Guidelines for Evaluating LANDFIRE Fuel Data

Overview

Local calibration and accuracy assessment are critical steps in the process of developing spatial data sets, and the LANDFIRE fuel team welcomes independent verification of LANDFIRE data. As use of LANDFIRE data increases, so will the number of independent verification efforts. For most, verification refers to the process of determining how well a map depicts reality. This literal interpretation does not always apply when evaluating LANDFIRE fuel data. For example, user A may think that region A should be assigned a fire behavior fuel model 8 (Anderson, 1982), whereas user B thinks it should be assigned a fuel model 6 (Anderson, 1982). Which assignment is correct? Because there may be multiple correct choices in this case, there is no correct answer; therefore, a true "accuracy assessment" based on field reconnaissance is not possible. Likewise, there is currently no infallible method for measuring the nebulous, theoretical, canopy base height, nor are there any practical methods for measuring canopy bulk density (though reasonable estimates can be obtained). For these reasons, users should focus on the efficacy of the data rather than on the accuracy. In other words, it is more helpful to understand how well the data meet their stated objectives, which are to 1) help answer questions related to strategic fuel management and 2) support wildland fire incident response.

Recognizing the situation, this document was prepared to facilitate the LANDFIRE fuel verification process by providing guidelines that users should consider prior to this endeavor. Moreover, if these guidelines are followed, the LANDFIRE fuel team can more readily use the critique to improve the data layers.

But we must first make clear the intended level of applicability of LANDFIRE data. For our discussion, LANDFIRE data products are most properly characterized as "mid-level" when evaluated in the context of Brohman and Bryant (2005). They define mid-level products as those that are "intended to support forest and multiforest information needs including forest planning, forest/region resource assessment and monitoring, and fire/fuels modeling." Further, mid-level products provide a synoptic and consistent viewpoint across all ownerships – a characteristic of all LANDFIRE data products.

By definition, mid-level products should exhibit a minimum map feature standard of at least five acres (approximately 22 LANDFIRE pixels at 30-meter resolution). While LANDFIRE does not develop minimum mapping units, field-based accuracy assessments should target stands greater than five acres. It therefore makes little sense to obtain a single GPS location, estimate a parameter at the location, and then compare the observation to the single pixel "underneath" this GPS location.

Following are our recommended guidelines for gathering field-based estimates of fuel parameters to compare with LANDFIRE data in addition to methods for the actual comparison in a GIS environment.

Guidelines

Data Collection Considerations

- Sample stands should be relatively homogenous for at least five acres.

- To minimize the effects of location error, GPS locations representing a stand should be obtained from the middle of a stand away from ecotones and steep draws. Figure 1 illustrates these concepts:

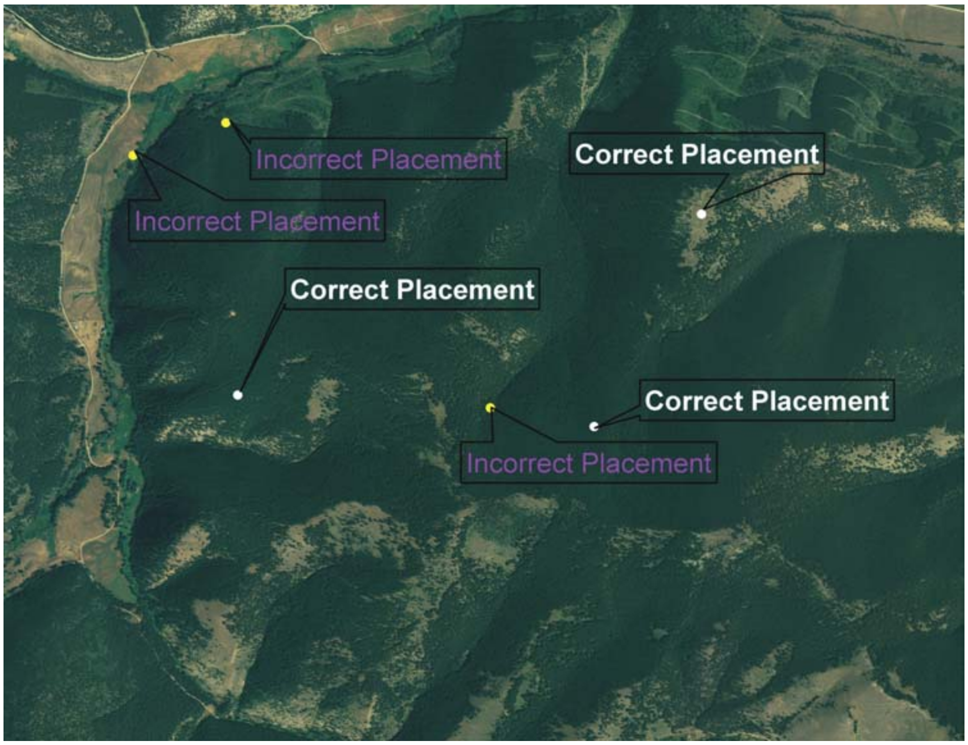

Figure 1. Demonstration of correct placement of reference data collection points. Notice that the properly located points are in the middle of large stands (> 5 acres) and are placed in homogeneous vegetation types.

- GPS locations should be obtained in Latitude/Longitude WGS84 and then properly converted to the LANDFIRE projection (table 1) in the GIS environment. Prior to analysis, care must be taken to re-project these data to the LANDFIRE projection using an appropriate datum transformation (where applicable).

Table 1. Parameters of the standard LANDFIRE projection.

Projection parameter	Parameter value
Projection	Albers Equal Area
False Easting	0
False Northing	0
Central Meridian	-96
1st Standard Parallel	29.5
2nd Standard Parallel	45.5
Latitude of Origin	23
Datum	NAD83
Spheroid	GRS80

- Ideally, three to five samples per stand should be taken to ensure that some measure of variability can be computed. For example, establish a point in the middle of the stand and take four samples separated from the central point (and from each other by approximately 100 meters). An advantage of this technique is that it permits assessment of positional accuracy of the GPS since the points are 100 meters apart (fig. 2).

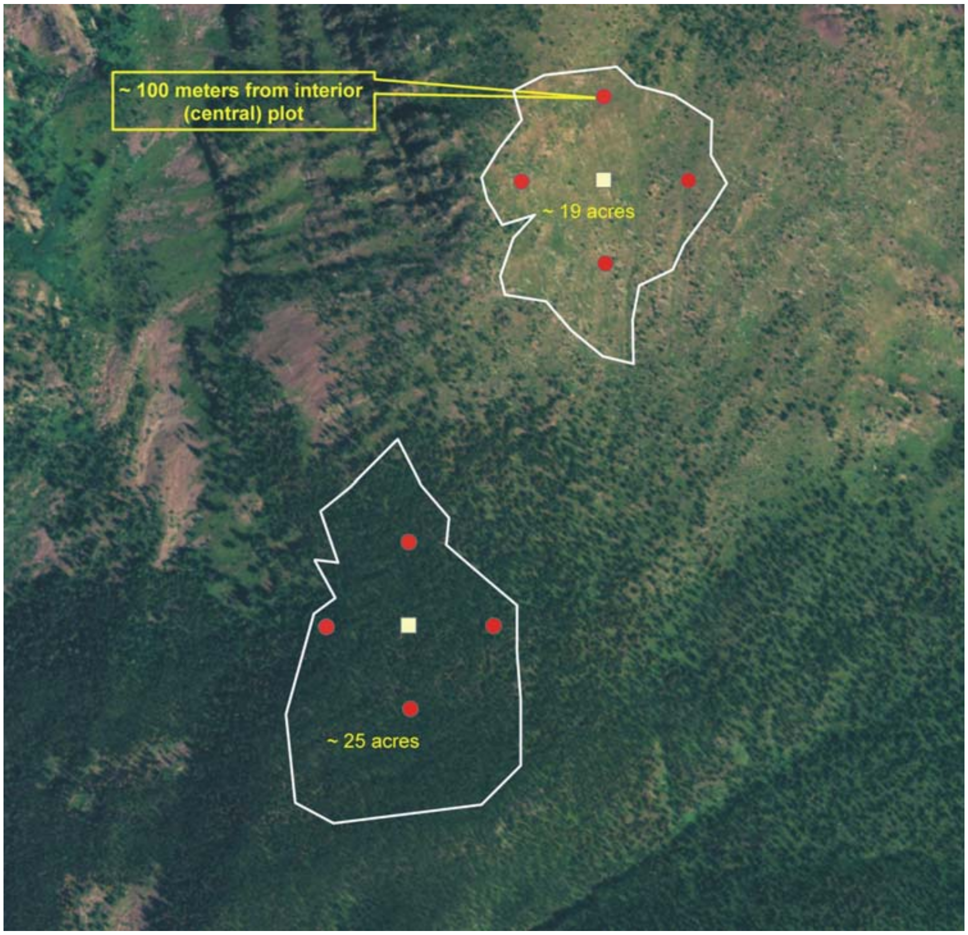

Figure 2. Example plot placement of subplots around a centrally located plot. Note that the plots are placed in the middle of large stands (> 5 acres). The red circles are placed 100 meters N, S, E, and W of the central plot. Placing multiple plots in a stand permits computation of variability and allows assessment of the positional accuracy of the GPS.

