Fire behaviour in a 6 year old *Eucalyptus globulus* plantation during conditions of extreme fire danger – a case study from south-western Australia

Lachlan McCaw and Bob Smith

Science Division, Department of Conservation and Land Management

Manjimup WA 6258

Abstract

This paper presents a case study of a wildfire that burnt from grazed pasture into a 6 year old bluegum plantation in the south-west of Western Australia. The fire burnt during conditions of extreme fire danger following an extended period of summer drought. The fire crowned extensively and about 20 per cent of the plantation was defoliated, with most of the remainder being fully crown scorched. Factors contributing to the severe behaviour of the headfire include extreme fuel dryness, very low relative humidity and the condition of the fuels within the plantation. There is a growing body of evidence from case studies to show that from an age of 6 years bluegum plantations carry sufficient fuel to support an intense fire and that when fire danger conditions are Extreme and all fine fuel is available to burn the difficulty of suppressing a fire in a bluegum plantation will be much greater than in grazed pasture. This study also highlights a need to better predict situations where dry air from aloft may mix down resulting in unexpectedly low relative humidity at ground level.

Introduction

Large areas of previously cleared agricultural land in the south-west of Western Australia have been afforested with plantations of Tasmanian bluegum (*Eucalyptus globulus*) since the early 1990s. In 2005 the area of bluegum plantation in the south

west was 150 000 ha with the majority owned and managed by the private sector. Bluegum plantations have been primarily established for short rotation pulpwood production, although opportunities for growing sawlog plantations on longer rotations are also being explored.

To date, unplanned (wild) fires have not inflicted any serious losses on the bluegum plantation estate and individual fires have mostly burnt less than 50 ha of plantation (Braun 2003, Gould and McCaw 2004). The limited wildfire losses can be attributed in part to implementation of fire planning guidelines and provision of fire suppression resources by the plantation industry. A further significant factor limiting wildfire losses has been the fuel conditions associated with the young age structure of the plantation estate (Gould and McCaw 2004). In a number of instances, bluegum plantations less than 7 years old have contributed to a reduction in the spread and intensity of wildfires burning under conditions of very high or extreme fire danger (Braun 2003).

This paper presents a case study of a wildfire that burnt from grazed pasture into a 6 year old bluegum plantation under conditions of extreme fire danger in autumn 2005 following an extended period of drought. The fire crowned extensively and most of the plantation was either defoliated or fully crown scorched. Fire burnt through the plantation and was eventually contained in pasture fuels. The purpose of the paper is to document information about the plantation, weather conditions and fire behaviour and to examine factors that may have contributed to the severe behaviour of this fire.

Methods

The landscape in which the fire occurred is a mosaic of state forest and private property, the latter being predominantly dryland pasture interspersed with bluegum plantation. Remnant eucalypts (*E. marginata*, *E. rudis*, *E. patens* and *Corymbia calophylla*) are common throughout pastured areas and along roadside verges. Limited areas of land are also cultivated for horticultural crops. Terrain is gently undulating with a mean elevation of 260 m ASL.

Weather observations representative of the fire-ground were available from automatic weather stations maintained by the Bureau of Meteorology at Bridgetown and Manjimup. These observation sites are respectively 24 km north and 11 km south of the fire origin. The Soil Dryness Index (Mount 1972) is calculated daily for both observation sites. The Bureau issues a daily fire weather forecast for Bridgetown as part of the forecasting service for the Department of Conservation and Land Management (CALM), and Bridgetown observations are used to validate the fire danger rating for the Southwest Inland forecast district. In Western Australia, fire danger ratings issued by the Bureau are based on the Grassland Fire Danger meter (CSIRO 1997), with the lower limit for the Very High category is set at 32 (not 20 as used in other states).

Information about the age, establishment technique and management history of the bluegum plantation was provided by staff of WA Plantation Resources. Several field inspections were conducted in the weeks following the fire to assess the severity of the fire and to collect information on stand characteristics including stocking, stem

diameter and tree height. Fuel conditions were also examined in parts of the plantation that remained unaffected by the fire.

Results

Weather conditions

The fire occurred in autumn 2005 following 3 months of substantially below average rainfall. Soil Dryness Index values were 175 mm at Bridgetown and 170 mm at Manjimup. No rainfall > 1 mm had been recorded in the vicinity for nine days prior to the fire.

The Bureau of Meteorology issued a High fire danger rating for the Southwest Inland forecast district for 23 March. Weather conditions at Bridgetown were expected to be fine, with a maximum temperature of 37°C, minimum relative humidity of 14 per cent, and minimum dew point of 5°C. Winds were forecast be 20-25 km h^{-1} in strength throughout the day, initially blowing from the N then shifting progressively through NW and WNW to WSW by 1700 hrs. Based on forecast conditions the expected range of Grassland Fire Danger Index was from 20 to 30. The jarrah forest fire danger index (Sneeuwjagt and Peet 1985) was 130 m/h (High) with jarrah litter fuel predicted to reach a minimum moisture of 4 per cent.

