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GUIDANCE FRAMEWORK FOR THE SELECTION OF DIFFERENT FUEL MANAGEMENT STRATEGIES

Mechanical Fuel Load Reduction Utilisation project

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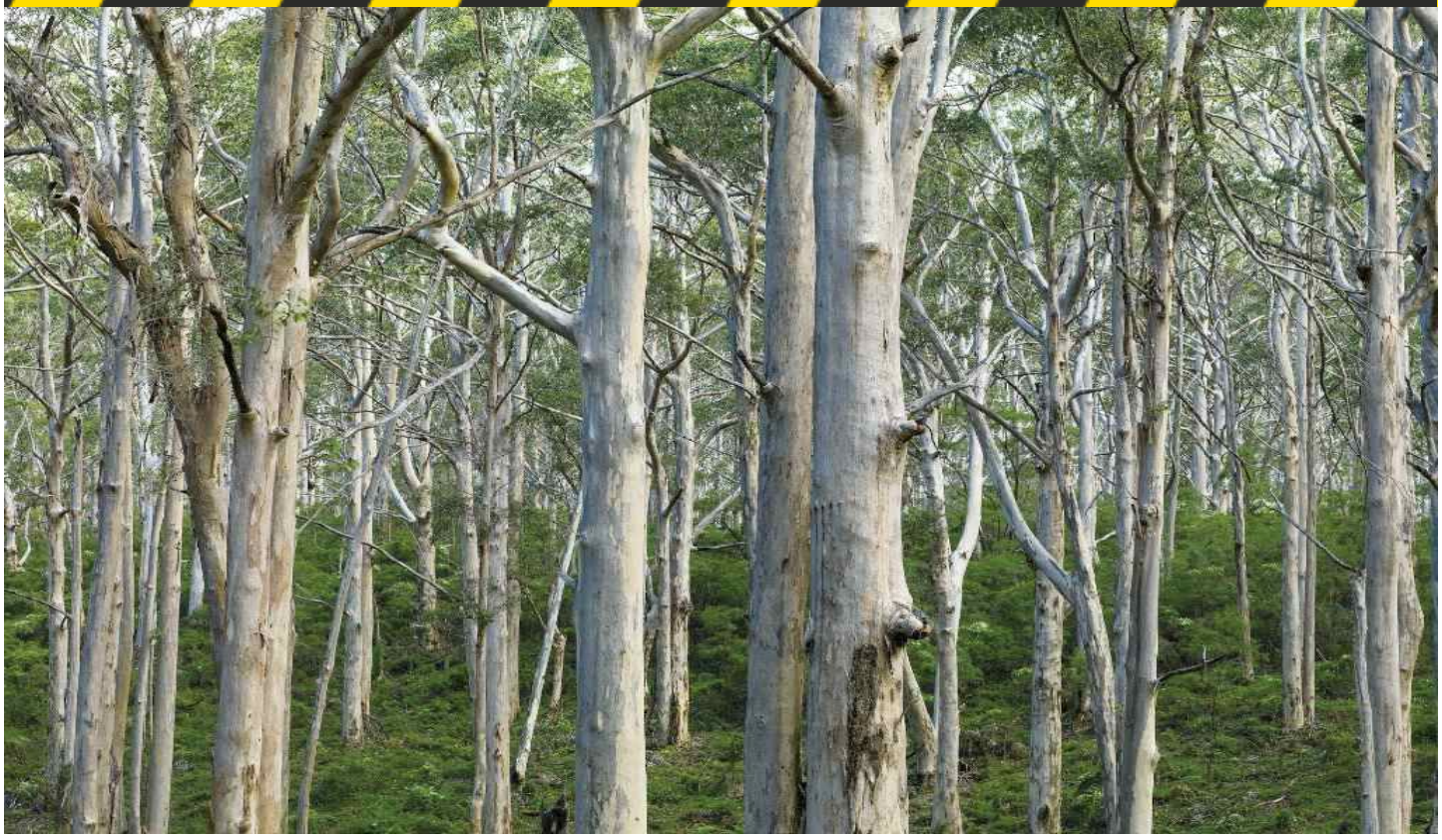

THE UNIVERSITY of ADELAIDE

GOVERNMENT OF WESTERN AUSTRALIA

DFES Department of Fire & Emergency Services

FOR A SAFER STATE

RIKS research institute for knowledge systems

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EXECUTIVE SUMMARY

Planned burning is one of the most utilised fuel management activities, but the safe application of this method is hindered by climate change (e.g. shrinking and shifting windows of opportunity) and adverse societal and environmental outcomes (e.g. smoke impact, risk of fire escape). For this reason, fire managers need access to detailed information to help them make informed decisions and select a fuel management strategy that is compatible with a range of factors.

This report focuses on the development and illustration of a general guidance framework that provides users with the information and knowledge they need to select suitable fuel management strategies for their particular circumstances, and hence assists them with preparing an effective fuel management plan. The framework is developed based on a review of literature and data collected from survey responses from local governments and their fire managers in Western Australia who conduct fuel management activities.

The framework provides information on a set of functions bushfire mitigation officers need to consider when developing fuel management plans for a range of fuel management techniques. The functions are divided into:

- specific drivers: timing of the activity (mainly linked to weather conditions and seasonality), terrain conditions (e.g. slope), landscape (e.g. vegetation, land use, soil type), presence of specific assets (e.g. residential developments, industrial developments, utility infrastructure, transport infrastructure, airports or cultural assets), presence of protected biodiversity elements, and other considerations;
- constraints, which can be linked to costs, benefits, and limitations (i.e. economic, social, environmental) related to the application of each fuel management activity; and
- resource availability, which can be connected to the equipment required to conduct mitigation activities or specific types of training.

The fuel management techniques include:

- mechanical fuel management techniques (forest thinning, scrub rolling / bush cutting, mulching, mowing / slashing, fire breaks and strategic access, parkland clearing); and
- other types of fuel management treatments (planned burning, pile burning, chipping, herbicide, grazing).

The utility of the framework is illustrated on two hypothetical scenarios, representing situations where a user would like to ascertain relevant attributes of a set of candidate fuel management techniques and where a user would like to identify the best fuel management technique for a given situation.

END-USER PROJECT IMPACT STATEMENT

Tim McNaught, *Department of Fire and Emergency Services, WA*

This research provides valuable insight into the decisions bushfire mitigation officers are making about bushfire mitigation treatment and the importance of local level context driving those decisions. Whilst this project has initially focused at the local government level, understanding the broader range of treatment activities that larger land management agencies undertake will be a complementary piece to this research.

This research has provided an important insight to guide the understanding and enhancements of policy and programs that can support local level management of bushfire related risk in Western Australia. It has provided insights into the varied range of activities that may be available to officers tasked with planning for and supervising treatment activities and identified where there are some gaps in experience and knowledge that may limit the range of treatment activities that local governments are utilising and raise further questions about why?

Additionally, this research will complement the Decision Support System for WA project with respect to providing insight into the suite of feasible treatment options currently utilised in WA.

1. INTRODUCTION

Planned burning is one of the most applied fuel management activities, but the safe application of this method is hindered by climate change (e.g. shrinking and shifting windows of opportunity) and adverse societal and environmental outcomes (e.g. smoke impact, risk of fire escape). For this reason, fire managers need access to detailed information to help them make informed decisions and select a fuel management strategy that is compatible with a range of factors.

This report focuses on the development and illustration of a general guidance framework that provides users with the information and knowledge they need to select suitable fuel management strategies for their particular circumstances, and hence assists them with preparing an effective fuel management plan. Use of the general guidance framework enables the following questions to be answered:

1. What are the most critical elements to consider when deciding if a fuel management activity can be conducted? Are there specific limitations?
2. When can each activity be conducted (i.e. window of opportunity)? When are these activities likely to be most effective?
3. Where can each activity be applied (e.g. proximity to classes of land use and vegetation type)?
4. What resources does each technique require, in terms of training, equipment, and materials?
5. What are the costs, benefits, and impacts (social and environmental) associated with each fuel management activity?

This framework can be used to define opportunities to apply different types of fuel management approaches under plausible future conditions for the locations identified in Milestone M3 (i.e. Gingin, Kalamunda, Mundaring and Margaret River) (M5, D3).

The remainder of this report is structured as follows. In Section 2, the general guidance framework is introduced, including the process used for its development. This is followed by an illustration of how the framework might be applied in practice under two different hypothetical scenarios in Section 3. This report concludes with an outline of future work (Section 4).

2. DEVELOPMENT OF GENERAL GUIDANCE FRAMEWORK

2.1 OVERVIEW

The general guidance framework was developed by identifying different potential fuel management strategies, as well as their various attributes (i.e. the information and knowledge needed to match different potential strategies with particular circumstances) (Figure 1). The attributes of the different potential fuel management strategies were determined with the aid of a combination of a literature review and an online stakeholder survey of local government in Western Australia (WA), thereby drawing on both general and local knowledge sources. Details of the different fuel management options considered, the literature review, the stakeholder survey and the developed general guidance framework are given in the subsequent sections.

