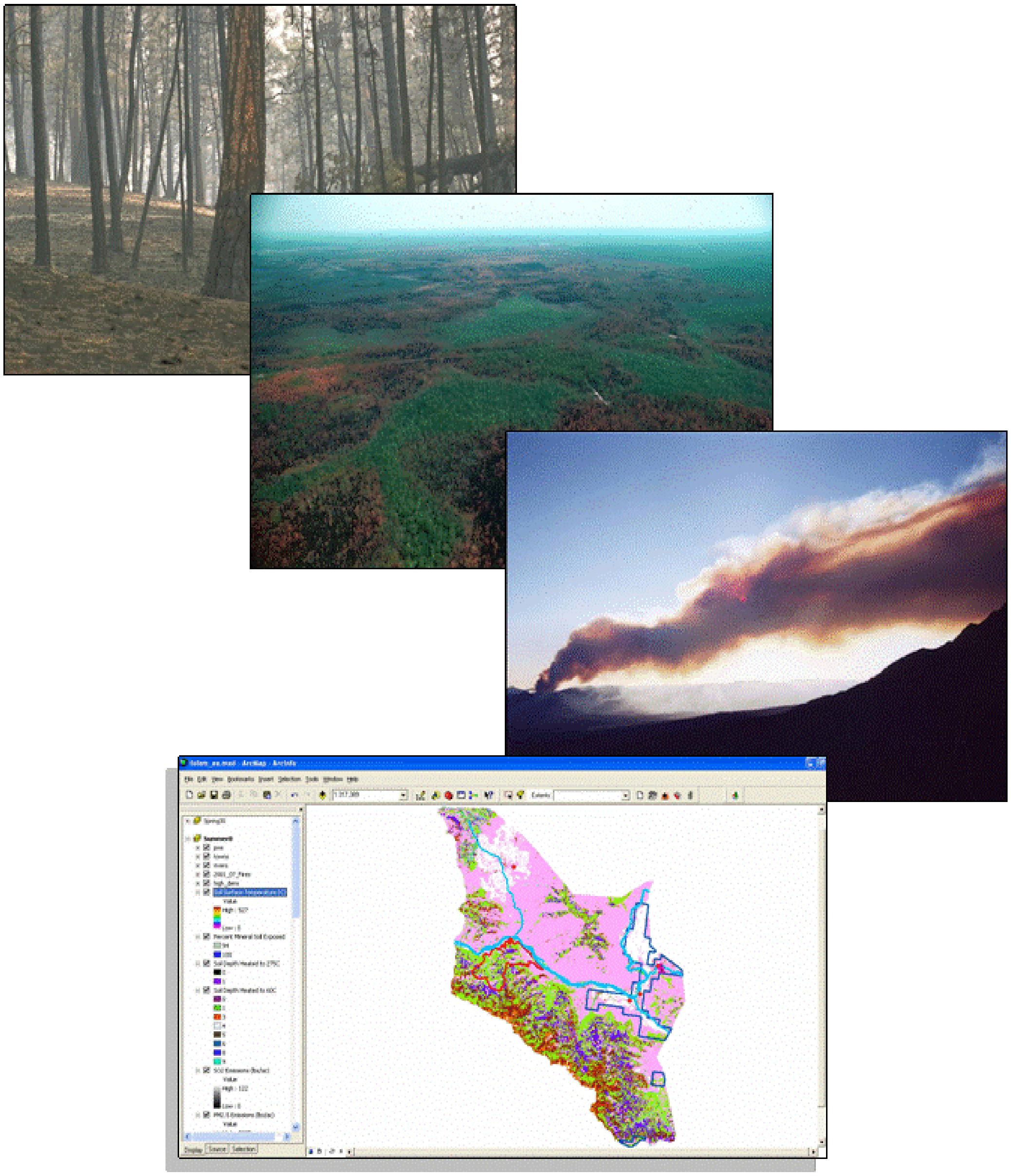

First Order Fire Effects Model Mapping Tool User's Guide

Version 1.1.0

March 30, 2009

National Interagency Fuels Technology Team

Preface

The First Order Fire Effects Model Mapping Tool (FOFEMMT) provides an interface between ArcGIS desktop software and the First Order Fire Effects Model (FOFEM) (Reinhardt 2003). FOFEM is a non-spatial fire effects analysis program that computes potential first order fire effects (fuel consumption, smoke emissions, soil heating, and tree mortality). First order fire effects are considered to represent the direct or immediate consequences of fire. The FOFEMMT is a custom ArcMap toolbar that integrates and runs FOFEM and other fire environment and fire behavior models in the background.

A primary objective behind the creation of the FOFEMMT was to develop a tool that would assist managers in predicting and planning for fire effects within a spatial context. The FOFEMMT enhances the non-spatial FOFEM by integrating spatial data that describe the fire environment and by simplifying the analysis of heterogeneous landscapes or multiple planning units.

Fire effects are determined largely by the flaming and smoldering consumption of duff and coarse woody debris after the initial flaming front has passed. However, certain fire behavior characteristics such as crown fire activity and scorch height may be used to estimate effects such as canopy consumption and tree mortality. Furthermore, fuel moisture greatly influences both fire behavior and fire effects by affecting the amount of oxygen available for combustion and heat flux, and by determining the duration of flaming and smoldering combustion. For these reasons, certain components of the fire behavior modeling system FlamMap were integrated into the FOFEMMT for estimating crown fire activity, scorch height, and fuel moisture.

Development of the FOFEMMT on the ArcMap platform allows users to easily integrate other spatial data (such as land ownership, areas of special concern, and digital imagery) into their analyses. The FOFEMMT uses spatial data that are in the ESRI Grid format and saves all outputs to this format as well. Consequently, there is no need to convert files back and forth between ASCII Grid and ESRI Grid formats as with other fire modeling systems.

Certain Photos Courtesy of Forestry Images and Fire Management Today.

The FOFEMMT is a planning tool that can be used to help:

- Identify the location of hazardous fuels
- Prioritize, design, and evaluate fuel treatment projects
- Develop burn plans for prescribed fire
- Predict fire effects for summary in planning and monitoring documents
- Assess appropriate management response to wildland fire

FOFEMMT outputs can be used to help identify the location of hazardous fuels within an analysis area and to prioritize, design, and evaluate the effectiveness of proposed fuel treatments in mitigating undesirable fire effects. For example, the tool can help answer the question "Where on a landscape are fire effects likely to be most problematic in regards to specific land management objectives?" And after a fuel treatment prescription is developed, the FOFEMMT can be used to address the question "Will the fuel treatment prescriptions actually achieve the desired fire effects?"

FOFEMMT outputs – such as maps showing potential smoke emissions or soil heating under different weather conditions and fuel moisture scenarios – can also be used to develop burn plans for prescribed fires. The tool can help answer the question "Which fuel moisture and weather conditions will result in desired fire effects?"

The FOFEMMT can also be used to assess the appropriate management response to wildland fire. Response to wildland fire depends on land management objectives and on whether a fire can be managed within a defined boundary with no adverse outcomes to life or property. FOFEMMT output maps showing potential fire effects can be used to support these decisions.

Release of this version of the FOFEMMT (1.1.0) is planned for the spring of 2009. Future versions may incorporate additional features, so be sure to check the NIFTT website (www.niftt.gov) for possible tool updates and enhancements as well as for associated updates to this user's guide.

Prerequisites

The FOFEMMT serves as an interface between ArcMap, FOFEM, and FlamMap, so users should be familiar with each of these software tools. More importantly, users should have at least a basic understanding of fire behavior and effects, including knowledge pertaining to fuels (such as fuel loading models and fire behavior fuel models), weather, topography, and wildland fire situations. Users should also understand the relationships between disturbance, vegetation attributes, and fuel characteristics. This understanding should be accompanied by an ability to use non-spatial fire behavior and effects prediction systems such as BehavePlus, NEXUS, and FOFEM. FOFEMMT users should be capable of using fire behavior and effects programs to directly analyze the effects of various input changes on outputs. In addition, because of its complexity, only those with the proper fire behavior and effects training and experience should use the FOFEMMT whenever the outputs are to be used in fire and land management decisions.

The FOFEMMT requires ArcGIS 9.2 software (or higher) and the necessary computer hardware for operation. Specific computer requirements are described in detail in Chapter 1 of this guide. The FOFEMMT has not yet been tested with the Microsoft Vista operating system or with ArcGIS version 9.3.

Obtaining copies

To obtain additional copies of this FOFEMMT User's Guide or to obtain the FOFEMMT Tutorial, follow these steps:

1. Go to www.niftt.gov
2. Click on **Tools & User Documents** under **NIFTT Resources** at the left side of the page.
3. Select the material you wish to download (User's Guide or Tutorial).

Obtain the latest version of FOFEMMT, as follows:

1. Go to www.niftt.gov
2. Click on **Tools & User Documents** under **NIFTT Resources** at the left side of the page.
3. Select the material you wish to download.

Credits

The FOFEMMT was developed for the National Interagency Fuels Technology Team (NIFTT) by Jody Bramel, Marc Dousset, and Chris Finlayson of Axiom IT Solutions and Dale Hamilton (NIFTT member) of Systems for Environmental Management (SEM), Missoula, Montana. Technical guidance was provided by Don Helmbrecht, Laurie Kurth, Duncan Lutes, Bob Keane, Elizabeth Reinhardt, Mark Finney, and Wendel Hann of the USDA Forest Service.

Support for the development of the FOFEM Mapping Tool was provided by the National Interagency Fuels Coordination Group through NIFTT. Funding was provided by the U.S. Department of Agriculture Forest Service and the U.S. Department of Interior.

This First Order Fire Effects Mapping Tool User's Guide was written by Don Helmbrecht and Jeff Jones of the USDA Forest Service and Deb Tirmenstein of SEM.

Lastly, we thank Christine Frame of SEM (and NIFTT member) for her editorial review.

Your input

We value your input. Please forward any questions, comments, reports of bugs, or ideas to the National Interagency Fuels Technology Team (NIFTT) at helpdesk@niftt.gov.

Table of Contents

Chapter 1: About the FOFEM Mapping Tool User's Guide

1.1 Before you begin

This user's guide describes the basic operation of the FOFEMMT, which serves as an interface between ArcMap, FOFEM, and FlamMap. Because we assume that FOFEMMT users have experience operating and understanding ArcMap, FOFEM, and FlamMap applications (as well as ArcGIS and Microsoft Windows in general), this user's guide will not repeat specific instructions for using any of these software packages. Instead, we encourage users to refer to the excellent help functions available with those software packages should any questions arise.

1.2 How to use this guide

You need not read the entire guide to carry out a specific task. Once you are familiar with the basic concepts associated with the FOFEMMT, you can quickly locate commonly performed tasks by reviewing the headings in the Table of Contents located near the beginning of this guide. You can then refer to the specific section pertaining to your needs. Wherever appropriate, screen captures are used to illustrate the steps required to complete a task.

The FOFEMMT User's Guide is not intended to provide step-by-step guidance on the tool's operation using specific examples; rather, it is intended to serve as a reference guide. The FOFEMMT tutorial, available at www.niftt.gov, provides step-by-step instructions using specific examples.

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1.3 Computer requirements

Ensure the following programs are installed and functioning properly on your computer:

- ArcGIS 9.2
- Spatial Analyst extension of ArcGIS 9.2
- Microsoft Access (2000 or higher)

Although system requirements to run ArcGIS 9.2 will suffice to run NIFTT tools, at least 10 GB of free hard drive space and 2 GB of RAM are recommended. Generally, faster processors, more memory, and increased free hard drive space will improve performance. In addition, NIFTT tools were developed for Windows Operating Systems.

> ***Note**: Make sure that you have sufficient space and adequate permissions for storing FOFEMMT outputs on your computer.*

> ***Note**: Make sure that the FOFEMMT version you are using correctly matches the version of ArcGIS on your computer. Use FOFEMMT version 1.1.0 only with ArcGIS 9.2. FOFEMMT version 1.1.0 has not yet been tested with ArcGIS 9.3 or the Microsoft Windows Vista operating system.*

Chapter 2: FOFEM Mapping Tool Function

2.1 What does the FOFEM Mapping Tool do?

The FOFEMMT provides an interface that allows FOFEM to be run from the ArcMap platform thus providing a spatial context for the non-spatial FOFEM. Accordingly, many of the inputs required for running non-spatial FOFEM are derived spatially. The FOFEMMT accomplishes this through the use of a spatial fire effects fuel model layer and a landscape (LCP) file that parameterizes the spatial fire environment as required by FlamMap and other fire behavior modeling systems. FlamMap is used to predict fuel moisture values and potential fire behavior that influences first order fire effects and FOFEM is used to predict those effects.

The FOFEMMT incorporates three main processing steps. First, the FOFEMMT builds the landscape (LCP) file required to run FlamMap (or FARSITE). Next, the FOFEMMT runs FlamMap to condition fuel moistures – if the user has opted to do so – and to predict potential crown fire activity and scorch height. Lastly, the FOFEMMT runs FOFEM for each unique combination of inputs to predict the potential first order fire effects of fuel consumption, smoke emissions, and soil heating. All of the FOFEMMT outputs are in the ESRI Grid format.

Chapter 3: Input Data

3.1 Description of input data

Prediction of potential fire behavior and effects requires site-specific information pertaining to fuels and topography, as well as information relating to the fuel moisture and fire weather scenario of interest. In the FOFEMMT, input data are split into three categories – spatial data, model inputs, and Coarse Wood Debris (CWD) profile. Each category is represented as a tab on the user interface. Fuel and topographic information is provided by spatial data layers specified on the **Spatial Layers** tab. Inputs required by the background models, including environmental factors describing a particular fuel moisture and fire weather scenario, are specified on the **Model Inputs** tab. Information about the coarse woody debris profile (down woody fuel greater than or equal to 3 inches (7.6 cm) in diameter) is specified on the **CWD Profile** tab.

3.2 Spatial layers

Before the FOFEM Mapping Tool can predict potential fire behavior and effects, it must first build a landscape (LCP) file that characterizes topography and fuels from nine rasters (see table 3-1). These layers must all be in ESRI Grid format.

In order to successfully build a landscape file, the FOFEMMT uses the same input theme requirements as FlamMap and FARSITE. That is, the input grids must have identical coordinate systems, spatial extents, cell resolutions, and cell alignments. The user must specify each spatial layer and its units. The FOFEMMT defaults to fuel loading model (FLM) (Lutes and others 2008) as the fire effects fuel model and LANDFIRE units for each of the other layers. The units used in the FOFEMMT must correspond to those shown in table 3-1.

Table 3-1. Input grids.

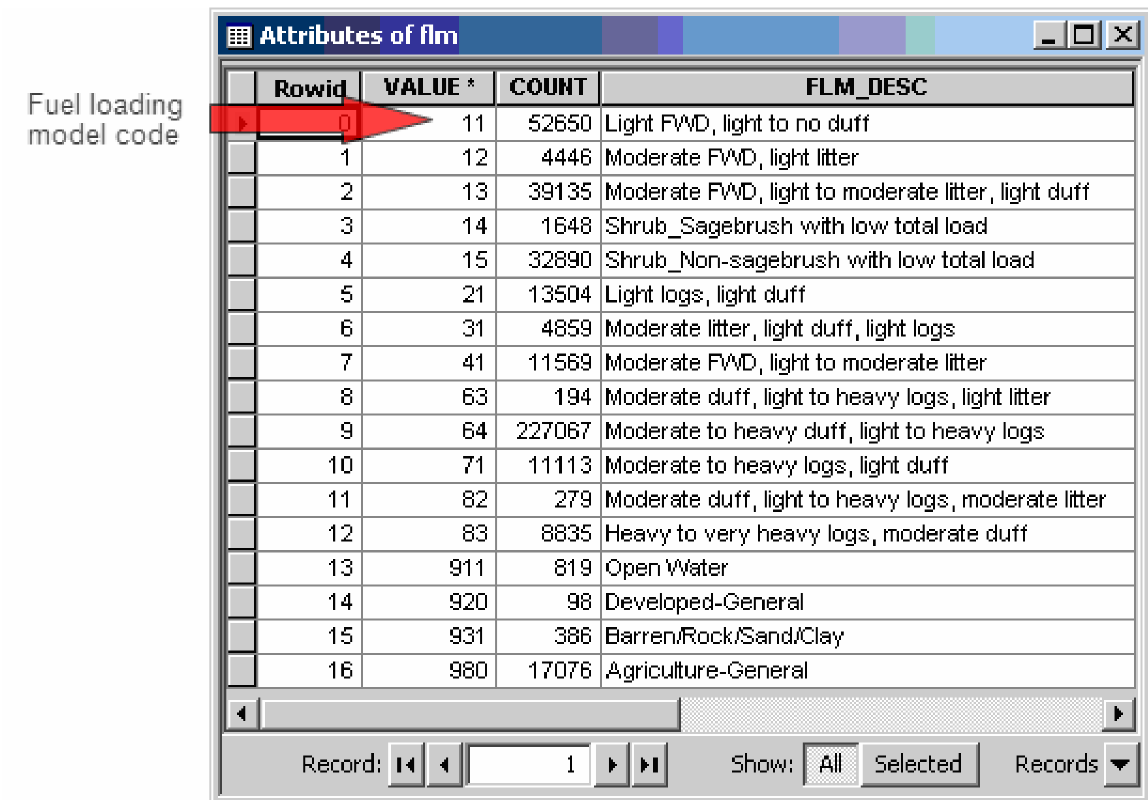
Description	Default Units	Alternate Units
Fire Effects Fuel Model (FEFM)	Fuel Loading Model (FLM)	Fuel Characteristics Classification System (FCCS), Custom
Elevation	Meters	Feet
Slope	Degrees	Percent
Aspect	Degrees	Class (1-25)
Fire Behavior Fuel Model	Standard fuel models (Anderson 1982; Scott and Burgan 2005)	
Canopy Cover	Percent	Class (0-4)
Canopy Height	Meters*10	Meters, Feet, Feet*10
Canopy Base Height	Meters*10	Meters, Feet, Feet*10
Canopy Bulk Density	kg/m^3*100	Kg/m^3, lb/ft^3, lb/ft^3*1000

The FOFEMMT can also be executed using a pre-existing landscape file derived using FlamMap, FARSITE, the Fire Behavior Assessment Tool (FBAT), or FOFEMMT.

3.2.1 Fire Effects Fuel Model

Fire effects models and modeling systems require different fuelbed inputs than do fire behavior models and modeling systems. The fuel characteristics quantified in fire behavior fuel models (FBFM) are limited to describing fuel qualities that contribute to the rate of spread of the flaming fire front. Fire effects fuel models (FEFM) represent the fuelbed characteristics needed by FOFEM to predict fire effects.

A major difference between the FEFM and the FBFM layers (see section 3.2.5) is that the FEFM layer includes coarse woody debris and duff characteristics (Scott and Reinhardt 2001). The FOFEMMT accepts two standard FEFM characterizations as mapped by the LANDFIRE Program: Fuel Loading Models (FLM) (Lutes and others 2008) and Fuel Characteristics Classification System (FCCS) (Ottmar and others 2007) fuelbeds – as well as a custom FEFM layer (table 3-1). FLMs classify the required fuelbed components into classes that significantly influence fire effects. The FCCS includes approximately 260 fuelbeds that represent the major vegetation types of the United States. Figure 3-1 shows the value attribute table of an FLM layer. A custom FEFM layer may be created in the ESRI Grid format with a value attribute table. Field names may vary and are matched to the appropriate component on the *Custom FEFM* tab.

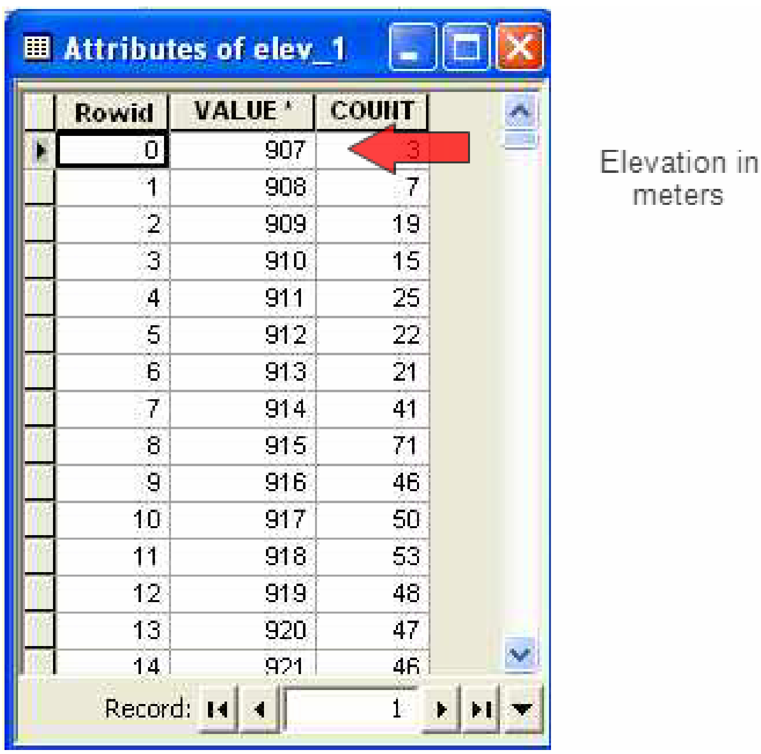


Rowid	VALUE *	COUNT	FLM_DESC
0	11	52650	Light FWD, light to no duff
1	12	4446	Moderate FWD, light litter
2	13	39135	Moderate FWD, light to moderate litter, light duff
3	14	1648	Shrub_Sagebrush with low total load
4	15	32890	Shrub_Non-sagebrush with low total load
5	21	13504	Light logs, light duff
6	31	4859	Moderate litter, light duff, light logs
7	41	11569	Moderate FWD, light to moderate litter
8	63	194	Moderate duff, light to heavy logs, light litter
9	64	227067	Moderate to heavy duff, light to heavy logs
10	71	11113	Moderate to heavy logs, light duff
11	82	279	Moderate duff, light to heavy logs, moderate litter
12	83	8835	Heavy to very heavy logs, moderate duff
13	911	819	Open Water
14	920	98	Developed-General
15	931	386	Barren/Rock/Sand/Clay
16	980	17076	Agriculture-General

Figure 3-1. Example value attribute table of a fuel loading model (FLM) layer. The **Value** field corresponds to fuel loading model codes (Lutes and others 2008).

