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MAPPING HOW OUTPUTS FROM VARIOUS BUSHFIRE AND NATURAL HAZARDS CRC PROJECTS COULD BE COMBINED TO ADDRESS THE ISSUE OF HOW TO BEST MANAGE FUEL TO REDUCE BUSHFIRE RISK INTO THE FUTURE

Mechanical Fuel Load Reduction Utilisation project

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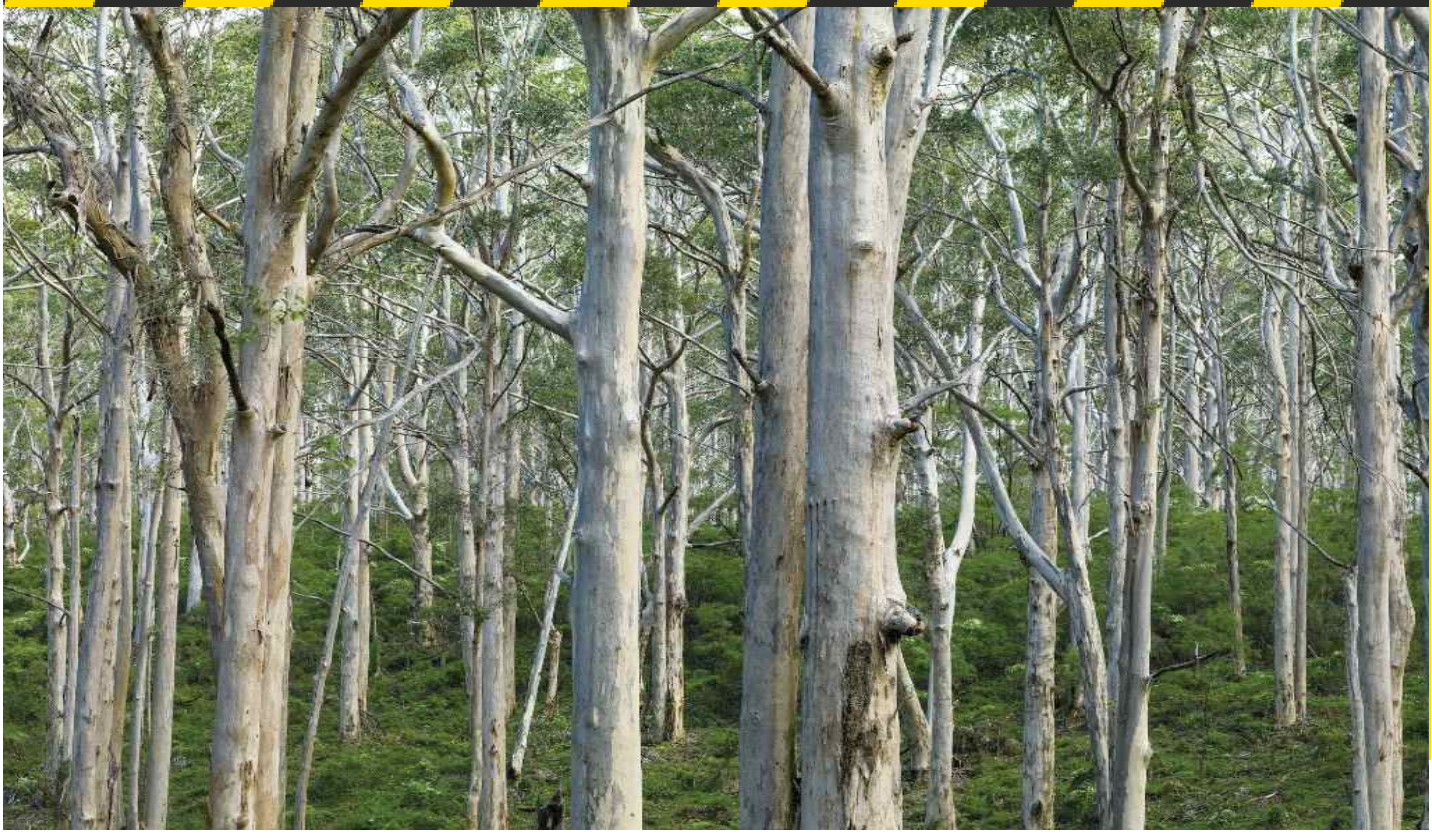

THE UNIVERSITY of ADELAIDE

GOVERNMENT OF WESTERN AUSTRALIA

DFES Department of Fire & Emergency Services

FOR A SAFER STATE

RIKS research institute for knowledge systems

Version	Release history	Date
1.0	Initial release of document	07/01/2022

Australian Government
Department of Industry, Science, Energy and Resources

AusIndustry
Cooperative Research Centres Program

Publisher:
Bushfire and Natural Hazards CRC

January 2022

Citation: Jeanneau A, Zecchin A, van Delden H, McNaught T & Maier H (2021) Mapping how outputs from various Bushfire and Natural Hazards CRC projects could be combined to address the issue of how to best manage fuel to reduce bushfire risk into the future, Bushfire and Natural Hazards CRC, Melbourne.

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ACKNOWLEDGMENTS

The project team at the University of Adelaide and the Research Institute for Knowledge Systems would like to thank our end-users in Western Australia and South Australia. Your insight and contributions were invaluable.

We would also like to thank everyone within the Bushfire and Natural Hazards CRC office who have supported this work in multiple ways, from funding, contracting, and business development.

EXECUTIVE SUMMARY

This project reviewed all of the Bushfire and Natural Hazard CRC (CRC) publications hosted on the CRC website to identify outputs that could be of interest in addressing the issue of how to best manage fuel to reduce bushfire risk into the future.

We identified 12 projects part of five research clusters involving a wide range of actors: Prescribed burning and catchment management, Economics and strategic decisions, Bushfire predictive services, Governance and institutional knowledge, Understanding and enhancing resilience which could offer potential synergies with the Mechanical Fuel Load Reduction (MFLR) Utilisation Project. The most relevant outputs were summarised in conceptual diagrams (mind-maps), and possible utilisation for the MFLR milestones was highlighted in each section.

1. INTRODUCTION

This task's main aim was to look for outputs from other Bushfire and Natural Hazards CRC (CRC) projects that could be of interest in addressing the issue of how to best manage fuel to reduce bushfire risk into the future.

First, we accessed the publications hosted on the CRC website and listed the most relevant ones for our project. These are classified into five clusters and include 12 projects (Table 1). The next step was to identify which information (outputs) would be the most relevant for our application and combine them in a conceptual diagram (mind-map) (Figure 1). In the mind-maps, each of the child nodes branching from project names represents a tool, an idea or group of information which can help us identify how to best manage fuel to reduce bushfire risk into the future. The subsequent nodes in the chart characterise these ideas/concepts in more detail. All the nodes containing ideas or outputs relevant for this current project have been highlighted in a similar shade as the corresponding parent CRC project.

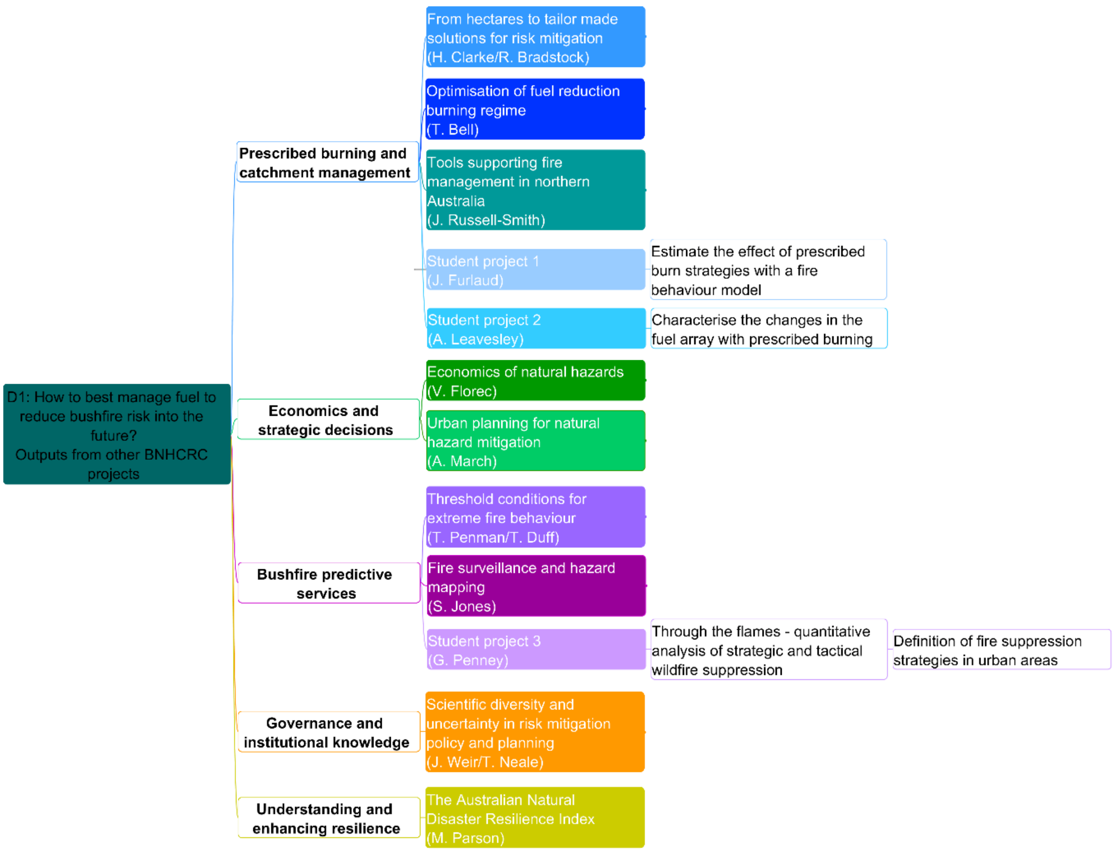

FIGURE 1. CONCEPTUAL MAP REGROUPING THE MOST RELEVANT PROJECTS FROM THE CRC.