Observed weather conditions during the early morning of 23 March differed considerably between Manjimup and Bridgetown (Table 1). At Manjimup, overnight conditions remained unusually warm and dry with a maximum overnight relative humidity of 58 per cent at 0200 hrs. From then on dew point and relative humidity fell steadily in association with a change in wind direction from ENE to NNE. By 0600

hrs the relative humidity had fallen to 36 per cent. In contrast, overnight conditions in Bridgetown were up to 7°C cooler and relative humidity exceeded 70 per cent between midnight and 0700 hrs. Temperatures rose rapidly during the morning with maxima close to 40°C at both sites. The dew point at Bridgetown fell sharply between 0900 and 100 hrs, probably coinciding with the lifting of a shallow surface inversion, and then continued to fall to a minimum of –4.5°C at 1400 hrs. The dew point at Manjimup declined in a similar fashion to a minimum of 0.5°C.

Grassland fire danger remained High at Manjimup throughout the day, and briefly reached Very High at Bridgetown in the early afternoon. Forest fire danger (McArthur 1967) reached Very High by 0900 hrs at Manjimup and by 1000 hrs at Bridgetown. Both locations experienced a number of hours of Extreme forest fire danger during the afternoon (Table 1).

Plantation characteristics

The plantation was approaching 6 years old at the time of the fire. All of the land on which the plantation was established had been cleared of native vegetation for some years prior to planting with bluegums in the winter of 1999. One paddock had been cultivated for vegetable cropping but much of the area had been cleared roughly into windrows and left fallow. Bluegum seedlings were planted at 5 m x 2 m spacing (1000 stems/ha) but by 2005 mortality had reduced stand density to 750-850 stems ha^{-1}. Basal area and mean stem diameter ranged from 11-14 m^2 ha^{-1} and 13-15 cm dbhob respectively. Codominant height was 16 m, with occasional dominant trees up to 20 m tall. The plantation had been grazed by sheep since 2001 and surface fuels consisted of dry grass, patches of bracken (*Pteridium esculentum*) and bluegum leaf litter and

twigs. Litter fuels tended to concentrate in furrows either side of planting mounds. Bluegum canopy closure had been relatively slow because the site had not been regularly fertilised in the years prior to plantation establishment.

Fire behaviour

The fire began adjacent to the South West Highway just north of Wilgarup Rd (Fig. 1) and was detected by a CALM fire spotter aircraft at 1206 hrs. The fire is believed to have been ignited by burning leaves or bark transported by the wind from inside the perimeter of a previously contained fire that resulted from a vehicle accident on 20 March 2005. Firefighters from CALM and volunteer bushfire brigades responded immediately the fire was detected and two Dromader waterbombing aircraft (2500 litre capacity) were despatched from the Manjimup airstrip. The rapid response of fire suppression resources prevented serious damage to a house and several outbuildings located within the plantation and close to the path of the headfire.

The fire spread rapidly on a NNE wind across 400m of heavily grazed pasture with scattered remnant eucalypt trees. At 1215 hrs the spotter reported that the fire was 10-15 ha in size and actively crowning inside the bluegum plantation. If the fire is assumed to have ignited the dry grass west of the Highway at about 1200 hrs then the rate of spread during the initial 15 minutes must have been 2-3 km h^{-1}. This is consistent with the rate of spread predicted by the CSIRO Grassland Fire Spread meter for eaten out pasture. Patterns of crown defoliation indicate that the fire began to crown extensively within 50 m of entering the bluegum plantation and air photographs show an almost continuous path of defoliated crowns from the north-east

corner to the south-west corner of the plantation (Fig.2). The headfire readily crossed a 30 m wide powerline easement that ran in an east-west direction across the path of the fire run and was cleared to bare mineral earth. Defoliation patterns indicate that extensive crowning re-developed less than 20 m downwind of this easement. The headfire also crossed a 10 m wide perimeter firebreak adjoining Wilgarup Road (Fig. 3) at XXXX hrs, the latter having a 6 m wide gravel running surface within a roadside reserve of remnant eucalypt forest. Based on this observation the average rate of spread since ignition at 1200 hrs would be been of YY mh-1. South of Wilgarup Rd the fire redeveloped in bluegum plantation, also resulting in extensive crown defoliation (Fig.2).

