Fire Growth in Grassfires

1 minute

2 minutes

4 minutes

Most grassland fuels in Victoria, whether natural or cropland, can be considered as spatially uniform with few bare patches separating clumps of grass when compared to hummock grasslands like spinifex. As a fire increases in intensity and flame height it does not consume more fuel per square metre as occurs in forests and shrubland. In fact, the greatest fuel consumption occurs when a fire is backing into the wind because the flames consume the fuel from the bottom up, often leaving only a white ash residue. A fire driven by the wind ignites the top of the grass and the flames burn downward depositing partially burned carbonised (black) ash on the fuels below which after the fire may still contain grass stems in the lowest compacted layer and may re-ignite later if the protective layer is blown away. Thus in grass fuels the structure of the fuel bed is not important in fire growth compared to forest fuels which are considered separately.

This section describes the fire growth process in a in a uniform grassland and is based on CSIRO experiments at Annaboroo and Gunn Point in the Northern Territory[1]. Figure 1 is an example of a grass fire in an open woodland that was ignites at a point. It was measured by defining the perimeter with metal markers every 2 minutes for 48 minutes. The fire is burning under a relatively uniform wind speed, measured at 2m at the back of the fire, of 6 - 7km/h.

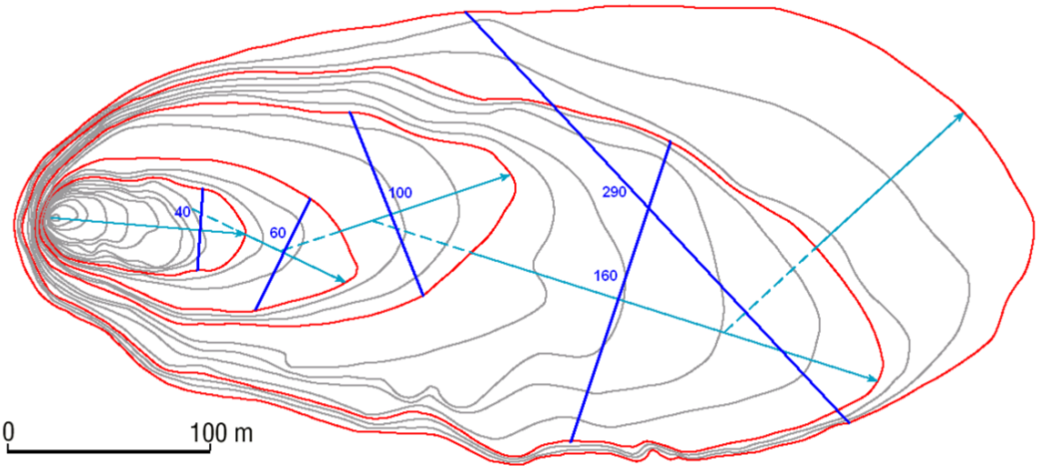

Figure 1. The progress of an experimental fire, ignited at a point. The red perimeters show the size of the fire at the time the wind direction changed; the light blue lines show the direction of the wind and the axis along which head-fire spread was measured.

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[1] Cheney NP and Gould JS 1995. Fire growth in grassland fuels. *International Journal of Wildland fire* **3:**237-247.

The width of the headfire was defined as the width of the fire measured normal to the direction of the wind where the flames were leaning over the unburned fuel. This is quite distinct from the flanks of the fire where flames were parallel to the perimeter or leaning over the burnt ground.

Figure 2 shows how the spread of this fire increased in a stepwise fashion whenever the wind direction changed, while the mean prevailing wind speed remained relatively constant.

