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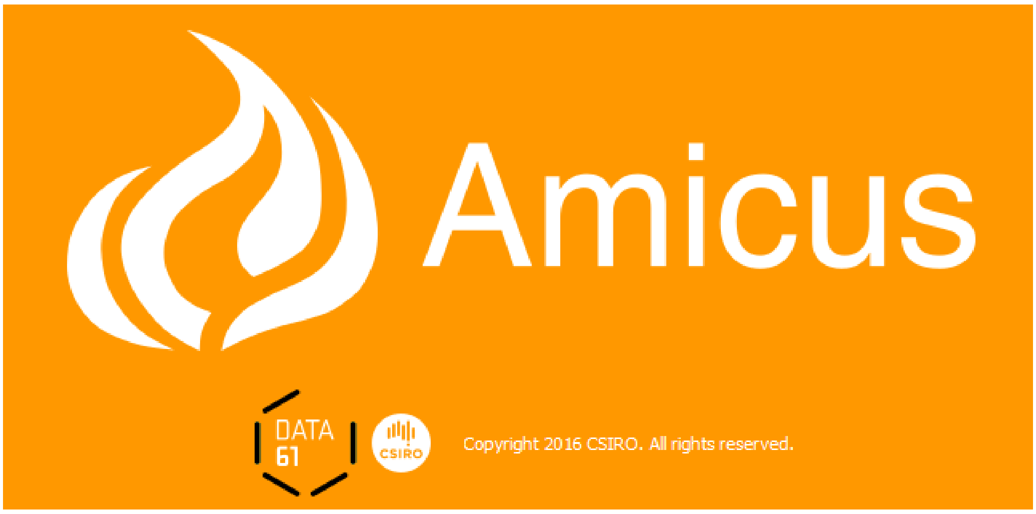
Amicus Version 0.7 beta Users' Guide

November 19, 2021



Copyright and disclaimer

Important disclaimer

Contents

1 About Amicus

Amicus is a fire behaviour prediction system within an easy to use stand-alone software package. It is designed to be used by fire behaviour specialists when preparing manual fire behaviour predictions. ***Amicus*** brings together the suite of recommended fire behaviour models for Australian fuel types in a way that facilitates the production and analysis of efficient rigorous fire predictions and effective reports.

Amicus calculates the forecast fire danger and fire behaviour from input values you provide for the fuel, weather and topography for your area of interest. Fire danger is calculated for grasslands and forests using the McArthur Fire Danger Rating Systems for these vegetation types and the Revised National Fire Danger Rating classifications. Fire behaviour is calculated for a broad range of fuel types within four dominant vegetation types using the recommended fire behaviour models (where available) for each fuel type as stated by Cruz *et al.* (2015*b*).

The fire behaviour models currently incorporated into ***Amicus*** relate to four major vegetation types: grasslands, forests, shrublands and forestry plantations. There are 13 specific fuel types within these that each relate to a different fire spread model recommended in Cruz *et al.* (2015*b*,*a*) . There are two sets of fire spread models for forests, which apply to either prescribed fire or wildfire conditions. Models for other fuel types are suited to both conditions except those for plantations which are only suited to wildfire conditions. A summary of the fuel types, burn conditions and the fire behaviour models incorporated into ***Amicus*** is presented in Table 1.1. No flame height or spotting models are listed in the table where there are no suitable models. This specific version of ***Amicus*** (v0.7) uses the 2018 published version of the Spinifex model (Burrows *et al.* 2018).

Table 1.1: Summary of the fuel and vegetation types used in ***Amicus*** and the corresponding fire behaviour models (rate of spread (ROS), flame height and maximum spotting distance).

Vegetation	Fuel type	Models and reference
Grassland	Continuous open	ROS: Cheney et al. (1998) with the Cruz *et al.* (2015*c*) curing factor. Flame height: Cheney and Sullivan (2008)
	Woodlands	ROS: Cheney et al. (1998) with the Cruz et al. (2015c) curing factor. Flame height: Cheney and Sullivan (2008)
	Open grassy forest (Northern Australia)	ROS: Cheney et al. (1998) with the Cruz et al. (2015c) curing factor. Flame height: Cheney and Sullivan (2008)
	Spinifex	ROS and flame height: Burrows et al. (2018)
	Buttongrass	ROS and flame height: Marsden-Smedley and Catchpole (1995)
Forest (wildfire conditions)	Dry eucalypt[1]	Vesta Mk 2: ROS: Cruz et al. (In Press), flame height: Cheney et al. (2012), Maximum spotting distance: Gould et al. (2007b)
		Vesta Mk 1: ROS and flame height: Cheney et al. (2012), Maximum spotting distance: Gould et al. (2007b)
	Wet eucalypt	Vesta Mk 2: ROS: Cruz et al. (In Press)
		Vesta Mk 1: ROS: Cheney et al. (2012) with wind reduction factors from Sneeuwjagt and Peet (1985)

[1] An option to use the McArthur (1967) Mk 5 Forest Fire Danger Meter is available and is described in Section 7.2.2

Table 1.1: (continued)

Vegetation	Fuel type	Models and reference
Forest (prescribed fire conditions)	Dry eucalypt	ROS and flame height: Gould (1994) equations for McArthur (1962)
	Wet eucalypt	ROS: Beck's (1995) equations for Sneeuwjagt and Peet's (1985) tables
Shrubland	Temperate shrubland	ROS: Anderson et al. (2015)
	Semi-arid heath	ROS: Cruz et al. (2010)
	Semi-arid mallee-heath	ROS and flame height: Cruz et al (2013)
Plantation (wildfire conditions)	Radiata pine	ROS and flame height: Cruz *et al.* (2008)
	Maritime pine	ROS and flame height: Cruz et al. (2008) and Cruz and Fernandes (2008)
	Short rotation eucalypt	Grass dominated- ROS: Cheney et al. (1998) is used (with a user-defined wind correction factor) and the Cruz et al. (2015c) curing factor, Flame height: Cheney and Sullivan (2008) Litter dominated- ROS and flame height: Cheney et al. (2012); Maximum spotting distance: Gould et al. (2007b)

Amicus is designed to enable you to edit any of the inputs and see an immediate change in predicted values.

Amicus provides you with the ability to construct, edit and save project files that incorporate fuel and weather conditions for particular purposes.

The models within ***Amicus*** have been validated against their original sources within the full extent of the input domains. Users are alerted when models are being used outside of their known reliability domains so that they are aware that these predictions may be compromised.

Examples in this user guide come from the Windows version of ***Amicus***, however ***Amicus*** is also available for MacOS X and Linux. All versions of ***Amicus*** have the same functionality and similar appearance.

More details on the manual fire spread prediction process and how ***Amicus*** can be effectively used for making operational fire spread predictions can be found in Plucinski *et al.* (2017).

1.1 Feedback

If you have any issues or difficulties installing or running ***Amicus***, please send an email to amicus@csiro.au. Feedback and suggestions for improvements are warmly welcomed and can also be sent to amicus@csiro.au.

1.2 Version history

1.3 Future development

Amicus is subject to continuing testing and development. Some high priority features in development include:

Table 1.2. Version history log

Version number	Changes and comments
0.5	First generally available beta version of Amicus
0.6 DBCA	Specific version developed for WA DBCA with Red Book models and BoM spot forecast download function (These features are only available in the DBCA versions of Amicus)
0.7	Revised slope output table in the fire behaviour outputs
	Revised meteorological wind inputs for different heights
	Addition of the Vesta Mk 2 (Cruz et al. In Press) model for dry and wet eucalypt forests
	Updated the spinifex model to Burrows et al. (2018)
	Incorporated the McArthur (1967) model as an option for dry eucalypt forests
	General bug fixes and minor improvements

- Ensemble model simulation to assess the impact of input uncertainty;
- Visualised output analysis that allows users to understand temporal trends and compare the effects of different drivers of fire spread;
- Direct downloading of weather forecasts for specific locations;
- Automated generation of prediction summary reports;
- Comparison of multiple weather streams;
- Integration with existing agency workflows and existing systems; and
- Specific version of ***Amicus*** for mobile devices.

The long-term vision for ***Amicus*** is for it to evolve into a complete knowledge base system that will enable users to upload details of their predictions along with relevant observations and documentation (e.g. photos and videos) of fire behaviour, fuels and weather Sullivan *et al.* (2013). This will improve future predictions by providing users with a searchable database that will allow them to make comparisons with historical incidents in similar conditions, effectively enhancing their expert knowledge.

2 Installing and launching Amicus

2.1 Installing Amicus

To install ***Amicus***, you must run the ***Amicus*** installation setup wizard (the installer application) specific for your operating system (i.e. Windows 7/8/10 (*.exe), MacOS X (*.dmg), Linux (*.rpm)) and processor (32-bit (x86) or 64-bit (_64)). This file can be obtained from the appropriate link on the ***Amicus*** web page: http://research.csiro.au/amicus. Download the file and *double click* it to run the setup wizard. The installer will then take you through the steps to select an install folder and install ***Amicus***..

License agreement (Fig. 2.1): This dialog displays the license agreement terms to use ***Amicus***. *Click* on the link to read the terms of the agreement.

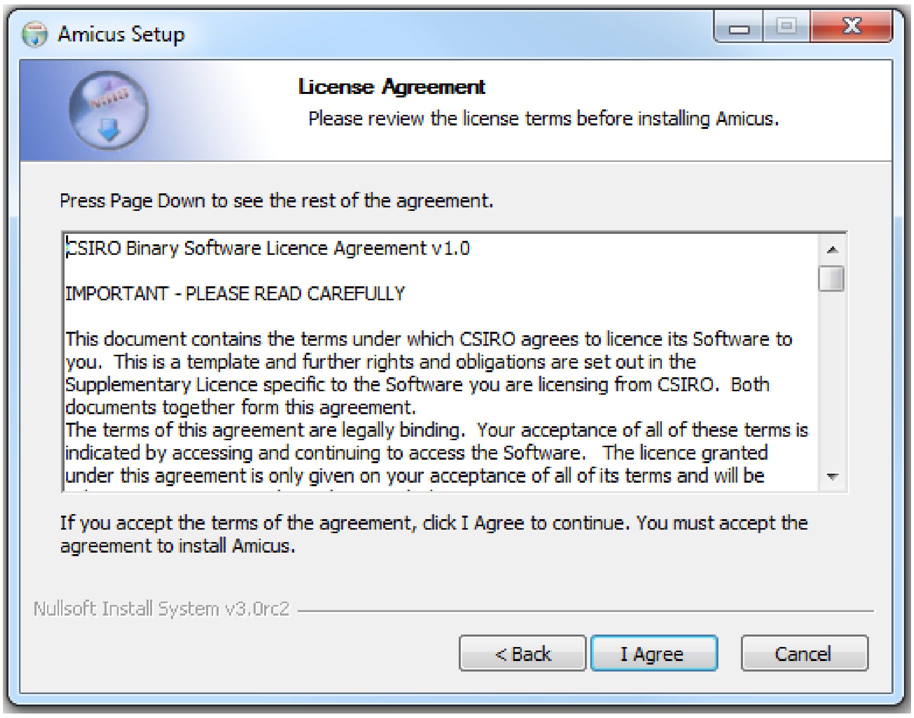


Figure 2.1. The license agreement screen of the installation (Windows).

Click `I Agree` to accept the terms once you have read them and continue.

Choose Install Location (Fig.2.2a): Enter a destination folder in which ***Amicus*** will be installed by *clicking* `Browse` or *click* `Next` to accept the default location.

Choose Start Menu Folder (Fig.2.2b): Select an existing Start Menu Folder into which a short-cut will be created or accept the default by clicking Install. If you do not wish to create a short-cut, *tick* the `Do Not Create Shortcuts` check box by clicking on it and then *click* `Install`.

The Setup Wizard will then install ***Amicus*** in the selected location. *Click* `Finish` when done to complete the install process (Fig. 2.3).

a) b)

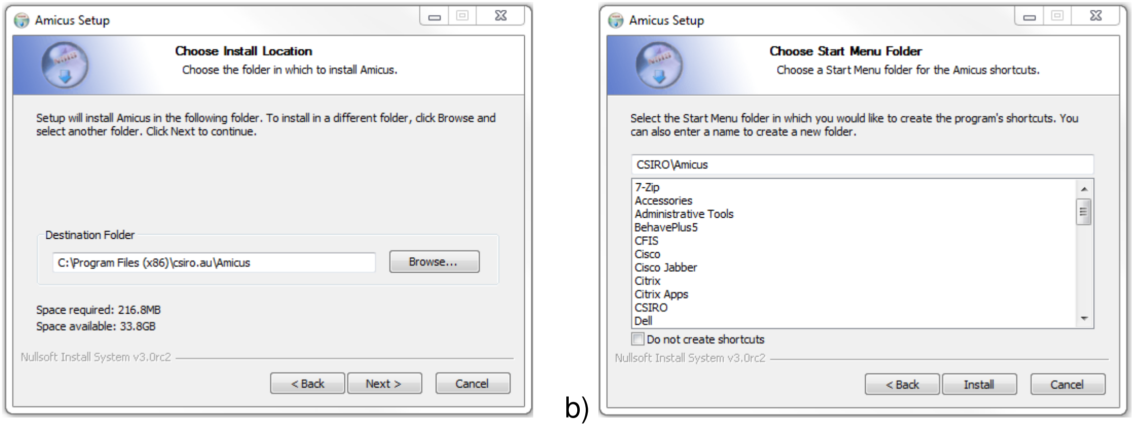


Figure 2.2. The installation location and start menu folder screens of the installation (Windows).

