LANDFIRE Modeling Dynamic Fuels with an Index System Comprehensive Plan

Background

The Landscape Fire and Resource Management Planning Tools (LANDFIRE) Program, with the assistance of numerous regional specialists, has assigned fuel attributes to all lands across the United States for the purpose of predicting wildland fire behavior. Various methodologies have been employed and several data versions have been created over the past 10+ years. The basis for the entire suite of fuel attributes, both surface and canopy fuel depictions, began with the allocation of the surface fuel model. The surface fuel model is determined through a set of rules that incorporate potential and existing vegetation type and structure of existing vegetation. The assigned fuel model is intended to represent average burning conditions and were calibrated during a series of regional workshops held in 2007-2008. In current fire behavior modeling systems, the surface fuel model is the primary factor in determining fire behavior and spread extent whether spread is along the surface, in the canopy, or carried on by spotting.

Reviews were held with fire and fuels specialists after several fire seasons where LANDFIRE fuels data were being used for supporting fire planning and incident response. Repeated discussions were raised about the idea of special fuel situations that were not addressed in the static fuel layers. Changes in inter- and intra-annual moisture and other conditions routinely affect fuel availability in different regions and on different time scales, generally shorter than the biennial updates currently made to the LANDFIRE data suite. To address this issue, the LANDFIRE team began working on defining a strategy and prototype project for mapping dynamic fuels. The goal was to identify indices with threshold values that quantify the range of fire environment conditions and/or special fuel situations, existing in an area, which could be used to vary fuel attributes in order to appropriately describe fire behavior for dynamic situations. It was expected that different indices and temporal scales would need to be utilized in different regions based on the local drivers of changing fuel conditions. This strategy became known as the Modeling Dynamic Fuels with an Index System (MoD-FIS) effort within LANDFIRE.

Dynamic fuels concepts and strategies

Two prototype study areas were chosen to demonstrate the viability of using two distinctly different indices to indicate conditions where fuel attributes may deviate from their average conditions. These two areas, with their distinctive indices, encompassed a range in fire behavior characteristics that could occur on specific sites, along with special fuel situations and some fuel model assignments that were inadequately calibrated. The resultant changes in fuel attributes were based on indicators for the specific fire season in which the data were produced. The two prototypes were:

- In the Southeast U.S., MoD-FIS was developed by LANDFIRE based on drought levels and coordinated for use within the Wildland Fire Decision Support System (WFDSS).

MoD-FIS in the Southeast is based on principles of the National Fire Danger Rating System (Revision of 1988) for additional fuel availability (weight and depth) due to drought as expressed by the Keetch-Byram Drought Index (KBDI). These data have been used to model current and historic fires in the Southeastern U.S. with improved results over using static fuels layers (details available in http://www.landfire.gov/downloadfile.php?file=LF_DBFD_in_SE_US_Dec2015.pdf).

- In the Great Basin and Southwest U.S., the MoD-FIS system was developed in response to seasonal fuel changes. This situation is brought on by varying levels of precipitation, affecting the resultant herbaceous production and growing season trends from year to year. This system correlates 10 years of 30 meter resolution Landsat Normalized Difference Vegetation Index (NDVI) to LANDFIRE herbaceous and shrub Existing Vegetation Cover (EVC). The corresponding relationship is then used to evaluate current year NDVI to the average and maximum of the 10 year period in terms of herbaceous and shrub cover. From this evaluation, surface fuel models are assigned in the herbaceous areas based on the maximum NDVI for the current growing season. In addition to varying the fuel models in a particular area, this process also successfully transitions previously non-burnable areas to burnable and previously burnable areas to non-burnable based on the seasonal herbaceous production of those areas. The Southwest/Great Basin MoD-FIS has completed its second season of proof of concept and has been used to model current year fires with good results (documentation forthcoming).

The experience gained in developing these two prototypes, with their differing methodologies, has demonstrated that planning and research into other indices or procedures are necessary to properly employ MoD-FIS across the country. MoD-FIS can be considered as analogous to a book title where each different component is another chapter in the book. The first chapter is the drought-based methods in the Southeastern U.S. and is currently available operationally. The fine fuels-based methods in the Great Basin and Southwest U.S. is the second chapter. The team has completed proof of concept testing for this effort and it is nearly ready to be made operational. The following discussion will display the areas covered by these two chapters and outline potential steps for subsequent chapters.