TABLE 1. LIST OF CLUSTERS AND PROJECTS SHORTLISTED.

Cluster name	Project name	Project leader(s)	Affiliation
Prescribed burning and catchment management	From hectares to tailor-made solutions for risk mitigation	Ross Bradstock	University of Wollongong
		Hamish Clarke	University of Wollongong
	Optimisation of fuel reduction burning regime	Tina Bell	University of Sydney
	Tools supporting fire management in northern Australia	Jeremy Russell-Smith	Charles Darwin University
	Student project 1	James Furlaud	University of Tasmania
	Student project 2	Adam Leavesley	ANU
Economics and strategic decisions	Economics of natural hazards	Veronique Florec	University of Western Australia
		Atakelty Hailu	University of Western Australia
	Urban planning for natural hazard mitigation	Alan March	University of Melbourne
Bushfire predictive services	Threshold conditions for extreme fire behaviour	Trent Penman	University of Melbourne
		Thomas Duff	University of Melbourne
	Fire surveillance and hazard mapping	Simon Jones	RMIT University
		Karin Reinke	RMIT University
	Student project 3	Greg Penney	Edith Cowan University
Governance and institutional knowledge	Scientific diversity and uncertainty in risk mitigation policy and planning	Jessica Weir	Western Sydney University
Understanding and enhancing resilience	The Australian Natural Disaster Resilience Index	Melissa Parsons	University of New England

Below are some of the key elements represented in the mind-map chart. These will be grouped by clusters and projects, respectively.

2. PRESCRIBED BURNING AND CATCHMENT MANAGEMENT

2.1 FROM HECTARES TO TAILOR-MADE SOLUTIONS FOR RISK MITIGATION

This project aims to identify the drivers of prescribed burning effectiveness across Australia and use predictive modelling to measure the effect of prescribed burning on subsequent bushfire behaviour. One of the most interesting findings from this project is the identification of future changes in prescribed burn windows for southern Australia. Their studies focussed primarily on southern Australia, but the method employed could be transferred to other Australian states, such as Western Australia (WA) (Clarke et al., 2019b, Di Virgilio et al., 2020). The authors used a combination of weather observations and future climate projections (NARCliM) to estimate the frequency of suitable prescribed burning days (e.g. maximum daily temperature, relative humidity, wind speed, fuel moisture, Forest Fire Danger Index). Overall, they did not identify significant changes in the total number of days with suitable conditions to conduct prescribed burning (i.e. "burning window"). Instead, they observed a shift in optimal conditions from late Spring and early Summer to Autumn, Winter or early Spring. This method could be applied to WA to see if these trends are applicable in this region and the results compared with those generated using the outputs from the bushfire model used in UNHaRMED (Deliverable 2).

Other relevant research from this group compared the effects of 22 planned burning scenarios on eight societal objectives (Driscoll et al., 2016). This paper aimed to identify which combination of prescribed burning levels and spatial burn plan would maximise house protection and water quality while minimising the impact of prescribed burning on carbon emissions and human health and limiting the decline of five species types. The results demonstrated that none of the approaches met all of the objectives; however, the scenarios "burning 4% or 8% of the surface on the edge of the Wildland Urban Interface (WUI)" satisfied seven out of eight objectives. This method could also be tested in UNHaRMED to evaluate the performance of different prescribed burning scenarios in the WA application (Milestone 4, Milestone 5, Deliverable 3).

Following this research, the project tried to characterise the most effective way to quantify changes in bushfire risk with prescribed burning (Cirulis et al., 2020). They used a combination of a fire behaviour model (PHOENIX) and a Bayesian Decision Network to estimate the effectiveness of several prescribed burn treatment rates (ranging from 0 to 10%) to reduce bushfire risk. The results indicate that an increase in treatment rate induces a decrease in the predicted area burnt, house loss, life loss, and length of powerline and road damage, but it leads to an increase in the area burnt below the minimum Tolerable Fire Interval (TFI). Nonetheless, the authors caution that Forest Fire Danger Index (FFDI) has much more influence on bushfire risk reduction than any prescribed burn treatment rates and that this information should not be overlooked in fire management planning. This observation is critical for our current application and could be tested as part of the development of the General Analytical Framework (M4).

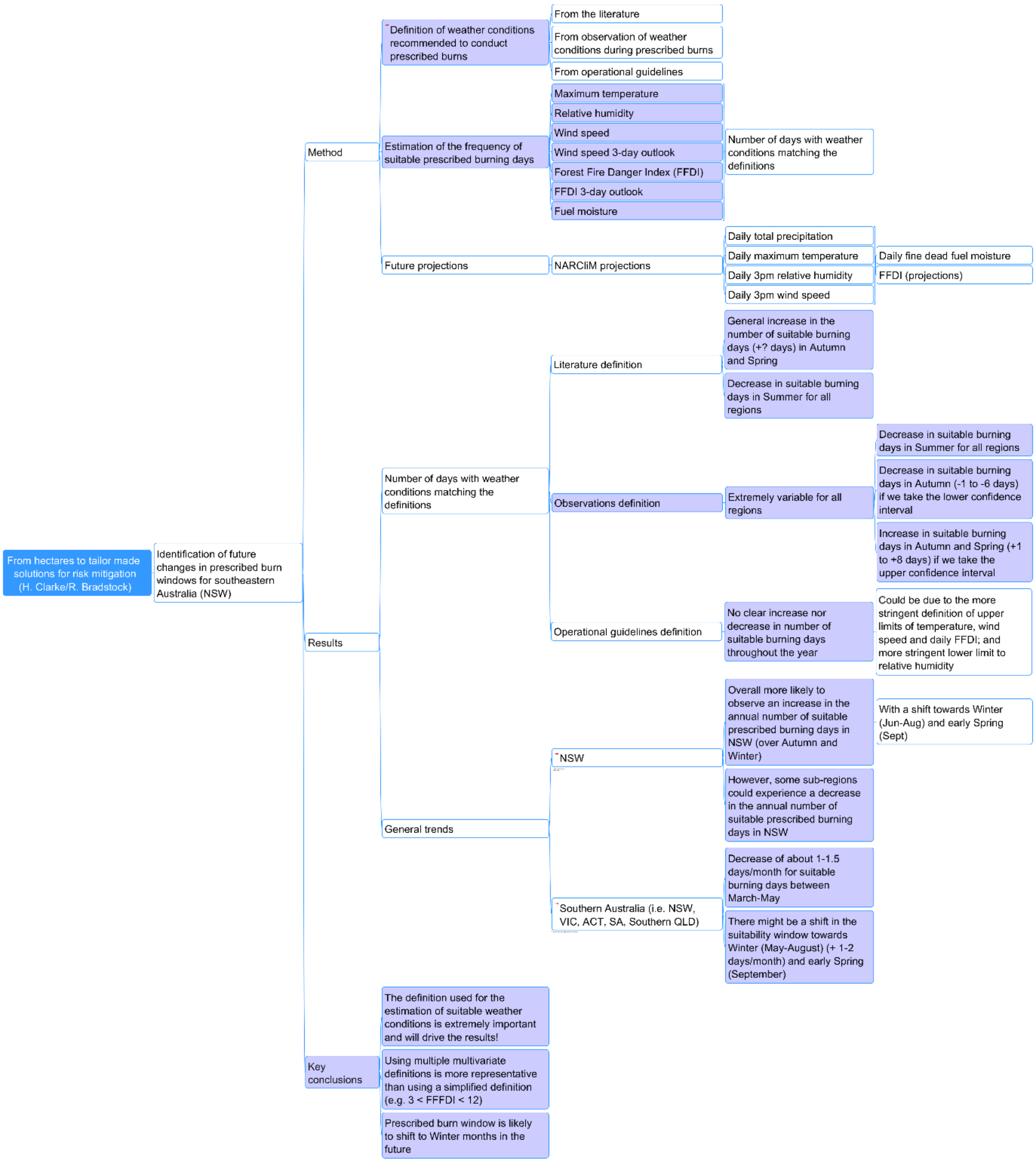

FIGURE 2. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "FROM HECTARES TO TAILOR-MADE SOLUTIONS FOR RISK MITIGATION" – PART 1/4: IDENTIFICATION OF FUTURE CHANGES IN PRESCRIBED BURN WINDOWS FOR SOUTHEASTERN AUSTRALIA.

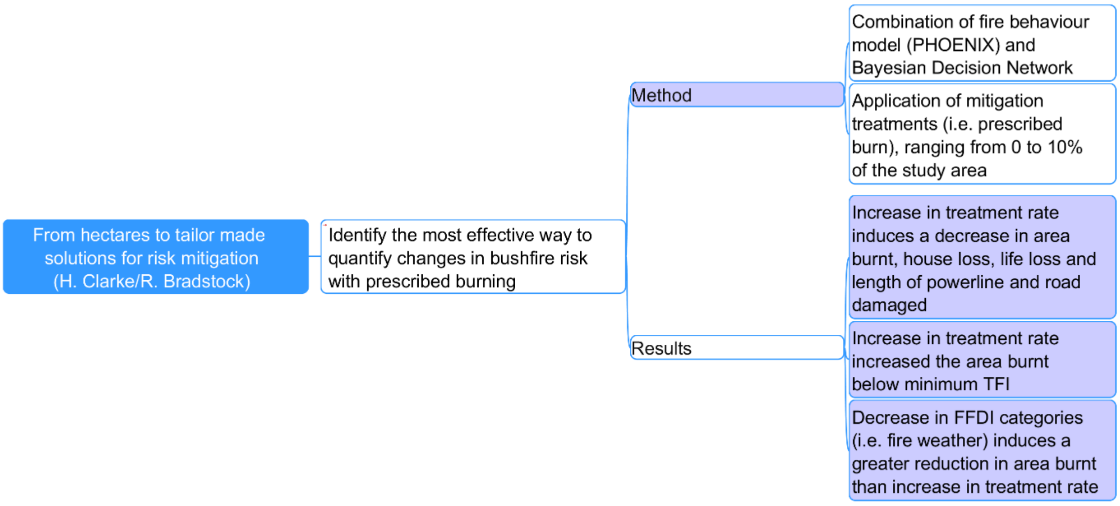

FIGURE 3. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "FROM HECTARES TO TAILOR-MADE SOLUTIONS FOR RISK MITIGATION" – PART 2/4: IDENTIFICATION OF THE MOST EFFECTIVE WAY TO QUANTIFY CHANGES IN BUSHFIRE RISK WITH PRESCRIBED BURNING.

