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Modeling Dynamic Fuels with an Index System: fine fuels based process in the Great Basin and Southwest United States

Introduction

The LANDFIRE (LF) Program strives to produce consistent and relevant fire behavior fuel model grids for the United States (U.S.). While these models are relevant for predicting fire behavior, including spread and intensity, during average conditions, they often fall short during drought or seasonably dry conditions. In a continuing effort to improve the functionality and accuracy of the fuel products, LF has developed the Modeling Dynamic Fuels with an Index System (MoD-FIS) for different geographic areas of the U.S. This report documents the development, methodology, testing and results, and conclusion of the fine fuels based MoD-FIS process in the Great Basin and Southwest (GB/SW) U.S.

Background

The need to address seasonal variations of fine fuels (herbaceous and shrubs) in the GB/SW was made apparent by fire and fuels specialists at LF “After Action Reviews” and various other meetings. The notion that increases in winter and spring precipitation in these areas increases herbaceous production and leads to increased wildfire activity (once cured), has been an accepted principle used by the SW Predictive Services in determining fire season potential for a number of years. The GB/SW MoD-FIS was designed to determine whether sites in the GB/SW have an increase or deficit in herbaceous production compared to average conditions.

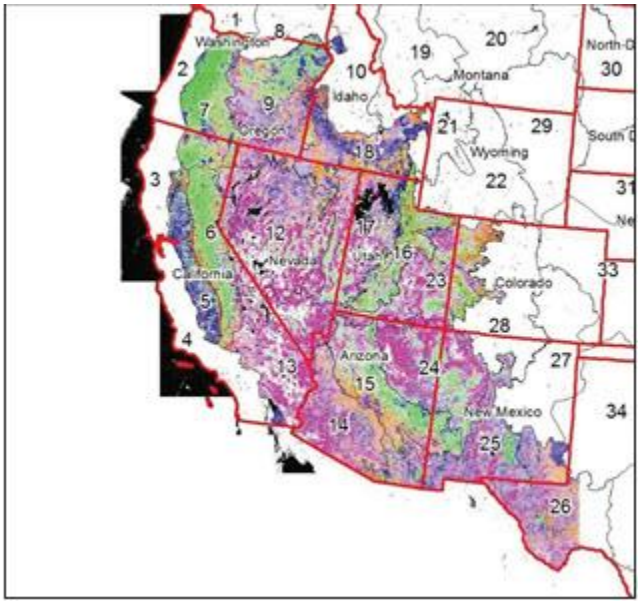

Figure 1: MoD-FIS prototype area in the Southwest U.S. (LF 2012 Existing Vegetation Cover map)

Methodology

The GB/SW MoD-FIS is based on the vegetation greenness values from the Landsat-based Normalized Differenced Vegetation Index (NDVI) and its relationship to LF Existing Vegetation Cover (EVC) for the herbaceous and shrub lifeforms. The current year NDVI values were compared to a ten year minimum, average, and maximum values calculated from the Web-Enabled Landsat Data (WELD; Roy et al., 2010) record. This 30 meter resolution data was the same scale as LF EVC and was temporally analyzed for the years 2003 through 2012. From this analysis, values that range from barren to sparse and then 10% cover classes for herbaceous pixels through 99% cover were calculated for minimum, average, and maximum NDVI. Average NDVI values were also calculated for all shrub pixels within the analysis area. Several key components that were developed within GB/SW MoD-FIS are described below to outline the workings of the system:

- A ten year (2003-2012) average NDVI value was calculated for each 30 m pixel within the analysis area which stretches from west Texas to southeast Washington (Figure 1).
    - The pixel average NDVI was combined with LF EVC and analyzed to calculate a weighted average NDVI value for each EVC cover class, by LF map zone.
    - A standard deviation test was developed for the average of all the map zones within the analysis area (14 map zones).
    - The cover classes for each zone were put to the standard deviation test. If a cover class in a particular map zone was greater or less than one standard deviation it was omitted as an outlier (see Appendix B).
    - A median value was then calculated for the accepted map zones values from the standard deviation test.
    - The median value was used in a regression equation, which was applied to NDVI to get a percentage of cover. The percent cover was then re-classed through LF cover classifications (see Appendix B).
    - Fire Behavior Fuel Model (FBFM) 40 fuel models were developed for the NDVI predicted increase and/or decrease in herbaceous fuel.
    - The fuel rulesets for change in fuel model by predicted herbaceous cover were developed in grid format for the 10 year average, ten year maximum, and the year 2012 for testing.
    - Shrub cover mapping
    - Shrub cover mapping was conducted using the 10 year average NDVI rather than current year NDVI so change from year to year in the shrub lifeform will not be apparent.
    - 10 to 19% shrub cover was added to the herbaceous lifeform cover class
    - With such sparse shrubs per pixel it was felt that if the reflectance picked up significant vegetation it would be herbaceous and that herbaceous vegetation would determine the fire behavior not the shrubs within those pixels.
    - Since NDVI is not zone specific, seam lines that had previously existed in the LF data do not exist in this product.
- Barren and sparse
    - The median NDVI linear model is used to determine the breakpoints for barren

and sparse and percent cover from the collected NDVI.