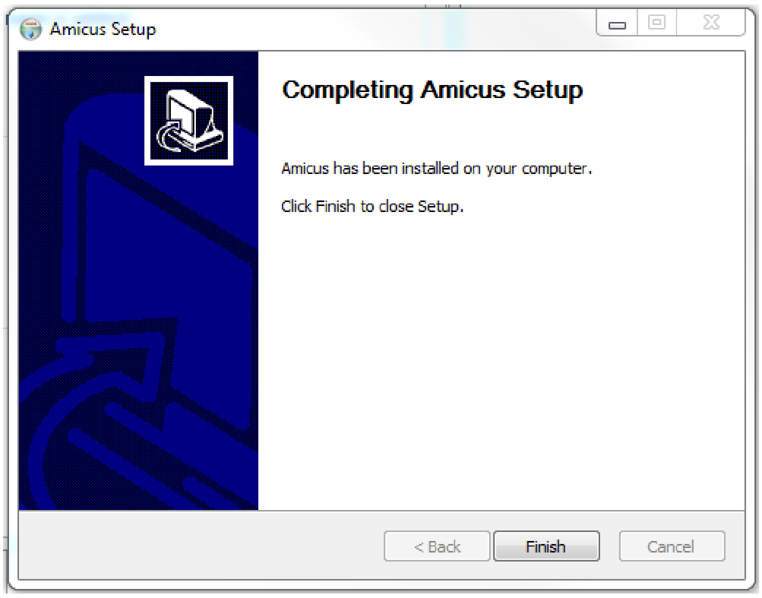


Figure 2.3. The installation location screen of the installation (Windows).

2.2 Launching Amicus

Launch ***Amicus*** by *double click*ing the ***Amicus*** icon in the installation location or, in Windows, from the Start Menu Folder. When ***Amicus*** runs it will display a Disclaimer that outlines the limitations and uses of the software (Fig. 2.4).

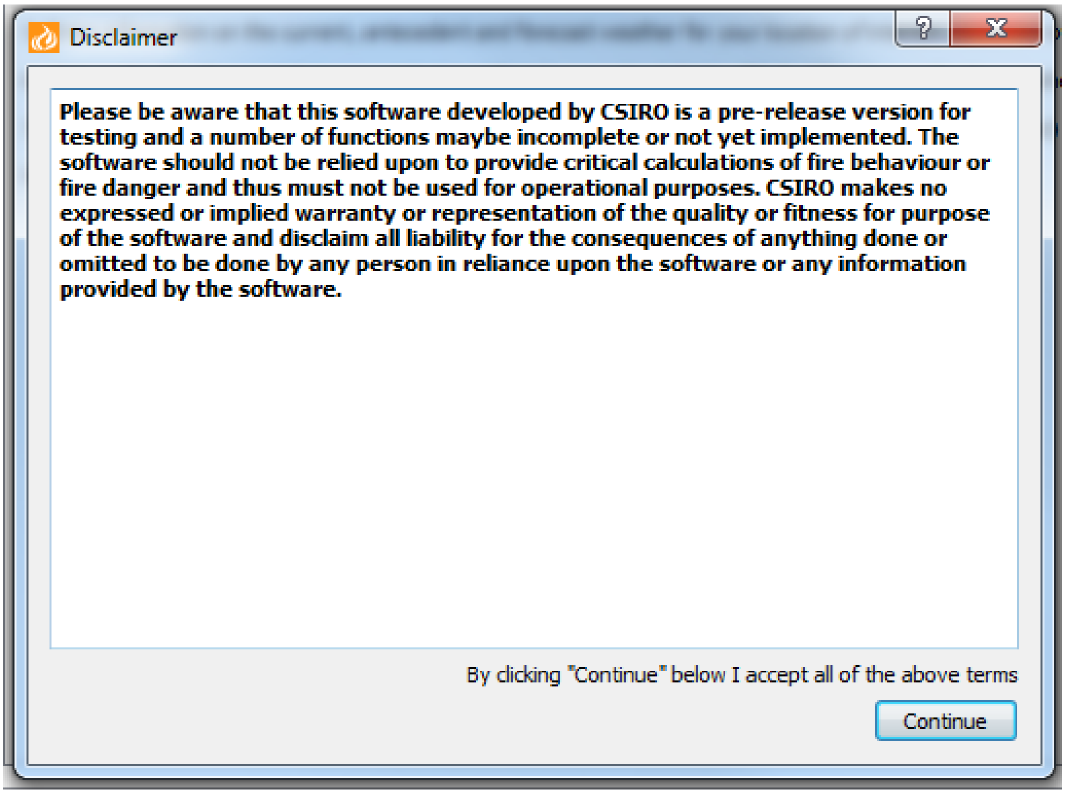


Figure 2.4. The disclaimer that appears when launching a new session.

2.3 Uninstalling Amicus

Amicus can be uninstalled, should you ever want to do this. Uninstall can be initiated by clicking on the `uninstall` option in your Windows Start menu (Fig. 2.5 a) or running the `Uninstall.exe` file within the ***Amicus*** directory (Fig. 2.5b). These will run the ***Amicus*** uninstaller (Fig. 2.6a) which will remove ***Amicus*** from your computer (Fig. 2.6b). The uninstaller will also work automatically upon prompting when you begin installing a newer version of ***Amicus***.

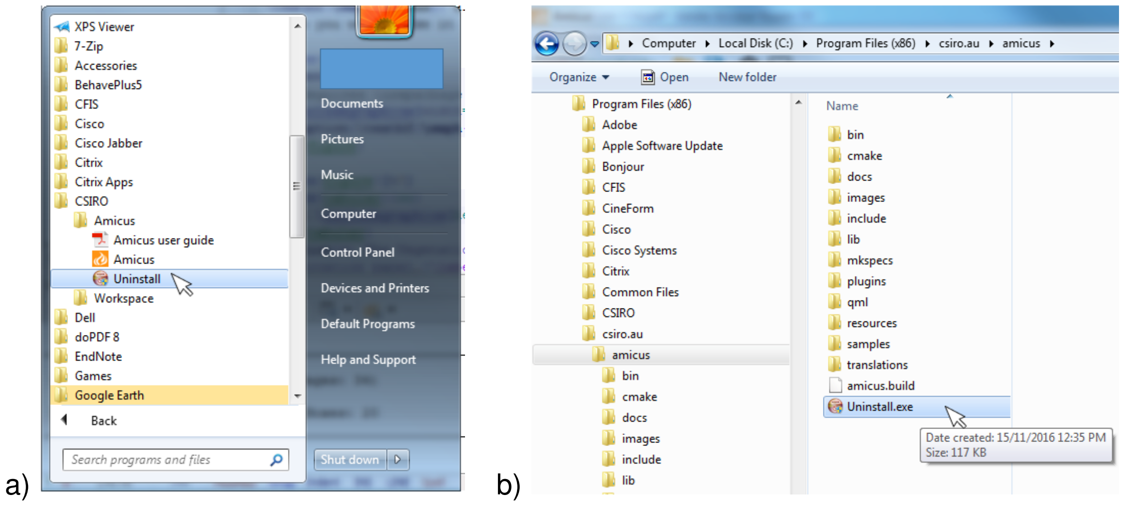


Figure 2.5. a) `Uninstall` option in the Windows Start menu (Windows version). b) `Uninstall.exe` file in the ***Amicus*** directory (Windows version).

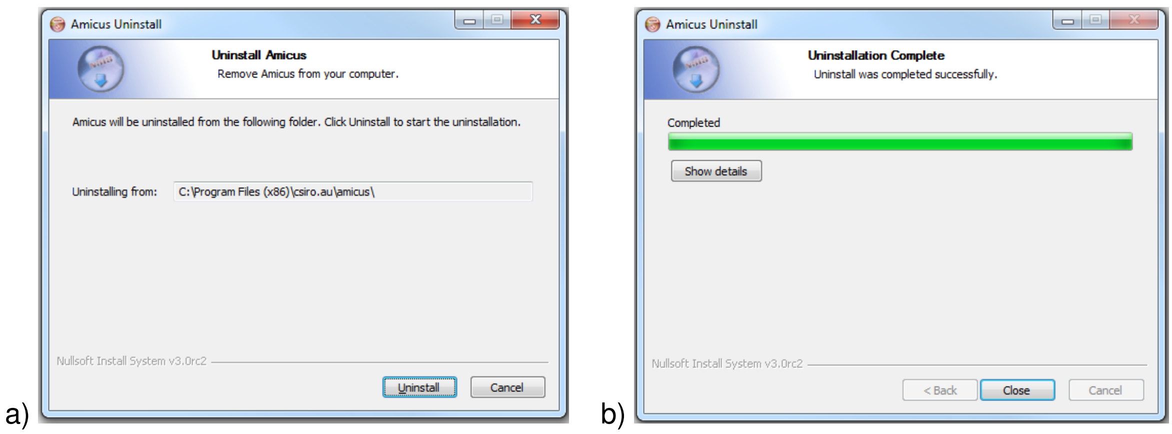


Figure 2.6. a) The ***Amicus*** uninstaller. b) A screen indicating that ***Amicus*** has been uninstalled.

3 The Amicus interface

3.1 Panels

There are three input panels: `Vegetation`, `Location` and `Meteorology`; and one output panel (Fig. 3.1).

Amicus allows you to arrange the interface in the easiest to use layout that suits you. This is done by *clicking* on the title of the panel you wish to move and *dragging* it where you would like it (Fig. 3.2). The panels can be quickly returned to their starting position by selecting the menu item `Options|Set default layout`.

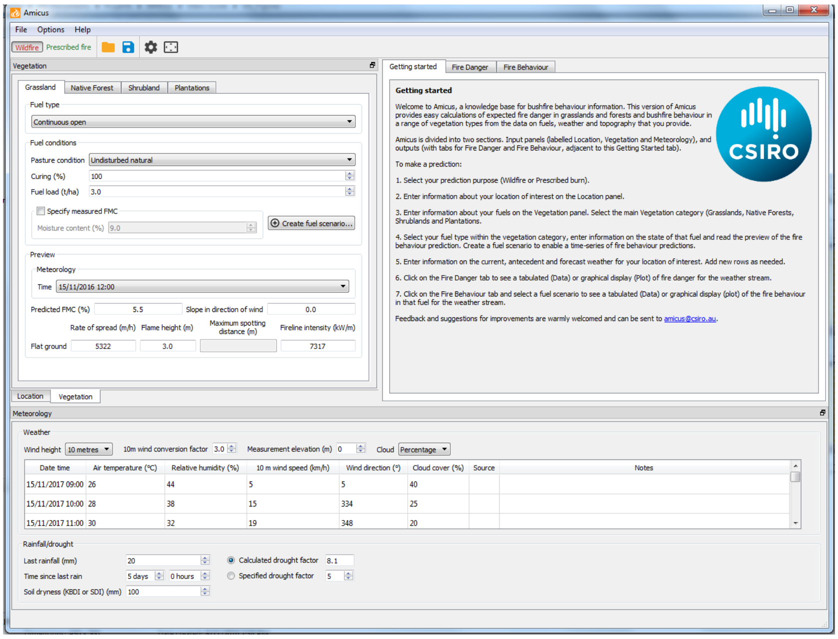
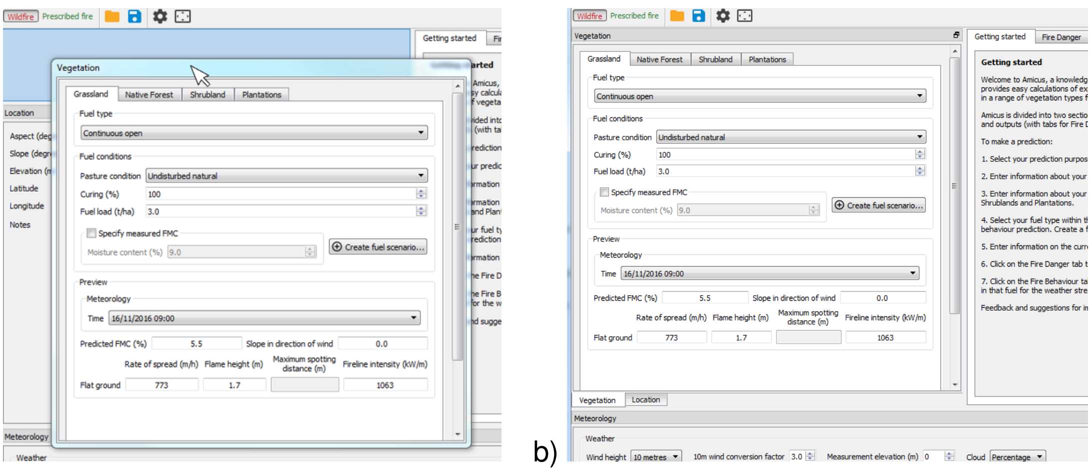


Figure 3.1. ***Amicus***' interface default layout with a mix on input panels and output tabs.



a) b)

Figure 3.2. a) The Vegetation tab has been selected to be moved and has formed a separate window for the moment. b) The Vegetation tab has been dropped into the space created by ***Amicus*** above the Location panel.

An input panel can be dropped on another input panel to create a combined panel with tabs for each of the individual panels. (Fig. 3.3a). Alternatively, a panel can be placed by itself within the main application window, or it can be placed by itself outside the main application window (Fig. 3.3b). When you first launch ***Amicus***, the `Location` and `Vegetation` panels are combined and accessed via the tabs at the bottom of these panels.