- Make the GPS locations available to LANDFIRE scientists for use in improving the mapping process.

- Ideally, four photos (N, S, E, and W from plot) should accompany each field plot location and be named for easy identification (for example, “Plot23_N”).

- Each field sampling exercise should contain a brief narrative describing the data collection methods used and/or reason(s) why a particular assignment was made.

If canopy characteristics such as bulk density or base height are being estimated, care must be taken to document the methods used to obtain the estimates.

- Estimate fire behavior fuel models under the severe, peak-season conditions.

  Note: LANDFIRE data products have been created under the assumption that it is preferable to over-estimate rather than underestimate fire behavior. For example, many desert types do not typically burn due to lack of fire-carrying herbaceous fuel; however, if rainfall has been sufficient, a dense layer of herbaceous material will be present and fire behavior can be severe. LANDFIRE data products are therefore assigned a fuel model assuming the fuelbed can be sufficiently dense to sustain a surface fire.

- The distribution of plots should ideally match the distribution of fuel on the ground. For example, if 50 percent of the landscape is dominated by timber fuel types and 50 percent is grassland, then 50 percent of the ground data should be collected in the grasslands and 50 percent in the forested types.

- Estimate more than one likely fire behavior fuel models for each point in the field because often there is no single correct answer. For example, a TL2 (182) and a TL3 (183) (Scott and Burgan 2005) provide similar rates of spread and flame length. Thus, either model could be appropriate in certain cases.

Data Comparison Techniques

1) Since reference points should be collected in homogeneous stands covering a minimum of five acres, at least 25 pixels (approx. five acres) surrounding the central pixel should be evaluated. It is not appropriate to obtain a GPS location and simply query the pixel "underneath" the point and compare it to the field-based estimate. This is invalid for three main reasons:

   - There is a large amount of error (usually +/- 5 – 10 m) in the GPS measurement depending on the make and model of the device and mode of data acquisition.
   - We can assume that there are at least 15 meters of geolocational error at each LANDFIRE pixel (sometimes considerably more).
   - Use of a point-in-cell extraction on a 30-m pixel assumes that the data were meant to be used at that "fine-level." As this is not the case with LANDFIRE data, it is not appropriate to use fine-level assessment techniques on a mid-level product.

2) Within the stand or landscape of interest, compare the average observed condition to the average condition in the corresponding area on a LANDFIRE map. Since most comparisons will be performed on fire behavior fuel model data, the GIS analyst should use the majority or median statistic, not the mean.

3) Consider using a watershed or watershed-size landscape for the analysis unit. For example, a valid comparison for evaluating LANDFIRE data could be comparing the dominant condition on the ground in a watershed to the dominant condition in the LANDFIRE data as demonstrated in figure 3.

