were implemented. Image compositing significantly reduced the impact of heavily clouded imagery. CONUS tiles were developed based on center image Julian dates of 175 and 250; however due to the limited availability of cloud-free imagery in Hawaii the date ranges were expanded. Different center image dates were investigated (60, 180, and 270) but the results were not improved, thus the 175 and 250 center days were used. As a deviation from RSLC mapping in CONUS, local expertise was utilized to assign causality to some disturbances that would have otherwise been labeled as unknown.

Results

A rigorous and repeatable method for generating total disturbance area and disturbance counts was used for statistical analysis. The disturbance statistics were generated from only the final disturbance grids using a series of processing-intensive GIS operations including recoding, clumping/clustering and sieving. The results were compiled in a database for statistical evaluation. A brief description of the process and selected results are given below:

Recoding the LANDFIRE Legend

The LF legend contains significant detail spread among 174 classes. In order to provide meaningful statistics in a manageable form, the disturbance legend was collapsed to the event-type level, Table 3. There are 19 disturbance event types, of which, classes 1-18 are known disturbances. Class 19 contains unknown disturbances detected through RSLC mapping. The initial step in producing both disturbance area and count was to recode the final CONUS disturbance legend into the event type classes as shown below.

Table 3. Disturbance legend classes recoded into corresponding event types.

Event Type	Legend Class Value
Biological:	581 - 583; 1081
Chemical:	531 - 533; 1031
Clearcut:	421 - 423; 921
Development:	411 - 413; 911
Disease:	551 - 553; 1051
Harvest:	431 - 433; 931
Herbicide:	571 - 573; 1071
Insecticide:	521 - 523; 1021
Insects:	541 - 543; 1041
Insects/Disease:	561 - 563; 1061
Mastication:	451 - 453; 951
Other Mechanical:	461 - 463; 961
Prescribed Fire:	491 - 493; 991
Thinning:	441 - 443; 941
Weather:	511 - 513; 1011
Wildfire:	11 - 234; 471-473; 971
Wildland Fire:	501 - 503; 1001
Wildland Fire Use:	481 - 483; 981
Unknown:	601 - 883; 1101 - 1134

Calculating Disturbance Area

Once the final disturbance grids were recoded into the event type classes shown above, pixel counts were generated for each class and mathematically converted to total number of acres. To obtain results by GeoArea the CONUS-wide grids were clipped to each of the six GeoArea boundaries. The attribute tables from each of the 19 classes were recorded in a database for tabulation/summation for each GeoArea.

Calculating Disturbance Counts

Deriving disturbance counts involved more effort than calculating disturbance area. Once the final disturbance legend was collapsed to event type the disturbances were clustered together using GIS clump analysis. Once clumped, clusters of five pixels or fewer were eliminated from analysis using the sieve operation to avoid counting single pixels or small clusters of pixels as separate disturbances (this can occur when a RSLC disturbance (unknown) intersects an event disturbance (known)). Similar to disturbance area, the CONUS-wide disturbance count data set was clipped to the GeoArea boundaries, summarized, and recorded in the master database for further analysis.

Statistical Summaries

Once all data were processed into an analysis-ready format a number of statistical summaries were computed. A selection of the results are provided below:

Inclusively:

- The fire program data captured the most acres of disturbance; however, the number of fire program disturbances are fractional compared to the number of Event and RSLC-captured disturbances (Figures 8-9).
- The majority of disturbances captured come from RSLC processes (Figure 9).

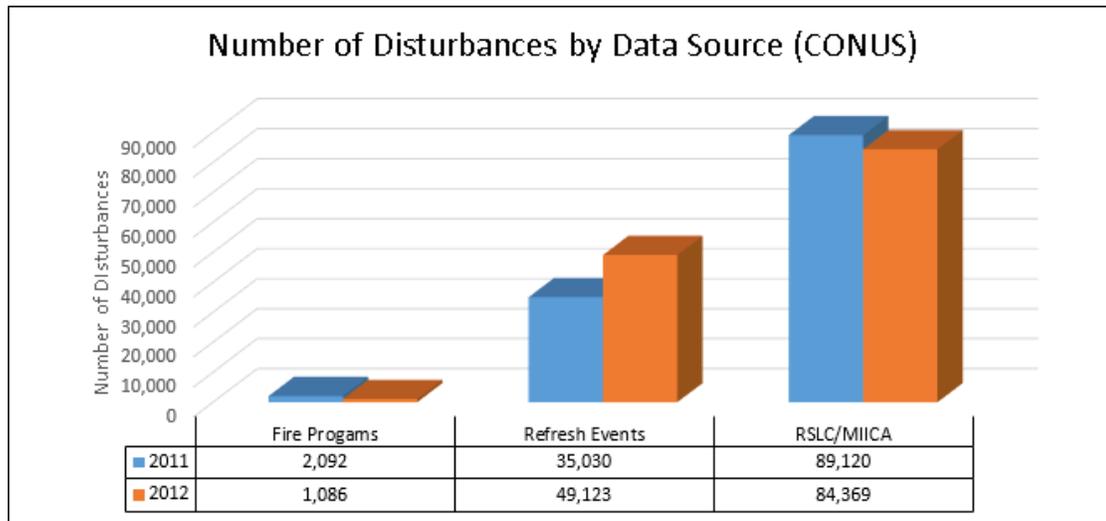


Figure 8. The total number of acres mapped for 2011 and 2012 according to the data source.

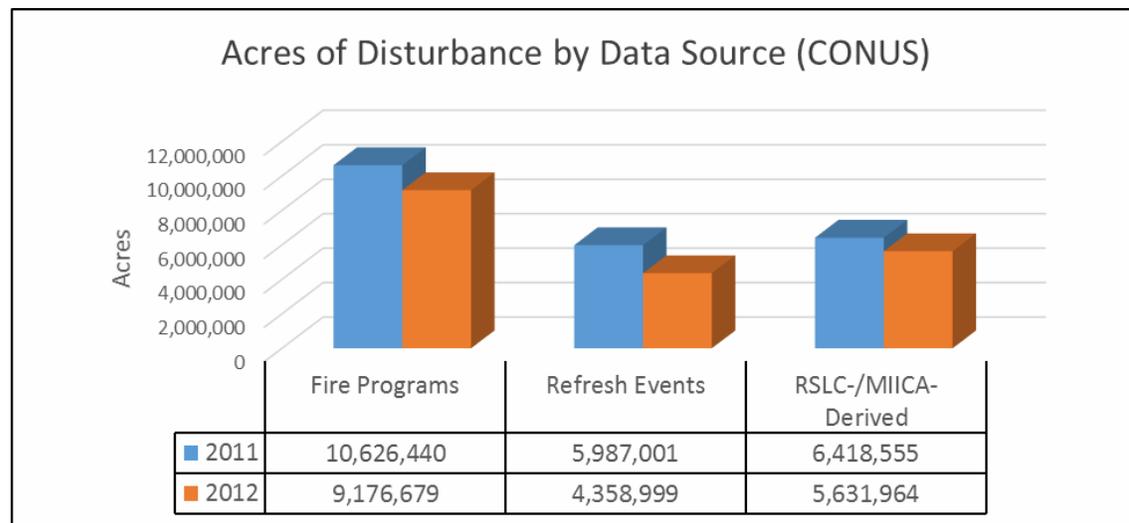


Figure 9. The total number of disturbances mapped for 2011 and 2012 according to the data source.

CONUS-Specific:

- Collectively, fire-related disturbances impacted the most land area (Table 4).
- The SE GeoArea contained the most disturbance in both number and area followed by the NW (Figures 10-11).
- The SW and SC GeoAreas showed significant disturbance, as well, mostly driven by fire events (Figures 10-11).
- The NE and NC GeoAreas typically reported the fewest acres of disturbance, although the number of disturbances were not far off of the SC and SW (Figures 10-11).
- Disturbance types 'Unknown' and 'Wildfire' account for approximately 80% of the acres disturbed for both 2011 and 2012 (Tables 4-5).

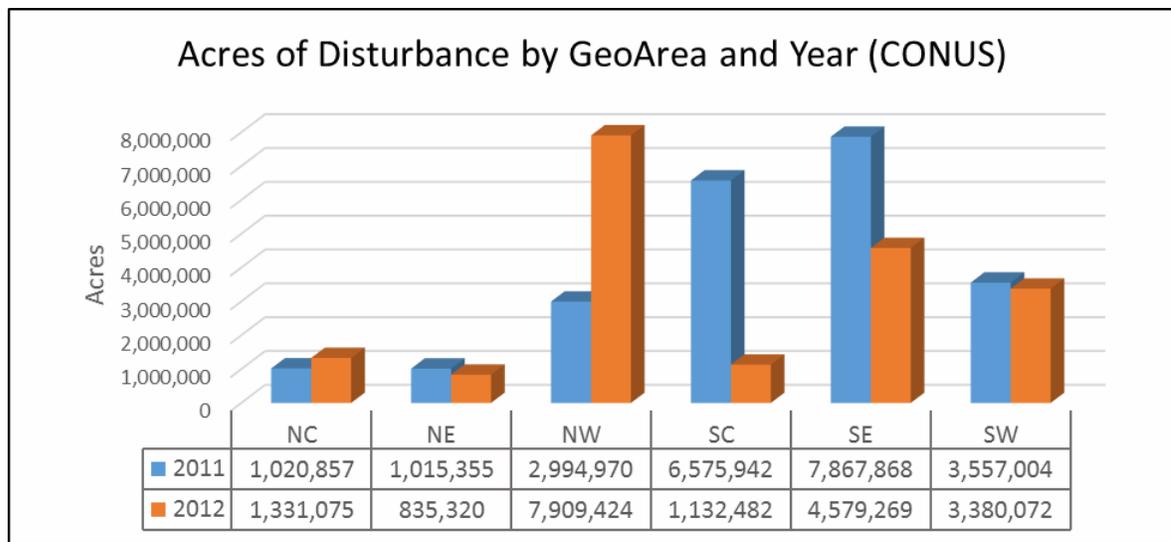


Figure 10. Total acres of disturbance for 2011 and 2012 within CONUS listed by GeoArea.

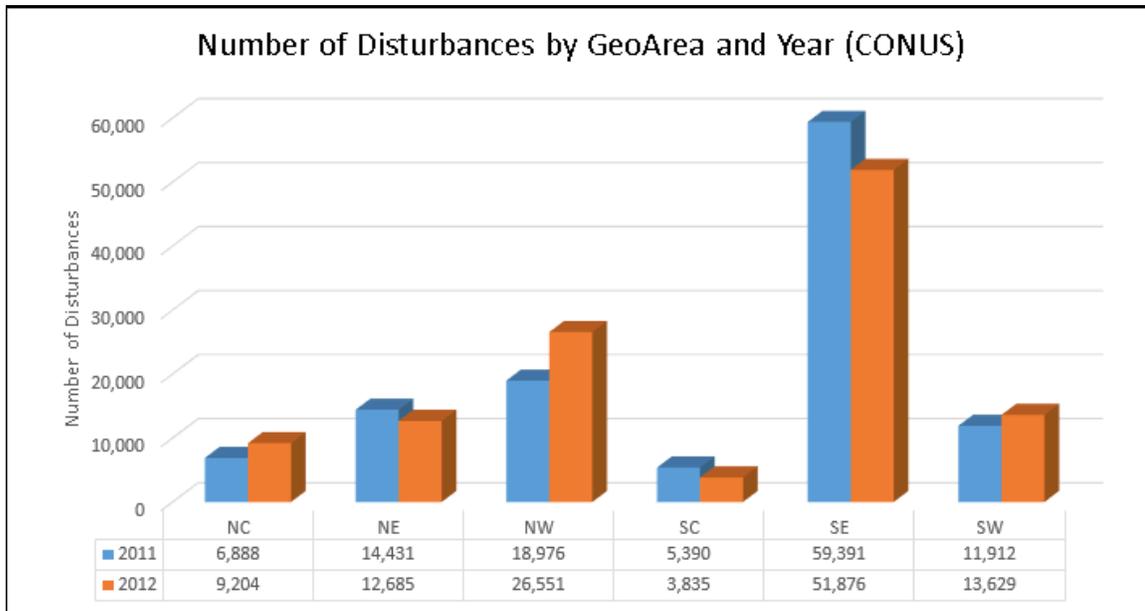


Figure 11. Total number of disturbances from 2011 and 2012 within CONUS reported by GeoArea.

Table 4. Acres of disturbance according to type and year within CONUS for 2011 and 2012.

	2011		2012	
	Sum of Acres	Percent of Acres	Sum of Acres	Percent of Acres
Biological	8,791	0%	28,330	0%
Chemical	253,178	1%	244,350	1%
Clearcut	41,106	0%	32,608	0%
Development	735	0%	546	0%
Disease	1,462	0%	5,651	0%
Harvest	92,645	0%	85,911	0%
Herbicide	726,977	3%	1,041,900	5%
Insecticide		0%	22	0%
Insects	25,993	0%	41,349	0%
Mastication	99,481	0%	47,267	0%
Other Mechanical	406,833	2%	490,372	3%
Prescribed Fire	726,872	3%	1,156,533	6%
Thinning	297,497	1%	232,744	1%
Unknown	6,336,020	28%	5,543,571	29%
Weather	2,387,146	10%	320,074	2%
Wildfire	11,489,474	50%	9,760,702	51%
Wildland Fire	137,360	1%	126,933	1%
Wildland Fire Use	427	0%	8,778	0%
Grand Total	23,031,997	100.00%	19,167,642	100.00%

Table 5. Number of disturbances according to type and year within CONUS for 2011 and 2012.

