A prescribed burning risk assessment tool (BRAT)

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Abstract

The Prescribed Burn Risk Assessment Tool (BRAT) aims to improve the planning and conduct of prescribed burns. It provides the fire manager with a means to assess the risk of the fire escaping (likelihood of impact), the potential to do damage if it does escape (consequence), the effects of escape mitigation strategies in reducing the probability of escapes, and the potential benefits of the operation in meeting fire management objectives (benefits). This tool uses the concepts outlined in the Australian Standard for Risk Management (AS/NZS 4360:2004), a Standard applicable to a wide range of industries and situations. This standard provides a framework for establishing the risk management context and methods of analysis, evaluation, treatment, monitoring and communication of risk.

The practitioner enters a ”low”, “moderate” or “high” rating for each of the escape risk factors, potential impact factors and the potential risk reduction benefit of the burn. These ratings are based on a defined range of conditions for each factor. The spreadsheet then calculates the risk score for that criterion and combines them for all factors to produce an overall risk rating for the likelihood of the fire escaping, the risk of causing damage and the level of benefit to be potentially gained by a successful operation.

Assessing the degree of risk associated with performing prescribed burning is by its nature a very subjective process. This Burn Risk Assessment Tool is an attempt to introduce a degree of objectivity, consistency and reproducibility into the process. This is achieved by quantifying the factors used, standardising their relative importance and putting them into a consistent framework.

The greatest advantage of performing this assessment is that it allows the practitioner to identify the criteria which have the greatest influence on the level of risk associated with a prescribed burn. If this risk assessment indicates that the burn has an unacceptable risk profile, then the practitioner can examine how modifying selected criteria will change the burn’s risk profile. By doing this, the optimum conditions, level and type of resources; type and level of pre-burn works can be identified and applied for the safer conduct of the burn. This process also provides a record of the risk assessment process for all prescribed burns which can be used to assess operational performance and to quantify improvements in risk management.

The concepts developed, methods used and some of the results will be discussed. Future use and development of the model are also discussed.