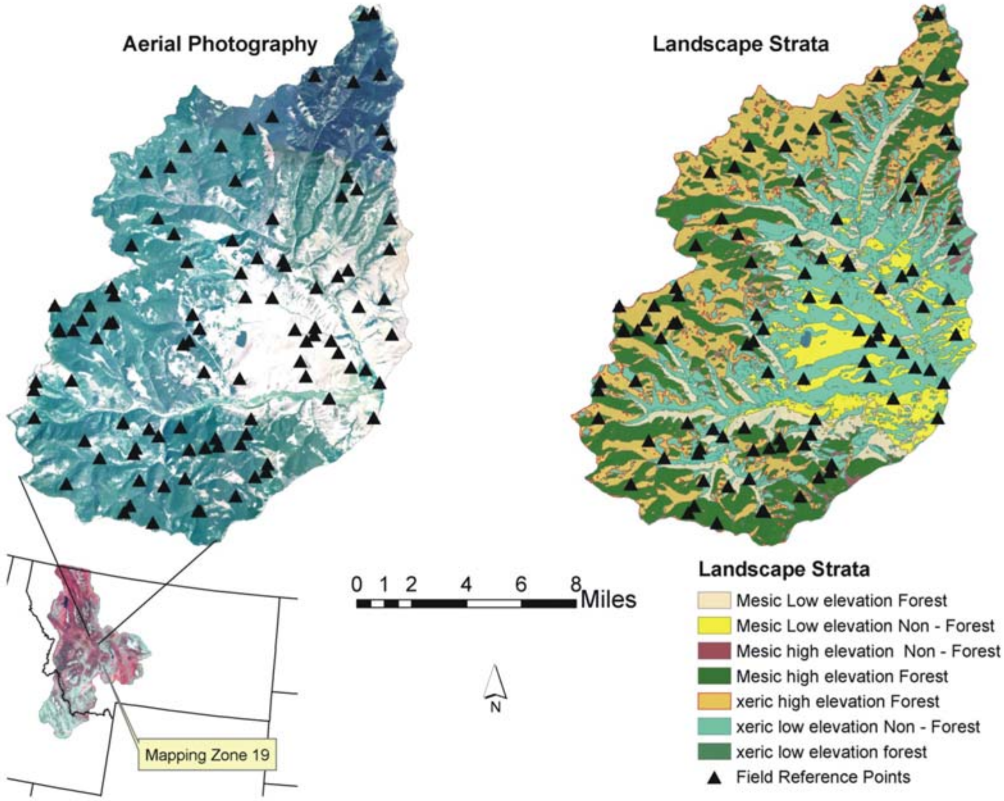

Figure 3. Location and land strata of a 5th code hydrologic unit code (HUC) in LANDFIRE Mapping Zone 19 used to exemplify a suggested method of evaluating LANDFIRE fuel data. Black triangles represent the central location of 100 field reference points located using a stratified random sampling approach. Four other points were taken 100 meters from the central point. Care was taken to locate the points far from strata boundaries. The number of points in each stratum is commensurate with the acreage each strata covers (see table 2 below).

A Simplified Example Validation Exercise

For demonstrative purposes, we provide below an example validation exercise highlighting use of some of the above proposed guidelines. Though the fire behavior fuel model data are provided by LANDFIRE, the reference data are fictitious and serve only to demonstrate a proposed mode of analysis. The analysis occurs on a 5th code hydrologic unit code (HUC) based in west-central Montana (LANDFIRE Mapping Zone 19) (see above figure 3).

For this exercise we assumed a field reference sample size of 500 points, which is not enough for a rigorous analysis (Lillesand and Kiefer, 1994) but is probably more than many units have the resources to collect. To allocate these 500 points on an area-weighted basis, the landscape was stratified based on elevation, life form, and aspect (table 2).

Table 2. Size (acres) and sample size allocation for landscape strata developed using life form, aspect, and elevation. Strata were developed to help determine appropriate allocation of 100 sample points designed to estimate fire behavior fuel models in a 5th code hydrologic unit code (HUC) watershed in west-central Montana.

Landscape strata	Acres	Sample size (out of 500)	Life form	Aspect	Elevation (ft.)
Mesic high elevation non-forest	1,528	5	Non-forest	N, S	≥ 4500
Xeric low elevation non-forest	8,214	35	Forest	S, W	< 4500
Xeric low elevation non-forest	8,221	35	Non-forest	S, W	≥ 4500
Mesic low elevation non-forest	11,121	50	Non-forest	N, S	< 4500
Mesic low elevation forest	12,454	55	Forest	N, S	< 4500
Xeric low elevation non-forest	17,519	75	Non-forest	S, W	< 4500
Xeric high elevation forest	26,122	120	Forest	S, W	≥ 4500
Mesic high elevation forest	28,238	125	Forest	N, S	≥ 4500

Although these landscape divisions are arbitrary, we expect different vegetation and fuel characteristics and therefore different fire behavior between the strata. For each of the hypothetical field reference plots, a series of plausible fire behavior fuel models were composed. Each of these was compared against the LANDFIRE fire behavior fuel model 13 (Anderson 1982) data layer. Table 3 represents the results of an error matrix using the *inappropriate* point in cell extraction, while table 4 represents the results using the most common fire behavior fuel model (majority) within the surrounding 25 pixels (5 by 5 pixel window) around each reference point. Many other spatial comparisons could be made.

Table 3. Error matrix for an evaluation of the fire behavior fuel model 13 (Anderson 1982) data layer. Reference data are hypothetical, but the sample image data were obtained from a 5th code hydrologic unit code (HUC) area in LANDFIRE Mapping Zone 19. Data were obtained using a point-in-cell extraction to show how changes in extraction or aggregation techniques can dramatically change the interpretation of the accuracy of a geographic data layer.