Development of MoD-FIS across the United States

Southeast United States

As mentioned above, MoD-FIS data in the Southeast U.S. is available for use within WFDSS. A request was received from the WFDSS team to consider expanding this effort to include additional areas into the current KBDI climatology and fuel model transition table. Several steps have been taken in order to address this request, including:

- Review of the climatology in five map zones on the northern border of the current project area (fig 1),
- Review of the Existing Vegetation Type (EVT) in these five zones to ensure the fuel model transitions match the current table, make revisions to the table accordingly, and
- Review transition table changes with disturbance transition logic.

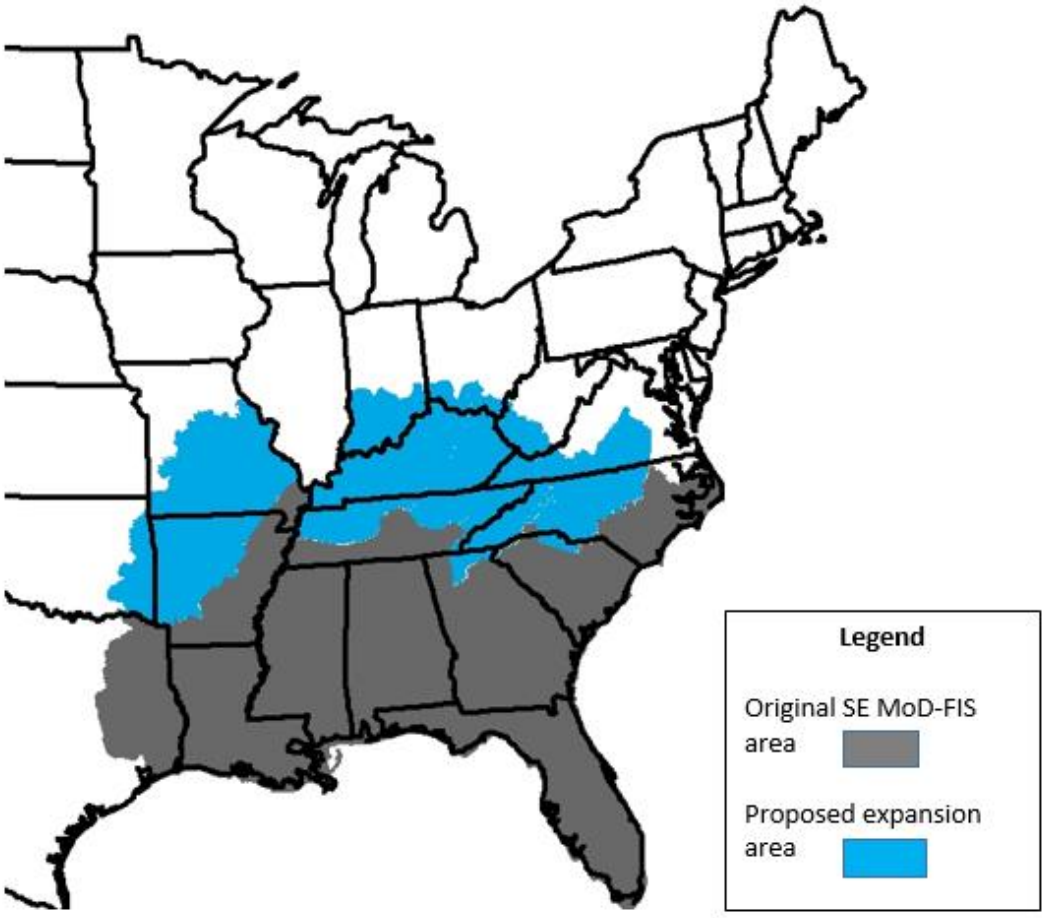

Figure 1: Existing study area for the Southeast MoD-FIS and proposed expansion area.

Several steps remain in order to complete this request and assess other adjacent areas for possible inclusion into this process:

- Re-structure tables in the LANDFIRE Total Fuels Change toolbar database to match the new transition table, and
- Evaluate zones 32, 35, and 43 (west of current area) for possible inclusion.