Keywords

Prescribed burning, risk assessment, likelihood, consequence

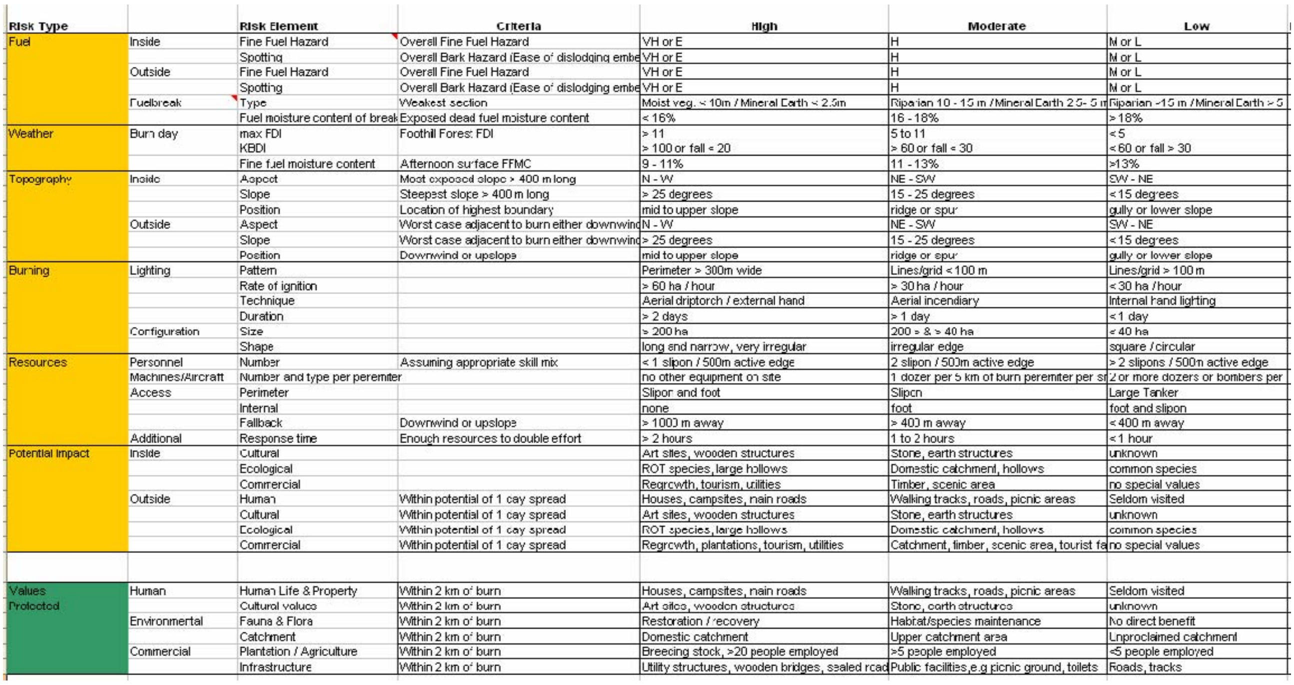
Background

Following a number of escaped prescribed burns over several years, the Department of Sustainability and Environment recognised the need for a prescribed burn risk assessment tool. In Australia, the only available risk assessment tool was the Forestry Tasmania burning risk assessment system (Marsden-Smedley and Chuter 1999). Although the system was designed for use in both low and high intensity prescribed burning, it is mainly used for post-harvest regeneration burning in eucalypt forest and does not cover all the factors required to be assessed for fuel reduction / ecological burning. Hence Tolhurst and Slijepcevic started to develop a tool which covered a broader range of factors and also differentiated between planning and operational phases of prescribed burning.

Tool development

The first tool was developed for foothill forests in Victoria. Initially, all elements that have impact on prescribed burns were listed and then divided into risk types: fuel, weather, topography, burning (lighting technique etc) and resources (Fig. 1 & 2). The tool was designed to allow the assessment at both phases, planning and operational. It also included the potential impact of burn inside and outside (if escape occurs) as well as the benefit to the "triple bottom line" if the burn is successful (social, environmental, economic).