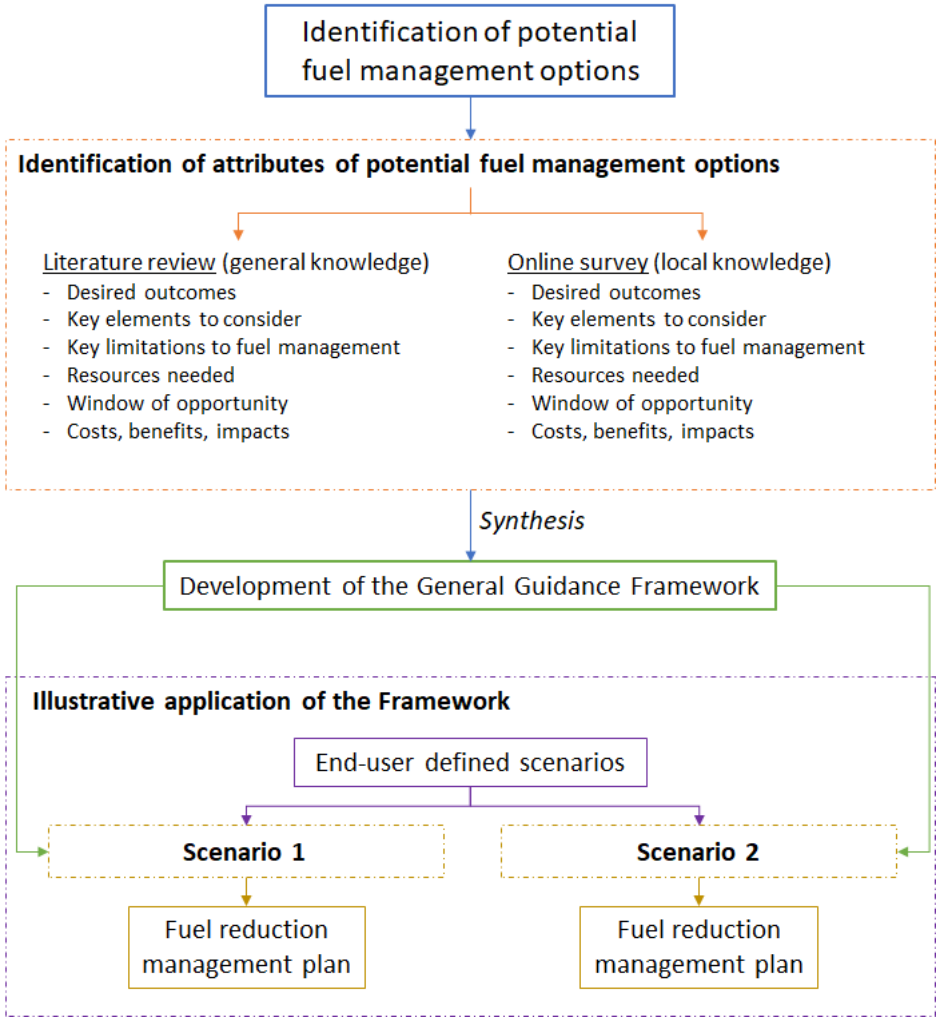

FIGURE 1. STEPS IN THE DEVELOPMENT OF THE GENERAL GUIDANCE FRAMEWORK.

2.2 POTENTIAL FUEL MANAGEMENT OPTIONS

Planned burning, mechanical fuel management and grazing are generally the most cited fuel reduction activities. However, the term "mechanical fuel management" is very broad and can be interpreted to mean different things by different people. To narrow down our research, we decided to focus on a selection of mechanical fuel reduction activities based on existing fuel management practices in WA. We give a brief description of each mechanical fuel reduction treatment below.

Forest thinning

Forest thinning is often used in plantation forests and aims to remove excess branches to encourage tree growth and increase diameter or remove young trees to increase spacing (Florence, 2004). In commercial forests, the main purpose of this technique is to make the stands more profitable for timber harvest. On the other hand, in conservation forests, ecological thinning favours the development of wildlife habitat, rather than focusing on increased timber yields (Horner et al., 2010, Gorrod et al., 2017). In these environments, thinning does not have to be applied uniformly and varying thinning densities can create structural and spatial heterogeneity, increasing biodiversity or wildlife habitat.

FIGURE 2. BEFORE AND AFTER EXAMPLE OF THINNING ACTIVITIES IN A EUCALYPT FOREST IN EAST GIPPSLAND (VICTORIA). SOURCE: KEENAN ET AL. (2020)

Scrub rolling

Scrub rolling is a form of mechanical fuel reduction commonly undertaken in vegetation communities with minimal ground cover and high levels of aerated fuels (mallee, mallee-heath, sandplains, scrub-heath) (OBRM, 2018). The aim is to 'lay over' vegetation to create a modified fuel zone or strip (20 -100m wide) strategically across the landscape to assist with both mitigation and suppression activities. These may be either permanent or temporary. Scrub rolling is only considered a cost-effective fuel reduction treatment when there is a commitment to ongoing management/maintenance to maintain risk reduction benefits over time.

The most common and cost-effective form of landscape-level scrub rolling involves dragging a large 'chain' between two bulldozers to create a fuel-reduced strip up to 100m wide, subsequently burnt under prescribed conditions. An alternative method is Blade-up Rolling, which involves using a bulldozer with a slightly elevated blade to push over vegetation. This produces a similar result, but is only cost-effective for treatment areas (strips) up to about 20m wide. There can be community acceptance issues with scrub rolling, as it is more commonly associated with broad-scale land clearing practices for mining or agricultural purposes, rather than as a targeted fuel management strategy.

FIGURE 3. SCRUB ROLLING. SOURCE: OBRM (2018)

FIGURE 4. SCRUB ROLLING RETREATMENT OF AN AREA THAT WAS PREVIOUSLY 'CHAINED'. SOURCE: OBRM (2018)

Mulching

Mulching is a land clearing method that uses a machine to cut, grind and clear vegetation (e.g. small trees, thinning products, shrubs). The mulch can then be spread across the cleared site to delay seedling regrowth, minimise erosion and return nutrient-rich organic matter to the soil. Mulching can become expensive in heavy forested fuels and the cost increases with distance form access roads. Mulching can also be visually unappealing if unsuitable equipment is used or if site is left untidy after treatment, thus reducing social acceptance (OBRM, 2018).

FIGURE 5. EXAMPLE OF MULCHING TREATMENT. SOURCE: WIKIMEDIA COMMONS (2013)

Slashing

Slashing involves the mowing of understorey vegetation and grasses, generally to less than 100mm high, to create a low-fuel area whilst still maintaining a live root structure. Slashed vegetation sits on top of the remaining live plants and acts as a mulch, which can also assist in slowing plant recovery, increasing long term benefits (OBRM, 2018).

FIGURE 6. BEFORE AND AFTER SLASHING WORK IN STURT GORGE RECREATION PARK (SOUTH AUSTRALIA). SOURCE: DEW (2020)

Parkland clearing

Parkland clearing can include a combination of mulching and slashing activities. It involves removing understorey vegetation and grasses to create a low fuel area whilst maintaining an overstory canopy (OBRM, 2018). Vertical separation can also be undertaken by either pruning or removing trees; however, mature

trees should be left in situ. The most effective method is mulching, where plant material is mulched and left on-site to decay. Ongoing management to maintain ground cover to less than 100mm high is recommended. While this is not the cheapest fuel reduction option, it is one of the most effective and easy to maintain once established.

FIGURE 7. 10M WIDE PARKLAND MULCHING NEXT TO EXISTING VEHICLE ACCESS TO CREATE A STRATEGIC BREAK. SOURCE: OBRM (2018)

Fire breaks and strategic access

Firebreaks involve the modification/separation of vegetation and are designed to slow or stop the spread of an unplanned fire or to provide a boundary for planned burning activities (OBRM, 2018). While the vegetation type, density and period since the last burn should all be considered when determining firebreak width and placement, private landholders must also ensure that they are compliant with the local government Section 33 Firebreak Notice relevant for their area. While these regulations do not bind state government agencies, it is good practice to ensure that where firebreaks are installed, they comply with the requirements outlined by the local government, as a minimum.

FIGURE 8. MAINTENANCE OF AN ACCESS TRACK (BEFORE AND AFTER). SOURCE: OBRM (2018)

Pile burning

Forest treatment residues (e.g. logging and thinning by-products) can be gathered in piles, which are then individually burned. Bundles are generally strategically placed before burning to minimise fire damage to nearby standing trees (Hunter et al., 2007). One of the main advantages of pile burning over large-scale planned burning is that the potential for an escaped fire is low and the prescription window is wide. Timber piles can be kept dry by covering them with plastic and burning them when environmental conditions are likely to prevent fire spread (autumn or winter) (Hunter et al., 2007).

FIGURE 9. EXAMPLE OF PILE-BURNING. SOURCE: YOSHIOKA ET AL. (2017)

Chipping

Chipping is a very similar technique to mulching, where a mobile chipper reduces trees into chips through slicing. One of the advantages of chipping, compared to mulching, is that it produces coarser material that is relatively uniform in size, and hence can be used for commercial applications (e.g. biomass energy). Chipping would be a good alternative to pile burning (i.e. reduced Co_2 emissions) if piles of timber had already been constructed (Rummer, 2010).

FIGURE 10. WOOD CHIPPER AND WOOD CHIPS. SOURCE: WIKIPEDIA

2.3 LITERATURE REVIEW APPROACH

To gather general knowledge on the attributes, suitability and requirements of the potential fuel management options summarised in Section 2.2, we searched for literature by the following criteria: keywords *fuel reduction* and **fire*[1] and the *name of the management* activity (Box 1) in the title, abstract, or the keywords of the Scopus indexed articles[2]. Then, all articles matching the selected keywords were downloaded and reviewed to answer the questions listed in Section 1.

BOX 1. SCOPUS QUERY AND LIST OF FUEL MANAGEMENT ACTIVITIES USED FOR THE LITERATURE SEARCH (IN THE TITLE, ABSTRACT, AND THE KEYWORDS OF THE SCOPUS INDEXED ARTICLES).

Scopus search

"fuel reduction" AND "*fire" OR:

"planned burning", "prescribed burning", "mechanic*", "slashing", "mulching", "scrub rolling", "forest thinning", "parkland clearing", "fire breaks", "grazing", "herbicide", "chemical treatment"

The Scopus search query produced 278 results including journal articles, book chapters, conference papers and technical reports. We screened these publications and excluded those that did not answer any of the questions listed in Section 1. If a publication answered at least one of the questions, it was retained. After the screening process, only 37 publications remained.