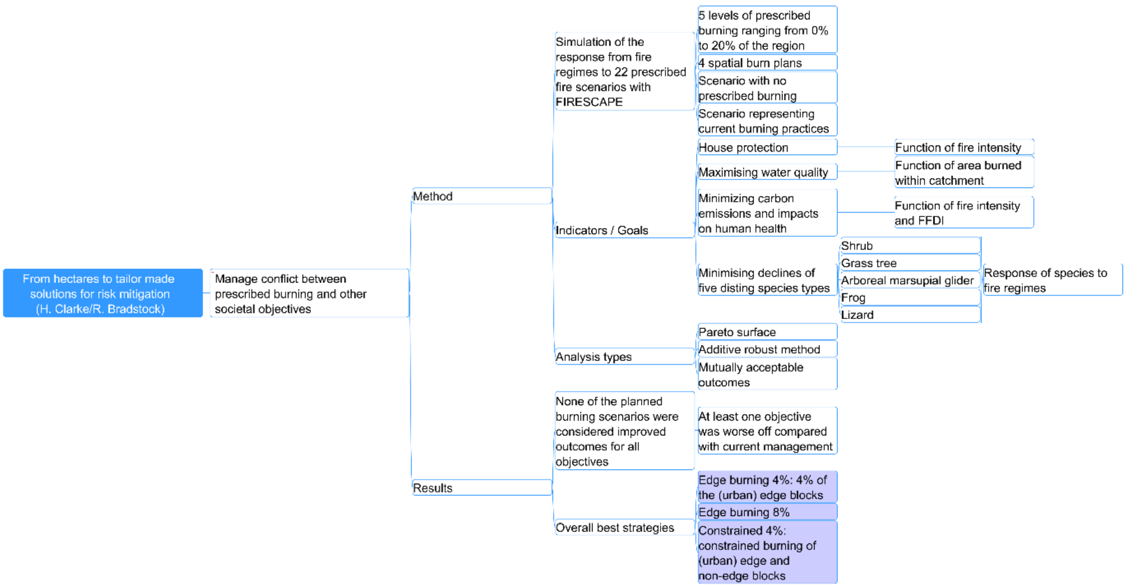

FIGURE 4. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "FROM HECTARES TO TAILOR-MADE SOLUTIONS FOR RISK MITIGATION" – PART 3/4: MANAGING CONFLICTS BETWEEN PRESCRIBED BURNING AND OTHER SOCIETAL OBJECTIVES.

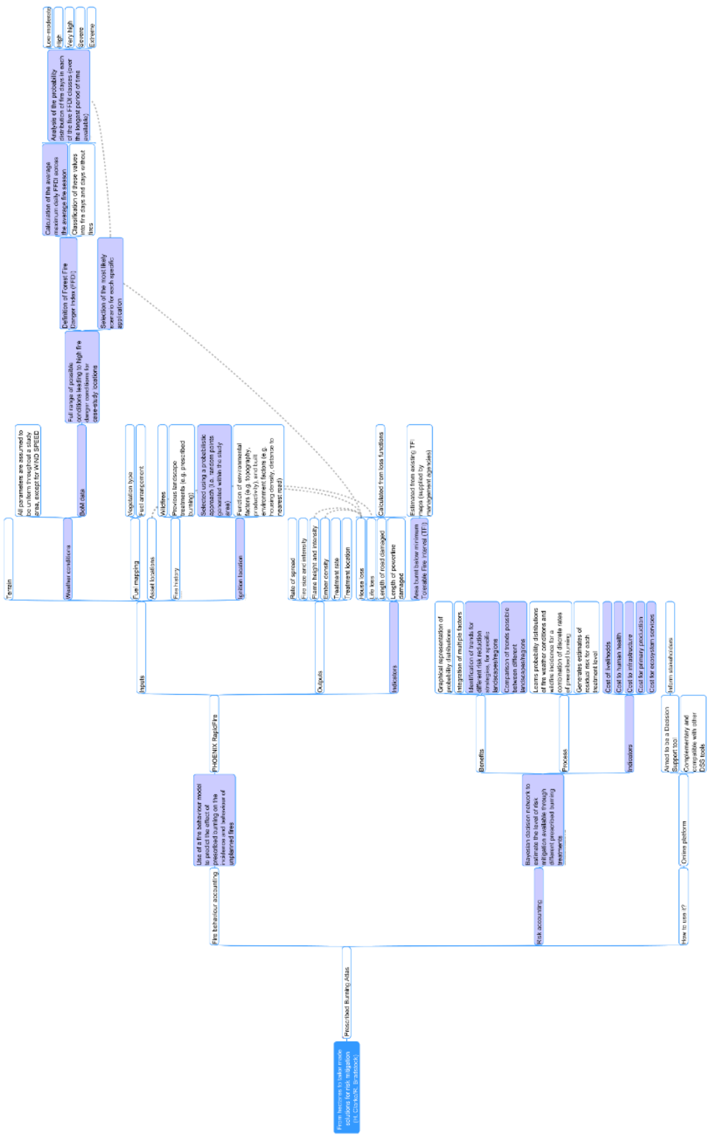

FIGURE 5. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "FROM HECTARES TO TAILOR-MADE SOLUTIONS FOR RISK MITIGATION" – PART 4/4: THE PRESCRIBED BURNING ATLAS.

Building on the information presented above, this research project has created the Prescribed Burning Atlas[1] (Clarke et al., 2020, Clarke et al., 2019a). This Atlas uses a fire behaviour model (PHEONIX) to predict the effect of prescribed burning on the incidence and behaviour of unplanned fires and a Bayesian Decision Network to estimate the level of risk mitigation available through different prescribed burning treatments. The results are then presented on an online platform with a Graphical User Interface (GUI). This enables end-users to compare the effect of different prescribed burning treatment options based on key indicators (e.g. house loss, life loss, road loss, length of power line loss, area affected by fire, area burnt below the TFI). For each application, the user can investigate the total cost (in $) of different prescribed burning scenarios when considering the percentage of the landscape treated or the amount of the Wildland Urban Interface treated. At the moment, only 13 case-study applications are available, which are located in southeastern Australia. Hamish Clarke mentioned during a webinar in December 2020 that the research group

[1] https://prescribedburnatlas.science/

would be open to extending their application to other states and regions (e.g. WA). We could potentially re-use the Bayesian Decision Network method used in the development of this tool to estimate the most effective fuel load management approach in the WA application (Milestone 4, Milestone 5, Deliverable 3). The second type of information that might be of interest for the UNHaRMED model is the method used to define the FFDI. The authors calculate the average maximum daily FFDI across the average fire season. Then they classify these values into fire days and days without fires. From there, they analyse the probability distribution of fire days in each of the five FFDI classes (low to extreme) over the longest period of time available. Finally, they select the most likely FFDI scenario for each specific application.

2.2 OPTIMISATION OF FUEL REDUCTION BURNING REGIMES

This project focuses on quantifying the effects of prescribed burning on water quality, carbon emissions, biodiversity conservation, and other environmental services to optimise fuel load management approaches. First, the research project has defined a range of metrics to evaluate the benefits of Fuel Reduction Burning (FRB) programs, based on extensive fieldwork conducted in NSW and the ACT (Bell et al., 2020, Bell et al., 2018). These indicators relate to information about vegetation (i.e. characterisation of the fuel load) and soil characteristics (e.g. pH, electrical conductivity, Carbon and Nitrogen), and recommendations about the optimal shape and number of sampling plots required to conduct the evaluation. The indicators proposed in this research could be used to calibrate and validate the UNHaRMED bushfire module's outputs (Milestone 2, Milestone 3, Milestone 6, Deliverable 2, Deliverable 4).

The research group also looked at the direct impact of FRB programs on carbon and nutrient stock, soil properties, water quality and vegetation diversity (Gharun et al., 2017). The authors explain that FRB can have temporary negative impacts on nutrient stock (e.g. reduced nitrogen content), soil properties (e.g. hydrophobicity) and water quality (e.g. runoff due to lack of protective cover to limited infiltrability). However, these effects can be easily controlled with improved knowledge of the local conditions pre-FRB (e.g. soil and fuel moisture content) and maintaining low-intensity fires. Another major benefit of FRB programs is reducing overall fire-related carbon emissions by up to 50%.

Based on the information presented above (results from ground surveys and modelling approaches), this research project proposed a framework for optimising FRB for the management of environmental values (Gharun et al., 2017) (Figure 6). The authors propose to consider the following components to optimise the planning of FRB programs: (1) define the objectives clearly (e.g. reduce fuel continuity, what is the purpose of the land being managed?), (2) identify when FRB need to be conducted (e.g. how long since last fire?, what are the fire conditions (i.e. behaviour, spread, intensity)?), (3) identify where the FRB will be conducted (possibility to compare the effects of FRB at multiple scales), priority areas should be defined based on local ecological information, (4) take into consideration logistics and cost of the treatment program. This information can be kept in mind when co-developing different mitigation scenarios with end-users in WA (Milestone 2, Milestone 3, Deliverable 2).

