



# Modeling Fire Hazard

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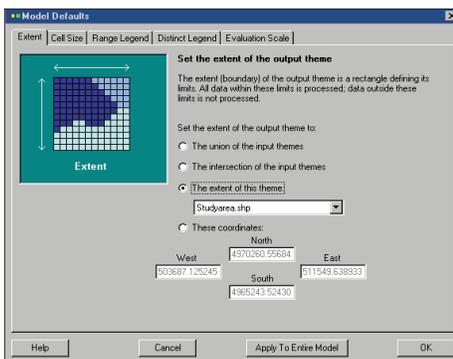
Spatial modeling technology is growing like wildfire within the emergency management community. In areas of the United States where the population has expanded to abut natural areas, the risk of wildland fire is great. The term Wildland/Urban Interface (WUI) is used to describe these areas. Special mitigation and response strategies have been developed to manage risk in these areas. The National Fire Protection Association (NFPA) has developed a set of standards for evaluating risk in developing areas threatened by wildfire.

This article presents a portion of very simple wildfire risk model. It shows how to use the ModelBuilder interface of ArcView Spatial Analyst 2 to model just two of the many factors that influence wildfire risk—slope and fuel. Together, these two factors make up one of the criteria specified in the NFPA 299 *Standards for Protection of Life and Property from Wildfire*. A realistic model of wildfire risk would use complex data that would include a very detailed breakdown of the vegetation into fuel classes and would model both slope and aspect. Additional data on weather history, the locations of structures, fire history, access, the evacuation routes available, and other factors that might affect fire ignition and spread would also be incorporated in the model.

ModelBuilder uses wizards to guide the user through the steps required for developing grid data using DEM to Grid, Vector to Grid, and Point Interpolation processes. In this exercise, digital elevation model (DEM) data and vector files will be converted to grid data and assigned a fire risk value and percentage of influence. When run, the model will generate a map showing overall fire hazard risk. Though very complex models can be created rapidly, this example demonstrates the basic procedures used to add data and processes, set model parameters, run the model, and output a map. One of the strengths of ModelBuilder is that smaller models can be combined into larger models for performing very complex analysis.

## Getting Started

1. Visit the *ArcUser Online* Web site to download firemodl.zip, the sample data set for this tutorial.
2. Using Windows Explorer or another file management system, create a directory called firemodl and unzip the sample data using Winzip or a similar file unzipping utility.
3. Start ArcView GIS. Choose File>Extensions and check the box next to the ModelBuilder extension.
4. Open a new project and view. Do not add data to the project.
5. Choose View>Properties and change the map and distance units to meters.

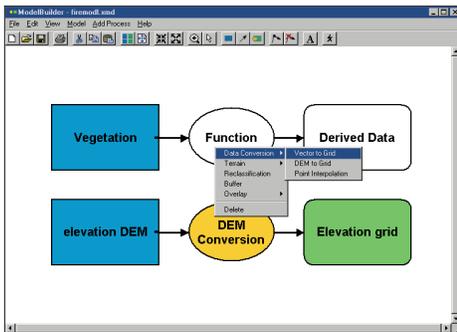


*The extent of the theme and the cell size can be set for the entire project through the project defaults.*



### Add Vegetation and Study Area Themes

1. Click the Add Themes button, making sure the Data Source is set to Feature Data Source. Navigate to the firemodel directory and add the vegetation.shp and studyarea.shp files to the view.
2. In the view Table of Contents, click on the studyarea.shp theme and drag it to the top.
3. Click the check boxes for the studyarea.shp and vegetation.shp themes to draw them.



Data conversion processing options that can be assigned to a function include Vector to Grid, DEM to Grid, and Point Interpolation.

A higher fire risk value is associated with certain types of vegetation. The study area theme limits the extent of the output themes created by the erosion model. The wildfire risk model will be built in the ModelBuilder window.