	Reference data										
LANDFIRE data	**1**	**2**	**5 (6)***	**6 (5)**	**8**	**9**	**10**	**92**	**Total**	**User accuracy** (%)**	**Prod. accuracy*** (%)**
1	13	6	0	0	0	0	0	0	**19**	68	68
2	2	6	0	1	0	0	3	0	**12**	50	38
5	2	1	0	0	12	0	3	0	**18**	0	0
6	1	1	0	1	1	0	3	0	**7**	100	33
8	0	0	0	0	9	0	13	0	**22**	41	35
9	0	0	0	0	0	0	0	0	**0**	0	0
10	1	2	2	1	4	2	23	0	**35**	66	51
92	0	0	0	0	0	0	0	3	**3**	100	100
Total	**19**	**16**	**2**	**3**	**26**	**2**	**45**	**3**	Overall accuracy = 55%		

*Numbers in parentheses represent an alternative fire behavior fuel model assignment that could realistically be made in the field.
**User accuracy is a statistic that can tell the user of the map what percentage of a class corresponds to the ground-truthed class.
***Producer accuracy shows what percentage of a particular ground class was correctly classified.

Table 4. Error matrix for an evaluation of the fire behavior fuel model layer (Anderson 1982). Reference data are hypothetical but the sample image data were obtained from a 5th code Hydrologic Unit Code (HUC) area in LANDFIRE Mapping Zone 19. Values represent the majority fire behavior fuel model obtained using a 5 by 5 pixel window around each reference point.

LANDFIRE data	Reference data 1	2	5 (6)	6 (5)	8	9	10	92	Total	User accuracy (%)	Prod. accuracy (%)
1	16	6	0	0	0	0	0	0	**22**	73	84
2	2	8	0	0	0	0	0	0	**10**	80	50
5	0	0	0	0	0	0	0	0	**0**	0	0
6	0	0	0	1	0	0	0	0	**1**	100	33
8	0	0	0	0	11	0	13	0	**24**	46	69
9	0	0	0	0	0	0	0	0	**0**	0	0
10	1	2	2	2	5	2	26	0	**40**	65	67
92	0	0	0	0	0	0	0	3	**3**	100	100
Total	**19**	**16**	**2**	**3**	**16**	**2**	**39**	**3**	Overall Accuracy = 65%		

For example, one could compute the proportion of the HUC occupied by each fire behavior fuel model and compare this to the proportion derived using the field reference plots. Similarly, the analyst could compute the most common fire behavior fuel model in each of the seven strata shown in figure 3 and compare these results to the field-referenced data summarized to the same spatial domain. These results are shown in table 5.

Table 5. Results of zonal statistics. The majority fire behavior fuel model was computed for each landscape stratum and compared with the majority fuel model assignment from reference data. In this hypothetical example, overall accuracy is 88 percent.

Landscape strata	Sample size (out of 100)	Reference data majority	LANDFIRE data zonal majority
Mesic high elevation non-forest	1	1	1
Xeric low elevation non-forest	7	10	10
Xeric low elevation non-forest	7	1	1
Mesic low elevation non-forest	10	8	10
Mesic low elevation forest	11	8	8
Xeric low elevation non-forest	15	1	1
Xeric high elevation forest	23	10	10
Mesic high elevation forest	25	1	1

As discussed at the beginning of this document, results derived from accuracy assessments such as these should focus on the efficacy rather than accuracy of the data; nevertheless, these analyses demonstrate use of some of the guidelines proposed in this document.

Specifically, note that points were located in relatively homogenous stands far from the transition between strata or stands. The number of plots in each landscape stratum proportionately matches the acreage of each stratum in the HUC. At each plot, where appropriate, two plausible fire behavior fuel models (Anderson 1982) were estimated. Of course, not all expected fire behavior can be described with two similar fuel models, but it is logical to assume that, in many instances, more than one model could be used. For example, a fuel model 5 is nearly identical to a fuel model 6 under extremely dry conditions (fig. 4).

In addition, depending on an analysts' preferences, a stand of juniper or pinyon-juniper could be modeled using a shrub model (such as a 5 or 6) or as a fuel model 8 with canopy characteristics in closed canopy situations. These considerations should be noted when determining fuel model estimates in the field. Finally, these spatial analyses focus on several different levels of spatial aggregation, including use of a 5 by 5 pixel majority – a usually inappropriate point-in-cell extraction – and a zonal analysis on each landscape strata at the level of a 5th code HUC. It is important to note that the mode or level (fine, mid, broad, etc.) will significantly influence the results of an accuracy assessment. In the case of LANDFIRE data, it is inappropriate to use a point-in-cell extraction to evaluate a mid-level product.