Currently, the Wildland Fire Assessment System (WFAS) produces a KBDI grid with the current drought values and WFDSS intersects those values with the fuel model grids generated by the LANDFIRE transitions table. This method of delivery for use by fire and fuel specialists has proven to work well and will continue into the future. In addition, LANDFIRE will work towards synchronizing production of Southeast MoD-FIS data with WFDSS and replicate distribution of these layers from the LANDFIRE web-based Data Distribution System (DDS). This will enable users to discover and interact with these data outside of the WFDSS environment and expose new users to the data. LANDFIRE will also make the information and tools available from their website to allow users to modify the drought-based MoD-FIS process and customize dynamic fuels for their specific areas.

Updates to the fuel model transition table will be carried on through the processes developed by LANDFIRE with inputs from WFDSS and other users as to their effectiveness. Several potential improvements to the Southeast MoD-FIS system have been identified. These improvements range in feasibility from short range ideas where necessary data are already available, to improvements that will require much more data acquisition and study to develop. For example some of the short term concepts that will be important to incorporate into the Southeast system are:

- Consideration of leaf-off versus leaf-on conditions using minimum NDVI in the deciduous forested areas and the resultant changes to the fire behavior, and
- Better evaluation of where residual table water may be at the surface even during high and extreme drought periods by incorporating better elevation data, such as from lidar, for areas with muck soils.

One of the longer term improvement ideas is to investigate alternative geographic divisions for developing index thresholds. Currently both prototype areas use LANDFIRE map zones for their analysis areas. For indices that are used in a percentile ranking that develop a threshold value for a variance in fuel availability, a climatology analysis based on the indices location may be useful to scale the values relative to their severity. The geographic area determined for index analysis would be determined by the climatology of the area based on the index being used. These short- and long-term improvements will be investigated as time allows.

Great Basin and Southwest United States

The Great Basin/Southwest MoD-FIS process has several components to it and is currently producing prototype data that are being evaluated by local and regional fuels experts within the areas being mapped. The data for the arid non-forested lands of the Western U.S. are based on LANDFIRE attributes of vegetation cover and height in herbaceous and shrublands. Currently, the LANDFIRE team is completing the third year of prototype processing for these data products. Much of the data processing steps have been automated including generation of the maximum NDVI image composites, conversion of NDVI to herbaceous and shrub cover, and assignment of surface fuel models based on these attributes.

Additional development is occurring to incorporate the Spatial and Temporal Adaptive Reflectance Fusion Model (StarFM) process for creating synthetic Landsat imagery based on 250m resolution Moderate Resolution Imaging Spectroradiometer (MODIS) data to fill in gaps where Landsat data are not available for the desired time period. The Great Basin/Southwest MoD-FIS process is quasi-operational with Landsat and MODIS imagery and processing capabilities available through the U.S. Geological Survey (USGS). Validation efforts have included modeling current and historical fires using the current LANDFIRE fuels data and the MoD-FIS data which have showed an overall improvement in the ability of the MoD-FIS fuels data to represent actual fire behavior over the static fuels data. LANDFIRE intends to begin public distribution of these prototype products during the 2017 fire season.

The products will be considered in a provisional or “beta” status and will be made available in order to facilitate broader analysis and review of them. Full documentation of the algorithms and processes used to develop these products will be provided on the LANDFIRE website to support these reviews.

The next step in development of the fine fuel-based MoD-FIS process will be to expand into additional non-forested areas of the Northwest U.S. and Great Plains regions (fig 2). Time series analysis of Landsat NDVI over the expanded areas will be completed in order to develop adjusted relationships between NDVI and vegetation cover for the new areas. Once the new relationships are developed and the desired time periods of data production defined, the expanded MoD-FIS process will use the existing operational system to produce data for the entire area. Additionally, annual review and adjustments to the fuel model assignment rules will continue with local fuels experts to ensure these data are accurately representing fuel conditions.