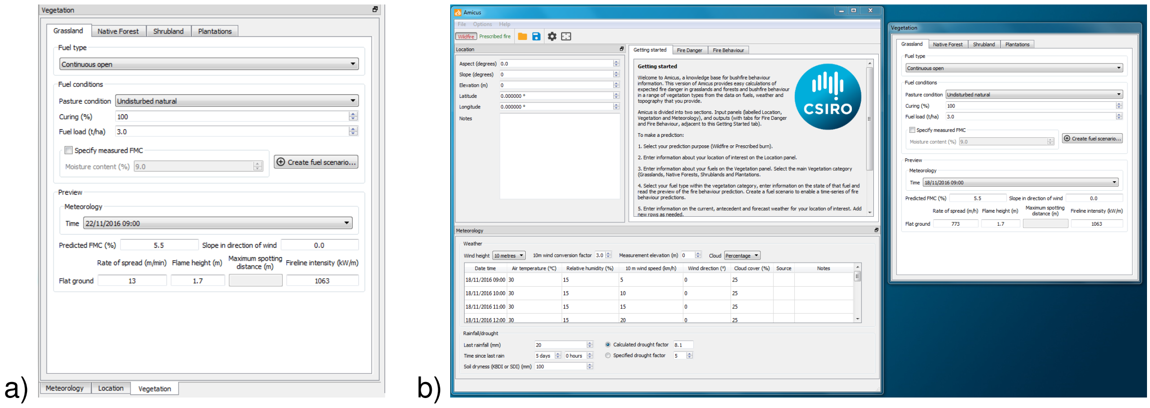


Figure 3.3. a) The Vegetation tab has been dropped onto the existing panel of Location and Meteorology to form a panel with three tabs at the bottom of the panel. b) The Vegetation tab has been dropped as a standalone window outside the ***Amicus*** interface.

The output panel contains three tabs: `Getting Started` instructions, `Fire Danger` and `Fire Behaviour` (Fig. 3.4). This panel remains within the main application window at all times.

If you wish to restore the layout of ***Amicus*** to how it was at the start of the session then click on `Options|Set default layout`.

Scroll bars appear at the bottom and right hand side of the panel if its contents will not fit into the current available area of the panel.

3.2 Menu and quick access buttons

Amicus utilises a standard menu structure to access features such as saving and loading project files, adjusting settings and the help file (this document). `Quick access buttons` are also available to access these features (Fig. 3.5).

From left to right these are:

- Open Amicus project file
- Save Amicus project file
- Change default settings
- Reset view

Simply `click` the quick access button to access the desired feature. The `Reset View` quick access button reorders the panels of *`Amicus`* back to the default layout (Fig. 3.1). This can also be done by clicking on `Options|Set default layout`.

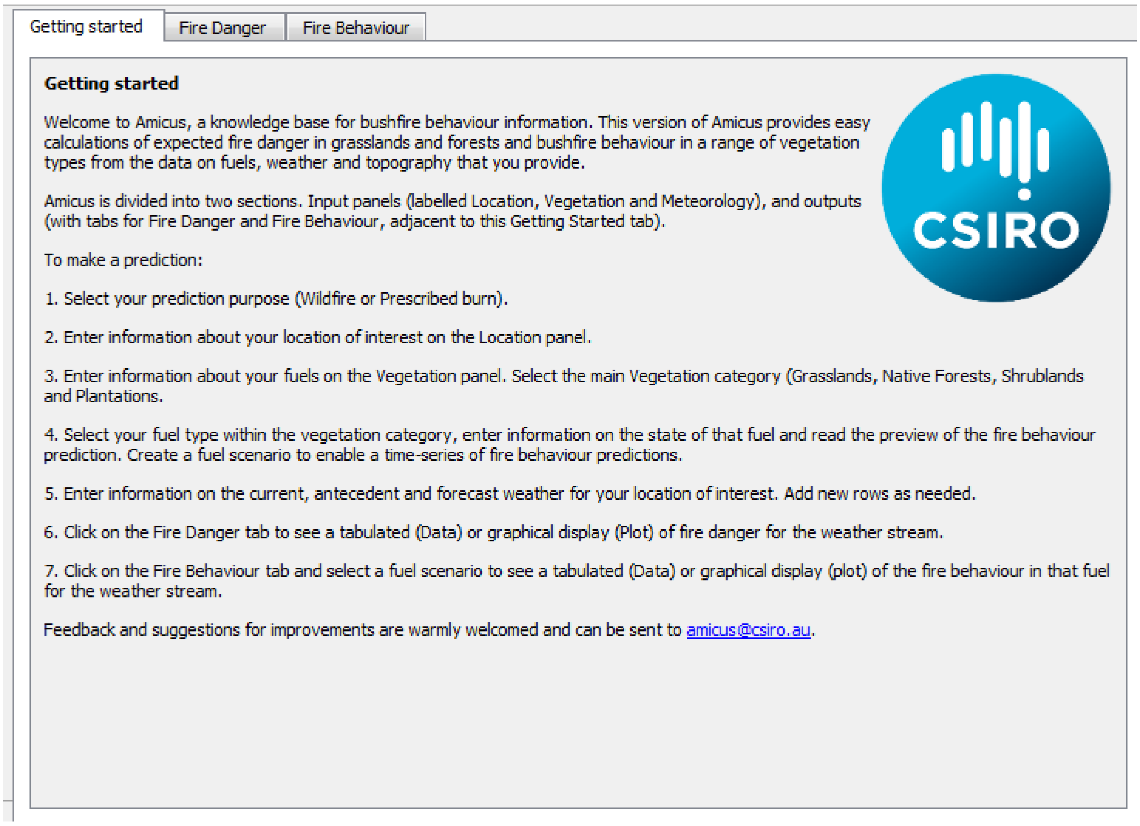


Figure 3.4. The output panel consists of tabs for Getting Started instructions, Fire danger output and Fire Behaviour output

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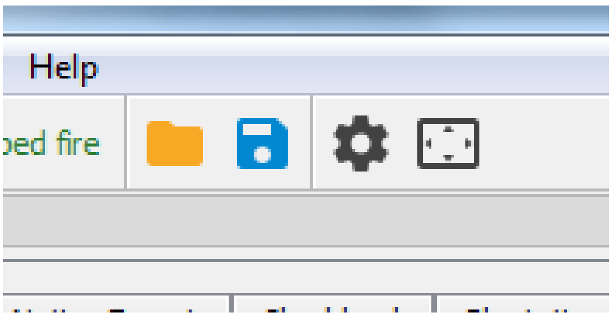


Figure 3.5. Quick access buttons can be used to frequently used menu items.

4 Entering data

Each input panel has required information that must be entered before calculations can be done. Initial starting values for all variables are given to provide output for Fire danger.

4.1 Prediction purpose

Amicus provides two sets of fire behaviour models, depending on whether the purpose of the prediction of fire behaviour is for wildfires or prescribed fires. If you are predicting the behaviour of a wildfire, *click* on the red `Wildfire` button in the top left of the application beneath the Menus (Fig. 4.1). If you are carrying out a prediction of fire behaviour for a prescribed burn operation, *click* the green `Prescribed fire` button.

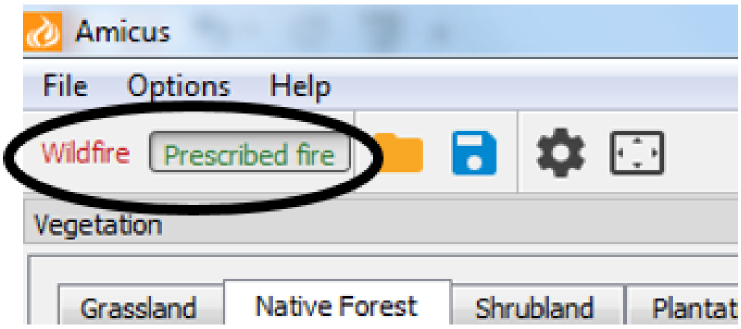


Figure 4.1. The Prediction Purpose option allows you to select models suitable for either Wildfire or Prescribed fire.

Choice of Wildfire or Prescribed fire does not change the calculation of fire danger. For most fuel types, the recommended fire behaviour model is the same for both purposes and so changing this selection will not change the available models.

4.2 Weather

Weather information is entered in the `Meteorology` panel (Fig. 4.2).

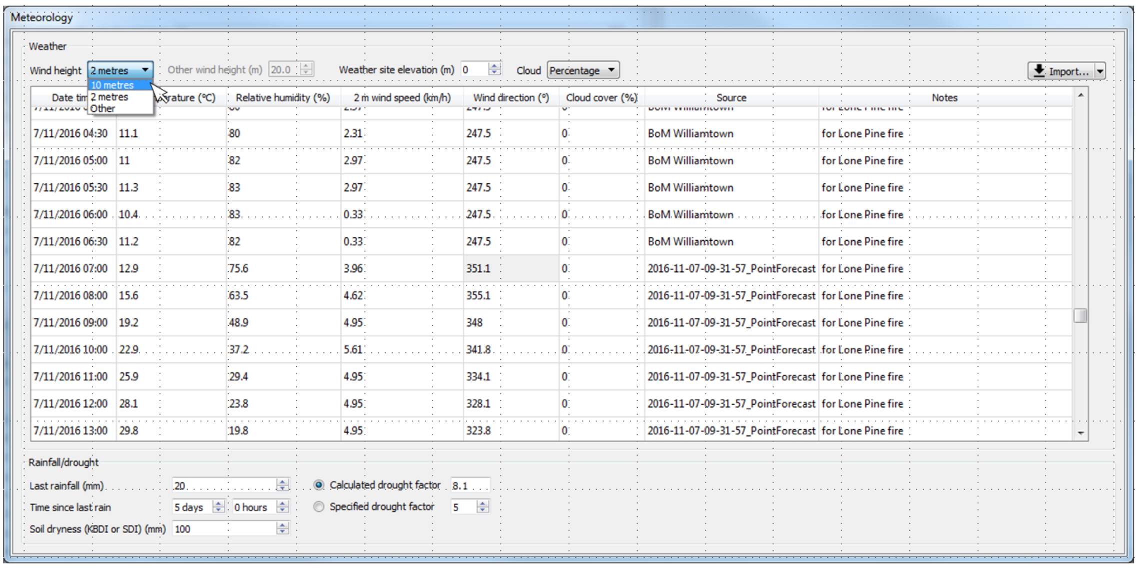


Figure 4.2. The weather data entry panel.

Data for any date and time is entered via the input table for air temperature, relative humidity, wind speed, wind direction and cloud cover. There is also a column for entering information on the data source and a column for entering any other relevant notes. ***Amicus*** only calculates fire danger and fire behaviour for times when all necessary weather inputs (date time, air temperature, relative humidity, wind speed, wind direction and cloud cover) have been entered.

Wind speed can be entered for heights of 10 m in the open (default), 2 metres or other heights via the wind height drop-down button (Fig. 4.2). When the 2 metre or other wind heights are selected, ***Amicus*** uses conversion factors to estimate the wind speed at 10 metres in the open. Wind conversions can be accessed and altered in the wind conversions section of the `Settings` dialog (Fig. 4.3). This dialog contains an explanation of role of conversion factors and a table with wind conversions examples from the literature. The `Settings` dialog can be accessed by going to the `Options|Settings` menu item or *click* on the `Settings` button beneath the main menu (see section 3.2).

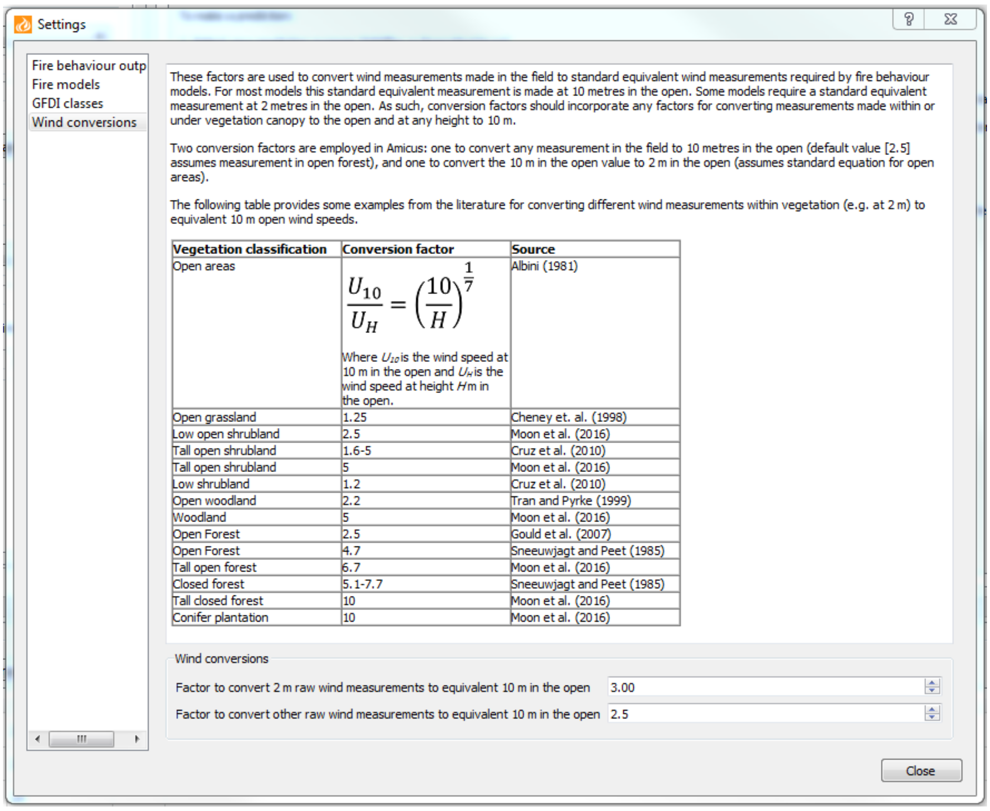


Figure 4.3. The wind conversion section within the `Settings` dialog.