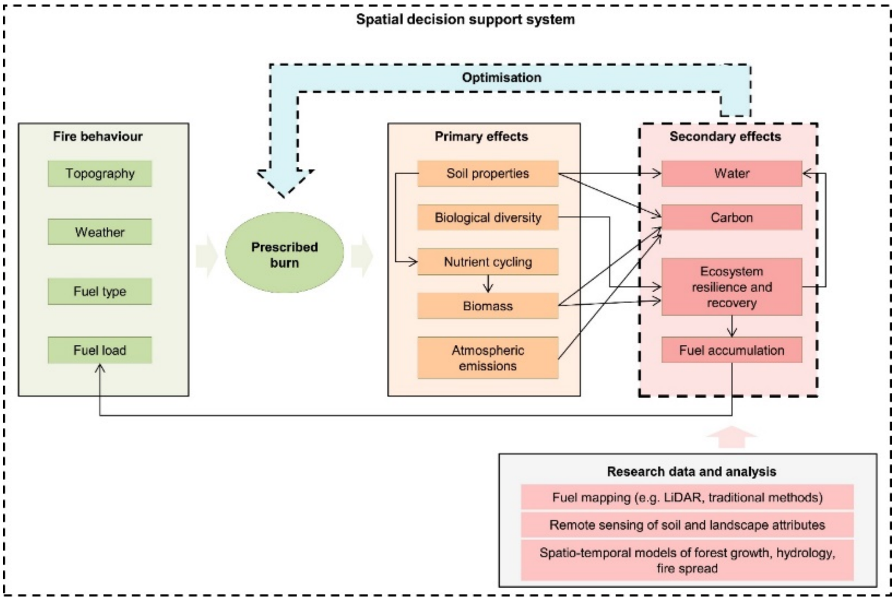

FIGURE 6. FRAMEWORK FOR OPTIMISING FRB FOR THE MANAGEMENT OF ENVIRONMENTAL VALUES. SOURCE: GHARUN ET AL., 2017.

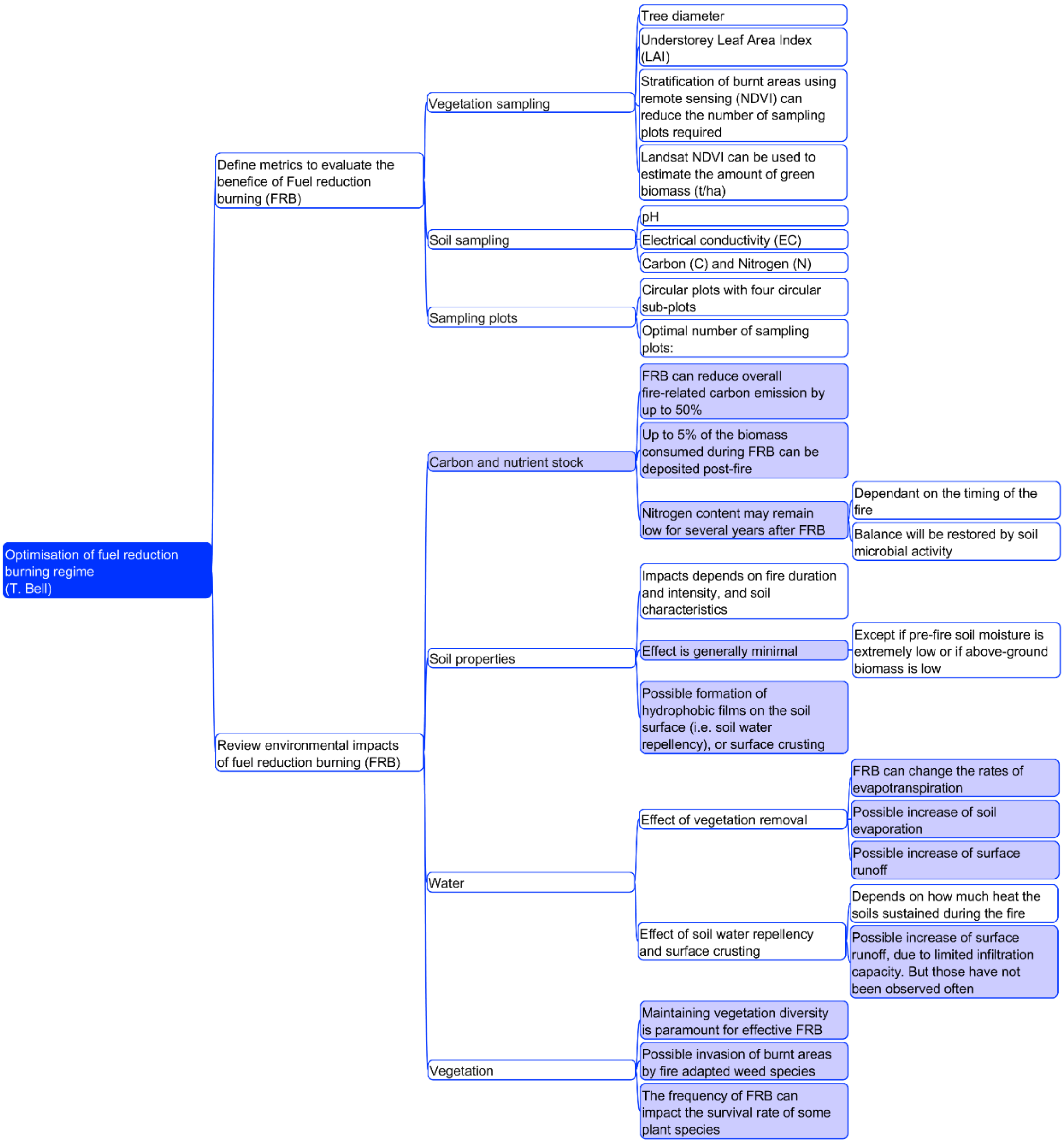

FIGURE 7. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "OPTIMISATION OF FUEL REDUCTION BURNING REGIME" – PART 1/2: DEFINITION OF METRICS FOR FUEL REDUCTION BURNING (FRB) EVALUATION & REVIEW ON THE ENVIRONMENTAL IMPACTS OF FRB.

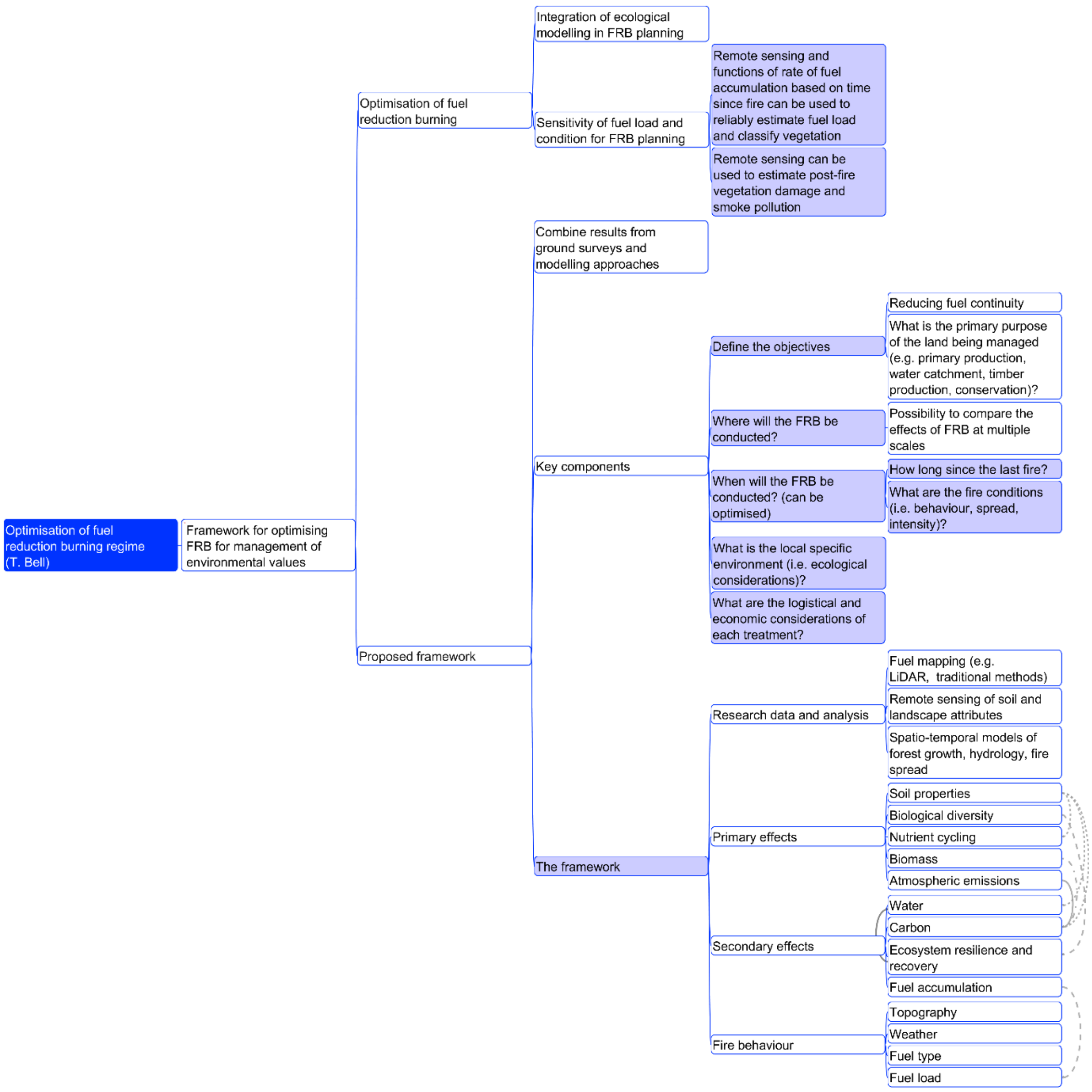

FIGURE 8. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "OPTIMISATION OF FUEL REDUCTION BURNING REGIME" – PART 2/2: DEFINITION OF A FRAMEWORK FOR OPTIMISING FRB FOR MANAGEMENT AND ENVIRONMENTAL VALUES.

2.3 TOOLS SUPPORTING FIRE MANAGEMENT IN NORTHERN AUSTRALIA

This project aims to develop effective approaches to fire management in the Northern Territory and remote Australia. They also defined metrics to set fire management targets for Northern Australia based on case-study examples (Russell-Smith et al., 2020, Evans and Russell-Smith, 2020). Outputs of this project are not directly relevant for the WA application, but their expertise in linking scientific evidence with policy development in remote communities could be of interest when scoping potential follow-up projects (Milestone 6, Deliverable 4).