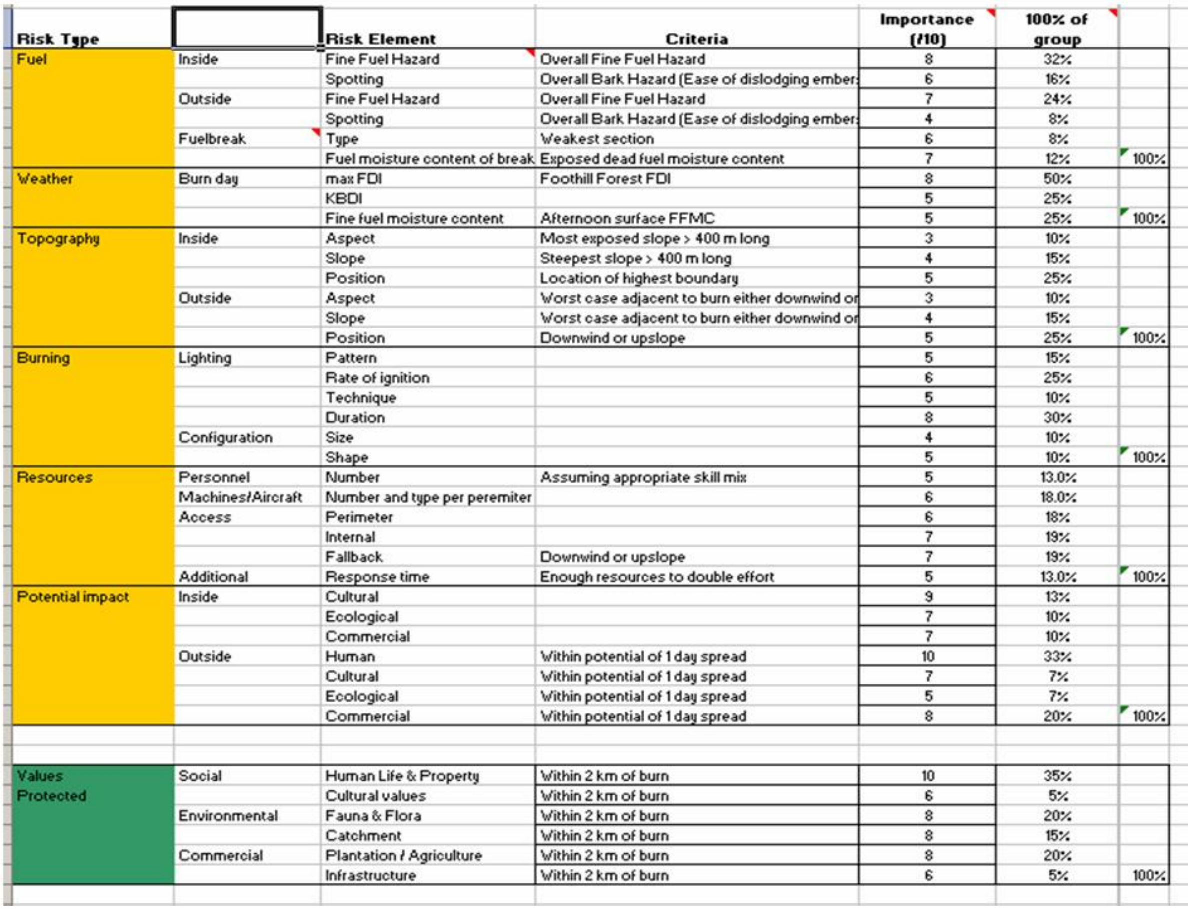
Each risk element has to be assessed as "low", "moderate" or "high" risk depending on the condition of each risk element. Critieria have been set up for each risk element. Some of these are shown in Fig. 1.



