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Quantifying the potential for long-distance spotting

Fires burning in forests of ribbon bark eucalypts such as *Eucalyptus viminalis* (manna gum) and *E. rubida* (candlebark) have a notorious reputation for producing firebrands that can travel enormous distances and start spotfires up to 40 kilometres downwind of the main fire. Recent work has investigated the mechanisms by which ribbon bark might travel these distances and determined that a key factor is the shape of the bark.

A uniquely Australian problem

Spotting, the transportation of firebrands downwind of a wildfire to ignite new fires or 'spotfires' is a major issue in many parts of the world and can contribute significantly to the difficulty of suppression and losses of properties and lives. However, long-distance spotting to tens of kilometres has long been considered a feature of fires in eucalypt forest. Reliable estimates of spotting distance are difficult to obtain but numerous reports exist of distances exceeding 25 km. During the Black Saturday fires, 7 February 2009, spotting up to 40 km was observed.

The bark of eucalypt trees is notorious for spotting and the spotting potential for ribbon-bark gums in particular is described as 'high'. It is this specific bark morphology that is believed to be responsible for all spotting in Australia that exceeds distances of about five to seven kilometres (Cheney and Bary 1967).

Ribbon barks typically shed their bark during periods of hot weather, producing strips up to several metres long. The strip typically curls about its long axis to produce a long ribbon that may be cylindrical or even rolled in on itself forming internal convolutions. This type of bark has historically been used in lieu of a drip torch while conducting burning off. Veteran *Eucalyptus viminalis* trees can accumulate localized surface fuel loads in excess of 10 kg/m^2 (100 tonnes/ha) (Jacobs 1955) which could potentially assist significantly in the initial ignition, detachment and lofting of suspended bark (Figure 1).

Quantifying the potential

Spotting distances of tens of kilometres require firebrand combustion times exceeding 20 minutes. This implies firebrands that are long, have relatively low terminal velocities (the maximum speed at which they fall) and which burn slowly from one end.

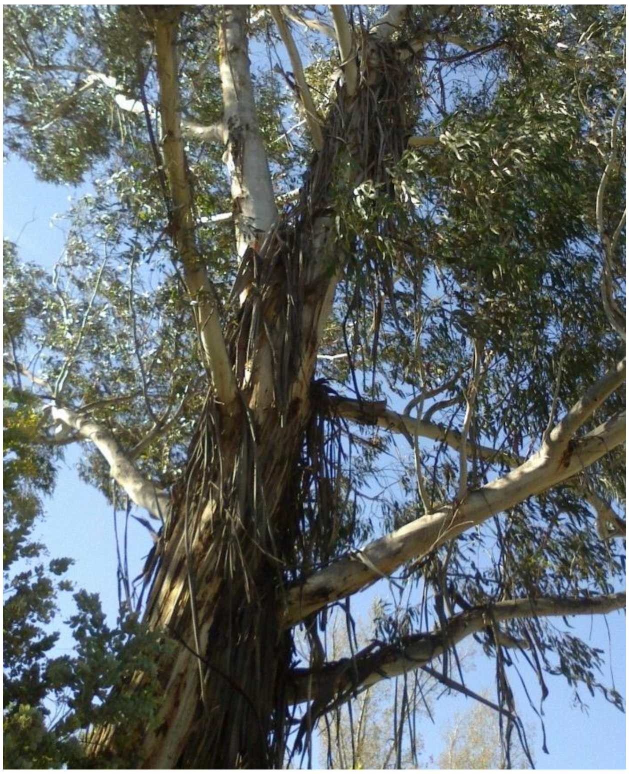

Figure 1. A typical *Eucalyptus viminalis* (Manna gum) in the ACT in summer showing large quantities of decorticating bark.

It had been surmised that convoluted cylinders of bark would be able to cause long distance spotting because combustion of the inner sections is protected from the relative air velocity (which is the firebrand terminal velocity) by the outer surface. However, there has been little research to demonstrate that this bark type can sustain combustion at its terminal velocity for the travel time required. A research project utilising the CSIRO Vertical Wind Tunnel was the first to investigate this problem.

Samples of *E. viminalis* bark ribbon, each 400 mm long, were divided into 3 categories based on their morphology as defined by the number of rotations of bark at any one point in the ribbon:

1. Flat plates (less than 0.4 rotations of bark)
2. Open simple cylinders (0.8-1.2 rotations of bark) and
3. Internally convoluted cylinders (more than 1.6 rotations of bark).