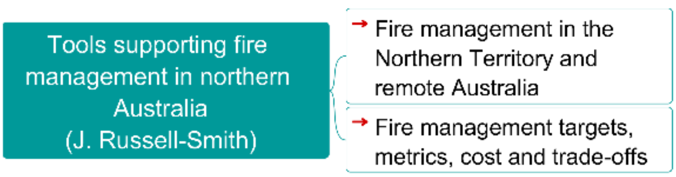

FIGURE 9. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "TOOLS SUPPORTING FIRE MANAGEMENT IN NORTHERN AUSTRALIA".

3. ECONOMICS AND STRATEGIC DECISIONS

3.1 ECONOMICS OF NATURAL HAZARDS

One of this project's most interesting research outputs is the cost/benefit analysis of fuel load reduction methods in WA (mostly prescribed burning) (Florec et al., 2020, Florec and Pannell, 2017). In these studies, the authors adapted an Investment Framework for Environmental Resources (INFFER, Gibson and Pannell (2014)) to evaluate the cost/benefit of fire mitigation techniques. This research compared three fuel load reduction methods: (1) increased fuel reduction (i.e. prescribed burning, mechanical work), (2) land-use planning to restrict future development in high-risk areas, and (3) encouraging landowners to manage fuels on their own land. The first method seemed to provide the most significant benefit in natural environments, high-value biodiversity and a smaller concentration of high-value human assets. However, the second one appeared to have more impact in high-density population hubs and in the presence of commercial buildings and high-value infrastructure (e.g. pre-urban environments). On the contrary, the third method did not influence fire behaviour, affecting only a small proportion of the landscape.

The adaptation of INFFER to WA conditions led to the creation of the Quick Economics Analysis Tool (QEAT) (Florec et al., 2019). This tool compares different hazard mitigation treatments by estimating each option's economic, social and environmental benefits (Figure 10). Such a method could be adapted to our application and transferred to the UNHaRMED framework to compare different bushfire mitigation options (Milestone 4, Milestone 5, Deliverable 3).

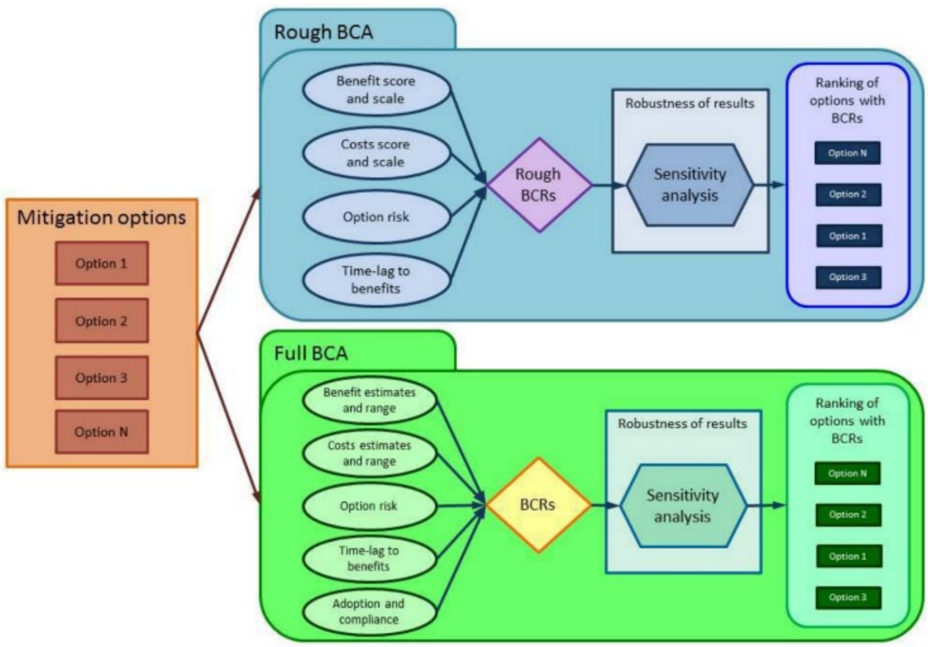

FIGURE 10. DIAGRAM REPRESENTING THE QUICK ECONOMICS ANALYSIS TOOL. BCA: BENEFIT-COST ANALYSIS, BCR: BENEFIT-COST RATIO. SOURCE: FLOREC ET AL. (2018).

This project also created a searchable database listing non-market valuation studies for intangible values affected by natural hazards and their management (e.g. fire, floods, earthquakes) (Rogers et al., 2018). This database is called the "Value Tool". It is destined to provide guidance on how the non-market value estimates should be used for specific policy contexts. The authors classify non-market value in three categories: health (physical and mental), environment (ecosystems, water quality), and social (recreational, amenity and safety, animal welfare). This tool could be used to identify potential benefits from fuel load mitigation strategies in our case-study application (Milestone 4, Milestone 5, Deliverable 3).

3.2 URBAN PLANNING FOR NATURAL HAZARD MITIGATION

This project aims to integrate natural hazard risk management in urban planning.

This project already uses UNHaRMED extensively. For instance, the lead researchers used UNHaRMED to test different scenarios to integrate bushfire risk reduction methods in urban planning (March et al., 2020a, March et al., 2020b). The main risk reduction methods tested were: avoidance of exposure to hazards, reduction of hazard impacts or exposure in situ, reduction in vulnerability or increase in resistance in situ, improvement of response, and improvement of recovery. Although the outputs produced by this project will not directly benefit the WA application for the optimisation of bushfire risk mitigation methods, we can still draw on the methodology employed to answer our questions (Milestone 4, Milestone 5, Deliverable 3).

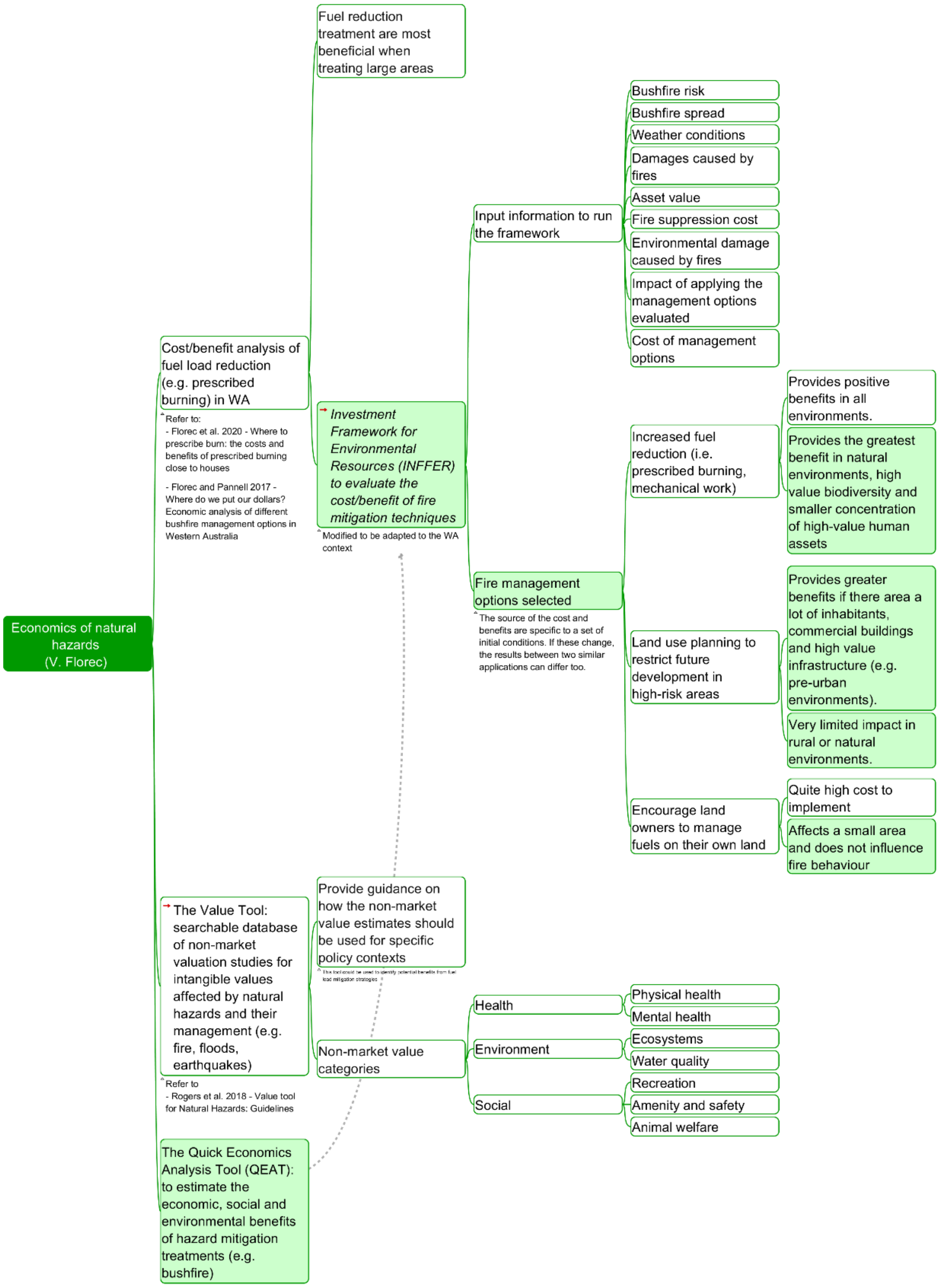

FIGURE 11. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT “ECONOMICS OF NATURAL HAZARDS”.