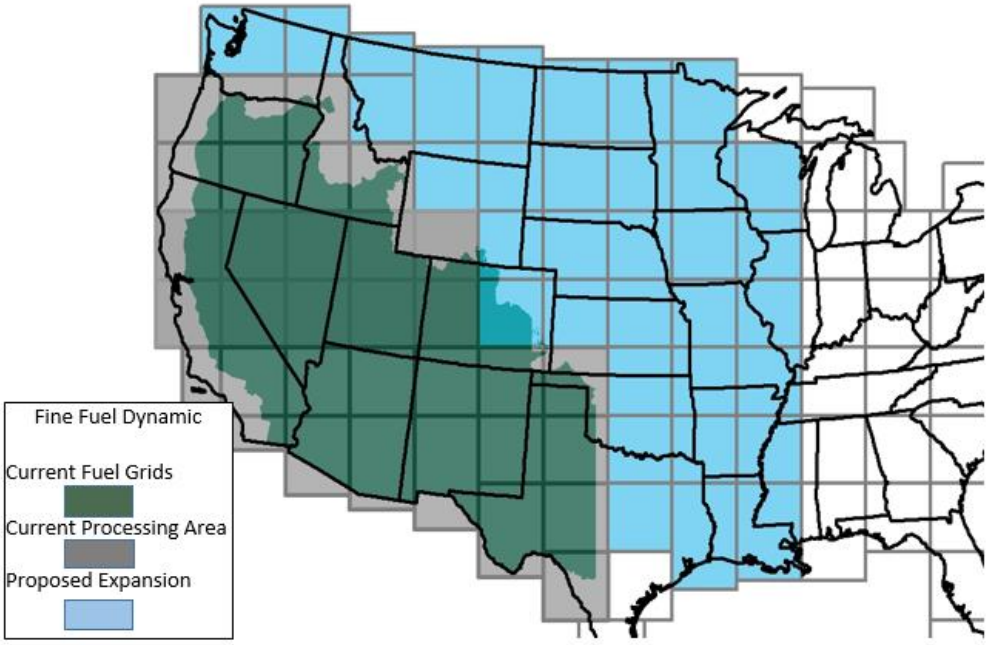

Figure 2: Current extent of LANDFIRE MoD-FIS processing for Great Basin/Southwest in green overlaid with LANDFIRE image tile boundaries in grey. The proposed expansion of MoD-FIS processing for additional non-forested lands is shown in blue.

The remaining steps necessary to bring the Great Basin/Southwest MoD-FIS process into a full operational state include modifying the LANDFIRE web pages and DDS to add documentation and distribution capabilities for these datasets. Since these data will be generated annually, or up to several times annually for some areas, distribution of these data will be easily accomplished through LANDFIRE's existing DDS. This will allow users to access these data through familiar interfaces, such as our interactive website, LANDFIRE Data Access Tool, and web services while the program maintains responsibility for production and distribution. Additionally, these data could easily be provided to WFDSS for ingestion into their system following the same process used for other LANDFIRE static layers. Once operational, LANDFIRE will offer these data to WFDSS for incorporation if they so choose.

Future refinement of the MoD-FIS concept in these areas is expected through synergies with a NASA-sponsored research project aimed at quantifying biomass dynamics across the Great Basin and relating these to changes in fuels. To date, the LANDFIRE team has successfully integrated

the StarFM process discussed above. The actual StarFM algorithm existed previously, but the NASA fuels project developed an efficient and expedient process for generating StarFM products. Other data products from the NASA effort are forthcoming but not ready for evaluation at this time. Specifically, models have been generated to map herbaceous biomass over time using Landsat imagery. Current work is focused on developing shrubland biomass models and extending the models to StarFM generated imagery. Work is also ongoing to integrate the data and models with the Rangeland Vegetation Simulator program that is currently under development. Once additional products become available, the LANDFIRE team will evaluate the data and processes to determine their utility in expanding and refining the MoD-FIS process.

Great Lakes states and Northeast United States

Several index systems have been studied to assess a climatological relationship for the Great Lakes States and Northeast U.S. areas. The KBDI process was investigated using climatological data from 42 Remote Automated Weather Stations across the region. The results of this study showed that the KBDI can provide adequate discrimination of fuel conditions, but different sets of breakpoints between low, moderate, and high drought conditions will need to be established for different parts of the area. Table 1 shows the current KBDI breakpoints for the Southeast U.S. and proposed breakpoints for other regions based on the climatology analysis. These breakpoints can easily be integrated within the existing MoD-FIS system to extend its application through much of the eastern U.S.

Table 1: KBDI breakpoints for different regions of the eastern U.S.

Southeast		Mid-Atlantic and Interior		New England and Lake States	
Class	KBDI	Class	KBDI	Class	KBDI
No drought	0 - 200	No drought	0 - 100	No drought	0 - 75
Low drought	201-400	Low drought	101 - 250	Low drought	76 - 150
Moderate drought	401-600	Moderate drought	251 - 400	Moderate drought	151 - 250
High drought	601-800	High drought	400 +	High drought	250 +

In addition to the KBDI process, the Build Up Index (BUI), part of the Canadian Fire Danger Rating System, and the Energy Release Component – Fuel Model G (ERCG), part of the US National Fire Danger Rating System, were evaluated for their suitability in discriminating varying levels of fuels conditions. An analysis of the 90th percentile BUI and ERCG, using weather data from across the region, showed that while some correlation existed with ERCG index, both indices inadequately represented seasonal conditions. Large variations in index values at the 90th percentile across the area indicated that basing fuel assignments on either of these indices for the entire region would likely result in significant variability and inconsistent fuels assignments.

