Australian Government
Bureau of Meteorology

AFDRS Grassland Model

The AFDRS Grassland Model is used for a variety of grassland fuels, including continuous and tussock grasslands, pasture, grassy crops, and gamba grass. Grassland fuels are widespread across Australia, dominating 46% of all FWAs and having a significant influence in 76% of FWAs.

What is the AFDRS Grassland Model?

The model used for grasslands in AFDRS is the CSIRO Grassland Fire Spread Meter, described in two key research papers: Cheyney et al (1998) and Cruz et al (2015). The researchers aimed to better capture the wind and fuel load effect compared to the McArthur meter. This model was developed using 121 experimental fires at Annaburroo Station in the NT in 1986 and using case studies of wildfires.

Inputs and outputs

As with the McArthur grassland meter, this model requires inputs of curing, temperature, relative humidity, and wind speed. The fuel state was also incorporated into this model to better capture the influence of differing fuel characteristics on the observed rate of spread in grass fires. This is a simple model and outputs Rate of Spread (ROS) and flame height.

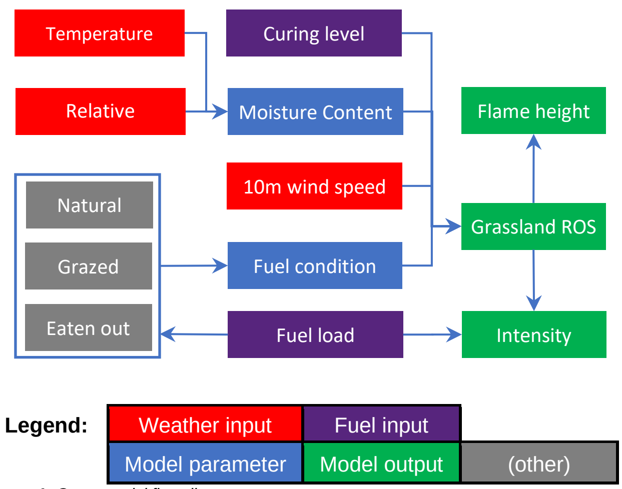

Figure 1: *Grass model flow diagram*

Model equations

First, fuel condition is obtained from the grass condition layer input by the agencies, w (in t/ha). If not available the following defualts are used:

$$\text{Fuel Condition} = \begin{cases} \text{natural} & \text{for } w \geq 6 \\ \text{grazed} & \text{for } 3 < w < 6 \\ \text{eaten out} & \text{for } w \leq 3 \end{cases}$$

Next, dead fuel moisture content (MC) is determined from the air temperature and relative humidity:

$$MC = 9.58 - 0.205T + 0.138RH$$

The Rate of Spread, in m/hr, is given by:

$$ROS_{grass} = \begin{cases} (54 + AU_{10})\Phi_{MC}\Phi_{Curing} & \text{for } U_{10} < 5\ km/h \\ (B + C(U_{10} - 5)^{0.844})\Phi_{MC}\Phi_{Curing} & \text{for } U_{10} \geq 5\ km/h \end{cases}$$

Where U_{10} is the 10 metre winds speed, A, B and C are constants set by the fuel condition, and Φ_{MC} and Φ_{Curing} are the moisture content and curing coefficients, respectively, given by:

$$\Phi_{MC} = \begin{cases} e^{-0.108 \times MC} & \text{for } MC < 12\% \\ 0.684 - 0.0342MC & \text{for } MC \geq 12\% \text{ and } U_{10} \leq 10\ km/h \\ 0.547 - 0.228MC & \text{for } MC \geq 12\% \text{ and } U_{10} > 10\ km/h \end{cases}$$

$$\Phi_{Curing} = \frac{1.036}{1 + 103.989e^{-0.0996(Curing - 20)}}$$

$$A = \begin{cases} 269 & \text{for Natural grasslands} \\ 209 & \text{for Grazed \& Eaten Out grassland} \end{cases}$$

$$B = \begin{cases} 1400 & \text{for Natural grasslands} \\ 1100 & \text{for Grazed grassland} \\ 550 & \text{for Eaten Out grassland} \end{cases}$$

$$C = \begin{cases} 838 & \text{for Natural grasslands} \\ 715 & \text{for Grazed grassland} \\ 357 & \text{for Eaten Out grassland} \end{cases}$$

Note that the curing coefficient equation is taken from the 2015 research paper, not the original 1998 paper.

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 the fuel load, w, is first converted to kg/m^2.

Flame height is then calculated using:

$$F_{height} = D\left(\frac{ROS}{3600}\right)^{0.295}$$

Where D is 2.66 for natural grasslands and 1.12 for grazed and eaten out grasslands.