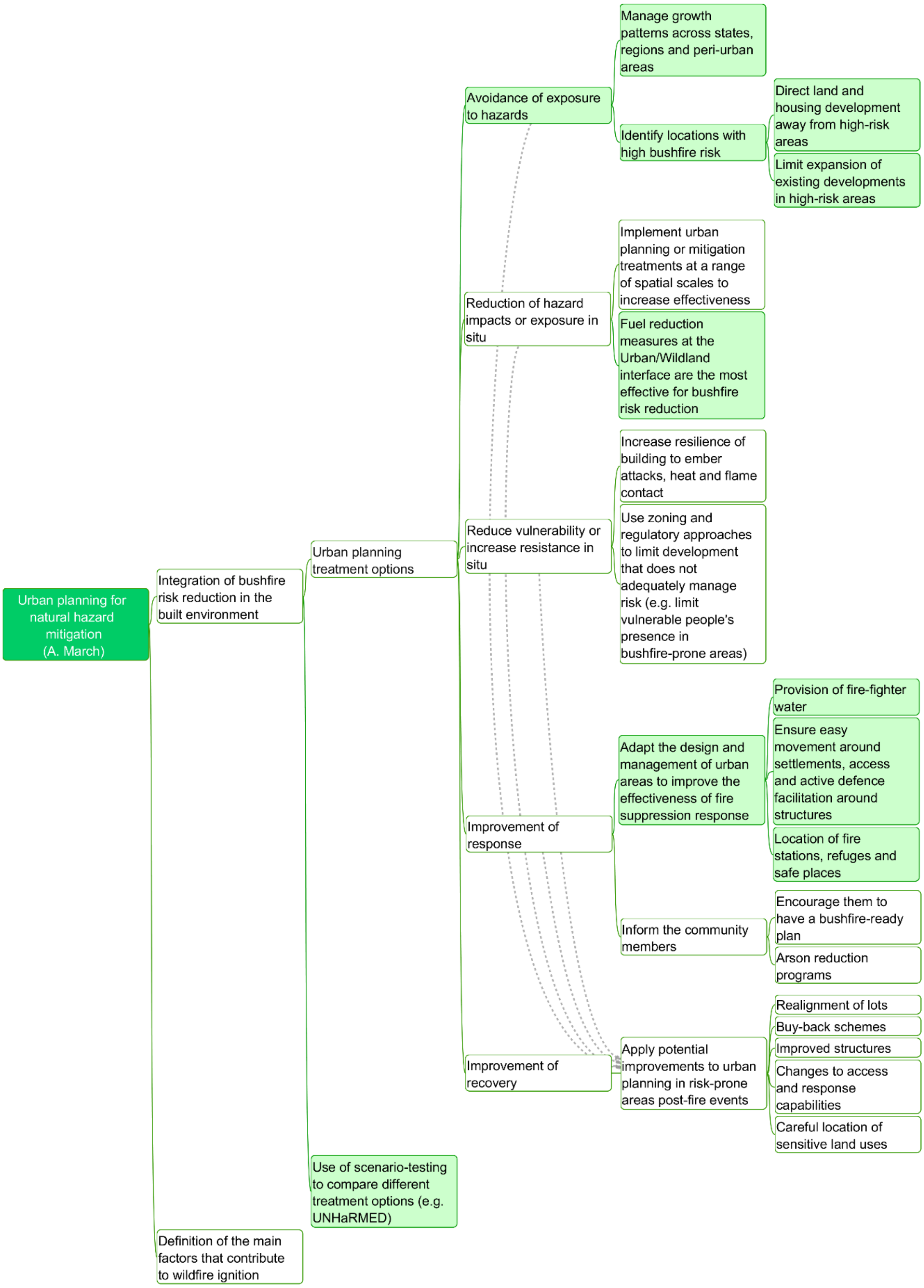

FIGURE 12. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "URBAN PLANNING FOR NATURAL HAZARD MITIGATION".

4. BUSHFIRE PREDICTIVE SERVICES

4.1 THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR

This research project aims to understand the conditions (e.g. weather) and factors leading to extreme fire behaviour by collating information from observations.

One of the most interesting outputs produced by the lead researchers relates to the cost-benefit analysis of future fire management strategies (Penman and Cirulis, 2020). The authors used a similar approach to Cirulis et al. (2020). They combined outputs from the PHOENIX fire behaviour model and a Bayesian Decision Network (BDN) to examine how mitigation treatments (prescribed burning and suppression) affected the risk to a range of assets and calculated the cost-benefit of each fire mitigation strategy. The authors concluded that large-scale prescribed burning was the most cost-effective approach and was most effective close to assets and in known fire paths. They also noted that the cost of not conducting prescribed burning increased over time (loss of assets > cost of fire management) but was more pronounced after five years without prescribed burning treatments. We could apply a similar methodology (UNHaRMED + BDN) when developing the generic analytical framework in our project to compare different fuel management strategies in WA and define under which conditions they are most effective (Milestone 4, Milestone 5, Deliverable 3).

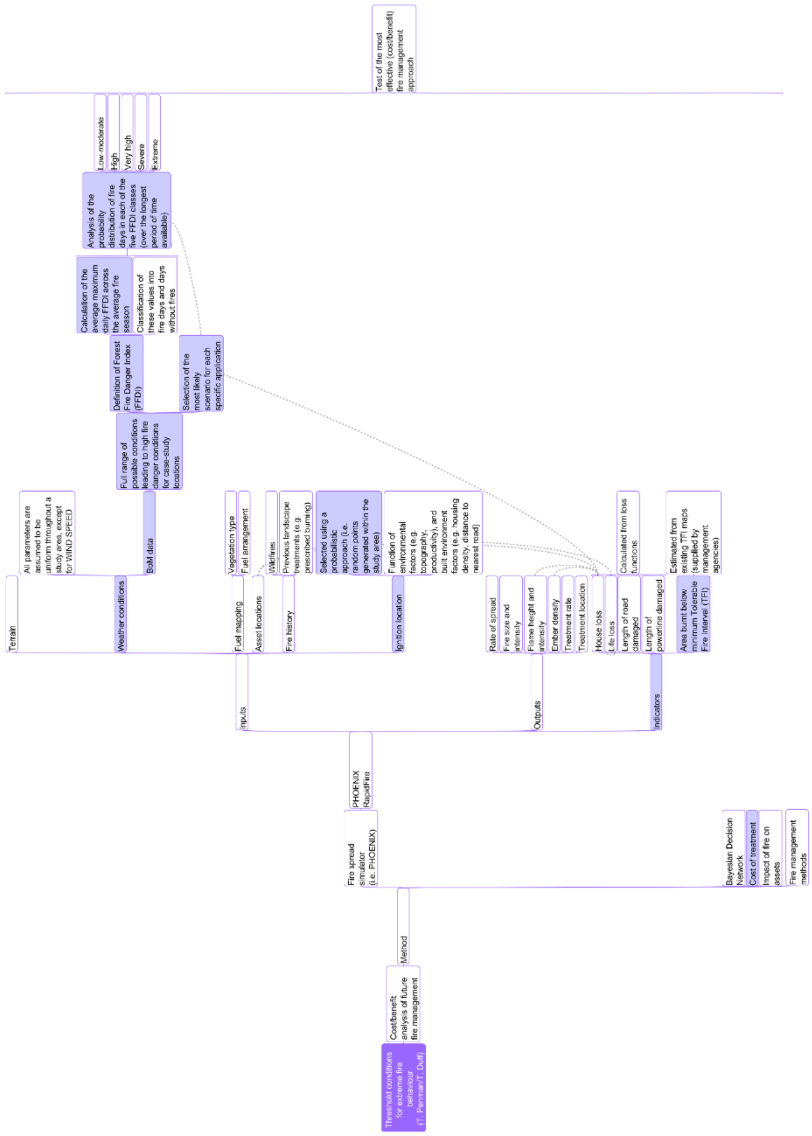

FIGURE 13. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR" – PART 1/6: COST-BENEFIT ANALYSIS OF FUTURE FIRE MANAGEMENT – METHOD: PHOENIX FIRE SPREAD SIMULATOR.

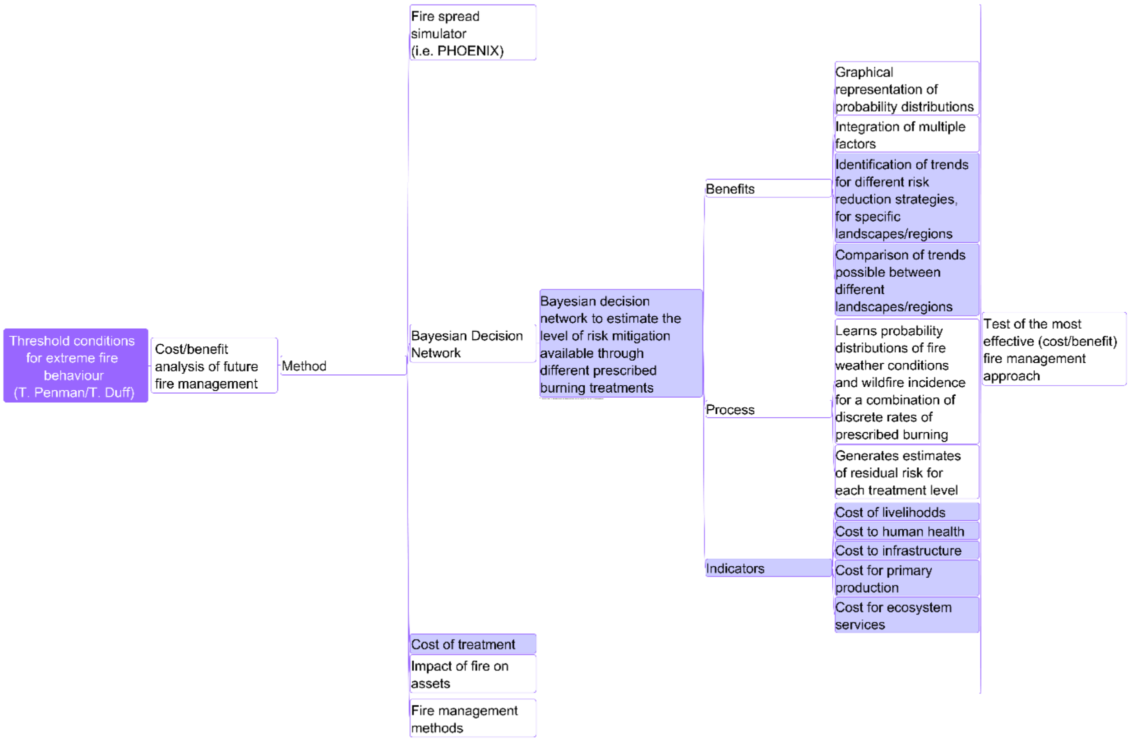

FIGURE 14. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR" – PART 2/6: COST-BENEFIT ANALYSIS OF FUTURE FIRE MANAGEMENT – METHOD: THE BAYESIAN DECISION NETWORK.