	2011		2012	
	Num of Disturbances	Percent of Total	Num of Disturbances	Percent of Total
Biological	47	0.0%	185	0.2%
Chemical	865	0.7%	2,179	1.9%
Clearcut	1,439	1.2%	1,190	1.0%
Development	31	0.0%	27	0.0%
Disease	11	0.0%	41	0.0%
Harvest	1,222	1.0%	907	0.8%
Herbicide	2,499	2.1%	5,357	4.5%
Insecticide	-	0.0%	2	0.0%
Insects	365	0.3%	3,505	3.0%
Insects/Disease	-	0.0%	-	0.0%
Mastication	940	0.8%	424	0.4%
Other Mechanical	5,403	4.6%	5,870	5.0%
Prescribed Fire	3,624	3.1%	3,233	2.7%
Thinning	4,444	3.8%	4,264	3.6%
Unknown	89,128	76.2%	84,369	71.6%
Weather	450	0.4%	92	0.1%
Wildfire	3,509	3.0%	2,384	2.0%
Wildland Fire	2,975	2.5%	3,750	3.2%
Wildland Fire Use	36	0.0%	1	0.0%
Grand Total	116,988	100%	117,780	100%

Alaska-Specific:

- The amount of change recorded was not significantly different between years 2011 and 2012 (Figures 12 -13).
- Of the 993,398 acres of disturbance for 2011, 749,552 acres were contributed events. The remaining 243,846 acres were fire-program related.
- Of the 830,627 acres of disturbance for 2012, 568,017 acres were contributed events. The remaining 262,610 acres were fire-program related.

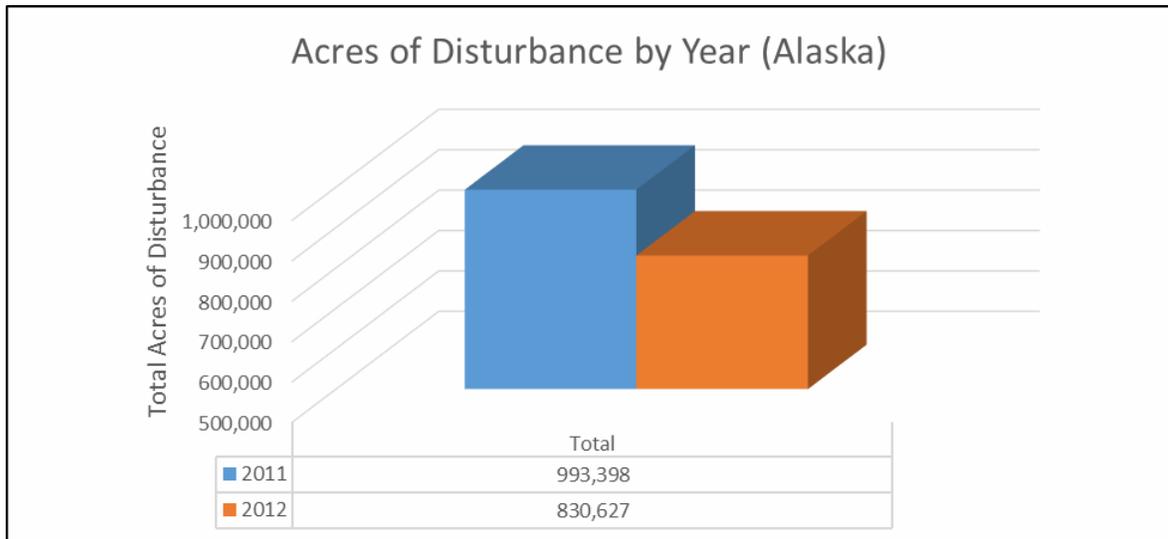


Figure 12. Total acres of disturbance by year for Alaska.

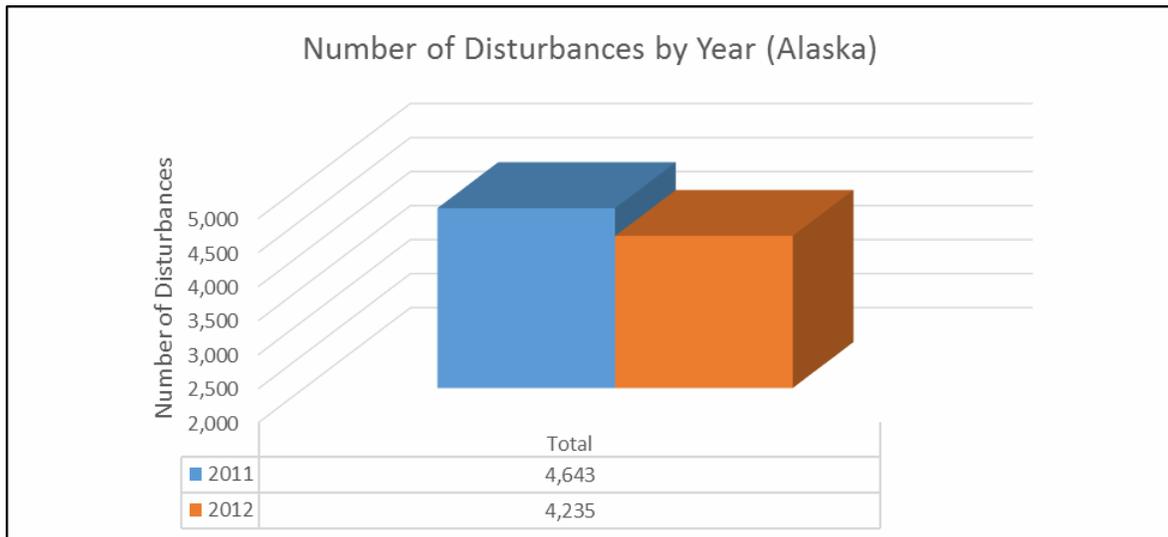


Figure 13. Total number of disturbances by year for Alaska.

Hawaii-Specific:

- A small geographic footprint, persistent cloud cover, and relatively few contributed events resulted in a small number of disturbances reported (Figure 15).
- Approximately 19,000 acres of disturbance were recorded for 2011 and 2012 combined (Figure 14).
- For 2011, 4,698 acres were contributed events; 4,103 acres were RSLC-captured; there were no MTBS fires.
- For 2012, 5,257 acres were contributed events; 2,100 acres were fire program-related and 2,986 acres were RSLC captured.

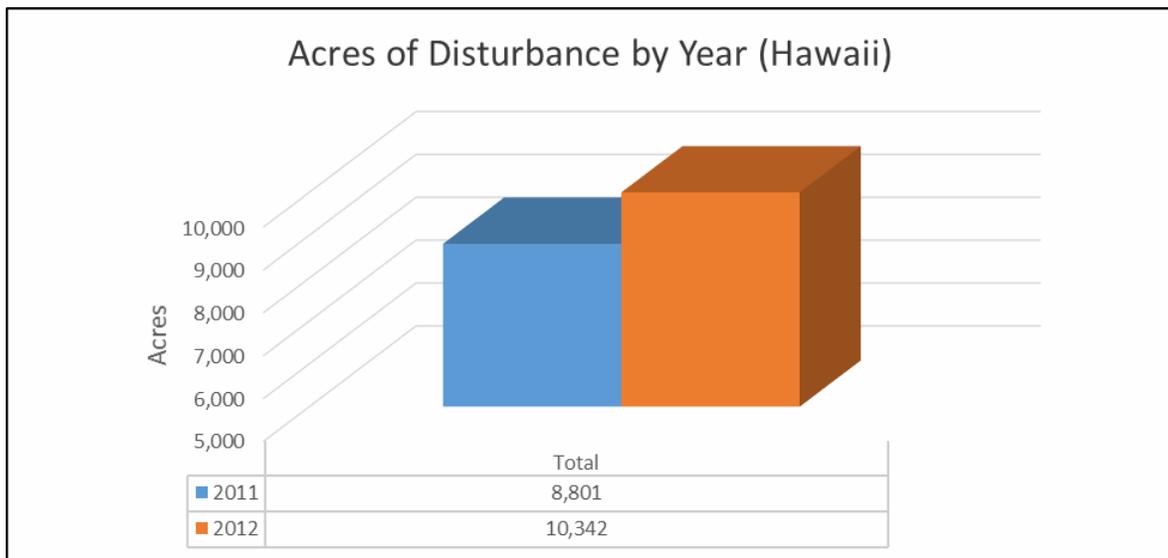


Figure 14. Total acres of disturbance by year for Hawaii.

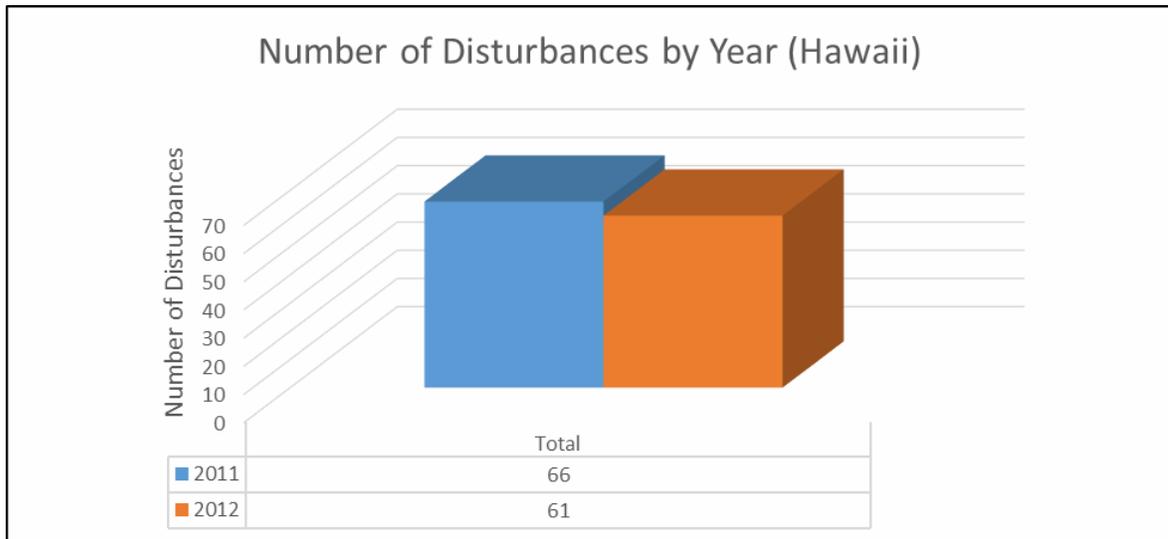


Figure 15. Total number of disturbances by year for Hawaii.

4.3 VEGETATION

Product Description

Existing vegetation layers for LF include EVT, EVC, and EVH. All three layers were originally mapped using predictive landscape models based on extensive field-referenced data, satellite imagery, biophysical gradient predictor layers, and classification and regression trees. The EVT layer represents the current dominant vegetation using a blend of map units derived from NatureServe’s Ecological Systems vegetation classification for natural vegetation (Comer and others, 2003) with other internally derived map units for non-natural and semi-natural vegetation. The EVC layer represents the average percent cover of the dominant lifeform vegetation of the corresponding EVT for each pixel. The EVH layer represents the average height of the dominant lifeform vegetation of the corresponding EVT for each pixel.

Update Process: CONUS

A brief description of the vegetation update process implemented in earlier LF versions is provided to better highlight the processing changes required for LF 2012. The vegetation data process genealogy explains the processing method, particularly for the EVC layer.

Data Process Genealogy

LF National

LF National utilized three vegetation lifeforms (tree, shrub, and herbaceous) and created EVC and EVH separately for each lifeform. The modeled shrub and herbaceous layers were created as intermediate layers and were not distributed as an end product. A normalization algorithm was applied that adjusted shrub and

herbaceous cover based on the amount of tree and shrub cover mapped for each pixel (Figure 16). The tree cover data used in LF National was based on the NLCD tree cover product. The final EVH and EVC layers were contingent on the LF EVT map, which was the determining factor in assigning lifeform to each pixel.