Cloud cover can be entered in oktas or percentages using the cloud cover units drop-down button. The elevation for the weather data can also be entered above the table. This input is currently not activated, but will be used to determine the difference in elevation between the weather data and fire in future versions of ***Amicus***.

An editing local menu is available by *right clicking* when hovering over the weather input table (Fig. 4.4). This menu allows the selection, copying, cutting, pasting and deleting (`clear selected values`) of data and the insertion and removal of rows. This menu also allows the automatic sorting of time series by *right clicking* the `Sort by date time` item and allows the importing and exporting of CSV (comma separated variable) files. Using these functions, weather data can be imported from and exported to other programs (e.g. spreadsheets or word processors).

Amicus automatically converts cardinal wind directions (e.g. NNE, SW, S) to degrees when importing weather data from other sources. ***Amicus*** also flags weather entries when they do not have unique time and dates (Fig. 4.5).

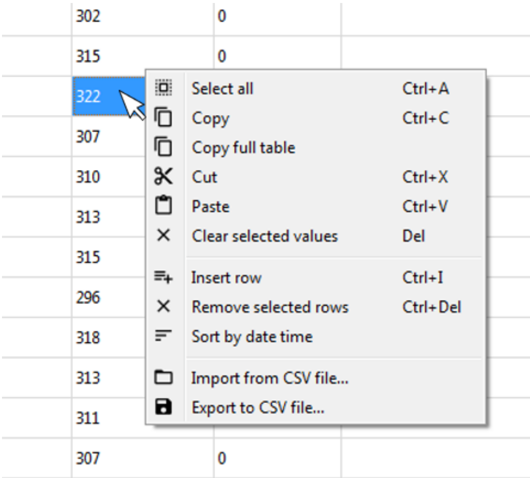


Figure 4.4. Table edit options with right click.

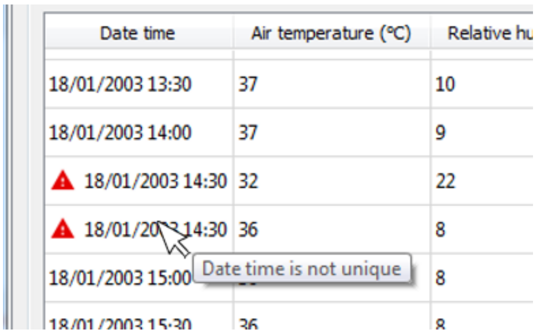


Figure 4.5. Warning for non-unique time and date information.

Data are not used in calculations unless all the data in a row are entered (i.e. no shaded boxes). This includes cloud cover data, which is often missing from weather observations and predictions, but is required for some fuel moisture calculations. In the case of absent cloud cover data, it is best to assume that there is no cloud cover by entering *0* into the cells in this column.

To delete a row, highlight the desired row by *clicking* on it and then *right clicking* on the `Remove seleted rows` button.

Daily information on rainfall and soil dryness is entered in the Rainfall/drought pane beneath the time series weather table. These inputs are required for the calculation of drought factor and Forest Fire Danger Index. Drought factor can also be specified manually (instead of being calculated). The last rainfall amount and time since last rain is also required for the calculation of fuel moisture in the Buttongrass fuel type, which is why time since last rain can also be entered in hours.

4.3 Topography

Topographic information for your location of interest is entered in the `Location` panel (Fig. 4.6).

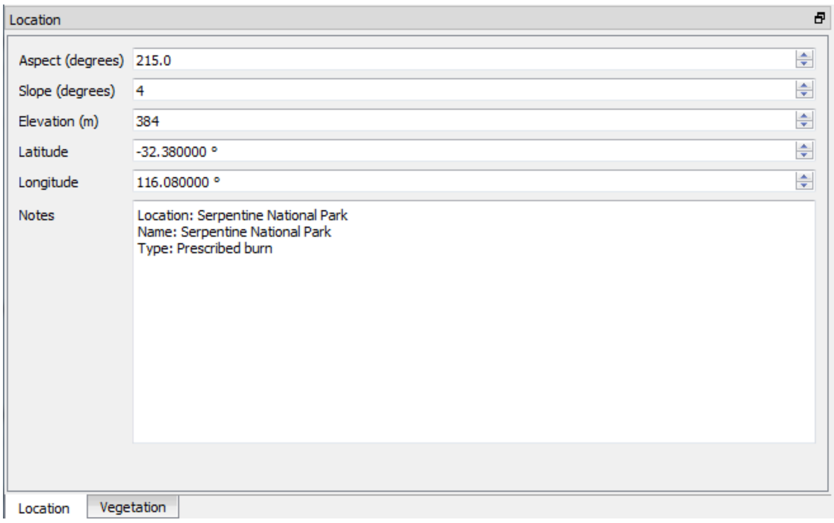


Figure 4.6. The topography data entry panel.

Aspect, slope, elevation and grid location are entered here. Slope and aspect are used to determine the amount of slope in the direction of the wind for each hour of weather provided.

4.4 Fuel

Fuel information is entered in the `Vegetation` panel (Fig. 4.7).

There are four primary vegetation types, each with a separate tab at the top of the panel: Grasslands, Native Forest, Shrublands and Plantations (Figs 4.8a-d).

For each vegetation type there are a number of possible fuel types that can be selected in the first pane of each tab (see Table 4.1 for the complete list currently implemented in ***Amicus***). The conditions of that fuel are then entered in the next pane. The type and extent of fuel conditions is dictated by the fuel type selected and is determined by the fire behaviour model assigned to each fuel type (Table 1.1). The name of the assigned fire behaviour model for each fuel type is given in the `Help|About fire models...` menu item as well as in section 7.

Table 4.1. All fuel types currently implemented in ***Amicus*** by dominant vegetation type

Grassland	Native forest	Shrubland	Plantations
Open continuous	Dry eucalypt (prescribed burning conditions)	Temperate shrubland	Radiata pine (wildfire conditions)
Woodlands	Wet eucalypt (prescribed burning conditions)	Semi-arid heath	Maritime pine (wildfire conditions)
Open grassy forest (Northern Australia)	Dry eucalypt (wildfire conditions)	Semi-arid Mallee-heath	Short-rotation eucalypt (wildfire conditions)
Spinifex	Wet eucalypt (wildfire conditions)		
Buttongrass			

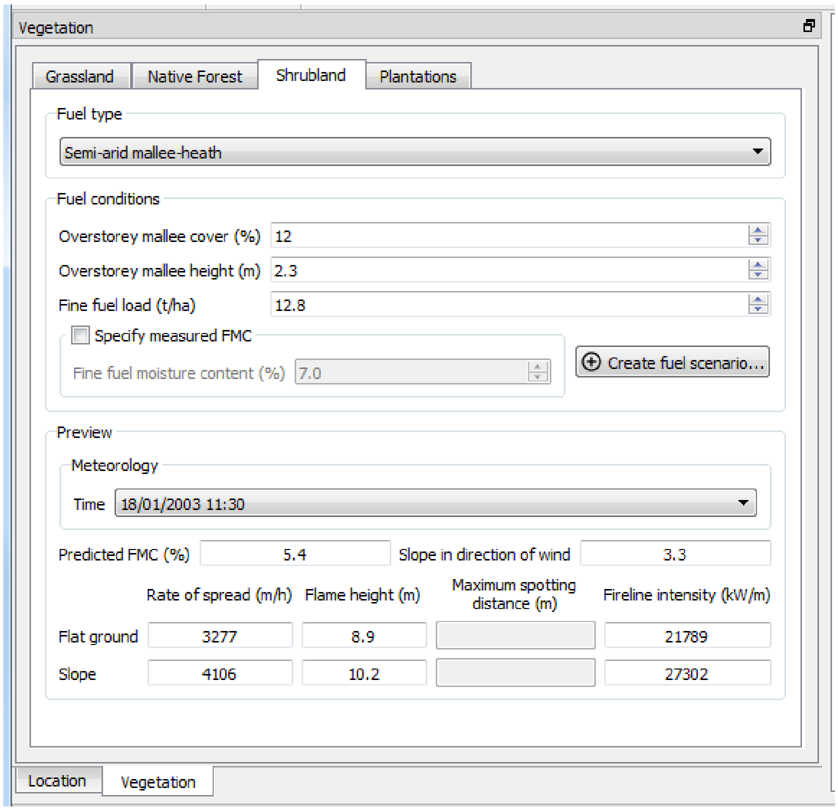


Figure 4.7. An example of a fuel data entry panel (for semi-arid mallee-heath.)

4.5 Fire behaviour preview

A preview of the predicted fire behaviour at a selected time in the weather stream is given in the final pane of the vegetation type tab (Fig. 4.9). The time can be changed in the `Preview|Meteorology` drop down. Output information includes predicted fuel moisture, slope in the direction of the wind for the location of interest as well as rate of spread, flame height, intensity and maximum spotting distance (if applicable) for flat ground and the slope in the direction of the wind.

4.6 Fuel scenarios

In order for a fire behaviour prediction time series to be constructed, a fuel scenario must be made. This is done by entering the necessary type and condition of the fuel and once you are satisfied that you have entered all the pertinent data *clicking* the `Create fuel scenario...` button (Fig. 4.10). Give the fuel scenario a suitable identifying name (and description if required) (Fig. 4.11). The data currently entered in the pane are then stored in that fuel scenario. The fuel scenario window also shows the prediction purpose used for the scenario.

A progress bar appears when creating fuel scenarios for Radiata and Maritime pine fuel types as these models take longer to calculate than the other models due to their iterative design.

It is only possible to have five fuel scenarios in this evaluation version of ***Amicus***. If you attempt to create more than five fuel scenarios, you will be presented with an error (Fig. 4.12) telling you you have reached the maximum number of scenarios.

The `Fire Behaviour` tab of the Output panel provides access to the `Fuel Scenario Manager` that will enable you to edit your scenarios and delete unwanted ones (see section

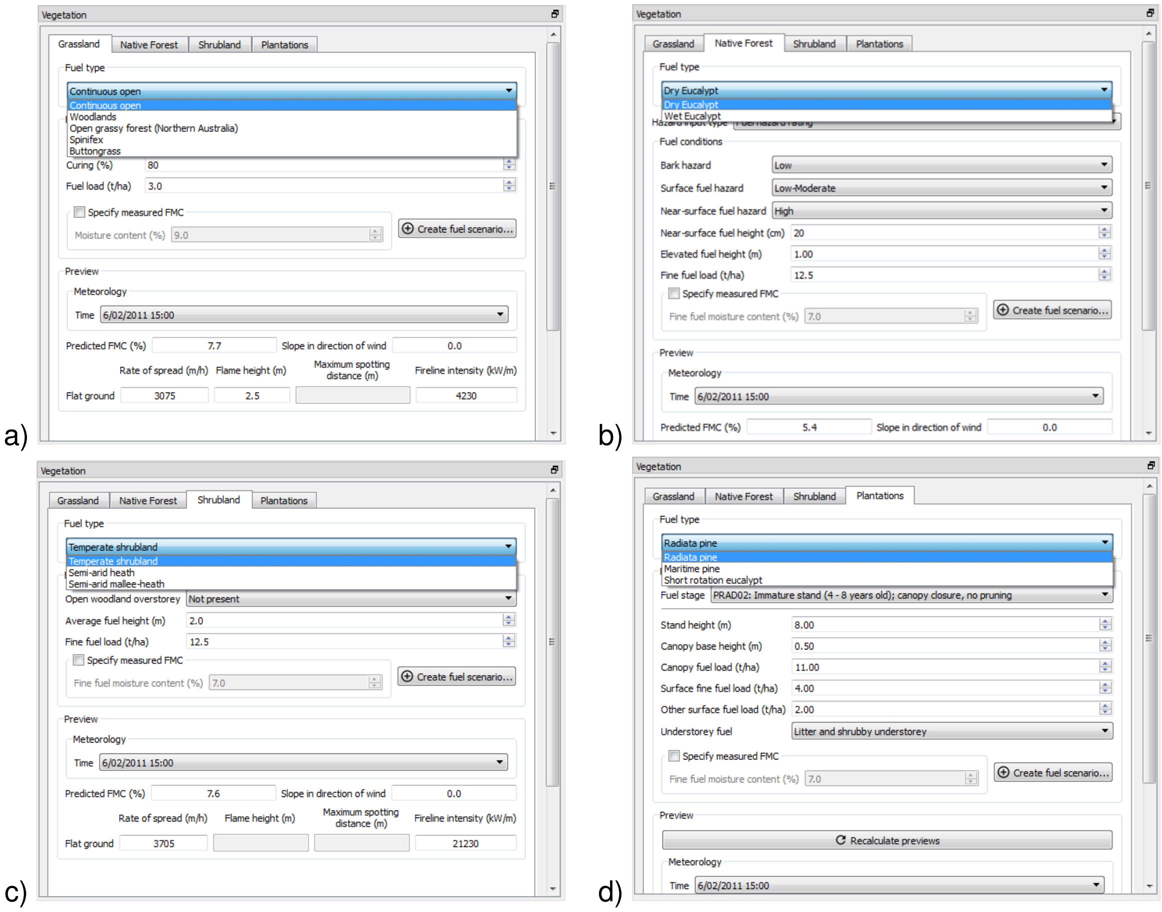


Figure 4.8. The four primary vegetation types as displayed in the Vegetation panel showing all of the fuel types within each. a) Grasslands. b) Native forests. c) Shrublands. d) Plantations.

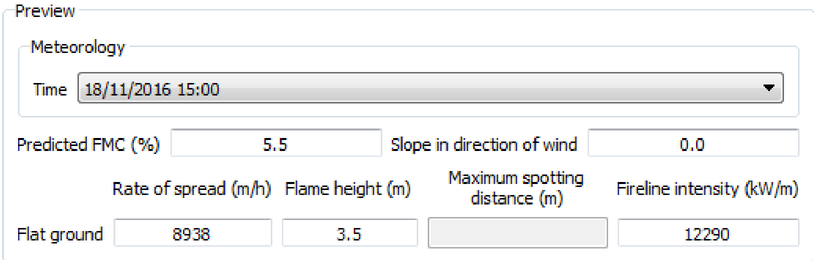


Figure 4.9. The preview of fire behaviour information for the weather data at the selected time. Outputs are grey where models do not exist (e.g. for flame height or maximum spotting distance).

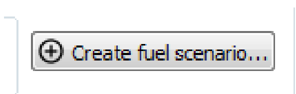


Figure 4.10. The `Create fuel scenario...` button found on the `Vegetation` panel

6.3).

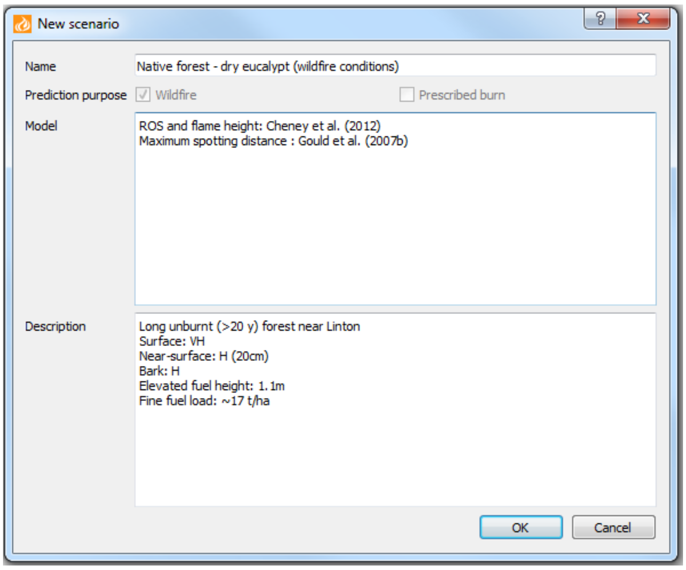


Figure 4.11. The new scenario window. Give the scenario a meaningful name and a useful description of the content

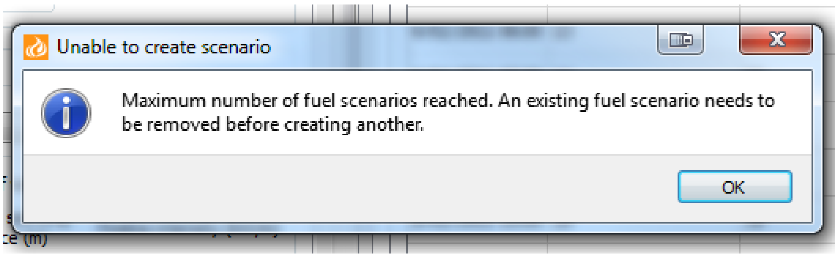


Figure 4.12. If you attempt to create more than five fuel scenarios you will see this error.

5 Output-Fire danger

Fire danger for both Grasslands and Forests is calculated automatically from the current weather stream. To view the results of the calculation *click* on the `Fire Danger` tab in the Output panel (Fig. 5.1). Two sub-tabs appear: `Data` and `Plot`.

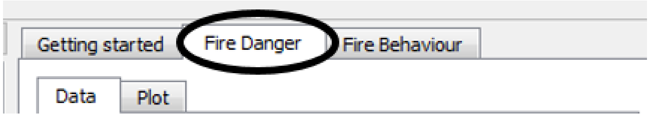
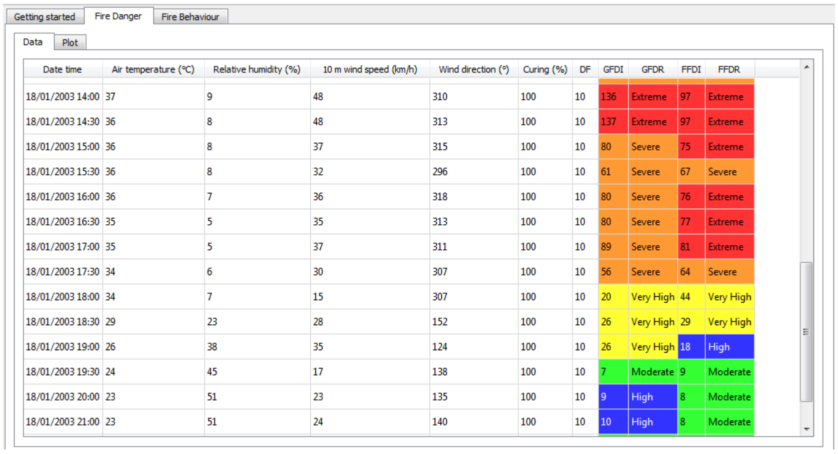


Figure 5.1. Click on the Fire Danger tab to see forecasts of fire danger for both grasslands and forests.

5.1 Fire danger table

The `Data` tab (Fig. 5.2) provides tabulated output of fire danger calculations (both fire danger index and fire danger rating) for both vegetation types for each row of weather entered in the `Meteorology` panel.



Getting started | Fire Danger | Fire Behaviour

Data | Plot

Date time	Air temperature (°C)	Relative humidity (%)	10 m wind speed (km/h)	Wind direction (°)	Curing (%)	DF	GFDI	GFDR	FFDI	FFDR
18/01/2003 14:00	37	9	48	310	100	10	136	Extreme	97	Extreme
18/01/2003 14:30	36	8	48	313	100	10	137	Extreme	97	Extreme
18/01/2003 15:00	36	8	37	315	100	10	80	Severe	75	Extreme
18/01/2003 15:30	36	8	32	296	100	10	61	Severe	67	Severe
18/01/2003 16:00	36	7	36	318	100	10	80	Severe	76	Extreme
18/01/2003 16:30	35	5	35	313	100	10	80	Severe	77	Extreme
18/01/2003 17:00	35	5	37	311	100	10	89	Severe	81	Extreme
18/01/2003 17:30	34	6	30	307	100	10	56	Severe	64	Severe
18/01/2003 18:00	34	7	15	307	100	10	20	Very High	44	Very High
18/01/2003 18:30	29	23	28	152	100	10	26	Very High	29	Very High
18/01/2003 19:00	26	38	35	124	100	10	26	Very High	18	High
18/01/2003 19:30	24	45	17	138	100	10	7	Moderate	9	Moderate
18/01/2003 20:00	23	51	23	135	100	10	9	High	8	Moderate
18/01/2003 21:00	23	51	24	140	100	10	10	High	8	Moderate

Figure 5.2. The Fire Danger data tab displays tabulated information on forecast fire danger for both grasslands and forests. Fire danger ratings are coloured according the currently accepted scheme.

The default fire danger rating thresholds are those used in the eastern states. To change the thresholds to those used in Western Australia or the Northern Territory, go the `Options|Settings` menu item or *click* on the `Settings` button beneath the main menu. When the `Settings` dialog appears, *click* on `GFDI classes` and select `Set grassland danger rating thresholds for Northern Territory or Western Australia`. The thresholds can be returned by deselecting this option.

The fire danger output table contents can be copied and exported to other programs by *right clicking* on the table (Fig. 5.3).

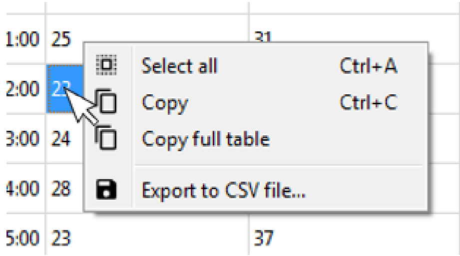


Figure 5.3. The dialog box that appears after selecting the `save to image` button on the Fire Danger plot.

5.2 Fire danger plot

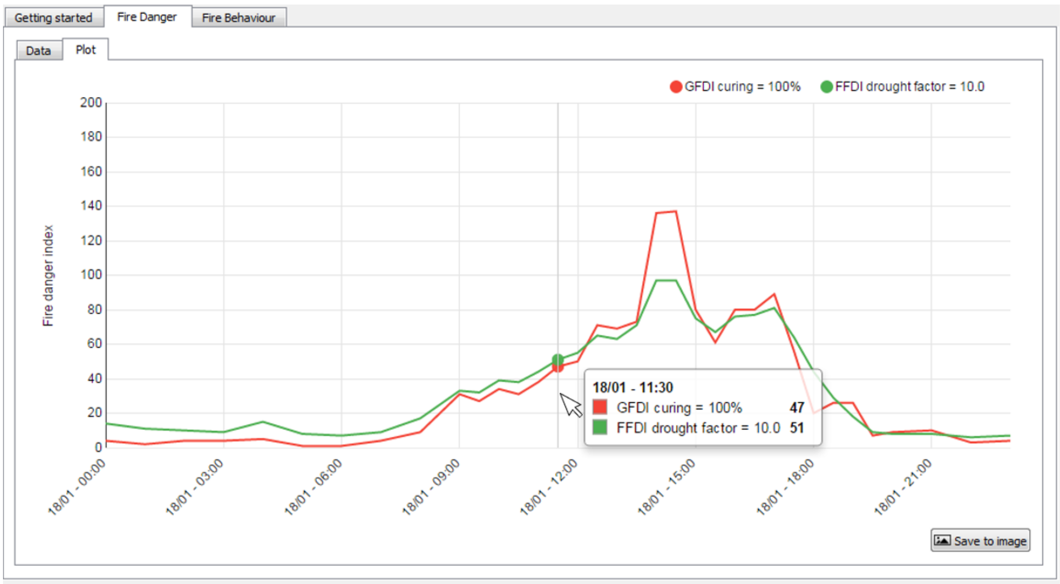


Figure 5.4. The Fire danger data tab displays a graph of the forecast fire danger for both grasslands and forests. Hovering the mouse pointer over this plot allows the predictions for a time to be displayed

.

The fire danger plot can be saved by pressing the `save to image` button on the bottom right corner of the Fire danger plot. Enter a filename and select a suitable directory by clicking the `open a file selection dialog` (Fig. 5.5). The height and width of the output image can also be adjusted in the `open a file selection dialog`.

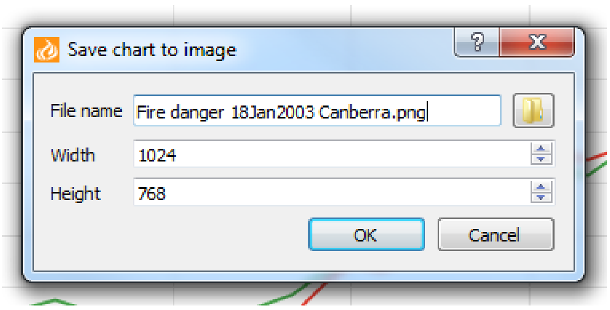


Figure 5.5. The dialog box that appears after selecting the `save to image` button on the Fire danger plot.

6 Output-Fire behaviour

The `Fire Behaviour` tab of the Output panel (Fig. 6.1) provides more detailed fire behaviour calculations for the entire weather stream (as entered in the `Meteorology` panel) than the auto-calculated preview for a particular time given in the `Vegetation` panel (See section 4.5). However, this information is only calculated for a particular fuel scenario (see section 4.6 above). If you haven't already created a fuel scenario or selection of fuel scenarios in the Vegetation tab then no information will be displayed in the fire behaviour tab.

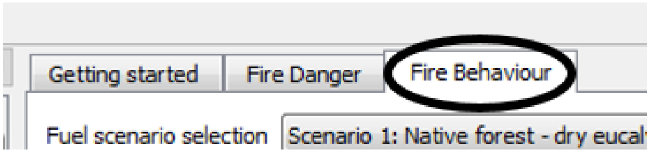


Figure 6.1. Click on the `Fire Behaviour` tab to see predictions of fire behaviour for each fuel scenario.

When you click on the `Fire Behaviour` tab in the Output panel, you will see a drop-down list of currently available fuel scenarios that you have created at the top of the pane (Fig. 6.2). Select a fuel scenario for which you wish to see the detailed fire behaviour results.

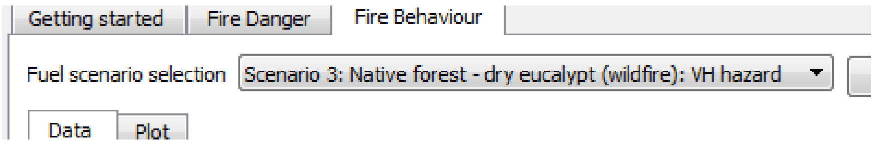


Figure 6.2. Select a fuel scenario from the drop down list to view the predicted fire behaviour.