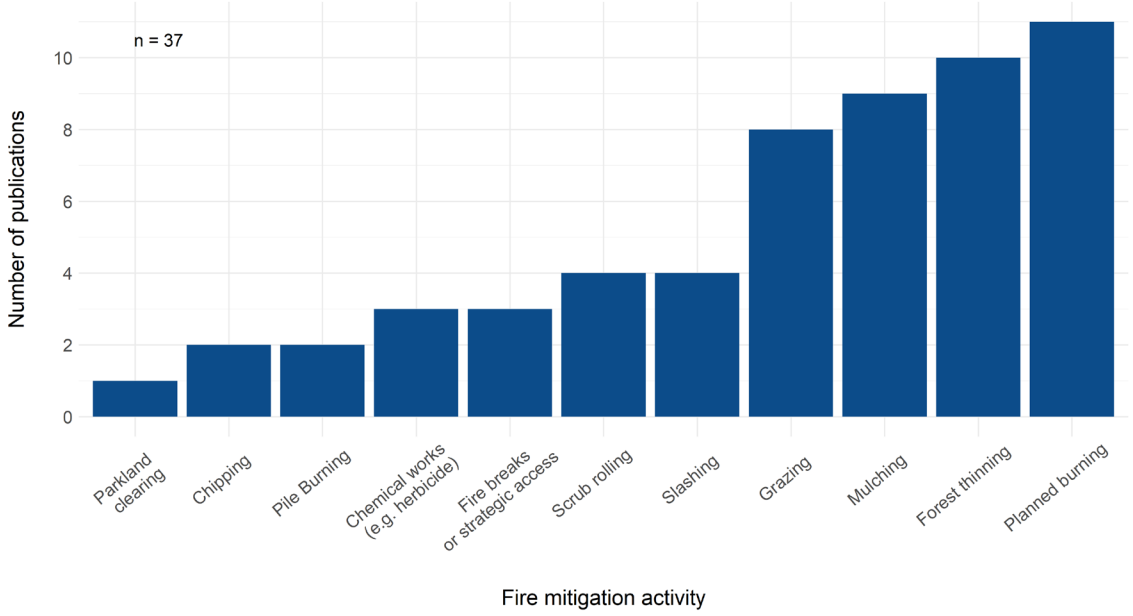

FIGURE 11. NUMBER OF PUBLICATION DISTRIBUTION AND FUEL MANAGEMENT ACTIVITIES.

There was a much greater number of publications covering planned burning (n = 12), forest thinning (n = 10), mulching (n = 9) and grazing (n = 8) as opposed to the other types of fuel management activities (Figure 11). However, we only found one reference mentioning parkland clearing (OBRM, 2018). This could be

[1] The wildcard symbol (*) represents the keywords: bushfire, wildfire and fire.

[2] https://www.scopus.com search conducted on 15/04/2021

explained by the choice of terminology, which might be specifically used in Australia, or the fact that parkland clearing involves the combination of multiple activities such as slashing, mulching or fire breaks.

2.4 ONLINE SURVEY

The online survey was designed for distribution to local governments and fire managers who conduct fuel management activities[3]. Use of a survey questionnaire, instead of interviews or focus groups, allowed for a larger number of participants to receive and respond to an exact set of questions within each location during a limited time period. The survey consisted of several short answer and multiple-choice questions, and both quantified and qualified answers using Likert scales and written responses (**Error! Reference source not found.**).

The questions were designed to collect local knowledge about the limitations and possibilities of applying different mitigation options at specific locations in WA to reduce bushfire risk. The survey was reviewed by the Department of Fire and Emergency Services (DFES) and was pre-tested by six DFES members over three iterations. Their feedback was used to improve the quality and readability of the final survey.

The questionnaire was designed to take respondents approximately 15 to 20 minutes to complete. It was distributed to 61 Local Government Bushfire Mitigation Officers (or similar) via the WA Local Government Association (WALGA) with an anonymous link to access the survey site over the internet. This survey was sent on 29 April 2021 and participants were given until 12 May 2021 to respond. Ideally, this survey could be replicated and sent to Bushfire Mitigation Officers from other states to obtain a broader picture of the factors needed to develop fuel reduction management plans in Australia.

Twenty responses were received from 20 distinct local governments by 14 May 2021 (Table 1). Overall, this corresponds to a 32.8% response rate, which is considered reasonable. In addition, four participants completed the survey for more than one activity, bringing the total number of entries to 25, covering seven out of the nine fuel management activities proposed (Figure 12).

[3] Bushfire Risk Mitigation Officers, Bushfire Mitigation Officers or contractors employed by Local Governments of southwest WA.

TABLE 1. PARTICIPATING LOCAL GOVERNMENTS AND ORGANISATIONS SUPPORTING MITIGATION IN THE LOCAL GOVERNMENT.

Local Government name	Organisations involved in fuel management activities
Albany	City of Albany, DFES, Department of Biodiversity, Conservation and Attractions (DBCA)
Augusta-Margaret River	Shire of Augusta-Margaret River, DBCA, DFES
Bassendean	Town of Bassendean
Boyup Brook	Shire of Boyup Brook
Bunbury	DFES
Claremont	DFES
Cockburn	City of Cockburn, DBCA, DFES
Cottesloe	Town of Cottesloe
Dardanup	Shire of Dardanup, DBCA
Donnybrook-Balingup	Shire of Donnybrook-Balingup, Forest Products Commission, DBCA
Fremantle	City of Fremantle
Gosnells	City of Gosnells, DFES
Jerramungup	Shire of Jerramungup, DFES
Kalamunda	Shire of Kalamunda - Contractor (Entire Fire), DFES, DBCA
Kwinana	City of Kwinana
Manjimup	Shire of Manjimup, DBCA, DFES
Melville	City of Melville
Rockingham	City of Rockingham - Parks Services, DFES
Serpentine-Jarrahdale	Shire of Serpentine-Jarrahdale, DFES
Stirling	City of Stirling, DFES, DBCA

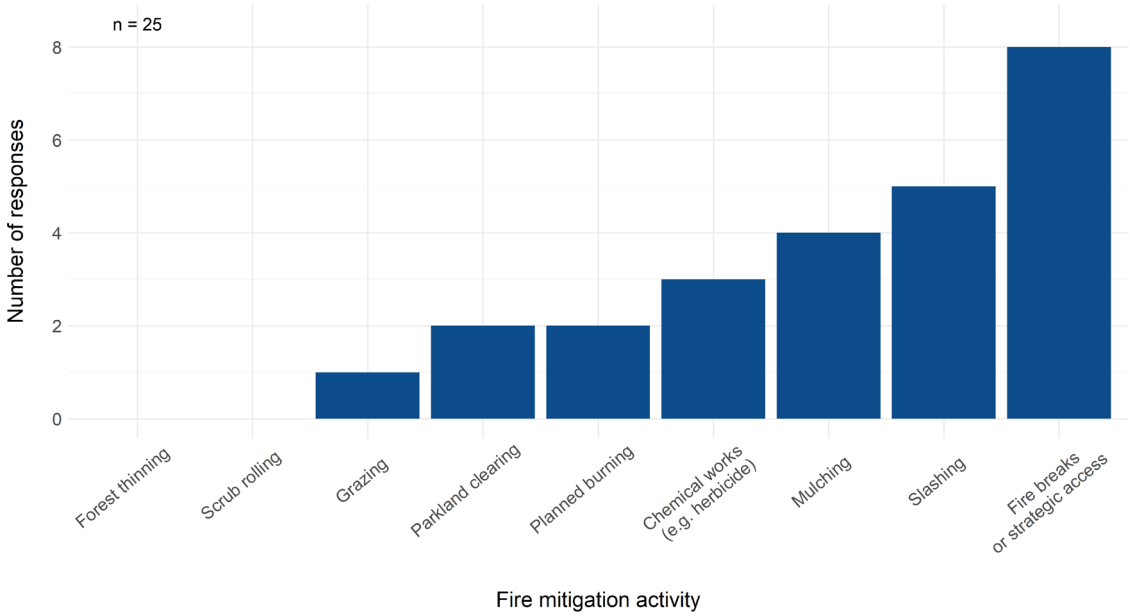

FIGURE 12. RESPONSE DISTRIBUTION AND FUEL MANAGEMENT ACTIVITIES.

All the mitigation activities for which we received data were covered at least twice, except for grazing. As it can be seen, no responses were received for scrub rolling and forest thinning as these activities are generally conducted by the Department of Biodiversity, Conservation and Attractions (DBCA) or Forest Products Commission, which were not included in the survey participants (Figure 12). However, these results had a minimal impact on the General Guidance Framework development as we collected enough general information through the literature review (Figure 11).

We also asked participants to rate their top four mitigation options for a range of land uses. Responses indicated that fire breaks and strategic access, herbicide application and slashing activities can generally be applied to most land-use types (Figure 13). On the other hand, planned burning is generally preferred for forestry, nature and conservation reserves, and unallocated crown (vacant) land. In contrast, grazing is generally preferred in agricultural landscapes such as intensive agriculture, mixed farming and grazing, livestock and pastures.

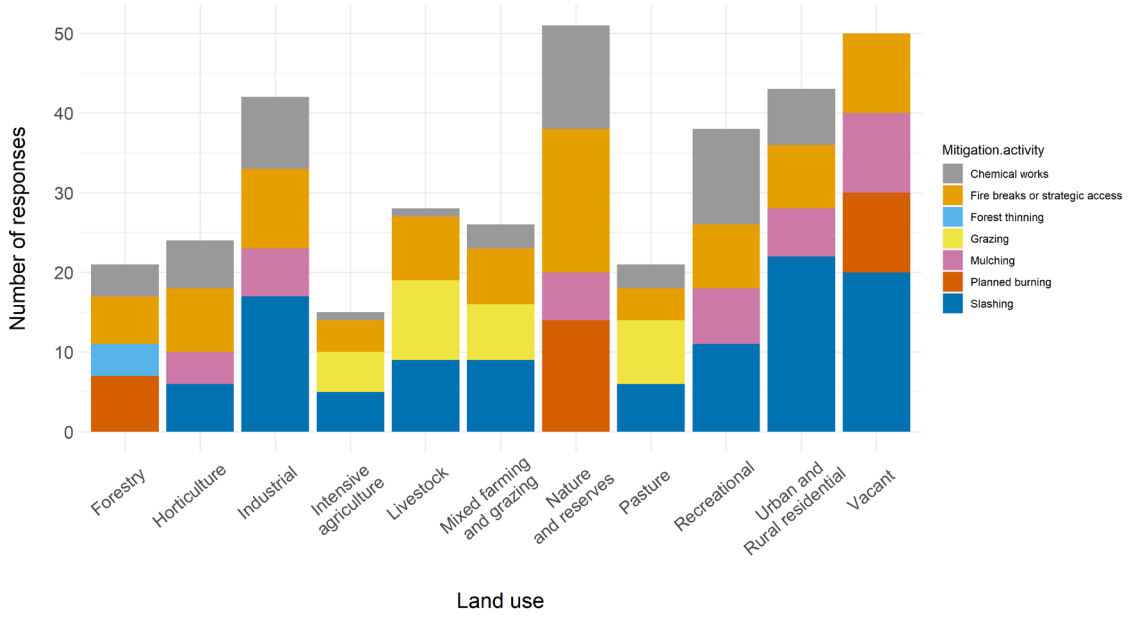

FIGURE 13. TOP FOUR MITIGATION ACTIVITIES PER LAND USES AND RESPONSE RATE.

