



ECONOMICS AND FUTURE SCENARIOS

FINAL PROJECT REPORT

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Research in this project was primarily undertaken at The Australian National University





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Cover:

Left - Firefighters battle a blaze. Photo by CFS Promotions Unit.

Right - The burnt hills outside Marysville, Victoria after the Black Saturday bushfire in 2009. Photo by Bushfire CRC.

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Summary

The Bushfire CRC's *Future Scenarios & Economics* project has provided new insights into future bushfire regimes and economic evaluation of bushfires in Australia. Our research indicates that fire activity is likely to increase in mesic (moister) environments, but decrease in arid environments. However, complex interactions between future climate and concentration of atmospheric CO₂, which both affect fuel load dynamics, may result in relatively little change in intensity of future fires in some locations. Economic evaluation is a potentially useful tool in exploring management adaptation to these changes, but it is currently under-utilised within Australian land and fire management agencies. Our research has identified a number of key actions that are needed to increase the use of economic evaluation methods, including: (i) increasing the economic expertise amongst bushfire management and policy professionals, and (ii) designing economic evaluation that connects to the broader social and political context of bushfire management decision-making.

The *Future Scenarios & Economics* project has contributed widely to the scientific literature on a diversity of topics. Contributions authored or co-authored by project members, with Bushfire CRC affiliation noted in the article, include:

- **Nine** peer-reviewed journal articles or book chapters resulting directly from the current project (two of which were initiated in an earlier Bushfire CRC project but which relied on significant effort from the current project);
- **One** further journal article (non peer-reviewed) arising directly from the current project;
- **Two** further peer-reviewed journal articles or book chapters resulting from collaboration between the current project and other Bushfire CRC projects (including previous 2003-2010 projects) or other external projects;
- **Two** further recent peer-reviewed journal articles on fire ecology arising from a previous Bushfire CRC project (2003-2010);
- **Eight** conference posters or abstracts on future scenarios and economics arising directly from the current project;
- **Two** *Fire Notes* (one awaiting publication) arising directly from the current project;
- **Ten** *Future Scenarios and Economics* quarterly reports arising directly from the current project.

Other key achievements include hosting a national workshop on Australia's future bushfire scenarios, which led to the publication of one journal article, and a national end-user engagement workshop on bushfire economics that presented research results and was critical in validating results from a project survey of bushfire economics.

The key research results are outlined below, drawing on formally published journal articles, book chapters and posters resulting from research directly relating to the future scenarios project, or from relevant research arising from collaboration with other researchers/projects. All publications reported here are formally affiliated with the Bushfire CRC in writing in the publication. Authors indicating affiliation with the *Future Scenarios and Economics* project are highlighted in bold text. Further discussion of progress can be found in the *Future Scenarios and Economics* project quarterly reports 1 – 10 (**Cary et al.** 2010 to 2013).

Acknowledgements

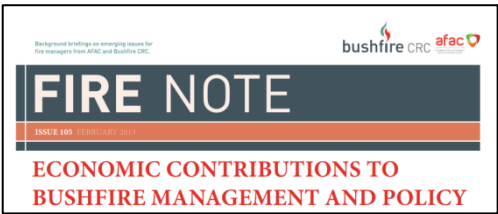
We gratefully acknowledge our project Lead End-Users – Andrew Stark, Chief Officer, ACT Emergency Services Agency, and Shane Wiseman, Manager, Fire Management Branch, Department of Environment, Water and Natural Resources, South Australia – for their collaboration, constructive feedback and critical insights throughout this project. We also gratefully acknowledge our collaborators from the Bushfire Cooperative Research Centre, including Gary Morgan, Richard Thornton, Lyndsey Wright, Annette Allen, Trevor Essex, Noreen Krusel, David Bruce, Vaia Smirneos, Mike Leonard and Nathan Maddock for their invaluable assistance, and we thank the Bushfire CRC Board for their interest in, and support of, this project. Numerous other Researchers and End-Users provided critical assistance with aspects of the research reported below and we have gratefully acknowledged them through co-authored contributions or in statements of acknowledgement in the individual publications arising from the various components of the project.