3.2.2 Elevation

The elevation layer represents meters or feet (table 3-1) above sea level, and zero values are used for those areas that are at or below sea level. Figure 3-2 shows the value attribute table of an elevation layer. The FOFEMMT uses the elevation layer to adjust fuel moistures using adiabatic lapse rates if the user opts to condition fuel moistures. The elevation layer is also used for conversion of fire spread between horizontal and slope distances.

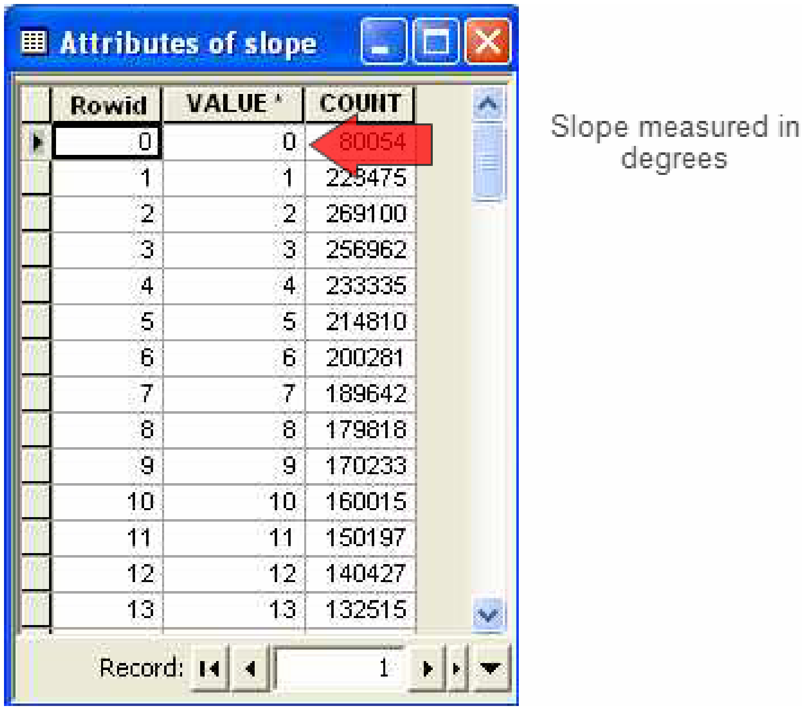


Rowid	VALUE *	COUNT
0	907	3
1	908	7
2	909	19
3	910	15
4	911	25
5	912	22
6	913	21
7	914	41
8	915	71
9	916	46
10	917	50
11	918	53
12	919	48
13	920	47
14	921	46

Figure 3-2. Example value attribute table of an elevation layer. The **Value** field must depict elevation in meters or feet above sea level.

3.2.3 Slope

The FOFEMMT uses the slope layer for computing slope effects on flame length, fire spread – and if fuel moisture conditioning is used – solar radiance. The slope layer can have cell values represented by either floating point numbers (decimals) or integers and the units may be expressed in either degrees or percent (table 3-1). Figure 3-3 displays the value attribute table of a slope layer.



Attributes of slope

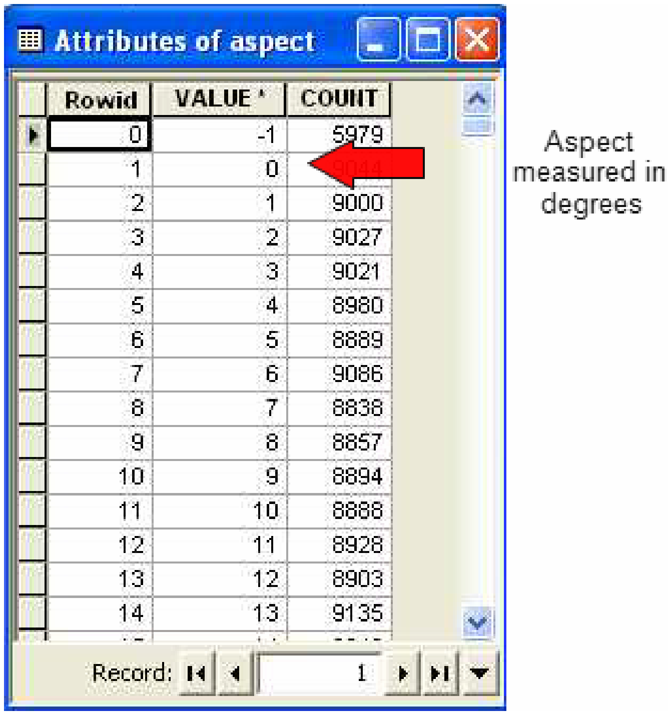
Rowid	VALUE *	COUNT
0	0	80054
1	1	223475
2	2	269100
3	3	256962
4	4	233335
5	5	214810
6	6	200281
7	7	189642
8	8	179818
9	9	170233
10	10	160015
11	11	150197
12	12	140427
13	13	132515

Record: 1

Figure 3-3. Example value attribute table of a slope layer. The **Value** field must show slope in degrees.

3.2.4 Aspect

The aspect layer determines the effect of slope orientation on fuel moisture with respect to solar radiance when fuel moisture conditioning is used. The FOFEMMT aspect layer must denote slope azimuth in degrees clockwise from the north (table 3-1). Cell values can be represented by either floating point numbers (decimals) or integers. Flat areas which lack an aspect are identified by a value of -1. Figure 3-4 displays the value attribute table of an aspect layer.

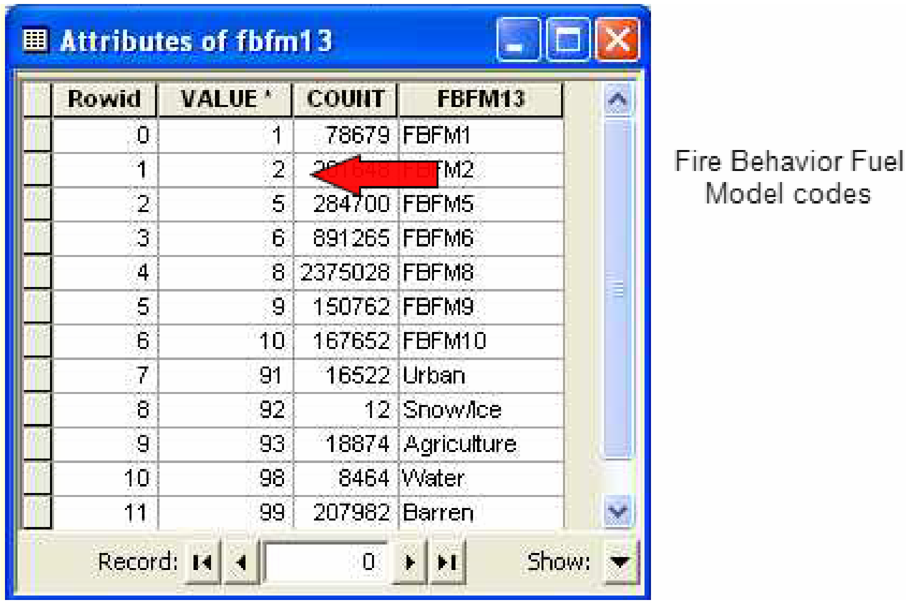


Rowid	VALUE *	COUNT
0	-1	5979
1	0	9044
2	1	9000
3	2	9027
4	3	9021
5	4	8980
6	5	8889
7	6	9086
8	7	8838
9	8	8857
10	9	8894
11	10	8888
12	11	8928
13	12	8903
14	13	9135

Figure 3-4. Example value attribute table of an aspect layer. The **Value** field must depict aspect in degrees. (A value of -1 denotes flat areas that have no aspect.)

3.2.5 Fire Behavior Fuel Model

A fire behavior fuel model (FBFM) is a set of fuelbed inputs used by the Rothermel (1972) fire spread model, which is incorporated into the FlamMap fire modeling system and therefore the FOFEMMT. The FOFEMMT uses the fire behavior fuel model layer to predict potential fire behavior that influences fire effects (crown fire activity and scorch height) as well as to initialize the fuel moisture values of the fine woody debris (less than 3 inches (7.6 cm) in diameter) for fuel moisture conditioning. The FOFEMMT can use either the 13 fire behavior fuel models characterized by Anderson (1982) or the 40 characterized by Scott and Burgan (2005) (table 3-1). However, the FOFEMMT cannot use a fuel layer containing custom fuel models. Cells must contain integers denoting the numeric codes of Anderson's (1982) models (values: 1 to 13) or the Scott and Burgan (2005) models (values: 91 to 204) (see fig. 3-5). Non-burnable fuels must be denoted by values 91, 92, 93, 98, and 99, which characterize urban/developed, snow/ice, agriculture, water, and bare ground, respectively. Additional attributes (such as a text descriptor of the model) are commonly included in the fuel model layer.



Rowid	VALUE *	COUNT	FBFM13
0	1	78679	FBFM1
1	2	[illegible]	FBFM2
2	5	284700	FBFM5
3	6	891265	FBFM6
4	8	2375028	FBFM8
5	9	150762	FBFM9
6	10	167652	FBFM10
7	91	16522	Urban
8	92	12	Snow/Ice
9	93	18874	Agriculture
10	98	8464	Water
11	99	207982	Barren

Figure 3-5. Example value attribute table for a fire behavior fuel model (FBFM) layer (Anderson 1982). The **Value** field must correspond to the numeric fire behavior fuel model codes of Anderson (1982) or Scott and Burgan (2005).

3.2.6 Canopy Cover

Canopy cover is a stand attribute that corresponds to the proportion of the ground that is covered directly overhead by the overstory canopy (that is, the vertical projection of the canopy to the ground). The canopy cover layer is used to compute the wind reduction factor attributable to the canopy and the subsequent wind speed at the mid-flame height. The canopy cover layer is also used to modify solar radiance when fuel moisture conditioning is used. The FOFEM Mapping Tool requires that the canopy cover layer be expressed in percent (0 – 100) (table 3-1) or in categories (0 – 4) (table 3-1). Categories are assumed to be the following:

0: 0%
1: 1-20%
2: 21-50%
3: 51-80%
4: 81-100%

A cell value of 0 indicates a non-forested setting. The cell values can be denoted by either floating point numbers (decimals) or integers. Figure 3-6 displays the value attribute table of a canopy cover layer.

Attributes of cc

Rowid	VALUE *	COUNT	CANOPYCOVER_PERC
0	0	1009711	Non-Forested
1	15	[illegible]	[illegible] CC < 20
2	25	538852	20 <= CC < 30
3	35	410617	30 <= CC < 40
4	45	351280	40 <= CC < 50
5	55	386181	50 <= CC < 60
6	65	363689	60 <= CC < 70
7	75	169659	70 <= CC < 80
8	85	50732	80 <= CC < 90
9	95	8735	90 <= CC <= 100

Record: 0 Show: All

Canopy Cover measured in percent

Figure 3-6. Example value attribute table for a canopy cover layer. In this example, the **Value** field denotes canopy cover in percent and canopy cover has been grouped into ten classes in which the cell value corresponds to the class mid-point. Thus, a cell value of 15 represents a canopy cover class with values ranging from 10 to 20 percent. A value of 0 indicates a non-forested setting. This is the LANDFIRE standard.

3.2.7 Canopy Height

Canopy height is a stand attribute that reflects the average height of the overstory dominant and co-dominant in a stand. The canopy height layer is used to compute the wind reduction factor attributable to the canopy and the subsequent wind speed at the mid-flame height. In FARSITE, the canopy height layer is also used for estimating spotting distances from torching trees. The FOFEMMT requires the canopy height layer units to be in meters*10 (fig. 3-7), meters, feet*10, or feet (table 3-1). A cell value of 0 indicates a non-forested setting. The cell values can be denoted by either floating point numbers (decimals) or integers.

Attributes of ch

Rowid	VALUE *	COUNT	CANOPYHEIGHT_MET
0	0	[illegible]	[illegible]-Forested
1	25	2892412	0 < CH < 50
2	75	902	50 <= CH < 100
3	175	498560	100 <= CH < 250
4	375	3	250 <= CH < 500

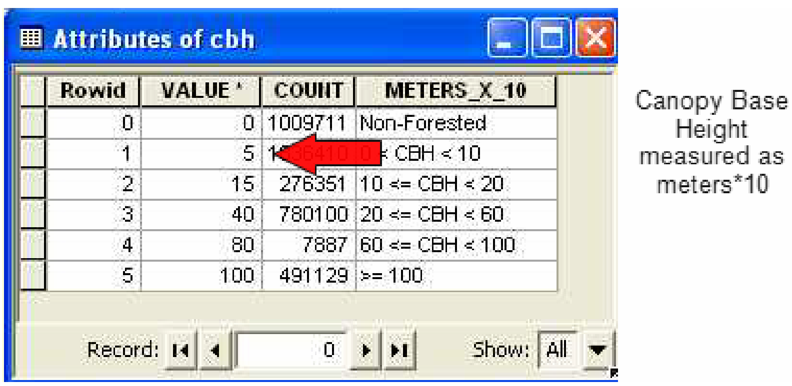
Record: 0 Show: All

Canopy height measured as meters*10

Figure 3-7. An example value attribute table for a canopy height layer. In this example, the units are meters*10 and the canopy heights have been grouped into five classes in which the cell value corresponds to the mid-point of the class. For example, a value of 25 relates to a canopy height class that ranges between 0 and five meters. This is the LANDFIRE standard.

3.2.8 Canopy Base Height

Canopy base height is a stand attribute that denotes the lowest height above the ground which has sufficient canopy fuel to propagate fire vertically. The canopy base height layer is necessary for determining the transition from a surface fire to a crown fire. Typically, lower canopy base heights increase the likelihood of torching (in other words, lower heights increase the likelihood of passive crown fires). The FOFEMMT requires the canopy base height layer units to be in meters*10 (fig. 3-8), meters, feet*10, or feet (table 3-1). A cell value of 0 characterizes a non-forested setting. Cell values can be denoted by either floating point numbers (decimals) or integers.



Rowid	VALUE *	COUNT	METERS_X_10
0	0	1009711	Non-Forested
1	5	[illegible]	[illegible] CBH < 10
2	15	276351	10 <= CBH < 20
3	40	780100	20 <= CBH < 60
4	80	7887	60 <= CBH < 100
5	100	491129	>= 100

Figure 3-8. Example value attribute table for a canopy base height layer. In this example, the **Value** field depicts heights expressed in meters*10. Thus, a cell value of 20 corresponds to a two-meter canopy base height. This is the LANDFIRE standard.

3.2.9 Canopy Bulk Density

Canopy bulk density is a stand attribute that refers to the weight (mass) of "available" canopy fuel, both dead and live, per unit volume of canopy. Available canopy fuel is of a size and type that would be consumed in the flaming front. FARSITE and FlamMap use canopy bulk density to determine the transition between passive and active crown fire. (See Scott and Reinhardt [2001] for a discussion on the derivation of crown fire activity). The FOFEMMT requires the units of the canopy bulk density layer to be expressed in kg/m^3 *100 (fig. 3-9), kg/m^3, lb/ft^3*1,000, or lb/ft^3 (table 3-1). Cell values can be represented by floating point numbers (decimals) or integers.

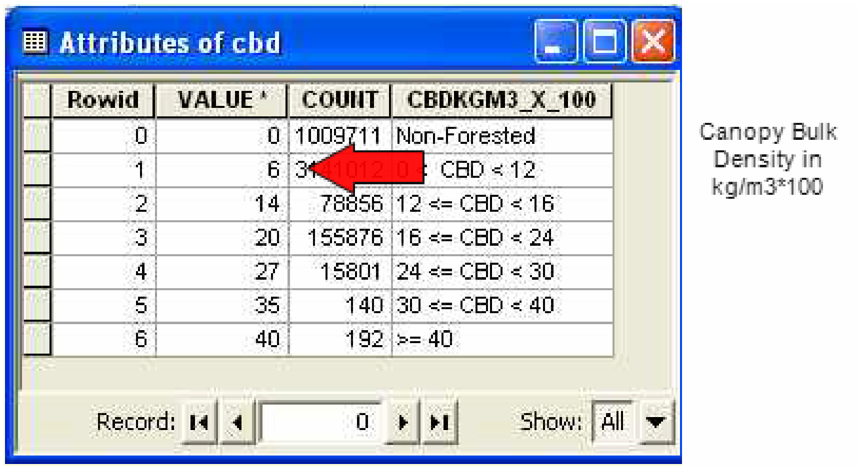


Figure 3-9. Example value attribute table for a canopy bulk density layer. In this example, the **Value** field depicts canopy bulk density in kg/m^3 *100. Thus a cell value of 20 corresponds to a 0.2 kgm^3 crown bulk density. A value of 0 identifies a non-forested area.

3.3 Model Inputs

Input parameters that describe the fire environment, specify the crown fire calculation method, and determine consumption algorithms in the FOFEMMT's background fire modeling systems – FlamMap and FOFEM – are specified on the **Model Inputs** tab. Figure 3-10 displays the **Model Inputs** tab.

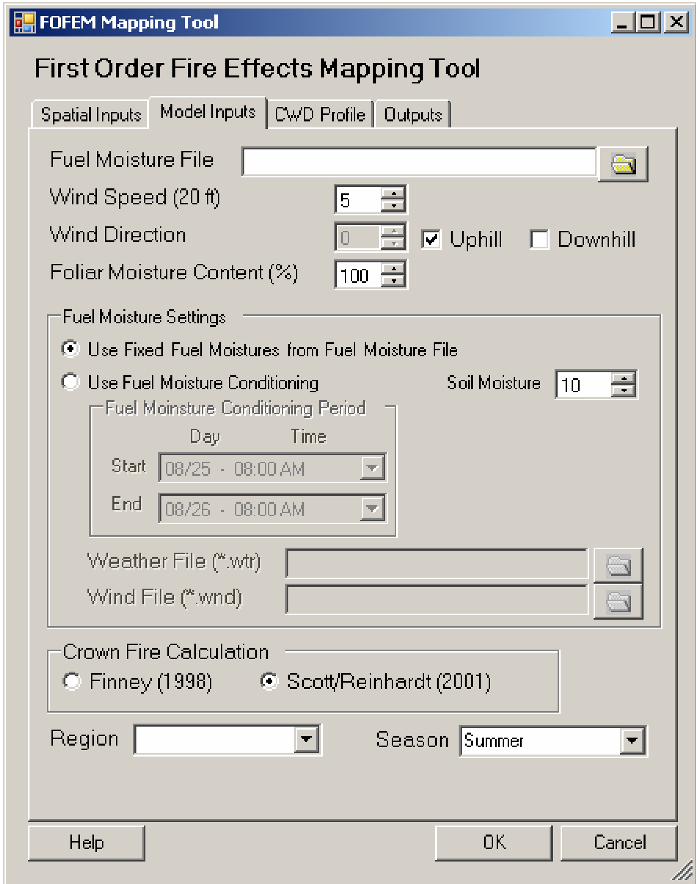


Figure 3-10. The **FOFEM Mapping Tool** dialog box showing **Model Inputs** tab.

3.3.1 Fuel Moisture File

Like FlamMap, the FOFEMMT requires a text file (.fms) that specifies the initial fuel moisture values (1-hr, 10-hr, 100-hr, live herbaceous, and live woody fuels) for each of the fire behavior fuel models (see fig. 3-11). The most important step in selecting appropriate fuel moisture values is to describe the type of fire weather and fuel moisture scenario to be simulated. For example, simulations designed for fire use or prescribed fire applications would likely have higher fuel moistures than those used for simulating rare event large wildfires in the extremes of the wildfire season. We recommend using data provided by the Weather Information Management System (WIMS) and FireFamily Plus software to identify fuel moisture values that are appropriate for specific simulation scenarios.

The fuel moisture file used by the FOFEMMT is a space-delimited text file that has an .fms extension instead of a .txt extension. A column header is not included in the file; it is therefore very important that users understand the format. There are six columns in the .fms file that denote fire behavior fuel model, 1-hour timelag dead fuel moisture (1-hr), 10-hour timelag dead fuel moisture (10-hr), 100-hour timelag dead fuel moisture (100-hr), live-herbaceous fuel moisture (LH), and live-woody fuel moisture (LW), respectively (see fig. 3-11). The values representing fire behavior fuel models (FBFM) correspond to the numeric codes used by Anderson (1982) or Scott and Burgan (2005). Fuel moisture values represent percent moisture and must be integers (in other words, no decimals). (See Appendix D for additional information on fuel moisture values).