The fire breached the perimeter firebreak on the southern edge of the plantation and continued to spread through remnant eucalypt forest on private property towards the rural settlement of Palgarup. Fire intensities in eucalypt forest were very high and sufficient to cause complete crown scorch, widespread defoliation, and complete bark charring of trees up to 30 m tall. The fire was contained during the later part of the afternoon in open pasture fuels just north of Palgarup as a result of suppression action and declining wind strength.

An assessment of crown damage from low-oblique air photos taken during the week following the fire indicated that of the total area of 117 ha planted to bluegums about 20 per cent (25 ha) had been completely defoliated by crown fire. About 70 per cent of the plantation had been fully crown scorched, and about 10 per cent had experienced low intensity fire insufficient to cause crown damage. Areas of low crown scorch included a narrow zone on the north-east edge of the plantation that

burnt as the fire moved from pasture into plantation fuels, and the south-western corner where the fire had been flanking parallel to the prevailing north-east wind.

Discussion

This case study clearly illustrates that bluegum plantations established on previously cleared agricultural land can burn at very high intensity if the weather conditions are severe and the fuels in the plantation are sufficient to support a continuous flame front. Several factors are likely to have contributed to the severe fire behaviour of the headfire in the plantation including extreme fuel dryness, very low relative humidity, and the condition of the fuels in the 6 year old plantation. The south-west of Western Australia experiences a Mediterranean climate with a regular pattern of drought during summer and autumn and fuels are often at their driest during February and March (McCaw and Hanstrum 2003). Grassy fuels within the plantation would have been fully cured, and leaf fall from tree canopies during the preceding summer would have added a layer of fresh, un-decomposed bluegum leaves to the surface fuel layer on the ground. Relative humidity was extremely low (<10 per cent) for a number of hours during the afternoon of 23 March and this would have directly affected the moisture content of dead fine fuels with a short response time including leaf litter, fine twigs, dead grass and outer bark. In addition, fine embers can become an important source of ignition for short distance spotting when the relative humidity is very low (Ellis 2000).

Fuel conditions were typical for a 6 year old plantation in the higher rainfall zone (>800 mm annual rainfall) of south-western Australia, with bluegum leaf litter, dead

grass and patches of native understorey shrubs making up the bulk of the surface fuel load. In 6 year old plantations leaf litter is often concentrated along planting mounds and does not form a continuous layer (Boness and Van Etten 1998, Braun 2003, Gould and McCaw 2004). The amount of suspended bark on the stems of bluegum trees appeared similar to that observed in other plantations, and is unlikely to have been a critical factor responsible for the extensive crowning observed during this fire. There was little difference in the extent of crown fire activity between areas of the plantation north of Wilgarup Rd that had been cultivated prior to establishment and areas south of the road that had been roughly windrowed, suggesting that prior land use history had limited influence on the behaviour of the fire. Remnant vegetation within the plantation was limited in extent and did not appear to have significantly affected the spread pattern or intensity of the fire.

The extent of crowning during this fire was much greater than has been observed in previous fires in bluegum plantations including a number that also burnt under conditions of Extreme fire danger. To some degree this reflects the fact that other case studies have mostly examined fires that impacted on plantations younger than 5 years old where grassy fuels have declined but litter fuels have not yet accumulated (Braun 2002, 2003). Two of the fires investigated by Braun (2003) also occurred in spring when grassy fuels were not fully cured. Braun (2003) reported that surface fires burnt through older plantations with more continuous surface fuels and noted localised torching of individual trees and even some limited crowning, mostly associated with intense fire in adjoining patches of remnant native vegetation. There is a growing body of evidence from case studies to show that from an age of 6 years bluegum plantations carry sufficient fuel to support an intense fire and that when fire

danger conditions are Extreme and all fine fuel is available to burn the difficulty of suppressing a fire in a bluegum plantation will be much greater than in grazed pasture. This finding has important implications for fire protection in rural districts where new plantations have been established. From a plantation industry perspective the average age of the plantation estate will have a major influence on the probability of serious fire losses being incurred.

The very low relative humidity during the afternoon of 23 March 2005 can be attributed to mixing down of dry air from aloft under conditions of strong convective heating,. Dew points recorded at Bridgetown were unusually low (G. Reader[1], pers. comm.). Entrainment of dry upper air has been observed during a number of major bushfires in southern Australia and is an important phenomenon worthy of further investigation. When relative humidity is very low and wind strength is moderate the fire danger rating from the McArthur forest meter may be at least one class higher than the danger rating from the grassland meter. This difference is accentuated in Western Australia where the lower limit for the Very High category is set at 32. In the case of this fire the danger ratings from the two meters appear to have correctly reflected the relative difficulty of suppression in the forest and pasture fuels.

Acknowledgements

Russell Walter from WA Plantation Resources provided information about the establishment and management history of the plantation. Aerial photographs were taken by Greg Simpson from CALM at Manjimup.