The LANDFIRE team plans to move ahead with expanding the KBDI-based approach into the Great Lakes and Northeast U.S. areas. Additional work is needed to expand MoD-FIS into these regions, including development of the fuel model assignments based on drought level, generation of prototype products using the existing MoD-FIS system, and conducting reviews with local and regional fuels experts including modeling of current and historical fires to ensure fuel model assignments accurately represent the seasonal conditions of fuels in these areas. Delivery of these data will be integrated

within WFDSS, as with the Southeast MoD-FIS data, using the KBDI grids operationally produced by WFAS, and added to the LANDFIRE DDS. As with the Southeast MoD-FIS, additional analysis will be undertaken in the future to examine the geographic boundaries used in analyzing the climatology and assigning fuel models.

Based on the results of the local reviews and performance of the KBDI-based MoD-FIS algorithm in these areas, other methods may need to be considered. Preliminary analyses show that the current plan has a reasonable probability of success, but if review of the prototype products show that this method is not acceptable, alternative approaches will be considered and this plan will be updated accordingly.

Western United States Forested Areas

In the dryer climates west of the Mississippi River, ERCG is a more useful indicator of seasonal and multi-season drying than KBDI. A daily ERCG map is available from WFAS which will enable fuel maps to be periodically generated that better represent current conditions. Little work has been accomplished towards this effort thus far. A full collection of climatology data from weather stations across the region will be obtained and analyzed to identify suitable breakpoints for assigning updated surface fuel models. Geographic stratification, including elevation, climatic zones, or other factors, will be evaluated and implemented as needed, based on the climatology analysis. Class breakpoints will then be developed separately for each defined area. Fuel model transitions will be assigned based on the ERCG class and the subsequent fuel layers will then undergo review and calibration by local and regional fuels experts. The resultant system will be processed by LANDFIRE and distributed through the existing DDS. In addition, the data will be offered to WFDSS for incorporation if they so choose.

As with the development of MoD-FIS in the Great Lakes and Northeast U.S., alternative methods are available. This plan indicates what is considered the most promising methodology investigated to date, but other approaches will be considered as needed based on development and review of prototype products. This plan will be updated in the future as further development and results become available.

Alaska

Several indices have been evaluated for their utility in mapping seasonal fuels for the state of Alaska. A ten year time series of 90th percentile KBDI values was analyzed over several weather stations in Alaska and shared with local fuels experts. The range and variation of KBDI values over this time period were found to be inadequate for discriminating fuel conditions over time. The BUI was also evaluated but was found to contain very wide variance across the different weather stations in Alaska, making it unsuitable for a regional modeling approach. The BUI was reassessed using Meso-West data (a cooperative project that provides access to current and archive weather observations across the nation) but again the variation appeared to be too great to provide a reasonable geographic correlation. Lastly, ERCG was evaluated and provided a more reasonable correlation across the state of Alaska, though still may not be the optimal solution for this process. Continued discussion with local experts is planned, though feedback thus far seems to indicate there may not be an optimal index for the entire state and other options may need to be explored.

Additionally, there are no operational index products currently being created that depict the tested indices (KBDI, ERCG, etc.) across the state. Any implementation using a defined index will also require the mapping of that index on a regular basis. As further discussions are held with local experts, the mapping of necessary indices will additionally be considered and planned. As further development takes place and more definitive methods are prototyped, this plan will be updated accordingly.

Hawai'i and Insular Areas

So far, there has been no work to define seasonal fuels in insular areas. Planning for this work will require connecting with local experts to determine the level of seasonality and special fuel conditions that warrant being captured and what would be required to adequately account for seasonal fuel dynamics. This effort will likely be considerably different than all other parts of the MoD-FIS effort given the unique vegetation, environmental conditions, and fuel characteristics of the region. For example, fuels in these areas likely respond more to wet and dry seasonal patterns that will require monitoring of precipitation and/or fuel moisture to quantify expected changes in fire behavior fuel models. LANDFIRE recognizes the importance of seasonal fuel products in these areas, and will continue to investigate and determine potential methods for accomplishing these products as time allows.