2.5 GENERAL GUIDANCE FRAMEWORK

As mentioned previously, the main aim of this framework is to provide a simple and flexible way to select a range of appropriate fuel management activities, given a set of drivers, resources and constraints. To design the framework, we consulted the WA end-users to define a set of functions that Bushfire Mitigation Officers need to consider when creating a fuel management plan. These functions can be divided into specific drivers, constraints and resource availability. The specific drivers include timing of the activity (mainly linked to weather conditions and seasonality), terrain conditions (e.g. slope), landscape (e.g. vegetation, land use, soil type), presence of specific assets (e.g. residential developments, industrial developments, utility infrastructure, transport infrastructure, airports or cultural assets), presence of protected biodiversity elements, and other considerations. The constraint factors can be linked to costs (i.e. economic, social, environmental), benefits, and limitations related to the application of each fuel management activity. Finally, resource availability can be connected to the equipment required to conduct a mitigation activity or specific types of training required.

In order to populate the categories of the framework outlined above, the results from the literature review and the online survey were combined into summary tables (Table 2 and Table 3). Table 2 compiles information about mechanical fuel management techniques, while Table 3 presents selection criteria for other types of fuel management treatments. These tables can be used as a checklist to select a range of suitable fuel management activities given a set of drivers, resources and constraints.

The main functions defined in the previous section (specific drivers, constraints and resources availability) were divided into sub-categories (selection criteria) and are presented in rows. In contrast, the different fuel management options

are presented in columns, allowing for an easy cross-comparison for each set of selection criteria.

The results from the literature review and the online survey highlighted that some mitigation activities were more well-documented than others (e.g. forest thinning, mulching, grazing and planned burning). We can also notice that it was very difficult to obtain reliable information on the economic cost of different mitigation activities, resulting in very large cost ranges. Consequently, these figures need to be adjusted on a case-by-case basis. Overall, the information provided by the literature review and online survey were very complementary. The survey provided more in-depth knowledge on the specific benefits and limitations of mitigation activities, type of equipment and expertise required, specific driving factors and land use types where each mitigation activity can be applied. In contrast, the review provided a base knowledge for the fuel management options that were not covered by the survey's results (e.g. forest thinning, scrub rolling, chipping and pile burning). Thus, the online survey could be provided to DBCA managers to complement the results collected through this survey and improve the general guidance framework.

TABLE 2. PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (MECHANICAL FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Forest thinning	Scrub rolling/ Brush-cutting	Mulching	Mowing/Slashing	Fire breaks and strategic access	Parkland clearing
Cost	US: $87 to $3000/ha	US: $90 to $110/ha	- Australia: highly variable[4] $100 to $280/hour, up to $3,000/ha; $6,000/ha in heavy forested fuels - US: $40 to $400/ha	- Australia: $100 to $120/hour - US: $10 to $16/ha	Australia: highly variable[4] $120/km to $1,000/ha	Australia: highly variable[4] $150 to $400/hour, up to $1,500/ha or $8,000/ha
Benefits	- Reduce the potential for active crown fire spread - Can be chipped and used as bio-fuel to generate energy - Sale of woodchips can reduce initial cost - Can remove invasive species (e.g. mistletoe, beetles, etc.)	- Fuel reduction - Blade-up and Chopper Rolling are much easier to manage around sensitive sites	- Fuel reduction - Reduce the potential for active crown fire spread - Improve the visual amenity of the area - Improve the amenity value - Improve ecological function of the area - Create a temporary buffer/fire break (for planned burning or wildfires)	- Fuel reduction - Provide mulch and minimise risk of fire - Improve the visual amenity of the area - Manage vegetation on verges and expanses of undeveloped land - Weed control - Productivity 3 to 5 times greater than mulching	- Fuel reduction - Improve ecological function of the area - Improve the visual amenity of the area - Create better access for future mitigation and suppression activities or for the search of missing person - Limit fire spread and size - Create a physical barrier between interfaces (e.g. rural-urban interface) - Easy to maintain	- Fuel reduction - Improve the visual amenity of the area - Alteration of fuel structure - Easy to maintain once established - Create a physical barrier between interfaces (e.g. rural-urban interface) - Easy to maintain once established - Minimal soil disturbance

[4] Will depend on depends on terrain, fuel load, state of existing tracks, contractor, type of treatment, extent of the area to treat, etc.

TABLE 2. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (MECHANICAL FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Forest thinning	Scrub rolling/ Brush-cutting	Mulching	Mowing/Slashing	Fire breaks and strategic access	Parkland clearing
Benefits (continued)					- Low impact on bush land - Reduce the perceived bushfire risk of neighbours.	
Limitations	- Soil moisture (for machinery accessibility) - Cost increases with distance to access roads - Transportation cost of hauling biomass - Nutrient removal	- Increases surface fuel density and continuity - Works better with dry or dead vegetation Only cost-effective if applied in strips of about 20m wide	- Risk of damaging trees when pruning (which can result in pathogen entry points for fungi) - Can be visually unappealing if unsuitable equipment is used or if site is left untidy after treatment - Cost increases with distance to access roads and tree diameter - Steep topography and poor site conditions (e.g. uneaven surface) - Does not produce merchantable forest products (e.g., saw logs or woodchips)	- Not species-specific - Risk of reducing the ecological function of the area if total vegetation removal (e.g. biodiversity, wildlife habitat) - Risk of causing fire with the mowing equipment - Limited to fine fuels - Limited equipment manoeuvrability in steep topography - Equipment availability - Dry roads to allow machinery access	- Increased erosion risk - Allows possible unauthorised access to area - Loss of vegetation - Increased maintenance costs - Not an effective fire break if not maintained properly (e.g. summer/during restricted period) - People may also assume fire breaks may actually stop all fires from progressing	Expensive

TABLE 2. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (MECHANICAL FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Forest thinning	Scrub rolling/ Brush-cutting	Mulching	Mowing/Slashing	Fire breaks and strategic access	Parkland clearing
Equipment	- Feller-bunchers - Chainsaw (hand felling) - Skidders and forwarders	- Large steel drums with cutting knives mounted on the face of the drum - Drums can be towed behind a wheeled or tracked by a tractor, or they can be pulled on a winch cable (for steeper slopes)	- Track and tyre based skid steer/Bobcat machines fitted with rotary drum nibbling heads - Excavators with a mastication head - Horizontal or vertical shaft cutting heads	- Ride on mowers - Whipper-snippers - Brush cutters - Chainsaws - Mulchers - Tractor mounted slashing equipment (3-point linkage equipment) - Steel-track tractor with a front-mounted rotating toothed drum	- Loader - Excavator - Skid Steer - Grader - Disc plough - "Posi-track" machines with mulching head - Bobcats - Chainsaws - Slashers - Chemical spray unit	- Mulching head - Bobcat
Experience and training	Machine operator	Machine operator	- Experienced machine operators - Understanding of forest types, environment and biodiversity - Fire and Land Management Training	- No specific training required - Conservation and Horticulture certificates. - Safety courses for equipment - Knowledge of machinery operations	- Understanding of the local regulations (e.g. Firebreak Notice, Bushfire Act, Environmental Protection Act, Biodiversity conservation Act, Aboriginal Heritage Act, etc.) - Experience in mapping and understanding the local topography - Contract management	- Very good machine operators - Background in horticulture and forestry

TABLE 2. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (MECHANICAL FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Forest thinning	Scrub rolling/ Brush-cutting	Mulching	Mowing/Slashing	Fire breaks and strategic access	Parkland clearing
Experience and training (continued)					- Project management - Knowledge of local fire activity/conditions to be able to take the path of least environmental damage	
Timing	- Autumn - Winter - Spring	When fuel is dry	- Summer[5] - Autumn[5] - Winter - Spring	- Summer[5] - Autumn - Winter - Late spring	- Late spring[5] - Summer[5] - Autumn - Winter	- Spring - Summer - Early autumn[5]
Vegetation	- Plantation forests (e.g. pine) - Overstory vegetation (for biomass harvesting)	- Shrubland - Plantation forests (e.g. eucalypts) - Mallee - Mallee-heath	- Forests (small hardwood species up to 25cm in diameter) - Shrubland - Woodland - Grassland	- Shrubland - Grassland - Spinifex	- Forests - Woodland - Shrubland - Grassland	- Woodland - Open forests
Driving factors	- Slope - Distance to access roads - Presence of protected biodiversity elements	- Terrain - Fuel dryness	- Slope - Distance to access roads - Distance to assets - Presence of protected biodiversity elements - Land use	- Terrain - Distance to access roads - Distance to assets - Distance to conservation areas -	- Terrain - Slope - Distance to assets - Distance to conservation areas - Presence of protected biodiversity elements	- Slope - Terrain - Distance to access roads - Distance to assets - Presence of protected biodiversity elements

[5] Seasons supporting the highest likelihood of an effective fuel management program (maximum consensus amongst the survey participants).