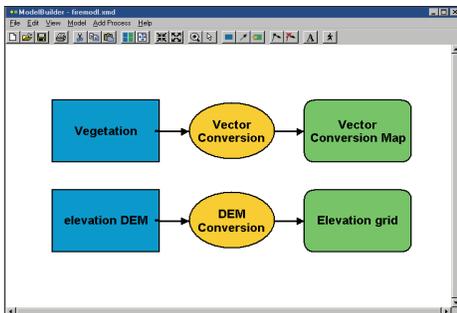
### Start ModelBuilder and Set Defaults

1. In the View menu, choose Model>Start ModelBuilder.
2. From the ModelBuilder interface, choose Model>Model Defaults. Default settings are automatically applied to all processes in a model but can be overridden.
3. Click on the Extent tab. Click on the Extent of This Theme option and choose studyarea.shp from the drop-down box. Click on Apply to Entire Model.
4. Click the Cell Size tab. Click the This Cell Size option and type in 30. Click on Apply to Entire Model and then OK to exit the dialog box. The model will now create new themes with a cell size of 30 meters.

### Add a DEM to Grid Data Conversion Process

The DEM to Grid conversion process converts a DEM file to an elevation grid theme that can be used to calculate slope data.

1. Choose Add Process>Data Conversion>DEM to Grid. The DEM Conversion wizard opens. Read the introductory panel and click Next.
2. In the next panel, click on the Browse button to locate and select the elevation.dem file in the firemodl folder and click Next.
3. This panel is used to define the properties of the output grid theme. The legend table determines how values in the output theme will be grouped in the output theme legend. Accept the default legend and click Next.
4. In the next panel, choose Green Monochromatic as the output color scheme and click Next.
5. The default extent for this model was set to the Study Area theme using the Model Defaults option, so click Next.
6. In the next panel, click Next to accept the default cell size of 30 meters that was set using Model Defaults.
7. In the documentation panel in the next panel type “This process converts DEM data to an elevation grid that will later be converted to slope data.” in the Comments text box and click Next.
8. In the next panel, type “Elevation Grid” for the theme name. Because these are grid files, use the DOS file naming convention and limit file names to eight characters. Name the DEM conversion output file elevgrd. Click Finish. A DEM conversion process is added to the fire hazard model. The process has nodes with property sheets that allow you to access the process properties entered using the wizard. Note that the process does not run or create the grid theme after exiting the wizard.
9. Choose File>Save and save the model to the firemodl directory.



Vegetation data from shapefiles and elevation data derived from a DEM can easily be added to the model.

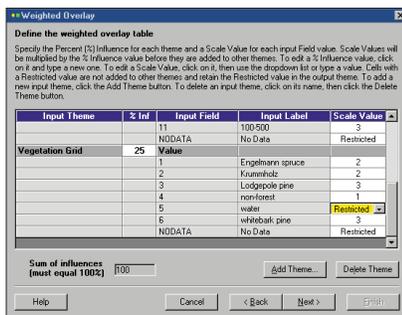
### Add and Define a Vector Conversion Process

The DEM to Grid process was added using a wizard, but processes can be added by dragging and dropping nodes on the model window. Node properties are set using property sheets that look like wizard panels but are not sequential. Using this method, a Vector conversion process will be added to the model so that the vegetation shapefile can be converted to a grid theme and overlaid with a slope grid derived from the elevation grid.

1. Click the Add Data button in the ModelBuilder interface. This button has a blue

# Spatial Operations in ModelBuilder

Spatial Operation Category	Function	Description
Data conversion	Vector to integer grid	Converts a point, line, or polygon theme to an integer grid
	DEM to floating-point grid	Converts a digital elevation model file to a floating-point grid
	Point interpolation	Converts a point theme to a floating-point grid
Reclassification	Reclassification	Groups the values in a grid theme into new classes and assigns them new values
	Contour	Converts a floating-point elevation grid to a contour line theme
	Slope	Converts a floating-point elevation grid to a slope grid
	Aspect	Converts a floating-point elevation grid to an aspect grid
	Hillshade	Converts a floating-point elevation grid to a hillshade grid
Distance	Buffer zones	Reclassifies all cells within a specified distance from a feature into a single buffer zone
Overlay	Additive overlay	Multiplies the values of two or more input themes by influence factors, then adds the values to produce an output grid
	Weighted overlay	Reclassifies the cell values of two or more input themes to a common scale, then multiplies the reclassified values by influence factors and adds the values to produce an output grid



The Weighted Overlay process combines different types of data by assigning evaluation scale values and the amount of influence to the values in each theme.

