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Grass fire and bushfire behaviour

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Chair

Tonight we have two presenters, Kevin Tolhurst and Justin Leonard. Kevin will talk about weather for the upcoming summer immediately followed by his presentation on grass and bushfire behaviour in the landscape. After a poll question Justin will give us his insights into how a house and property is impacted by a grass fire and a bushfire. And then I'll have a discussion and question answering session with Kevin and Justin including your questions.

Welcome Kevin.

Kevin

Thanks Malcolm. I'm glad to be back. I think it's interesting that we're dealing with grass fires tonight because often people see them as being less threatening. But that's not really the case. They're different but we still need to understand them.

It's interesting too to think that this year the seasonal conditions basically follow three years of above average rainfall. If we look across the country we see that the vast majority of the country has had above average rainfall. This map from the Bureau of Meteorology shows the average for the last two years. So everywhere apart from Western Australia, some areas along the coast in Queensland, and in Southwest Tasmania basically have had above average rainfall.

However what's interesting if we look at the root zone moisture content, again from the Bureau of Meteorology, we see that a lot of Eastern Australia, Western Australia and Southern Australia the soils are below average moisture content already. This is not so important in the forest areas because a certain amount of buffering goes on there so the variation is not that extreme. But in some of our semi arid grassland areas that does make a big difference.

A recent map put out by AFAC in conjunction with the fire agencies across Australia show the area of Australia that's expected to be of higher fire risk this spring. The outlook for summer hasn't been produced yet, that's to come shortly. The areas highlighted are areas that normally would have grassland but the grassland would be relatively well spaced. But after wet years there's infill in that grass area and so fires can spread across areas that would normally be difficult for fire to spread except under stronger wind conditions. We see here a big chunk of Western Queensland, New South Wales, Northwest of Victoria and a big area in Northern Territory. Up in the northern part of the country in Northern Queensland, Northern Territory and West Australia fires occur there basically every year so they're not being shown as being exceptionally bad. But the red areas are showing unusually bad areas.

Along the coast down in Southern New South Wales and Victoria these areas are pretty limited but a lot of those areas were burnt in 2019-2020 and the fuels there really haven't reaccumulated. So even though the weather conditions might be conducive to fire it really will mainly be in more grassland or unburned areas. Already, there are reports coming through of fire spreading in southern Northern Territory. This is the Barkly region. And what you can see in this image if you look at the flames is how continuous that flame front is. That's because of the infill of grass because of the recent rainfalls. And what that means is the fire will continue to burn overnight and restart the next day and spreading the next day when the winds and the temperature increases.

That continuity of fuel means that the grassland areas are likely to be quite extensive in terms of the area burned. We're seeing that starting already. And from last night the sentinel hotspots that are currently showing active fire across the country. Again we can see those areas in the southern part of Northern Territory, the areas in inland Queensland and Western Australia. They're the areas where fires currently are burning before we go into fire season as well as what you'd normally expect in the dry season in the top end in the savanna woodlands. But you see there's a strong correlation between where the fires currently are occurring and the forecast areas of expected increased fire activity.

What this says to us in a sense is that it's not that we won't have fires in forested areas but we're unlikely to have extensive fires in that forested area until the drought conditions develop. And that's not a certainty at this stage but we are looking towards, particularly in eastern Australia, with El Nino kicking in. We're likely to see low rainfall so it's the beginning of a drying out period. In the next two or three years if that drying pattern continues then we might see some significant fires in forested areas. But for this year it will largely be in the semi arid grassland areas which could burn very large areas of the country. Millions of hectares but largely in low population density areas and areas where there's fewer assets in terms of houses and infrastructure. But keep your eyes open for how the season then develops beyond this summer.

I hope that provides some explanation as to what the seasonal conditions might be. I've heard some expression saying this is going to be the worst ever fire season. There may be some very large areas burnt of grassland. The similar sort of thing happened in 1974 where about 200 million hectares got burnt after a wet period. But that's a natural part of the cycling if you like so it's something to be aware of but not necessarily to be considered to be disastrous at this point. But be aware of grassland areas because grasses dry out quite quickly as soon as the rain stops.