Nationwide data

As all the various components of MoD-FIS are developed and operationalized across the country, a comprehensive seamless dataset will be produced at a defined temporal scale and distributed through various mechanisms (e.g. LANDFIRE DDS, WFDSS). Once operational, the components and overall system will require a small amount of maintenance to continue supporting them. This includes obtaining or generating the required imagery and derived products (NDVI, KBDI, etc.) to determine the current index values needed for each region, apply the fuel model assignments to the index values to generate the updated fuel model products, ensure the generated products are reasonable, and make the data available for distribution. Much of these processes are already automated and further automation will be accomplished as other components are defined. The last two steps, controlling the data quality and making the data available, will require ongoing levels of effort commensurate with the temporal frequency of the regional products. Image processing methods are adapted from existing systems used in generating disturbance products for LANDFIRE updates, and will be refined in sync with those efforts. Other processes will be run initially independent of comprehensive LANDFIRE updates, as the temporal requirements differ. As updated fuels data are produced, the MoD-FIS base layers will incorporate the most recent versions of the fuels data to remain in sync with the static layers. If future LANDFIRE updates are able to be accomplished on an annual basis, the timing would sync with the MoD-FIS requirements in some regions and a gradual blending of static and dynamic fuels data will be made possible. This merging of efforts to where the dynamic fuels become the base LANDFIRE product is the eventual goal but requires the components in all other regions to first be developed, validated, and made operational.

An annual, or semi-annual review of climatology breaks and fuel model assignments will be accomplished, comparing fire behavior modeling experiences using the MoD-FIS data to identify

potential shortcomings. Modifications and improvements will then be made to the different components to address these issues and other feedback received from data users. Innovations to the MoD-FIS methodologies will also be periodically reviewed in light of newly available data sources, research results, and algorithms. A coordinated review effort and research coordination with other scientific programs will enable the LANDFIRE program to further develop and innovate the MoD-FIS components and products to ensure the best available science and data sources are incorporated. LANDFIRE plans to work with programs such as the Joint Fire Sciences Program, NASA, USGS fire science, and other groups, as opportunities arise, to collaborate on fuels research beneficial to the goals of each program. This type of review and coordination will need to be incorporated into the LANDFIRE program schedule and priorities to ensure its success alongside other LANDFIRE production and development activities. In this way, once operational, the MoD-FIS system will continue to be supported and provide users with current, consistent, and accessible data for supporting real-time fire behavior modeling.

User support and review of MoD-FIS data

Support to users of MoD-FIS data will be provided through existing LANDFIRE support mechanisms, including the LANDFIRE help desk, website, documentation from various sources, and the LANDFIRE communications group. Complete documentation of individual components of MoD-FIS and overall connectivity of the different efforts across the country will be published to the LANDFIRE website and other outlets (e.g. scientific journal articles).

As significant progress is made, users will be kept informed through program communications channels, including website announcements, bulletins, postcards, and social media. Further attempts to reach users and communicate the status and availability of these products will be accomplished through webinars, conferences, and direct engagement with local and regional users. For questions related to MoD-FIS products or assistance in understanding, obtaining, and applying the data for different parts of the country, the LANDFIRE help desk will be equipped to provide this support, as it does for other aspects of the LANDFIRE program.

As additional MoD-FIS data are developed and provided, peer review of the algorithms, processes, and products is desired. LANDFIRE plans to release prototype products in different parts of the country as they are developed and approved for provisional release. Once available, LANDFIRE will communicate the product's availability with regional fire/fuels contacts and other interested users to solicit review and feedback of the data. This will be accomplished through existing LANDFIRE communications mechanisms including direct email, social media, the LANDFIRE product review website, the LANDFIRE homepage, and direct contact with interested parties.

Documentation of the methods and processes used to develop the data will be provided upon provisional release and used to facilitate review. As feedback is received, necessary modifications to the methods and data products will be made to address systematic issues and improve the utility of the data products. Once the products are deemed acceptable and of sufficient utility, they will be upgraded from provisional status to official LANDFIRE products.