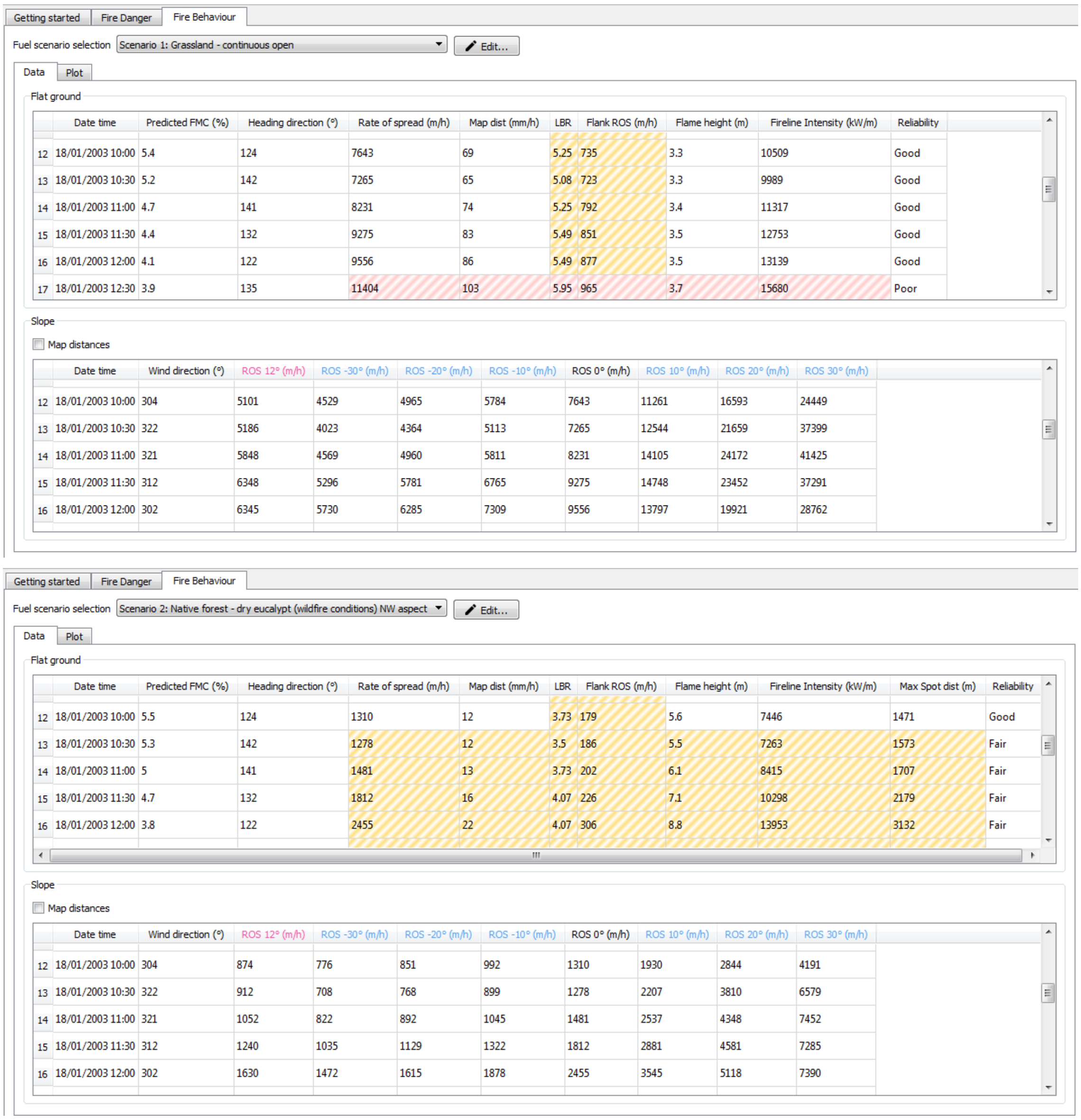
For the currently selected fuel scenario two tabs are visible: `Data` and `Plot`. `Data` provides detailed tabulated fire behaviour information for each entry in the weather stream. `Plot` provides a graph of rate of spread for selected fuel scenarios for the available weather data. Table outputs are discussed in section 6.1 and plot outputs in section 6.2.

6.1 Fire behaviour tables

The fire behaviour output table (Fig. 6.3) is the primary means for presenting modelled fire behaviour in ***Amicus***. Two tables are presented on this tab, one for flat ground and one for slope conditions. There are many outputs presented in these. The outputs on the `flat ground` table can include all available outputs for the selected fuel type, but do not show the effect of slope. The tabulated fire behaviour outputs can be copied or exported to other programs by *right clicking* on the table (as for the fire danger output table, Fig. 5.3).

Orange and red cross-hatching are used to indicate when the *reliability* of the model output is compromised within the fire behaviour output table. The details of the reliability warnings are presented in section 6.4. The `slope` output table shows the predicted rates of spread for flat ground and a range of selectable slope angles.

The `slope` output table is designed to show the impact of slope on rates of spread. The slope table can show the rate of spread for flat ground (0°, column with black heading text), selected slopes (-30 → +30° when selected in settings, columns with blue heading text) and user-entered slopes (calculated from slope, aspect and wind direction, column with pink heading text) (Fig.



a)

b)

Figure 6.3. a) Fire behaviour data for scenario 1. b) Fire behaviour data for scenario 2.

6.3). As with the `flat ground` output table, all of the items in the `slope` output table can be selected to be visible or not. Only the user-entered slope column is affected by the aspect provided in the `Location` panel (Fig. 4.6). The relative slope used for the calculation of rate of spread in this column changes with wind direction.

6.1.1 Settings for displayed outputs

The available outputs for the `flat ground` table depend on the fuel type as not all fuel types have models for all fire behaviour outputs. The displayed outputs and their units can be selected to appear or not in the `Outputs` section of the `Settings` dialog (Fig. 6.4). The `Settings` dialog can be accessed by going to the `Options|Settings` menu item or *clicking* on the `Settings` button beneath the main menu (Fig. 3.5). The full list of outputs for all fuel types includes:

- `Weather interval` is the time period between the time of this row's weather observation and the next row's weather observation (based on inputs in the meteorology table).

Units can be hours or minutes.

- `FMC` is the modelled fuel moisture content for that time. Units are in percent.
- `Heading direction` is the direction of fire spread, which is the inverse of wind direction. Units are in degrees.
- `Rate of spread` is the modelled rate of forward spread. Units can be in km/h, m/h or m/min (see: Section 7.2).
- `Map distance` is the rate of spread converted to a map scale specific distance for plotting a fire progression map (see: Section 7.3.6). Can be either expressed as mm/h or mm/weather interval.
- `Length to breadth ratio` is the ratio between the length (distance between the backing fire and head) and breadth (distance between the flanks) of a fire (see: Section 7.3.4).
- `Flank rate of spread` is the estimated spread distance in the direction perpendicular to the heading direction. Units are the same as those selected for rate of spread.
- `Flame height` is the modelled height of head fire flames. Units are in m (see: Section 7.3.2).
- `Fire line intensity` is the calculated Byram fireline intensity of the head fire. Units are in either kW/m or MW/m (see: Section 7.3.1).
- `Maximum spotting distance` is the maximum distance in front of the head fire that spot fires can be expected. Units are in m or km (see: Section 7.3.3).
- `Fire type` is the type of fire in terms of crowning activity. This output is only available for Radiata and Maritime pine fuel types where it can be either ”surface fire”, ”passive crown fire” or ”active crown fire”.
- `Reliable` is a worded flag for the presence of reliability warnings (does not consider warnings for length to breadth ratio or flank rate of spread) (see: Section 6.4).

Selecting the `map distance` check box converts the rates of spread in the fire behaviour output tables into the units selected for plotting maps (see: Section 7.3.6 for details). This will be in the units selected for `Map distance` in the output settings box (Fig. 6.4). Similarly output units in terms of map scale factor (map distance per kilometre) can also be set in this way.

6.2 Fire behaviour plots

`Plot` (Fig. 6.5) provides a graphical representation of the rate of spread predictions. Up to five fuel scenarios can be displayed at any one time however only the first five scenarios in the list can be displayed at this stage. Fuel scenarios can be easily compared and contrasted for the same weather inputs. The plot for the selected fuel scenario is represented by the thickest line. Fuel scenarios can be removed from the plot by *deselecting* the `show plot` check box in the `fuel scenario manager` (Fig. 6.7).

The mouse pointer can be moved along the time scale (x axis) of the plots and a pop-up box will reveal the rate of spread predictions for the closest time (Fig. 6.5). If the pointer is on the line at a particular time then the relevant point in the pop up box will be highlighted.

Plot images can be saved by clicking on the `save to image` button on the bottom right corner, as for the Fire danger plot and a filename can be entered in the `open a file selection`

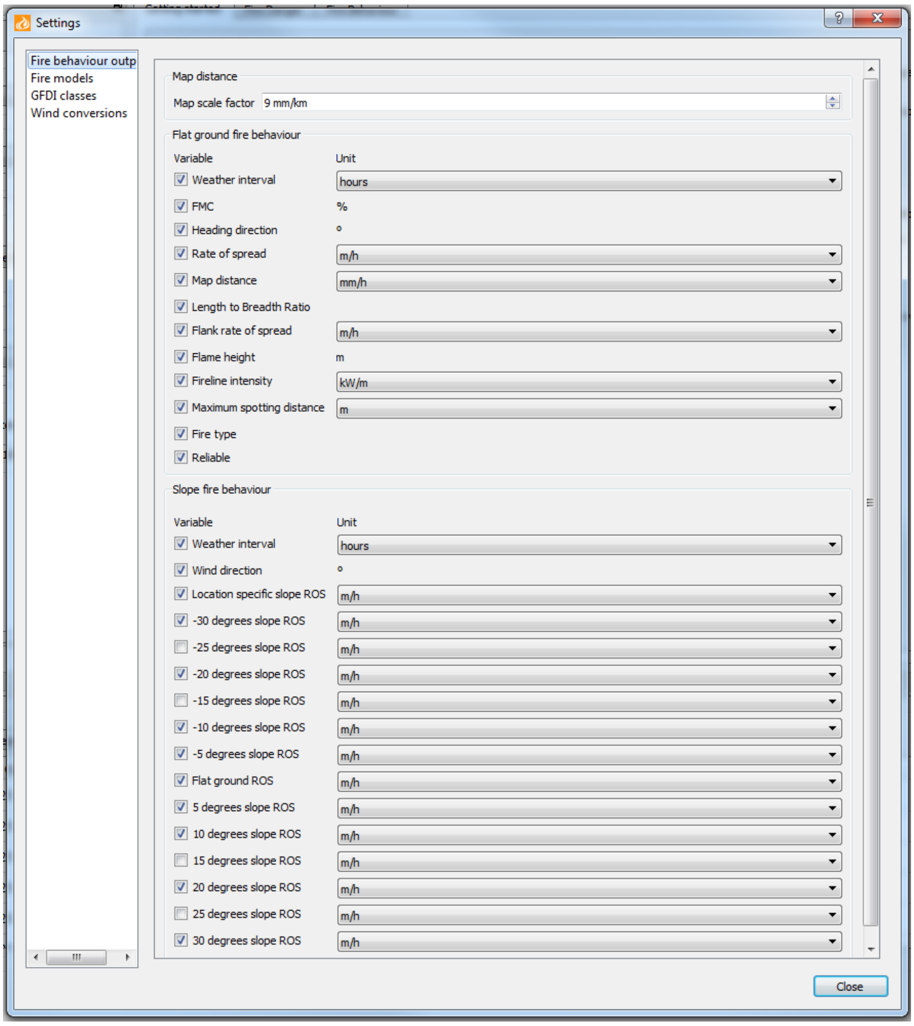


Figure 6.4. Settings dialog for changing outputs.

dialog (Fig. 5.5).

Slope affected fire spread is presented as dashed lines in the fire behaviour output plots (Fig. 6.6). These are the same colour as the non-slope affected fuel scenarios in the plot. The slope and aspect used are displayed at the top of these plots, along with the legend for the different fuel scenario fuel types. As only a single combination of the slope and aspect are used, the relative effect of slope will change when the wind changes direction, such as in Figure 6.6, where there is a significant wind change ($\sim$ 130°) at 18:30. This plot also shows times (11:00 – 17:30, 19:00) when the rate of spread in the Radiata pine is not affected by slope because the fire is crowning (see sections 7.2.4 and 7.3.5).

6.3 Fuel scenario manager

The `Fuel Scenario Manager` allows you to view the details of your current saved fuel scenarios and modify them if required. Click on the `Edit` button (Fig. 6.7a) to the right of the fuel scenario selector to open the `Manage Scenarios` dialog (Fig. 6.7b). You can rename, enter or change a description or delete any scenario using this dialog. `Click` the `Delete scenario` button to delete the selected scenario. Be aware that once you have deleted a scenario you cannot bring it back.

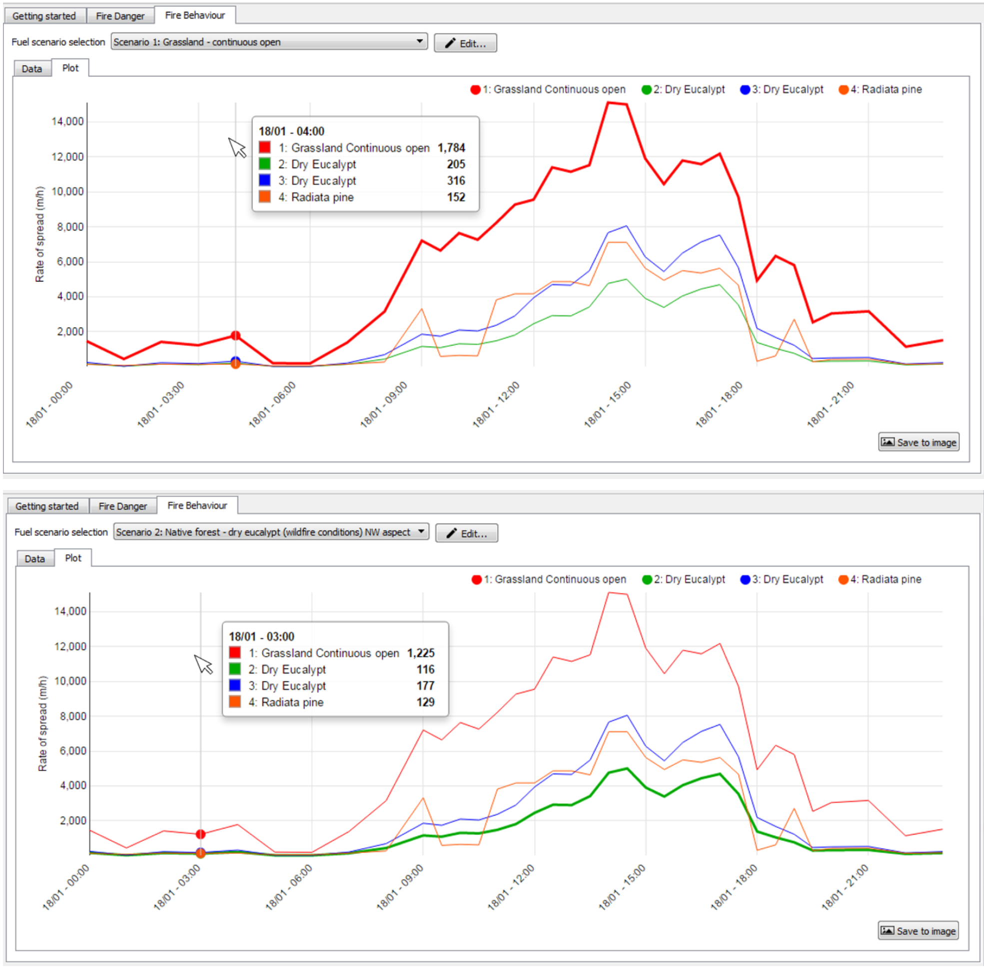


Figure 6.5. a) Fire behaviour plots for scenario 1. b) Fire behaviour plots for scenario 2.