Research establishing the state of knowledge

Cary, Bradstock, **Gill** and Williams (2012) published a comprehensive, peer-reviewed chapter on 'Global Change and Fire Regimes in Australia' in the book 'Flammable Australia: Fire Regimes, Biodiversity and Ecosystems in a Changing World' (Bradstock, Gill, Williams Eds, CSIRO Publishing). This chapter comprehensively reviewed literature on global change scenarios, subsequent impacts on weather, fuel and ignition patterns, and insights into global change effects on fire regimes from palaeoecological, simulation and process-model sources.

Gill (2012) published a comprehensive update on 'Bushfires and biodiversity in southern Australian forests', also in 'Flammable Australia', reviewing literature on key processes resulting in bushfire-related dynamics in southern Australian forests. This chapter reviews the critical concept of the fire regime, which underpins future scenarios for bushfires, explores interactions between fire regimes and biodiversity, and considers fire management in an ever changing environment.

Clayton, Dovers & Cary (2013), in a Bushfire CRC Fire Note on 'Economic contributions to bushfire management and policy', presented a framework defining contributions that economic ideas and analysis can make to bushfire management and policy, set against a categorisation of decisions that identifies the range of decisions commonly made in the sector. Making the link between economic approaches and decisions in the sector is critical to answering the overarching question about what economics has to offer.



Cary, Dovers & Gill (2010) and Cary, Dovers, Gill, Williams & Collett (2011) presented aspects of these findings to the Australasian Fire and Emergency Service Authorities Council (AFAC) and Bushfire CRC conferences in 2010 and 2011.

Future Bushfire Scenarios and Economics

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The problem

Understanding of bushfire impact on human communities, the environment and the economy is limited and, in some cases, anecdotal at best (although see Wetherhall 1975, Healey 1985, Benveniste & Cullen 1997 for preliminary economic analyses).

Understanding of this under future alternate scenarios of climate/global change are largely lacking because the scenario and economic modelling have been undertaken independently.

Thus policy and decision-making is not fully informed (See Dovers et al. 2004).

The challenge is to do rigorous work in a new area, involving a synthesis of scenarios and economics, that will contribute enhanced solutions to fire, which is "multi-stakeholder, multi-scale, multi-variable problem" (Gill 2005).

Proposed research

Future Scenarios

Questions

- What are the key variables of future bushfire scenarios relevant to projects, including economics, in the Bushfire CRC?
- What critical, evidence-based knowledge is available to parameterise a range of alternate future scenarios of bushfire in Australia?
- What are the likely future scenarios of bushfire in selected areas of Australia?
- How will these future scenarios impact on bushfire-related dynamics, including economics?

Approach

Workshop with selected key research leaders

Knowledge review (literature, state/federal agencies)

Synthesis of new scenarios based on requirements of researchers and knowledge available

Application of future bushfire scenarios with selected economic, and other, scenarios

Economics

Questions

- What are appropriate economic methods for understanding bushfire costs & benefits across a range of values?
- What are key examples of economic costs and benefits (from viewpoint of view) associated with major bushfire events in Australia?
- What are key examples of the preliminary projected economic costs and benefits associated with future bushfires in Australia, based on future scenarios developed by this project?

Approach

Knowledge review and economist workshop

Selected economic analyses informed by milestone question 1. Aiming for robust/simple models capable of flexible interface with the fire scenarios, and accessibility and transparency

Selected economic analysis driven by future scenarios of bushfire in selected regions of Australia

Expected outcomes

- Better insight into a range of alternate future fire scenarios
- Insights into key examples of likely economic consequences
- Facilitation of significantly improved decision making/policy among a range of stakeholders and within specific 'industries' (e.g. insurance, water)
- Enhanced mutual understanding between fire modelling groups, and between science, economics and policy communities
- Peer-reviewed, published science on the interaction between fire scenarios and economic consequences

Future Scenarios for Australian Bushfires

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Global Change and Fire

Global change will affect factors that influence the key drivers of fire activity. These drivers can be conceptualised as switches that all need to be activated for a fire to occur (Figure 1). Changes in weather and climate may affect area burned (Figure 2). Fuel production is sensitive to rainfall; predictions indicate regional changes in rainfall patterns. Litter production and decomposition may be affected by increased levels of CO₂. Introduced plant species can increase fuel loads and fire intensity (Image 3). Ignition are likely to increase over much of Australia as lightning activity increases and population grows.