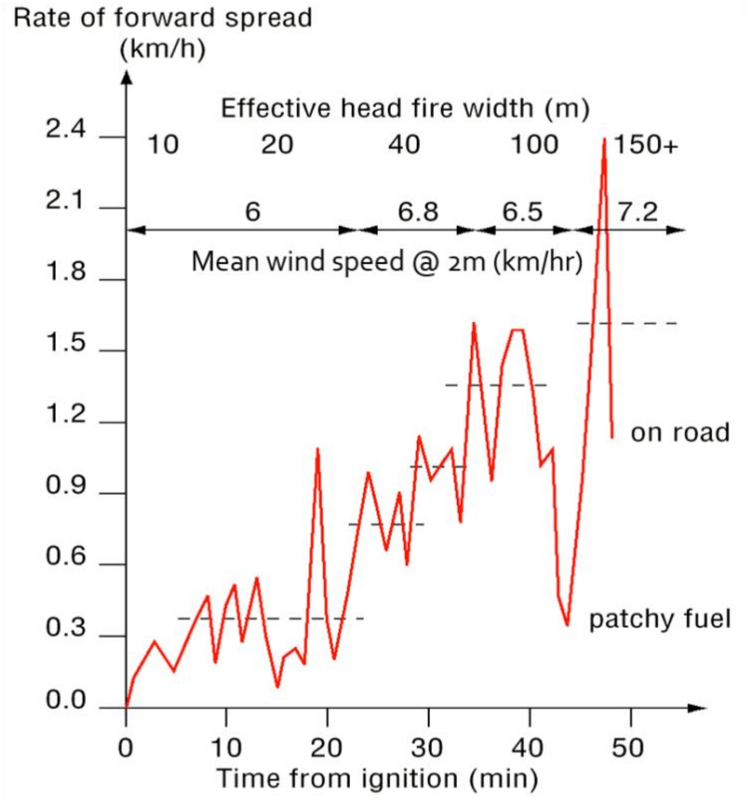

Figure 2. The 2-minute rate of spread increasing in a stepwise fashion.

An initial analysis of more than 50 fires which excluded the headfire-width as a variable showed that the rate of spread was not statistically related to wind speed – a result that would be difficult to sell to anyone.

Further experiments involved lighting lines of fire of different width See Figures 3, 4, and 5. These experiments have shown that the rate of spread is indeed related to the width of the headfire and that, depending on the speed of the prevailing wind, a certain width must be reached to produce the potential rate of spread for the prevailing conditions of temperature, relative humidity, fuel moisture content and mean wind speed.

The following photos illustrate shows the development of simultaneous fires burning under similar wind speed (Wind speed @ 2 m was measured at the four corners of the block).