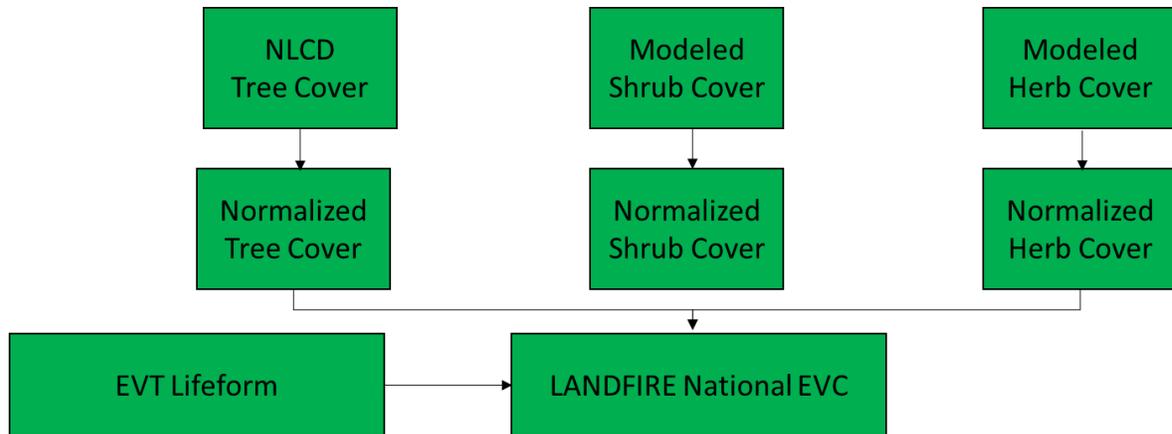


Figure 16. LF National mapping process for EVC. All boxes are green indicating the original LF processing methods used to create LF National.

LF 2001

During the LF 2001 mapping efforts, tree cover was remapped using USFS FIA stem mapped plot data (Figure 17, yellow boxes). The intermediate LF National modeled shrub and herbaceous cover layers (previously undistributed) were used to provide structure information for the pixels that changed lifeform. These intermediate cover layers did not have the normalization algorithm applied. Shrub and herbaceous pixels that did not change lifeform kept the LF National EVC pixel values (Figure 17).

LF 2008

LF 2008 used the same mapping process as LF 2001 EVC. The only difference was updating vegetation transitions based on disturbance or succession from 1999 through 2008 (Figure 17).

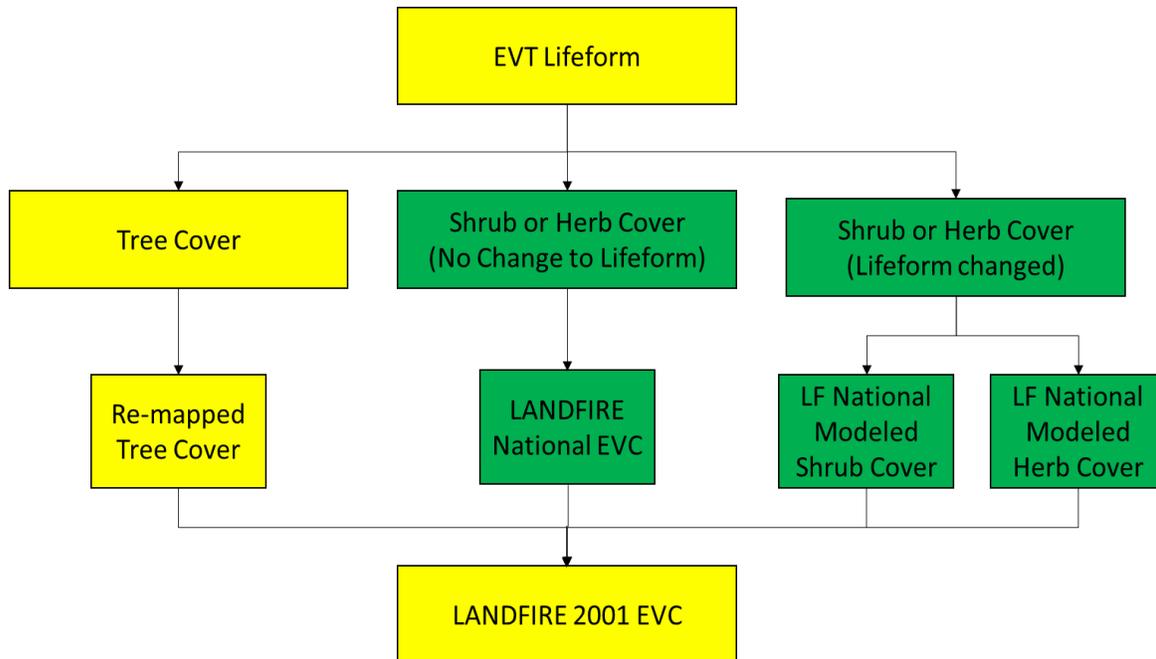


Figure 17. LF 2001 and LF 2008 mapping process for EVC. All boxes in green were original from the LF National processing methods. The boxes in yellow were updated processing steps for LF 2001 EVC.

LF 2010

LF 2010 EVC products were created using a baseline 2001 layer that combined the LF 2001 re-mapped tree cover with the LF National modeled (non-normalized) shrub and herbaceous layers based on the lifeform of the EVT (Figure 18). This layer was then updated to reflect vegetation change, due to disturbance or succession, from 2001 through 2010. Analysis of the LF 2010 products revealed significant changes in the distribution of shrubland fuels. These changes were not caused by disturbance or succession, however were traced back to the use of the non-normalized LF National intermediate shrub and herbaceous layers that were applied to all shrub and herbaceous pixels.

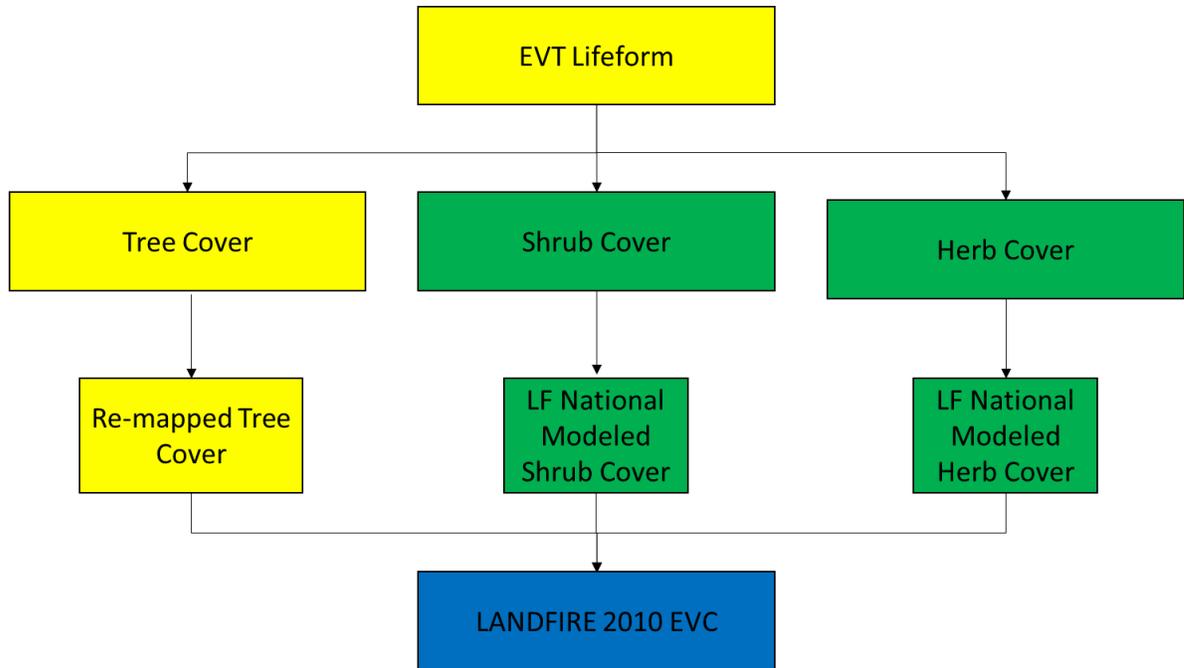


Figure 18. LF 2010 mapping process for EVC. All boxes in green were original from the LF National processing methods. The boxes in yellow were updated processing steps for LF 2001 EVC. For LF 2010, the final EVC product is shown as a blue box.

LF 2012

To mitigate the distribution shift in the LF 2010 products, and bring the EVC data back in line with previous LF releases, the LF 2012 products were reverted back to the normalized EVC data where available. This was accomplished by modifying the LF 2010 EVC product to use the LF 2001 herbaceous and shrub EVC data (Figure 17 and Figure 19). The areas that had changed since 2010, due to disturbance or succession, were then transitioned using the re-mapped LF 2001 tree cover for pixels with a tree lifeform, and the modeled (non-normalized) LF National intermediate shrub and herbaceous data only where the lifeform changed to shrub or herbaceous. The LF 2012 process resulted in EVC data that is more compatible with data from pre-LF 2010 and the distribution shift seen in the LF 2010 is no longer apparent in the data.

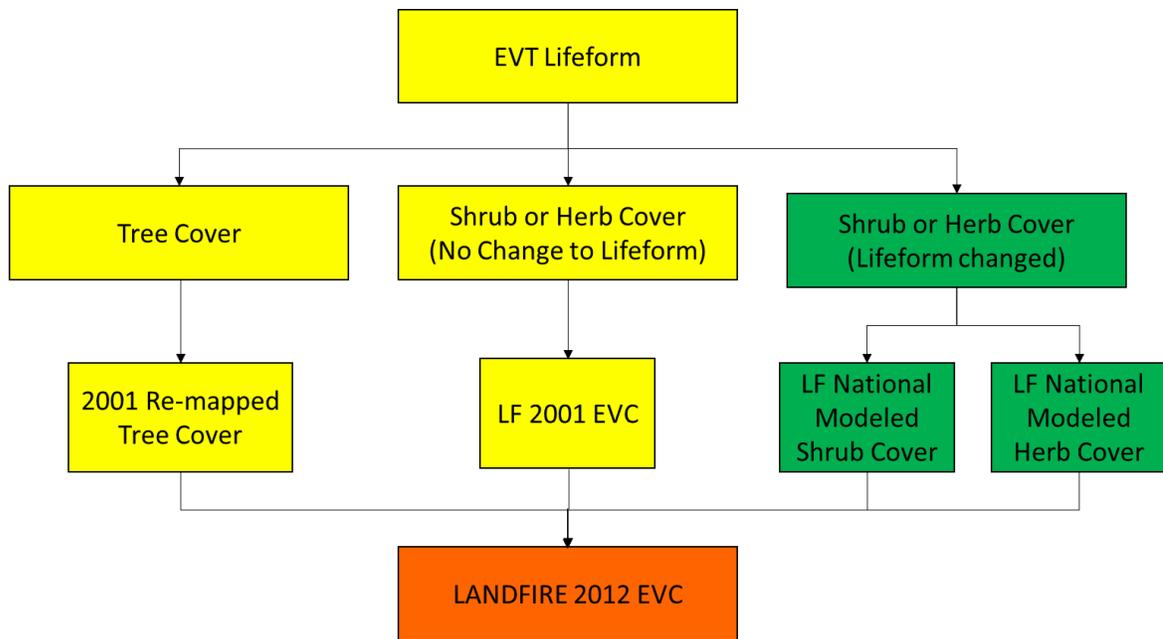


Figure 19. LF 2012 mapping process for EVC. All boxes in green were originally from the LF National processing methods. The boxes in yellow were updated processing steps for LF 2001 EVC. For LF 2012 the final EVC product is shown as an orange box.

Vegetation Transition Modeling

The LF VTM layer provides a summary of the relationship between disturbance types and resulting effects on the vegetation in terms of changes in lifeform and canopy cover. Information about the disturbance type and the resulting change to vegetation lifeform or tree canopy cover are used to characterize this change. This layer is generated concurrent with the updating process using tables and a series of database queries on a spatial overlay of vegetation and disturbance raster data.

The effects of disturbances on the vegetation are modeled or predicted using a series of tables that link pre-disturbance EVT, EVC, EVH, and a range of possible disturbance types and severities with post-disturbance EVT, EVC, and EVH. For forested vegetation, these tables were informed by computer simulations in the Forest Vegetation Simulator (FVS, Dixon 2002, Crookston and Dixon, 2005,) while for non-forest vegetation, they were informed by a series of simple rule-sets generated heuristically for each individual map zone. Final updating occurred when the tables were linked with a spatial overlay of vegetation and mapped occurrences of disturbance and used to assign LF 2012 EVT, EVC, and EVH. Finally, a unique code was assigned to all pixels that associate them with a particular disturbance type as well as categories of change magnitude expressed either in a change in vegetation lifeform or a change in tree cover.

Update Process: Alaska

Alaska followed the same steps as CONUS in defining rulesets and transitioning vegetation. The only key difference was that FVS was only used in the southeast part of Alaska where there was current FIA data, otherwise the forests in the rest of the state followed the same process as non-forest in AK and CONUS.

EVC Remap of Alaska

The forested component of the EVC product for Alaska was updated to provide a better representation of the heterogeneity of forested canopy cover across the landscape, and to bring the Alaskan canopy cover classification into agreement with the CONUS products. LF National Alaska forested canopy cover was mapped using a 3-class legend (10-25%, 25-60%, and 60-100%), which differed from CONUS in having a 9-class (10-20%, 20-30%...and 90-100%) legend. The limited thematic precision was due to the lack of field data available for the original Alaskan mapping effort. To address this lack of data, the LF 2012 mapping relied on observations made by the Geoscience Laser Altimeter System (GLAS) onboard the Ice, Cloud, and Land Elevation Satellite. GLAS collected data from 2003 to 2009. It was a large-footprint (~65 m diameter), waveform-digitizing lidar system that provided discrete samples (spaced ~172 m apart) across the landscape along orbital tracks. From each waveform sample on the landscape, vegetation structure, including canopy cover, can be inferred.