Paleoecological Records Change

There is a long history of fire in Australia that encompasses changes in climate and human influence. Charcoal records indicate that fire activity is greatly influenced by global temperatures and associated vegetation changes (Mooney et al. 2011). Dry periods are generally associated with reduced fire activity in arid areas (Lynch et al. 2007). Peaks of charcoal often occur during periods of frequent ENSO activity where cycles of wet and dry lead to a build-up of fuel then drought and fire (Lynch et al. 2007). Human influence is less clear, with some localised evidence but little to suggest continental changes in fire regimes.

Future Fire Scenarios

Based on current knowledge regarding future global change, fire activity is likely to decrease in drier environments, where fuel productivity limits bushfires. In wetter forest ecosystems, fire activity may increase as more fuel becomes available to burn as a result of drier conditions. Changes are likely to be unique to particular environments and reflect the influence of climate change on which ever of the key drivers of fire is limiting (Table 1). These changes are complex so that any predictions will contain considerable uncertainty (Cary et al. in press).

Figure 1. Influences of biogeographic factors (climate, soil, habitat, plant functional types) on fire regimes via four pathways: biomass growth - R, fuel availability for burning - A, human influence - H, and ignition - I. Possible effects of changing climate, human activity and atmospheric CO₂ are indicated by dotted lines. (Source: Bradstock 2010)

Figure 2. Area burned under climate scenarios (see Cary et al. 2006) using the model FIRESCAPE for south-eastern Australian bushfires. Warmer climate assumes a 3.0°C temperature increase over current climate. The wetter climate equates to a 20 per cent increase in precipitation and the drier climate assumes a 20 per cent precipitation decline. The model shows increased area burned for warmer climate (drier, wetter, or both). (Source: Williams et al. 2009)

Global change attribute	Tropical open forest	Arid woodlands	Temperate grassy woodlands	Temperate dry sclerophyll forests	Cool temperate wet sclerophyll forests
Fire Danger	Increased	Increased	Greatly increased	Increased	Increased
Main fuel type	Annual grasses	Perennial grasses and annual herbs/grasses	Grasses and woody plant litter	Woody plant litter and shrub crowns	Woody plant litter
The impact on productivity of:					
• Climate change	• Decrease	• Decrease	• Increase	• Increase	• Decrease
• Elevated CO ₂	• Decrease	• Decrease	• Increase	• Increase	• Increase
Introduced Plants	Gamba grass (Image 3)	Buffel grass	Tree plantations	Exotic grasses	
Forest conditions	Increased grass	Increased anthropogenic	Increased anthropogenic	Increased anthropogenic	Increased anthropogenic

This research is part of the Future Scenarios and Economics project: Helena Eddy, Eddy Collett, Geoff Cary, Steve Dovers, Malcolm Gill, Andrew Stark and Siân Williams.



The 2009 Black Saturday Fires highlighted the imperative for understanding future fire regimes and effects on tangible and non-tangible assets. Pictured is part of the Churchill Fire (Photo: Geoff Cary).

Progression of research

Progression of research in the *Future Scenarios & Economics* project matched the project milestones established at the project's commencement. Key activities included:

September 2010	Poster on 'Future Bushfire Scenarios and Economics' presented at AFAC 2010 conference, Darwin.
September 2011	Poster on 'Future Scenarios for Australian Bushfires' presented at AFAC 2011 conference, Sydney.
October 2011	Publication of relationship between fire response strategy and ecological attributes of plants, in <i>Annals of Botany</i> . This research originated in an earlier Bushfire CRC project (2003 – 2010).
November 2011	National workshop on future scenarios held at the Australian National University.
February 2012	Poster on 'What does economics have to offer?' presented at the Australian Agricultural and Resource Economics Society Conference, Fremantle.
February 2012	Publication of review of 'Global change and fire regimes in Australia' in 'Flammable Australia: Fire Regimes and Ecosystems in a Changing World'.
February 2012	Publication of review of 'Bushfires and biodiversity in southern Australian forests' in 'Flammable Australia: Fire Regimes and Ecosystems in a Changing World'.
June 2012	Publication of climate and CO ₂ effects on grassland fire in south-eastern Australia, in <i>International Journal of Wildland Fire</i> . This research was undertaken in collaboration with an external research project.
July 2012	Publication of 'Future scenarios for Australian bushfires: Report on a Bushfire CRC workshop', in <i>Australian Journal of Emergency Management</i> .
July 2012	Publication of modelling of the potential for prescribed burning to mitigate carbon emissions from wildfires in fire-prone forests of Australia, in <i>International Journal of Wildland Fire</i> . This research was undertaken in collaboration with other Bushfire CRC researchers and was initiated in an earlier Bushfire CRC project (2003 – 2010).
August 2012	Poster on 'Future Bushfire Scenarios' presented at AFAC 2012 conference, Perth.
August 2012	Poster on 'What does economics have to offer?' presented at AFAC 2012 conference, Perth.
December 2012	Publication of review of socially disastrous landscape fires in southeastern Australia, in <i>Wildfire and Community: Facilitating Preparedness and Resilience</i> .
February 2013	Publication of Bushfire CRC <i>Fire Note</i> on economic contributions to bushfire management and policy.
March 2013	Presentation of economics and future scenarios research progress and outputs to Business Managers of the Member Groups of AFAC.
March 2013	Publication of review concerning the worldwide "wildfire" problem, in <i>Ecological Applications</i> .
March 2013	Publication of empirical research on the effect of patch area on birds in central Australian Mulga (<i>Acacia aneura</i>) woodland of different times-since-fire, in <i>Pacific Conservation Biology</i> . This research originated in an earlier Bushfire CRC project (2003 – 2010).
April 2013	Publication of simulation results for contrasting fire responses to climate and management: insights from two Australian ecosystems, in <i>Global Change Biology</i> . This research was initiated in an earlier Bushfire CRC project (2003 – 2010), but has relied on significant research effort from the <i>Future Scenarios and Economics</i> project.
June 2013	National End-user engagement workshop on 'Economics and Future Scenarios' held at the Australian National University.
June 2013	Critical review of benefits and costs of wildland fires submitted to <i>Environmental Hazards</i> .
July 2013	Submission of 'Landscape Fires: Social Disasters? Ecological Necessities?' chapter to be published in <i>Ten Commitments</i> , CSIRO Publishing
August 2013	Manuscript on exploring the use of economic evaluation in Australian wildland fire management decision-making submitted to <i>International Journal of Wildland Fire</i> .
September 2013	Publication of exploration of the role of fire, succession, climate, and weather on landscape dynamics using comparative modelling, in <i>Ecological modelling</i> . This research was initiated in an earlier Bushfire CRC project (2003 – 2010), but has relied on significant research effort from the <i>Future Scenarios and Economics</i> project.
September 2013	Poster on 'Future Scenarios for Australian Bushfires' presented at AFAC 2013 conference, Melbourne.
September 2013	Poster on bushfire management and economics presented at AFAC 2013 conference, Melbourne.
October 2013	Presentation on 'Using economics to support complex, multiobjective and politicised decision making: insights from the Australian bushfire sector' at the Australia New Zealand Society for Ecological Economics (ANZEE) 2013 Conference, Canberra.

Research results

Biophysical context

Key contributions were made to understanding of underpinning biophysical controls of future fire regimes.

King, **Cary**, Bradstock, and Marsden-Smedley (2013), *Global Change Biology*, demonstrated contrasting fire responses to mesic (south-west Tasmania) and arid (central Australia) ecosystems using simulation modelling. For future climates, unplanned fire incidence and area burned increased in the mesic landscape (see also Keane, **Cary et al.** (2013), *Ecological Modelling*), but decreased in the drier landscape as predicted from an understanding of factors that determine fire occurrence. Simulated prescribed burning reduced unplanned fire in the mesic landscape, but the effect was not as strong as the increase in fire incidence and burned area resulting from climate change. In the drier landscape, prescribed burning resulted in an additional reduction in area burned to that resulting from the climate change scenarios. *Global Change Biology* and *Ecological Modelling* are widely read international journals with an impact factor of 6.86^a and 2.07^a respectively.