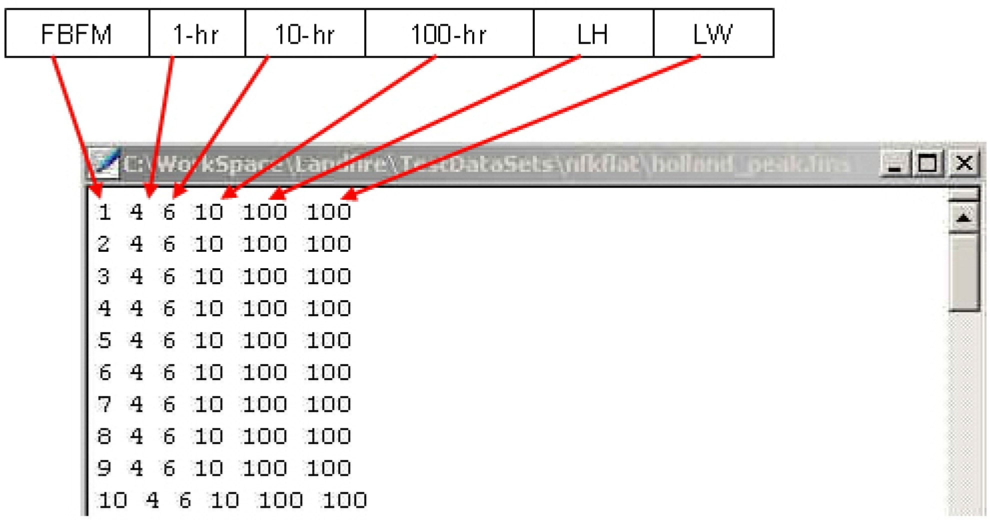


Figure 3-11. Example fuel moisture file that includes the first ten fuel models characterized by Anderson (1982). (FBFM = fire behavior fuel model; 1-hr = 1-hr fuel moisture; 10-hr = 10-hr fuel moisture; 100-hr = 100-hr fuel moisture; LH = live herbaceous fuel moisture; LW = live woody fuel moisture.)

3.3.2 Wind Speed

The user must input the 20 ft (6.1 m) wind speed for predicting potential fire behavior. The wind speed refers to the speed of the wind that occurs 20 ft (6.1m) above the canopy of the dominant vegetation. Thus, in grasslands, the wind speed denotes winds at 20 ft (6.1m) above the herbaceous canopy, whereas in forests, the value represents winds 20 ft (6.1m) above the canopy. Values must be integers that express wind speed in miles per hour.

3.3.3 Wind Direction

Three options are available for entering wind direction. FOFEMMT users may specify that the wind is blowing uphill, downhill, or they may enter an azimuth in degrees indicating the direction that the wind is blowing from. Selecting the **Wind Direction Uphill** option will maximize potential fire behavior for any given pixel.

3.3.4 Foliar Moisture

Foliar moisture represents the percent moisture contained by live leaves or needles of the overstory. Foliar moisture influences the transition between surface and crown fires. Typical foliar moisture values range from 80 to 130 percent. A value of 100 percent is frequently used for typical conditions and is used as the default value in the FOFEMMT. A value of 80 percent typically reflects the effects of cumulative drought in systems where average annual precipitation is less than 30 inches (76 cm), while 100 percent would reflect those same areas having recovered from drought. A value of 130 percent would reflect moist forest systems in a normal year, whereas 100 percent may reflect moist forest systems experiencing cumulative drought.

***Tip**: In general, short needle species appear to have lower foliar moisture than long needle species and dry faster during dry seasons.*

3.3.5 Fuel Moisture Settings

In the FOFEMMT, fuel moisture values may either be fixed or conditioned. Under the fixed fuel moisture scenario, fuel moistures in the initial fuel moisture (.fms) file (1-hr, 10-hr, 100-hr, LH, and LW) correspond to the fire behavior fuel model layer and therefore vary spatially only with the fire behavior fuel model. Likewise, the 1,000-hr+ fuel moisture values, specified in the Coarse Woody Debris (CWD) profile (see section 3.4) correspond to the fire effects fuel model layer and vary spatially only with the fire effects fuel model.

If fuel moisture conditioning is used, a separate fuel moisture value is calculated for each cell in the landscape based on topography, shading, weather, and conditioning period length. The user must specify a weather (.WTR) file, wind (.WND) file, and conditioning period.

A general duff moisture model does not exist, so the FOFEMMT uses the empirical relationship developed by Harrington (1982) to predict duff moisture content from the 100-hr dead fuel moisture value. If fuel moisture conditioning is used, the duff moisture equation is applied after conditioning the 100-hr fuels.

Soil moisture is held constant in the FOFEMMT. Typical soil moisture values range from 5% (very dry) to 25% (wet).

3.3.6 Crown Fire Calculation Method

The FOFEMMT allows the user to specify which crown fire calculation method is to be used by FlamMap. The choice is largely dependent on the source of the canopy bulk density (CBD) data being used. If the source of the CBD data is based on a method that uses biomass equations (running mean methods), the Scott and Reinhardt method (2001) should produce the best results whereas the Finney (1998) method should under-predict active crown fire potential. Examples of CBD data sources based on biomass equations include LANDFIRE National, FFE-FVS, FuelCalc, and FMAPlus. If the CBD data were created or modified (for example, multiplying biomass equation derived CBD by a factor of 1.5 – 2.0) to work well with the Finney method, then the Finney method should produce the best results and the Scott and Reinhardt method should over-predict active crown fire potential. Example data sources that have modified biomass equation derived CBD include LANDFIRE Rapid Refresh (in some areas) and some *ad hoc* data projects.

Note*: If non-biomass equation estimates of CBD are used, canopy consumption estimates and the resultant contribution to emissions may be inaccurate (see* *section 4.2.1**).*

3.3.7 Region

A major internal component of FOFEM is an algorithm decision key that selects the best available algorithm for predicting fire effects based on the conditions specified by the user. Region is one of the variables used within this key for selecting shrub and duff consumption algorithms. The available regions in the FOFEMMT are Interior West, Pacific West, Southeast, and Northeast (see Appendix C).

3.3.8 Season

Season is another variable used in the FOFEM algorithm decision key. Season is one of the variables used within this key for selecting herbaceous and shrub consumption algorithms. The available seasons in the FOFEMMT are Spring, Summer, Fall, and Winter (see Appendix C).

3.4 Coarse Woody Debris (CWD) Profile

Coarse Woody Debris (CWD) refers to down dead woody material greater than or equal to 3 inches (7.6 cm) in diameter. This is also sometimes referred to as the 1,000-hr and greater dead timelag fuel class. The CWD profile specifies additional data describing CWD. This additional information is used to predict flaming and smoldering combustion of these larger fuels. The **CWD Profile** tab (figure 3-12) allows the user to specify a CWD profile for each value in the fire effects fuel model layer. This is similar to the process used by the post-frontal combustion model in FARSITE version 4.

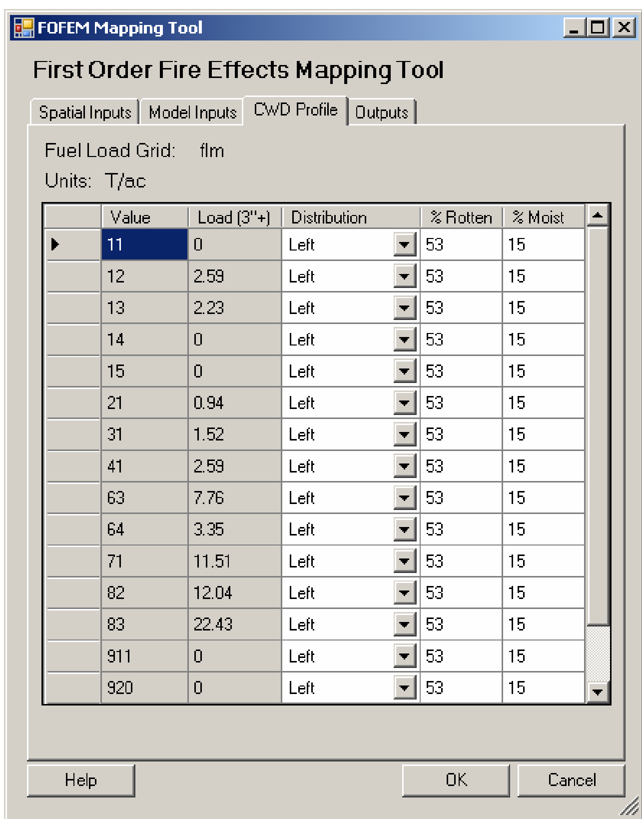


Figure 3-12. The FOFEMMT **CWD Profile** tab. In this example, fuel loading model (FLM) values are displayed.

3.4.1 Log Distribution

Log distribution refers to the distribution of the coarse woody debris fuel load across four diameter classes (3-5.9, 6-8.9, 9-19.9, and 20 inch and greater (7.6-15.0, 15.2-22.6, 22.9 -50.6, and 50.8 cm and greater)). Distributing the total coarse woody debris load among diameter classes improves model precision when simulating burning rate and total consumption (Lutes 2005). The FOFEMMT uses five generic representations of CWD load distribution as follows:

1. Left – most of the load is in pieces 3-8.9 inches (7.6-15.0 cm) in diameter
2. Right - most of the load is in pieces 9 inches (22.9 cm) and larger in diameter
3. Center – load is concentrated in the 6-19.9 inch (15.2 -22.9 cm) diameter range
4. End – load is in pieces 3-5.9 inches (7.6-15.0 cm) and 20 inches (50.8 cm) or greater in diameter
5. Even – the load in all diameter classes is within 10% of each other.

Log distribution is expressed graphically as follows (fig. 3-13):

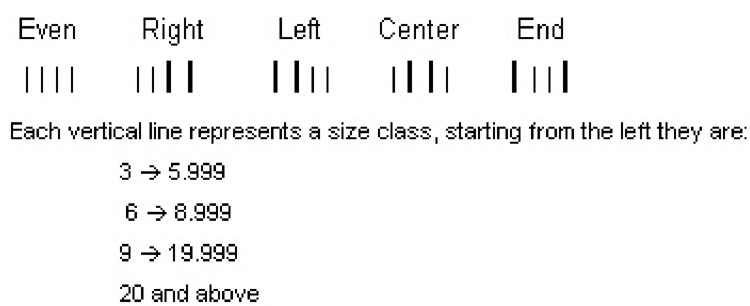


Figure 3-13. An example log distribution.

The FCCS fuelbeds have already distributed the CWD load into three diameter classes (3-8.9, 9-19.9, and 20 inch (7.6-22.6, 22.9-50.6 and 50.8 cm) and greater). To accommodate the FOFEM distribution classes the 3-8.9 inch (7.6-22.6 cm) class is first split equally into the 3-5.9 (7.6-15.0 cm) and 6-8.9 inch (15.2-22.6 cm) classes.

Regardless of the fire effects fuel model characterization used (FLM, FCCS, or custom) the distribution may be specified for each fire effects fuel model on the **CWD Profile** tab. That is, the total load will be redistributed from the default.

3.4.2 Log Percent Rotten

Percent rot of CWD is specified for each fire effects fuel model on the **CWD Profile** tab. Rotten wood has both a lower density and ignition temperature than sound wood. The proportion of rot within the fuel complex significantly influences consumption (Lutes 2005).

3.4.3 Log Percent Moisture

Fuel moisture greatly influences fire effects by affecting the amount of oxygen available for combustion and heat flux, and by determining the duration of flaming and smoldering combustion. Initial fuel moisture values for each fire effects fuel model are specified on the **CWD Profile** tab. If fuel moisture conditioning is used these values will be modified (section 3.3.5).

Chapter 4: Output Data

4.1 Utility of outputs

FOFEMMT outputs can be used to spatially identify problematic areas from a fire effects perspective based on fuel consumption, emissions, and soil heating. Outputs may be useful for assessing the appropriate management response to wildland fires (including wildland fire use), locating fuel treatment opportunities, evaluating fuel treatment effectiveness, and for predicting fire effects for summary in planning and monitoring documents. For example, information on potential smoke emissions, soil heating, and tree mortality can aid in decisions regarding the appropriate management response to wildland fire or prioritizing suppression resources. Outputs are also helpful in assessing fire risk relative to ecological and social values and in subsequent prioritization of fuel treatment opportunities.

Once a project is identified, FOFEMMT outputs can be used to help formulate fuel treatment prescriptions, for example, setting acceptable upper and lower fuel moisture values for conducting prescribed burns or for determining the number of acres that may be burned on a given day without exceeding particulate emission limits. After a project is designed, pre-treatment fire effects can be compared to post-treatment effects to evaluate whether the proposed fuel treatment produced the desired outcome.

4.2 Description of outputs

Three categories of spatial layers are generated by the FOFEMMT: fuel consumption, emissions, and soil heating. Table 4-1 lists both the layer and ESRI Grid names, as well as the pixel type of the individual spatial outputs in each of these categories. The following sections discuss individual outputs further; however, for a detailed description of the science and assumptions behind each of the individual models within FOFEM see the "Scientific Content" section of the FOFEM help documentation.

Table 4-1. Spatial outputs generated by the FOFEMMT characterizing potential fire effects.

	Layer Name (units)	Grid Name	Grid Format
Consumption	**Postburn Litter Load (T/ac)**	litter_pos	Floating point
	Postburn 1-Hour Load (T/ac)	one_hr_pos	-
	Postburn 10-Hour Load (T/ac)	ten_hr_pos	-
	Postburn 100-Hour Load (T/ac)	hun_hr_pos	-
	Postburn CWD Sound Load (T/ac)	cwd_snd_pos	-
	Postburn CWD Rotten Load (T/ac)	cwd_rot_pos	-
	Postburn Duff Load (T/ac)	duff_pos	-
	Postburn Herbaceous Load (T/ac)	herb_pos	-
	Postburn Shrub Load (T/ac)	shrub_pos	-
	Postburn Crown Load (T/ac)	crown_pos	-
	Total Postburn Load (T/ac)	total_pos	-
	Postburn Fuel Loading Model (FLM)	flm_pos	Integer
	Consumed Litter Load (T/ac)	litter_cns	Floating point
	Consumed 1-Hour Load (T/ac)	one_hr_cns	-
	Consumed 10-Hour Load (T/ac)	ten_hr_cns	-
	Consumed 100-Hour Load (T/ac)	hun_hr_cns	-
	Consumed CWD Sound Load (T/ac)	cwd_snd_cns	-
	Consumed CWD Rotten Load (T/ac)	cwd_rot_cns	-
	Consumed Duff Load (T/ac)	duff_cns	-
	Consumed Herbaceous Load (T/ac)	herb_cns	-
	Consumed Shrub Load (T/ac)	shrub_cns	-
	Consumed Crown Load (T/ac)	crown_cns	
	Total Consumed Load (T/ac)	total_cns	-
Emissions	**PM10 Emissions (lbs/ac)**	pm10	Integer
	PM2.5 Emissions (lbs/ac)	pm2_5	-
	CH4 Emissions (lbs/ac)	ch4	-
	CO Emissions (lbs/ac)	co	-
	CO2 Emissions (lbs/ac)	co2	-
	NOX Emissions (lbs/ac)	nox	-
	SO2 Emissions (lbs/ac)	so2	-
Soil Heating	**Soil Depth Heated to 60C (cm)**	dep_60c	Integer
	Soil Depth Heated to 275C (cm)	dep_275c	-
	Percent Mineral Soil Exposed (percent)	min_exp	-
	Soil Surface Temperature (C)	surf_temp	-

4.2.1 Fuel Consumption

The FOFEMMT allows the user to specify the fuel components of interest and whether to calculate post-burn fuel load, consumed fuel load, or both. Fuel components include duff, litter, 1-hr, 10-hr, 100-hr, sound and rotten CWD (1,000-hr, or 3 inches (7.6 cm) and greater), herbaceous, shrub, and canopy fuels affected by crown fire.

One major assumption FOFEM makes in predicting fuel consumption is that the entire area of concern experienced fire. FOFEM does not predict fire effects for patchy or discontinuous burns. For these situations, results should be weighted by the percent of the area burned.

FOFEM uses the Burnup model to predict consumption of woody fuels (Albini and Reinhardt 1995; Albini and others 1995; Albini and Reinhardt 1997). Consumption of herbaceous fuels, shrub, and duff is predicted using the best available algorithm as determined by an algorithm decision key that takes into account the region, season, and cover type of the project area (see Appendix C).

Duff: A number of duff consumption algorithms are incorporated in the FOFEMMT. Separate predictions are made of percent duff consumption, duff depth consumed, and mineral soil exposure. The most appropriate algorithm is determined by the algorithm decision key. Variables in the FOFEMMT that affect the selection of the duff consumption algorithm include region and cover type. Region is a user-selected variable and cover type is pre-set for fire effects fuel models in both the FLM and FCCS characterizations.

***Note**: FLMs assign cover type only to shrub models: FLM 14, 15, 53, 54, 65, and 66: the forested FLMs by design do not refer to any specific cover type.*

Two other variables used to determine the duff consumption algorithms in FOFEM, fuel category (natural, activity, or piles) and duff moisture method (for example, lower, upper, entire) are defaulted to natural and entire (average) in the FOFEMMT.

Litter: The consumption of litter is calculated by Burnup. Generally 100% of the litter is consumed.

1-hr, 10-hr, and 100-hr down dead woody fuel: The consumption of the 1-, 10-, and 100-hour down dead woody fuel is calculated by Burnup. The amount of consumption is highly dependent on the amount, distribution, and moisture of the fuel components as well as the contribution of duff consumption. Although FOFEM allows the user to specify the fuel category (natural, activity, or piles), the FOFEMMT assumes that the fuel category is natural.

***Note**: Burnup does not treat consumption of natural and activity fuels differently. In the current version of FOFEM this variable is used only to adjust screen settings for default fuel loads.*

CWD: The consumption of CWD is also calculated by Burnup. The amount of consumption is highly dependent on the amount, distribution, moisture, and percent rot of the CWD as specified in the CWD profile (section 3.4).

Herbaceous: Herbaceous fuels generally represent a small component of the total fuel load. However, for completeness, especially in the modeling of emissions, their consumption is computed in the FOFEMMT. Generally, 100% of the herbaceous fuels are assumed to burn. If the cover type is "grass" and the season "spring," however, only 90% of the herbaceous fuels are consumed.

Shrub: Shrub consumption is modeled according to general rules summarized as follows:

- If the cover type is sagebrush and the season is fall, shrub consumption is 90%; for all other seasons consumption is 50%.
- For other cover types dominated by shrubs (except in the southeast), shrub consumption is assumed to be 80%.
- For cover types not dominated by shrubs, shrub consumption is set to 60%.
- For the southeastern region and the pocosin cover type, in spring or winter shrub consumption is 90%, in summer or fall it is 80%.
- For non-pocosin types in the southeast, Hough's (1968, 1978) research was used to predict shrub consumption: percent consumption = ((3.2484 + 0.4322 * preburn litter and duff loading + .6765 * preburn shrub and regeneration loading - .0276* duff moisture – (5.0796 / preburn litter and duff loading) – litter and duff consumption) / preburn shrub and regeneration loading) * 100%.

Canopy: Canopy fuel load (CFL) is the oven-dry mass of available canopy fuel per unit ground area. Available canopy fuel refers to the foliage and fine branchwood (0 – 0.25 inch (0 – 6 cm)) biomass available for consumption in a crown fire.

The canopy fuel load is calculated in the FOFEMMT using the following general rule of thumb equation: CFL = (CBD * (CH – CBH))/2

Where,

CFL is canopy fuel load (kg/m^2)
CBD is canopy bulk density (kg/m^3)
CH is stand height (m)
CBH is canopy base height (m)

***Note**: This equation assumes that the canopy bulk density data being used is based on a method that uses biomass equations (for example, running mean methods), such as those used in LANDFIRE National, FFE-FVS, FuelCalc, and FMAPlus. If non-biomass equation estimates of CBD are used, canopy consumption estimates and the resultant contribution to emissions may be inaccurate (see section 3.3.6).*

The FOFEMMT uses the crown fire activity predicted by FlamMap to estimate the proportion of canopy affected by crown fire. Under passive crown fire (CFA = 2) we assume that 50% of the canopy is affected. Under active crown fire (CFA = 3) we assume that 100% of the canopy is affected.

We further assume that the canopy fuel load consists of 10% branch biomass and 90% foliage biomass (Reinhardt personal communication). The FOFEMMT then applies the proportion of canopy affected, as based on CFA, to 100% of the foliage biomass and 50% of the branch biomass so that consumption of these fuels is represented for purposes of estimating smoke production.

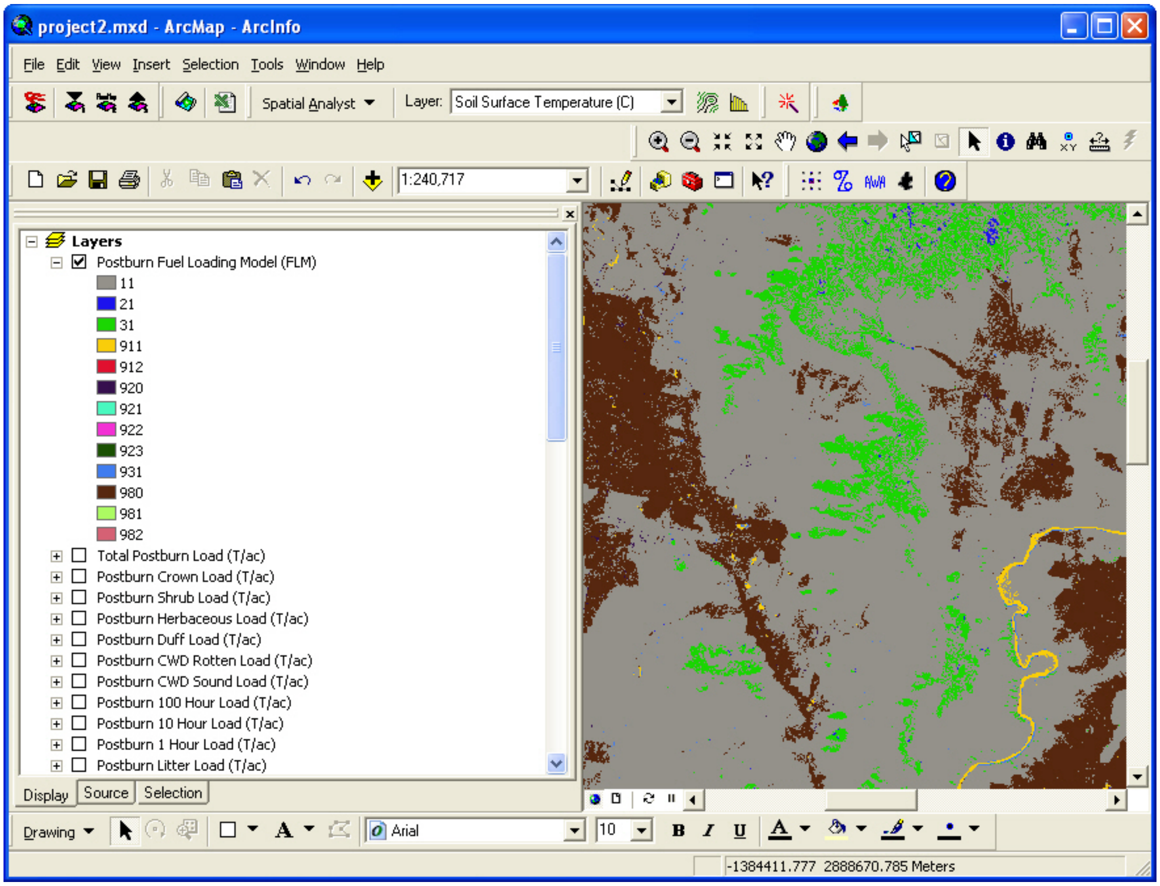


Figure 4-1. Fuel consumption output layers.