- Sparse breakpoints are at 0.1 to 9% cover and is given a burnable fuel model (GR1). Areas with less than 0.1% cover are Barren

- Areas that have not produced vegetation, represented in the maximum NDVI dataset, for the entire 10 year WELD record are suggested to be mapped as barren in future versions of the LANDFIRE data. Additional areas added to analysis
  - Due to input received from SW Geographic Area Coordination Center and the Texas Forest Service personnel, additional areas were included into the analysis which cover eastern New Mexico and more of the panhandle and western Texas. These additional areas are currently being mapped with the same relationship developed for the original 14 map zones.

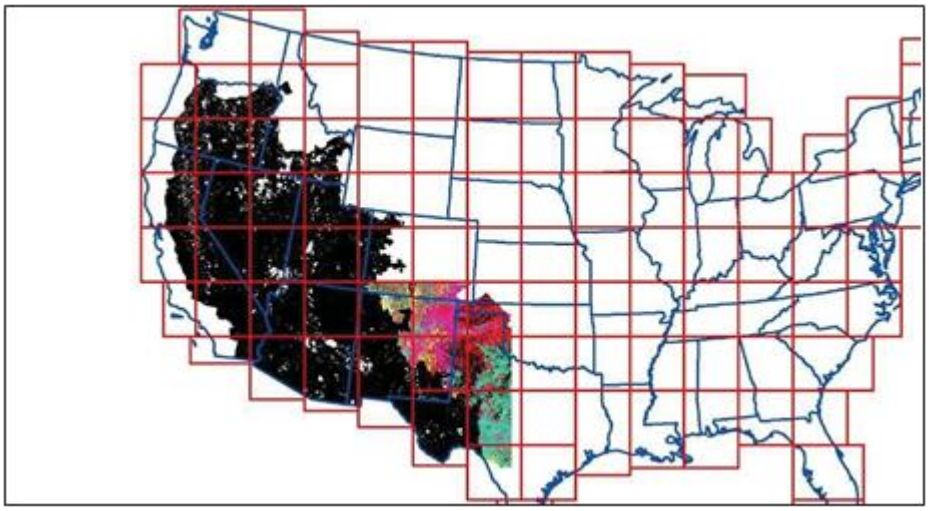

Figure 2: MoD-FIS prototype area in the Southwest U.S. (black back-fill) with additional area added (LF 2012 EVC map)

Current year NDVI values for the late season of 2014 and the spring season of 2015 were derived from Landsat 8 (L8) images where possible. When L8 images are not available, due to clouds or other reasons, substitution is made with Landsat 7 data first, and any remaining data gaps are removed using focal filled data. Later tests in 2016 also utilized synthetic Landsat images derived from Moderate Resolution Imaging Spectroradiometer data, through the Spatial and Temporal Adaptive Reflectance Fusion Model, which showed promising results, though increased processing time. Seasonal boundaries were defined by local experts and vary across the analysis area based on the expected period of seasonal herbaceous growth. Maximum NDVI composites are then generated to depict current year conditions and are used to predict EVC and FBFM40 values.

Testing and Results

- We compared gNexus fire behavior output layers using EVC and FBFM40 predictions derived from WELD 10 year average, maximum, and current year NDVI. In general, more intense fire behavior was predicted using maximum NDVI compared to average. Fire behavior using current year products generally fell between the average and maximum NDVI conditions.

- We tested large historic fires via the Fire Area Simulator (FARSITE) model to see if we could get similar fire perimeters to what was reported in inferred perimeter shapefiles. Using the NDVI from the associated year of the fire, better modeling results were achieved compared to using standard LF fuels data.
- We compared fire perimeters from 1984 – 2013 to areas we assessed as barren and sparse in average and maximum NDVI cover prediction products. We found that where fires occurred we had some predicted fuel and where we had barren predicted there were no fire perimeters.
- We reviewed the current year fall predictions (EVC and FBFM40) with SW predictive services and Texas Forest Service experts for the southern tier of the analysis area. The local experts felt that the GB/SW MoD-FIS products, in general, characterized the actual fuel conditions better than standard LF fuels data.
- We tested large fires from 2015 and 2016 via FARSITE with current year EVC predicted from Landsat derived NDVI and met with Great Basin experts to review modeling. Similar to the SW region, the GB experts felt that the GB/SW MoD-FIS products were generally more representative of the landscape conditions than standard LF products.