While GLAS data can provide valuable observations about canopy cover throughout Alaska, certain steps were taken to ensure that only high-quality data were used. Data-quality filters were applied to the GLAS waveform data. These filters identified waveforms with high noise, signal saturation, and cloud contamination, as well as outlier data. GLAS data were only used if the footprint was located entirely within areas identified as forest in the LF EVT map. Additionally, only data collected in the spring/summer operational periods (i.e., leaf-on conditions) were used. The GLAS waveforms passing the quality control checks were processed to derive canopy cover using Gaussians fit to the waveform. The benefit of the Gaussian approach was that it simplified ground-finding, assuming that one of the Gaussians corresponds to ground. High spatial-resolution imagery was used to assess the GLAS-derived forested canopy cover metric estimates prior to their inclusion in the set of observations used to build the regression tree models.

To ensure even sampling over the entirety of the Alaskan forested regions, a sampling grid (8x8 km) was placed over the area to be mapped. This grid was divided into 1 km cells. Within each cell of the larger 8 km grid, the 1 km cell closest to the center was selected for sampling, with the specific quadrant selected based on the position of a clock's minute hand at the time sampling was begun. If there were no GLAS waveforms within a given 1 km cell, the next closest cell to the center, progressing in a clockwise fashion around the center was selected. In some cases more than one cell was sampled if the samples were very sparse, covered diverse landscapes, or the GLAS waveforms in the area were of consistently good quality.

Forested canopy cover was derived for all waveforms selected for model development (n=5254). Regression tree models were built and then applied to generate forested canopy cover maps for the entire state. A composite of Landsat imagery, Digital Elevation Model and derivative layers, the LF EVT and EVH layer values were extracted at the retained GLAS footprint locations. These data, along with the GLAS-based forested canopy cover estimates, were used to generate the inputs required to generate a regression tree model. This model was then spatially applied to the geospatial data layers to create a forested canopy cover map. The initial map appeared to underrepresent the high forested canopy cover range, so a second model was generated in an attempt to correct for this (Correlation Coefficient = 0.65, Average Error=16 %). For this second model the data from the upper half of the forested canopy cover range (> 50%) were tripled and added back to the training data. This second model was then also applied to the geospatial data layers to create the forested canopy cover map. For the final map, forested canopy cover was binned at 10% increments to match the classification developed for CONUS.

Update Process Hawaii

The vegetation layers for Hawaii were processed the same as CONUS. The transitions were defined by local experts, no FVS runs were done due to lack of appropriate variants and field data.

Results: CONUS

The LF 2012 vegetation update process resulted in the following top ten changes in cover class (Table 6). All anthropogenic EVC classes from LF 2010 and LF 2012 were removed. With the anthropogenic EVC classes removed, the resulting changes based on number of acres occurred between the shrub cover classes and the herbaceous cover classes. The majority of the changes occurred in the shrub cover classes.

Table 6. The top ten changes in cover from LF 2010 to LF2012, with anthropogenic classes removed.

LF 2010 Cover Class	LF 2012 Cover Class	Acres
Shrub Cover >= 10 and < 20%	Shrub Cover >= 20 and < 30%	15,952,158
Shrub Cover >= 20 and < 30%	Shrub Cover >= 30 and < 40%	11,982,496
Shrub Cover >= 30 and < 40%	Shrub Cover >= 40 and < 50%	6,996,925
Shrub Cover >= 10 and < 20%	Shrub Cover >= 30 and < 40%	6,894,140
Herb Cover >= 40 and < 50%	Herb Cover >= 50 and < 60%	6,196,985
Shrub Cover >= 20 and < 30%	Shrub Cover >= 40 and < 50%	5,776,655
Herb Cover >= 40 and < 50%	Herb Cover >= 60 and < 70%	5,762,582
Herb Cover >= 80 and < 90%	Herb Cover >= 70 and < 80%	5,487,330
Shrub Cover >= 30 and < 40%	Shrub Cover >= 20 and < 30%	5,329,842
Herb Cover >= 40 and < 50%	Herb Cover >= 30 and < 40%	5,290,824

Results: Alaska

Results of EVC Remap of AK

The forested canopy cover map was assessed using FIA data available for the southeastern part of the state. FIA-reported forested canopy cover was modeled based on canopy structure measurements made in the field. For a subset of the FIA plots, forested canopy cover was also estimated based on ocular observations. Forested canopy cover values were extracted from the maps for each plot location and compared to the FIA estimates (RMSEmap vs. ocular observations = 25.92 %, n=407; RMSEmap vs. modeled cover = 29.26 %, n=1472).

Results: Hawaii

The majority of disturbed pixels were assigned to the “non-native” vegetation type. Therefore, no statistical analyses was performed due to an insignificant number of pixels that changed values.

4.4 FUELS

Product Description

The LF fuels data describe the composition and characteristics of both surface and canopy fuel. Geospatial surface fuel products included the 13 Anderson FBFM (FBFM13; Anderson, 1982), the 40 Scott and Burgan FBFM (FBFM40; Scott and Burgan, 2005), and the CFFDRS (Stocks and others, 1989). Canopy fuel layers included CBD, CBH, FCC, and FCH. These data are generally used within

simulation models to predict various aspects of wildland fire behavior and are useful for strategic fuel treatment prioritization and tactical assessments of fire behavior.

Update Process

Surface Fuels – Historical Setting

During production of the LF FBFM13, FBFM40, and CFFDRS geospatial products in LF National, a series of rules were developed for mapping fuel models based on input provided by regional fuel specialists and the LF team. In general, surface fuel models were dependent upon the type of vegetation described in the EVT layer, the amount of overstory cover of the vegetation from the EVC, and the height of the vegetation expressed by EVH. At times, the bio-physical setting of the site was leveraged to more accurately portray fuel models on the landscape. For most fuel models, fuel model assignments were given breakpoints of EVC and EVH for each EVT to determine the fuel model. For instance, in a forested EVT in an open condition, a grass or shrub model might be used in the low cover ruleset to describe the surface fuel. As the stand closed, represented by higher EVC classes, a timber understory or timber litter model would often be used in a subsequent ruleset. There are fuel model mapping rule sets for every mapping zone used in the LF National production process.

In order to efficiently apply these rules geospatially, the LFTFC tool was developed. The tool is an ArcGIS toolbar that links to the fuel mapping rules stored in a Microsoft Access database. The tool quickly translates the fuel mapping rules into spatial layers allowing for iterative changes to LF fuels data. The Toolbar has the ability to copy and auto-rule fuel rulesets from previous versions of the LF data, as well as edit any of the fuel attributes within each individual ruleset, including the fuel model. All these capabilities within the Toolbar become important when there are changes to the vegetation (EVT, EVC, EVH, Biophysical Settings, or disturbance) which cause fuel attributes to fall outside previously developed rulesets. Fuel attributes that are outside the previously developed rulesets are identified by the Toolbar where editing is done to address fuel rules. Once edits are completed and all pixels are covered by fuel rulesets the seven primary fuel grids are recreated through a function on the Toolbar.

Surface Fuels – LF 2012 Changes

The LFTFC tool was restructured with several enhancements during the production of LF 2012 fuels. The major enhancements were:

- Conversion from a standalone software package to an “add in” to the ArcMap program.
- Added sorting capabilities by number or name in fuel rulesets.
- Added functionality to only copy rules into an empty ruleset (no rules currently in the ruleset) so multiple rulesets can be copied into a single management unit without rules doubling or overlapping.

- Added functionality to the Pixels Left Behind error box to expand the window and identify missing or overlapping rules.
- Pixel counts get updated once from calculations at the beginning.

In areas that had been disturbed over the last ten years, a different set of fuel mapping rules were used that incorporated disturbance. These rules were generally based on the original fuel mapping rules used for undisturbed vegetation, but accounted for disturbance type, intensity, and the time since disturbance (TSD). Fuel mapping rules separate TSD into two categories, or time steps: 0-5 years and 6-10 years post-disturbance. The only exceptions to these categories were in geographic areas with very prolific vegetation growth such as the Southeastern U.S. and Hawaii. In such areas, the time steps were 0-3 years and 4-10 years post-disturbance. For each time step, one FBFM13, one FBFM40, and one CFFDRS (where applicable) class was assigned to represent the surface fuel characteristic for the period. Generally, the first step was visualized as a full growing season and the second step was seven years post disturbance. The transitions of surface fuel models in disturbed areas were assigned by the LF team and then sent to regional experts for review and editing. In the case of LF 2012 CONUS production almost all fuel rules for surface fuel models were copied from the LF 2010 rulesets. Some editing of surface fuel rules occurred due to disturbances that had not been covered in the previous version. A much smaller set of surface fuel model rules required adjustments due to vegetation changes in lifeform, EVT, EVC, and EVH.

Canopy Fuels

Canopy Base Height: Regression Tree Analysis Method

The primary focus for updating CBH mapping in LF 2012 was to develop a regression tree modeling process using canopy fuel characteristics. Similar processes were implemented in previous LF versions and focused on different cover/height groupings. Although this method performed well, it proved somewhat cumbersome to develop and tedious to update. In an attempt to streamline the process, reduce processing time, and simplify updates, an RTA approach was implemented, leveraging the FVS FIA-plot analysis (Figure 20). Utilizing the FVS outputs an RTA was performed for each LF vegetation type (and associated sub-groupings) based on associated canopy characteristics (cover/height). Analysis was batched using the R statistical software package (R Core Team, 2012) and resulted in a CBH assignment equation for each vegetation type. Prior to implementation, comparisons were made against previous LF versions by testing performance using Nexus 2.1 (Scott, 2014).

In areas that had been disturbed over the last ten years, values for FCC, FCH, and CBD were recalculated using the post-disturbance EVT, EVC, and EVH. The change in CBH attributes due to disturbance were modeled through FVS and then modelled through the same RTA process for each disturbance type, severity, and TSD. The CBH data layers were updated by leveraging these disturbance type, severity, and time-step specific RTA-CBH equations.

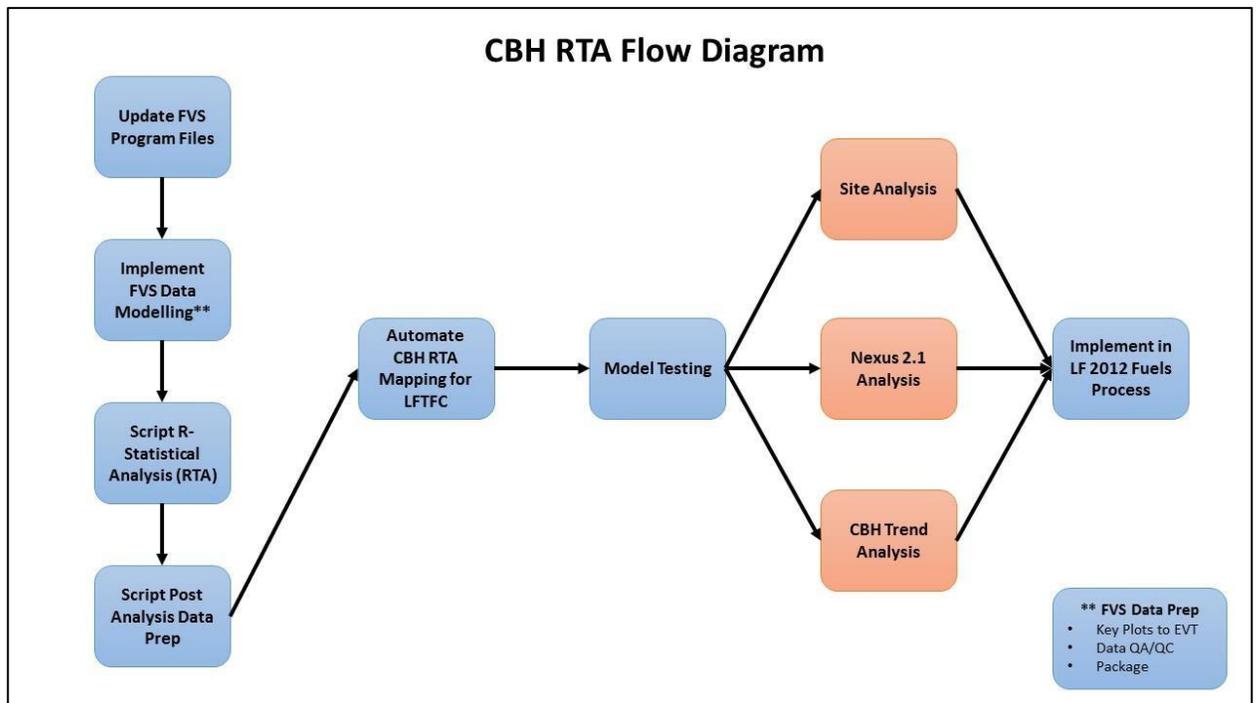


Figure 20. Flow diagram of the CBH RTA process.

Canopy Bulk Density: Potential Fire Behavior

The CBD data layer was developed through exploratory analysis of the LF plot data as part of LF National. The entire collection of LF plot data compiled for the western U.S. was statistically analyzed to search for relationships between the plot level variables and CBD. A Generalized Linear Model was developed that expresses the relationship between CBD, FCC, FCH, and EVT (Reeves and others, 2009). For LF 2012 the updated EVT data was used to recalculate CBD.