TABLE 2. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (MECHANICAL FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Forest thinning	Scrub rolling/ Brush-cutting	Mulching	Mowing/Slashing	Fire breaks and strategic access	Parkland clearing
Driving factors (continued)			- Vegetation type - Fuel structure - Amount of fuel - Size of the area to treat	- Presence of protected biodiversity elements - Land use type - Fuel structure - Amount of fuel - Soil conditions - Size of the area to treat	- Fuel structure - Amount of fuel - Soil conditions - Ability to keep burn within containment lines	- Amount of fuel - Size of the area to treat
Landscape	- Slopes: 0 – 30% - Treatment scale: > 10 ha	- Slopes: 0 – 35% - Treatment scale: 20 – 200 m wide strips	- Slopes: 0 – 16% (up to 35% with adapted machinery) - Treatment scale: 5 – 20 m wide	- Slopes: 0 – 16% - Treatment scale: small plots	- Slopes: 0 – 30% - Treatment scales: o Land vacant or over 4000 m² require fire breaks; o 3 – 5 m wide directly adjacent to assets o Slope 0-5% → 30m wide o Slope 5-15% → 40m wide o Slope>15% → 50m wide o Within 30 to 100 m from building zones - Within 300 m from plantation forests	- Slopes: 0 – 10% - Treatment scales: 20 m wide starting from structures and around the boundary of reserves within townsites

TABLE 2. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (MECHANICAL FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Forest thinning	Scrub rolling/ Brush-cutting	Mulching	Mowing/Slashing	Fire breaks and strategic access	Parkland clearing
Land use	- Plantation forests - Nature reserves and conservation forests	- Plantation forests - Nature reserves and conservation forests - Mixed farming and grazing	- Vacant plots - Nature reserves and conservation forests - Recreational areas - Residential and rural residential - Industrial	- Vacant plots - Nature reserves and conservation forests - Recreational areas - Residential and rural residential - Industrial - Pasture - Horticulture - Mixed farming and grazing	- Vacant plots - Nature reserves and conservation forests - Residential and rural residential - Industrial - Plantation forests - Intensive agriculture - Livestock grazing - Mixed farming and grazing	- Nature reserves and conservation forests - Residential and rural residential - Industrial - Utilities and infrastructure
Other considerations	- Removal of fine fuel in the understory to limit fire hazard - Set minimum distance and maximum surface treated in the presence of protected or endangered species - Consider combining with planned burning to maximise fuel reduction	- Can be used as a treatment for wildlife habitat improvement - Cost-effective if there is a commitment to ongoing management/maintenance to maintain risk reduction benefits over time	- Can be used to complement planned burning to reduce fuels in the landscape adjacent to assets - Follow up maintenance program to remain effective in the longer term - Vertical shaft cutting heads are generally lighter	- Prefer hand slashing where sensitive/endangered species are identified - Only apply where there is a significant need rather than removing all the vegetation	- Use contours and appropriate water runoff (e.g. fallen tree branches) to limit erosion risks - Consider offset planting to limit erosion risks - Use gates to reduce un-authorised access - Develop consistent firebreak specifications across different Local Governments	- Apply treatment as close as possible from assets to maximise fuel reduction Consider combining with planned burning to maximise fuel reduction

TABLE 2. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (MECHANICAL FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Forest thinning	Scrub rolling/ Brush-cutting	Mulching	Mowing/Slashing	Fire breaks and strategic access	Parkland clearing
Other considerations (continued)			- Horizontal shaft cutting heads provide more mulching action		- Promotion of property requirements, active annual property inspections, education programs and enforcement practices to minimise complacency risk	
Sources	Endress et al. (2012) Forestry Tasmania (2001) Hunter et al. (2007) Loudermilk et al. (2014) Metlen and Fiedler (2006) Nader et al. (2007) Stephens et al. (2009) Stephens et al. (2012) Volkova et al. (2017) Windell and Bradshaw (2000)	Burrows (2015) OBRM (2018) Rummer (2010) Windell and Bradshaw (2000)	Halbrook et al. (2006) Hunter et al. (2007) Jain et al. (2018) Kane et al. (2006) Kreye et al. (2014) Martorano et al. (2021) OBRM (2018) Rummer (2010) Windell and Bradshaw (2000)	Nader et al. (2007) OBRM (2018) Potts and Stephens (2009) Pyke et al. (2014)	Burrows (2015) Leask and Smith (2011) Partners in Protection (2003)	OBRM (2018)

TABLE 3. PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (OTHER FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Planned burning	Pile burning	Chipping	Herbicide	Grazing
Cost	- Australia: highly variable[6] $500/ha to less than $100/ha - US: $14 to $120/ha	US: $18 to $300/ha	US: $1600/day	- Australia: highly variable[6]; less than $150/km to up to $500/ha - US: $10 to $100/ha	US: $25 to $30/ha
Benefits	- Fuel reduction - Improve ecological function of the area - Cheapest fuel management method	- Wider window of opportunity than planned burning - Low risk of fire escape - Minimal damage to surrounding trees	- Good alternative to pile burning if piles have already been constructed - Chips can be used for erosion protection - Promotes nutrient cycling - Selling of wood by-product	- Fuel reduction - Improve ecological function of the area - Improve the visual amenity of the area - Reduce invasive weeds into bushland - Can target specific plant species	- Fuel reduction - Short-term treatments to reduce flammable vegetation - Hoof incorporation of fine fuels (burial, mixing with soil)
Limitations	- Risk of damaging fire-sensitive vegetation - Burn cost per hectare is higher on small areas - Difficult to control (risk of fire escape) - Impact air quality - Limited window of opportunity - Difficult to implement if fuel load is too high	- Cost increases with distance to access roads	- Expensive technique - Towed chippers are limited to roadside processing	- Risk of killing vegetation outside the range of intended species - Can increase fuel load if left and not removed - Cost increases with distance to access roads - Contamination risk (leaching)	- Removal of native species - Spread of weeds - Risk of overgrazing - Grazing in non-palatable environments (e.g. conifer forests) can result in an increase in fuel loads - Livestock cannot effectively control mature bush plants - Risk of trampling/soil compaction (if stock density is too high)

[6] Will depend on depends on terrain, fuel load, state of existing tracks, contractor, type of treatment, extent of the area to treat, etc.

TABLE 3. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (OTHER FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Planned burning	Pile burning	Chipping	Herbicide	Grazing
Equipment	- Utility mounted flamethrower - Hand firelighters - Aerial ignition with drip torches - Four wheel drive mounted water firefighting units and larger truck mounted units	-	- Swing machine with a brush-cutter or saw-head attachment - Self-levelling feller-buncher (for slopes > 50%)	- Tank hose - Spray gun and backpacks - Fixed-wing aircraft or helicopter	- Livestock (e.g. cattle, goats, sheep) - Vehicles to transport stock
Experience and training	- Highly skilled operation officers (e.g. senior firefighter)	-	-	- Accredited supervisors and applicators - Experienced operator	Knowledge of livestock and local poisonous plant species
Timing	- Autumn[7] - Spring[7] - Winter	- Autumn - Winter	- Spring - Summer - Autumn - Winter	- Spring - Summer[7] - Autumn[7] - Winter	- Spring - Summer - Autumn - Winter
Vegetation	- Forests - Shrubland - Grassland - Woodland	- Biomass resulting from thinning operations (up to 1.5m height, 8.5m diameter)	- Small trunks and branches - Piled wood	- Shrubland - Forests - Spinifex - Grassland	- Forests - Grassland - Rangelands
Driving factors	- Slope - Distance to assets - Distance to conservation areas - Presence of protected biodiversity elements	- Distance to access roads - Fuel structure - Amount of fuel	- Slope - Distance to access roads	- Presence of protected biodiversity elements - Distance to riparian environments - Vegetation type - Distance to access roads	- Presence of protected biodiversity elements - Vegetation type - Structure of the fuel - Soil conditions - Size of the area to treat

[7] Seasons supporting the highest likelihood of an effective fuel management program (maximum consensus amongst the survey participants).

TABLE 3. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (OTHER FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Planned burning	Pile burning	Chipping	Herbicide	Grazing
Driving factors (continued)	- Ability to keep burn within containment lines - Fuel structure - Amount of fuel			- Distance to conservation areas - Land use type - Soil conditions - Size of the area to treat	
Landscape	- Slopes: 0 – 16% - Treatment scales: o < 200 ha around townships; o > 200 ha on Crown lands, National Parks and Nature reserves	-	Slopes: 0 – 10%	- Slopes: 2 – 15% - Treatment scale: 3 – 10 m wide	- Slopes: 0 – 30% (possible up to 60 in alpine environments) - Treatment scale: 1.5 to 65 ha
Land use	- Vacant plots - Nature reserves and conservation forests - Recreational areas - Residential and rural residential	- Nature reserves and conservation forests - Allowed near residential areas	-	- Vacant plots - Nature reserves and conservation forests - Recreational areas - Residential and rural residential - Industrial - Plantation forests - Horticulture	- Plantation forests - Intensive agriculture - Pasture - Livestock grazing - Horticulture - Mixed farming and grazing - Allowed near residential areas
Other considerations	- Ensure good planning to limit the risk of fire escape - Check weather conditions to control when to start/stop planned burning activities - Encourage the development of post-fire landscape mosaics	-	-	- Removal of dead fuel loads after treatment - Training to limit risk of off-target damages - Use chemicals as per label	- Consider combining with other management activities to maximise fuel reduction - Consider nutritional value of the feed

TABLE 3. (continued) PRESENTATION OF THE GENERAL ANALYTICAL FRAMEWORK (OTHER FUEL MANAGEMENT ACTIVITIES). THE TEXT IN BLACK REPRESENTS INFORMATION COLLECTED THROUGH THE ONLINE SURVEY, IN BLUE INFORMATION COLLECTED FROM THE LITERATURE ONLY, AND IN ORANGE INFORMATION FOUND IN THE LITERATURE REVIEW AND THE ONLINE SURVEY.

	Planned burning	Pile burning	Chipping	Herbicide	Grazing
Other considerations (continued)	- Potentially combine with other management activities				- Control stocking density during grazing; grazing duration; plant secondary compounds; and animal physiological state
Sources	Cirulis et al. (2020) Clarke et al. (2019) Dwire et al. (2016) Furlaud et al. (2018) Gazzard et al. (2020) Hartsough et al. (2008) Howard et al. (2020) Hunter et al. (2007) Leavesley et al. (2013) Morgan et al. (2020) OBRM (2018) Rummer (2010)	Hunter et al. (2007) Rummer (2010)	Rummer (2010) Windell and Bradshaw (2000)	Hunter et al. (2007) Nader et al. (2007) Pyke et al. (2014)	Bruegger et al. (2016) Davies et al. (2010) Davies et al. (2020) Endress et al. (2012) Fuhlendorf and Engle (2004) Nader et al. (2007) Porensky et al. (2018) Ruiz-Mirazo and Robles (2012)

3. ILLUSTRATIVE SCENARIOS

3.1 OVERVIEW

In order to highlight how the general guidance framework can be used in practice, its application to two hypothetical scenarios is considered (Figure 14). In the first scenario, decision-makers consider alternative fuel management strategies and, in this setting, the framework can be used to compare the different attributes of these strategies (e.g. how much each costs, what their respective benefits are, and under what circumstances they can be used). In the second scenario, the framework can assist decision makers in determining the most suitable fuel management strategy in a given setting (e.g. you have a set of conditions (drivers, constraints and resources) and would like to know which mitigation activities are the most suitable). In both cases, use of the framework can inform the development of fuel reduction management plans. Details of how the framework can be used in the context of these scenarios are given in the following subsection.