I'll move on to my main point for this evening which is really trying to understand grassland fire behaviour. Because grassland fire behaviour is quite important. Technically bushfire refers to all types of vegetation fire whether it be in forests, woodlands, heathlands, or grasslands. But often you hear agencies and people refer to bushfires and grass fires. Bushfires is meant to be a generic term. So we can talk about bushfires but bushfires might be grass fires, they might be forest fires, they might be shrub fires, they might be heath fires. But just be aware of the terminology and try and use it accurately if you can. Bushfires are meant to be a generic term.

What's important is that grass fires can be lethal. We have a record of fatalities of people being killed in grass fires so they shouldn't be considered to be some lesser quantity in a sense. And Justin will help drive you through some of the hazards associated with grass fires in his talk. Grass fires can destroy homes and other assets so they really need to be taken seriously.

What I want to discuss is what's special about grass fires. If we look at the fuels in grasslands in the same way that we assess any other fuel in the landscape they basically are made up of surface and near surface fuels. Surface fuels being the dead horizontally spread component and near surface being the more vertical elevated fuel above the ground but connected to the ground. That's all described in detail in the overall Fuel Hazard Guide that Francis Hines and others produced in 2010. Hopefully you've come across that before.

Near surface fuels have a strong vertical orientation. And as we go through our discussion about the grassland fire behaviour that vertical orientation should seem increasingly important. That vertical orientation exposes the fuel to the wind, the sun and therefore the rate at which the fuel heats and dries is quite rapid because of that well aired exposed orientation. But in a fire situation it is also a structure that allows for rapid heat transfer when it's burning. It's not about having more oxygen it's really about the structure for heat transfer. And about 80% of the heat that comes from a fire is coming from convective heat or the hot gases. Because that can move through the fuel more freely when it's vertical the rate of heat transfer is greater and so the rate of combustion and the rate of spread is greater.

Looking at an image here of a grassland we can see that the grass dry grass here has a vertical structure. It's burning quite well. Flames are unlikely to be any more than 8m, and often it's only more like 2-4m high in grassland just because the quantity of fuel is not that great but its arrangement is ideal for fire spread. This is another image of what you might call a grassland. In fact this is canola stubble. What you might notice here is the black smoke because of the high oil content of the material. So the chemical composition is of some importance as well as the dryness of the fuel. But here we've got higher flames and more intense fire behaviour just because of the chemical composition of the fuel that's burning even though it's a grassland. Crops can be considered grassland as well.

Understanding a little more about grasses. Grasses can be either annual or perennial. Annual grasses dry off each year after setting seed. As they dry off we describe their degree of dryness according to the curing percentage. Curing is just a measure of percentage dead grass out of the total amount of grass present. If you like the proportion of dead to live. The live grass is taking up moisture through the root system from the soil and because it's still alive has higher moisture content than the dead grass is likely to have because it's still a functioning organism and will be determined by its growth state. So whether it's vigorously growing or senescent stage.

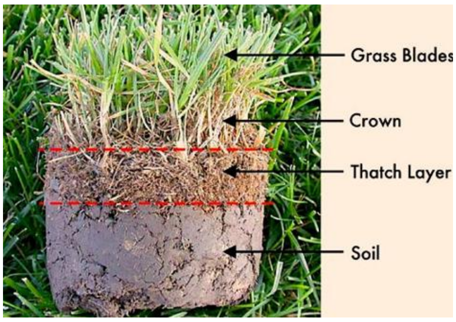
Dead grass on the other hand basically varies according to the weather conditions: recent rain, air temperature, relative humidity, wind and the solar radiation. So it can change very rapidly. And because it's vertically oriented and it's very fine in its structure that rate of drying is incredibly rapid. In forest fuels it might take a couple of hours to readjust. In grass fuels the moisture is taken up from the change in air temperature and relative humidity basically in seconds. Annual grasses have this annual cycle of growth and dying off. Perennial grasses on the other hand live for many years and so there are always some green parts but there are also the dead parts from previous year's growth.

Generally the perennial grasses are deep rooted so they get access to more moisture than the annual grasses. Some of them even have a special growth metabolic pathway. A C4 pathway - which means that they can basically photosynthesize under really dry conditions. So Kangaroo grass and Phalaris are a couple of grasses that basically have this ability to grow even when conditions are dry. Generally there's a greater biomass in this perennial grass because it accumulates over time. It is important to distinguish between perennial grasses and annual grasses when you're looking at the grasses as a fuel and understand those cyclic processes that are going on.