Risk Type		Risk Element	Criteria	High	Moderate	Low
Fuel	Inside	Fine Fuel Hazard	Overall Fine Fuel Hazard	VH or E	H	M or L
		Spotting	Overall Bark Hazard (Ease of dislodging embe	VH or E	H	M or L
	Outside	Fine Fuel Hazard	Overall Fine Fuel Hazard	VH or E	H	M or L
		Spotting	Overall Bark Hazard (Ease of dislodging embe	VH or E	H	M or L
	Fuelbreak	Type	Weakest section	Moist veg. < 10m / Mineral Earth < 2.5m	Riparian 10 - 15 m / Mineral Earth 2.5- 5 m	Riparian >15 m / Mineral Earth > 5
		Fuel moisture content of break	Exposed dead fuel moisture content	< 16%	16 - 18%	> 18%
Weather	Burn day	max FDI	Foothill Forest FDI	> 11	5 to 11	< 5
		KBDI		> 100 or fall < 20	> 60 or fall < 30	< 60 or fall > 30
		Fine fuel moisture content	Afternoon surface FFMC	9 - 11%	11 - 13%	>13%
Topography	Inside	Aspect	Most exposed slope > 400 m long	N - W	NE - SW	SW - NE
		Slope	Steepest slope > 400 m long	> 25 degrees	15 - 25 degrees	< 15 degrees
		Position	Location of highest boundary	mid to upper slope	ridge or spur	gully or lower slope
	Outside	Aspect	Worst case adjacent to burn either downwind	N - W	NE - SW	SW - NE
		Slope	Worst case adjacent to burn either downwind	> 25 degrees	15 - 25 degrees	< 15 degrees
		Position	Downwind or upslope	mid to upper slope	ridge or spur	gully or lower slope
Burning	Lighting	Pattern		Perimeter > 300m wide	Lines/grid < 100 m	Lines/grid > 100 m
		Rate of ignition		> 60 ha / hour	> 30 ha / hour	< 30 ha / hour
		Technique		Aerial driptorch / external hand	Aerial incendiary	Internal hand lighting
		Duration		> 2 days	> 1 day	< 1 day
	Configuration	Size		> 200 ha	200 > & > 40 ha	< 40 ha
		Shape		long and narrow, very irregular	irregular edge	square / circular
Resources	Personnel	Number	Assuming appropriate skill mix	< 1 slipon / 500m active edge	2 slipon / 500m active edge	> 2 slipons / 500m active edge
	Machines/Aircraft	Number and type per peremiter		no other equipment on site	1 dozer per 5 km of burn peremiter per sh	2 or more dozers or bombers per
	Access	Perimeter		Slipon and foot	Slipon	Large Tanker
		Internal		none	foot	foot and slipon
		Fallback	Downwind or upslope	> 1000 m away	> 400 m away	< 400 m away
	Additional	Response time	Enough resources to double effort	> 2 hours	1 to 2 hours	< 1 hour
Potential Impact	Inside	Cultural		Art sites, wooden structures	Stone, earth structures	unknown
		Ecological		ROT species, large hollows	Domestic catchment, hollows	common species
		Commercial		Regrowth, tourism, utilities	Timber, scenic area	no special values
	Outside	Human	Within potential of 1 day spread	Houses, campsites, main roads	Walking tracks, roads, picnic areas	Seldom visited
		Cultural	Within potential of 1 day spread	Art sites, wooden structures	Stone, earth structures	unknown
		Ecological	Within potential of 1 day spread	ROT species, large hollows	Domestic catchment, hollows	common species
		Commercial	Within potential of 1 day spread	Regrowth, plantations, tourism, utilities	Catchment, timber, scenic area, tourist fa	no special values
Values Protected	Human	Human Life & Property	Within 2 km of burn	Houses, campsites, main roads	Walking tracks, roads, picnic areas	Seldom visited
		Cultural values	Within 2 km of burn	Art sites, wooden structures	Stone, earth structures	unknown
	Environmental	Fauna & Flora	Within 2 km of burn	Restoration / recovery	Habitat/species maintenance	No direct benefit
		Catchment	Within 2 km of burn	Domestic catchment	Upper catchment area	Unproclaimed catchment
	Commercial	Plantation / Agriculture	Within 2 km of burn	Breeding stock, >20 people employed	>5 people employed	<5 people employed
		Infrastructure	Within 2 km of burn	Utility structures, wooden bridges, sealed road	Public facilities,e.g picnic ground, toilets	Roads, tracks

Figure 1. Some of the risk elements and the criteria used to classify them as being "low", "moderate" or "high" levels of risk.

Each element received an importance value which is a number from 1 to 10 used to indicate the level of contribution to the likelihood of a prescribed burn escape (Fig. 2). Also each element within each risk type was weighted according to the relative contribution it made to the risk type (the sum of all elements in a risk type totals 100%). Initially, the risk was calculated for each separate risk type and if any risk type returned a "high" risk value, the overall risk rating for a burn was considered to be "high". After testing, it was realised that the majority of burns would be "high" risk burns as for almost every burn at least one of the risk types "high".