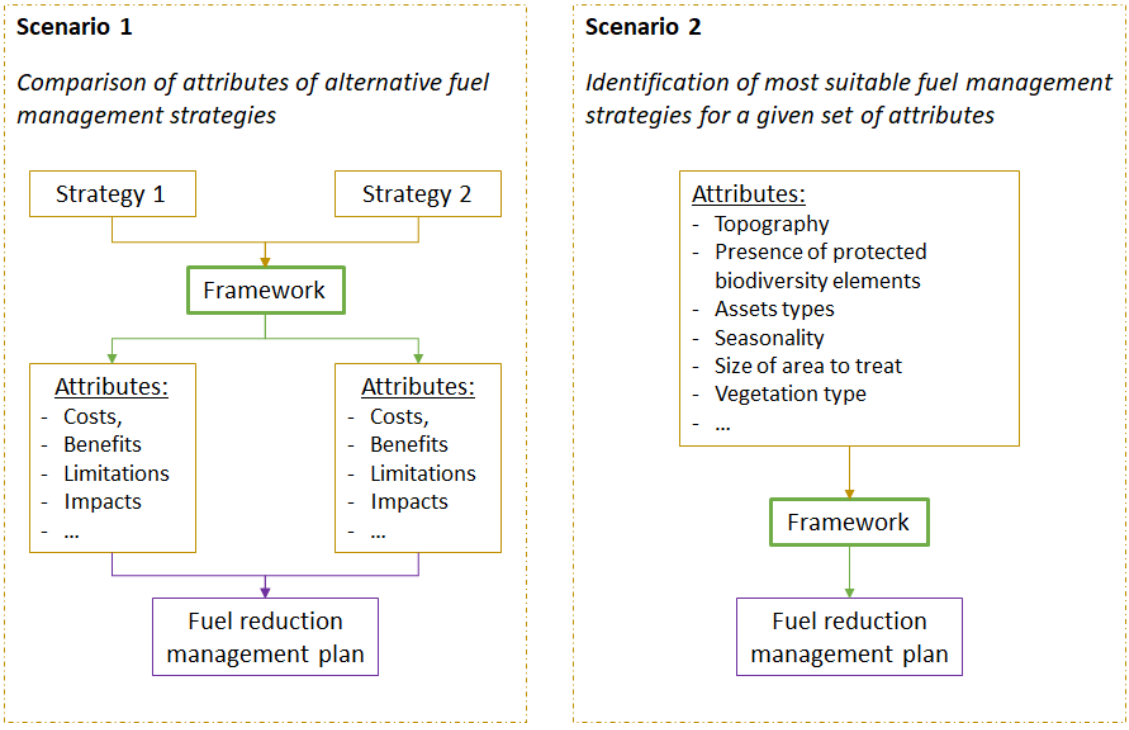

FIGURE 14. DETAILS OF SCENARIOS USED TO ILLUSTRATE THE POTENTIAL UTILITY OF THE GENERAL GUIDANCE FRAMEWORK.

3.2 SCENARIO 1: CROSS-COMPARISON OF DIFFERENT FUEL MANAGEMENT OPTIONS

In this scenario, you are a planned burning expert, but you would like to know more about mulching, parkland clearing and slashing activities to develop a fuel management plan for a local conservation reserve. The reserve is a 2.5 hectares

relatively open Eucalypt forest with a shrub understorey that is located on moderate slopes (5 to 8%). You would like to know how the different fuel management strategies under consideration compare in terms of costs, benefits and limitations, and learn more about the type of training and equipment you would need to apply.

First, you will consult Table 2 and look at the columns Mulching, Mowing/Slashing, and Parkland clearing. Then you will select the rows *Cost*, *Benefits*, *Limitations*, *Equipment*, *Experience and training*. You may also want to check the rows *Vegetation* and *Landscapes* to ensure that any of the fuel management activities can be applied to your conservation reserve.

Cost:

You notice that the cost for each of the three activities is highly variable, but they are within the same order of magnitude (c.a. $100 to $200/hour).

Benefits:

All three activities provide fuel reduction and improve the visual amenity of the area. However, only mulching and slashing result in an improvement of amenity value or ecological functions. On the other hand, mulching and slashing provide additional fire management benefits as they can create a temporary buffer/fire break, reduce the potential for active crown fire to spread and the resulting mulch can minimise fire risk.

Limitations:

All three fuel reduction treatments are quite expensive and if not used correctly, mulching and slashing can damage trees, reduce ecological function if too much biomass is removed and can be visually unappealing. Unfortunately, none of the treatments produces merchantable forest products (e.g., saw logs or woodchips); they are limited to the treatment of fine fuel and are difficult to manoeuvre in steep topography.

Equipment, experience and training:

All three treatments require a similar type of equipment. They can use excavators, Bobcats or tractors fitted with mulching or slashing equipment. Depending on the type of surface to treat, ride-on mowers, whipper-snippers or chainsaws can be used to conduct slashing activities. A similar type of training and experience is also applicable for all three techniques. They require a good understanding of local forest types, environment and biodiversity, as well as an experienced machine operator to minimise damages to the trees/landscape treated.

Vegetation and landscape:

All three activities can be applied in shrubland and woodland environments while mulching and parkland clearing can treat forests with small hardwood species. All treatments can be applied on slopes of up to 16% and are generally applied in strips of 5 to 20m starting from assets and around the boundary of reserves. Given the type of vegetation and topography of your conservation reserve, you could potentially apply all three treatments.

Conclusions:

All three mitigation activities could be applied in your conservation reserve, given the local landscape and topography. While mulching and slashing could improve the ecological function of the area, they could also prove beneficial for fire spread management by creating temporary buffers and fire breaks. However, you would need an experienced machine operator with a background in forestry and horticulture to minimise damages to the vegetation treated. The cost of treatment will depend on the amount of surface you want to treat and the equipment required to conduct the fuel management works.

3.3 SCENARIO 2: CHECKLIST SCENARIO

In this scenario, you are a Bushfire Mitigation Officer and would like to develop a fuel management plan for a range of vacant plots on the fringe of an urban centre. The vegetation consists of a mix of dry grasses and shrubs and some of the plots are on moderate slopes (c.a. 6-10%). These plots are also directly adjacent to main access roads and on the edge of a National Park, which hosts a colony of Southern brown bandicoots (Isoodon obesulus obesulus).

Using the information contained in Table 2 and Table 3, you would like to find the best mitigation options for your fuel management plan. You would first look at the rows of these two tables one by one and tick the boxes where the conditions listed above are met. Then you would tally the number of ticks for each mitigation activity and retain the options with the most ticks (or use the ticks to inform a short list of options, if additional criteria impact the decision). Once you have pre-selected a range of fuel management activities, you can relate to Scenario 1 to compare them directly.

TABLE 4. NUMBER OF CHECKMARKS FOR EACH SELECTION CRITERIA AND CORRESPONDING FUEL MANAGEMENT ACTIVITIES.

	Forest Thinning	Scrub rolling	Mulching	Slashing	Fire breaks	Parkland clearing	Planned burning	Pile purning	Chipping	Herbicide	Grazing
Vegetation	NA	0	1	1	1	0	1	NA	NA	1	1
Landscape	NA	1	1	1	1	1	1	NA	NA	1	0
Land use	NA	0	1	1	1	0	1	NA	NA	1	1
Benefits	NA	1	1	1	1	1	1	NA	NA	1	1
Limitations[8]	NA	1	1	0.85	1	1	1	NA	NA	0.5	0.33
Total	**NA**	**3**	**5**	**4.85**	**5**	**3**	**5**	**NA**	**NA**	**4.5**	**3.33**

Based on the results from Table 4, mulching, fire breaks, planned burning and slashing would be your best options. However, due to the presence of protected biodiversity elements and the proximity to residential developments, you might want to use a combination of mitigation activities.

[8] If none of the limitations are encountered give a score of 1, otherwise a suggested approach is to assign a score between 0 and 1 if one or more limitations is encountered. For example, if one limitation out of seven is recorded, you assign a score of (7 – 1)/7 = 0.85

4. FUTURE WORK

The next step will be to use the General Guidance Framework presented in this report in combination with detailed local knowledge from the online survey to create maps of opportunity for each fuel management activity (Milestone M5). We will then combine them with UNHaRMED outputs to define opportunities to apply different types of fuel management approaches under plausible future conditions for the locations identified in Milestone 3 (i.e. Gingin, Kalamunda, Mundaring and Margaret River) (Deliverable D3).

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APPENDIX A: EXAMPLE OF THE GENERIC QUESTIONNAIRE SENT TO WALGA MEMBERS

THE UNIVERSITY of ADELAIDE

GOVERNMENT OF WESTERN AUSTRALIA | DFES Department of Fire & Emergency Services

FOR A SAFER STATE

RIKS research institute for knowledge systems

bushfire&natural HAZARDSCRC

Reducing Future Bushfire Risk Via Fuel Management

This research project examines local fire managers' knowledge of a range of fuel management activities required to build efficient fuel reduction programs to reduce bushfire risk.

This research also examines the knowledge gaps and resources limitations that management authorities face in successfully planning and implementing fuel reduction programs in different regions of Australia.

We will use different approaches to look at factors that may influence the development of a fuel management program and also specific factors to consider to evaluate the suitability of different fuel management approaches.