LF 2010 was developed and then used for LF 2012 following the same process described below. In order to evaluate surface and canopy fuel layers as inputs to fire modeling simulations, a spatial variant of the Nexus 2.1 fire behavior modeling software (Scott, 2014) was used to produce gridded fire behavior outputs for all of CONUS. First, the FLAMMAP model (Finney, 2006) was used to create conditioned fuel moisture grids for each geographic area based on topographic units and location of the nearest Remote Automated Weather Station (RAWS). The fire weather data for each area were generated from the RAWS data using the Fire Family Plus (FFP, Bradshaw and McCormick, 2000) software. The fire weather data generated from FFP include the following Nexus inputs: fuel moisture file, weather file, wind file, 20-ft wind speed, and fuel moisture conditioning period. FFP was used to generate the fire weather data from the 90th percentile fine fuel moistures for a five-day precipitation-free period within the active fire season combined with wind speed. Proximity to the RAWS location was used to weight the effect each station had on each pixel's weather information. These data provided the Fuel Moisture Condition grid for the spatial Nexus simulations. Other inputs were LF 2012 fuel data (FBFM40, CBH, CBD, FCC, and FCH) and slope. Nexus 2.1 outputs

included: crown fraction burned, crowning index, effective mid-flame wind speed, flame length, fire type, standard fire type, rate of spread state, and torching index.

Results: CONUS

Surface Fuels

The distribution of FBFM40 for the entire CONUS are shown in Table 7. The number of acres in each FBFM40 class, as mapped in LF 2010 and LF 2012, were compared. For each FBFM40 class, the percent changes relative to the LF 2012 product were also compared. This comparison showed the large scale effects of refinements that were made in the LF 2012 existing vegetation product by mapping different shrub and herb cover classes using the normalized data. The percent difference, in most cases, was due to disturbed areas that occurred between LF 2010 and LF 2012. In these disturbed areas, a different set of fuel mapping rules that incorporate disturbance were used. Only minor changes to the surface fuels data occurred.

Potential Fire Behavior

In order to evaluate surface and canopy fuel layers as inputs to the fire modeling simulations, a spatial variant of the Nexus 2.1 (Scott, 2014) fire behavior modeling software was used. Table 8 shows the results of this modeling exercise for the SW GeoArea in terms of "Fire Type," one of the outputs predicted in the model. Fire Type represents the landscape in terms of areas with no fire activity, fire in non-forest vegetation, surface fire in forest vegetation, passive crown fire in forest vegetation, conditional crown fire in forest vegetation, and active crown fire in forest vegetation. Table 8 compares hectares for each Fire Type from LF 2008, LF 2010, and LF 2012. This comparison showed the large scale effects of refinements that were made in the LF 2012 canopy base height product, as well as differences due to area that was disturbed between LF 2008, LF 2010, and LF 2012.

Table 7. FBFM40* percent change from LF 2010 to LF 2012 for CONUS.

FBFM40	LF 2010 Acres	LF 2012 Acres	% Difference	FBFM40	LF 2010 Acres	LF 2012 Acres	% Difference
NB1	75,956,081	76,975,110	1.3%	SH5	19,506,279	22,401,920	12.9%
NB2	400,540	429,153	6.7%	SH6	1,627,427	1,589,111	--2.4%
NB3	270,995,698	277,255,692	2.3%	SH7	13,907,701	15,243,818	8.7%
NB8	107,307,339	107,324,580	0.02%	SH8	638,626	609,191	--4.8%
NB9	45,444,984	47,446,703	4.2%	SH9	2,261,521	2,443,764	7.4%
GR1	149,942,986	120,324,580	--24.6%	TU1	44,622,291	45,385,008	1.7%
GR2	380,180,099	386,045,928	1.5%	TU2	10,148,645	10,055,531	--0.9%
GR3	40,575,310	41,656,933	2.6%	TU3	13,793,647	13,567,108	--1.7%
GR4	7,699,071	9,743,322	21%	TU5	49,715,777	48,502,894	--2.5%
GR5	14,908,803	15,999,936	6.8%	TL1	10,919,184	7,163,904	--5.2
GR6	5,770,382	5,852,976	1.4%	TL2	103,336,713	102,487,388	--0.8%
GR7	2,638,549	2,112,647	--24.9%	TL3	39,399,323	39,280,313	--0.3%
GR8	7,384,389	7,391,582	0.1%	TL4	4,541,657	4,500,429	--0.9%
GS1	63,858,962	83,057,688	23.1%	TL5	18,101,591	18,006,659	--0.5%
GS2	180,035,194	177,559,034	--1.4%	TL6	199,597,548	194,458,801	--2.6%
GS3	4,138,879	4,378,959	5.5%	TL7	1,535,584	1,498,495	--2.5%
GS4	88,919	94,369	5.8%	TL8	17,895,856	17,370,163	--3.0%
SH1	33,396,116	35,599,963	6.2%	TL9	7,767,014	7,945,984	2.2%
SH2	28,673,313	26,194,069	--9.5%	SB1	28,145	214,775	86.9%
SH3	13,831,328	14,240,251	2.9%	SB2	43,407	52,172	16.8%
SH4	4,201,237	4,353,033	3.5%	SB3	13,339	15,523	14.0%

*See Appendix for the FBFM40 fuel model abbreviations and corresponding definitions.

Table 8. SW GeoArea Fire Type Comparison between LF 2010 and LF 2012

Fire Type	LF 2008 Hectares	LF 2008 % of Area	LF 2010 Hectares	LF 2010 % of Area	LF 2012 Hectares	LF 2012 % of Area
No Fire	20,201,843	13.3%	21,928,855	14.5%	23,143,286	15.3%
Surface Fire Non Forest	89,453,297	59.1%	88,805,717	58.7%	87,734,065	58.0%
Surface Fire Forest	11,058,063	7.3%	12,805,400	8.5%	10,586,573	7.0%
Passive Crowning	13,412,814	8.9%	11,880,008	7.9%	14,097,642	9.3%
Conditional Crowning	2,755,922	1.8%	3,216,146	2.1%	2,395,252	1.6%
Active Crowning	14,462,679	9.6%	12,668,447	8.4%	13,352,809	8.8%

Results: Alaska Surface Fuels

There was little change in the Alaska surface fuels from LF 2010 to LF 2012. Table 9 displays the FBFM40 for the Alaska GeoArea that experienced significant change between LF 2010 and LF 2012, and covered significant area. Only the FBFM40 models identified with significant change in the Alaska GeoArea are represented in (Table 9). Significant change for this assessment was considered to be $\geq 1.0\%$.

Table 9. FBFM40 covering $\geq 1.0\%$ of Alaska GeoArea and experiencing $\geq 1.0\%$ change LF 2010 to LF 2012.

FBFM40	Hectares 2010	% Area 2010	Hectares 2012	% Area 2012	% Difference 2010 to 2012
GR1	20,108,618	12.6%	50,307,608	12.7%	1.2%
GS1	7,895,247	5.0%	8,007,501	5.0%	1.4%
SH2	10,757,612	6.7%	10,955,406	6.8%	1.8%
TU1	12,276,494	7.6%	12,550,047	7.8%	2.2%
TU2	4,273,520	2.6%	3,928,314	2.4%	--8.8%
TU4	12,389,688	7.7%	11,820,891	7.4%	--4.8%
TU5	9,868,387	6.2%	9,591,479	6.0%	--2.9%
TL2	3,466,841	2.2%	3,432,885	2.1%	--1.0%

The most noteworthy changes between LF 2010 and LF 2012 fuels layers were the introduction of additional canopy cover classes in the forested areas, which had an effect on CBH. The changes in CBH resulted in areas where crown fire activity occurs. For example, in the Timber Understory (TU) fuel models that would easily support crown fire (TU2, TU3, TU4, TU5) there was a 3.5% increase in areas with a CBH < 1.0 meter from LF 2010 to LF 2012. This allowed for fire to transition into the tree crowns and initiate crown fire activity in the fire spread models.

FARSITE Fire Behavior Analysis

To evaluate the relative differences between LF fuel datasets when used for fire behavior modeling, several analyses were conducted with the Fire Area Simulator (FARSITE; Finney, 2004) fire behavior modeling system. In each analysis, an actual wildfire event from 2014 was identified and the burning conditions (wind, weather, etc.) were replicated as closely as possible to the conditions at the time of the fire. Each fire was then modeled using LF 2010 fuel and topographic data, then modeled again using LF 2012 fuel and topographic data, keeping the burning conditions constant in order to capture the differences in modeled fire behavior based only on the changes to LF data. The goal of these analyses was not to re-create the actual fire perimeter, rather to use that perimeter as a calibration guide and then show the differences in modeled fire behavior between the two LF datasets.

Assayi Lake Fire, New Mexico, 2014

The Assayi Lake Fire ignited in mid-afternoon (1530 hrs) on June 13, 2014. The first two days it exhibited little spread. The incident report on June 14, 2014 showed a perimeter of 443 acres. By morning (0800 hrs) of June 17, the fire spread to 8,434 acres. The site conditions were extremely dry with a National Fire Danger Rating System Energy Release Component (an indicator of dryness in this type of ecosystem) well above the 90th percentile. The fire spread through a variety of vegetation types, but was primarily carried through the tree crowns in the form of torching, spotting, and active crown fire. This assessment attempted to replicate the spread of June 16, with fuels layers from LF 2010 and LF 2012 and the most available environmental condition information.

Fuels and Vegetation

The surface fuels and vegetation between the two LF versions were similar. An estimate of the amounts of area by EVT and surface fuel model are described below in Table 10.

Table 10. Comparison of vegetation and fuel types for LF 2010 and LF 2012 for the Assayi Lake Fire area.

EVT 2010	EVT 2012	FBFM40 2010	FBFM40 2012	% of Area
2054 So. Rocky Mtn. Ponderosa Pine Woodland	2054 So. Rocky Mtn. Ponderosa Pine Woodland	TL8	TL8	75%
2052 So. Rocky Mtn. Mesic Montane Mixed Conifer Forest	2052 So. Rocky Mtn. Mesic Montane Mixed Conifer Forest	TL8	TL8	10%
2159 Rocky Mtn. Riparian Systems	2159 Rocky Mtn. Riparian Systems	TU1	TU1	5%
2164 Rocky Mtn. Wetland- Herbaceous	2164 Rocky Mtn. Wetland- Herbaceous	GR2	GR4	5%
2001 Inter Mtn. Basins Sparsely Vegetated Systems	2219 Inter Mtn. Basins Sparsely Vegetated Systems II	NB9	NB9	5%

Environmental Conditions at the Time of the Fire

The Washington Pass RAWS was located just over a mile north of the fires edge. The observations from this station for June 16 recorded fuel moistures in the single digits during daytime hours, indicating very low fuel moisture. Fuel moistures of 3, 4, 5, 20, and 60% were applied to all fuel models in the FARSITE simulations for one hour, ten hour, hundred hour, live herbaceous, and live woody fuels respectively. Fuel moisture was also used to develop the burn period for the simulations. The burn period was set at 10:00 am on June 16, when the one hour fuel moisture lowered to 3% and continued until 10:00 pm when it went up to 4%.

Wind and weather files were produced from the RAWS data which recorded no rainfall during that period and single digit relative humidity (7%) on the day of high fire spread. The ten minute average windspeeds for the burn period ranged from 10 to 15 mph. A summary of the model simulation inputs is shown in Table 11, and a depiction of the fire area and perimeter is shown in Figure 21.

Table 11. Simulation inputs for the Assayi Lake Fire, NM, 2014.