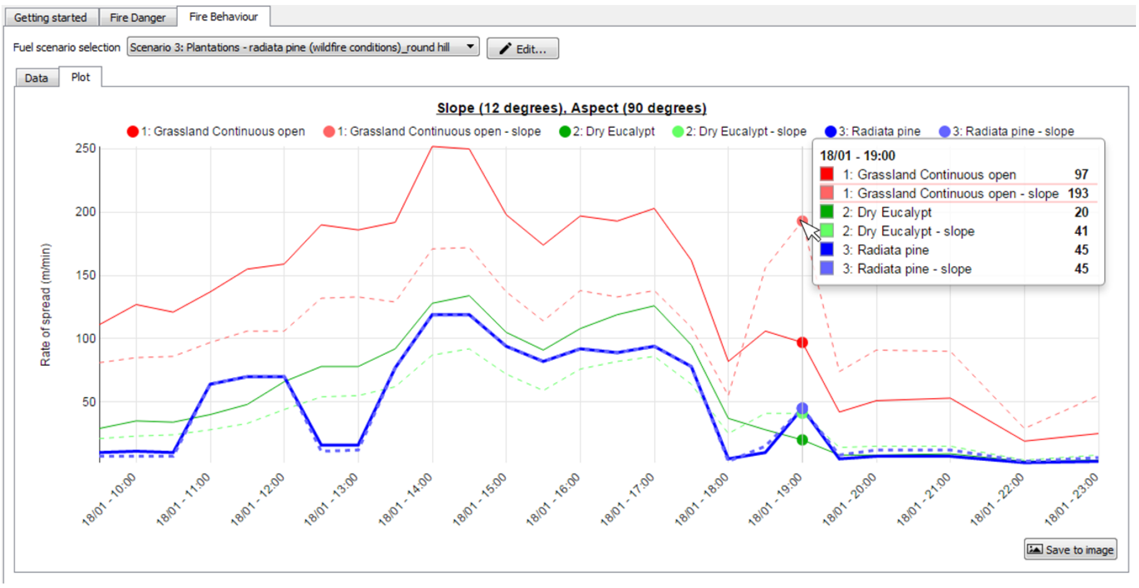
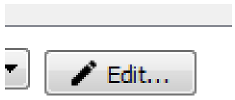
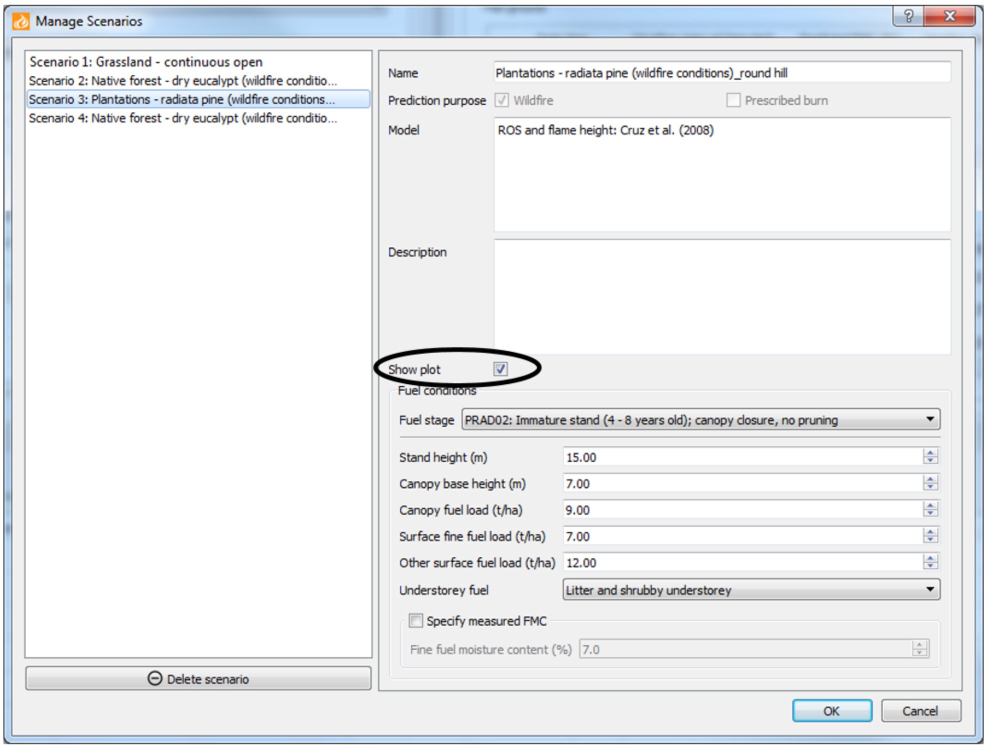


Figure 6.6. Fire behaviour output plot showing rate of spread with the effect of user-entered slope and aspect (dashed lines) for three different fuel scenarios.



a)



b)

Figure 6.7. a) `Click` on the `Edit` button to manage your scenarios. b) The Manage Scenarios dialog. Use this to modify or delete your scenarios. The show plot check box is circled.

The `Manage Scenarios` dialog box also shows the fire type (wildfire or prescribed burn) for each scenario, though these cannot be changed. The `Show plot` checkbox allows you to choose whether a fuel scenario will be displayed on the fire behaviour output plot or not (Fig. 6.7b).

6.4 Model reliability bounds

All models used to calculate fire danger, rate of forward spread or other metrics such as maximum spotting distance or flame height have bounds of reliability within which the results of a model's prediction are deemed to be reliable. These bounds are often defined by the burning conditions (i.e. weather, fuel, topography) used to collect the data that were used to construct the model but also often represent limits of reliability of the underlying mathematical functions that are used in the model. Very often these bounds are narrow ranges of the possible values that an input variable (e.g. wind speed or air temperature, etc.) can have in reality.

In order to provide some indication of the limits of performance on any particular model (i.e. model reliability), ***Amicus*** colours the output cells (Fig. 6.8) according the values of the input variables and the scope of the model. Table 6.1 defines the three classes of prediction reliability.

To find out more about a low reliability prediction in a shaded cell, place the mouse over the cell and a note will appear detailing the root cause of the reduced reliability (Fig. 6.1).

Breaches in model reliability bounds are also flagged in the `reliability` output column

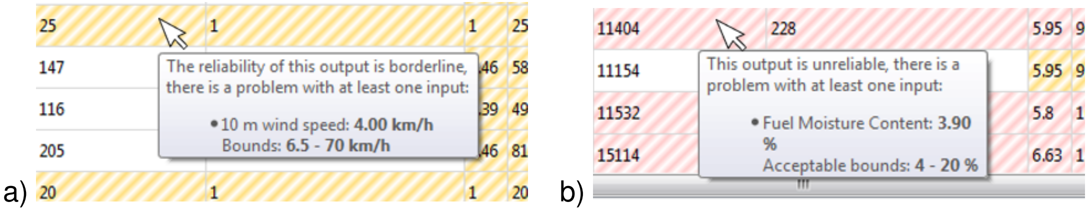


Figure 6.8. a) One or more of the input values to this cell have been determined to be just outside the confirmed reliability range for the selected model and thus the cell has been shaded with orange stripes. b) One or more of the input values to this cell have been determined to be well outside the confirmed reliability range for the selected model and thus the cell has been shaded with red stripes. In each case a mouse-over note provides an indication which variable is out of range.

Table 6.1. Three colouring schemes are used to highlight whether a prediction in a cell is within input and model bounds, just outside (shoulder or borderline) or well outside (unreliable).

Reliability	Shading	Description
Reliable	Clear (Black text on white background)	All input values and model function are within design tolerances
Borderline	Orange (Black text with orange/white striping)	Some input values or model function are just outside design tolerances
Unreliable	Red (Black text with red/white striping)	Some input values or model functions are well outside design tolerances

(far right column) within the flat ground fire behaviour output table (Fig. 6.3). This provides a nominal description of either *good* (all inputs within model design tolerances), *fair* (one or more inputs are just outside of design tolerances) or *poor* (one or more inputs are well outside of design tolerances). The details of any breaches are not provided in the text of the output table. Warnings associated with `length to breadth ratio` and `Flank ROS` predictions are not considered as these are present for all applications.

7 Fire models

This section provides information on the fire danger indices and fire behaviour models used within ***Amicus***. Further information on these is available in the book *A Guide to Rate of Fire Spread Models for Australian Vegetation* (Cruz *et al.* 2015*a*) which can be downloaded from https://research.csiro.au/firemodelsguide/.

7.1 Fire danger

Fire danger is currently only calculated for the two dominant vegetation types in Australia. These are grasslands and forests. Where both occur within a fire danger region, either both can be given or a method for determining which to use implemented.

7.1.1 Grassland Fire Danger Index

This is calculated using the McArthur Mk 4 Grassland Fire Danger Meter (McArthur 1966) which was developed as a circular slide rule by Alan McArthur in the 1960s and published by the Forestry and Timber Bureau (which later (1975) became the CSIRO Division of Forestry).

The algorithmic form of the Grassland Fire Danger Meter employed in ***Amicus*** is that of Noble *et al.* (1980). This was the first formally published retro-engineering of McArthur's meters carried out in consultation with McArthur.

7.1.2 Forest Fire Danger Index

This is calculated using the McArthur Mk 5 Forest Fire Danger Meter (McArthur 1967). As with the Grassland Fire Danger Index, this was also developed by Alan McArthur, published by the Forestry and Timber Bureau in the 1960s.

As with the GFDI, the algorithmic form of the Forest Fire Danger Meter employed in ***Amicus*** is that of Noble *et al.* (1980). This was the first formally published retro-engineering of McArthur's meters carried out in consultation with McArthur.

Both fire danger indices are restricted to a maximum value of 200. Each are represented using the revised National Fire Danger Ratings classifications, which can be customised for those jurisdictions that use modified class boundaries.

7.2 Fire Spread models

The fire spread models implemented in ***Amicus*** are those recommended for use in the major fuel types by Cruz *et al.* (2015*b*) and in the book *A Guide to Rate of Fire Spread Models for Australian Vegetation* (Cruz *et al.* 2015*a*). The input details for each of fire behaviour models used in ***Amicus*** is provided in the `Help|About fire models...` menu item.

7.2.1 Vegetation = "Grassland"

Fuel type = "Continuous open", "Woodlands" and "Open grassy forest (Northern Australia)".

These fuel types use the CSIRO Grassland Fire Spread model (Cheney *et al.* 1998) designed for in fires in continuous open grasslands but which can also be applied to woodlands and open forest with grassy understoreys (predominantly open forests in Northern Australia) (Cheney and Sullivan 2008, Sullivan 2010). 'Continuous open' refers to grasslands with less than 10% tree cover. 'Woodlands' refers to treed vegetation with up to 30% cover and dominant grassy understorey. 'Open grassy forest' refers to treed vegetation up to 70% cover with a tall grassy understorey, common in Northern Australia.

Fuel type = "Spinifex"

Rate of spread and flame height models for this fuel type were developed from 186 experimental fires conducted by Neil Burrows and colleagues from the Western Australian Department Parks and Wildlife (Burrows *et al.* 2018). This rate of spread model replaced an earlier version of the model published in 2009 (Burrows *et al.* 2009) that is used in previous versions of ***Amicus*** ($\leq$v0.6).

Fuel type = "Buttongrass"

This fuel type uses the model of Marsden-Smedley and Catchpole (1995). This fuel type is mainly only present in western Tasmania.

7.2.2 Vegetation = "Native forest"

There are multiple models available for native forest fuel types.

Fuel type = "Dry Eucalypt", Condition = "Wildfire", Model = "Vesta Mk 2"

This model (Cruz *et al.* In Press) is the newest and most comprehensive model for wildfires in eucalypt forests, and is referred to as the Vesta Mk 1 model. The model incorporates the effects of wind speed, fine dead fuel moisture, understorey fuel structure, long term landscape dryness and slope steepness and has three different phases that are used in different burning conditions. Detailed instructions on the implementation of this model are given in Cruz (2021).

Other papers associated with this model include (Cheney *et al.* 2012) and Gould *et al.* (2011).

