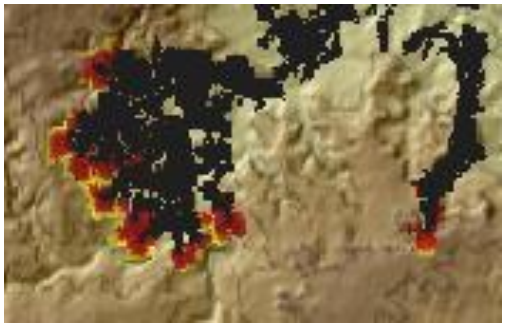
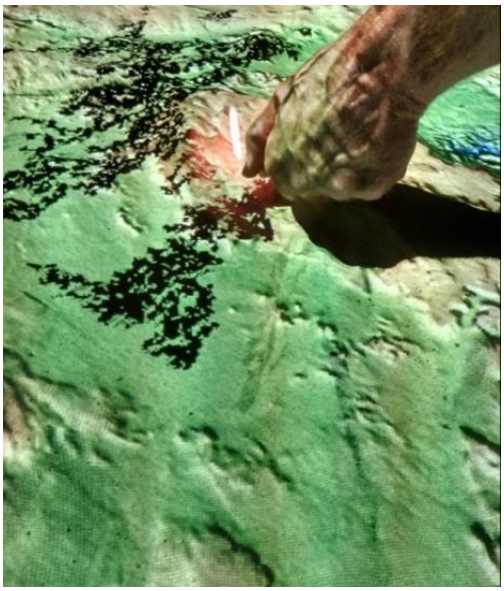
Understanding fire behaviour in tropical savannas “Incendiary” simulation models.

Dhimurru “Incendiary” fire models Rohan.Fisher@cdu.edu.au May 2017

1. Introduction





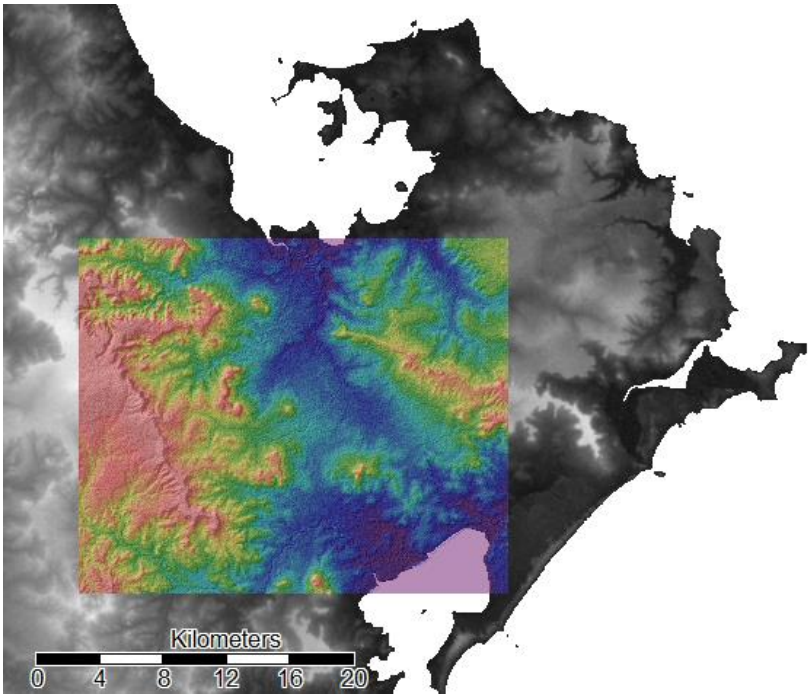
The way in which fires move through country can be very complex and hard to predict particularly when they burn for many days over large areas, as is common in the tropical savannas of northern Australia. Described in this document is a fire spread geo-simulation tool designed to help explore some of the environmental variables that affect the spread of savanna fires.

How fire moves and where and when it stops is determined by the amount of fuel available, how dry the fuel is and current weather conditions. Most fires in northern Australia are grass fires; the amount of fuel available is primarily a function of what type of grass is on the ground and the time since it was last burnt. Using satellite data, which shows when an area was last burnt, combined with grass vegetation maps, we can estimate how much fuel there is in a landsacape. Using this fuel estimation togeather with other spatial terrain data a simulation game or model has been created to allow us to ‘play’ with and explore how fire might spread through the landscape.

The primary purpose of the model is to show how a range of variables effect fire spread when conducting fire management burns early in the dry season and how these fuel reduction fires are likely to affect the spread of late season wild fires. The model is **not** attempting to predict fire spread but rather provide a useful teaching and planning tool when thinking about fire management operations in Northern Australia. For this participatory planning activities and the models can be displayed as a projection onto sand that is shaped to fit the terrain. Creating a 3D terrain surface to run the model over helps us think about the topographic and vegetation effects on fire.

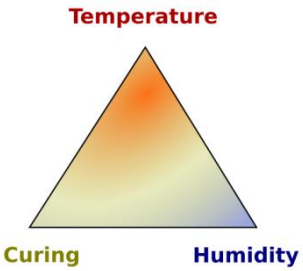
Model location.

One model has been produced for the Dhimurru IPA as shown in the coloured region below.



2. Model parameters

2.1 Fire Danger



In this model the **fire danger** variable simulates the combined effects of **curing**, **temperature** and **humidity** on fire ignition and spread likelihood.

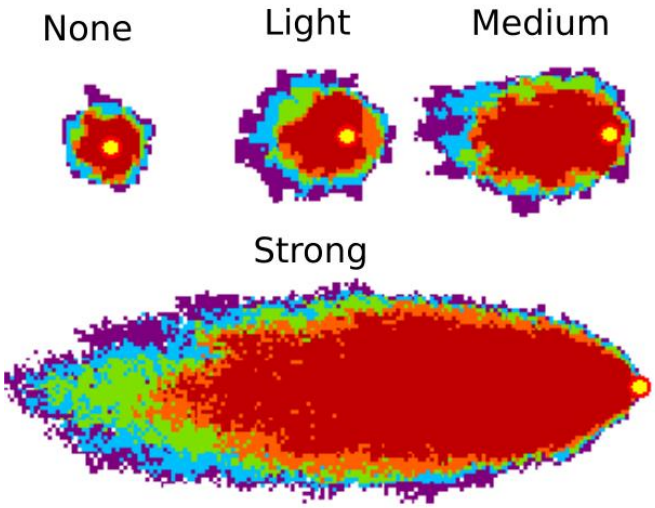
As a model parameter the fire danger is set as a number from one to ten that conceptually relates to fire danger levels and Yolngu seasons as shown here:

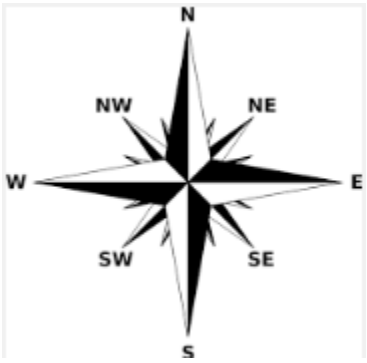
- 1-3 is Low (Barraˈmirria mayaltha)
- 4-5 is Medium (Midwarr)
- 6-7 is High (Dharratharra)
- 8 is Very High (Rarranhdharr)
- 9-10 is Extreme (Dhuludur)

Source: www.wairoadc.govt.nz/wairoa/index.htm

2.2 Wind speed and wind direction.

Wind speed plays a significant role in fire spread effecting both rate and direction of spread. Within the model wind can be set to none, light, medium or strong. The influence of wind speed of fire spread direction and rate is illustrated below with easterly at a range of speed setting:





Wind direction can be set to one of the eight cardinal and inter-cardinal directions:

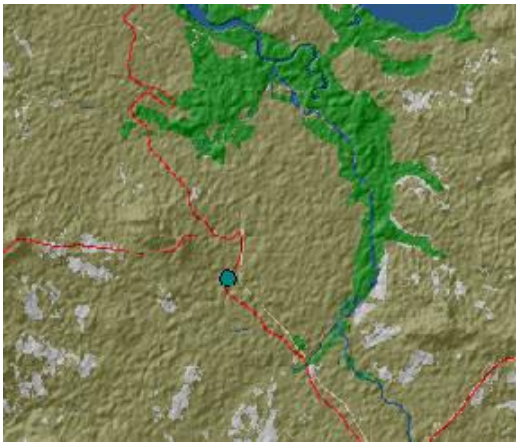
Common wind direction related to Yolgnu season:

NW: Barra'mirria mayaltha
E-SE: Midwarr
S-SE: Dharratharra
SE-NE: Rarranhdharr
N-NW: Dhuludur

Vegetation 2.3

For the Dhimurru model the model area has been classified into four main land cover types:

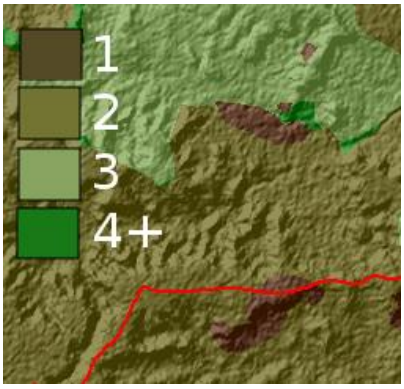
- Grass - olive
- Low cover (Sandy) areas - Grey
- Mangroves - Green
- Roads - Red



Roads and Mangroves will not burn. Grass will burn more easily than low cover and flamability increases with times since last fire as described following.

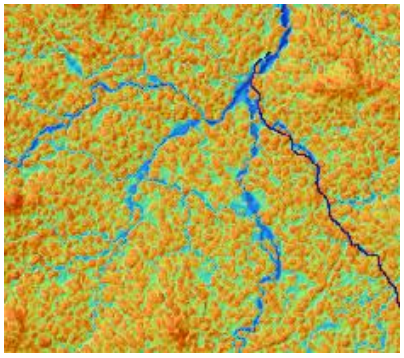
2.3 Fuel Loads

When assessing how a fire will spread it is helpful to understand the time since an area was last burnt in to estimate fuel loads. In the model it is possible to view a map layer that shows the time since last burnt and grass type. The map shows when an area was last burnt; from last year (1) through to four, or greater, years ago (4+).

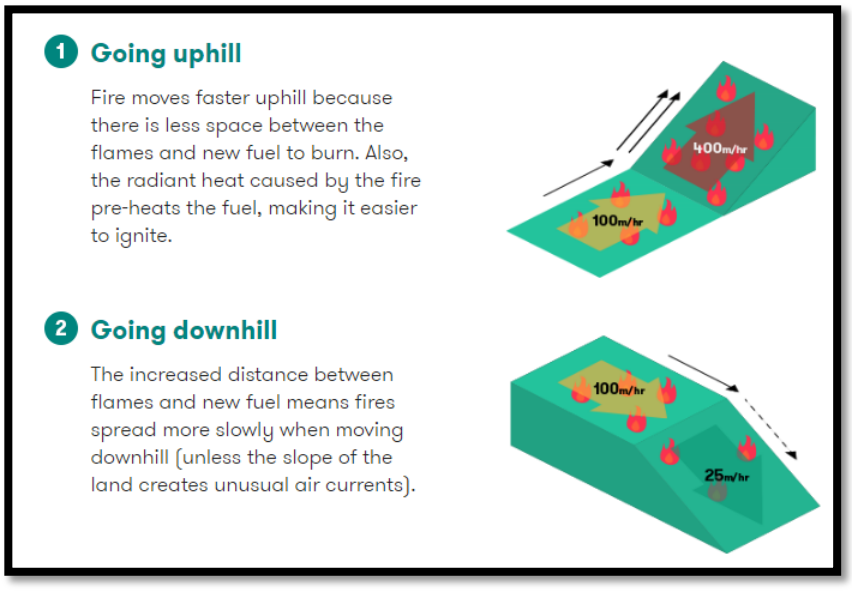


2.4 Topographic wetness

Different parts of the landscape will remain wet for longer than others. In the model this is represented as a **topographic wetness** layer. Viewing this layer might help determine where a fire will be pulled up.

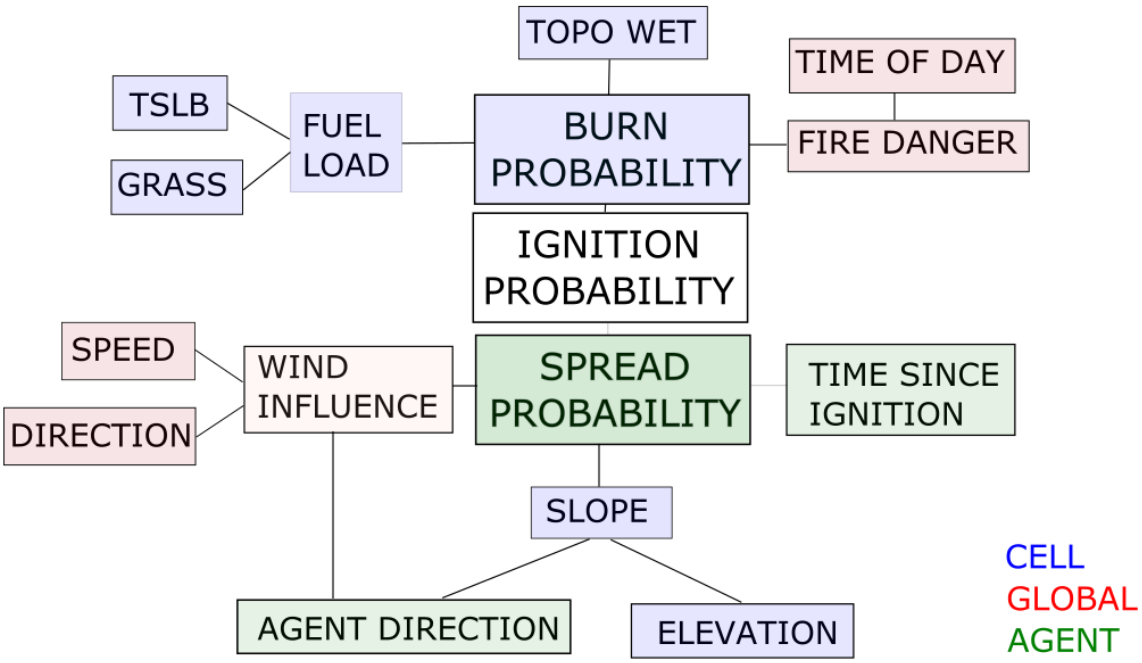


2.5 Slope affects the spread of fire, increasing ignition probability and speed up hill and decreasing it going down slope. Slope is determined by direction of the wind and location of the fire.



3. How these variables interact

The schematic diagram below shows how all these variable interact to determine how and when a fire spreads.



Three additional factors important for fire spread, as shown in the diagram above, are time of day, time since ignition and slope.

Time of day significantly effects temperature, humidity and wind speed. To simulate this within the model after a set period of time the model will switches between time of day setting which effects **fire danger** (reflecting changes in temperature and humidity) and in some cases wind speed as shown here:

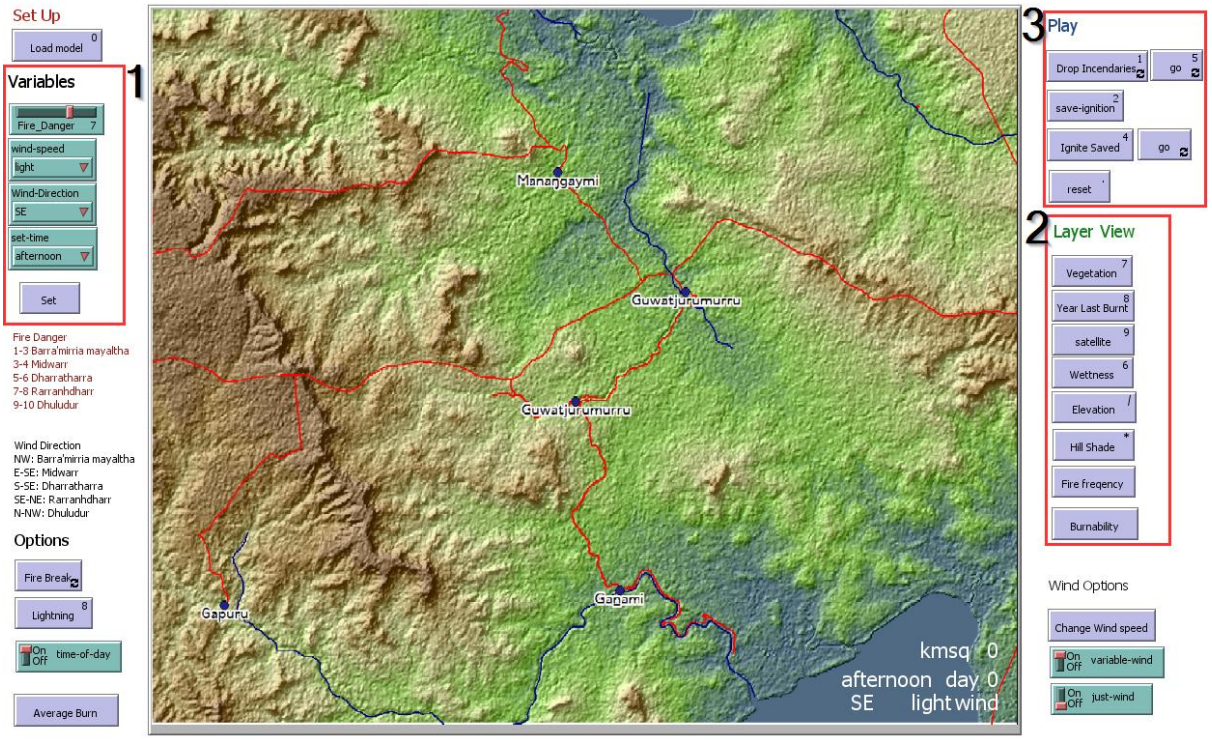
- **Morning** (Fire Danger is reduced by 1)
- **Noon**
- **Afternoon** (Fire danger is increased by 1)
- **Early Evening** (Wind speed reduced by one increment)
- **Late evening – Early morning** (Wind speed reduced by one increment, Fire Danger decreased by 2)

Embers are able to initiate burning for some time after an initial fire front has died down. This is simulated by recording a **time since ignition** for each burnt cell. Each cell remains a live 'ember' for a period after its initial burn with a decreasing probability for 'flare-up' as a function of **time since ignition.**

4. How to run the model

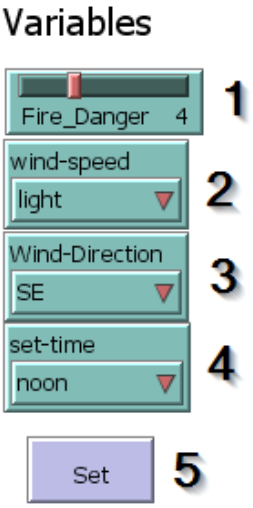
The simulation has been developed in NetLogo, free open source modelling software. https://ccl.northwestern.edu/netlogo/. **To run netlogo download and install NetLogo 6.1 or later.**

Once you have NetLogo running you will need to load **(File>Open)** the fire spread models provided with the training. Once you opened the model you need to **'load'** the model layers by pressing the **"Load Model"** button on the top left of the software window under the 'Set-Up' heading. A map of the model area will then appear as shown below.



The figure above shows the three main model control regions: 1) the fire weather **variable** settings, 2) the **layer view** and 3) **play** region for 'igniting' and running a simulation.

To interact with the model:



In the Variables window areas set the fire weather related variables:

1. Fire danger
2. Wind Speed
3. Wind Direction
4. Time of day to start fire spread
5. Press 'Set' to save these settings before running the model. Note if using saved ignition points the 'ignite saved' button, as described following, automatically uses ('sets') the current variable settings.

Layer View

Has a number of button that allow you to view a number of key landscape fire influencing variables:

1. Vegetation
2. Year Since Last Burnt
3. Topographic curing.
4. Elevation
5. Satellite image
6. Fire frequency

.

Play

Use these controls to 'ignite' areas of the model. To play with the model you need to:

1. Press the '**Drop Incendiaries'** button and draw ignition points across the model with the mouse and cursor.
2. Start the fire spread by pressing the "**Go**" button. It is possible to ignite extra fires as the model runs by if both the '**go'** and '**Drop Incendiaries'** button are both depressed.
3. It is also possible to save a set of ignition points, before pressing '**go'** so they can be tried under different weather conditions using the 'Save-Ignition' button.
4. To ignite saved ignitions use the '**Ignite Saved'** button before pressing '**go'** after altering fire weather condition variables.
5. To clear previous fires and saved ignition points use the '**reset'** button.

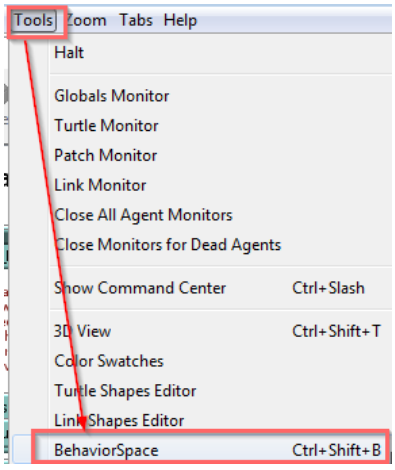
Additional settings

1. **Fire Break:** Allows the drawing of burnt areas (Firebreaks) in the landscape, using the mouse (with mouse button activated).
2. **Lightning:** Ignites a random patch in the landscape.
3. **Time-of-day**: Allows you to turn of time of day related variables.
4. **Average burn** shows all the burns from multiple runs of the model if initiated through the behaviour space function of the model. This is described more below.

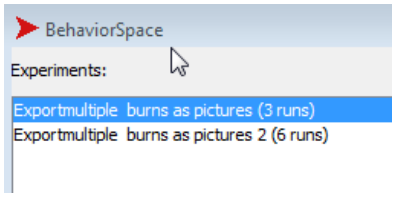
Using the Behaviour Space

The behaviour space function allows you to automatically run the model multiple times with different or the same settings. It is also set up to automatically export pictures of each burn and add burn outcomes from model runs together. This allows us to explore in more detail outcomes from different burn settings.

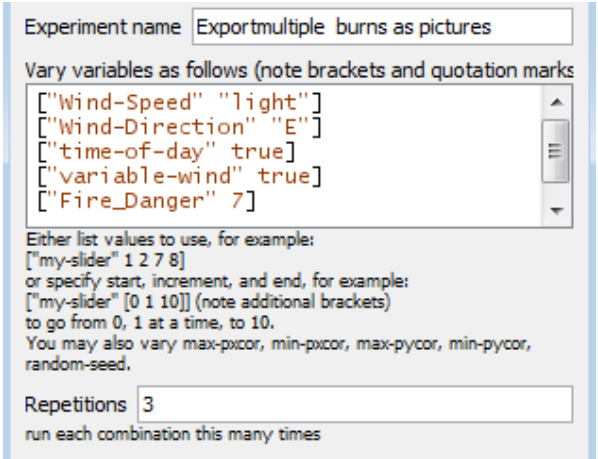
Find the behaviour space function under **Tools>BehaviourSpace**:



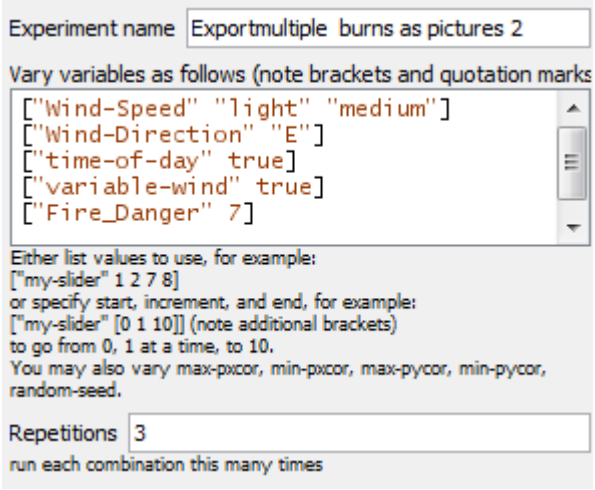
When you open behaviour space you will see a couple of experiment examples. To view the experiment settings double click on one.



If you open the first one you will see the variable settings that will be used for each model run and the number of runs or repetitions. In the case shown the model will run three times based on the set variables.

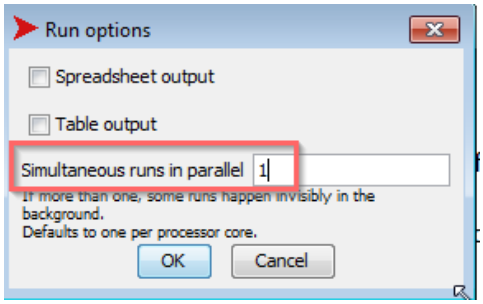


In the second example with have two different wind speed values. In this case the model will run 3 times for each wind speed setting making a total of 6 model repetitions.



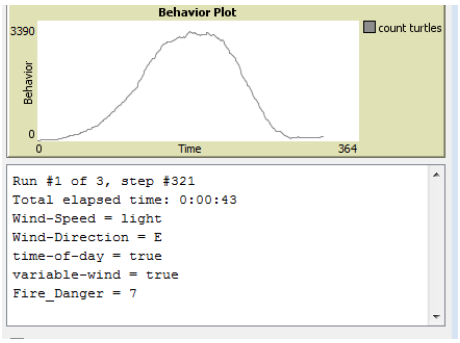
NOTE: To run a model using a Behaviour Space experiment you must first have dropped and saved some ignition points:

When you run a model make sure you set the "Simultaneous Runs in Parallel" setting to 1.



When you click ok the model will automatically start running with a window showing the current run settings and a plot of number of fires over time.

When all the runs are finished the model will stop.



When the experiment has finished running you can view the average burn values. This shows the sum of all the burns in the experiment.

In the example to the left after three runs with the same conditions we can see that most fires burnt a small area and were pulled up by a road whilst one fire got caught by some wind gusts and burnt further. White represents areas burn 3 times and dark red once.

You will also notice in the Behavior Space setting window, in the 'Final Commands area, there is a command to output the final state of each model run as a picture file.

Final commands:

```
save-iter
export-view (word "Output/" iteration ".png")
```

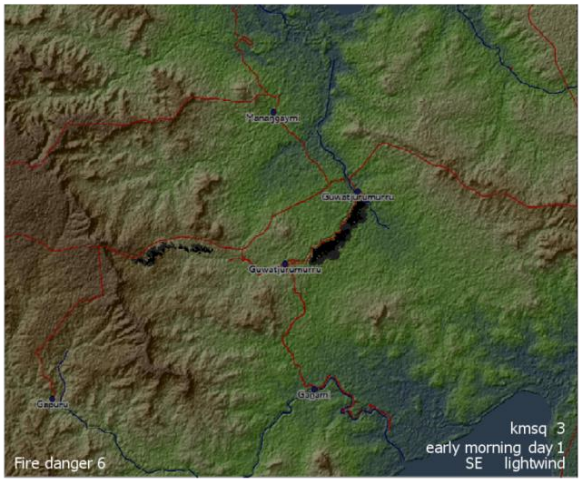
The example on the following page shows the image outputs from six burn scenarios; three fire danger settings with two different wind speeds. This method can be used to quickly visualise and communicate potential outcomes from varying fire weather conditions.

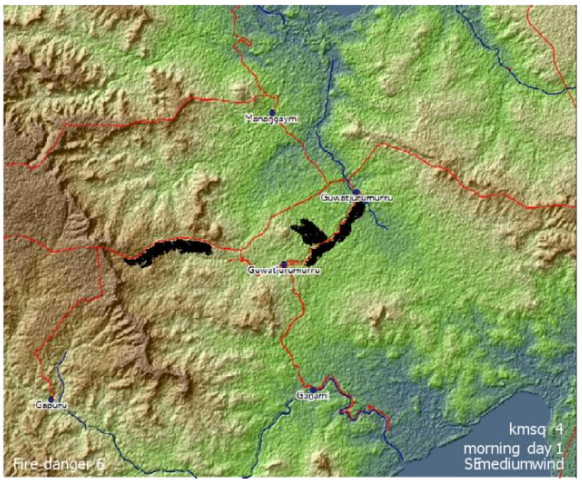
Fire Danger

Light Wind

Medium Wind

6





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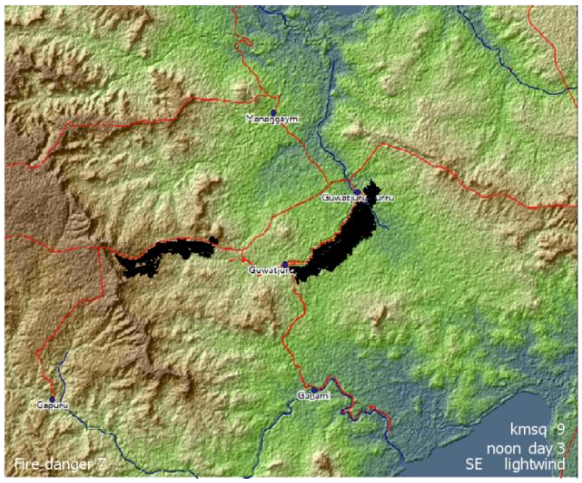

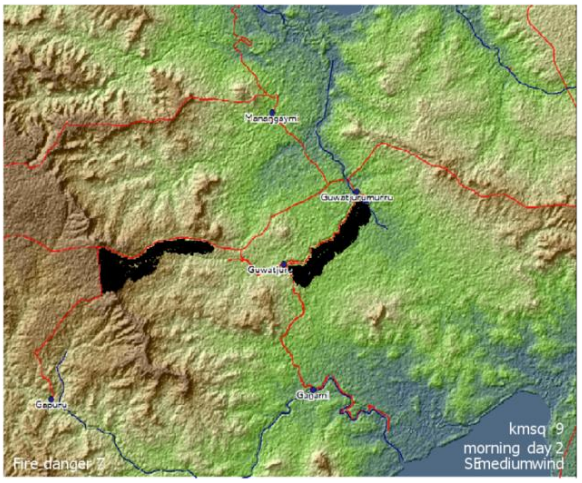

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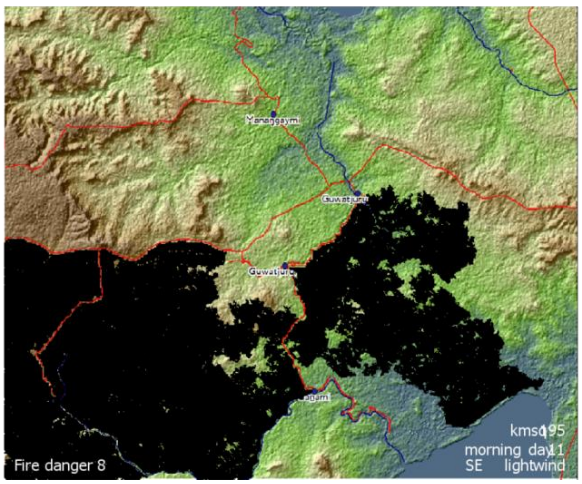

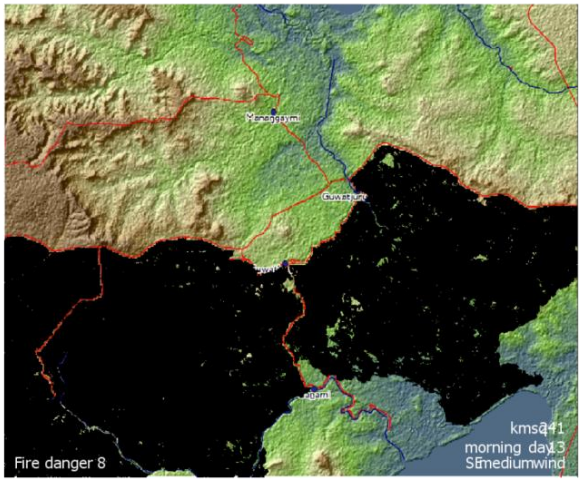

- A video screen shot demonstration of the how to use the model can be found at: **https://rohanfisher.wordpress.com/dhimurru-fire-spread-an-incendary-model/**

- **Additional videos of the model in action can be found here: https://rohanfisher.wordpress.com/incendiary-a-fire-spread-modelling-tool/**

When using the model think about:

- **How can you burn a good fire break considering.**
  - **Where in the landscape**
  - **What time of year (fire danger)**
  - **What sort of break would we require to protect a particular site?**
- **How good are my fire breaks**
  - **What happens there is a late dry season lightning strike?**
- **What might happen if someone isn't careful with their fires late in the dry season?**
- **What happens if a fire jumps into our Acacia plantations?**

- **How difficult it can be to predict what a fire will do.**