Fuel Moisture	1 hour	10 hour	100 hour	Herbaceous	Woody
	3%	4%	5%	20%	60%
Weather	Max temp	Min RH	Wind low	Wind high	
	71°F	7%	10 mph	15 mph	
Burn Period	Start	Stop			
	1000 hours	2200 hours			

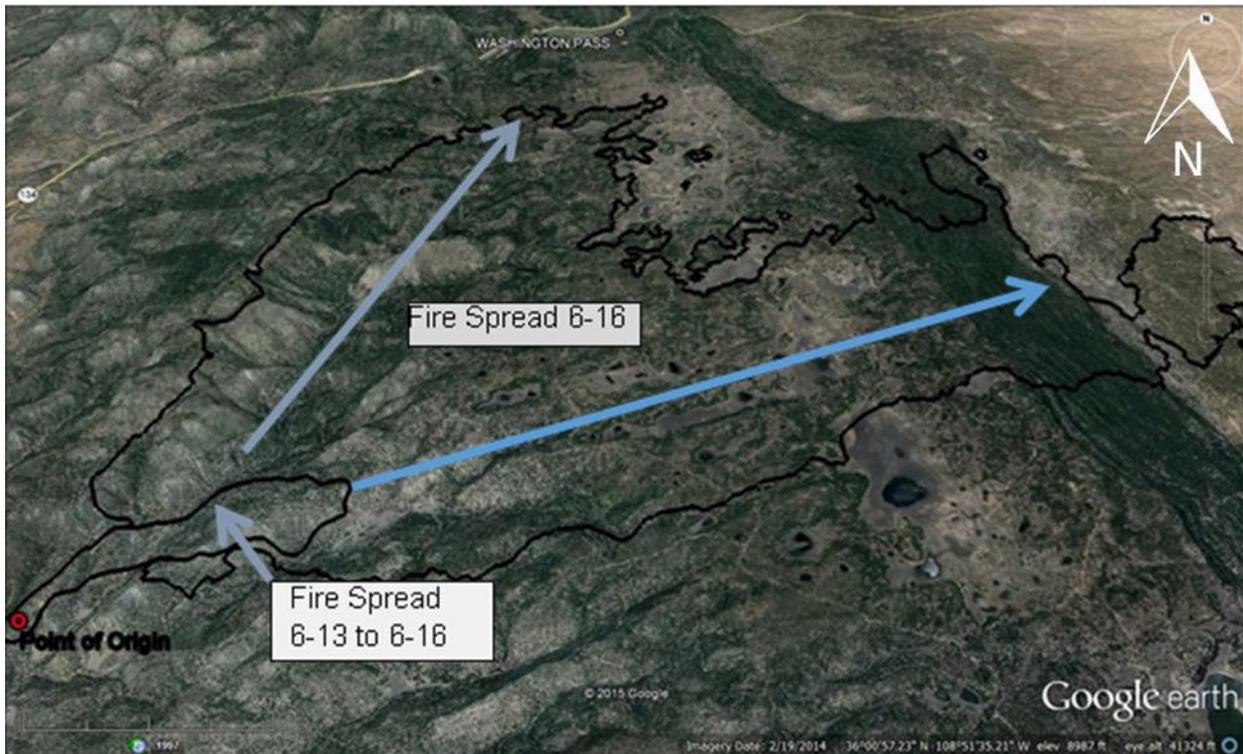


Figure 21. The 2014 Assayi Lake Fire perimeter (outlined in black) and area.

FARSITE Modeling

Model specific inputs included:

- Default resolution (in feet) of fire expansion bands, which were then grouped into 4 hour bands
- Crown fire enabled with the Scott-Reinhardt method
- Spotting and spot growth enabled with ignition frequency set at 2.0%
- Fuel moisture conditioning from June 13, 2014 until ignition on morning (0838 hrs) of June 16 with the burn period beginning mid-morning (1038 hrs)

- RAWs wind directions were adjusted by 10 to 20 degrees from west to southwest to emulate up canyon effect
- Ignition line is from infrared perimeter of June 14 (0838 hrs)

Results

The LF 2012 simulation showed a landscape that was similar to the actual fire spread, as compared to the LF 2010 simulation (Figure 22 & 23). The amount of torching and active crowning in LF 2012 was increased due to slightly lower canopy base heights of the trees in fuel model TL8, which covered much of the area. The 10 minute average wind speeds from RAWs were used in the wind file of the simulation; the velocity changed slightly hour to hour on the date of fire spread. Most of the area that had canopy base heights less than 0.6 meters exhibited some crown fire behavior, either torching or active crowning. Areas that had CBH 0.7 through 0.9 meters showed crown fire activity dependent on slope, actual wind speed for the time the area burned, and fire activity in adjacent pixels. Most of the area with CBH of 1.0 meter and above remained a surface fire. The percent area of each landscape in each CBH range is shown in Table 12 and the percent area of each landscape in each Fire Type class is shown in Table 13.

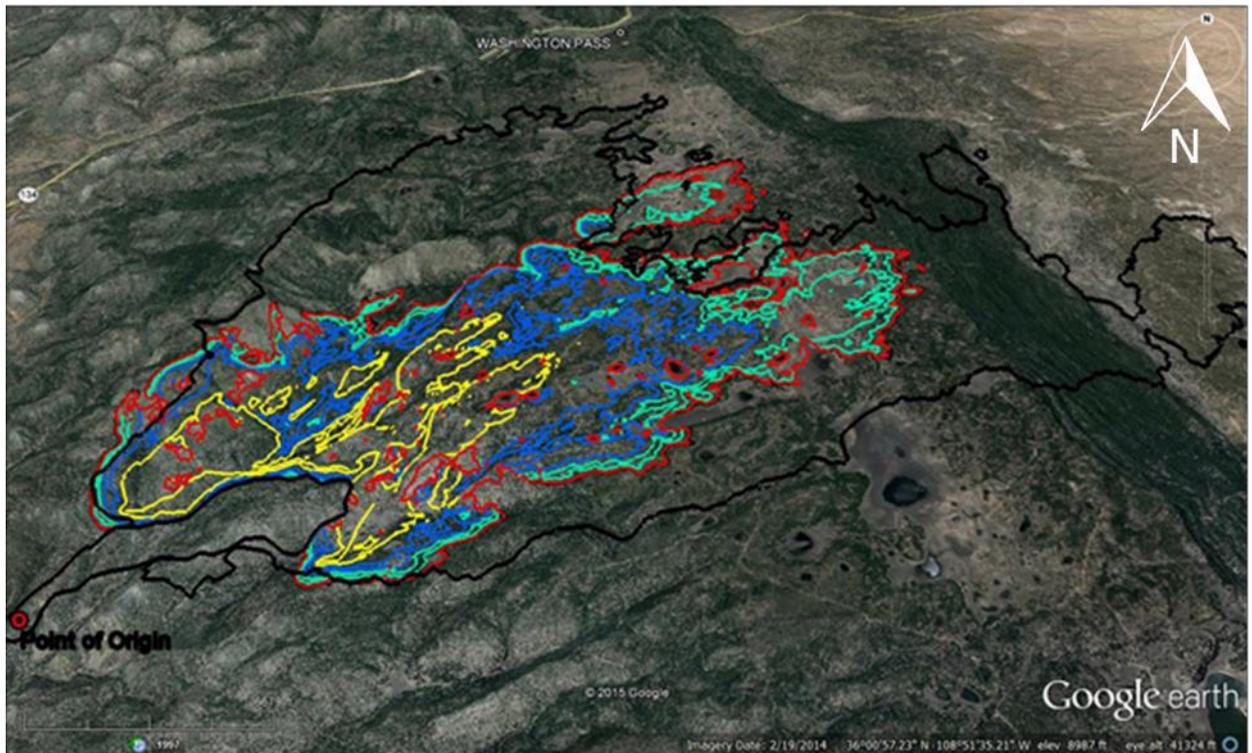


Figure 22. LF 2010 Landscape Simulation June 16, 2014.

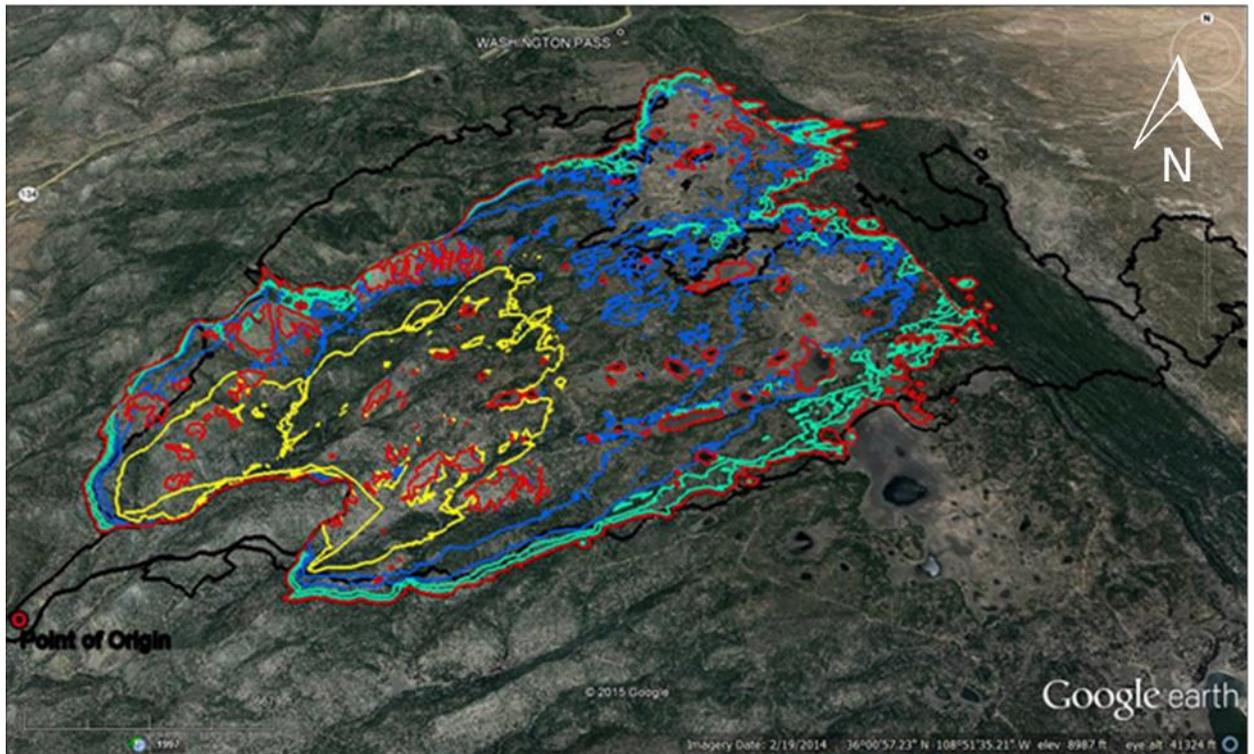


Figure 23. LF 2012 Landscape Simulation June 16, 2014.

Table 12. Percent Area by CBH Class within Fire Perimeter

LF Version	Non-Forest	CBH ≤ 0.6 meters	CBH ≥ 0.7 < 1.0 meters	CBH ≥ 1.0 meters
LF 2010	9.3%	1.3%	31.4%	58%
LF 2012	9.3%	57.7%	17%	16%

Table 13. Percent Area by Fire Type within the Fire Perimeter

LF Version	No Fire Activity	Surface Fire	Passive Crowning	Active Crowning
LF 2010	3%	62.7%	27%	7.2%
LF 2012	3%	17.9%	63%	16.1%

Without crowning and torching, the actual fire spread could not be predicted accurately. The surface fire rate of spread for this model (fuel model TL8), considering slope and the RAWS 10 minute average wind speed, was 3 to 10 chains per hour. LF 2012 canopy data attempted to address the issue with timber litter models (slow rates of spread and low flame lengths) by assigning a CBH that would allow crown fire activity in stands that had historically demonstrated that type of fire behavior.

790 Fire, Oregon 2014

The 790 fire burned in southwest Oregon between late August and early September of 2014. While it did not display large spread events it was important to look at the type of fire spread in relation to the LF fuel attributes and the actual fire perimeters. In the western parts of Washington and Oregon, nearly a quarter of burnable areas were represented by FBFM40 TL5, a full third of the area had timber type fuel models in the LF 2012 data. TL5 is described as:

“High Load Conifer Litter; the primary carrier of fire in TL5 is high load conifer litter, light slash, or mortality fuel. Spread rate is low, Flame Length is low” (Scott, Burgan 2005).

Where this fuel model occurs in the LF 2010 and LF 2012 data throughout the west are often in areas that do exhibit stand replacement and mixed severity fire regimes. This is particularly true in western Oregon and Washington.

The 790 fire burned in the Sky Lakes Wilderness area and had limited suppression action. The fire appeared to move sporadically with several days of small fire growth (surface fire), then days with relatively large fire growth (torching, crowning). In the LF 2010 and LF 2012 fuels data, half of the fire area that burned from August 3, 2014 through August 29, 2014 burned through TL5. An overview of the fire area and perimeters is shown in Figure 24.

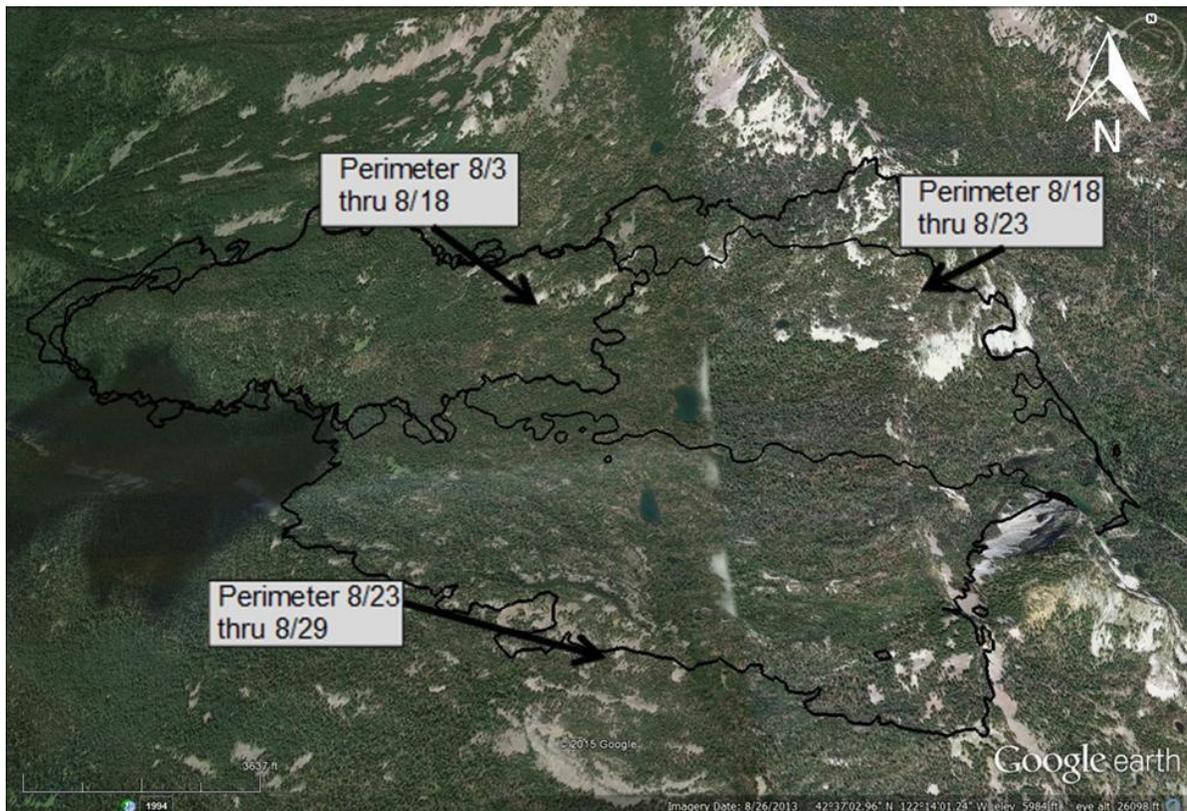


Figure 24. 790 fire perimeters August 18, 2014 through August 29, 2014.

The surface fuels and vegetation types between the two versions of LF data were the same throughout the fire area. The area was comprised of LF data listed in Table 14.

Table 14. LF vegetation and fuels within 790 fire perimeter.

EVT and EVC	FBFM40	Percent
2041 No. Pacific Mountain Hemlock Forest (closed)	TL5	45%
2041 No. Pacific Mountain Hemlock Forest (open)	TU1	12%
2032 Mediterranean California Red Fir Forest (open)	TL4	20%
2032 California Red Fir 2032 Mediterranean Forest (closed)	TL8	8%
2028 Mediterranean California Mesic Mixed Conifer Forest	TU5	8%
Water and Barren	NB8 & 9	5%

The fire spread rate was tracked through infrared detection during the entire month of August. In Figure 24, the first perimeter (August 3 through 18) exhibited fairly slow fire growth rates. This area was where all the TU5 occurred. The first infrared detection occurred on August 3, and was reported at 209 acres. From August 3 through 18, a total of 333 acres burned. Most of the growth was surface fire spread with the exception of August 11, when 60% of those acres burned in one spread event (an average of 24 acres growth for each 2 day period). From August 21, through 29, the amount of fire spread each day is shown in Table 15.

Table 15. 709 Fire spread rates from the IR.

August 21, 2014	103 acres	August 26, 2014	254 acres
August 23, 2014	548 acres	August 27, 2014	155 acres
August 24, 2014	119 acres	August 29, 2014	165 acres
August 25, 2014	374 acres		

The acres that burned from August 21 through 29 were not from surface spread. With FBFM40 TL5, TL4, TU1, and TL7, unusually high wind speeds would have had to occur in order to account for the daily fire spread during this time. Crowning (passive or active) would need to have occurred in the fire spread model for these FBFM40's to emulate the acres of fire spread.

The FLAMMAP program (Finney 2006) using the Scott-Reinhardt crown fire method, was used in this assessment to demonstrate the difference in fire type for the 790 fire area, based on LF 2010 and LF 2012 fuel data. Fuel moisture and wind

speed information for the assessment were from the Zimmerman RAWS, located north and west of the fire area. Wind speeds at this RAWS were light. The following Figures 25 through 29 depict the wind speed and corresponding fire type for the fire area in the two versions of LF fuels data.

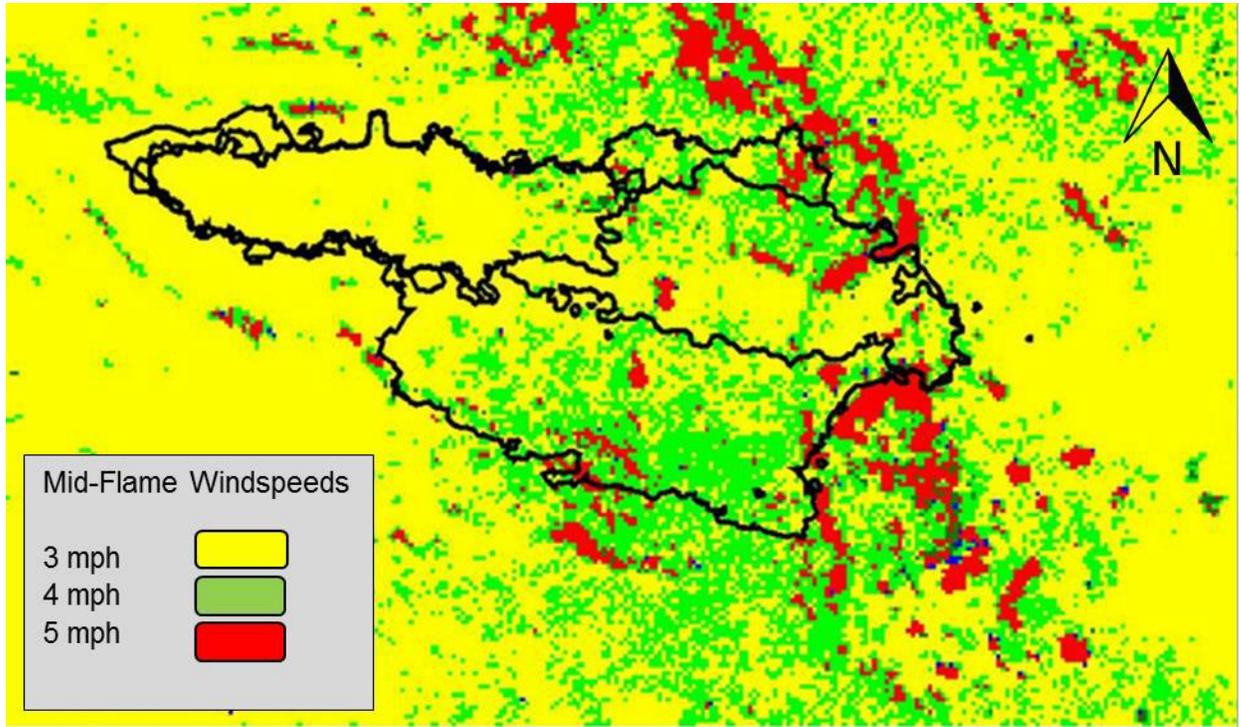


Figure 25. The 790 Fire with light mid-flame wind speed.

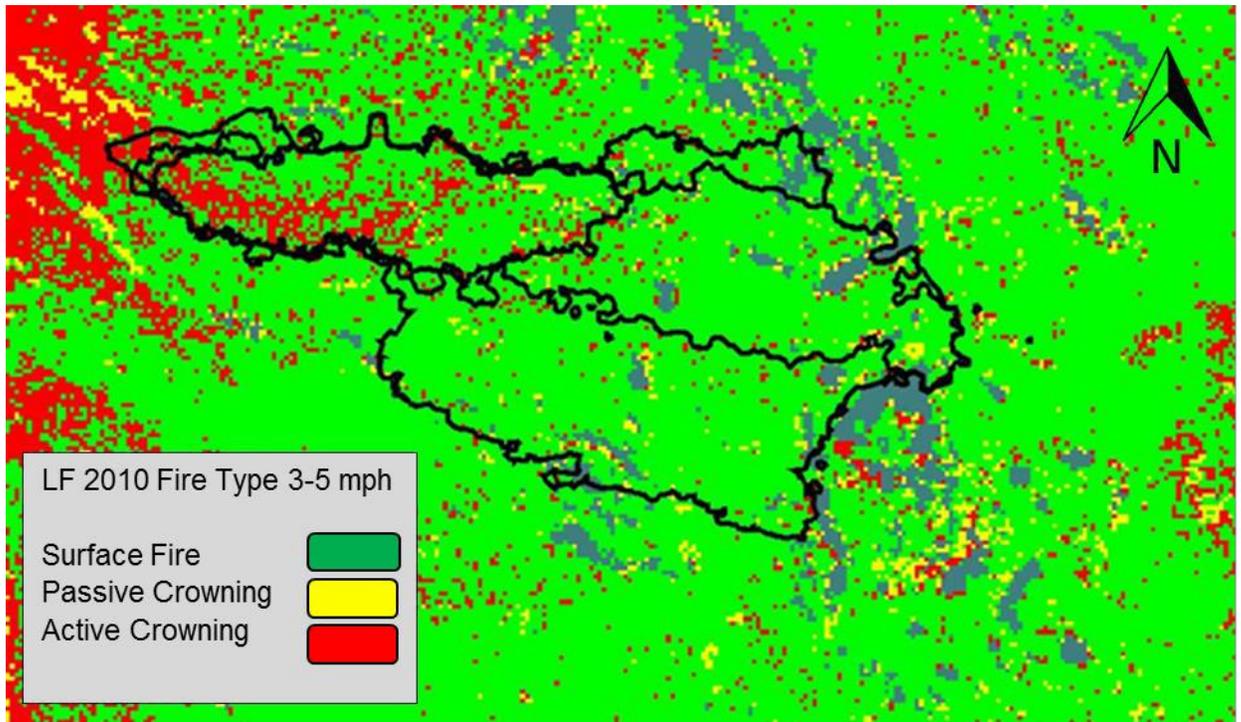


Figure 26. LF 2010 fire type with wind speeds of 3 to 5 mph.

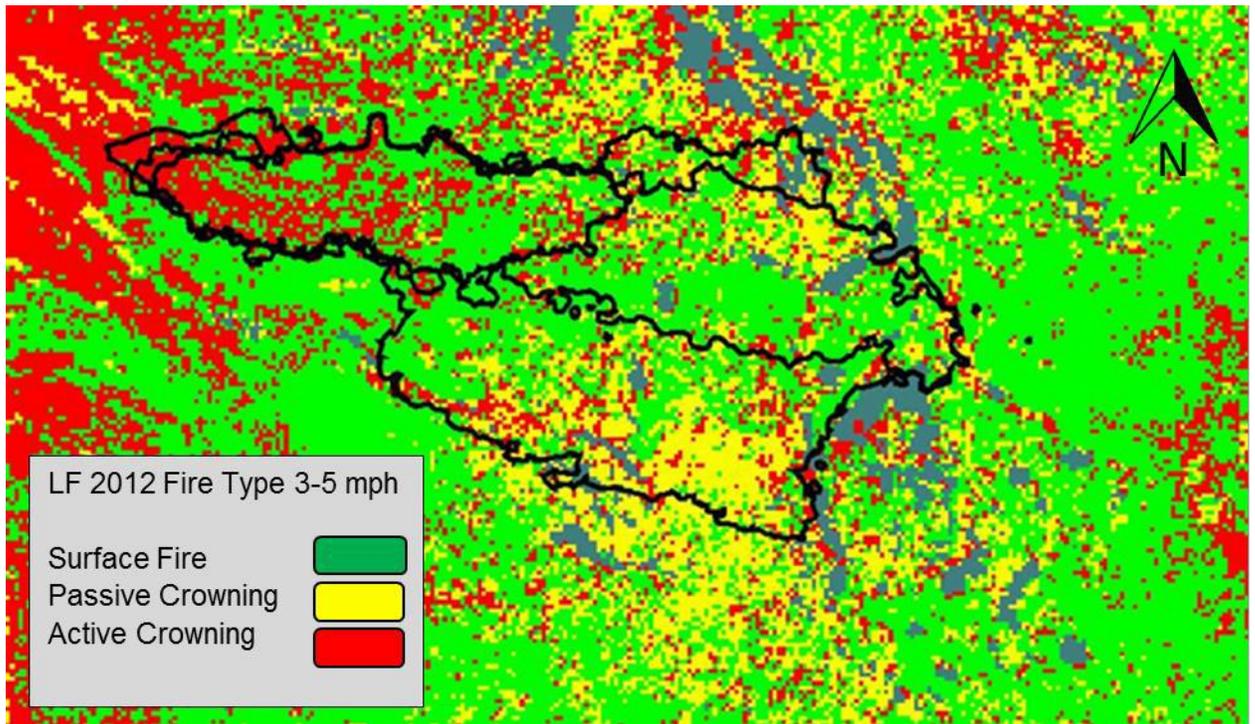


Figure 27. LF 2012 fire type with wind speeds of 3 to 5 mph.

A slight increase in mid-flame wind speed to 4 to 6 mph had the following results (Figures 28 and 29).