Fuel type = "Dry Eucalypt", Condition = "Wildfire", Model = "Vesta Mk 1"

This Dry Eucalypt Forest Fire Model (Cheney *et al.* 2012) is commonly known as the Vesta model, and now referred to as the Vesta Mk 1 model. It utilises the Fuel Hazard Score variant for both Fuel Hazard Score and Fuel Hazard Rating inputs, using the conversion method of Hines *et al.* (2010) to convert Hazard rating to Score.

Other papers associated with this model include Gould *et al.* (2011) and McCaw *et al.* (2012).

Fuel type = "Wet Eucalypt", Condition = "Wildfire", Model = "Vesta Mk 2"

This is the adaptation of the Vesta Mk 2 model (Cruz *et al.* In Press) for wildfires in wet eucalypt forests, using the recommended steps for adaptation in the user guide for this model (Cruz 2021), which include adjustments to the determination of dead fuel moisture content and drought factor (fuel availability).

Fuel type = "Wet Eucalypt", Condition = "Wildfire", Model = "Vesta Mk 1"

This is the adaptation of the Vesta Mk 1 Dry Eucalypt Forest Fire Model (Cheney *et al.* 2012) for wildfires in wet eucalypt forests. It uses wind speed correction factors (i.e. three coefficients that modify the wind speed in the open to that under the canopy) are taken from the Forest Fire Behaviour Tables for Western Australia (Sneeuwjagt and Peet 1985) for Karri forests .

Fuel type = "Dry Eucalypt", Condition = "Prescribed fire"

This fuel type for the condition of prescribed burning uses Alan McArthur's Controlled Burning Guide for Eucalypt forests (McArthur 1962). The equations for the guide are those of Gould (1994) published in Australian Forestry.

Fuel type = "Wet Eucalypt", Condition = "Prescribed fire"

For this fuel type for the condition of prescribed burning, the model for Karri forest from the Forest Fire Behaviour Tables for Western Australia (Sneeuwjagt and Peet 1985), converted to equations by Beck (1995). However, fuel moisture content is predicted using the same FMC model as the

Dry Eucalypt Forest Fire Model, i.e. that of Matthews *et al.* (2010).

Fuel type = "Dry Eucalypt", Optional model

If selected in `Settings|Fire models`, the McArthur (McArthur 1967) Mk 5 Forest Fire Danger Meter spread model may be used for wildfire and prescribed fire conditions. As the model has been shown to under-predict (McCaw *et al.* 2008) an unreliable warning is given (Table 6.1, Fig. 6.8).

7.2.3 Vegetation = "Shrubland"

Fuel type = "Temperate shrubland"

This fuel type refers to closed shrublands, typical of coastal and high rainfall areas. It uses the model of Anderson *et al.* (2015). This model was developed from a combined dataset from a range of different locations and conditions from a large set of authors.

Fuel type = "Semi–arid heath"

The model for this fuel type, a more open type of shrubland, was developed by Cruz *et al.* (2010) from CSIRO in collaboration with others and was published in a Bushfire CRC report.

Fuel type = "Semi–arid mallee-heath"

The model for this fuel type, similar to the semi-arid heath above but with a mallee overstorey, was developed by Cruz *et al.* (2013) from CSIRO in collaboration with others and was published in the Environmental Modelling and Software journal.

7.2.4 Vegetation = "Plantations"

Fuel type = "Radiata pine" (Wildfire only)

The model for this fuel type is that of Cruz *et al.* (2008) and implements specific fuel models for the US BEHAVE system (Andrews 1986, 2014) for seven stages of development of radiata pine plantation, which can be edited, and specific crown fire spread models developed in Canada. Unlike the other models used in ***Amicus***, this model is iterative and more time is required to calculate it's outputs. A progress bar at the bottom of the ***Amicus*** window indicates the remaining time required to undertake the fire behaviour calculations for the weather stream. This model outputs a column called `Fire type`, which is the type of fire in terms of crowning activity. This can be either "surface fire", "passive crown fire" or "active crown fire".

Fuel type = "Maritime pine" (Wildfire only)

The model for this fuel type uses the same model as for radiata pine but with a specific set of default fuel parameters for a mature maritime pine plantation.

`Note that slope only affects the Radiata pine and Maritime pine models when fire type is in the surface phase.`

Fuel type = "Short rotation eucalypt" (Wildfire only)

At this time there are no formal models specifically for fire spread in short-rotation eucalypt plantations such as blue gum. Because the structure of the fuel layers that carry fire changes as the plantation ages from planting through to maturation, the choice of applicable fire spread model to be employed depends on the age and productivity of the plantation. In ***Amicus*** if the plantation is relatively young and the ground cover is dominated by grass then the CSIRO Grassland Fire Spread model of (Cheney *et al.* 1998) is used (with a user-defined wind correction factor). If the plantation is more well established with a dominate litter ground cover (usually an indication of canopy closure) then the Dry Eucalypt Forest Fire Model (Cheney et al. 2012) is be used. At this time no specific model for prescribed burning is available.

7.3 Other fire behaviour metrics

The four primary metrics of fire behaviour calculated in ***Amicus*** are rate of spread, flame height, maximum spotting distance and fireline intensity. Models for rate of fire spread are given in the preceding section. More details on inputs for these metrics are provided in the `Help|About fire models...` menu item.

7.3.1 Fireline intensity

Fireline intensity is calculated using Byram's equation (Byram 1959) which requires the estimate of rate of forward spread, the amount of fuel consumed (generally assumed to be the available fuel load) and an estimate of the heat yield of the fuel. In the current version of ***Amicus***, this value is set as 16500 kJ/kg for grass fuels and temperate shrubland, 18300 kJ/kg for buttongrass, 18600 kJ/kg for native and plantation forests, and 18700 kJ/kg for semi-arid heath and semi-arid mallee-heath shrublands.

7.3.2 Flame height

Flame height and maximum spotting distance are only given where an appropriate model exists. Where a model does not exist, the output box is greyed out. In all cases where a flame height prediction is given, this is an ancillary model published with the rate of spread model, so please refer to the reference for the rate of spread model for the particular fuel type list in the previous section.

7.3.3 Maximum spotting distance

Maximum spotting distance is only presented for dry eucalypt fuels in wildfire conditions. The maximum spotting distance model published in the interim Dry Eucalypt Forest Fire Model field guide Gould *et al.* (2007). This model only considers the maximum distance lofted firebrands (firebrands entrained within the plume) will travel and be able to initiate a spotfire. Short distance spotting from embers that are not lofted (i.e., they are blown directly ahead of the fire front without being lofted) will nearly always happen in dry eucalypt forest (and many other fuel types) under wildfire conditions and are often incorporated into the rate of forward spread calculation. This maximum spotting distance will only generate numbers if certain conditions are satisfied. If the wind is too strong for a given fire intensity, then the output will be '*NL*' or no lofting, meaning that the convection column will not be formed enough to loft firebrands. If the intensity of the fire is too strong for the prevailing winds, then the output will be '*NVE*' or no viable embers, meaning that lofting will occur but the updraughts in the convection column will be so strong that embers will burn out before they hit the ground and be unable to start a spot fire.

7.3.4 Length to breadth ratio and flank rate of spread

Length to breadth ratio and flank rate of spread are calculated assuming elliptical fire shapes for all continuous fuel types (i.e. all fuel types other than spinifex, semi-arid heath and semi-arid mallee-heath). The length to breadth ratio for fires in grassland and heathland vegetation is determined using (Cheney 1981) model based on McArthur's (1966) figure, while the model for forest and plantation vegetation types is based on the table presented in the Field guide to the Canadian Forest Fire Behavior Prediction System (Taylor *et al.* 1997). These are both functions of wind speed with higher wind speeds resulting in higher length to breadth ratio's (narrower fires). Flank rate of spread is calculated using the length to breadth ratio and the forward rate of spread.

The calculation of length to breadth ratio requires the assumption that the fire is a point origin, on flat ground, with a consistent wind direction and fuel type. As a result of these assumptions the length to breadth ratio and flank rate of spread estimates always have warnings associated with them in the fire behaviour output table.

7.3.5 Incorporation of slope effects

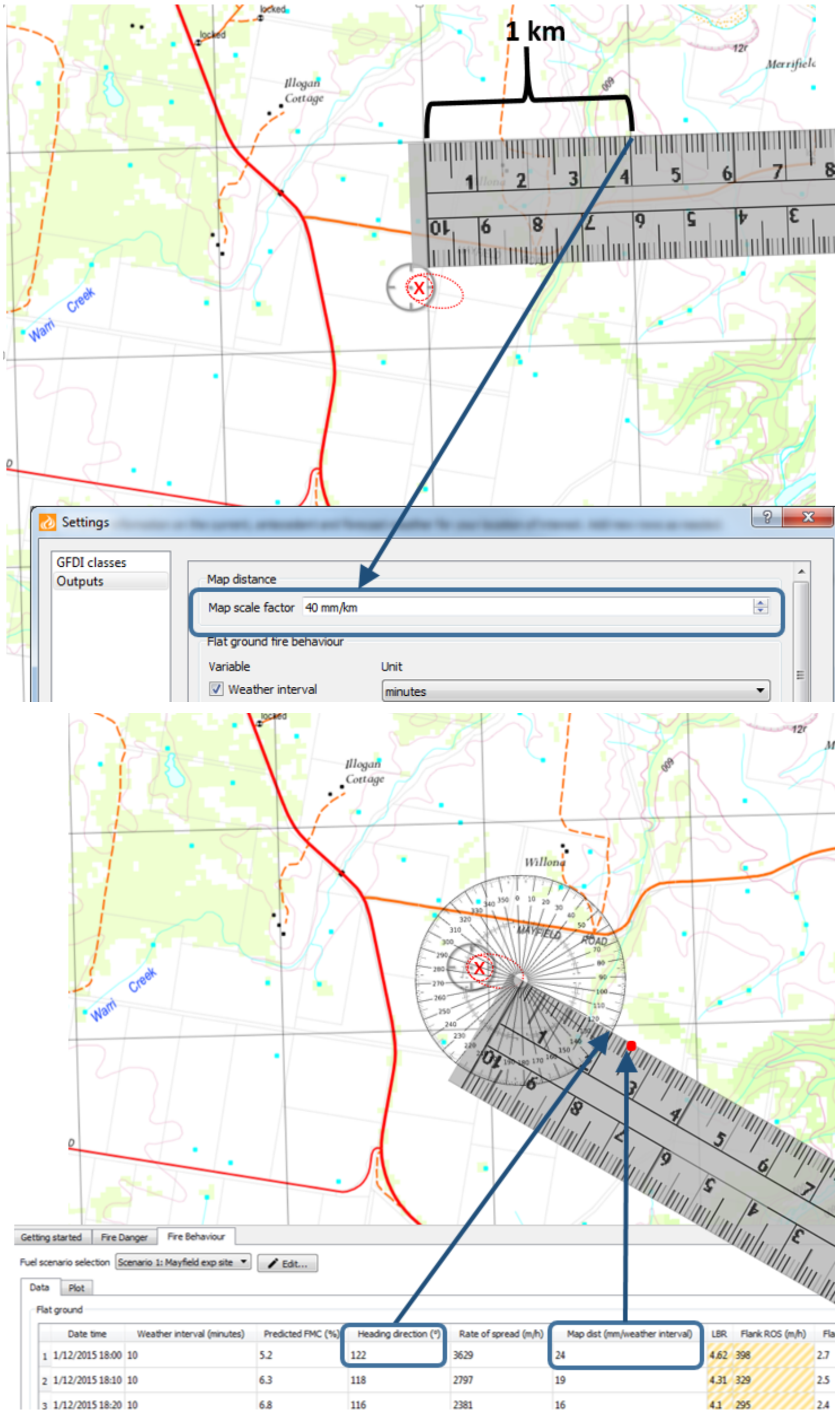
Within ***Amicus***, slope is used to modify head-fire rate of spread calculations for all fuel types, other than the Radiata and Maritime pine when they are in crowning state. This is done using Noble et al.'s (1980) equation for McArthur's (1967) slope function for positive (windward) slopes or the Kataburn function (Sullivan *et al.* 2014) for negative (leeward) slopes.

Predictions for fire behaviour on slopes are presented in both the fire behaviour output tables and the fire behaviour plots. A specific output table is provided on the `Fire behaviour|Data` tab (See section 6.1). The fire behaviour output table for slopes (Fig. 6.3b) shows rates of spread for flat ground (0°, column with black heading text), selected slopes (-30 $\rightarrow$ +30°, columns with blue heading text) and user-entered slopes (column with pink heading text). All of the items in the `slope` output table can be selected to be visible or not in the `Settings` dialog (Fig. 6.4). Only the user-entered slope column is affected by the aspect provided in the `Location` panel (Fig. 4.6. As a result the relative slope used for the calculation of rate of spread in this column changes with wind direction, so predictions may seem counter intuitive when the aspect is opposed to the wind direction. The other columns in this table assume alignment with the wind direction.

7.3.6 Map distances

Amicus provides a specific rate of spread output for plotting fire spread on maps by hand. The `Map dist(m)` column in the fire behaviour output table provides a rate of spread value that has been scaled according to the `Map scale factor` set in `Settings|Output units` (Fig. 6.4). This is intended to provide a direct map-specific distance of spread for each weather period or hour.

`Map scale factor` is set by measuring how long a kilometre is on your map (Fig. 7.1a). This can be changed if plotting on another map with a different scale. The `map distance` option on the `Settings|Output units` can be expressed in mm/hour or in mm/time interval. The outputs will be the same if the weather interval is hourly. Once the `Map scale factor` has been set the `map distance` and `heading direction` can easily be used to begin plotting a fire progression map (Fig. 7.1b).



a)

b)

Figure 7.1. a) Determining and entering the map scale factor (in mm/km). b) Hand plotting the map distance rate of spread onto a fire spread map using the Fire behaviour output table and a protractor and ruler.

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