Here is a couple of photos of grassland on the left. It's a roadside. Pure grass but there's often a few trees around. And those trees and shrubs can actually affect the wind speed but also provide embers for spotting. So grasslands are rarely just continuous grass. They're often mixed with some other vegetation. But we can see here an extensive area of grass. On the bottom right there is also a grassland but with trees. Now why I'm calling it a grassland is because the predominant fuel across the ground is grass but the trees are affecting the wind and sun and the exposure to the drying process. So the trees have an influence but they're not contributing a lot to the fuel on that site.

There's a distinction to be made here between what you'd call a forest or woodland and what you would call a grassland with trees if you like. Hopefully I can explain that a little better to you. Here's an aerial image of an area in Victoria at Yan Yean Reservoir. Here we've got a clear area of forest, it'll have forest fuels. Down here we've got an area that's largely grassland but the some of the grassland has borders of trees or shrubs along fence lines. Over here we've got an area that's grassland. What we're looking at here is the fuel is predominantly grass but the trees will be slowing the wind down and therefore reducing the rate at which fire will spread through there but also reducing the rate at which those grasses will dry. So a little bit like the photograph I showed you in the previous slide. Compared with this little patch of treed area here which is dense enough that the main fuels underneath it will be forest fuels.

Just because you have trees present doesn't necessarily mean that you have a grassland or a forest. It depends on what the dominant fuel is along the ground whether you call it a grassland or a forest. The things that are important to you are basically how the trees might affect the wind reduction - slow the wind down. But the trees will also potentially provide a source of spotting material. Embers can go ahead and dramatically increase the rate at which fires spread across the landscape and whether or not fire breaks are effective. The presence of trees are important even though you still may have predominantly grassland areas.



Something else that's worth considering is this idea of thatch. In this image on the right we're looking at a layer of dead grass underneath the live grass. This layer of dead grass basically provides continuity of fuel on the ground. But because it's dead it's likely to be more available for fuel. Sometimes you can find fires burning in grassland that looks as though it's totally green, but when you dig underneath it you'll find that there's this layer of dead material underneath which is called thatch. It's hidden out of sight. It's from previous year's growth and forms this continuous layer. It means the fire can continue to burn overnight and it can spread basically in all directions depending on the continuity of the fuel. So don't be tricked by thinking because it's green on top that it won't burn.

The thatch significantly increases the amount of heat that's generated by the fire even though it might be a slower smouldering type fire because it has a horizontal orientation rather than the vertical orientation. It's this burning overnight and continue to smoulder that creates a problem with thatch. And thatch tends to develop in areas that haven't been burned or grazed. So that would be the case in a lot of properties for example where the grass might be just slashed so you get this continuous layer. That's why burning an area has an advantage over just slashing it.

Moving on to a bit more about grassland behaviour. Grasses tend to be more open and exposed to the wind and the wind drives the flames and heat forward increasing the rate of spread. That openness to the wind means that the wind has a greater influence. The grass fuels tend to be more vertically orientated. So again that's great for exposure to the wind and the sun which means more rapid drying. But it also means from the fire point of view better heat transfer. The heat that's generated from the flaming part of the fuel is effective in preheating the fire ahead of it. In grassland fuels generally speaking we're talking about fuels that are less than about 2mm thick whereas in forest fuels we're talking about fuels up to 6mm. But that fineness of the fuels means that the grass fuels respond to changes in temperature and relative humidity and therefore the dryness of that fuel much quicker than forest fuels will.

The fineness of the fuel also means that the burnout time of that fuel is much quicker. So within about 5 - 10 seconds compared with forest fuels which normally are about 40 - 120 seconds. So about eight times shorter than forest and that affects the depth of the flaming front. So that persistence of flaming affects the total amount of heat that's being given out at any particular time. The maximum flame height is likely to be less than 8m, 5-8m is a pretty high flame for grassland. Often it's more 2-4m high. But because the fuels are finer and likely to be drier they're easier to ignite and therefore they're more likely to be prone to spot fire development especially if you have trees and shrubs around that are likely to provide embers and burning materials to start these spot fires.