Figure 2. The three bark morphologies studied: Flat plate, open simple cylinder, and internally convoluted cylinders.

Samples were oven-dried to a moisture content of about 3.5% oven-dried weight, typical of wildfire conditions. Individual samples were then tethered at one end in the CSIRO vertical wind tunnel using a purpose-built device that allowed motion in a vertical direction. The velocity of the air flow was then increased until the sample reached a position where its longest axis was horizontal (i.e. perpendicular to air flow), representative of its orientation when in freefall and the air velocity then taken to be its terminal velocity.

Each sample was then ignited completely at one end using a butane torch while being held in a horizontal orientation. The time of flameout, measured as the time at which flaming combustion was no longer visible, and burnout, the time at which any combustion was no longer visible, were both measured at terminal velocity in the wind tunnel as time since ignition. In addition, the way in which flaming and glowing combustion proceeded along the length of samples was also noted.

Results

Figure 3 shows a summary of results of measured burnout times for 17 flat plate, 14 open cylinder and 20 convoluted cylinder bark samples. Mean terminal velocity and burnout time were, respectively, 5.4 m/s and 251 s; 5.2 m/s and 122 s; and 5.8 m/s and 429 s. The maximum burnout times were 785 s, 353 s and 1304 s. One convoluted cylinder flamed continuously and consumed its entire length of 368 mm in 271 s.

Assuming an updraft velocity of 23.4 m/s and a mean horizontal wind of 90 km/h (values associated with extreme fire weather and high intensity fire), the maximum spotting distance calculated for the sample within each morphology that had the longest burnout time were 16.6 km, 8.1 km and 29.4 km for flat plates, open cylinders and convoluted cylinders, respectively.

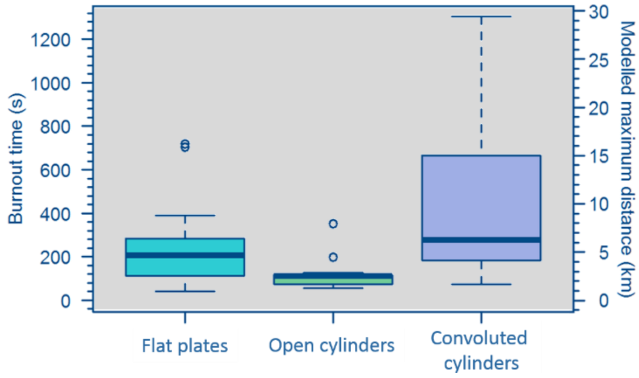

Figure 3. Plot of burnout time and modelled maximum spotting distance. Outliers are examples of possible spotting distances.

Implications

Figure 3 also shows that given extreme fire conditions it is feasible that convoluted cylinders can be transported tens of kilometres. The potential for this bark to continuously flame for this journey is supported by the sample which maintained flaming combustion for its entire length. This would correspond to a flameout time of over 30 minutes for a sample 2.7 m long; lofted to a height of 9600 m, it would result in a spotting distance of about 37 km.

The combination of extended burnout times, long lengths and low terminal velocities (~6 m/s) mean that potential spotting distances for ribbon barks are optimised. Although there were few samples in the study that had combustion times exceeding 1000 s, implying that the occurrence of firebrands with the characteristics necessary for very long spotting distances is relatively rare, the number of potential firebrands that exist in many Australian ribbon bark forests at any one time means that spotting to these distances under extreme conditions must be considered likely.

Further reading

Hall J, Ellis PF, Cary GJ, Bishop G and Sullivan AL. (2015) Long-distance spotting potential of bark strips of a ribbon gum (*Eucalyptus viminalis*). *International Journal Wildland Fire* 24, 1109-1117.

References

Cheney NP, Bary GAV (1969) The propagation of mass conflagrations in a standing eucalypt forest by the spotting process. In *Mass Fire Symposium*, 10-12 February 1969, Canberra, ACT. Paper A6. (Defence Standards Laboratories: Melbourne).

Jacobs MR (1955) *Growth Habits of the Eucalypts*. Forestry and Timber Bureau, Canberra, ACT, Australia. 262 pp.

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