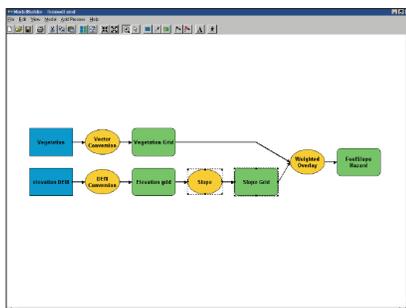
- rectangle icon. Click anywhere inside the model window to place a Data node.
- Pass the cursor over the ModelBuilder buttons to access the Tool Tips and locate the Add Function button. Click on it. Click inside the model window to the right of the Data node to place the oval Function and rectangular Derived Data nodes.
- Locate and click the Add Connection button. Drag a line between the Data and Function nodes.
- Click the Auto Layout button to arrange the layout. If necessary, click the Full View button to make the model fit in the window. The next steps define the properties of the Vector conversion process just specified.
- Right-click on the Data node and choose Theme from the context menu. The Data node changes to a Theme node. Right-click on the new Theme node and choose Properties. In the Project Theme property sheet, type “Vegetation” as the project data name and select vegetation.shp from the drop-down box next to Choose input theme. Choose vegtype as the input field. Click OK. The Theme node name changes to Vegetation.
- Right-click on the Function node and choose Data Conversion>Vector to Grid from the context menu. The function changes to a Vector Conversion and the Derived Data node changes to Vector Conversion Map.
- Right-click the Vector Conversion node and click Properties. In the output file, each cell corresponding to a particular vegetation type stores the associated Class Value. This table shows those values. Click OK.
- Right-click the Vector Grid node and choose Properties. Select the Output Theme and type “Vegetation Grid” for theme name and veggrid for file name. Click OK. Click on the Save button in the ModelBuilder interface.

The Vector conversion process will now create a grid theme from the vegetation shapefile. The next step will be to create a Slope process.

## Create and Define a Slope Process

The rate of elevation change or slope is one of the factors that affects the hazard associated with fire in an area. Along with aspect, it affects the speed at which a fire will spread and the accessibility of an area to firefighters. Elevation data can be used to derive slope. The Elevation Grid output theme from the DEM conversion process will be used as the input theme to the Slope process.

- Click the Zoom Out button once to make room for a new process. Click the Add Function button and click inside the model window to add a Function node and its connected Derived Data node to the model.
- Right-click the Function node and select Terrain>Slope from the context menu. The Function name changes to Slope and the Derived Data node changes to Slope Map.
- The Slope wizard will be used to define the properties for the Slope process. The input data for this process is the output theme from the DEM conversion process, Elevation Grid. The wizard automatically connects the Slope and DEM conversion processes.
- Right-click on the Slope node and choose Wizard from the context menu. Click Next after reading the introductory panel.
- In the input panel, choose Elevation Grid as the input theme. Click Next.
- In the method panel, select Percent as the method for calculating slope and click Next.
- In the output theme type panel, choose discrete as the grid theme. The Slope process output can be a continuous grid theme of slope values or a discrete grid theme of slope classes. The Weighted Overlay process used to combine slope and vegetation data requires discrete grid themes. Click Next.
- In the classification panel, slope classes can be customized by editing the table. Click



The Fuel/Slope Hazard model combines derived vegetation and slope data through a Weighted Overlay process.

Next to accept the default classifications.

9. In the color scheme panel, accept the default color scheme of red monochromatic and click Next.
10. The extent was previously set to Studyarea.shp, so click Next.
11. The cell size was also set to 30 meters by the model default. Click Next.
12. In the documentation panel, select the Comments tab and type “This process converts elevation data into slope data.” in the text box and click Next.
13. In the output theme panel, type “Slope Grid” for theme name and slopegrid for file name. Click Finish to exit the wizard. Maximize the ModelBuilder window.

The Slope function is automatically connected to its input data, Elevation Grid. The vegetation and slope data can now be combined in a Weighted Overlay process.

