Australian Government
Bureau of Meteorology

AFDRS Mallee Heath Model

The AFDRS Mallee Heath Model will be used for semi-arid shrublands with a mallee-form eucalypt canopy and shrubby understorey. Mallee heath covers approximately 3.5% of Australia, is found in WA, SA, NSW and VIC, and has a significant influence in 21 Fire Weather Areas.

What is the AFDRS Mallee heath model?

The model used for mallee heath fuels in AFDRS is the Semi-arid mallee heath model by Cruz et al (2013). It combines data sets from previous research into mallee heath fuels. This model has a go/no-go threshold for fire spread.

Inputs and outputs

This model run three separate processes:

- Determines the likelihood of fire spread
- Determines the likelihood of a crowning fire
- Calculates the outputs (rate of spread, etc.).

These processes require input values for 10m wind speed, moisture content of dead litter fuels, overstorey coverage, and overstorey height. Moisture content is derived from temperature and relative humidity as usual, but also includes terms for precipitation over the previous 48 hours, time since precipitation/dewfall stopped, cloud cover and the time of year/day. The calculation for fuel load (required for intensity calculation) also needs the steady state fuel loads and fuel accumulation rates for the surface and the overstorey, as well as time since fire (TSF). This is summarised in the flow diagram on the right, with the following legend:

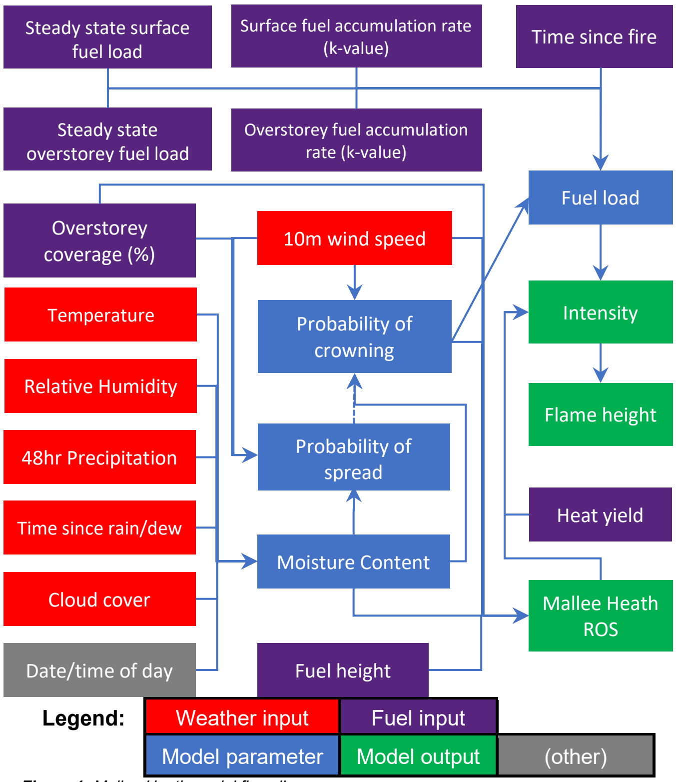

Figure 1: Mallee Heath model flow diagram

Model equations

Moisture content, MC, appears in all of the equations this model uses to generate the rate of spread output. It is calculated using:

$$MC = MC_1 + MC_2$$

MC_1 is the Moisture Content calculation from the original research paper:

$$MC_1 = 4.79 + (0.173 - 0.027\Delta)RH - 0.1(T - 25)$$

Where RH is relative humidity (%), T is temperature (°C), and Δ is 1 for sunny days from 12-5pm during October to March and otherwise 0.

AFDRS also applies a fuel moisture modifier, MC_2, based on recent rainfall similar to that which is applied to buttongrass:

$$MC_2 = 67.128(1 - e^{-3.132r_{48}})e^{-0.0858t_r}$$

Where r_{48} is the precipitation in the last 48 hours (mm), and t_r is the time (hours) since rainfall or dewfall stopped.

The probability of fire spread, P_{spread}, is calculated:

$$P_{spread} = (1 + e^{-A})^{-1}$$

where A is calculated from the 10m wind speed, U_{10}, moisture content, MC, and overstorey coverage (%), Cov_0:

$$A = 14.624 + 0.2066U_{10} - 1.8719MC - 0.30442Cov_0$$

If $P_{spread} < 0.5$, no significant fire spread is expected. If $P_{spread} \geq 0.5$, fire spread is likely, and the model will calculate the likelihood of a crowning fire:

$$P_{crown} = (1 + e^{-B})^{-1}$$

where $B = -11.138 + 1.4054U_{10} - 3.4217MC$.

If $P_{crown} \leq 0.01$ no crowning is expected and for overstorey height, H_0, the rate of spread of the surface fire (in m/hr) is given by:

$$ROS_{surface} = 200.22\ U_{10}\ e^{-0.1284MC}\ H_0^{-0.7073}$$

If $P_{crown} > 0.99$ crowning is likely and the rate of spread of the crown fire is given by:

$$ROS_{crown} = 574.506\ U_{10}\ e^{-0.1795MC} \left(\frac{Cov_0}{100}\right)^{0.3589}$$

If $0.01 < P_{crown} \leq 0.99$, the fire will propagate as a combination of surface and crowning fires and the rate of spread is a weighted combination of the two ROS equations above:

$$ROS_{Mallee} = (1 - P_{crown})ROS_{surface} + P_{crown}ROS_{crown}$$

A similar weighted combination is also used to get the fuel load estimations for fireline intensity calculations:

$$FuelLoad_{surface} = FL_s(1 - e^{-k_s t})$$

$$FuelLoad_{crown} = FL_s(1 - e^{-k_s t}) + FL_o(1 - e^{-k_o t})$$

where k_s and k_o are the fuel accumulation rates for the surface and overstorey respectively, the values for which can be found in the fuel table in Chapter 4 of the NFDRS report.

As with the other fuels, fireline intensity, I_B, uses Byram's (1959) equation:

$$I_B = h \times w \times ROS$$

Where h is the heat yield, assumed to be 18,600 kJ/kg, and w is the fuel load available for combustion (chosen based on Surface load + crown load weighted by crown probability) converted to kg/m^2.

Flame height (in m) is then calculated using:

$$F_{height} = e^{-4.142} I_B^{\ 0.633}$$

Model behaviour and limitations

This model is directly applicable to prescribed burn operations (this is what it was developed for), but it is also considered suitable for first-order approximations of wildfire behaviour.

The original model assumes the fuels are dry and does not account for recent rainfall. For AFDRS, a moisture content modifier was added to account for recent rainfall and the subsequent progressive drying of fuels. Mallee Heath fuels are expected to become flammable more rapidly than forests, so the moisture modifier function originally developed for buttongrass fuels was chosen as it has a response time of 1-2 days.

The model uses generalised mallee heights and coverage as indicators for overall fuel state (to make the model easier to run), but this does not account for variation in the understorey fuel characteristics.

This model is most sensitive to wind speed and less sensitive to fuel condition and dead fuel moisture content. Wind is necessary to sustain fire propagation for fuel moisture contents of 6% or higher.

Note that the descriptions of mallee heath, spinifex woodland and acacia woodland fuels are very similar; the NFDRS report notes that the classifications of these semi-arid vegetation types could use more careful review.

Fuel sub-types

This fuel type does not have defined sub-fuels. Semi-arid woodlands and shrublands with similar structure, such as mallee, acacia, and casuarina woodlands or shrublands, have been grouped into this fuel type. This type of fuel consists of fine materials less than 6mm in diameter which becomes flammable quicker than forest type fuels. Vegetation classified as mallee that has a spinifex understorey has been classified to the spinifex woodland fuel sub-type as spinifex is the dominant influence on fire spread in that vegetation

Figure 2: *Mallee Heath, image courtesy of AFDRS project*

Figure 3: *Mallee Heath, Kangaroo Island example, image courtesy of AFDRS project*

Figure 4: *Mallee Heath, arid example, image courtesy of AFDRS project*

Original research paper: Cruz, M.G., McCaw, W.L., Anderson, W.R., Gould, J.S., 2013. Fire behaviour modelling in semi-arid mallee-heath shrublands of southern Australia. Environmental Modelling & Software 40, 21-34.

FIND OUT MORE

For more information about the Buttongrass Model, contact the **Fire Weather, Heatwave and Air Quality Environmental Prediction Services Team** at **fireweather@bom.gov.au**.