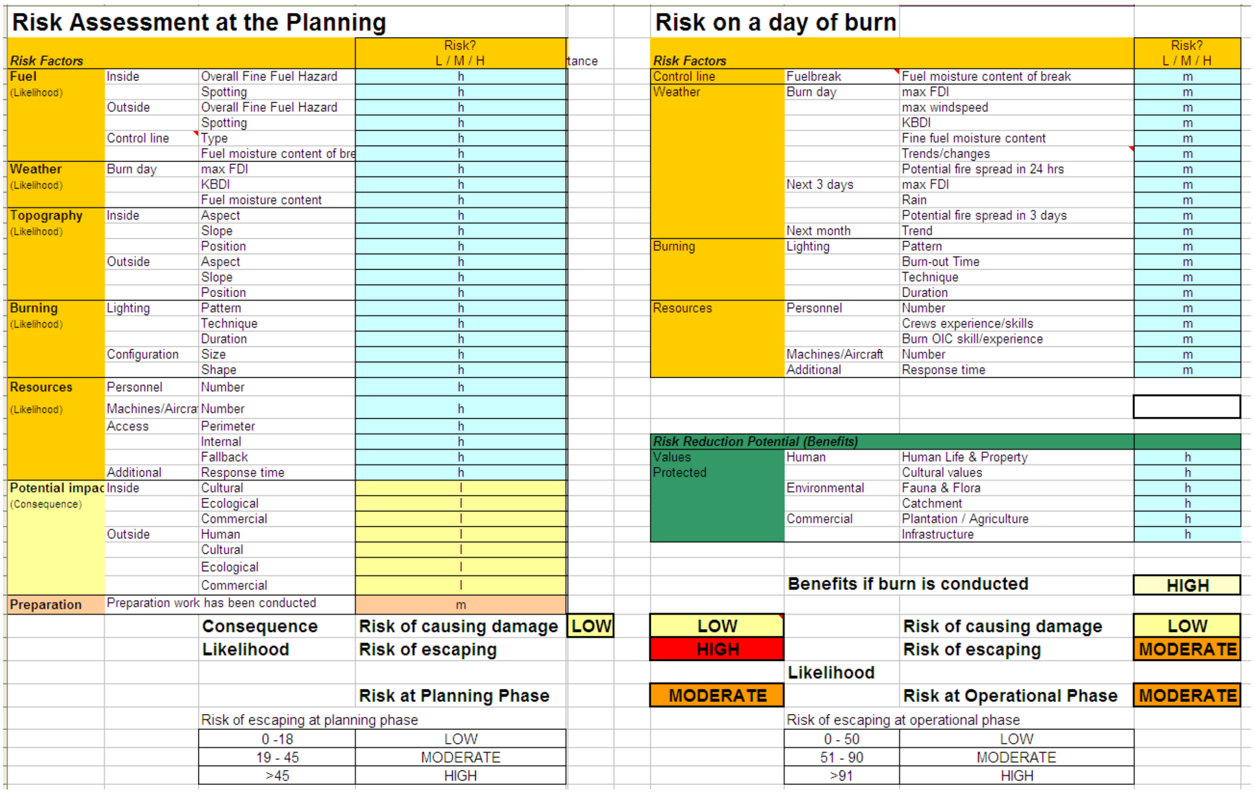


Risk Type		Risk Element	Criteria	Importance (/10)	100% of group	
Fuel	Inside	Fine Fuel Hazard	Overall Fine Fuel Hazard	8	32%	
		Spotting	Overall Bark Hazard (Ease of dislodging ember	6	16%	
	Outside	Fine Fuel Hazard	Overall Fine Fuel Hazard	7	24%	
		Spotting	Overall Bark Hazard (Ease of dislodging ember	4	8%	
	Fuelbreak	Type	Weakest section	6	8%	
		Fuel moisture content of break	Exposed dead fuel moisture content	7	12%	100%
Weather	Burn day	max FDI	Foothill Forest FDI	8	50%	
		KBDI		5	25%	
		Fine fuel moisture content	Afternoon surface FFMC	5	25%	100%
Topography	Inside	Aspect	Most exposed slope > 400 m long	3	10%	
		Slope	Steepest slope > 400 m long	4	15%	
		Position	Location of highest boundary	5	25%	
	Outside	Aspect	Worst case adjacent to burn either downwind or	3	10%	
		Slope	Worst case adjacent to burn either downwind or	4	15%	
		Position	Downwind or upslope	5	25%	100%
Burning	Lighting	Pattern		5	15%	
		Rate of ignition		6	25%	
		Technique		5	10%	
		Duration		8	30%	
	Configuration	Size		4	10%	
		Shape		5	10%	100%
Resources	Personnel	Number	Assuming appropriate skill mix	5	13.0%	
	Machines/Aircraft	Number and type per peremiter		6	18.0%	
	Access	Perimeter		6	18%	
		Internal		7	19%	
		Fallback	Downwind or upslope	7	19%	
	Additional	Response time	Enough resources to double effort	5	13.0%	100%
Potential impact	Inside	Cultural		9	13%	
		Ecological		7	10%	
		Commercial		7	10%	
	Outside	Human	Within potential of 1 day spread	10	33%	
		Cultural	Within potential of 1 day spread	7	7%	
		Ecological	Within potential of 1 day spread	5	7%	
		Commercial	Within potential of 1 day spread	8	20%	100%
Values Protected	Social	Human Life & Property	Within 2 km of burn	10	35%	
		Cultural values	Within 2 km of burn	6	5%	
	Environmental	Fauna & Flora	Within 2 km of burn	8	20%	
		Catchment	Within 2 km of burn	8	15%	
	Commercial	Plantation / Agriculture	Within 2 km of burn	8	20%	
		Infrastructure	Within 2 km of burn	6	5%	100%