However because of the fineness of the fuel they're unlikely to form a plume or convection driven processes unless they're associated with significant areas of forest. Why is that important? In 2019/2020 fires we saw a lot of plume driven convection driven fires. And that is a scale above what we would see in grasslands alone. You've got to be careful to understand there's a difference between grass fires and forest fires in this respect of how much they can scale up and interact with the atmosphere. So to try and help get a picture of how fires propagate and why the vertical structure is so important I've got a little video. And what I want you to watch is how the heat is not just all going up. Some of it is actually being drawn back into the fuel bed. And because it's a deep fuel bed and an open fuel bed the heat can go down and preheat the fuel and basically ignite the fuel from the bottom. It's not just burning across the top of the fuel here it actually burns down into it because of these hot gas vortices are driving the fuel down.

As this video starts this is the starting image. You'll see the hottest part of the fire is in the centre of the image. But as it progresses the hottest part keeps oscillating from left to right, left to right. So the flames are not just going up. You'll see some of them actually being curled back into the fuel bed. So the flame gives you a bit of a tracer of what's happening. But there's hot gases going down that you can't see as well into the fuel bed that's preheating the fuel. And it's one of the reasons why slashing a fuel and getting it flat on the ground for example reduces the rate of spread of the fire even though the total amount of heat output is still the same. It slows it down considerably because the heat transfer process is nowhere near as efficient.

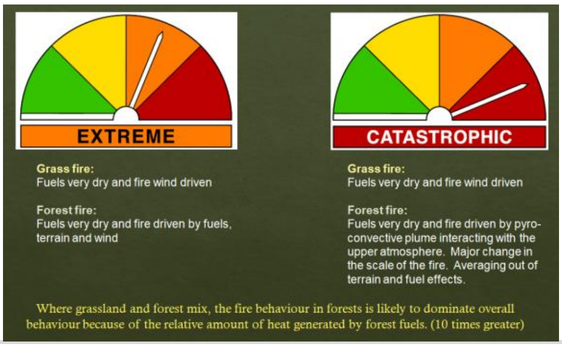
This has been done in a wind tunnel in Missoula in a lab in the US using an artificial fuel bed here which is actually cardboard rather than grass. But it simulates grass or stubble crops in itself. So we need to get our understanding that fires are being driven by convective heat and that heat is not just all going up. A lot of that heat is getting recirculated back down to ground level. And that's really important. So 80% of the heat being generated comes from this convective heat. And whilst the majority of it goes up into the atmosphere some of it does come back to the ground and a small proportion of 80% is still a lot of heat compared with the radiated heat. We focus too much on radiation because our eyes are attracted to that and we don't see the hot air as easily. We might see it if there's smoke in it or in this case radiating particles that we see as flames.

Here's an image of a grass fire in Western Victoria. What we can see here is the flame depth is very narrow. So it's only about 300mm deep. The flame height is about a metre high and that's largely to do with the height of the grass. But the depth of the flame is quite narrow and because the burnout time the residence time of the fuel is very short. Here's an image from a CSIRO experiment from quite a while ago back in the early 1990s late 1980s. This is fairly pure grasslands. Few trees scattered in here. But there are a number of things that I want you to see. One is that all these three fires were lit at the same time. This was from a point ignition. That was a 50m line. This was a 100m line. And what you can see here is that the fire that started with 100m has burned much quicker than the one from 50m or a point ignition. So the scale of the fire is important to how well it engages with the weather and is driven by the fire.

But what I want you also to see is that even though these fires were lit from a straight line they've ended up with a parabolic sort of head to them in the same way that the point ignition has. And that's partly because the heat that's rising off the burnt ground as well as the flame front is basically being drawn into the centre. And that heat drawing is basically controlling the flames pulling the flames in. So as the smoke or the heat from this fire is being directed by the wind the fire direction also changes. So in this case here there's a little bit of a shift of the wind to the left. This flank of the fire is quite active whereas the right hand flank here is quiet because the wind is just fluctuating in its direction a little bit and that will change from time to time.

But what we see again is a pretty shallow flame width because of the rapid burnout time. But the two heat sources the wind that's being driven horizontally across the ground and then the heat driving air upwards and the resultant of those two interactions is what we see in the fire. So grass fires can spread quite fast, 20km/hr for an average rate of spread is quite fast compared with a forest where the maximum might be around 12km/hr. However it's important to say and you'll hear lots of people make reports but the fire can spread quicker than that for up to 200-400m in about 10 or 20 seconds. So basically what's happening there is you have these pyrolyzed flammable gases being blown ahead of the fire setting fire to the grass in front of it. But it can't sustain for very long because it's just been a build up of these gases that's being blown forward. But 200 to 400m is quite a distance. To suddenly think you're a long way from the fire to suddenly have the fire at your feet because the gases have been blown across the fuel and suddenly set fire to it. So there can be instances where the fire spreads as fast as the wind but it can't be sustained. It's only for a matter of seconds.