4.2.2 Emissions

Flaming and smoldering combustion can be simulated simultaneously in the FOFEMMT. For example, flaming combustion in woody fuels may be occurring at the same time that smoldering combustion is occurring in the duff or CWD. By distinguishing fuel weight consumed in flaming and smoldering phases of combustion, the Burnup model allows emission factors to be applied separately to the fuel consumed in each phase. The emission factor for a particular pollutant is defined as the mass of pollutant produced per mass of fuel consumed (Hardy and others 2001). Emission factors vary by pollutant and type and arrangement of fuel. In the FOFEMMT emission factors for particulate and chemical emissions are applied to the fuel consumed in flaming and smoldering combustion assuming the values of combustion efficiencies of 0.97 for flaming and 0.67 for smoldering. For example:

Total emission = mass x combustion efficiency x emission factor

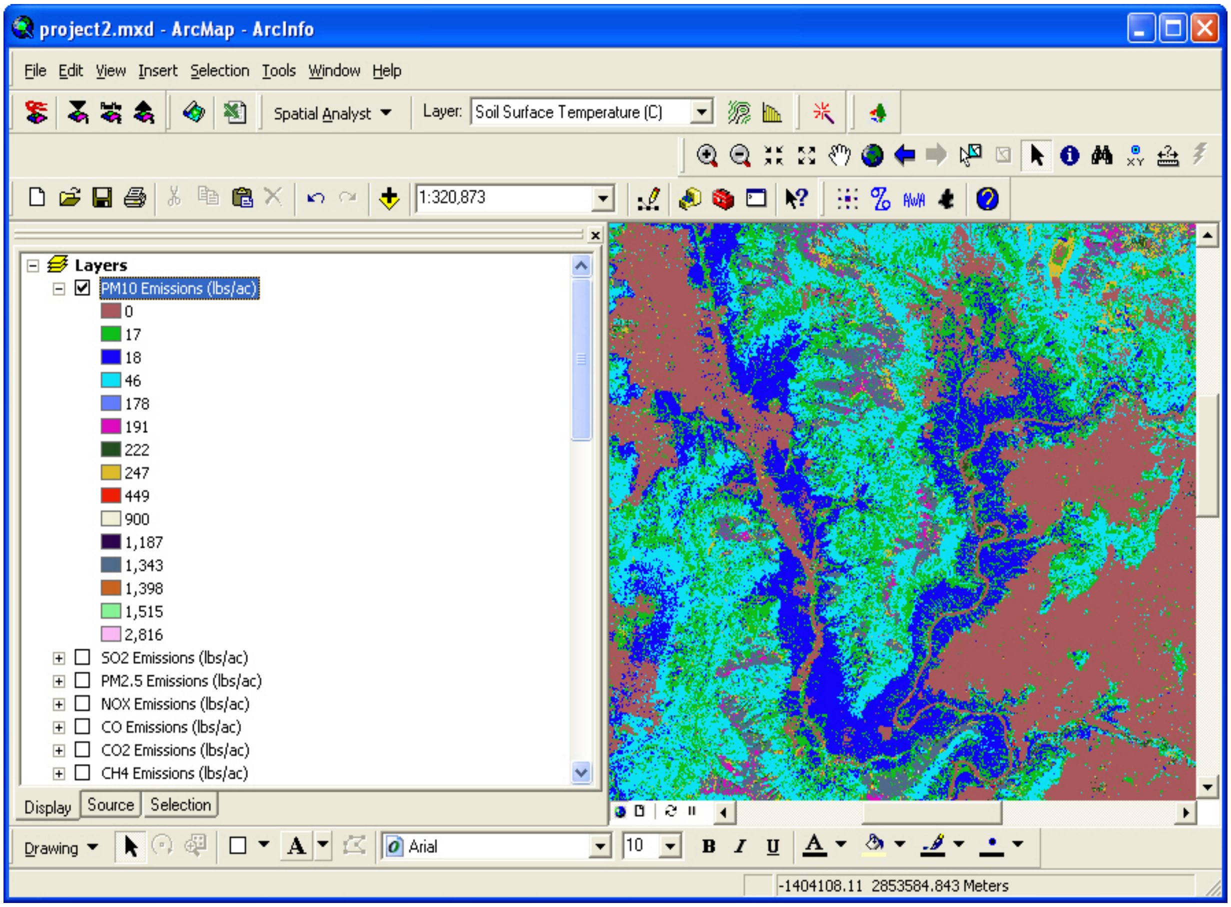


Figure 4-2. Emissions output layers in Table of Contents.

4.2.3 Soil Heating

Two variations of the soil heating model were developed in FOFEM in order to simulate soil heating under conditions with burnable duff material and where there is an absence of any burnable duff. In the later case, soil heating is attributed to the surface fire rather than the slower moving, lower intensity smoldering duff fire.

The FOFEMMT assumes the duff depth (inches) to be 1/10th of the duff load (tons/acre). By knowing the depth and density of duff, the FOFEMMT computes the total amount of heat that is released when it burns. This heat is released over a period of time, which is determined by the rate of spread of the fire, which in turn is correlated to the moisture of the duff material. The dryer the duff, the faster it will burn. Duff moisture is based on 100-hr fuel moisture in the FOFEMMT (see section 3.3.5).

Part of the heat produced by the fire is radiated and convected away at the duff surface, and part flows into the soil. Attempting to separate these values is difficult and highly variable depending on the fire behavior; therefore, the FOFEMMT assumes a worse-case scenario with the model and applies all of the heat generated from the burning duff into the soil. It is often observed that not all of the duff material is consumed in the fire and the remaining unburned duff acts as a soil insulator. In such cases the model accounts for the amount of heat absorbed by the unburned duff and predicts soil heating based not only on the amount of heat generated from the burning duff, but also from the amount of heat absorbed by the unburned duff layer.

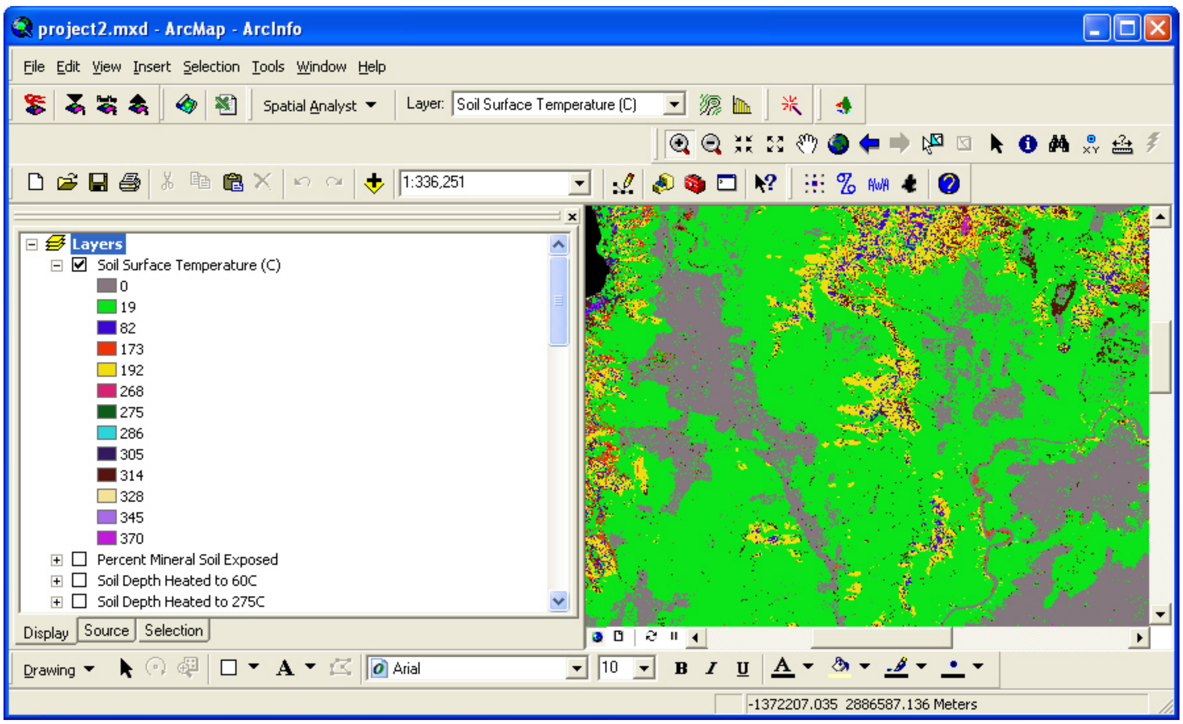


Figure 4-3. Soil output layers.

Chapter 5: Installing the FOFEM Mapping Tool

5.1 General installation instructions

All NIFTT tools, including the First Order Fire Effects Model Mapping Tool (FOFEMMT), are now downloaded and installed as single tools. A complete or package install is no longer available for versions of NIFTT tools compatible with ArcMap 9.2.

> ***Note***: *For FOFEMMT version 1.1.0 to operate properly, you will need to verify that you are using ArcGIS 9.2.*

If you have an earlier version of the FOFEMMT installed on your computer, you will first need to uninstall it before proceeding with installation of the current version.

To determine which version is currently installed on your computer, go to **Start > Control Panel > Add or Remove Programs** as shown:

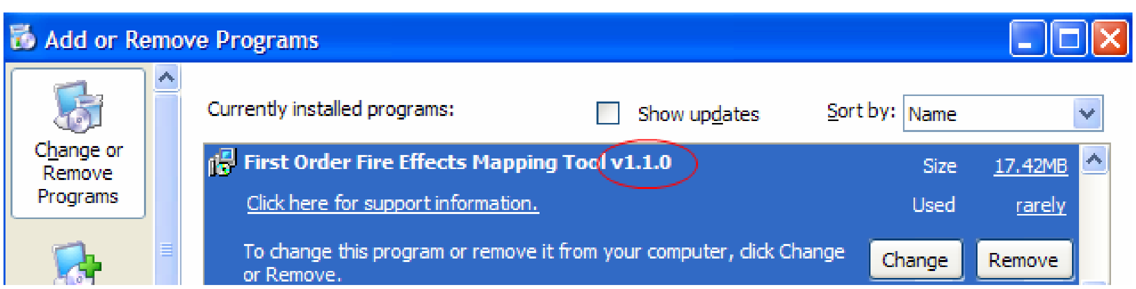


Figure 5 -1. FOFEM Mapping Tool version 1.1.0.

> ***Note**: NIFTT naming conventions are as follows: FOFEMMT_Setup_110_081008 indicates that this "install" is version 1.1.0 and was completed on 8/10/2008.*

You may need administrative privileges to install the FOFEMMT. Contact your system administrator if you experience problems with the installation.

5.2 FOFEM Mapping Tool installation

5.2.1 Downloading the FOFEM Mapping Tool

Install or reinstall the First Order Fire Effects Model Mapping Tool (FOFEMMT) as follows:

> ***Note**: If you have an earlier version of FOFEMMT installed on your computer, you will first need to uninstall it before proceeding with installation of the current version. Refer to section 5.1 for more information on this subject.*

Download FOFEMMT from the website at www.niftt.gov. Click on **Tools & User Documents** under **NIFTT Resources** on the left side of the page.

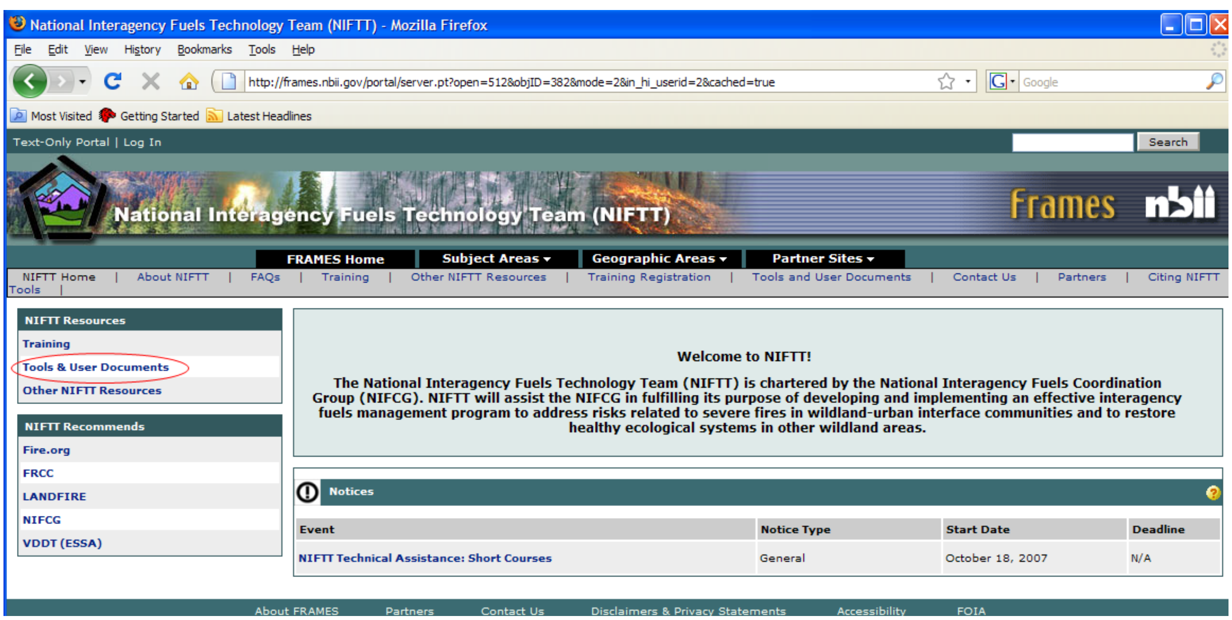


Figure 5-2. Select Tools & User Documents.

Click on the most recent **FOFEMMT Install File** from the table to begin the download process.

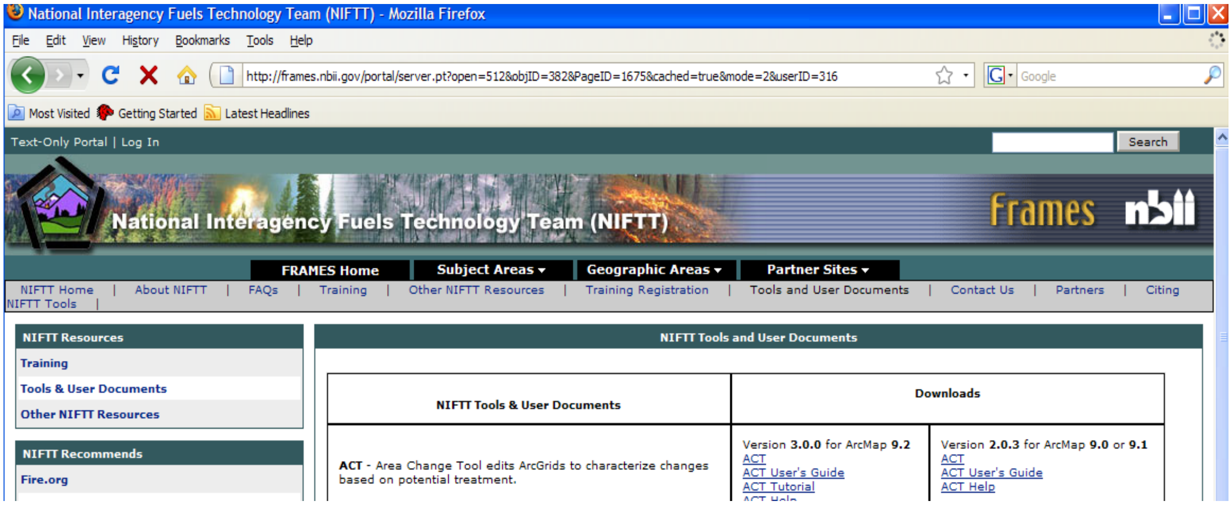


Figure 5-3. Click on FOFEMMT Install File.

***Note**: To continue with the download, you will need to have WinZip or a similar program installed on your computer.*

Click **OK** or **Save File** to download the self-extracting WinZip FOFEMMT installation file and then save it to a convenient location on your computer.

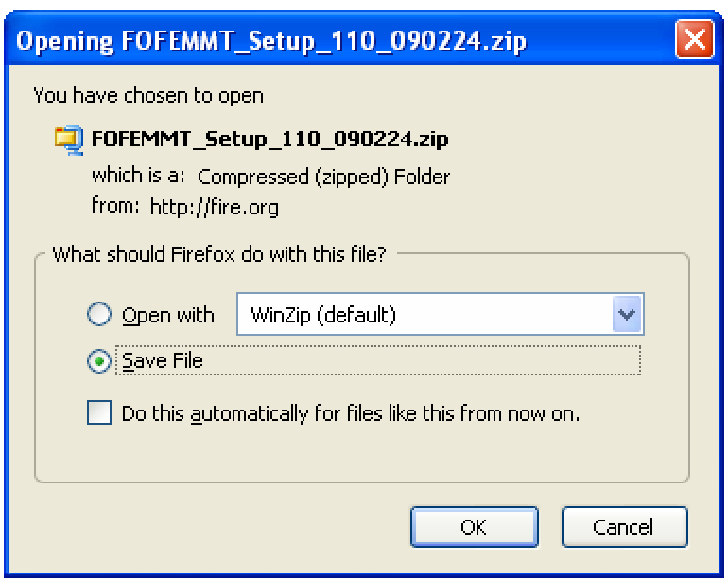


Figure 5- 4. Download and save installation file.

5.2.2 Beginning the installation process

Go to the file in which you stored the FOFEMMT zip file and double-click on the file as shown in figure 5-5.

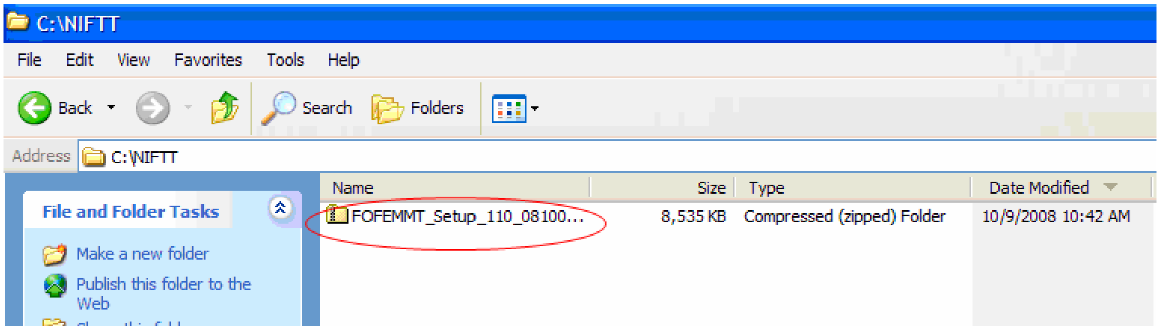


Figure 5- 5. Self-extracting FOFEMMT installation file has been downloaded and saved.

The box shown in figure 5-6 will open. Unzip the files to either the default location (C:\\NIFTT as shown in figure 5-5) or to another location of your choice by using the browse button. Next, navigate to the directory in which you have saved your extracted FOFEMMT files.

Note: *Do not install the FOFEM Mapping Tool or any other NIFTT tool to a pathway that may contain a space in the folder name such as "My Documents" or "Program Files."*

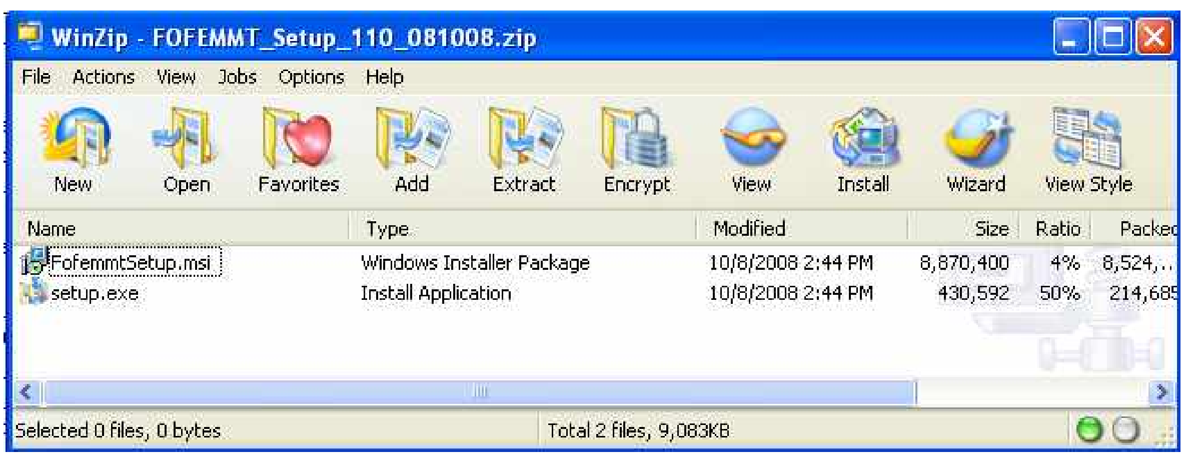


Figure 5- 6. FOFEMMT installation files.