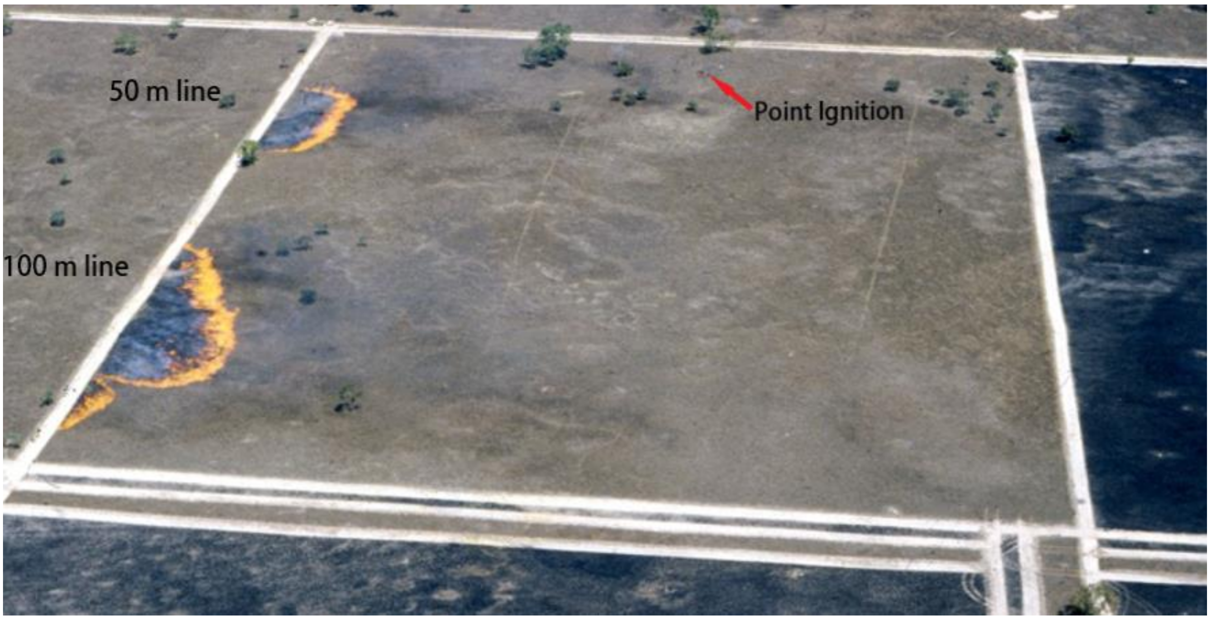

Figure 3. Grass fires lit at a point, 50 m line and 100 m line after 40 seconds. *The ignition of the 100 m line is not yet complete. The point ignition is barely visible at the top centre of the plot.*

Figure 4: Simultaneously lit grass fires 100 seconds after ignition.

In Figure 4 all fires are forming and elliptical shaped headfire. The 100 m line is now travelling at its potential rate of spread for the prevailing conditions. If the line had been ignited instantaneously it would have immediately spread at its potential rate. The width of the headfire from the 50m ignition line has decreased and this fire is slowing when compared to the 100 m line ignition.

Figure 5: Simultaneously lit grass fires 160 seconds after ignition

In Figure 5 the fire from the 50 m line has now developed a head fire that is narrower that the fire originating from the point ignition and is now spreading slower than the headfire from the point ignition. The 100 m line fire has also developed a pointed head but a slight shift in wind direction is turning the left flank into a broad heading fire which will soon expand the width of the head fire. Wind speed was measure at the 4 corners of the plot and although the winds entering the back of each fire were similar the development of pointed headfires occurred when atmospheric up-drafts positioned above the fire.

Under uniform conditions of fuel and fuel moisture content, the point at which the fire reaches it potential rate of spread is defined by the width of the head fire and the mean wind strength (Table 1).

Wind Strength (km/h)	Headfire width (m)	Potential rate of Spread (km/h)
0	any	0.06
7	20 +	1.5
14	100 +	4
21	150	7

Table 1 Relationship between wind strength and the width of the head fire for a fire to reach its potential rate of spread for uniform grassland and a moisture content of 4.5% (Annaburroo) NT

Under strong wind the potential rate of spread may not be reached until the head fire width exceeds 200m. The convective interaction with the atmosphere above the fire determines the shape of the head fire. If the fire forms a pointed head and the fire will spread at a rate that is well below its potential. This is illustrated in Figure 6.