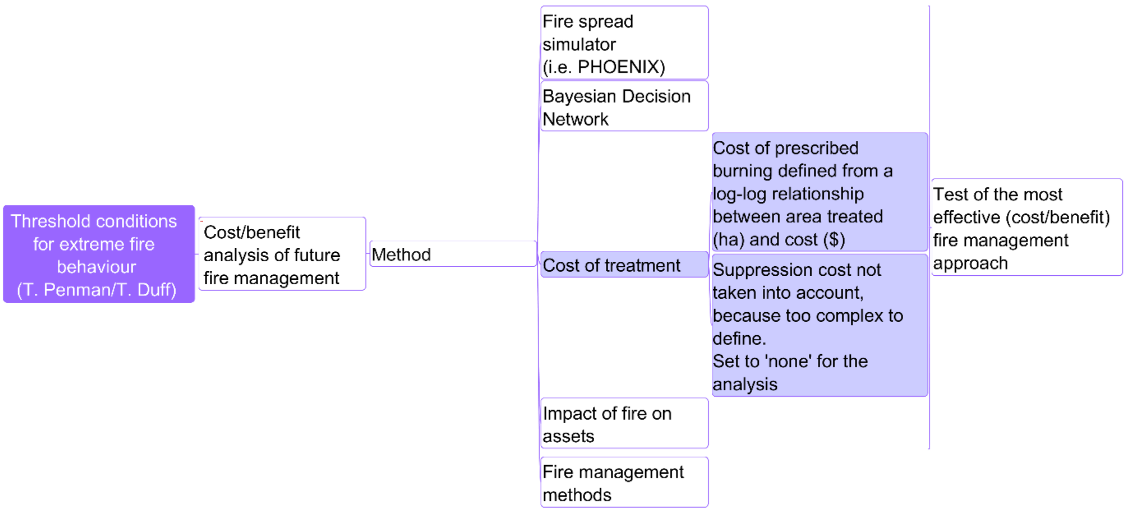

FIGURE 15. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR" – PART 3/6: COST-BENEFIT ANALYSIS OF FUTURE FIRE MANAGEMENT – METHOD: THE EVALUATION OF THE COST OF TREATMENT.

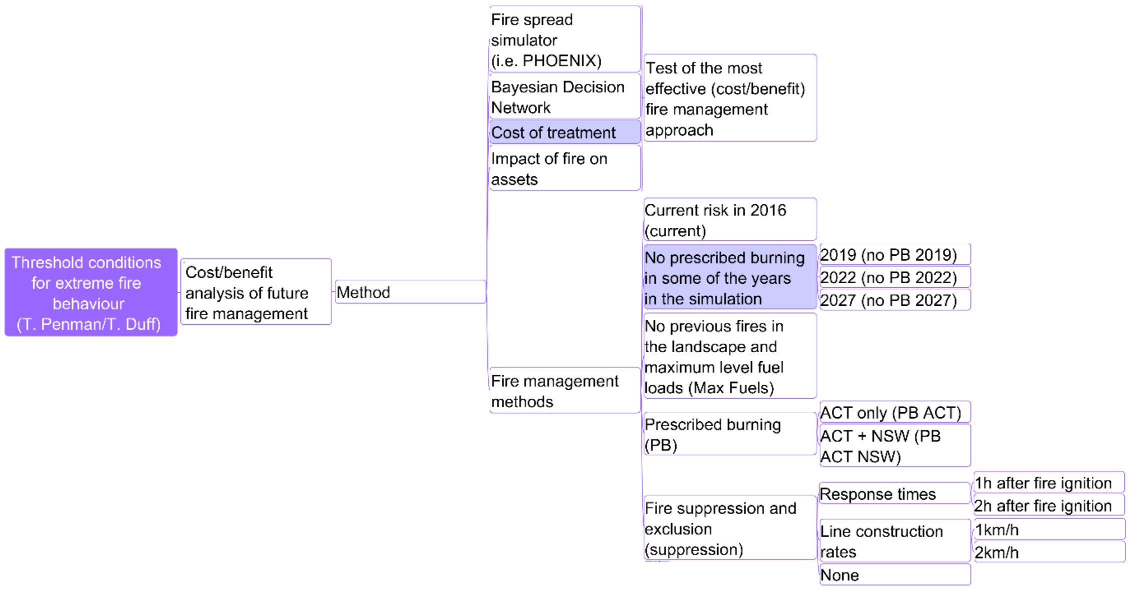

FIGURE 16. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR" – PART 4/6: COST-BENEFIT ANALYSIS OF FUTURE FIRE MANAGEMENT – METHOD: FIRE MANAGEMENT METHODS COMPARED.

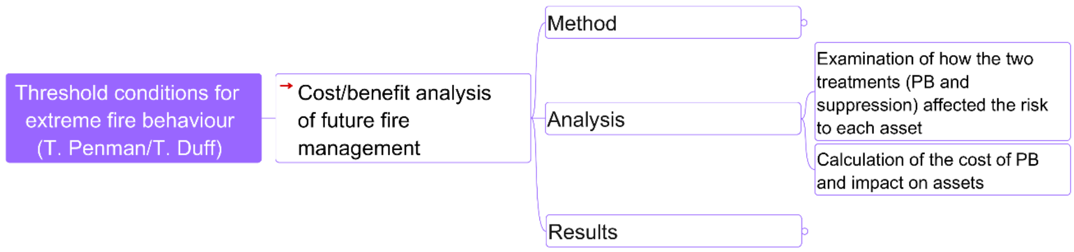

FIGURE 17. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR" – PART 5/6: COST-BENEFIT ANALYSIS OF FUTURE FIRE MANAGEMENT – ANALYSIS.

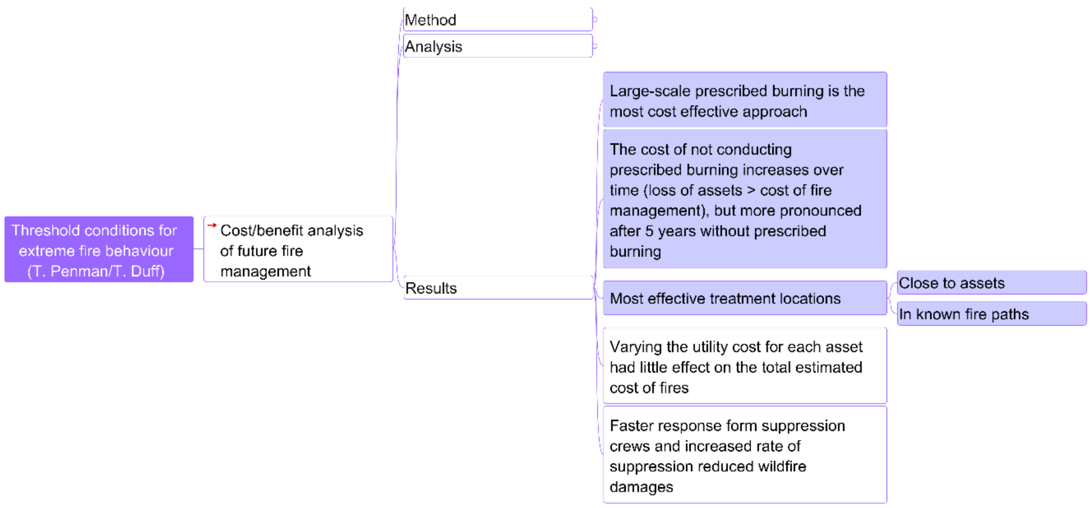

FIGURE 18. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR" – PART 6/6: COST-BENEFIT ANALYSIS OF FUTURE FIRE MANAGEMENT – RESULTS.

4.2 FIRE SURVEILLANCE AND HAZARD MAPPING

This research project looks at using earth observation systems to optimise active fires monitoring and improve post-fire extent and severity mapping. This project also uses remote sensing to monitor pre- and post-fire changes in fuel load. To this end, a smartphone application was developed as part of the project: Fuels3D, which allows land managers to collect imagery in the field and estimate vegetation structure and fuel load rapidly (Wallace et al., 2017a, Wallace et al., 2020, Hally et al., 2019, Hally et al., 2020, Reinke et al., 2019). This app can also be used to compare changes in fuel load before and after fire events (e.g. wildfires or prescribed burn) (Wallace et al., 2016, Wallace et al., 2017b).

This project might not have direct implications for the current project, but the outputs (Fuels3D app) are interesting. The app could potentially be used for ground-truthing results from the UNHaRMED predictions during the calibration/validation phase (Milestone 2, Milestone 3, Milestone 6, Deliverable 2, Deliverable 4).

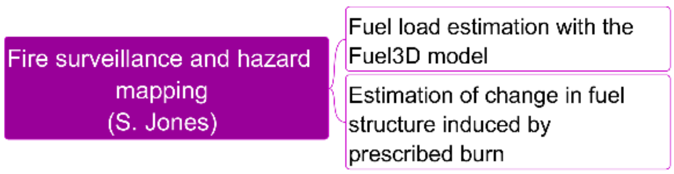

FIGURE 19. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "FIRE SURVEILLANCE AND HAZARD MAPPING".

5. GOVERNANCE AND INSTITUTIONAL KNOWLEDGE – SCIENTIFIC DIVERSITY AND UNCERTAINTY IN RISK MITIGATION POLICY AND PLANNING

This project's main goal was to increase the integration of scientific research in the policy-making process and provide tools to policymakers and practitioners so they can explain risk mitigation and translate its scientific basis.