Conclusion

LF MoD-FIS data have now been released as provisional products to allow further testing and review by operational users of LF fuels data. Feedback is sought from users and any further refinements needed to the MoD-FIS data will be considered before the data and processes are finalized. Data distribution through the LANDFIRE website and data distribution system has been enabled and the layers are also available through the LANDFIRE Data Access Tool. Discussions have been initiated with the Wildland Fire Decision Support System team, which currently utilizes MoD-FIS data in the Southeast U.S., to integrate the GB/SW MoD-FIS data. This is likely to occur sometime in the future, though not currently available.

References

Roy, D.P., Ju, J., Kline, K., Scaramuzza, P.L., Kovalskyy, V., Hansen, M., Loveland, T.R., Vermote, E., and Zhang, C., 2010, Web-enabled Landsat Data (WELD): Landsat ETM+ composited mosaics of the conterminous United States: Remote Sensing of Environment, v. 114, no. 1, p. 35-49.

Contact Information

Please contact the LANDFIRE Help Desk (landfire@usgs.gov) with any questions or feedback.

Appendix A

GB/SW MoD-FIS Processing Steps

- Download and process WELD NDVI outputs from 2003 through 2012
- Calculate average NDVI for the ten year period
- Calculate shrub cover by applying the average shrub linear model to the average NDVI
- Calculate herbaceous cover by applying the average herbaceous linear model to the average NDVI
- Calculate herbaceous cover by applying the average herbaceous linear model to the current year NDVI
- Take 10% of the previous years' continuous herbaceous cover and add it to current year as hold-over
- Re-classify current year herbaceous cover to LF herbaceous cover codes
- Apply average herbaceous cover where average is greater than the current year herbaceous cover to ensure that current year herbaceous cover never drops below average year values.
- Replace LF shrub cover with predicted shrub cover in non-disturbed areas
- Replace herbaceous cover where the values are sparse, herbaceous, or two digit cover codes with predicted current year herbaceous cover plus hold-over
- Replace 10 -19% shrub cover with predicted herbaceous cover if greater than 10% herbaceous cover
- Replace Existing Vegetation Height (EVH) values with class 101 for cover values less than 50% and 102 for cover values greater than 50% in herbaceous areas
- Add two digit LF codes from original LF EVC to predicted herbaceous cover where LF EVC is
- code 11, ≥ 13 ≤ 25, and ≥ 61 ≤ 69 to account for non-vegetated areas
- Add two digit LF codes from original LF EVH to adjusted herbaceous height where LF EVH is
- code 11, ≥ 13 ≤25, and ≥ 61 ≤ 69 to account for non-vegetated areas
- Apply the following fuel rules to the average, max, and current year cover:
- 0% herb cover = barren 31
  - 9% herb cover = sparse GR1
- 10-29% herb cover = GS1
- 30-69% herb cover = GR2
- ≥70% herb cover = GR3
- Create FBFM40 for the analysis area for average NDVI cover, max NDVI cover, and current year NDVI cover using LF Total Fuel Change tool

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Appendix B

In Table 1, the LF map zones in the analysis area are in the left column and the LF EVC classes are across the top 100 and 121 to 129. 100 signifies 0.1-9.9% herbaceous cover, 121 = 10 to 19.9% herbaceous cover, and 129 = 90 to 99.9% herbaceous cover. In the field of the table are the weighted average NDVI values for each cover class by map zone from the WELD average.

Below these values are: 1) the mean NDVI value of all map zones by LF cover class (avg_all); 2) the standard deviation of the mean (std_p); 3) the value of 1 standard deviation above the mean (av_all+std_p); 4) the value of 1 standard deviation below the mean (av_all-std_p).

The NDVI values in the table colored in yellow fall within 1 standard deviation above and below the mean.

The last row in the chart (median_sel) is the median of all those values in each cover class that are within one standard deviation of the mean (yellow).

Table 1: Weighted average NDVI values for each LF map zone within the analysis area by LF EVC

LF Map Zone	100	121	122	123	124	125	126	127	128	129
Z05	4629	4711	4584	5012	5492	5876	6255	5780	5822	6442
Z06	2870	1753	2114	3321	3362	3012	3049	3173	3446	
Z09	3590	2264	2886	3655	4255	4384	4540	4472	4593	
Z12	1460	1019	1159	1415	2132	2556	2767	3635	4664	5071
Z13	1288	5723	2369	2329	2483	2484	4053	5448		
Z14	1973	1877	1964	2119	2328					
Z15	1837	2795	2740	2797	2940	3328	3496	3915	4450	4454
Z16	3438	4128	4054	4343	3600	3249	3610			
Z17	1329	1564	2159	2596	2927	3195	3303	3663	3924	
Z18	2124	3057	3555	3424	3391	3619				
Z23	1542	1992	2105	2225	2495	2829				
Z24	1341	1694	2032	2220	2196	2132	2047	1855	1739	1687
Z25	1513				2342	2631	2558	2397	2104	2554

LF Map Zone	100	121	122	123	124	125	126	127	128	129
Z26	1919	2856	2552	2471	2747	2767	2736	2776	3049	
avg_all	2204	2726	2636	2917	3049	3236	3492	3711	3754	4042
std_p	995	1323	902	957	897	940	1102	1194	1234	1718
av_all+std_p	3199	4049	3539	3874	3947	4176	4594	4906	4988	5759
av_all-std_p	1209	1402	1734	1960	2152	2295	2391	2517	2521	2324
median_sel	1542	1992	2159	2533	2747	2921	3303	3649	4187	4454

The median_sel herbaceous values from table 1 are used to chart the herbaceous cover from 15% to 95% by 10% increments, the midpoints of LF cover classes except for sparse and barren (Figure 3). The resultant linear model was then used to calculate the predicted cover values based on the median_sel herbaceous to see how closely they would relate to the LF cover midpoint. Once the cover classes from 15% through 95% are charted, the linear progression is extended back to 0 and negative values to arrive at NDVI values for sparse, 5% LF cover midpoint, and barren, 0% LF cover midpoint (Table 2). After the linear model was studied in relation to our data it was felt that it could be used to map current year NDVI values to LF cover class and then FBFM40.

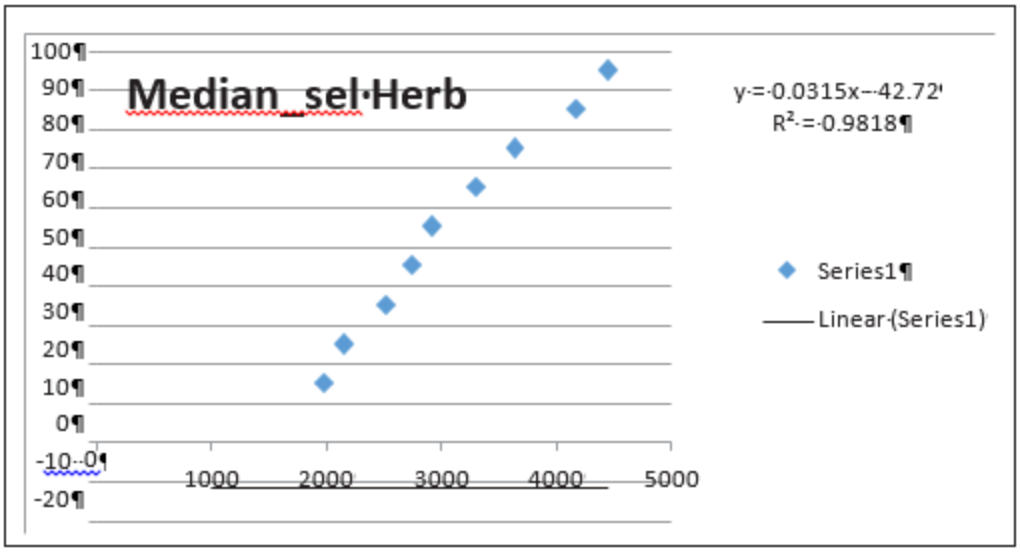

Figure 3: The median select herbaceous values

Table 2: The median select herbaceous values, LF cover midpoints, and predicted cover

Median_sel Herbaceous	LF Cover midpoint	Predicted Cover
1312		-1.392
1356	0	-0.006
1542	5	5.853
1992	15	20.028
2159	25	25.2885
2533	35	37.0826
2747	45	43.8218
2921	55	49.2834
3303	65	61.3245
3649	75	72.2235
4187	85	89.1705
4454	95	97.581