Model behaviour and limitations

This is generally a well-balanced model and not overly sensitive to the inputs, though wind and dead fuel moisture content generally have the greatest influence. There are, however, a few things to note:

- Accurate assessment of fuel condition in all areas is difficult; "grazed" is used as default in absence of observed/known condition. Additionally, AFDRS assumes a standard correlation between fuel load and fuel condition, rather than a direct observation of fuel conditions in an area.
- Choice of fuel condition has a large impact on model output, except in extreme burning conditions where ROS similar for all 3 conditions.
- The original model was developed for natural and grazed fuels. The eaten-out condition was added later and was assumed to halve the ROS of grazed fuels for wind speeds over 5km/h. It likely overestimates ROS in mild weather conditions.
- If curing is < 20%, fires will self-extinguish.
- Curing generally has less of an influence as the dry season/summer progresses; for southern Australia grasses tend to be fully cured by the end of January so this input effectively becomes a constant.
- The influence of wind follows an almost linear effect, with a critical threshold of 5km/h.
- The fuel moisture content follows an exponential decay when dead fuel moisture content, MC, is < 12%, and linear decay otherwise (i.e. MC > 12%).
- If MC > 20%, no fire propagation will occur.
- When MC > 5%, the CSIRO grassland fire spread model tends to predict faster rates of fire spread compared to the McArthur meters for wind speeds up to 50-60 km/h, after which McArthur meters yield faster fire spread rates.
- For MC<5%, this wind speed threshold lowers; McArthur meters will predict faster rates of fire spread at wind speeds above 30-40 km/h.

Fuel sub-types

There are six sub-fuels defined in AFDRS that use the grassland model, with Gamba grass having been added as a separate sub-fuel after the completion of the NFDRS report. These sub-fuels are:

- Grass
- Pasture
- Crop
- Low wetland
- Chenopod shrubland
- Gamba grass

Grass

Grass includes continuous and tussock grasslands. This is the fuel that this model was specifically developed for, so it does not have additional variation applied as a sub-fuel.

Figure 2: *Left: Ungrazed grassland, southern Australia. Right: Grassland, dominated by Mitchell grass. From a hierarchical classification of wildland fire fuels for Australian vegetation types, Cruz et al. 2015*

Pasture

Modified or native pasture where the primary land use is grazing. The fuel availability will vary depending on the land management approach used. This sub-fuel does not have a specific variation set for AFDRS (fuel condition is set by reported fuel load).

Figure 3: *Typical grazed grassland found in southern Australia.. From a hierarchical classification of wildland fire fuels for Australian vegetation types, Cruz et al. 2015*

Crop

Non-irrigated grassy cropping land; for crops such as cereals, hay, sugar, etc. Currently, crop and pasture fuels are treated the same in AFDRS but are being kept separate in the fuel classification to allow for future improvements. Fuel availability varies with land management approach. This sub-fuel does not have a specific variation set for AFDRS (fuel condition is set by reported fuel load).

Figure 4: *Fuel profile in 2-year old sugarcane plantation in Northern NSW. From a hierarchical classification of wildland fire fuels for Australian vegetation types, Cruz et al. 2015*

Low wetland

Wetland with low or no overstorey; for example, low swamp heath, sedgeland, and rushland. Fuel availability is limited by moisture content in this sub-type. Drought and lowering of the water table will increase the flammability of this fuel. This sub-fuel has no influence on setting FDRs and only covers 0.6% of Australia.

Both the buttongrass and grassland models were considered for this sub-fuel. Buttongrass is most suitable for coastal swamps where there is flammable material above inundated ground, however the substantial majority of the low wetland fuel type is inland floodplain wetlands where fire is most likely to be associated with ephemeral grass growth, so the grassland model with the eaten out fuel condition was chosen.

Figure 5: *Flammable wetland dominated by herbaceous species. From a hierarchical classification of wildland fire fuels for Australian vegetation types, Cruz et al. 2015*

Chenopod shrubland

Low arid shrublands dominated by chenopod (saltbush) species or similar non-arid vegetation with samphire species. This fuel covers approximately 22% of SA and dominates 1 FWA in each of SA and WA. These fuels do not have a suitable fire behaviour model, however there is limited flammability in these fuels except when there is a high cover of ephemeral grasses, so the grassland model is used with the eaten out fuel condition chosen to try and minimise overprediction of fire behaviour.

Gamba grass

A highly invasive introduced species that grows to 4m tall and produces very high fuel loads. Mainly found in the tropics, especially in the NT between Katherine and Darwin. Note that the fuel loads and fuel height of this sub-type are outside the original range of application for the grassland model. The fuel condition is always set to natural with this sub-fuel.

Original research paper: Cheyney, N.P., Gould J.S., Catchpole, W.R., 1998. Prediction of Fire Spread in Grasslands. International Journal of Wildland Fire 8, 1-13.

FIND OUT MORE

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