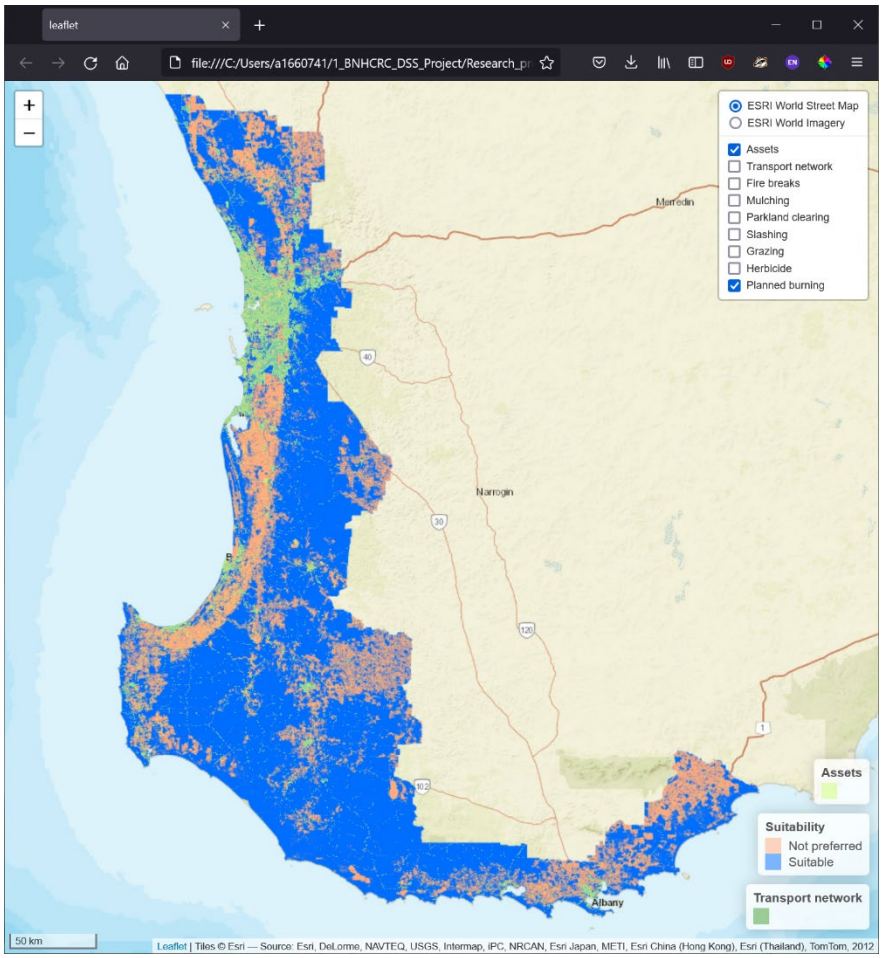


FIGURE 15. EXAMPLE OF FINAL OUTPUT MAPS WHICH CAN BE CREATED FROM THE SURVEY RESULTS

We would like to know more about your expert knowledge on different fuel mitigation activities conducted in your region.
This survey will aims to answer the following questions:

1. What are the most critical elements to consider when deciding if a fuel management activity can be conducted? Are there specific limitations or ideal application sites?
2. When can each activity be conducted (i.e. window of opportunity)? When are these activities likely to be most effective?
3. Where can each activity be applied (e.g. proximity to different classes of land use and vegetation type)?
4. What resources does each technique require in terms of training, equipment, and materials?
5. What are the costs, benefits, and impacts (social and environmental) associated with each fuel management activity?

This survey's results will be used to develop a generic tool to assess the suitability of a range of vegetation management options for a particular location based on a variety of features at that location. Fire and land managers will then be able to use the tool to develop local Bushfire Risk Management Plans under current or plausible future conditions.

We are particularly interested in learning more about the following fuel management activities to progress scientific knowledge:

- Mechanical fuel load reduction
- Chemical works
- Fire breaks or strategic access
- Grazing

You will be asked to answer questions about one specific fuel management activity (based on your expertise) but you will have the option to comment on other activities if you want to. It should take

- 15-20min to answer questions for 1 type of activity,
- 20-30min for 2 types*,
- 30-45min for 3 types of fuel reduction activities*.

**You will be able to access the survey at any time if you would like to comment on other mitigation activities later.*

All responses will be held confidentially and securely following the University of Adelaide data protocols and information will be anonymised for inclusion within this initiative.

Participation in this project is completely voluntary. If you agree to participate (start filling the survey), you can stop at any time and decide not to submit your results.

Please answer all questions that are relevant to you. If you feel that you are not able to answer a question, you can choose the option *"I don't know"* or put *NA* in the response field.

We would appreciate if you could forward the link of the survey to other people who may be able to respond.

If you have any questions please contact Dr Amelie Jeanneau
amelie.jeanneau@adelaide.edu.au

Next

Background information and selection of a case-study area

This section aims to characterise the local landscape of YOUR region and better understand how fuel management is conducted in YOUR region.

1. Which local government do you work in?

e.g. City of Albany, Adelaide Hills Council, City of Melbourne, Glenorchy, etc.

2. What organisation are you predominantly working with?

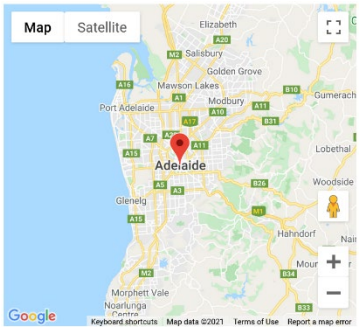
e.g. Department of Fire and Emergency Services, Local council, Country Fire Services, etc.

3.1. Which case-study area(s) would be the most representative of the locations where you conduct fuel reduction activities in your region?

Please select up to three areas and move the location pin on each of the three maps below.
Keep these in mind when answering questions from this survey

Location 1

Location 2



Location 3

3.2. Could you give a brief description of the bushfire risk profile for each of the locations selected above?

e.g. low, medium or high bushfire risk. Presence of highly flammable vegetation. Presence of vulnerable populations. Presence of threatened or endangered ecological species and communities. Climate influences.

3.3. What type of assets (natural and build) can be impacted by bushfires in your chosen area(s)?

e.g. recreation or road reserves of interest for the community, critical infrastructure, transport networks, residences/houses, etc.

3.4. Are there specific protected, endangered or threatened fauna or flora species/communities in your chosen area(s)?

☐ Yes ☐ No ☐ I don't know

Could you list the most important ones?

4. To the best of your knowledge, how is bushfire risk managed in your chosen area(s)?

e.g. by reducing fuel load around key (natural and built) assets; by encouraging landholders to manage vegetation on their property; by communicating on bushfire risk at local event or community meetings, etc.

5. What is the main aim of fuel load reduction activities in your chosen area(s)?
e.g. reducing bushfire risk, reducing fuel load, amenity, using wood by-products, selling wood by-products, etc.

6. Where do you generally conduct fuel reduction activities in your chosen area(s)?
e.g. road reserves, along access roads, conservation reserves, etc.

7. Could you list the community stakeholders involved in the development of fuel management plans in your chosen area(s)?
e.g. local NRM board, community leaders, local elders, Department of Conservation, general community consultation/notification/warning (ahead of conducting a fuel reduction activity), etc.

8. Are there heritage spaces in your chosen area(s)?

☐ Yes ☐ No ☐ I don't know

How do you deal with local community leaders and elders in these heritage spaces when it comes to fuel management?

9. To the best of your knowledge, are there any planned fuel management activities that had to be delayed, postponed or cancelled in your chosen area(s)?

☐ Yes ☐ No ☐ I don't know

What was the reason for delaying or cancelling the planned activities?
e.g. budget constraints, weather conditions, community complaints, etc.

Did you adapt your fire management plan? If so, which actions did you take?

If you decided to postpone these activities, how long after the initial planned date did you conduct the fire management activities?

How often does this situation occur in your chosen area(s)?

☐ 1 Not often ☐ 2 ☐ 3 ☐ 4 ☐ 5 On a regular basis

Back Next

Your expertise in fuel management

The following section focuses on assessing your knowledge on a range of fuel mitigation activities conducted in the three regions that you selected on the previous page.

1 What level of expertise WOULD YOU CONSIDER having for the following mitigation approaches?

	Not my field	Some knowledge	Expert
Planned burning	O	O	O
Slashing	O	O	O
Mulching	O	O	O
Scrub rolling	O	O	O
Forest thinning	O	O	O
Parkland clearing	O	O	O
Fire breaks or strategic access	O	O	O
Chemical works (e.g. herbicide)	O	O	O
Grazing	O	O	O

2. Can you select the top 3 fuel management activities COMMONLY APPLIED for each land use?

	Planned burning	Slashing	Mulching	Scrub rolling	Forest thinning	Parkland clearing	Fire breaks or strategic access	Chemical works (e.g. herbicide)	Grazing	I don't know
Vacant	O	O	O	O	O	O	O	O	O	O
Nature Reserves/Conservation/ Forests	O	O	O	O	O	O	O	O	O	O
Recreational	O	O	O	O	O	O	O	O	O	O
Residential/Rural residential	O	O	O	O	O	O	O	O	O	O
Industrial	O	O	O	O	O	O	O	O	O	O
Forestry	O	O	O	O	O	O	O	O	O	O
Intensive agriculture	O	O	O	O	O	O	O	O	O	O
Pasture	O	O	O	O	O	O	O	O	O	O
Livestock	O	O	O	O	O	O	O	O	O	O
Horticulture	O	O	O	O	O	O	O	O	O	O
Mixed farming and grazing	O	O	O	O	O	O	O	O	O	O

3. To the best of your knowledge, do the following treatments have measurable effects where they are used? (in terms of fuel reduction OR risk reduction)

	Yes	No	Not used	I don't know
Planned burning	O	O	O	O
Slashing	O	O	O	O
Mulching	O	O	O	O
Scrub rolling	O	O	O	O
Forest thinning	O	O	O	O
Parkland clearing	O	O	O	O
Fire breaks or strategic access	O	O	O	O
Chemical works (e.g. herbicide)	O	O	O	O
Grazing	O	O	O	O

The text box below will be automatically filled based on your answers to the question above. Your input will not be required.

Input not required

4. To the best of your knowledge, what level of measurable effect do you think each of the following treatment has?

Level of measurable effects in terms of facilitating an effective fire suppression

Planned burning

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Mulching

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Scrub rolling

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Forest thinning

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Parkland clearing

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Fire breaks or strategic access

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Chemical works (e.g. herbicide)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Grazing

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

No measurable effects — Very effective

Back Next

Selection of a fuel management activity

In the next section (next page), the questions will be tailored to a specific fuel management activity to fill knowledge gaps relating to this management technique. To this end, we ask you to select one of the following eight fuel management options. When filling this questionnaire, please keep in mind the **case-study area(s)** you selected in the first part of the survey.