Input Theme	% Inf	Input Field	Input Label	Scale Value
<b>Slope Grid</b>	<b>75</b>	<b>Value</b>		
		1	0-10	1
		2	10-20	1
		3	20-30	1
		4	30-40	2
		5	40-50	2
		6	50-60	2
		7	60-70	3
		8	70-80	3
		9	80-90	3
		10	90-100	3
		11	100-500	3
		NODATA	No Data	Restricted

### Define an Evaluation Scale

The Weighted Overlay process combines slope and vegetation data to assess the overall fire hazard. Because these themes do not contain similar data, the values in each theme must be converted to a common value scale. The common scale for this model will assign a value of 1 to areas with the lowest wildfire potential and 3 to areas with the highest wildfire potential. The Weighted Overlay table will be used to define the input themes, their weights, and the scale values of each input in each theme.

1. From the Add Process menu, choose Overlay > Weighted Overlay from the menu. Read the introductory panel and click Next.
2. In the evaluation scale panel, the predefined evaluation scale is set to 1 to 3. Accept this scale and click Next.
3. In the Weighted Overlay table panel, choose Add Theme to open the Theme and Field dialog box. Click the input theme dropdown arrow and choose Slope Grid. Leave the input field dropdown list set to Value, the field that contains the slope values. Click OK.
4. The Slope Grid theme is added to the Weighted Overlay table.
5. On the Weighted Overlay panel, click Add Theme again. In the Theme and Field dialog box, choose Vegetation Grid as the input theme and leave Value as the input field. Click OK.
6. Scroll to the bottom of the Weighted Overlay table to see that the Vegetation theme has been added.

### Set Influence Factors and Assign Evaluation Scale Values

In the Weighted Overlay table, the Percent Influence field (%Inf) is used to assign the influence each theme has on the fire hazard assessment. In this model, slope will be deemed a more important factor in fire hazard than vegetation type.

1. Click in the %Inf field next to the Slope Grid theme. Type 75. Now 75 percent of the fire hazard value for the output theme will be determined by the slope.
2. Scroll down to the Vegetation Grid theme. Click in the %Inf field and type 25.
3. The Sum of Influences field at the bottom of the panel now equals 100 percent.

The Scale Value field assigns fire hazard potential (from 1 to 3) to slope or vegetation data. A special value, Restricted, is used for areas where no data is available or there is a body of water.

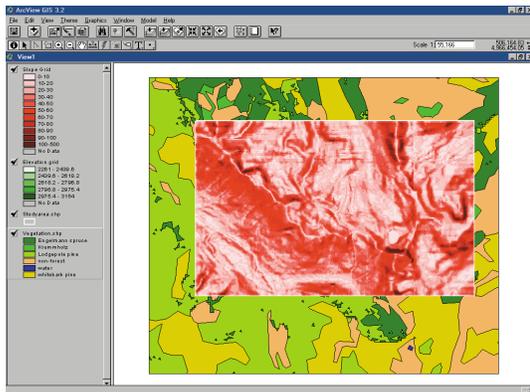
1. For the Slope Grid theme, the fire hazard potential increases as the slope increases. Click in each cell of the Scale Value field and type the numbers shown in Figure 1. Choose the input values from the drop-down lists in each cell.
2. For the Vegetation Grid theme, set the scale values as shown in Figure 2. Barren areas have very low fire potential and water bodies have no fire potential. Forested areas have fire potential based on the ignition characteristics of each type of vegetation. Click Next.

With each theme’s overall influence set and each slope and vegetation category ranked, this information can be overlaid into a single fire hazard theme.

Figure 1

Input Theme	% Inf	Input Field	Input Label	Scale Value
		9	80-90	3
		10	90-100	3
		11	100-500	3
		NODATA	No Data	Restricted
<b>Vegetation Grid</b>	<b>25</b>	<b>Value</b>		
		1	Engelmann spruce	2
		2	Krummholz	2
		3	Lodgepole pine	3
		4	non-forest	1
		5	water	Restricted
		6	whitebark pine	3
		NODATA	No Data	Restricted

Figure 2



The elevation grid derived from the DEM data is converted to slope data using the Slope process.

## Define Properties for the Output Theme

1. Restricted areas have a light red default color. Change these areas of no data and water to gray.
2. On the color scheme panel, double-click on the Restricted color in the Color field. The Color dialog box opens. In the Basic colors palette, click on a shade of gray and click OK. The color of the Restricted class changes to gray. Click Next to continue.
3. In the extent panel, the extent of the output theme is already set to Studyarea.shp. Click Next.
4. In the cell size panel, the cell size of the output theme is set to 30 meters. Click Next.
5. In the documentation panel, select the Comments tab and type “This process determines the fire hazard by combining slope and vegetation data.” in the text box. Click Next.
6. In the output theme panel, click in the Theme Name text box and type “Fuel Slope Hazard”. Click in the File Name text box and type “hazard”.
7. Click Finish to add the process to the model. Click the Full View button. The input themes have been connected automatically to the Weighted Overlay process.
8. Click Save.