When we're talking about how far a fire can spread in an hour 20km is getting up there. There are reports of up to about 30km/hr for 40 minutes but not sustained for the full hour. Grassfire spreads strongly driven by wind. So the rate of spread of grass is approximately equal to 20% (or a fifth of the average wind speed). So there's a little rule of thumb you can use. Miguel Cruz came up with that one. If you double the wind speed you basically double the rate at which the fire goes - there's a proportional relationship. So if the wind speed goes from 20km/hr to 40km/hr the rate of spread would go from 4km/hr to 8km/hr. So if you're doubling the wind speed you're doubling the rate of spread of the fire. Wind is really important in driving it once it's cured.



Under Extreme conditions the grass fuel will be very dry and strongly wind driven. In forest fuels very similar. So it'd be driven by the wind but also terrain. In Catastrophic conditions we're basically looking at same for grass but forest fires can go that one step further and be basically convection driven or plume driven because of the interaction with the upper atmosphere. There's just not enough heat being able to be generated at one time to have that same interaction. But as the winds get stronger the fires will go faster. So where grassland and forest mix the fire behaviour of forests is likely to be dominated by the forest fuels just because of the amount of fuel that's there. So it's often about 10 times as much fuel in a forest as there is in grassland.

Grass condition is considered to be more relevant to fire behaviour than the quantity. On the top left hand corner all the seed heads are still basically intact. Grazed on the top right where there's been some disruption to it such as slashing it or grazing it. And the rate of spread here would only be 80% of what it would be in the natural. And then there's eaten out with a rate of spread that'd only be about half of that in the natural because the fuels are so discontinuous. Compared with a bushfire where we can see here because of the convection being driven. All these spot fires are being drawn into the main plume. So this is when people talk about the fire creating their own weather. That's less likely to occur in grass fire because there's not as much heat being generated.

A simulation from 2009 on Pine Ridge Road. We can see the fire is largely being driven by the prevailing winds so that's the direction the fires going. But when you look closely at what's happening with the fires, they're coming from all directions. So people in Pine Ridge Road would

have experienced fires coming at them from all directions because of the wind terrain interaction. And that wind terrain interaction is very complex. This is like a weather simulation of wind across landscape. What we're seeing here the different colours are showing different wind strength. But we've got the prevailing wind coming from the west. But here's some wind channelling showing the wind going from the south. At the ridge top it's going faster because of the acceleration over the top. On the lee side of the hill there's eddy formation. The wind's coming in the opposite direction so it's much more complex than you might imagine.

Where you live in the landscape and the direction the wind is coming from may affect the winds and the direction the fire might travel to. Just because you're on a sheltered slope or an easterly slope or a southerly slope doesn't necessarily mean you're going to be less exposed to fire. In fact you could be even more severely impacted by fire because the winds are being affected by the topography. So you can get a lot more information from this fantastic book Grassfires Fuel, weather and fire behaviour second edition Phil Cheney and Andrew Sullivan 2008 And if you go searching on the internet you'll find a number of PyroPages that CSIRO have published. They talk about lots of things including our grass fires.

In summary. Grass fires can be lethal. Grass fires can travel rapidly across the landscape, faster than forest fires. Grass fires spread at rates vary dependent on the fuel dryness and the wind speed and direction. But winds can be very variable depending on the topography. Grass fuel structure rather than fuel load has the biggest impact on fire behaviour. So even slashing grass will reduce the rate of spread of the fire even though all the fuel is still there. If you remove the fuel as well that's even better. Grass fires alone cannot become pyro convective like forest fires so there's a limit to how much they can scale up in comparison. But where they're mixed with forest they can be very dangerous because you're getting almost the worst of both worlds. Very fast moving fires but also the spotting process and the ability to have very large fires. And then you can have interactions with plumes.

Thank you for listening. That was quite a quick run through but hopefully you'll get a bit of a feeling for what grass fires can do. Thank you.