[1] Grahame Reader, Bureau of Meteorology, Perth Regional Forecasting Centre.

References

Braun, K. (2002) Valley View plantation wildfire. ICS Group and Integrated Tree cropping, Albany, Western Australia.

Braun, K. (2003) Wildfire behaviour in Blue Gum plantations. ICS Group and Integrated Tree cropping, Albany, Western Australia.

Boness, P.R. and Van Etten, E. (1998) Fire and fuel loads in bluegum plantations in south-west Australia. In: *Proceedings of the 13th Conference on Fire and Forest Meteorology, Lorne, October 27-31 1996*. International Association of Wildland Fire.

CSIRO (1997) Grassland Fire Danger Meter (CSIRO-modified McArthur Mk 4 meter).

Ellis, P.F. (2000) The aerodynamic and combustion characteristics of eucalypt bark – a firebrand study. PhD thesis, Department of Forestry Australian National University, Canberra, ACT.

Gould, J.S. and McCaw, W.L. (2004) Risk and behaviour of fires in hardwood plantation. 11th Annual Australasian Fire Authorities Council and Inaugural Bushfire Cooperative Research centre Conference, 7-9th October, Perth, Western Australia.

McArthur, A.G. (1967) Fire behaviour in eucalypt forests. Commonwealth of Australia Forestry and Timber Bureau Leaflet No. 107.

McCaw, L. and Hanstrum, B. (2003) Fire environment of Mediterranean south-west Western Australia. In: Abbott, I. And Burrows, N. (eds) *Fire in ecosystems of south-west Western Australia; Impacts and management.* Backhuys Publishers, Leiden, the Netherlands, pp 87-106.

Mount, A.B. (1972) The derivation and testing of a soil dryness index using run-off data. Forestry Commission Tasmania Bulletin No. 4.

Sneeuwjagt, R. J. and Peet, G. B. (1985) Forest Fire Behaviour Tables for Western Australia. Department of Conservation and Land Management, Perth.

TABLE 3. Weather observations from Bridgetown and Manjimup automatic weather stations on 23 March 2005. Data provided by the Bureau of Meteorology, Perth. Wind speed represents the mean speed recorded over a 10 minute period prior to the observation time.

	Bridgetown								**Manjimup**						
Time (WST)	Temp (ºC)	RH (%)	Dew point (ºC)	Wind speed (km/h)	Wind dir.	GFDI	FFDI		Temp (ºC)	RH (%)	Dew point (ºC)	Wind speed (km/h)	Wind direction	GFDI	FFDI
0600	14	87	11.8	calm	-	0 Low	0 Low		21	36	5.7	11	NNE	4 Mod	10 Mod
0700	14	85	11.4	calm	-	0 Low	0 Low		22	33	4.9	18	N	8 High	13 High
0800	19	68	13.0	calm	-	0 Low	2 Low		24	29	5.0	18	N	10 High	16 High
0900	26	35	9.4	7	S	3 Mod	11 Mod		29	21	4.3	17	N	12 High	24 V High
1000	32	16	3.2	13	NNE	11 High	28 V High		32	18	4.7	22	N	19 High	34 V High
1100	36	9	-2.1	15	N	17 High	45 V High		35	14	3.6	20	N	22 High	41 V High
1200	38	7	-3.5	18	N	25 High	55 Ext		38	10	1.1	20	N	26 High	52 Ext
1300	39	7	-2.8	22	N	34 V High	62 Ext		39	10	2.0	22	NNE	31 High	56 Ext
1400	40	6	-4.5	17	N	26 High	60 Ext		39	9	0.5	17	NNE	23 High	51 Ext
1500	40	6	-4.4	18	ENE	28 High	62 Ext		39	10	1.7	13	N	16 High	46 V High
1600	38	7	-3.4	13	N	17 High	50 Ext		39	10	2.2	17	NNE	22 High	50 Ext
1700	38	8	-1.8	17	NNW	23 High	52 Ext		37	12	2.9	11	N	12 High	38 V High
1800	35	12	1.1	6	NW	7 Mod	30 V High		35	18	7.3	17	SW	16 High	33 V High

Figures.

Fig. 1. Aerial view looking south-east across the path of the fire. The fire originated in the centre left of the picture adjacent to the highway. This photograph illustrates the clearly defined initial run of the fire in the open pasture and the path of defoliation from the north-east to south-west corner of the bluegum plantation.

Fig. 2. View of the south-west corner of the plantation showing the powerline easement and the corridor of remnant eucalypt forest along Wilgarup Rd. Extensive patches of plantation defoliated by crown fire are evident in plantation north and south of Wilagrup Rd.

Fig. 3. Defoliated bluegums immediately north of the firebreak adjoining Wilgarup Rd. Trees are about 16 m tall.