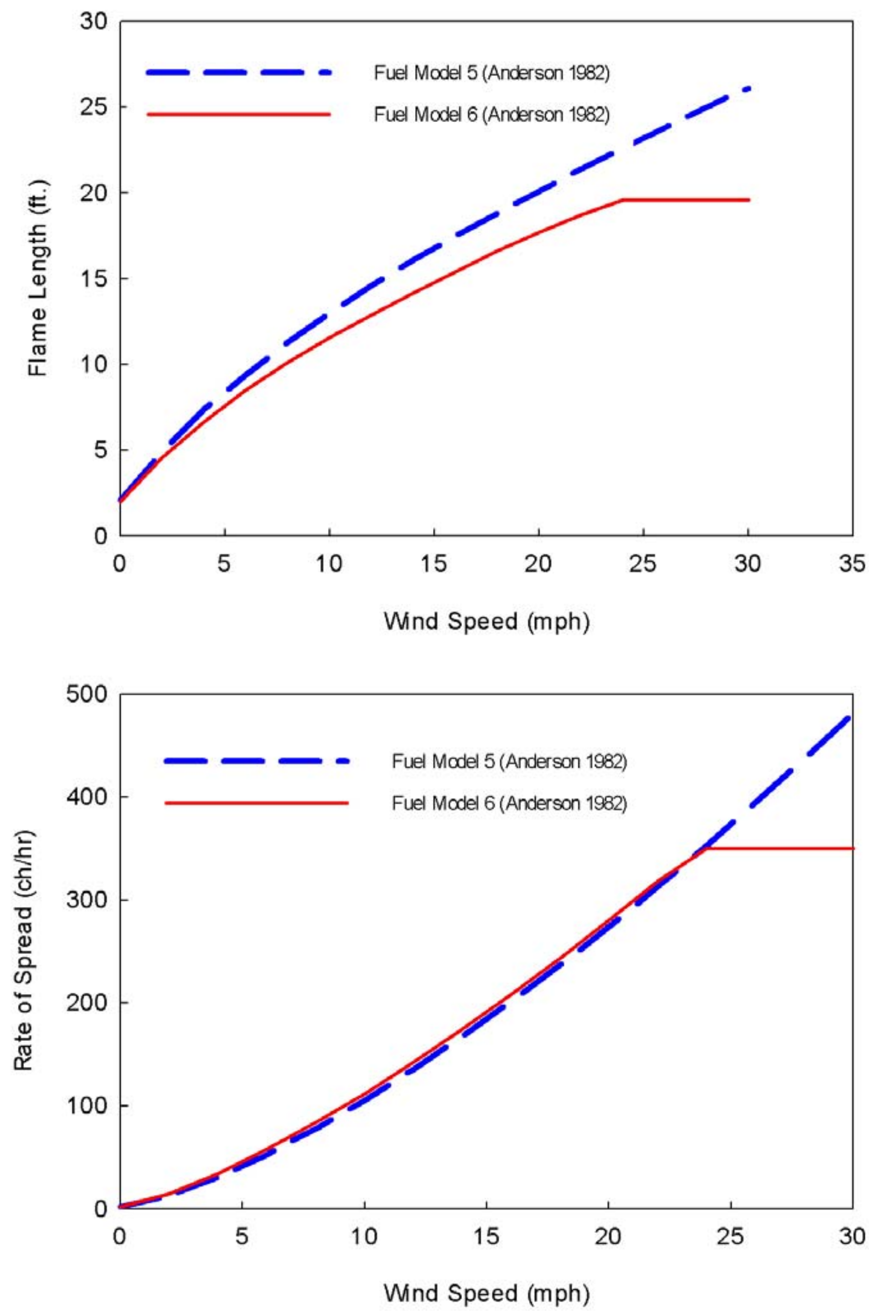

Figure 4. Comparison of rate of spread and flame length of fire behavior fuel models 5 and 6 (Anderson 1982). The moisture scenario assumes fine dead fuel moistures of 3, 4, and 5 percent for 1-, 10-, and 100-hour time-lag fuel, respectively. Herbaceous moisture is assumed to be 30 percent, whereas the moisture content of live woody fuel is assumed to be 60 percent. Under these conditions, either fuel model could be used to describe the observed or expected fire behavior.

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