Figure 2. A portion of the list of risk criteria and their relative importance rating and percentage contribution to each Risk Type.

The method of calculating the risk levels was modified so that the combined risk score was divided into three classes. These class divisions were based on the factors contributing to situations where prescribed burns had escaped in the past. In addition, feedback from operational personnel, indicated the need to include whether or not there had been prior preparation works conducted in the days or weeks in advance of the prescribed burn such as edge lighting or candling as a risk minimisation factor. The final risk assessment form is shown in (Figure 3).

A subsequent version included the interaction between various elements. For example interaction between and the impact of fine fuel moisture, KBDI and overall fuel hazard (McCarthy *et al.* 2003) on level of risk associated with prescribed Forest Fire Danger Index (McArthur 1973). These interactions were developed using the expert assessment.



Risk Assessment at the Planning

Risk Factors			Risk? L / M / H	tance
Fuel (Likelihood)	Inside	Overall Fine Fuel Hazard	h	
		Spotting	h	
	Outside	Overall Fine Fuel Hazard	h	
		Spotting	h	
	Control line	Type	h	
		Fuel moisture content of bre	h	
Weather (Likelihood)	Burn day	max FDI	h	
		KBDI	h	
		Fuel moisture content	h	
Topography (Likelihood)	Inside	Aspect	h	
		Slope	h	
		Position	h	
	Outside	Aspect	h	
		Slope	h	
		Position	h	
Burning (Likelihood)	Lighting	Pattern	h	
		Technique	h	
		Duration	h	
	Configuration	Size	h	
		Shape	h	
Resources (Likelihood)	Personnel	Number	h	
	Machines/Aircra	Number	h	
	Access	Perimeter	h	
		Internal	h	
		Fallback	h	
	Additional	Response time	h	
Potential impac (Consequence)	Inside	Cultural	l	
		Ecological	l	
		Commercial	l	
	Outside	Human	l	
		Cultural	l	
		Ecological	l	
		Commercial	l	
Preparation	Preparation work has been conducted		m	

Risk on a day of burn

Risk Factors			Risk? L / M / H
Control line	Fuelbreak	Fuel moisture content of break	m
Weather	Burn day	max FDI	m
		max windspeed	m
		KBDI	m
		Fine fuel moisture content	m
		Trends/changes	m
		Potential fire spread in 24 hrs	m
	Next 3 days	max FDI	m
		Rain	m
		Potential fire spread in 3 days	m
	Next month	Trend	m
Burning	Lighting	Pattern	m
		Burn-out Time	m
		Technique	m
		Duration	m
Resources	Personnel	Number	m
		Crews experience/skills	m
		Burn OIC skill/experience	m
	Machines/Aircraft	Number	m
	Additional	Response time	m

Risk Reduction Potential (Benefits)			
Values Protected	Human	Human Life & Property	h
		Cultural values	h
	Environmental	Fauna & Flora	h
		Catchment	h
	Commercial	Plantation / Agriculture	h
		Infrastructure	h