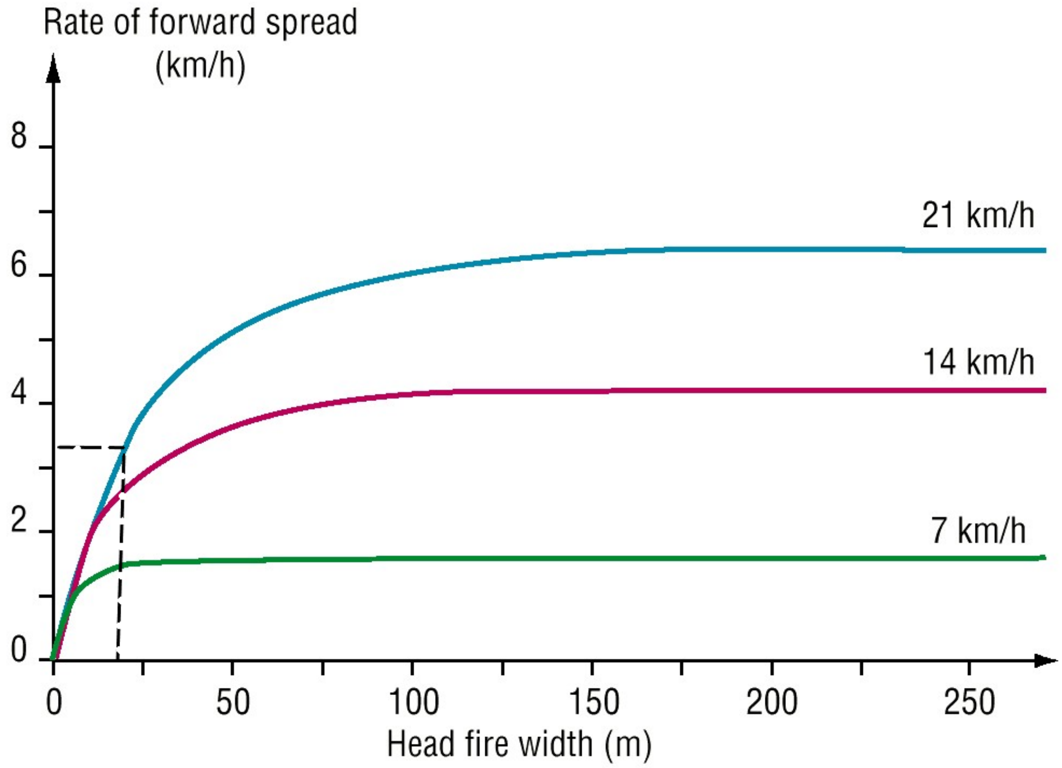

Figure 6. Relationship describing the rate of spread that will be attained by grassfires burning at different head fire widths at increasing wind speeds.

If for example a fire burning under 21 km/hr wind speed has a pointed head of only 20 m then it will maintain a rate of spread around 3 km/hr. This is half the potential rate of spread for the prevailing conditions and the fire will maintain this rate until the width increases. Above the nominated head fire width the fire will continue to spread at its potential ROS for the nominated wind speed.

The time that a point fire takes to reach its potential rate of spread in continuous fuel under strong winds depends on the frequency of significant changes in wind direction. This is unpredictable because of the random nature of wind changes. The shortest time of all experimental fires was only 14 minutes, while the fire illustrated in Figure 1 was still increasing after 40 minutes. However, if a 90°change of wind direction changes a slowly expanding flank fire into a very wide head fire it will **IMMEDIATELY** spread at the maximum potential rate of spread.

Hummock grasslands

Hummock grasslands like spinifex occupy vast areas of the arid zone of Australia. In most seasons there is bare ground between the hummocks. Before a fire will spread continuously flames must be long enough to breach the gap between hummocks. The length of the flame depends on the size of the hummock, while the angle of the flames depends on the wind speed. In a long unburned grassland spinifex humps may cover 40 – 50 % of the land. A threshold wind speed of 15 to 20 km/h is required for the fire to start to spread. If exceptional rainfall creates ephemeral grasses between the hummocks fires will develop like those in continuous pastures.

Application

Rapid initial attack that catches the headfire before it reaches its potential rate of spread will obviously be the most effective way of limiting the area burnt. However, this time is short when weather conditions are extreme. In Victoria on extreme days, northerly winds will gradually back towards the west as the frontal change approaches with strong west to south-westerly winds. Suppression of the eastern flank may limit the width of the headfire by restricting lateral spread during periods when the wind backs towards the west and allow suppression forces to take advantage of natural barriers and lulls in wind speed that also limit headfire width and slow the fire. It is essential to control as much of the eastern flank as possible before the wind change occurs to prevent huge areas being burnt after the wind change.

Further reading: Grassfires fuel, weather and fire behaviour. Phil Cheney and Andrew Sullivan. CSIRO Publishing 1997.