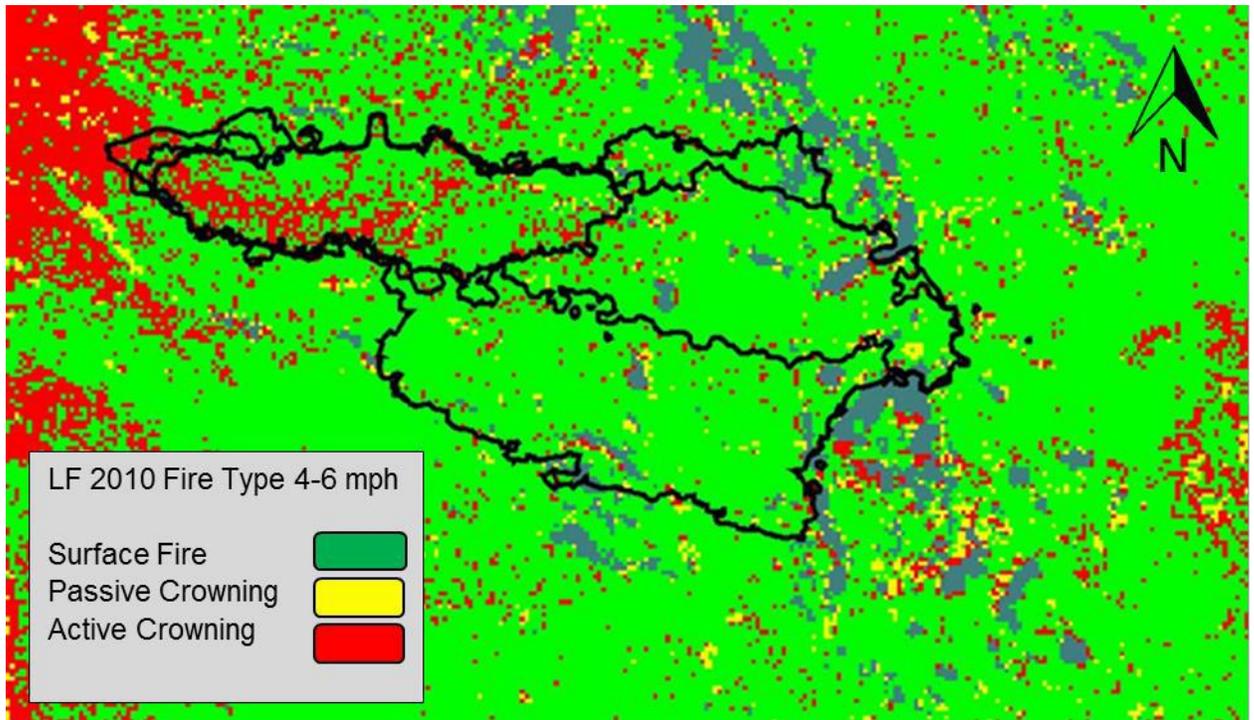


Figure 28. LF 2010 fire type with wind speeds of 4 to 6 mph.

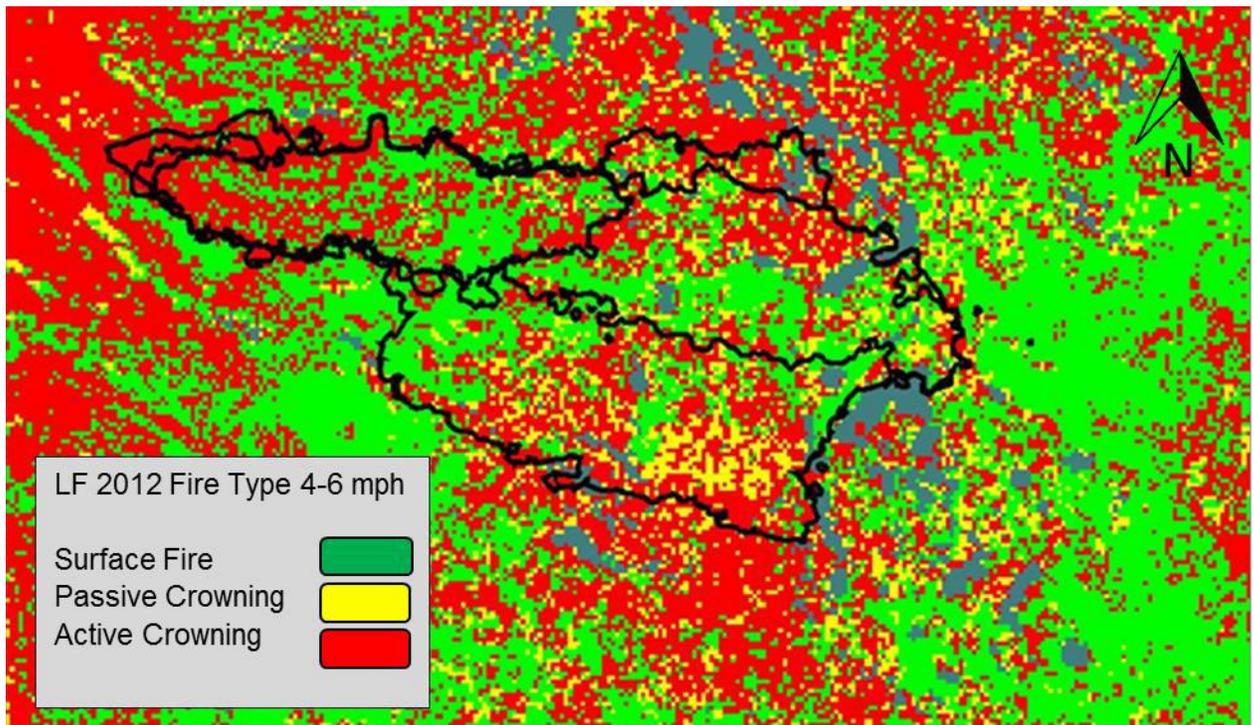


Figure 29. LF 2012 fire type with wind speeds of 4 to 6 mph.

Table 16 shows the percent of the fire area in each fire type using the different wind speeds.

Table 16. Percent of 790 fire area in each fire type class by mid-flame wind speed.

Fire Type	LF 2010/ 3 to 5 mph	LF 2012 / 3 to 5 mph	LF 2010 / 4 to 6 mph	LF 2012 / 4 to 6 mph
No fire	4.6%	4.6%	4.6%	4.6%
Surface Fire	81.8%	49.1%	81.4%	37.5%
Passive Crowning	3.3%	23.4%	2.8%	13.8%
Active Crowning	10.4%	22.9%	11.1%	44.1%

Results

The main difference in the fuels layers between LF 2010 and LF 2012 was the CBH attribute. The CBH allowed the surface fire to transition into the tree crown. This provided additional spread due to spotting and larger flame lengths in the passive stage and increased rate of spread in the active stage. Due to the low flame lengths simulated, the CBH would have needed to be below 1.0 meters to allow for torching and crowning in the fire models at relatively low wind speeds. With the additional torching and crowning simulated using the LF 2012 fuels data and 3 to 5 mph mid-flame wind speed, the model could meet the actual acres produced for the days of larger spread events.

The TL fuel models showed a specific challenge for the fire models in terms of crowning under less than extreme environmental conditions. They are prevalent in many forested areas that are in stand replacement and mixed severity fire regimes. In order to replicate known fire behaviors for these sites in the current models, CBH is a determining variable. The LF 2012 RTA method for calculating CBH is an improvement over the previous methods used. This is detailed in Table 17.

Table 17. The percent of the 790 fire area in each CBH range between LF 2010 and LF 2012 for fuel models TL5 and TL4.

CBH (meters)	LF 2010 TL4	LF 2012 TL4	LF 2010 TL5	LF 2012 TL5
≥ 1.0	77%	0	99%	10%
> 0.7 < 1.0	0	3%	0	2%
≤ 0.6	23%	97%	1%	88%

4.5 REFERENCES

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5 ADMINISTRATIVE CLOSURE

The following is a list of GeoArea Specific approvals for release:

South Central

Delivered for Approval: July 31, 2014

Approved for Release: September 29, 2014

North Central

Delivered for Approval: August 7, 2014

Approved for Release: September 29, 2014

Southwest

Delivered for Approval: September 5, 2014

Approved for Release: September 29, 2014

Northwest

Delivered for Approval: October 23, 2014

Approved for Release: December 19, 2014

Northeast

Delivered for Approval: October 23, 2014

Approved for Release: December 19, 2014

Southeast

Delivered for Approval: December 15, 2014

Approved for Release: December 19, 2014

Alaska

Delivered for Approval: April 9, 2015

Approved for Release: April 27, 2015

Hawaii

Delivered for Approval: April 24, 2015

Approved for Release: April 27, 2015

Appendix

The LF FBFM40 model abbreviations with their descriptions.

NB1 = Urban

NB2 = Snow/Ice

NB3 = Agriculture

NB8 = Water

NB9 = Barren

GR1 = Short, sparse dry climate grass is short, naturally or heavy grazing, predicted rate of fire spread and flame length low

GR2 = Low load, dry climate grass primarily grass with some small amounts of fine, dead fuel, any shrubs do not affect fire behavior

GR3 = Low load, very coarse, humid climate grass continuous, coarse humid climate grass, any shrubs do not affect fire behavior

GR4 = Moderate load, dry climate grass, continuous, dry climate grass, fuelbed depth about 2 feet

GR5 = Low load, humid climate grass, fuelbed depth is about 1-2 feet

GR6 = Moderate load, continuous humid climate grass, not so coarse as GR5

GR7 = High load, continuous dry climate grass, grass is about 3 feet high

GR8 = High load, very coarse, continuous, humid climate grass, spread rate and flame length may be extreme if grass is fully cured

GS1 = Low load, dry climate grass-shrub shrub about 1 foot high, grass load low, spread rate moderate and flame length low

GS2 = Moderate load, dry climate grass-shrub, shrubs are 1-3 feet high, grass load moderate, spread rate high, and flame length is moderate

GS3 = Moderate load, humid climate grass-shrub, moderate grass/shrub load, grass/shrub depth is less than 2 feet, spread rate is high and flame length is moderate

GS4 = High load, humid climate grass-shrub, heavy grass/shrub load, depth is greater than 2 feet, spread rate is high and flame length very high

SH1 = Low load dry climate shrub, woody shrubs and shrub litter, fuelbed depth about 1 foot, may be some grass, spread rate and flame low

SH2 = Moderate load dry climate shrub, woody shrubs and shrub litter, fuelbed depth about 1 foot, no grass, spread rate and flame low

SH3 = Moderate load, humid climate shrub, woody shrubs and shrub litter, possible pine overstory, fuelbed depth 2-3 feet, spread rate and flame low

SH4 = Low load, humid climate timber shrub, woody shrubs and shrub litter, low to moderate load, possible pine overstory, fuelbed depth about 3 feet, spread rate high and flame moderate

SH5 = High load, humid climate grass-shrub combined, heavy load with depth greater than 2 feet, spread rate and flame very high

SH6 = Low load, humid climate shrub, woody shrubs and shrub litter, dense shrubs, little or no herbaceous fuel, depth about 2 feet, spread rate and flame high

SH7 = Very high load, dry climate shrub, woody shrubs and shrub litter, very heavy shrub load, depth 4-6 feet, spread rate somewhat lower than SH6 and flame very high

SH8 = High load, humid climate shrub, woody shrubs and shrub litter, dense shrubs, little or no herbaceous fuel, depth about 3 feet, spread rate and flame high

SH9 = Very high load, humid climate shrub, woody shrubs and shrub litter, dense finely branched shrubs with fine dead fuel, 4-6 feet tall, herbaceous may be present, spread rate and flame high

TU1 = Low load dry climate timber grass shrub, low load of grass and/or shrub with litter, spread rate and flame low

TU2 = Moderate load, humid climate timber-shrub, moderate litter load with some shrub, spread rate moderate and flame low

TU3 = Moderate load, humid climate timber grass shrub, moderate forest litter with some grass and shrub, spread rate high and flame moderate

TU4 = Dwarf conifer with understory, short conifer trees with grass or moss understory, spread rate and flame moderate

TU5 = Very high load, dry climate shrub, heavy forest litter with shrub or small tree understory, spread rate and flame moderate

TL1 = Low load compact conifer litter, compact forest litter, light to moderate load, 1-2 inches deep, may represent a recent burn, spread rate and flame low

TL2 = Low load broadleaf litter, broadleaf, hardwood litter, spread rate and flame low

TL3 = Moderate load conifer litter, moderate load conifer litter, light load of coarse fuels, spread rate and flame low

TL4 = Small downed logs moderate load of fine litter and coarse fuels, small diameter downed logs, spread rate and flame low

TL5 = High load conifer litter, light slash or dead fuel, spread rate and flame low

TL6 = Moderate load broadleaf litter, spread rate and flame moderate

TL7 = Large downed logs, heavy load forest litter, larger diameter downed logs, spread rate and flame low

TL8 = Long needle litter, moderate load long needle pine litter, may have small amounts of herbaceous fuel, spread rate moderate and flame low

TL9 = Very high load broadleaf litter, may be heavy needle drape, spread rate and flame moderate

SB1 = Low load activity fuel, light dead and down activity fuel, fine fuel is 10-20 t/ac, 1-3 inches in diameter, depth < 1 foot, spread rate moderate and flame low

SB2 = Moderate load activity fuel or low load blowdown, 7-12 t/ac, 0-3 inch diameter class, depth about 1 foot, blowdown scattered with many still standing, spread rate and flame low

SB3 = High load activity fuel or moderate load blowdown, heavy dead down activity fuel or moderate blowdown, 7-12t/ac, 0-.25 inch diameter class, depth > 1 foot, blowdown moderate, spread rate and flame high