Benefits if burn is conducted		**HIGH**

Consequence	**Risk of causing damage**	**LOW**	**LOW**		**Risk of causing damage**	**LOW**
Likelihood	**Risk of escaping**		**HIGH**		**Risk of escaping**	**MODERATE**
				Likelihood		
	Risk at Planning Phase		**MODERATE**		**Risk at Operational Phase**	**MODERATE**

Risk of escaping at planning phase

0 -18	LOW
19 - 45	MODERATE
>45	HIGH

Risk of escaping at operational phase

0 - 50	LOW
51 - 90	MODERATE
>91	HIGH

Figure 3. Prescribed burning assessment tool.

The possible use of the tool

It is envisaged that this tool will be incorporated into the DSE's FireWeb (fireweb.dse.vic.gov.au) and be a standard component of the burn records. Also the risk assessment will determine the required level of approval based on risk category. For example a moderate risk burn will require approval from the local Fire Management Officer while high risk burn will require approval from the Regional Fire Manager.

As this tool was developed for foothill forests, it will have to be adapted to other vegetation/fuel types as weather prescriptions are fuel type dependent. Also not all risk elements will be applicable to all other fuel types and some new could be potentially introduced. The following section provides an example of tool adaptation to buttongrass moorland in Tasmania.

Operational use of the tool

Limited "field testing" of the tool has been undertaken to determine risks for a range of prescribed burns. At the planning phase use of the tool identified proposed prescribed burns with high risk levels. Risk modelling of such burns using the tool enabled quick identification of one or more risk elements which could be modified to reduce the risk level. This was generally achieved by reducing burn size, adjusting burn boundaries (shape) or varying the ignition pattern proposed. Planning to conduct burns under more appropriate seasonal conditions was also shown to effectively reduce the risk level at the planning stage.

At the implementation stage use of the tool was used to ensure the combination of burn day weather parameters and operational resourcing enabled burns to be conducted with managed risk levels.

As mentioned above incorporation of the tool into DSE's Fireweb will improve its useability with many risk factors/parameters being automatically populated using the spatial characteristics of each burn.

Further refinement and development of the tool

Some retrospective application of the tool to well documented prescribed burn escapes enabled both investigation recommendations to be confirmed, and the tool's element importance values to be tested and verified. Application to a wider set of such events will help to refine the tool further.

Eventually a condensed version of the tool focussing on spatially recorded risk factors could be developed to assist DSE's fire operations planning process (medium timeframe) by quickly delineating potential areas for prescribed burning which would have manageable risk and yet provide maximum community benefits.

Tool adaptation - Modifying the risk assessment tool for prescribed burning on buttongrass moorland.

In Tasmania, prescribed burning is conducted in buttongrass moorlands for a variety of reasons (Marsden-Smedley *et al.* 1999; Marsden-Smedley and Kirkpatrick 2000), including:

- maximising public safety and minimising economic costs through the reduction of wildfire threat;
- protecting rare and/or vulnerable fire sensitive vegetation in the adjacent areas;
- maintaining buttongrass moorland biodiversity through the provision of a mosaic of age classes, fire sizes, fire intensities and season of burning, and;
- asset protection for agricultural, forestry and built infrastructure.

During buttongrass moorland prescribed burning the high rates of fire spread and intensity are such that direct fire control is not normally possible. In addition, burning is conducted using two main strategies: bounded versus unbounded burning. Bounded burning involves utilising hard fuel boundaries to stop the fires while unbounded burning requires fires to self-extinguish within the buttongrass moorland without relying on firebreaks. During bounded burning the key factor determining the burn's risk is the flammability of the moorland's boundary which is estimated using the soil dryness index (SDI, Mount 1972). During unbounded burning the key factors determining the burn's risk are the overnight wind speed, humidity and precipitation which influence the probability of the fire's self-extinguishing (see Marsden-Smedley *et al.* 1999, 2001).