Additional fuel model issues to be addressed through future improvements

A number of issues with the calibrated fuel model layer and other fuel attributes have been identified since their inception in the original LANDFIRE fuel layers:

- LANDFIRE encouraged regional specialists to assign fuel models based on the expected fire behavior for an average or typical fire season day, where fire environment conditions would neither be extreme nor innocuous.
- In some cases, more extreme conditions were represented in the calibrated data, accounting for when the most acres typically burn. This interpretation resulted in the inability to effectively model fire behavior under less than extreme conditions for those areas. In most areas around the country, the large majority of fire ignitions occur under low to moderate fire environment conditions, though the small portion of ignitions that occur during extreme conditions tend to burn the most acres. There is an increasing need for versatility in the ability to accurately model fires that burn in varying fire environment conditions. In some cases, portions of fires may have species, lifeforms, or environmental conditions that cause fires to burn extremely while other portions of the same fire may have species, lifeforms, or environmental conditions that burn less severely and may be used to achieve strategic management objectives.
- In other cases, less extreme conditions were represented so that the calibrated fuel models in those areas rely on fuel moisture and other fire environment elements to address the full range of fire behavior characteristics that the site can exhibit. In some instances, along with the additional fire behavior activity from crowning, the assigned fuel model can address the full range of fire behavior characteristics. In other instances, the fuel model assigned, in relation to the canopy attributes, falls short in the ability to represent the fire behavior characteristics under extreme conditions.
- This discrepancy in the interpretation of a “typical” fire season day, between ignitions and acres burned, resulted in problematic inconsistencies for national fire analyses. Adjustments to the data were required in different regions to normalize the expected fire environment across the country. Local analyses are also affected when boundaries exist within an analysis area and different calibrated rules are used in different portions of the area.
- Feedback received after the initial release of LANDFIRE National data indicated that very high Canopy Base Height (CBH) and very low Canopy Bulk Density (CBD) values were prevalent in the original LANDFIRE canopy fuel layers and these layers were subsequently updated to address the identified concerns. The calibrated surface fuel model layer for some geographic areas was developed with the original CBH and CBD values, with only the surface fuel models being edited during the calibration workshops. Other geographic areas had their calibration workshops after LANDFIRE had updated the canopy attributes. With the adjusted canopy attributes, some of the surface fuel models tended to over-predict crown fire activity in areas that were calibrated based on the original CBH and CBD values.
    - For more information on the canopy fuel layers updates, see

http://www.landfire.gov/geoareas_report.php and http://fireecologyjournal.org/docs/Journal/pdf/Volume09/Issue02/080.pdf.

- The calibrated surface fuel models did not take into account the additional rates of spread or spotting that occur when using the Scott & Reinhardt crown fire calculation method.

- LANDFIRE surface fuel models are ruleset based with EVT, EVC, and Existing Vegetation Height (EVH) being the primary elements, and the Biophysical Settings and Disturbance layers also utilized at times. LANDFIRE canopy fuel attributes are calculated primarily with information from EVT, EVC, EVH, and Disturbance. With this process, the calibrated rulesets that determine the surface fuel models are constant between versions of the data, but the vegetation layers that dictate where those fuel models exist on the landscape are updated with each successive version. The same is true for the calculation of canopy fuel attributes that change as a result of updated vegetation data. Further, the fire behavior characteristics of each version of surface and canopy fuels data are modeled and compared across data versions (i.e. LF 2008 to LF 2010 to LF 2012 to LF 2014) to check for consistency and areas of change. The vegetation characteristics are correlated back to specific versions and have little to no dependence on the vegetation of versions in between in terms of succession or regeneration (i.e. LF 2010 uses LF 2001 as a base for vegetation transition and does not consider LF 2008; LF 2014 vegetation relates back to LF 2010 and does not consider LF 2012). In order to best support fire behavior simulations, it is important that fuels data are available that are based on actual elements within the current fire environment rather than, or in addition to, successive changes in the vegetation layers which can impact both surface and canopy fuel components and may prohibit accurate modeling of more extreme fire conditions.

As part of the LANDFIRE remapping effort to produce new base maps of the LANDFIRE product suite and subsequent updates to the data, these issues will be investigated further and modifications to the data and processes are expected to address them. The feasibility of mapping fuels at several defined environment levels (e.g. high, medium, low burning conditions) is also being investigated as part of the LANDFIRE Remap. As additional components of MoD-FIS are developed, and these Remap ideas are considered, further integration of the static LANDFIRE fuels layers with the dynamic MoD-FIS layers may become possible.