If you are not familiar with any of the techniques proposed, you can select the option *None of the above* and will be offered to fill the survey for *Planned burning* activities instead. However, we would be grateful if you could **help us fill knowledge gaps** on **other** fuel management **activities** as well.

Once you have completed the survey, you will be offered the choice to comment on other mitigation activities (including *Planned burning*) or submit your results.

Which mitigation option are you most familiar with? (after planned burning)

☐ Slashing
☐ Mulching
☐ Scrub rolling
☐ Forest thinning
☐ Parkland clearing
☐ Fire breaks or strategic access
☐ Chemical works (e.g. herbicide)
☐ Grazing
☐ None of the above

Would you like to comment on planned burning activities instead?

☐ Yes
☐ No thank you

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[Fuel management activity name]

These questions will relate to [activity name]. Please keep in mind the case-study areas you selected at the beginning of the survey to answer the following questions

1. What do you think are the desired outcomes of [activity name] conducted in YOUR chosen area(s)?

☐ Fuel reduction
☐ Modification of fuel structure
☐ Improve ecological function of area
☐ Improve the visual amenity of the area
☐ I don't know
☐ Other

2.1. What do you think are the expected POSITIVE side-effects of [activity name]?

2.2. Do you think that [activity name] have NEGATIVE side-effects?

☐ Yes
☐ No
☐ I don't know

2.3. What do you think are the expected NEGATIVE side-effects of [activity name]?

2.4. How likely do you think these NEGATIVE side effects will occur?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Not likely				Extremely likely

If you listed multiple side-effects in question 2.3 and you think that they would need a different likelihood rating, please use the "Comments" section below as well.

Comments:

2.5. Which key stakeholders or community groups would be the most likely be impacted by these NEGATIVE side effects?
e.g. traditional owners, elderly, etc.

2.6. What strategies do you or could you put in place to mitigate the NEGATIVE side effect?

3. What do you think are the most important elements to consider when deciding if [activity name] can be conducted?

	Important	Moderately important	Not important	I don't know
Slope	O	O	O	O
Distance to access roads	O	O	O	O
Distance to assets (e.g. transport, utilities, residential developments, airports, cultural assets, etc.)	O	O	O	O
Availability of suppression resources (e.g. fire stations, airstrips, etc.)	O	O	O	O
Distance to suppression resources	O	O	O	O
Presence of vulnerable communities (e.g. schools, hospitals, nursing homes, etc.)	O	O	O	O
Distance to vulnerable communities	O	O	O	O
Distance to conservation areas	O	O	O	O
Presence of protected biodiversity elements (e.g. TECs*, DRF*)	O	O	O	O
Distance to protected biodiversity elements (e.g. TECs, DRF)	O	O	O	O
Land use type	O	O	O	O
Vegetation type	O	O	O	O
Amount of fuel	O	O	O	O
Structure of fuel	O	O	O	O
Elevation	O	O	O	O
Terrain (e.g. uniform, broken)	O	O	O	O
Soil conditions (e.g. erosiveness, soil texture)	O	O	O	O
Size of area to treat	O	O	O	O
Burn security (ability to keep burn within containment lines)	O	O	O	O

*Threatened Ecological communities (TECs); Declared Rare Fauna (DRF)

Comments:

The text box below will be automatically filled based on your answers to the question above. Your input will not be required.

Input not required

4. Do you have additional comments or considerations regarding [activity name] and their applicability?

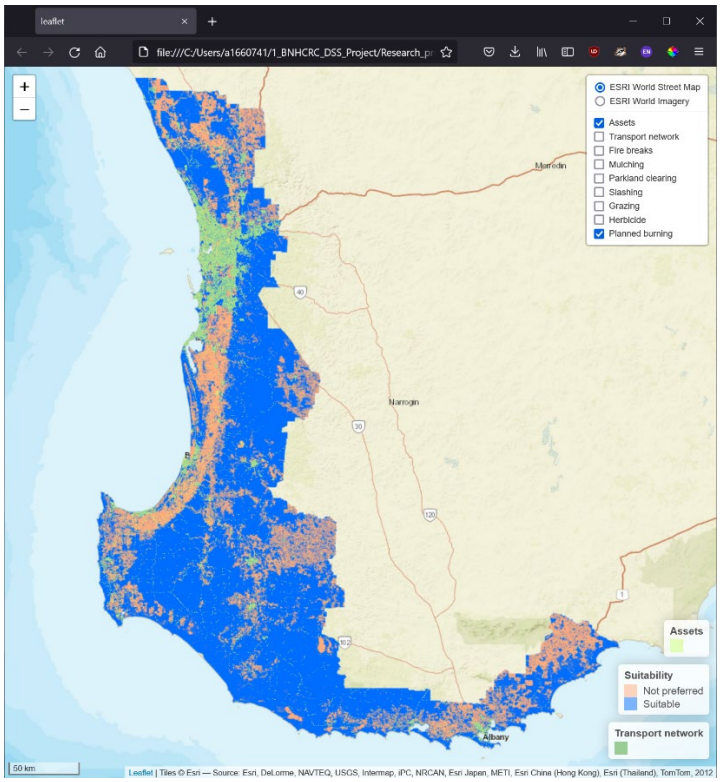
Back

Next

[Activity name] - Selection criteria

The following questions will help us define the suitable conditions to conduct [activity name] in southern Australia based on the elements you considered "Important" in question 3 (previous page).

We will use your answers to create interactive suitability maps for a range of fuel mitigation activities in WA. An example is provided below.



What do you think are suitable SLOPES for application of [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Flat (0-2%)	○	○	○	○
Gentle (2-5%)	○	○	○	○
Moderate (5-8%)	○	○	○	○
Rolling (8-16%)	○	○	○	○
Hilly (16-30%)	○	○	○	○
Steep (30-60%)	○	○	○	○
Very steep (>60%)	○	○	○	○

Comments

What do you think is a suitable DISTANCE to ACCESS ROADS for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-50m)	O	O	O	O
Near (50-100m)	O	O	O	O
Moderate (100-500m)	O	O	O	O
Far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to SUPPRESSION resources for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to VULNERABLE COMMUNITIES for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

Next to which of the following ASSETS would YOU conduct [activity name] in your chosen area(s)?

	Yes	No	I don't know
Residential developments	O	O	O
Industrial developments	O	O	O
Utilities infrastructure (e.g. power stations, communications towers, water supply facilities, waste-water treatment plants, etc)	O	O	O
Transports infrastructure (e.g. roads, railways, etc.)	O	O	O
Airports	O	O	O
Cultural assets (e.g. protected sites, heritage buildings, government buildings, etc.)	O	O	O

Comments:

The text box below will be automatically filled based on your answers to the question above. Your input will not be required.

Input not required

What do you think is a suitable DISTANCE to RESIDENTIAL developments for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to INDUSTRIAL developments for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to UTILITIES infrastructure for [activity name] in your chosen area(s)?

Here utilities infrastructure can be represented by power stations, communications towers, water supply facilities, waste water treatment plants, etc.

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to TRANSPORT infrastructure for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to AIRPORTS for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to CULTURAL assets for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to CONSERVATION areas (e.g. reserves, national parks, etc.) for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to PROTECTED BIODIVERSITY elements for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to WATER BODIES (i.e. rivers, creeks and dams) for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable DISTANCE to RESERVOIRS for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Very near (0-25m)	O	O	O	O
Near (25-50m)	O	O	O	O
Moderate (50-100m)	O	O	O	O
Far (100-500m)	O	O	O	O
Moderately far (500m-1km)	O	O	O	O
Very far (1-5km)	O	O	O	O
Extremely far (>5km)	O	O	O	O

Comments

What do you think is a suitable SOIL TEXTURE for [activity name] in your chosen area(s)?

	Ideal	Not preferred	Not possible	I don't know
Coarse/light (sand)	O	O	O	O
Medium (loam)	O	O	O	O
Fine/heavy (clay)	O	O	O	O

Comments

What strategies do you or could you put in place to ensure that [activity name] remain within containment lines?

What are the most common VEGETATION types where you can conduct [activity name] in your chosen area(s)?

☐ Grassland (continuous)
☐ Grassland (Spinifex)
☐ Shrubland
☐ Coastal scrubs
☐ Heathland
☐ Mallee
☐ Woodland
☐ Dry eucalypt forest
☐ Wet eucalypt forest
☐ Pine plantation
☐ Other

Comments

Back

Next

[Activity name] - Seasonality

Is seasonality an issue for [activity name] in your region?

☐ Yes
☐ No

Generally, WHEN can [activity name] be applied in your region?

☐ January
☐ February
☐ March
☐ April
☐ May
☐ June
☐ July
☐ August
☐ September
☐ October
☐ November
☐ December

Comments

Generally, WHICH MONTH supports the highest likelihood of an effective [activity name] program?

☐ January
☐ February
☐ March
☐ April
☐ May
☐ June
☐ July
☐ August
☐ September
☐ October
☐ November
☐ December

Comments

Back Next

[Activity name] – Socio-economic criteria

Is there a desirable spatial scale for conducting [activity name] in your region?

☐ Yes
☐ No
☐ Maybe

What is the desirable minimum and maximum spatial scale (in m or ha or m2)?

What would drive the choice of this desirable spatial scale?

What is the cost associated with [activity name] (in $/ha or $/km)?

What is the type of experience and training required to plan and supervise [activity name]?

What type of equipment is required to conduct [activity name]?

Back

Next

Would you like to comment on another mitigation activity?

☐ Slashing
☐ Mulching
☐ Scrub rolling
☐ Forest thinning
☐ Parkland clearing
☐ Fire breaks or strategic access
☐ Chemical works (e.g. herbicide)
☐ Grazing
☐ No thank you

Back Next

Thank you for taking the time to fill this survey

You are welcome to retake this survey **later** if you want to comment on other mitigation activities by re-using the link provided to you.

Would you like to be contacted regarding the results of this survey (e.g. follow-up questions)?

☐ Yes
☐ No

Please enter you email address below

Back Submit

Access to the online survey: