LANDFIRE Drought Based Fuel Dynamic Methods for the Southeast US

Summary:

This report documents the methodology utilized to generate an adjusted LANDFIRE surface fuel model layer that automatically applies conversions based on the bi-weekly calculated Keetch-Byram Drought Index (KBDI) within the Wildland Fire Decision Support System (WFDSS). The conversions are based on look-up table values derived by adding additional fuel loading and depth, based on the level of drought expressed by KBDI, and cross-walking subsequent fuel loading values to the LANDFIRE Fire Behavior Fuel Model 40 (FBFM40) layer for each of four KBDI drought classifications.

Background:

It is generally held that as wildland fuels dry out additional fuel material is available for combustion and heat release. In terms of climate, drought can be used to express this relationship between dry conditions and increased fuel availability. Changing amounts of available fuel can be the result of seasonal trends, vegetation phenology, and changing water table levels as well as long term climatological trends. While it can be difficult to capture this variation on a large scale, trends in increased fire spread potential with increased drought conditions are important factors to consider when modeling anticipated fire behavior.

The inclusion of dynamic fuel models in fire behavior modeling has greatly improved modeling success by shifting live fuel loading to dead to simulate curing of herbaceous vegetation; however, this approach still does not capture the impacts of drought on fuel availability. For this reason, the LANDFIRE program has initiated an endeavor to capture these trends. As a starting point, the Southeast United States (SE) was chosen as a pilot area to test methods to capture this variation. This product is the first of its kind and its success will be used to inform future exploration into capturing seasonal fuel model variability at various geographic scales due to regional conditions.

Introduction:

The LANDFIRE Drought Based Fuel Dynamic (LF_DBFD) methods for the SE are based on concepts founded and developed through the National Fire Danger Rating System (NFDRS) revision of 1988 (Burgan 1988). These concepts include additional fuel loading and depth by fuel model for severe drought conditions based on the KBDI (Keetch and Byram 1968) and respond to issues of determining fuel dryness in humid climates.

KBDI is a mathematical system for relating current and recent weather conditions to potential or expected fire behavior. This system was originally developed for the SE and is based primarily on recent rainfall patterns. The KBDI is the most widely used drought index system by fire managers in the SE. It is also one of the only drought index systems specifically developed to equate the effects of drought with potential fire behavior. The result of this system is a drought index number ranging from 0 to 800 that describes the moisture deficit of the top eight inches of soil. A rating of 0 defines the point where there is no moisture deficiency and 800 is the maximum drought.

In the SE, drought conditions affect fuel availability in two primary ways:

1. Water tables recede in low lying areas that are either permanently or seasonally flooded, resulting in exposure of previously submerged vegetation and drying of previously moist fuels.
2. Persistent dry conditions result in a very dry upper soil and fuelbed profile with additional live and larger dead fuels being available to burn.

Methodology:

The following steps describe the process followed in development of the LF_DBFD layer. Additional details are provided in the appendices.

1. The NFDRS method of adding fuel load by size class and fuelbed depth under drought conditions was utilized to generate a table of FBFM40 under four classes of drought condition using the following procedures:
    a. The LANDFIRE Existing Vegetation Type (EVT) and LANDFIRE FBFM40 layers, and an NFDRS fuel model map for the SE from the Wildland Fire Assessment System (WFAS) were visually compared to determine relevant combinations of EVT, FBFM40, and NFDRS fuel model to guide assignment of FBFM40 transitions.
    b. A climatological assessment of KBDI was completed for all the map zones within the LANDFIRE SE GeoArea, indicating the point at which the 90th percentile KBDI value was reached utilizing Remote Automated Weather Station (RAWS) data from within each zone. The 90th percentile values ranged from574 in Northern NC to 680 in Southern FL. Additional details of this analysis is shown in Appendix A.
    c. The climatological assessment was then used to sub-divide the KBDI scale of 0 to 800 into four drought classes and assign proportions of additional fuel load weight and fuelbed depth based on the class. The classes are:
        i. 0-199 KBDI = no drought; original fuel model with its loading and depth is used.
        ii. 200-399 KBDI = low drought; 20% of the additional weight and depth are added to the original fuel model
        iii. 400-599 KBDI = moderate drought; 55% of the additional weight and depth are added to the original fuel model
        iv. 600-800 KBDI = severe drought; 100% of the additional weight and depth are added to the original fuel model
    d. For each NFDRS fuel model, the total fuel weight and depth for each drought class was calculated. An example of this for fuel model D is shown in Appendix B. This additional fuel weight and depth was added to the original values for each FBFM40 class based on the combinations of NFDRS fuel model, EVT, and FBFM40 defined in step 1a, for each of the four drought classes.
    e. The new fuel weight and depth, for each combination class, was correlated with FBFM40 fuel weights and depths; FBFM40 values were then transitioned based on 1hr fuel load, total fuel load, live fuel load, fuel bed depth, and moisture of extinction (MXT) where appropriate. A concerted effort was made to convert the original LANDFIRE FBFM40 to fuel models with a higher MXT (if they were a lower MXT) as the increased loading and depth dictated a transition in fuel model. Transitions from timber litter models to timber understory models were also emphasized in non-developed EVT's, unless it was an obvious dominant deciduous-hardwood EVT.
    f. A look-up-table (LUT) of fuel model transitions was created and, combined with a map of KBDI from WFAS, is used for mapping FBFM40 based on the current drought class.

Results

The fuel models transitions were tested in two ways. First, FBFM40 grids were created for each drought class by applying the transitions in the LUT. Utilizing the gNEXUS fire behavior processor, and representative percentile weather conditions, the results showed a gradual increase in fire behavior characteristics as the drought level increased. Next, KBDI maps were obtained from WFAS for time periods with known fire activity and the LUT was applied to develop updated FBFM40 grids for the time periods that the KBDI maps represented. Farsite was used to model fire perimeters for known fires using the updated FBFM40 layers and actual weather conditions. The modeled perimeters were then compared with the actual fire perimeters from those incidents. In general, the perimeters showed good agreement, indicating that the updated FBFM40 layers were more consistently representing actual fuel conditions on those incidents. Some of the fuel model transitions were modified based on these modeling results to better reflect expected fire behavior. The final LUT is shown in Appendix C.

Product Distribution

WFDSS personnel were contacted during development and testing of this product as a possible way to provide data to fuels and fire behavior practitioners. Several meetings were held with WFDSS and WFAS to discuss the concepts and develop mechanisms to provide these data as a product within WFDSS. Initially, the updated FBFM40 layers were offered to WFDSS as a suggested product. After further discussion, it was decided that WFDSS would instead ingest the LUT, pull the KBDI grids directly from WFAS, and produce the updated FBFM40 layers on the fly. This functionality is currently available within the WFDSS Training site and could be moved to WFDSS Production in the future, once the products have been adequately described and reviewed.

Future Development:

There are a couple of issues affecting the drought based transition of surface fuel models in the SE that will require additional research to address. First, some areas, including many with muck soils, may be given a transitioned fuel model, while in reality they are low enough in elevation to still be retaining water, especially in moderate drought, and thus the fuel model should not be modified. Additional data sets including lidar-based, high-resolution elevation data, National Wetlands Inventory, SSURGO soils data, and layers depicting muck soils are being investigated for their utility in identifying these areas. If the areas of concern can be adequately identified, additional combinations will be added to the LUT to account for these characteristics and the fuel model transitions adjusted accordingly.

The second issue relates to the relationship of fire behavior and the leaf-on versus leaf-off condition of deciduous vegetation in the SE area. LANDFIRE calibrated FBFM40 data assumes a leaf-on condition. The reduction in cover and the additional leaf litter available during leaf-off periods could have serious effects on the fire behavior characteristics of these sites. Phenological transitions of surface fuel models are being investigated as an addition to the drought-based fuel transitions, but will require different data and processes to capture these changes.

References

Burgan, Robert E. 1988. 1988 revisions to the 1978 national fire-danger rating system. Research Paper SE-273. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 144 pp.

Keetch, John J., and Byram, George. 1968. A drought index for forest fire control. Research Paper SE-38. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 32 pp.

Appendix A

Climatology based on 90th percentile KBDI

Table 1 is a listing of the RAWS used for the climatological assessment in each map zone along with the state they reside in and the zone number. Using the KBDI as a surrogate for dryness, ten years of daily weather observations for each station were sorted from lowest to highest to assess the percentile KBDI values that represent critical dryness. The 90th percentile KBDI value from each station was used to assess how the stations related to one another in terms of dryness and how that relationship would associate to a KBDI of 600, which is the threshold for severe drought in the LF_DBFD system. It was found that RAWS with a 90th percentile KBDI value between 550 and 680 represented the majority of the SE area, and that the percentile values at these stations of KBDI 600 was within a range of 75-95%.

This climatology analysis covers a large geographic area from east to west and north to south with many variations in soil types and other variables that affect the KBDI computation. In general, the LF_DBFD process assures that an area is not classified as severe drought until it has reached at least its 75th percentile dryness as determined by KBDI, on the high end. On the low end, the process generally assures that the area represented by the weather station does not exceed its 95th percentile dryness as determined by KBDI before it reaches the severe drought stage. This process placates the largest portion of the area with reasonable breakpoints for no, low, moderate, and high drought conditions, though local variations do exist that impact the relative dryness at which the drought class thresholds are met (e.g. LkWales, FL).

Table 1 - RAWS both used and excluded for climatological analysis of KBDI, showing the 90th percentile KBDI values and the percentile value at KBDI 600, 400, and 200.

Station name	State	Map zone	90th percentile KBDI Value	Percentile value at KBDI 600	Percentile value at KBDI 400	Percentile value at KBDI 200
SE Geo-Area						
Bankhead	AL	48	575	92	67	43
Dayton	TX	37	658	84	62	37
JonesOkee	GA	55	624	86	49	20
LkWales	FL	56	680	76	35	12
Oconee	GA	54	581	92	60	35
Whiteville	NC	58	574	92	67	32
Winborn	MS	45	678	82	55	38
Others nearby						
BigSpr	MO	44	539	95		
Flatwood	WV	61	391	99		
MIO	MI	51	154	N/A		
Tomilson	WV	62	356	99		

Appendix B

Fuel weight and depth change due to drought level in NFDRS fuel model- D

Figure 1 demonstrates the process of adding proportionally additional fuel weight and depth attributes from NFDRS fuel model D to each dead fuel size class and live fuel class for each drought level. This process was completed for each NFDRS Fuel Model that linked to a LANDFIRE EVT/FBFM40 combination.

- To the right in the chart are two columns (with blue shading) showing the default NFDRS fuel attributes for fuel model D with the last line indicating the suggested weight (in tons per acre) of additional available fuel in severe drought.
- At the top of the chart (with orange shading), are the same NFDRS fuel attributes with the calculation for the proportion of each size class of dead fuel, live fuels, and fuel bed depth.
- The center of the chart (white), calculates the amount of the additional loading for each drought class from the total weight being added.
- The bottom section (green), calculates the proportion of additional fuel for each fuel class based on the percentage of each drought class. It also calculates the additional fuel bed depth by drought class. These are the fuel attributes compared to the FBFM40 fuel attributes for defining fuel model transitions by drought level.

	NFDRS D	Trees with shrub understory								
	1hr	10hr	100	1000	herb	woody	sum			
pre-drought NFDRS D	2	1			1	3	7		NFDRS_88	D-Tr/Sh
% of original loading	0.286	0.143			0.143	0.429			1hr	2
depth	3.5								10hr	1
added	0.00214								100hr	0
									1000hr	0
	total Droug	KBDI 200-400		KBDI 400-600		KBDI 600-800			herb	1
D-Tr/SH	1.5	0.3		0.525		0.675	1.5		woody	3
				0.825		1.5			sum	7
									depth	2
1hr		2.086		2.236		2.429			MXT	40
10hr		1.043		1.118		1.214			drought	1.5
100hr		0.000		0.000		0.000				
1000hr		0.000		0.000		0.000				
herb		1.043		1.118		1.214				
woody		3.129		3.354		3.643				
sum		7.300		7.825		8.500				
depth		2.09		2.24		2.43				

Figure 1- Example worksheet for calculation of additional fuel weight and depth for NFDRS fuel model D by drought class.

Appendix C
LUT for Fuel Model Transitions

Table 2 is a copy of the final LUT, which specifies the fuel model transitions for each drought class based on combinations of FBFM40, NFDRS fuel model, and EVT.

Table 2 - Final LUT for SE GeoArea drought-based fuel model transitions.

LUT_10based on LUT08					
FBFM40	NFDRS	evt	kbdi_2_4	kbdi_4_6	kbdi_6_8
101	L		101	102	103
101	A	2916	101	102	102
		2966	101	102	102
		2967	101	102	102
		2417	101	102	102
102	L		102	102	103
		2960	102	102	103
		2966	102	102	103
		2967	102	102	103
102	C	2194	102	103	105
103	N		103	105	106
103	D	2582	103	103	105
		2584	103	103	105
		2584	103	103	105
		2585	103	103	105
		2367	103	103	105
		2367	103	103	105
		2368	103	103	105
		2371	103	103	105
		2372	103	103	105
		2527	103	103	105
		2546	103	103	105
		2586	103	103	105
		2587	103	103	105
		2378	103	103	105
		2588	103	103	105
		2589	103	103	105
		2455	103	103	105
		2590	103	103	105
		2591	103	103	105
		2458	103	103	105

LUT_10based on LUT08					
FBFM40	NFDRS	evt	kbdi_2_4	kbdi_4_6	kbdi_6_8
104	L		104	104	107
105	N		105	106	108
105	D	2406	105	105	106
		2488	105	105	106
		2556	105	105	106
		2557	105	105	106
		2377	105	105	106
106	N		106	106	108
107	T		107	107	107
108	N		108	108	109
109	N		109	109	109
121	L		121	122	123
121	L	2917	121	121	102
122	E		122	122	123
122	D	2936	122	123	123
123	D		123	124	103
124	O		124	103	149
141	E		142	143	186
142	E		143	185	165
143	E		186	188	165
143	D	2194	143	146	148
		2349	143	146	148
		2473	143	146	148
		2480	143	146	148
		2535	143	146	148
		2550	143	146	148
		2551	143	146	148
		2552	143	146	148
		2553	143	146	148
		2527	143	146	148
		2546	143	146	148
144	D		144	146	149
145	D		145	145	106
146	D		148	163	149
147	D		147	149	145
148	O		148	163	149
149	O		149	149	145

LUT_10based on LUT08					
FBFM40	NFDRS	evt	kbdi_2_4	kbdi_4_6	kbdi_6_8
161	E		186	188	165
162	E		162	165	163
163	D		163	103	149
164	Q		146	148	163
165	G		165	163	163
181	E		183	185	186
182	C	2450	186	163	103
		2451	186	163	103
		2453	186	163	103
182	E		186	188	165
182	D	2380	143	163	149
		2382	143	163	149
		2459	143	163	149
		2461	143	163	149
		2468	143	163	149
		2478	143	163	149
		2462	143	163	149
		2480	143	163	149
182	P	2356	186	188	162
		2347	186	188	162
		2372	186	188	162
182	R	2333	183	185	186
		2336	183	185	186
		2337	183	185	186
		2913	183	185	186
183	P		186	188	162
184	P		186	188	162
185	P		186	188	162

LUT_10based on LUT08					
FBFM40	NFDRS	evt	kbdi_2_4	kbdi_4_6	kbdi_6_8
186	E		188	162	163
186	D	2461	144	146	163
		2468	144	146	163
		2501	144	146	163
186	C	2346	186	163	103
		2348	186	163	103
		2349	186	163	103
		2358	186	163	103
		2450	186	163	103
		2451	186	163	103
		2453	186	163	103
		2454	186	163	103
186	P	2372	162	146	163
		2535	162	146	163
		2550	162	146	163
		2551	162	146	163
		2552	162	146	163
		2553	162	146	163
187	E		186	188	165
188	P		162	146	163
189	E	2448	165	162	163
189	P		162	146	163
201	K		201	165	202
202	K		202	202	203
203	J		203	203	204
204	I		204	204	204