Click on **setup.exe**.

Note*: If the setup determines that an earlier version of FOFEMMT is already installed on your computer, go to* ***Start > Control Panel*** *and* *select **Add/Remove Programs.** Uninstall the previous version of FOFEMMT and then rerun **setup.exe**.*

If the setup.exe determines that you already have the proper .NET Framework (2.0) installed on your computer, the FOFEMMT zip file contains everything that you will need to install the tool. A series of dialog boxes will now open. Skip to section 5.2.4 to continue installation.

5.2.3 Obtaining the latest .NET Framework

If the installer determines that the setup requires a .NET Framework that has not been previously installed on your computer, you will see a dialog box similar to the one displayed in figure 5-7 instead of the first FOFEMMT Setup Wizard screen as shown in figure 5-14.

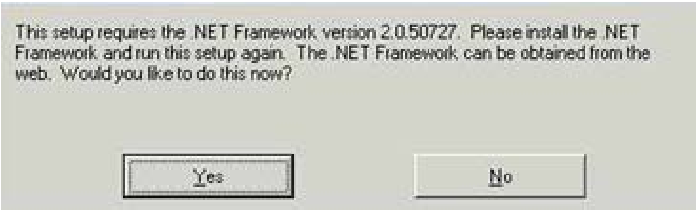


Figure 5-7. Dialog box indicating the need to first install .NET Framework for installation to proceed.

Click on **Yes** and follow all prompts as directed. If the .NET Framework 2.0 has not been previously installed on your computer, the setup will at this point direct you to a website where you will be able to download the appropriate file (fig. 5-8).

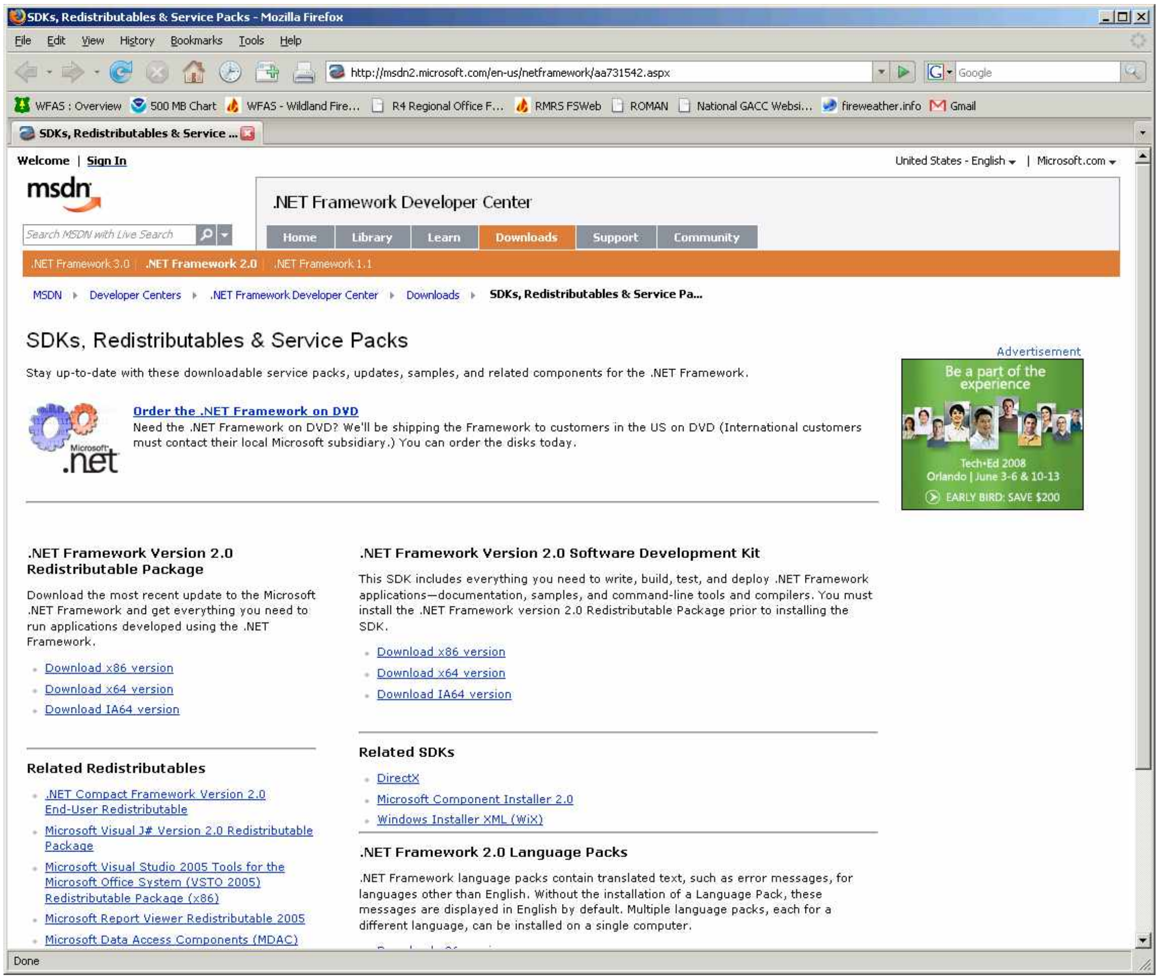


Figure 5-8. Website for downloading .NET Framework 2.0.

As shown in figure 5-9, you will now need to specify which version of .NET Framework you would like to install on your computer. Select the x86 version if you have a Pentium (or other 32-bit) computer. Click on **Download x86 version**.

Tip: *Most users will need to specify the x86 version of NET Framework 2.0. If you are unsure, contact your system administrator.*

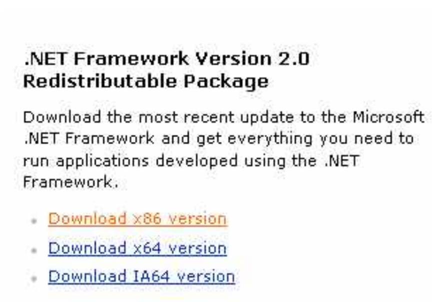


Figure 5-9. Select an appropriate version of .NET Framework.

A screen similar to the following (fig. 5-10) will appear after your selection has been made. Click on the **Download** button to continue.

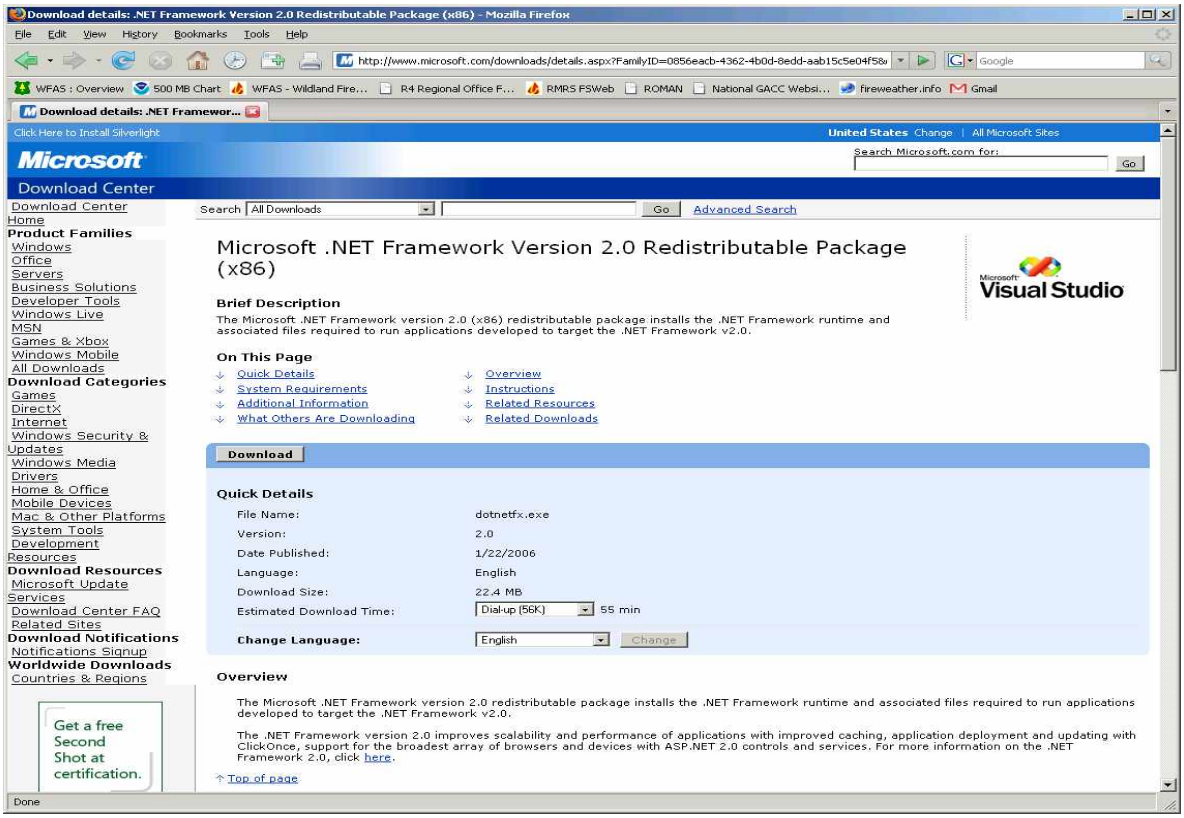


Figure 5-10. Microsoft .NET Framework Version 2.0 (x86) download page.

Browse to a location of your choice. Download and save the dotnetx.exe file as shown below (fig. 5-11).

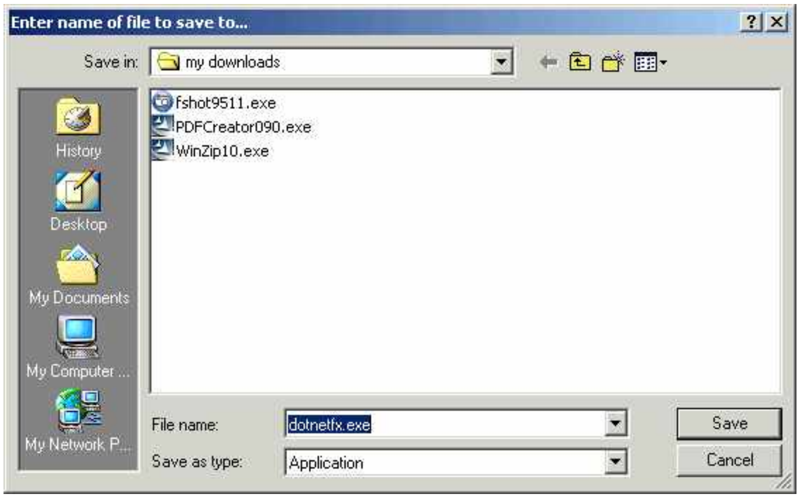


Figure 5-11. Save the file to a location of your choice.

Figure 5-12. Progress bar for download of dotnetfx.exe.

The Microsoft .NET framework 2.0 will automatically download, extract and install as shown in figures 5-12 and 5-13.

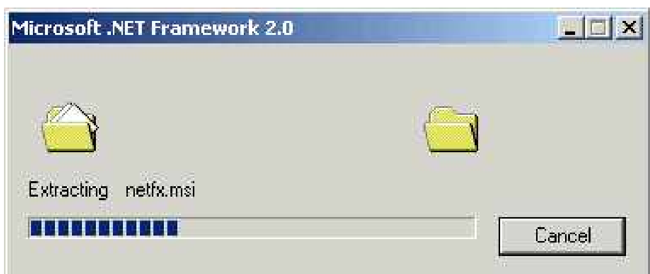


Figure 5-13. .NET Framework installation.

Click on the setup.exe file as shown in figure 5-6 to initiate the setup wizard and to continue installation of FOFEMMT.

At this point, you may need administrative privileges to continue. Contact your system administrator if you experience problems

5.2.4 Finishing the installation

After clicking on the setup.exe file, the first in a series of FOFEMMT Setup Wizard dialog boxes will open. Follow all instructions as directed by the dialog boxes in the FOFEMMT Setup Wizard. During the installation process you may see a radio button asking you to specify whether the tool is to be installed for "Everyone" or "Just Me." Select the "Everyone" option.

***Note**: With FOFEMMT version 1.1.0, it is no longer necessary to reboot your computer during the installation process.*

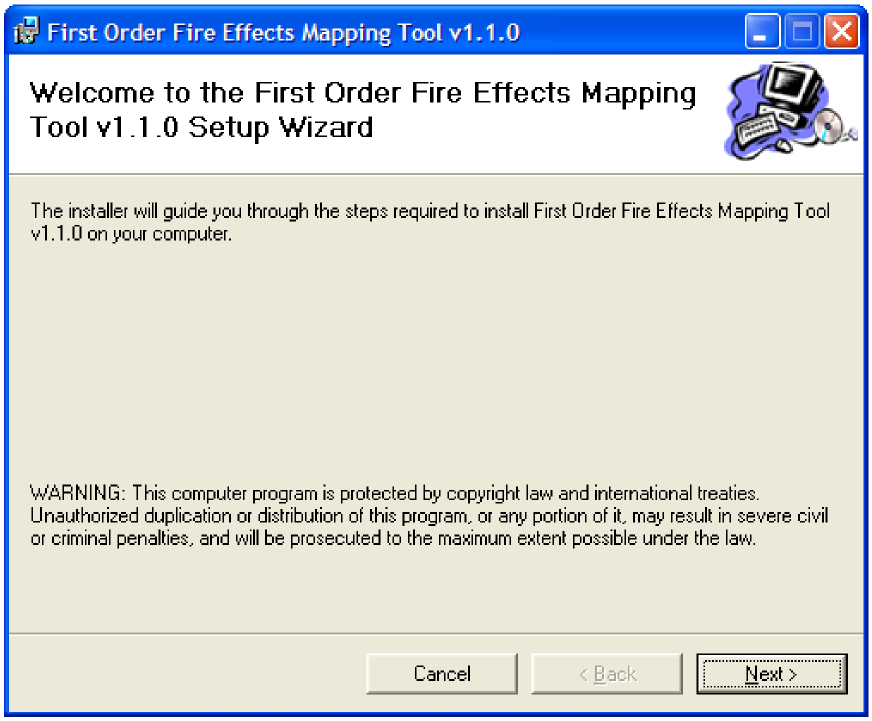


Figure 5- 14. FOFEMMT setup wizard.

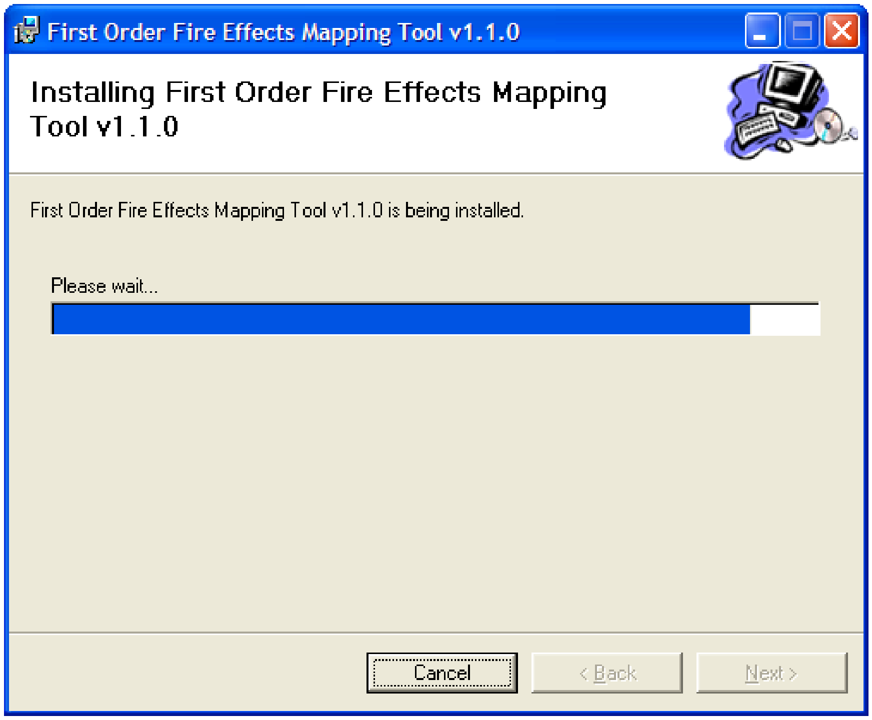


Figure 5-15. Setup Wizard continues installation process.

Click on **Finish** when the FOFEMMT installation is complete.

Open ArcMap and make sure that the FOFEMMT toolbar  is visible.

Note: *The FOFEMMT toolbar may be "floating." If so, you will need to anchor it in a convenient location.*

***Tip**: For best results, make sure that you have installed the most recent ArcGIS service packs and patches. Go to www.esri.com to verify that you have the most recent versions for 9.2 already installed on your computer. If you do not, download the newer service packs and patches as directed on the website.*

5.3 Troubleshooting FOFEM Mapping Tool installation

If the FOFEMMT toolbar as shown at right  does not install automatically, select **View > Toolbars** and check the box to the left of **FOFEMMT** as shown in figure 5-16:

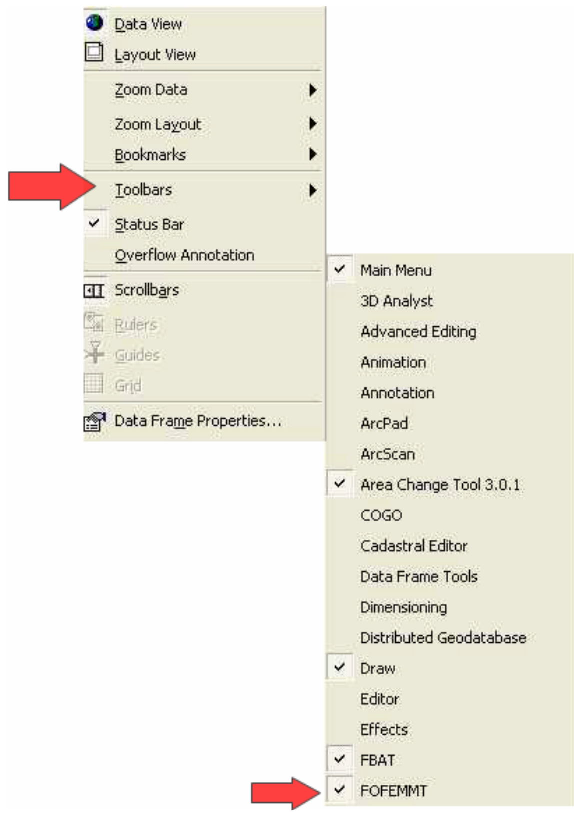


Figure 5- 16. Verify that the box to the left of FOFEMMT is checked.

In ArcMap, select the **Tools** menu and click on **Customize**. Again, make sure that the box to the left of FOFEMMT is checked.

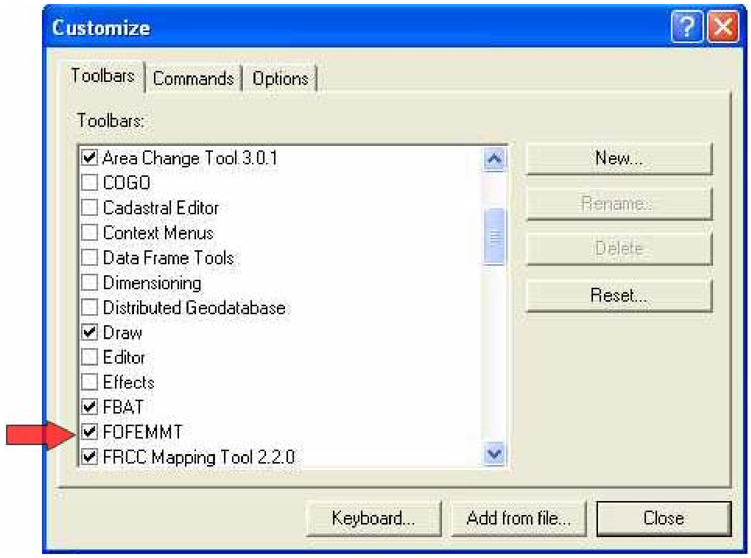


Figure 5- 17. Check the box to the left of **FOFEMMT.**

If the FOFEMMT box is still unavailable in the **Toolbars** list, click on **Add from file** (fig. 5-18).

> ***Note**: To continue this process, you must first log on as an "Administrator." Contact your systems administrator if you experience problems.*

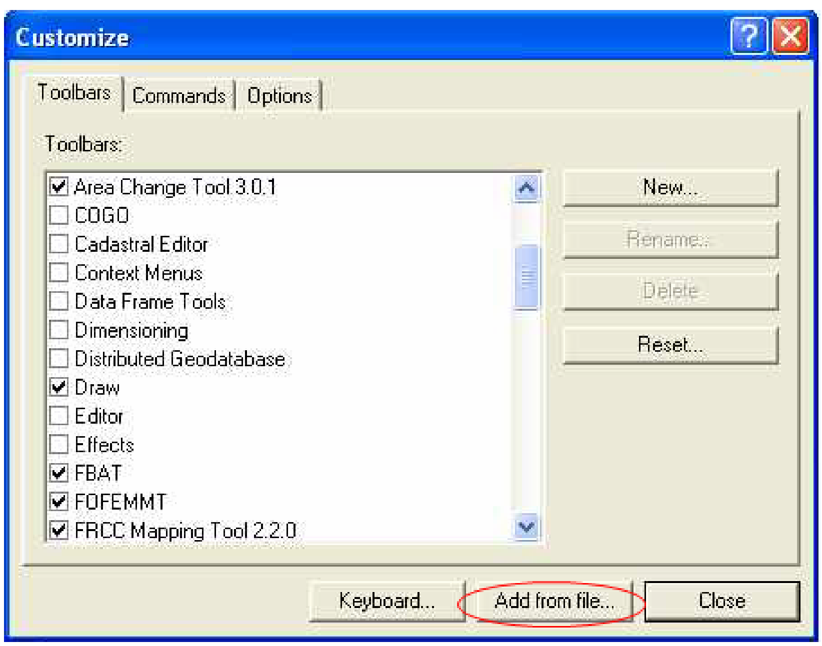


Figure 5- 18. Select **Add from file...**

Navigate to the directory in which you have saved your extracted FOFEMMT files (the default location is (C:\\NIFTT)) and select **FOFEMMT.dll** from the **First Order Fire Effects Mapping Tool** folder as shown in figure 5-19.

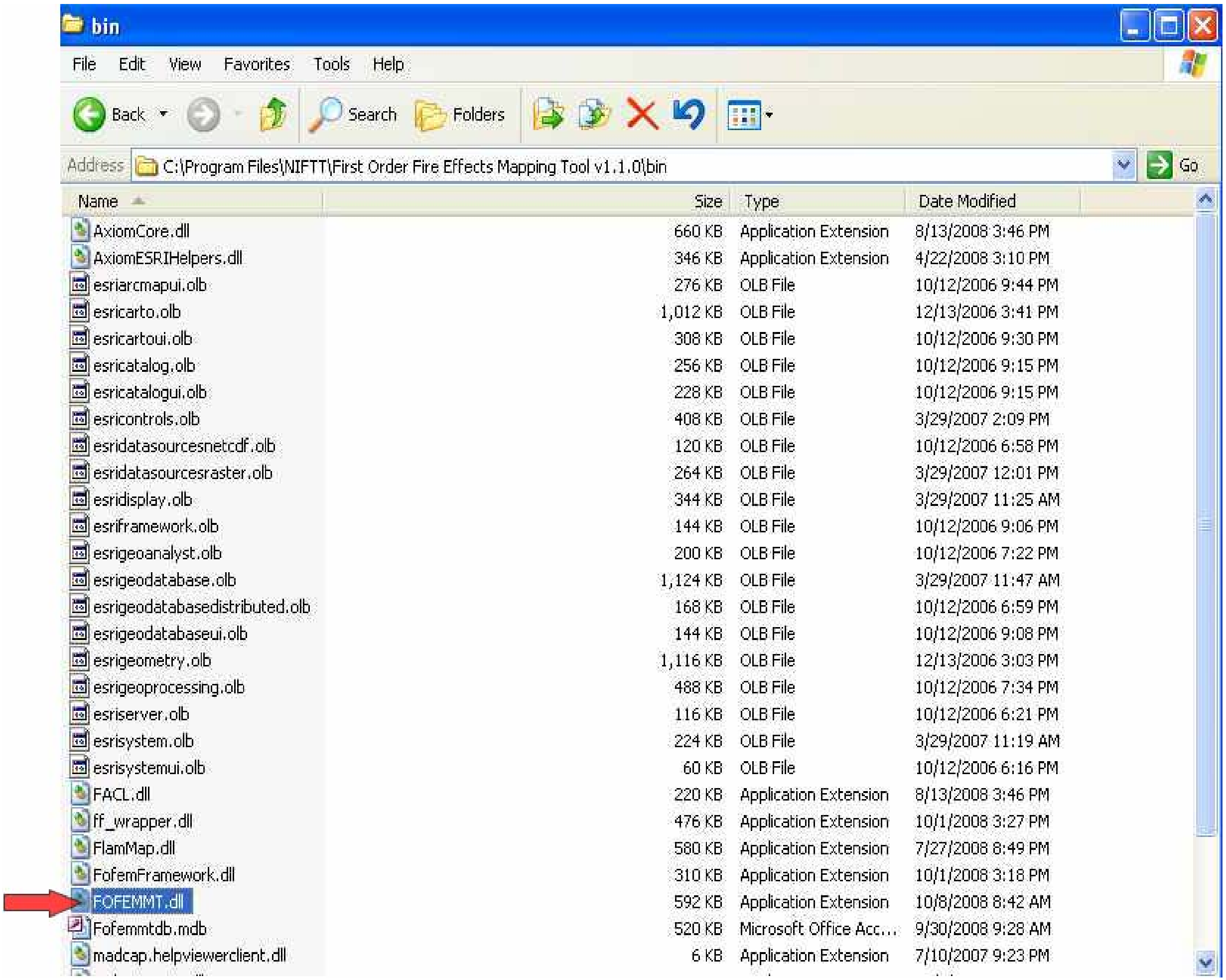


Figure 5- 19. Select FOFEMMT.dll from bin.

The FOFEMMT toolbar should now be enabled and ready for use. Check it now if it is not already selected.

> ***Note**: For all NIFTT tools, including FOFEMMT, to function properly, the Spatial Analyst extension must be installed and activated. To make sure, open ArcMap, go to the **Tools** menu and select **Extensions**. Make sure that the box to the left of **Spatial Analyst** is checked and click **Close**.*

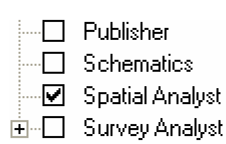


Figure 5- 20. Check the box to the left of Spatial Analyst.

Direct any questions on FOFEMMT installation to helpdesk@niftt.gov.

Chapter 6: Running the FOFEM Mapping Tool

6.1 The FOFEM Mapping Tool toolbar

The FOFEMMT toolbar consists of a single icon as shown in figure 6-1.

Figure 6-1. FOFEM Mapping Tool toolbar.

Clicking on the FOFEMMT toolbar opens the **FOFEM Mapping Tool** dialog box (fig. 6-2). This dialog box is used to specify spatial and model inputs, a CWD profile, as well as desired outputs.

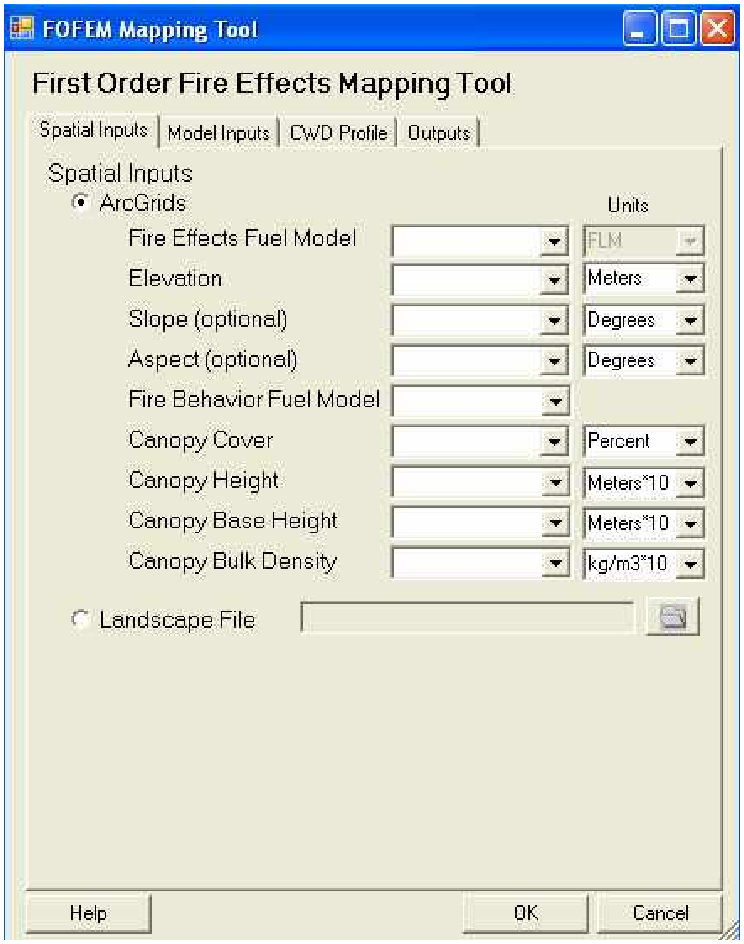


Figure 6-2. FOFEM Mapping Tool dialog box showing the Spatial Inputs tab.

***Note**: The FOFEM Mapping Tool dialog box consists of several tabs but initially opens to the **Spatial Inputs** tab. Default units are shown in figure 6-2.*

6.2 How to run the FOFEM Mapping Tool – an overview

To run the FOFEM Mapping Tool:

1. Start ArcMap and load spatial input layers into your ArcMap project by clicking the **Add Data** icon (fig. 6-3):

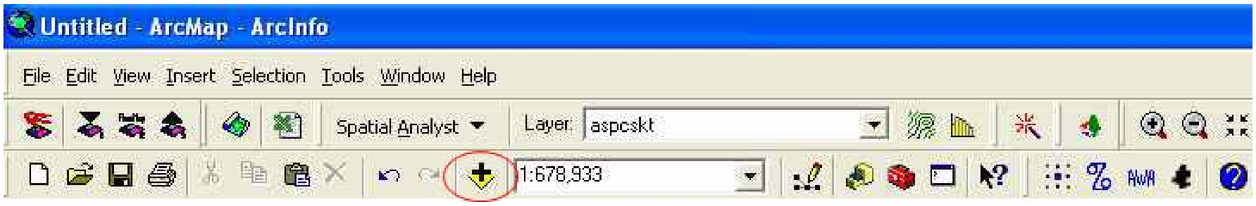


Figure 6-3. Loading spatial input layers.

2. Navigate to the directory where your data layers are stored and add the following spatial input layers: Fire Effects Fuel Model, Elevation, Aspect and Slope, Fire Behavior Fuel Model, Canopy Cover, Canopy Height, Canopy Base Height, and Canopy Bulk Density.

Tip: *At this point, you may see several "Create pyramids" dialog boxes similar to the box shown in figure 6-4. Click **No** to speed up processing. If you do not want to see this box again, put a check in the lower left-hand corner to disable it.*

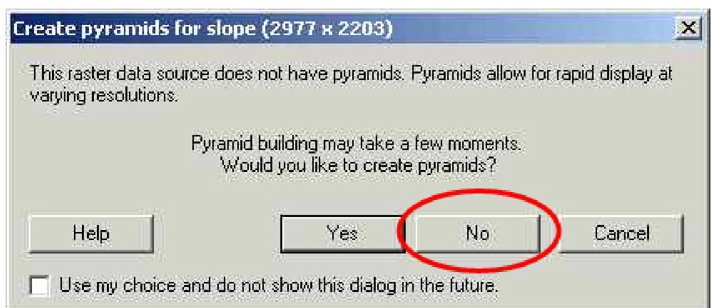


Figure 6-4. Create pyramids dialog box.

3. Ancillary layers can be added at this time. Layers such as cities, roads, streams, wildland-urban interface, ownership, and other files can often be useful for interpretation and description, as well as for consideration of management implications.

4. Select **Model Inputs**, a **CWD Profile**, and then specify outputs by clicking on the appropriate tabs on the **FOFEM Mapping Tool** dialog box. Fill in all required fields (fig. 6-2). (Sections 6.2.1 through section 6.2.5 discuss these steps in detail).

5. Click **OK**.

6. Save your project with the file name of your choice.

Note: *You do not need to include the extension .mxd when naming your project.*

6.2.1 Selecting spatial inputs for the FOFEM Mapping Tool

Click on the FOFEM Mapping Tool icon in ArcMap as shown in figure 6-5:

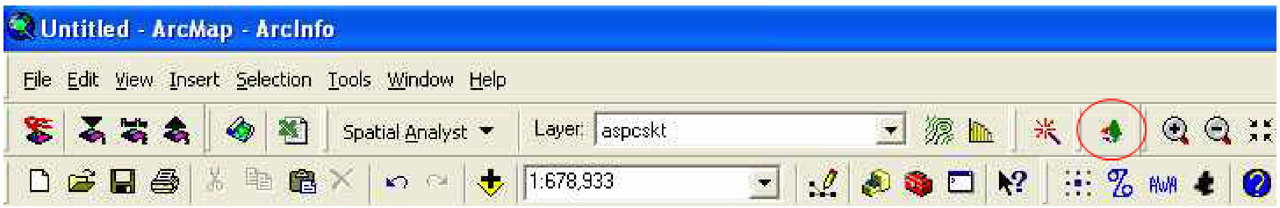


Figure 6-5. FOFEM Mapping Tool icon.

The following **FOFEM Mapping Tool** dialog box will open:

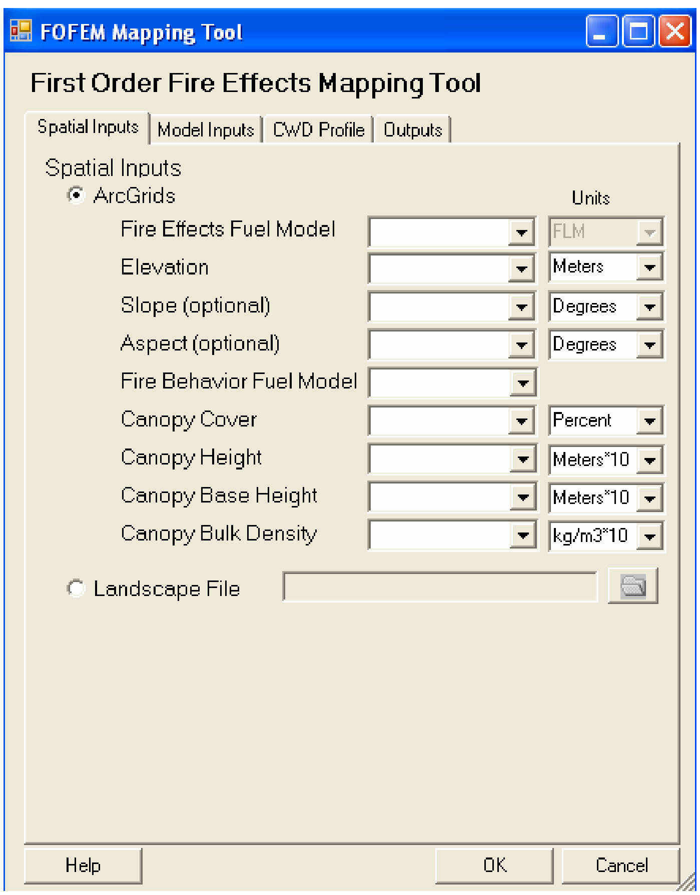


Figure 6-6. The **FOFEM Mapping Tool** dialog box with **Spatial Inputs** tab selected.

***Note**: First click on the "Spatial Inputs" tab if this screen is not already active (fig. 6-6).*

Spatial Input layers

Select a fire effects fuel model characterization to describe fuelbed inputs from the drop-down box to the right of the FEFM layer. Three choices are currently available: FLM (LANDFIRE Fuel Loading Model), FCCS (LANDFIRE Fuel Characteristic Classification), and Custom (fig. 6-7). Custom layers must be created in the ESRI Grid format with a value attribute table. (See section 3.2.1 for more information). Select Elevation, Slope, and Aspect from the drop-down options available.

The FOFEMMT can use either the original 13 fire behavior fuel models described by Anderson (1982) or the 40 fire behavior fuels models as characterized by Scott and Burgan (2005). Custom fire behavior fuel models cannot be used.

Enter Canopy Cover, Canopy Height, Canopy Base Height, and Canopy Bulk Density.

***Note**: All spatial input layers must be in ESRI Grid format.*

Where applicable, you can select English or metric units from drop-drown menus associated with each spatial input layer (fig. 6-6). A summary of available units for each spatial layer is provided in table 3-1. Default units are displayed in figure 6-6.

***Note**: Default unit selections correspond to LANDFIRE units.*

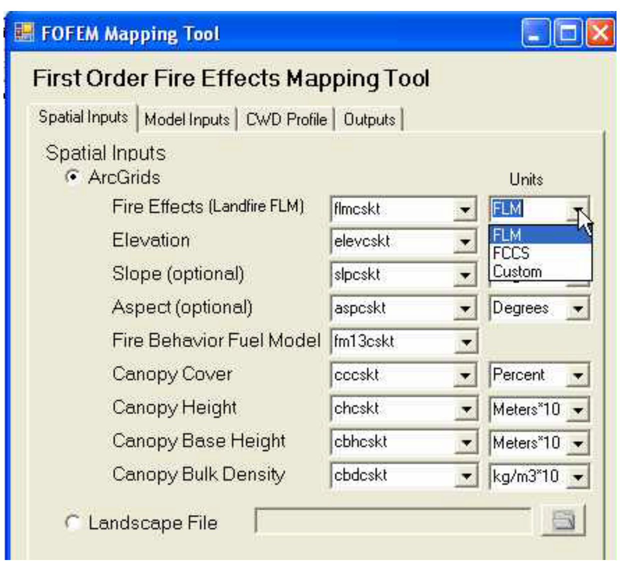


Figure 6-7. Fire Effects Fuel Model options.

***Note**: Relative advantages of fuel bed characterization models are discussed in Lute and others (2008).*

If a "Custom" FEFM layer is selected, an additional tab (**Custom FEFM**) will be added to the **FOFEM Mapping Tool** dialog box as shown in figure 6-8. If using a custom fuelbed characterization, you will need to select field names for each corresponding attribute by using the drop-down menu to the right of each attribute box (fig. 6-8).

***Note**: If you have selected a FLM or FCCS fuelbed characterization for your run, the Custom FEFM tab will not appear at the top of the dialog box. Only four tabs will be visible (fig. 6-7).*

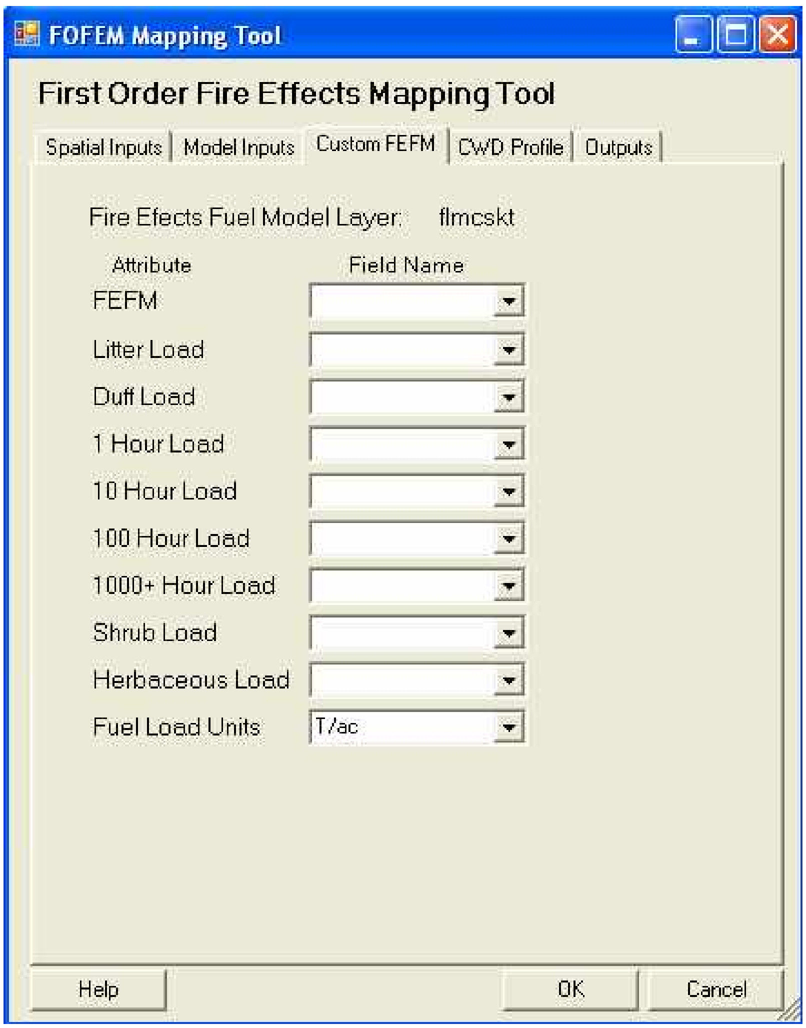


Figure 6-8. **Custom FEFM** tab in **FOFEM Mapping Tool** dialog box.

Do not click **OK** until you have completed the **Model Inputs**, **CWD Profile**, and **Outputs** tabs. You will also need to specify an output folder location before running the FOFEMMT.

Landscape Files

As an alternative to specifying each spatial input layer, you can use a preexisting landscape file or (.lcp) that was derived using FlamMap, FARSITE, FBAT, or the FOFEMMT. Check the radio button to the left of **Landscape File** and use the browse button to navigate to the .lcp you would like to use for your analysis (fig. 6-9). You will also need to specify a fire effects fuel model.

Figure 6-9. Use the browse button to select a preexisting Landscape File (.lcp).

Do not click **OK** until you have completed the **Model Inputs, CWD Profile**, and **Outputs** tabs. .

6.2.2 Selecting model inputs

After you have completed the **Spatial Inputs** tab, click on the **Model Inputs** tab as shown below (fig. 6-10):

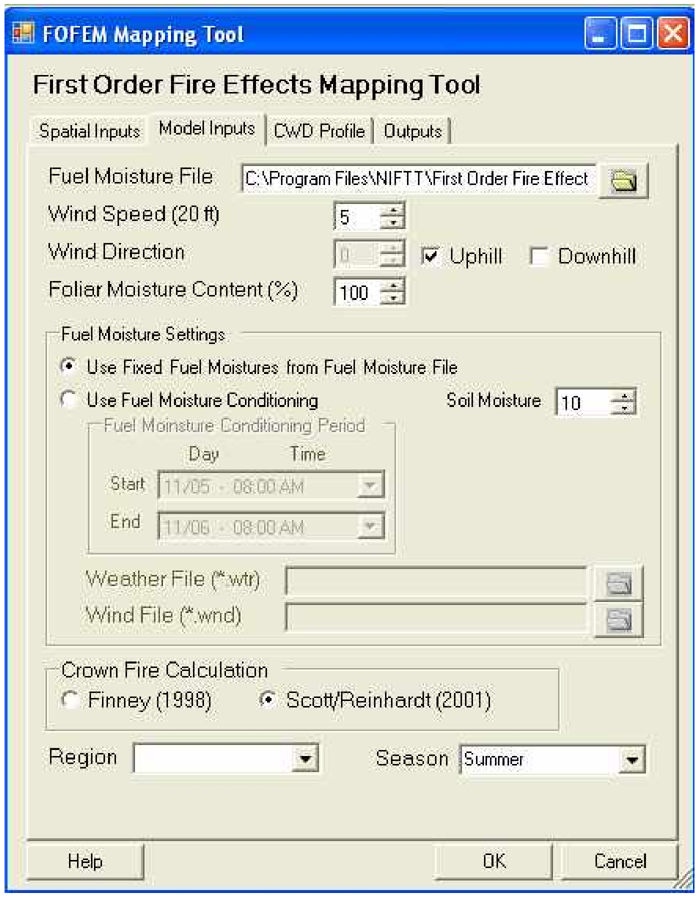


Figure 6-10. **Model Inputs** tab of the **FOFEM Mapping Tool** dialog box showing default values.

This dialog box is used to specify model inputs to the FOFEMMT including fuel moisture values, wind speed and direction, crown fire calculation method, region, and season (see section 3.3 for more information).

1. First use the browse button to the right of the **Fuel Moisture File** box to navigate to the file you would like to use to specify initial fuel moisture values for each of the fire behavior fuel models (fig. 6-11). The Fuel Moisture File includes values for 1-hr, 10-hr, 100-hr, live herbaceous and live woody fuels. (See section 3.3.1 for specific information on the derivation and use of this file).

***Note**: 1000-hr initial fuel moistures are specified in the CWD Profile.*

Figure 6-11. Use the browse button to select a Fuel Moisture File.

***Tip**: You can use data obtained from WIMS and FireFamily Plus to create a fuel moisture file appropriate for specific simulation scenarios by developing a space-delimited text file as described in section 3.3.1.*

2. Next enter a 20 ft (6.1 m) wind speed in the box to the right of **Wind Speed** (20 ft). You can type in the value directly, or you can use the spinner box to raise or lower the value. This parameter represents the wind speed occurring 20 feet (6.1 m) above the canopy as expressed in *miles per hour*. The default wind speed is 5 miles per hour (8.1 km/hr).

3. Enter **Wind Direction** by using either the drop-down menu (make sure that both **Uphill** and **Downhill** are unchecked to enable this selection), or by checking one of the boxes to the left of **Uphill** or **Downhill**. Wind Direction is expressed in azimuth in degrees in the direction the wind is blowing *from* (fig. 6-12). Check the **Uphill** box if you want to maximize potential fire behavior on any particular site.

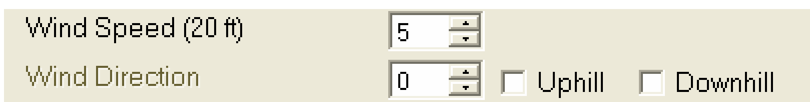


Figure 6-12. Select Wind Speed and Direction.

4. Next enter the **Foliar Moisture Content** (in percent) of live leaves or needles in the overstory by typing in the value directly, or by using the spinner box to raise or lower the value. Foliar moisture content usually ranges between 80 and 130 percent. Typical conditions are often represented by a value of 100 percent foliar moisture content (see section 3.3.4 for additional information).

5. Specify **Fuel Moisture Settings** by checking the radio button to the left of the options shown in figure 6-13. Two selections are included in the dialog box: **Use Fixed Fuel Moistures from Fuel Moisture File**, the default selection, and **Use Fuel Moisture Conditioning**. Fixed fuel moisture values correspond to the fuel moistures in the initial fuel moisture (.fms) file and vary spatially only with the fire behavior fuel model (see section 3.3.5). Fuel moisture conditioning corresponds to adjusting fuel moisture values spatially based on topography, shading, weather, and conditioning period length.

6. Next enter a Soil Moisture value. You can type in the value directly or you can use the spinner box to raise or lower the value. Typical

soil moisture values range from approximately 5% (very dry) to 25% (wet) (see section 3.3.5).

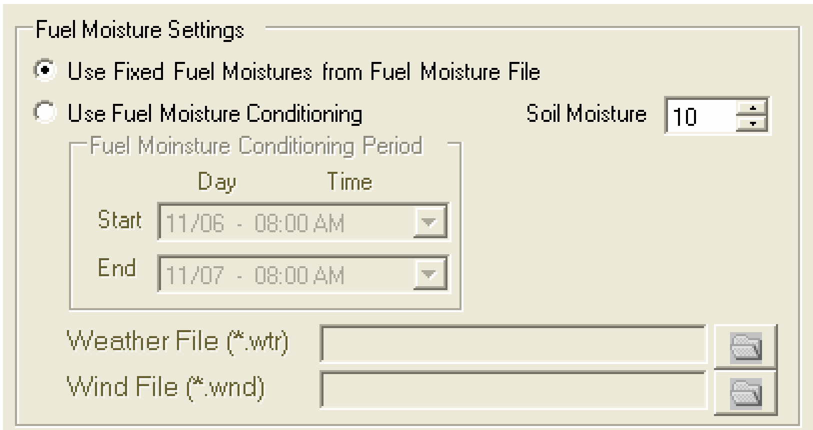


Figure 6-13. Fuel Moisture Settings.

Note: Weather (.WTR) and Wind (.WND) files are ASCII text files that are required to run the optional dead fuel moisture model in FlamMap. This is the same format used in FARSITE and FlamMap, so files are interchangeable between the applications.

7. Select one of two available Crown Fire Calculation Methods: Finney (1998) or Scott/Reinhardt (2001) to model the transition between passive and active crown fire. Select the radio button to the left of the algorithm that you prefer to use (see section 3.3.6).

8. Select a Region from the options available by using the drop-down menu to the right of the box as shown (fig. 6-14) (see section 3.3.7 for additional information).

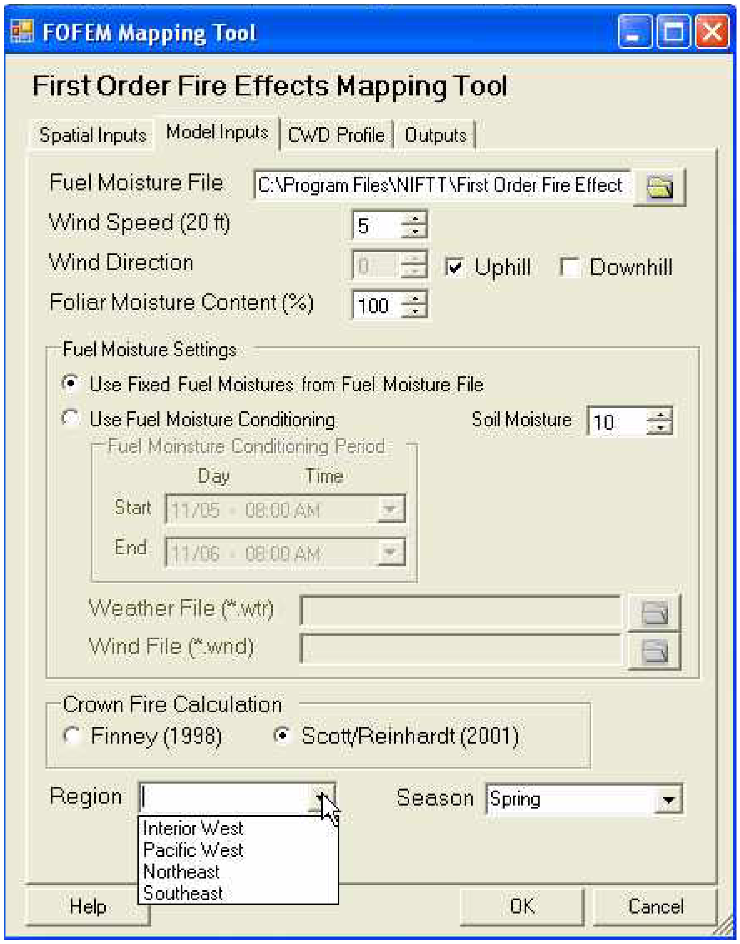


Figure 6-14. Drop-down menu showing options for **Region**.

9. Finally, choose **Season** from the drop-down list at the bottom right of the dialog box (fig. 6-15). (See section 3.3.8 for more information).

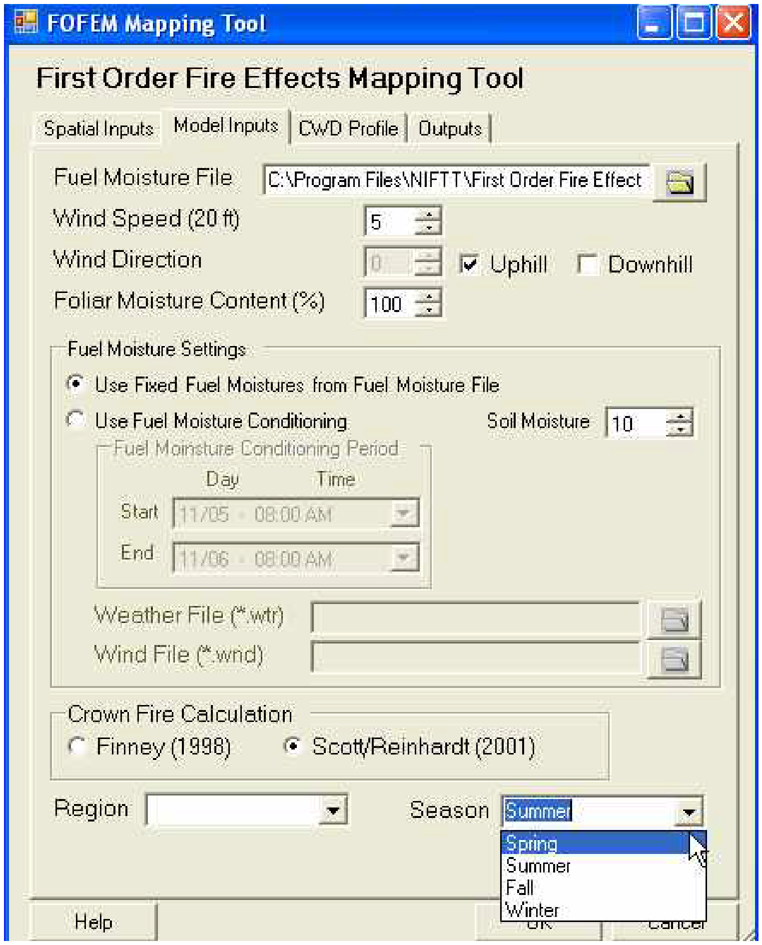


Figure 6-15. Drop-down menu showing Seasons.

Do not click **OK** until you have completed the **CWD Profile**, and **Outputs** tabs in addition to the tabs (**Spatial Inputs** and **Model Inputs**) you have already completed.

6.2.3 Selecting a Coarse Woody Debris (CWD) Profile

Coarse Wood Debris (CWD) refers to down woody material greater than or equal to 3 inches (7.6 cm). Click on the **CWD Profile** tab at the top of the **FOFEM Mapping Tool** dialog box and the following screen will open (fig. 6-16):

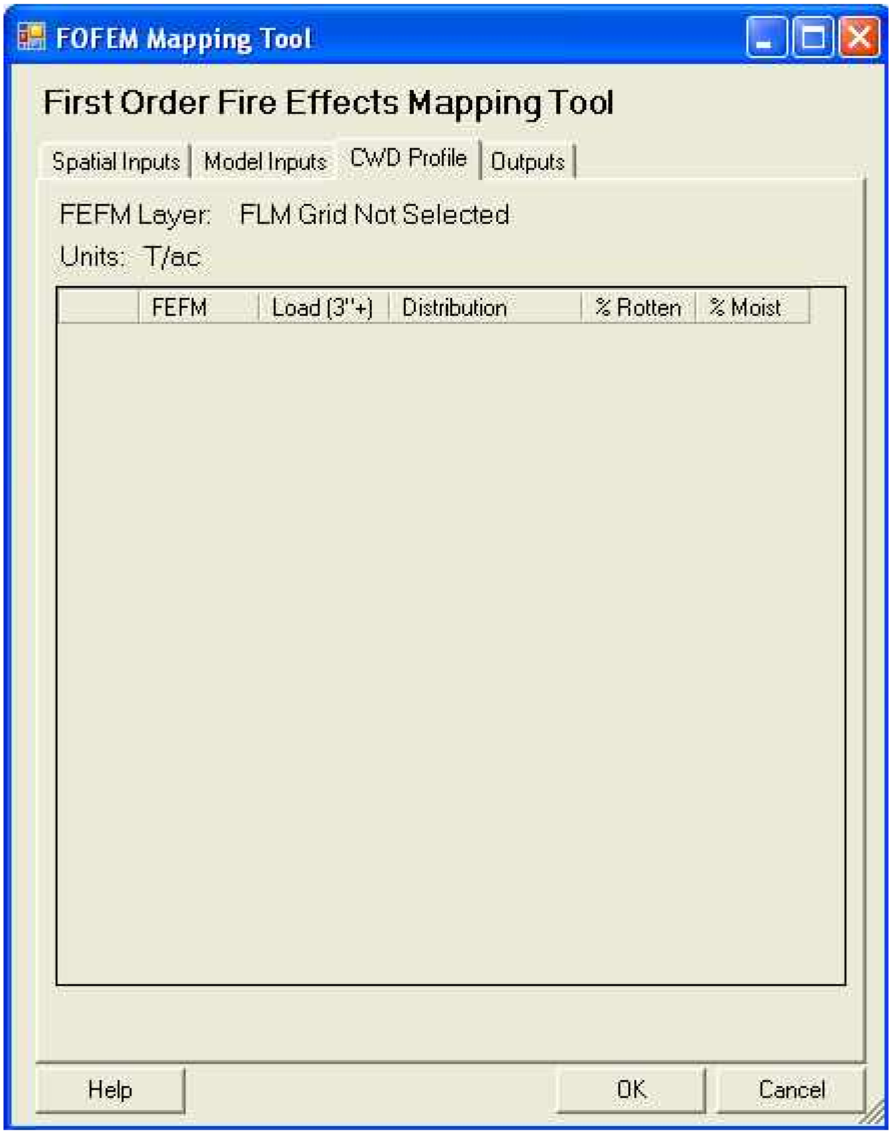
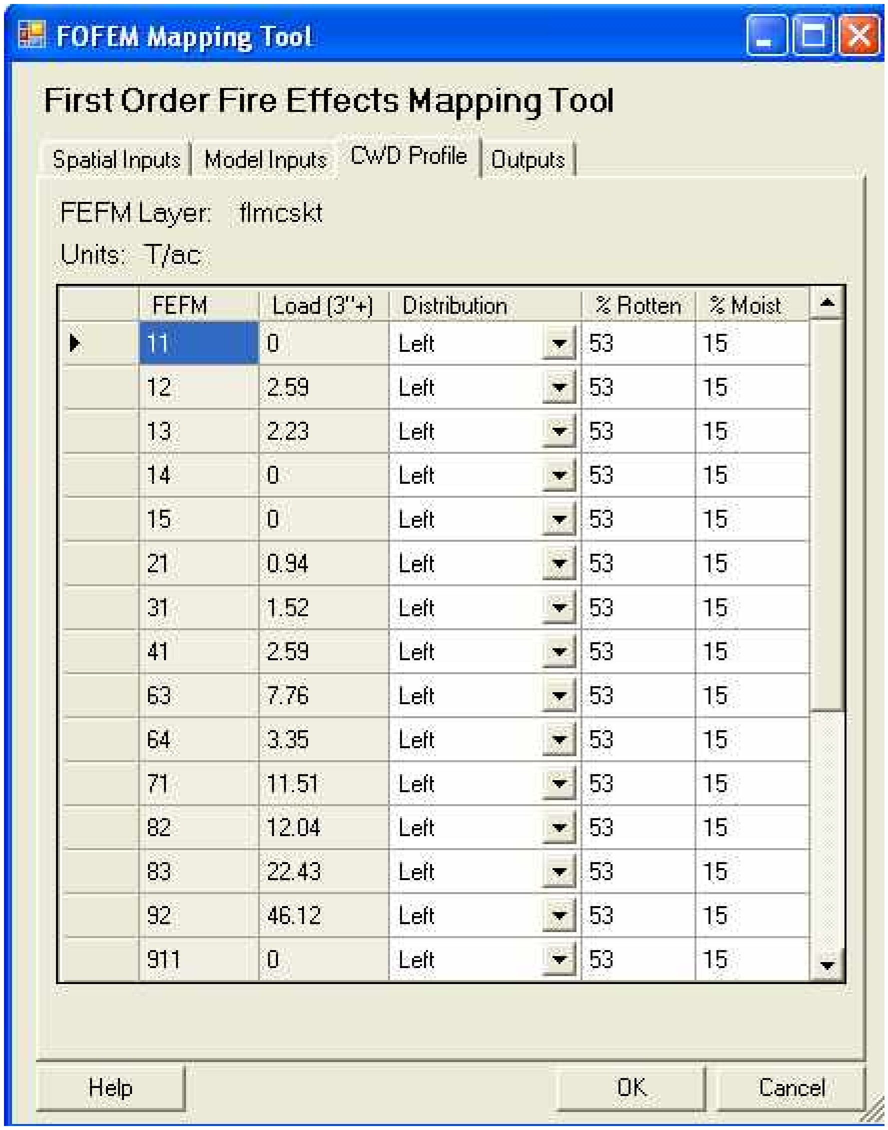


Figure 6-16. **CWD Profile** tab on **FOFEM Mapping Tool** dialog box.

Once you have completed the **Spatial Inputs** tab, including the Fire Effects Fuel Model drop-down selection, the **CWD Profile** tab is populated using the FEFM layer you specified.

An example CWD Profile for a FEFM layer (FLM) is shown below (fig. 6-17):



FEFM	Load (3"+)	Distribution	% Rotten	% Moist
11	0	Left	53	15
12	2.59	Left	53	15
13	2.23	Left	53	15
14	0	Left	53	15
15	0	Left	53	15
21	0.94	Left	53	15
31	1.52	Left	53	15
41	2.59	Left	53	15
63	7.76	Left	53	15
64	3.35	Left	53	15
71	11.51	Left	53	15
82	12.04	Left	53	15
83	22.43	Left	53	15
92	46.12	Left	53	15
911	0	Left	53	15

Figure 6-17. Example FEFM layer on **CWD Profile** tab.

***Note**: The "Load (3"+)" column displays the total fuel load of the CWD. If an FLM or Custom FEFM is selected, a default "Left" distribution and 53% rot is applied to the load for each FEFM. FCCS fuelbeds include information on the distribution and percent rot of the CWD load and are shown in the dialog box. Any modifications made here will redistribute the load from its original values. (See section 3.4 for more information on this subject.)*

Use the **CWD Profile** tab to specify a CWD profile for each value in the FEFM layer. Values include fuel load 3 inch or greater (7.6 cm) in tons per acre, load distribution, percent rotten, and percent moisture (see section 3.4).

1. To edit values, click in the cell within the FEFM that you would like to change.

2. Highlight the cell and type in a new value if desired.

3. The third column, "Distribution" contains a drop-menu for convenience. Use the drop-down menu to select a new log distribution (Left, Center, Right, Even, or End) for each value you would like to edit (fig.6-18).

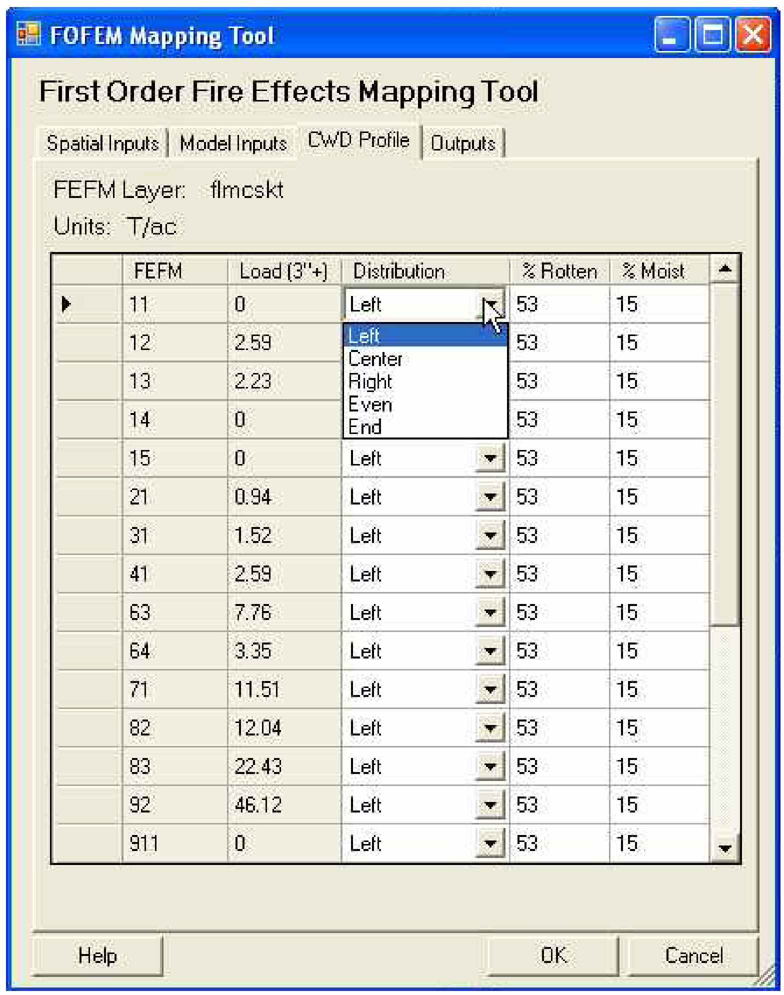


Figure 6-18. Distribution drop-down menu on **CWD Profile** tab.

4. Finish all edits on the **CWD Profile** tab, but do not click **OK** until you have completed required information on all tabs and have specified an output folder name and location.

6.2.4 Selecting output layers

1. Click on the **Outputs** tab located at the top right of the **FOFEM Mapping Tool** dialog box and the following screen will open (fig. 6-19):

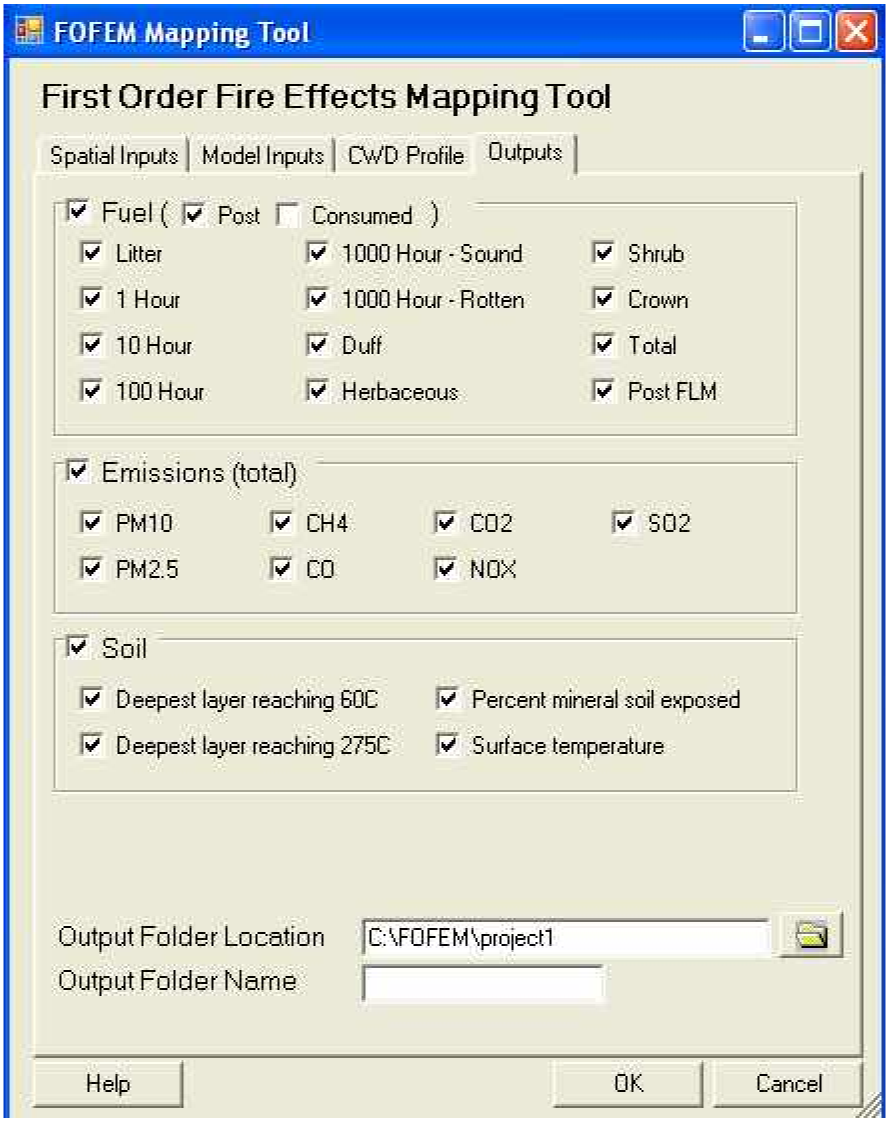


Figure 6-19. **Outputs** tab of the **FOFEM Mapping Tool** dialog box. Default values are shown.

Three categories of spatial outputs are generated by FOFEMMT: fuel consumption, emissions, and soil heating.

2. View the **Outputs** tab and select all layers to be generated in each category. (Chapter 4 provides a detailed discussion of available output layers.)

The upper portion of the **Outputs** tab of the dialog box shown below (fig. 6-20) provides options for fuel consumption. You can select post burn fuel load (Post), the amount of fuel load that is consumed (Consumed) or both options by checking the appropriate boxes. (The default selection is "Post"). See section 4.2.1 for further information.

3. Check all of the layers you would like to generate.

Figure 6-20. **Fuel Consumption** output layers showing default selections.

The middle section of the **Outputs** tab screen (fig. 6-21) provides emissions estimates (see section 4.2.2).

4. Check the boxes to the left of the emission layers you would like to generate. Click the box to the left of **Emissions (total)** to select all emission layers shown. For more information on emissions, refer to FOFEM's Help utility.

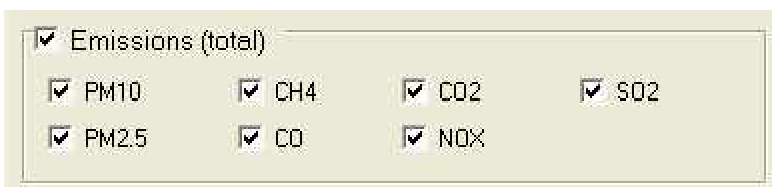


Figure 6-21. **Emissions** output layers showing default selections.

The following output layers address soil heating and the percent of mineral soil exposed (fig. 6-22):

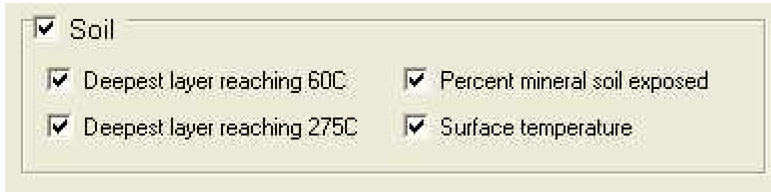


Figure 6-22. **Soil** output layers showing default selections.

5. Select the soil heating layers you would like to generate by checking the boxes to the left of each. Click the box to the left of **Soil** to select all soil layers shown. (For additional information refer to section 4.2.3.)

Note: *Important – do not click **OK** until you have completed the **Outputs** tab.*

6.2.5 Selecting output location and name of output folder

Once your output layer selections have been made, you will need to specify an output folder name and path for your run. All of the FOFEMMT outputs are stored in an output folder with the name you specified (fig. 6-23).

1. Click on the browse button to the right of the **Output Folder Location** box and navigate to a folder of your choice.

2. Next, enter an **Output Folder Name** for your FOFEMMT run. The folder will be located in the pathway identified (fig. 6-23).

Figure 6-23. Select output location and name for output folder.

3. After completing the **Spatial Inputs**, **Model Inputs**, **CWD Profile**, and **Outputs** dialog boxes click **OK**. FOFEMMT will now begin processing.

Tip: *Be patient. Processing may take a few minutes.*

The individual output layers will appear in your ArcMap Table of Contents and the FOFEMMT user interface will disappear automatically when the run is complete (fig. 6-24).

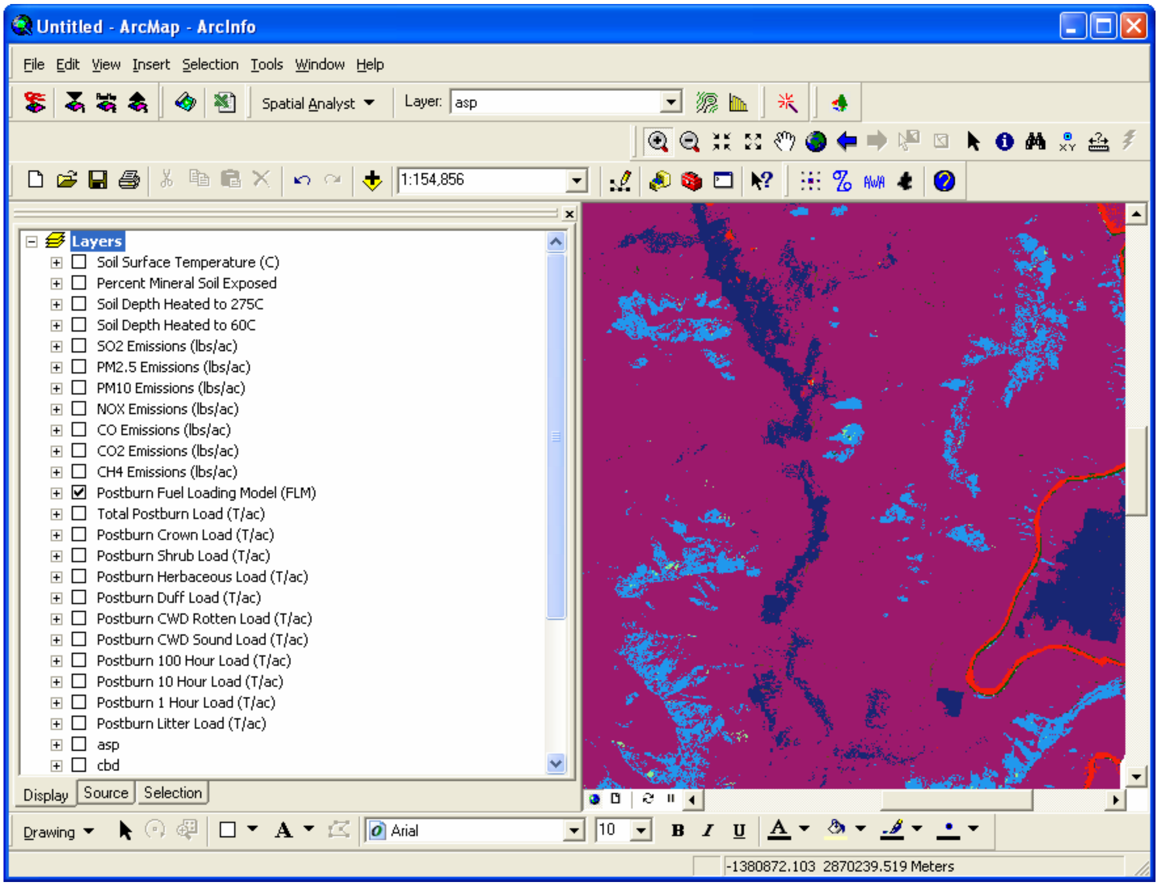


Figure 6-24. FOFEMMT output layers in ArcMap's Table of Contents.

We recommend that users save their ArcMap project as soon as the FOFEMTMT run has finished. Saving the ArcMap project will preserve the label and color schemes for each output layer.

***Note**: The names of the output layers that appear within ArcMap's Table of Contents are descriptive labels; they are not the ESRI Grid names that will appear in the output folder (specifically, the "Output Folder Name" you identified in the "Output Folder Location"). (See table 4-1 for the layer names as they will appear in ArcCatalog).*

Appendix A: References

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Appendix B: Introduction to FlamMap

B.1 About FlamMap

(from http://www.fire.org)

FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics (such as spread rate, flame length, and fireline intensity) over an entire FARSITE landscape for constant weather and fuel moisture conditions.

FlamMap is widely used by the National Park Service (U.S. Department of the Interior), Forest Service (U.S. Department of Agriculture), and other federal and state land management agencies in support of fire management activities. It is designed for those familiar with fuels, weather, topography, wildfire situations, and the associated terminology. Because of FlamMap's complexity, only those with proper fire behavior training and experience should use the application when outputs are to be used in support of fire and land management decisions.

B.2 Using FlamMap

- FlamMap software creates raster maps of potential fire behavior characteristics (spread rate, flame length, crown fire activity, etc.) and environmental conditions (dead fuel moistures, mid-flame wind speeds, and solar irradiance) over the entire FARSITE landscape. These raster maps can be viewed in FlamMap or exported for use in a geographic information system, image, or word processor.

- FlamMap is not a replacement for FARSITE or a complete fire growth simulation model. There is no temporal component in FlamMap. It uses spatial information on topography and fuels to calculate fire behavior characteristics at one instant.

- FlamMap uses the same spatial and tabular data as FARSITE.

- FlamMap incorporates the following fire behavior models:
    - a Landscape (.LCP) File,
    - Initial Fuel Moistures (.FMS) File,
    - optional Custom Fuel Model (.FMD),
    - optional Conversion (.CNV) File,
    - optional Weather (.WTR) File, and
    - optional Wind (.WND) File.
    - Rothermel's 1972 surface fire model,
    - Van Wagner's 1977 crown fire initiation model,
    - Rothermel's 1991 crown fir spread model, and
    - Nelson's 2000 dead fuel moisture model.

- FlamMap runs under Microsoft Windows operating systems (Windows 95, 98, ME, NT, 2000, and XP) and features a graphical user interface.

  ***Note**: FlamMap has not yet been tested with the Microsoft Windows VISTA operating system.*

- Users may need the support of a geographic information system (GIS) analyst to use FlamMap. Rasters must be in the same projection system and pixel size must also match.

- In addition to the usual menus, commands, and toolbar buttons, FlamMap has a hierarchical tree interface that makes it easy to navigate throughout a fire behavior analysis.

- Instead of using the same dead fuel moisture values for all cells of a fuel model, FlamMap has the ability to use weather data so as to estimate dead fuel moisture based on slope, shading, elevation, aspect, and the weather stream.

- Because FlamMap uses fuel moisture values at one point in time, and of course topography does not change, FlamMap is an ideal tool to compare relative fire behavior changes resulting from fuel modifications. However, FlamMap will not simulate temporal variations in fire behavior caused by weather and diurnal fluctuations, nor will it display spatial variations caused by backing or flanking fire behavior. These limitations need to be considered when viewing FlamMap output in an absolute rather than relative sense.

B.3 What's new in FlamMap version 3.0?

FlamMap version 3.0 (FlamMap3) was released in March 2006. Major recent feature additions include support for the Scott and Burgan (2005) Fire Behavior Fuel Models, the Minimum Travel Time fire growth model (described below), and the Treatment Optimization Model (also described below). In addition, a second method for calculating crown fire behavior has been added. All of the features found in FlamMap2 are still available in this newer version.

The Minimum Travel Time (MTT) fire growth model is a two-dimensional fire growth model. It calculates fire growth and behavior by searching for the set of pathways with minimum fire spread times from point, line, or polygon ignition sources. In theory, the results are identical to those of the wave-front expansion simulation technique used in FARSITE with the exception that all weather and fuel moisture conditions are held constant over time in MTT but allowed to vary in time in FARSITE.

The Treatment Optimization Model's (TOM) calculations rely on the MTT calculations to identify major fire travel routes, and then the model attempts to efficiently block these routes with fuel treatments. Given target weather conditions, the model will select the fuel treatments that best reduce fire growth rates.

> ***Tip****: See "What's New in FlamMap3" in online help for more information on these features.*

B.4 Downloading FlamMap

To download FlamMap, go to http://www.fire.org and click on **FlamMap > Downloads >** FlamMap3Setup.msi.

FlamMap3Setup.msi (6.4 MB) is a Windows installer module containing all files as well as Help and Tutorial data. Download this file to a temporary directory and install by using the Add/Remove Programs control panel or by simply double-clicking.

> ***Note****: The msi file referenced above requires the latest version of Windows Installer. During the installation process, you will be notified if your system does not contain the most recent Windows Installer distribution from Microsoft, and your computer system will attempt to update Windows Installer from Microsoft's website.*

If you select the full installation package as shown above, you will get the FlamMap install, a helpful tutorial with sample data, as well as full on-line help.

Appendix C: Decision Key; Decision Dependency

This section details the algorithm decision key used by FOFEM to select the most appropriate algorithm for predicting the consumption of the herbaceous, shrub, and duff fuel components.

Herbaceous Calculations:
- Cover Type
- Season

Shrubs Calculations:
- Cover Type
- Season
- Region

Duff Calculations:
- Region
- Cover Type
- Fuel Category
- Moisture Method

Litter, Crown Branch/Foliage, Down Woody
These fuel components are always calculated using the same equations regardless of Cover Type, Season, etc.

Herbaceous

Herbaceous fuels: Herbaceous fuels generally are a small component of the total fuel load. However, for completeness, especially in modeling emission production, their consumption is computed by FOFEM. Generally, all the herbaceous fuels are assumed to burn (eq. 22). If the cover type is a grass type, and the season of burn is spring, only 90% of the herbaceous fuels are consumed (eq 221).

Shrubs

Shrub consumption is modeled with rules of thumb that will eventually be replaced when additional shrub consumption work is available. General rules can be summarized as follows:

- If the cover type is sagebrush and the season is fall, shrub consumption is 90% (eq 233); for all other seasons, 50% (eq 232).

- For other cover types dominated by shrubs (except in the southeast), shrub consumption is assumed to be 80% (eq 231).
- For cover types not dominated by shrubs, shrub consumption is set to 60% (eq 23).
- For the southeastern region, for the pocosin cover type, in spring or winter shrub consumption is 90% (eq 233), in summer or fall 80% (eq 235).
- For non-pocosin types in the southeast, Hough's (1968, 1978) research was used to predict shrub consumption (eq 234): percent consumption = ((3.2484 + 0.4322 * preburn litter and duff loading + .6765 * preburn shrub and regeneration loading - .0276* duff moisture – (5.0796 / preburn litter and duff loading) – litter and duff consumption) / preburn shrub and regeneration loading) * 100%.

Duff

A number of different duff consumption algorithms are incorporated into FOFEM5. Separate predictions are made of percent duff consumption and duff depth consumed. These equations, their sources, and the circumstances under which each is used by FOFEM are summarized below.

Equation 2:

%DR (duff depth reduction, %) = 83.7 - 0.426 EDM (entire duff moisture, %)

Brown and others 1985

Used for predicting percent duff consumption from entire or average duff moisture content in the Interior West and Pacific West. This equation is also the default equation that FOFEM uses when it cannot find another duff consumption algorithm.

Equation 6

DR = (duff depth reduction in inches) 0.8811 - 0.0096 EDM + 0.439 DPRE

Brown and others 1985

Used for predicting duff depth consumption from entire or average duff moisture content in the Interior West and Pacific West. This equation is also the default equation that FOFEM uses when it cannot find another duff consumption algorithm.

Equation 10

MSE (mineral soil exposure, %) = 167.4 - 31.6 log (EDM)

Brown and others 1985

Used for predicting mineral soil exposure from average duff moisture content in the West. This is also the default equation FOFEM uses for predicting mineral soil exposure.

Equation 14

MSE = -8.98 + 0.899 %DR

Brown and others 1985

Used for predicting mineral soil exposure from percent duff reduction – a robust equation used when other information is lacking.

Equation 15

RD (residual duff depth in inches) = -0.791 + .004 EDM + 0.8 DPRE + 0.56 PINE (PINE = 1 if long needle type, 0 if otherwise)

Reinhardt and others 1991

Used for predicting residual duff depth from average duff moisture and preburn duff depth, this equation was based on data assimilated from many studies and is used where a more site specific equation is lacking.

Equation 16

W (loading of forest fuel consumed – litter plus duff in tons per acre) = 3.4958 + 0.3833 WPRE (WPRE = preburn loading of forest fuel litter plus duff in tons per acre) - 0.0237 EDM - 5.6075/WPRE

%DR = 0 if W ≤ L (preburn loading of litter in tons per acres)

= ((W-L)/ (WPRE-L))*100%, if W > L

Hough 1978

Used in the Southeast except in pocosin cover types.

Equation 19

%DR = 100% (chaparral)

Equation 20

DR = DPRE - 4 (pocosin)

Hungerford 1996

For deep organic soils in the pocosin type, preburn duff depth is defined to be the depth above the water table. This depth is set to be 1 inch if moisture conditions are wet, 5 inches if moderate, 14 inches if dry, and 25 inches if very dry. These defaults can be changed by changing the preburn duff depth. It is assumed that the duff is consumed to within 4 inches of the water table.

Equation 201

%DR (pocosin)

Hungerford 1996

It is assumed that the top 8 inches of the duff is root mat with a bulk density of 0.1, and the muck below has a bulk density of 0.2. The duff loading consumed and percent duff consumption are calculated by assuming that this material burns from the top down to within 4 inches of the water table.

Equation 202

MSE = 0% (pocosin)

Hungerford 1996

For deep organic soils in the pocosin type, we assume mineral soil is never exposed.

From Reinhardt and others, 1997.

Appendix D: Default Fuel Moisture File (.fms)

Dead fuel moisture content values (percent) for the dead fuel moisture scenarios.

	Very low	Low	Moderate	High
1-hr	**3**	**6**	**9**	**12**
10-hr	**4**	**7**	**10**	**13**
100-hr	**5**	**8**	**11**	**14**
Live herbaceous	**30**	**60**	**90**	**120**
Live woody	**60**	**90**	**120**	**150**

From Scott and Burgan, 2005.