This very simple fire hazard model is complete. It converts an elevation DEM file to an elevation grid theme and the elevation theme to a slope theme. It converts a vegetation theme to a vegetation grid theme. Slope and vegetation types are ranked on a fire hazard evaluation scale. Finally, these themes are given weights and combined to create an overall fuel slope hazard value based on a uniform scale of 1 to 3. These fire hazard values become the values of the cells in the output theme.

## Save and Run the Model

The entire model can be run, or just selected processes within the model. Right-clicking a function node and choosing Run causes only the process to which the node belongs and any dependent processes to run.

1. Right-click the Slope function node and click Run.
2. After the process runs, the Slope Grid theme and the Elevation Grid theme are created in the view.
3. Because the Slope process is dependent on the DEM conversion process, both of these processes run and are now marked with drop shadows in the ModelBuilder window.
4. Return to the ModelBuilder window and click the Run button to run the entire model. The Elevation Grid, Vegetation Grid, and Fuel Slope Hazard themes are created in the view. In the model window, all nodes have drop shadows, indicating that the entire model has been run.

## Analyze Results and Modify Model

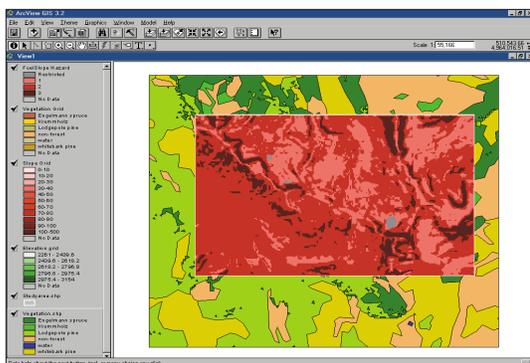
After looking at the Fuel Slope Hazard theme created by the model, you might decide to modify some of the fire hazard values. Because all the properties are saved in the model, you can adjust properties and rerun the model to get new results.

1. In the ModelBuilder window, right-click the Weighted Overlay function node. Click on Properties to open the Weighted Overlay property sheet.
2. Select the Overlay Table tab and scroll down to the Slope theme. Change the Scale Value for Value 4 to 1 and the Scales Values for Values 7 and 8 to 2. Click OK.
3. Click the Run button.
4. A new version of the Fuel Slope Hazard theme overwrites the old one. The new theme has more light red areas and fewer dark red areas, indicating lower overall fire hazard than the previous version.

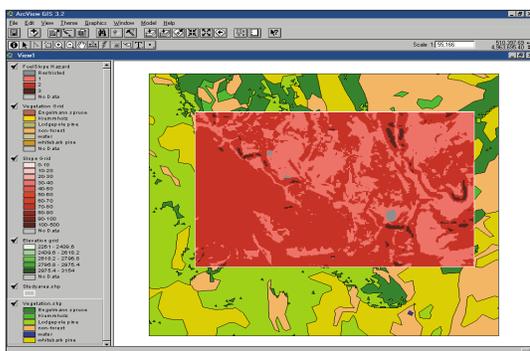
## Exit ModelBuilder

1. In the ModelBuilder window choose File > Exit and click Yes to save changes to the current model document.
2. In ArcView GIS, choose File > Close All and File > Close Project. Click Yes to save changes to the project.

After completing this exercise, you can appreciate how easy it is to convert and add data, incorporate analysis functions, and modify the resulting model to rapidly examine many “what-if” scenarios. For more information on ArcView Spatial Analyst 2 with ModelBuilder, visit the ESRI Web site ([www.esri.com/software/arcview/extensions/spatext.html](http://www.esri.com/software/arcview/extensions/spatext.html)).



The areas colored dark red are the areas of highest fuel/slope hazard.



Changing the evaluation scale and rerunning the model lets the user change the amount of risk assigned to various factors in the model. In the new version of the model, a much smaller area is colored dark red.