Australian Government
Bureau of Meteorology

AFDRS Grassy Woodland Model

The AFDRS Grassy Woodland Model, originally called the Savanna Model, will be used for the tropical savanna woodlands of northern Australia and other structurally similar vegetation throughout the country. This fuel covers the greatest area of Australia out of the eight fuel types, though it affects less Fire Weather Areas than grass It dominates in 20% of FWAs and influences 51%. Grassy woodlands are most common in QLD and NT, covering just over 40% of these regions.

What is the AFDRS Grassy Woodland Model?

This model is an extension of the CSIRO Grassland Model. In woodland-like vegetations (grass with a sparse overstorey of trees) the tree overstorey reduces the wind speed near the ground and therefore the rate of spread of fire through the surface and near-surface fuels. This model can be considered a rule-of-thumb model as it applies the grassland model with an estimated reduction to the rate of spread.

This model maintains the three fuel conditions from the grassland model: natural (also called undisturbed), cut/grazed, and eaten out. The model will use the reported grass condition layer input from agency observations. If no inputs are given, or for some of the fuel sub-types, a default value of fuel condition is used (see sub-types below). The default for grassy woodland is natural.

Inputs and outputs

As with the grassland model, the grassy woodland requires inputs of curing, temperature, relative humidity, wind speed and fuel state. This is a simple model and outputs Rate of Spread (ROS), fireline intensity, and flame height. This model also requires an overstorey height to determine the rate of spread reduction factor (wind speed reduction factor):

Vegetation type	Overstorey height	ROS reduction factor	10m : 2m wind speed ratio
Grassland	-	1	10 : 8
Grassy woodland	5 – 7m	0.5	10 : 6
Grassy open forest	10 – 15m	0.3	10 : 4.2

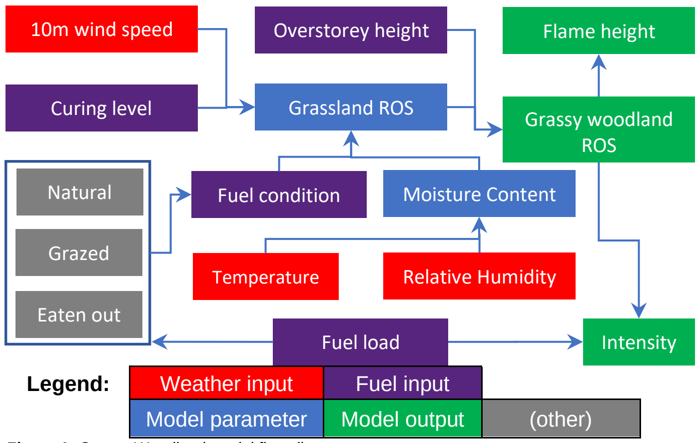

Figure 1: Grassy Woodland model flow diagram

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 defaults are used:

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

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

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

To determine Rate of Spread for grass we first need to define a moisture content coefficient and a curing coefficient, Φ_{MC} and Φ_{Curing}, respectively. These are given by:

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

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

Where U_{10} is the 10-metre wind speed

The Grassland fire Rate of Spread is then 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 A, B & C are constants set by the fuel condition.

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

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

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

We then apply a reduction to the grassland ROS based on the overstorey type:

$$ROS_{grassy\ woodland} = \begin{cases} 0.5 \times ROS_{grass} & \text{for grassy woodland} \\ 0.3 \times ROS_{grass} & \text{for grassy open forest} \end{cases}$$

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.

As the grassland model calculates a flame height, we also have an output of flame height for grassy woodlands:

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

Where α is a constant equal to 2.66 for natural grasslands/grassy woodlands, and equal to 1.12 for grazed and eaten out grasslands/grassy woodlands.

Model behaviour and limitations

This is generally a well-balanced model and is not overly sensitive to any of the inputs, though wind and dead fuel moisture content generally have the greatest influence.

This model has a default fuel state of natural rather than grazed as per the grassland model, so this model may overpredict fire spread in open woodlands/forests that are grazed.

Choice of condition has a large impact on model output (stronger effect than fuel load) except in extreme burning conditions where ROS is 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 half the ROS of grazed fuels for wind speeds over 5km/h. It likely overestimates ROS in mild weather conditions.

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 < 12%, and linear decay otherwise (MC > 12%).

Based on experimental fire results, for this fuel no fire propagation will occur if $MC > 20\%$ and fires will self-extinguish if curing is less than 20%.

Fuel sub-types

There are currently five sub-fuels defined in AFDRS that use the Grassy Woodland model:

- Woodland
- Acacia woodland
- Woody horticulture
- Rural
- Urban.

Woodland

This sub-fuel is for woodland and shrubland with a continuous grass understorey and minimal shrub or litter component in the fuel makeup. It includes tropical savanna woodland, temperate grassy woodlands, and semi-arid woodlands or shrublands with a perennial continuous grass understorey. The fuel condition is set by the reported fuel load (see equations, above). If no input is given the default for grassy woodland is natural.

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*

Acacia woodland

This fuel sub-type is defined as arid acacia woodlands or shrublands (such as mulga), and similar vegetations (such as casuarina or eucalypts) where there is little ground fuel except for chenopod (saltbush) shrubs and herbaceous plants, with ephemeral grass occurring only after sufficient rain. There is no dedicated fire spread model for acacia woodlands/shrublands; both savanna and mallee heath were considered, and both were deemed likely to over-predict fire behaviour. This sub-fuel uses the eaten-out grass condition.

Woody horticulture

Perennial woody horticulture which usually has a managed (morn and/or irrigated) grass understorey. This includes orchards and vineyards. Some fire propagation is possible in this sub-fuel, however the condition of potential fuel will be highly variable. This sub-fuel uses the eaten-out grass condition.

Figure 3: *Vineyard with grass growing between rows. From a hierarchical classification of wildland fire fuels for Australian vegetation types, Cruz et al. 2015*

Rural

This sub-fuel is for rural residential areas and hobby farms, which typically consist of continuous grass with variable tree cover. Fuel management strategies in this fuel sub-type may be highly variable. This sub-fuel uses the grazed grass condition.

Figure 4: *Example of fuel arrangement around isolated houses in rural southern Australia.From a hierarchical classification of wildland fire fuels for Australian vegetation types, Cruz et al. 2015*

Urban

This sub-fuel is for urban residential areas with grass or gardens and variable tree cover. It includes suburbs with tree cover and recreational areas within the urban landscape such as parks and golf courses. Fuel management practices within these areas may be highly variable. Note that this does not include areas that are highly built up, such as city CBDs, apartment towers, and industrial areas; these are covered by the "built up" fuel sub-type in the non-combustibles fuel. This sub-fuel uses the grazed grass condition.

Original research papers:

- Cheney, N.P., Gould, J.S., Catchpole, W.R., 1998. Prediction of Fire Spread in Grasslands. International Journal of Wildland Fire 8, 1-13.
- Cruz, M.G., Gould, J.S., Kidnie, S., Bessell, R., Nichols, D., Slijepcevic, A., 2015. Effects of curing on grassfires: II. Effect of grass senescence on the rate of fire spread. International Journal of Wildland Fire 24, 838-848.

FIND OUT MORE

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