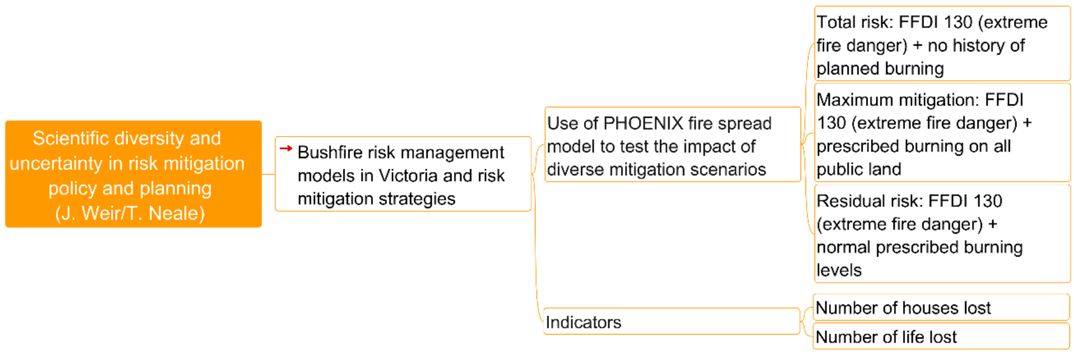

FIGURE 20. CONCEPTUAL MAP REPRESENTING THE OUTPUTS OF INTEREST FROM THE PROJECT "SCIENTIFIC DIVERSITY AND UNCERTAINTY IN RISK MITIGATION POLICY AND PLANNING".

The lead researchers have conducted pilot projects in Victoria, where they engaged with local governmental agencies who used the PHEONIX fire spread model to test the impact of diverse mitigation scenarios (Neale, 2016). These particular research results are not directly important for our current project, but the methodology can be translated to the UNHaRMED framework. We will work closely with local authorities in WA to ensure that UNHaRMED is correctly calibrated and that it will be reliably used to compare the effect of diverse mitigation strategies (Milestone 2, Milestone 3, Deliverable 2).

6. UNDERSTANDING AND ENHANCING RESILIENCE – THE AUSTRALIAN DISASTER RESILIENCE INDEX

This project developed an index listing the current state of resilience in Australian communities at a large scale: the Australian Natural Disaster Resilience Index (Parsons et al., 2016). This tool is designed to be used by national, state, and local governments to engage more easily with local communities and provide valuable inputs for policy-making and strategic planning to better manage the response to natural hazards.

Although this project outputs are not directly significant for our project, it might be useful to understand better how to present our final results, compare the relative index values with the plausible future bushfire risk hot-spots (Milestone 2) and discuss the potential implications for fuel management activities in these regions (Milestone 3, Milestone 4, Deliverable 3).

TEAM MEMBERS

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REFERENCES

1 BELL, T., PARNELL, D. & POSSELL, M. 2018. Sampling and data analysis of field sites in NSW. Melbourne: Bushfire and Natural Hazards CRC.

2 BELL, T., PARNELL, D. & POSSELL, M. 2020. Sampling and data analysis of field sites of 40 prescribed burns. Melbourne: Bushfire and Natural Hazards CRC.

3 CIRULIS, B., CLARKE, H., BOER, M., PENMAN, T., PRICE, O. & BRADSTOCK, R. 2020. Quantification of inter-regional differences in risk mitigation from prescribed burning across multiple management values. *International Journal of Wildland Fire,* 29**,** 414-426.

4 CLARKE, H., BRADSTOCK, R., PRICE, O., CIRULIS, B., PENMAN, T. & BOER, M. 2020. The Prescribed Burning Atlas: a new system to plan effective prescribed burns. Melbourne: Bushfire and Natural Hazard CRC.

5 CLARKE, H., CIRULIS, B., BRADSTOCK, R., BOER, M. M., PENMAN, T. & PRICE, O. 2019a. A new decision support tool for prescribed burning risk assessment. *Bushfire and Natural Hazards CRC & AFAC conference.* Melbourne.

6 CLARKE, H., TRAN, B., BOER, M. M., PRICE, O., KENNY, B. & BRADSTOCK, R. 2019b. Climate change effects on the frequency, seasonality and interannual variability of suitable prescribed burning weather conditions in south-eastern Australia. *Agricultural and Forest Meteorology,* 271**,** 148-157.

7 DI VIRGILIO, G., EVANS, J. P., CLARKE, H., SHARPLES, J., HIRSCH, A. L. & HART, M. A. 2020. Climate Change Significantly Alters Future Wildfire Mitigation Opportunities in Southeastern Australia. *Geophysical Research Letters,* 47**,** e2020GL088893.

8 DRISCOLL, D. A., BODE, M., BRADSTOCK, R. A., KEITH, D. A., PENMAN, T. D. & PRICE, O. F. 2016. Resolving future fire management conflicts using multicriteria decision making. *Conservation Biology,* 30**,** 196-205.

9 EVANS, J. & RUSSELL-SMITH, J. 2020. Delivering effective savanna fire management for defined biodiversity conservation outcomes: an Arnhem Land case study. *International Journal of Wildland Fire,* 29**,** 386-400.

10 FLOREC, V., BURTON, M., PANNELL, D., KELSO, J. & MILNE, G. 2020. Where to prescribe burn: the costs and benefits of prescribed burning close to houses. *International Journal of Wildland Fire,* 29**,** 440-458.

11 FLOREC, V. & PANNELL, D. 2017. Where do we put our dollars? Economic analysis of different bushfire management options in Western Australia. *Bushfire and Natural Hazards CRC & AFAC conference.* Sydney.

12 FLOREC, V., ROGERS, A., HAILU, A. & PANNELL, D. 2019. Economics of Natural Hazards Annual Report 2018-2019. Melbourne: Bushfire and Natural Hazards CRC.

13 GHARUN, M., POSSELL, M., BELL, T. L. & ADAMS, M. A. 2017. Optimisation of fuel reduction burning regimes for carbon, water and vegetation outcomes. *Journal of Environmental Management,* 203**,** 157-170.

14 GIBSON, F. L. & PANNELL, D. 2014. Integrated economic assessment of fire risk management strategies: case studies in central Otago, New Zealand, and Mount Lofty Region, South Australia–final report for the Integrated Assessment of Prescribed Burning project. Melbourne: Bushfire CRC.

15 HALLY, B., REID, K., WALLACE, L. & JONES, S. 2019. Quantifying fuel hazard assessments - Fuels3D: Annual Project Report 2018-2019. Melbourne: Bushfire and Natural Hazards CRC.

16 HALLY, B., REINKE, K., WALLACE, L. & JONES, S. 2020. Quantifying fuel hazard assessments - Fuels3D: Annual Project Report 2019-2020. Melbourne: Bushfire and Natural Hazards CRC.

17 MARCH, A., DE MORAES, L. N., RIDDELL, G., DOVERS, S., STANLEY, J., VAN DELDEN, H., BEILIN, R. & MAIER, H. 2020a. Integrating bushfire risk reduction and statutory mechanisms in South Australia: assessment of the draft Planning and Design Code 2019. Melbourne: Bushfire and Natural Hazards CRC.

18 MARCH, A., RIDDELL, G., DE MORAES, L. N., STANLEY, J., VAN DELDEN, H., BEILIN, R., DOVERS, S. & MAIER, H. 2020b. Urban planning capabilities for bushfire: treatment categories and scenario testing. *Australian Journal of Emergency Management, The,* 35**,** 32.

19 NEALE, T. 2016. Burning anticipation: Wildfire, risk mitigation and simulation modelling in Victoria, Australia. *Environment and Planning A: Economy and Space,* 48**,** 2026-2045.

20 PARSONS, M., GLAVAC, S., HASTINGS, P., MARSHALL, G., MCGREGOR, J., MCNEILL, J., MORLEY, P., REEVE, I. & STAYNER, R. 2016. Top-down assessment of disaster resilience: A conceptual framework using coping and adaptive capacities. *International Journal of Disaster Risk Reduction,* 19**,** 1-11.

21 PENMAN, T. D. & CIRULIS, B. A. 2020. Cost effectiveness of fire management strategies in southern Australia. *International Journal of Wildland Fire,* 29**,** 427-439.

22 REINKE, K., WALLACE, L., HILLMAN, S., HALLY, B. & JONES, S. 2019. Fuels3D: barking up the wrong tree and beyond. *Bushfire and Natural Hazards CRC & AFAC conference.* Melbourne.

23 ROGERS, A., GIBSON, F. L., BOXALL, P. C., BURTON, M., HAWKINS, J. I., JOHNSTON, R. J., KRAGT, M. E., ROLFE, J. & PANNELL, D. 2018. Value tool for Natural Hazards: Guidelines. Melbourne: Bushfire and Natural Hazard CRC.

24 RUSSELL-SMITH, J., EDWARDS, A. C., SANGHA, K. K., YATES, C. P. & GARDENER, M. R. 2020. Challenges for prescribed fire management in Australia's fire-prone rangelands – the example of the Northern Territory. *International Journal of Wildland Fire,* 29**,** 339-353.

25 WALLACE, L., GUPTA, V., REINKE, K. & JONES, S. 2016. An Assessment of Pre- and Post Fire Near Surface Fuel Hazard in an Australian Dry Sclerophyll Forest Using Point Cloud Data Captured Using a Terrestrial Laser Scanner. *Remote Sensing,* 8.

26 WALLACE, L., HALLY, B., HILLMAN, S., JONES, S. & REINKE, K. 2020. Terrestrial Image-Based Point Clouds for Mapping Near-Ground Vegetation Structure: Potential and Limitations. *Fire,* 3**,** 59.

27 WALLACE, L., HILLMAN, S., REINKE, K. & HALLY, B. 2017a. Non-destructive estimation of above-ground surface and near-surface biomass using 3D terrestrial remote sensing techniques. *Methods in Ecology and Evolution,* 8**,** 1607-1616.

28 WALLACE, L., REID, K., JONES, S., HALLY, B., HILLMAN, S. & SPITS, C. 2017b. Mapping the efficacy of an Australian fuel reduction burn using Fuels3D point clouds. *Bushfire and Natural Hazards CRC & AFAC conference.* Sydney.