CSIRO PyroPage
Putting science into practice
www.csiro.au
Number 28 | **August 2020**

Calculating bushfire rate of forward spread

Accurate estimation of the speed of a bushfire is critical for understanding the level of threat it represents. However, a bushfire's rate of spread can be determined several ways. The difference between cumulative rate of spread (the total distance travelled by a fire divided by the total time of travel) and interval rate of spread (the maximum distance and minimum time between observations) was investigated using a range of experimental fires in dry eucalypt forest litter. Average rates of spread were greater for the interval method than the cumulative method for fires that were still developing.

Fire rate of spread

Speed is defined as the time rate at which an object travels a given distance. In a bushfire, the most common speed attribute is that the progression of the head of the fire, the fastest section of the fire, and is known as the rate of forward spread or head fire rate of spread (Sullivan and Gould 2019). The direction of head fire spread is generally not explicitly given but implied from the direction of the wind.

However, the rate of change of location of the head of a bushfire is not consistent, responding to fluctuations in environmental burning conditions (i.e. fuel, weather and topography). Short-lived changes in the wind speed and direction (from gusts and lulls) and localised changes in fuel and topography will affect the speed of propagation of the flame front at that time and location. As a result, the speed of the fire will depend on *when* the fire front is observed as well as *where* it is observed in the landscape.

There are several ways to measure the rate of forward spread of a bushfire. The two most common ways are: (1) measurement of the time taken for the fire front to travel between two locations of known separation, and (2) measurement of the distance the fire front has travelled between two known times. Shorter observation periods will provide more 'instantaneous' rate of spread observations. Longer observation periods will result in a more 'average' fire spread observation.

Interval versus cumulate rate of spread

Similarly, there are two ways of calculating the rate of forward spread from multiple observations of fire speed – the cumulative rate of spread and the interval rate of spread (Fig. 1). Cumulative spread rate is the rate of spread calculated at each observation determined from the total time taken and the total distance travelled to that point from some originating observation. The cumulative rate of spread is essentially an average speed of the fire to each observation and at the final observation will be the average rate of spread for the life of the fire.

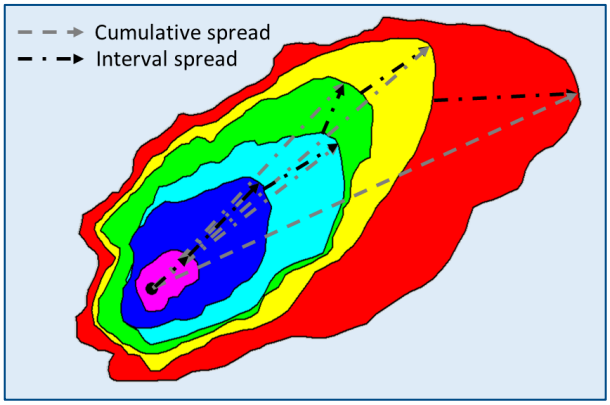

Figure 1. Interval rate of spread (black dash) is the average speed for each interval of observation (as indicated by the different colour isochrones). Cumulative rate of spread (grey dash) is the average speed over the life of the fire.

Interval spread rate is the rate calculated for each individual observation interval and is determined from the minimum travel time and the maximum distance travelled between observations. This rate of

spread reveals the 'instantaneous' change in the rate of spread between observations. The degree to which it reveals the instantaneous speed of the fire depends on the length of the period of or distance between observations.

Understanding the differences between, and implications of, these spread rates is essential to determining the factors that influence rate of spread, particularly acceleration. The two spread calculation methods were examined using a mix of point and line ignited experimental fires conducted the laboratory and the field.

Experimental fire data

Data from both small scale (~5 m) laboratory and large scale (~100-200 m) field experimental fires were used for this study. The laboratory experiments were conducted in the CSIRO Pyrotron in dry eucalypt forest litter. Three ignition types (point, 400-mm line and 800-mm line) were employed with 39 experiments providing 312 spread observations. The field experiments consisted of two studies: point ignition fires conducted by Alan McArthur in dry eucalypt forest in the ACT (Fig. 2) with 27 fires providing 293 spread observations and 120-m-long line ignition fires conducted during Project Vesta (McCaw *et al.* 2012) in dry eucalypt forest in south-west Western Australia with 17 fires providing 104 spread observations.

Findings

Comparisons of the two methods of calculating rate of forward spread using multiple observations of fire location and travel time found that interval spread rates were significantly greater than the cumulative spread rates for all the laboratory and the field point ignition fires. No significant difference between the two methods was found for the 120-m line ignition field fires but interval rate of spread was more variable than the cumulative rate of spread.

This suggests that while fires are still developing from ignition toward a steady-state rate of spread,

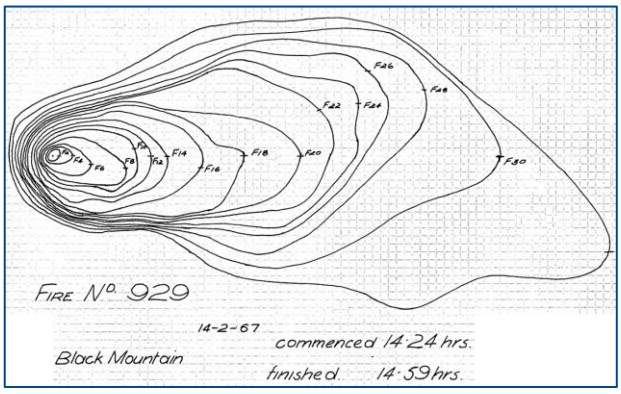

Figure 2. Example of a point ignition experimental fire conducted by Alan McArthur in dry eucalypt forest on Black Mountain, ACT. Fire isochrones are drawn at 2-min intervals.

use of interval spread rate will tend to overestimate the average speed of the fire. However, this method will better quantify the rapid changes in fire speed (i.e., acceleration and deceleration), in response to frequent changes in burning conditions (gusts and lulls or changes in fuel or wind direction).

If a fire has completed its acceleration phase and is spreading under more consistent burning conditions, cumulative spread rate provides a more meaningful estimate of the fire's speed. The general state of the fire (i.e. whether it has completed its development phase or a major change in its spread has occurred) should be considered when determining which method of fire rate of spread calculation should be employed.

Further reading

Gould JS, Sullivan AL (2020) Two methods for calculating wildland fire rate of forward spread. *International Journal of Wildland Fire* **29**, 272–281. DOI:10.1071/WF19120.

References

McCaw L W, Gould J S, Cheney N P, Ellis P F M, Anderson W R (2012) Changes in behaviour of fire in dry eucalypt forest as fuel increases with age. Forest Ecology and Management 271, 170–181. doi:10.1016/j.foreco.2012.02.003_.

Sullivan A.L., Gould J.S. (2019) Wildland Fire Rate of Spread. In: Manzello S. (eds) Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires. Springer, Cham. DOI:10.1007/978-3-319-51727-8_55-1.

CONTACT U
t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

FOR FURTHER INFORMATION
Land and Water
Dr Andrew Sullivan
t +61 2 6246 4051
e Andrew.Sullivan@csiro.au
w www.csiro.au/en/Research/LWF

An archive of this and previous CSIRO PyroPages is available from: http://research.csiro.au/pyropage