Due to buttongrass moorland prescribed burning utilising different strategies to those used in dry forests, some of the parameters required for assessing risk also need to be significantly different. Within the risk parameters that remained consistent for both vegetation types, some of the factors require modification to comply more closely with Tasmanian requirements. The following paragraphs detail some of the specific changes made.

Fuel

For dry forest burning, the fuel risk is based on the Overall Fuel Hazard Guide (McCarthy *et al.* 2003). In contrast, in buttongrass moorlands the fuel risk is best described using the time since fire (Marsden-Smedley and Catchpole 1995). The spotting hazard within buttongrass moorland is best associated with the height of the flashy vegetation (heath and shrubs).

The outside fuel risk is very dependent on the type of vegetation that borders the moorland. This can vary from more moorland, to sclerophyll shrub or wet forest. To try and capture all these possible variations, the fuel load (t/ha) has been used.

Boundary

The burn's boundary is the key driver of the overall likelihood risk (Marsden-Smedley *et al*. 1999). This risk element is a combination of the boundary type, the boundary width of the, and the SDI. The risk assessment tool has been set up so the operator inputs the three different elements, and the overall risk for the type is based on the relationship between the three elements. Determining the risk in this manner allows the different risk profiles between bounded and unbounded burns to be compared.

Weather
Unlike dry forest vegetation, the weather parameter for moorland fire behaviour is a combination of the Moorland Fire Danger Rating (Marsden-Smedley *et al.* 1999) and the soil dryness index (rather than fuel moisture content). These risk elements are measured for the burn day, the next day and maximum forecast for the next five days. These are important elements for operators to consider, as these parameters need to be defined, especially for unbounded burning, at the planning stage.

Seasonal Conditions
The time of year (month) and the number of days since it last rained (≥2 mm) has been introduced to the risk assessment system. This has been done to address seasonal limitations in the SDI and since different weather conditions typically occur between the autumn and spring prescribed burning seasons.

Topography
This element is not as critical in buttongrass moorlands as it is in dry forests. Only the slope is seen as a contributor, for both inside the burning block and in the adjacent area.

Burning
In buttongrass moorlands the critical ignition risk factor are considered to be the time available for weather changes to occur (and hence adversely affect fire behaviour) and the ignition spacing where a grid ignition of more than 100 m apart allows for increased fire build-up time and therefore increased fire intensity when the fires draw together.

Resources
The boundary type and SDI have a major bearing on the resources required for burning. Also, as some buttongrass fires are unbounded with no vehicular access, the burn's risk has been determined by integrating the boundary type with resources required. For example, if the overall boundary risk is high, with poor access, then more resources may be required. However a low risk boundary, with good access, significantly reduces the risk profile of the resource requirements.

Potential Impact
The additional consideration of recreational value has been added to this section. The distance parameters have also been changed, reflecting the typically different fire behaviour of buttongrass and faster rates of spread.

Conclusion

Assessing the degree of risk associated with performing prescribed burning is by its nature a very subjective process. This risk assessment tool (BRAT) is an attempt to introduce a degree of objectivity into the process which is managed by quantifying the factors used, standardising their relative importance and putting them into a consistent framework. BRAT integrates the effect of variation in importance between different criteria and the effect of variation within each criterion.

The greatest benefit of performing this assessment is that it allows the practitioner to identify the criteria which have the greatest influence on the level of risk associated with a prescribed burn. If this risk assessment indicates that the burn has an unacceptable risk profile, then the practitioner can examine how modifying selected criteria change the burn's risk profile. By doing this, the optimum conditions, level and type of resources; type and level of pre-burn works can be identified and applied for the safer conduct of the burn. This process also provides a record of the risk assessment process for all prescribed burns which can be used to assess operational performance and to quantify improvements in risk management.

Acknowledgments

We would like to thank all DSE and Parks Victoria staff that tested various draft versions of this tool, especially Kevin Giblin for his frank feedback. The feedback received significantly improved this tool.

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