➤ Read the full abstract for this research at: <http://onlinelibrary.wiley.com/doi/10.1111/gcb.12115/abstract>

King, Cary, **Gill** and Moore (2012), *International Journal of Wildland Fire*, in collaboration with an external project, explored implications of changing climate and atmospheric CO₂ for grassland fire in south-east Australia. Using an agricultural pasture growth model (GRAZPLAN), daily grass fuel curing and load dynamics were derived and used to calculate potential Grassland Fire Danger Index (GFDI) and predicted fire-line intensity for future climate–CO₂ combinations. Simulations were undertaken for a range of grass types common in the Canberra, Sydney and Melbourne regions. For future climate scenarios, grass curing and GFDI were generally higher, but fuel load declined. Consequently, there was minimal effect on projected fire-line intensity because the effects of higher fire danger, and hence spread rate, were offset by lower fuel load in many circumstances. *International Journal of Wildland Fire* is the leading international journal in wildland fire studies with an impact factor of 2.23^a.

➤ Read the full abstract for this research at: <http://www.publish.csiro.au/paper/WF11103.htm>

Societal context for future fire

The *Future Scenarios and Economics* project also generated new insights into the overall bushfire problem, exploring the issue from a broader perspective to provide a foundation for understanding bushfires and economics.

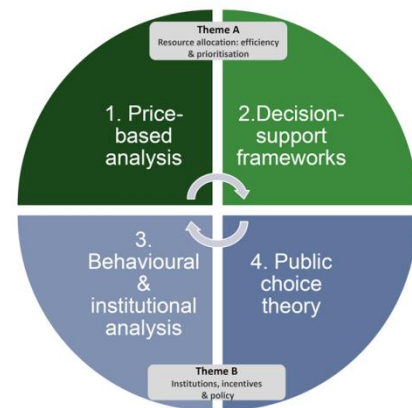
Gill, Stephens and **Cary** (2013), *Ecological Applications*, considered the worldwide “wildfire” problem in a broad contextual analysis for the future scenarios work. This problem is highly complex, and addressing it needs a good understanding of stakeholders, landscapes, and ecosystems at a variety of scales. **Gill et al.** (2013) identified four key approaches to reducing undesirable results from bushfires including controlling fires and fire regimes, increasing the resistance of assets to fires, locating or relocating assets away from the path of fires, and assisting recovery in the short term while promoting the adaptation of societies in the long term. *Ecological Applications* is a high-level international journal with an impact factor of 5.10^a.

➤ Read the full abstract for this research at: <http://www.esajournals.org/doi/abs/10.1890/10-2213.1?prevSearch=cary&searchHistoryKey=>

Gill and **Cary** (2012) published an analysis of impacts, responses and implications associated with socially disastrous fires in south-eastern Australia, in a peer-reviewed chapter in '*Wildfire and Community: Facilitating preparedness and resilience*'. Understanding future bushfire scenarios is partly about understanding interactions between people and fire-prone landscapes. **Gill** and **Cary** note that 'socially disastrous fires are dramatic, eliciting superlatives, strongly focussing community attention. They are full of emotion and tragedy and they challenge individual and community resilience. They highlight landscape – fire interactions, people – landscape interactions and people – people interactions of many types'.

^a Higher Impact Factors indicate more highly cited journals. Impact Factors for indicative journals include: *Australian Forestry* IF = 0.623; *International Journal of Wildland Fire* IF = 2.23; *Forest Ecology and Management* IF = 2.45; *Ecological Applications* IF = 5.10; *Global Change Biology* IF = 6.86, *Frontiers in Ecology and the Environment* IF = 9.11

Clayton, Dovers and Cary (manuscript in preparation for *Environmental Hazards*) reviewed the economics literature and identified that the economic evaluation methods relevant to bushfire management and policy can be summarised under three key areas: (i) decision-support frameworks (which include benefit-cost analysis), (ii) institutional and behavioural analysis, and (iii) political-economic analysis. The review highlighted the diversity of economic evaluation methods, each suited to a specific decision setting.



Milne, Clayton, Dovers and Cary (2014), *Environmental Hazards*, identified the need for critical review of literature on costs and benefits of wildland fires and their management, to better inform potential users. **Milne et al.** (2014) reviewed 60 economic studies to identify the nature of evaluations undertaken. They produced a systematic framework of the types of economic evaluations and methods available to inform fire management and policy. A majority of the studies reviewed focused on pre-suppression and suppression activities, and were dominated by studies from the USA, and there is significant scope for economic evaluations addressing other applications and other geographical locations.

Clayton, Mylek, Schirmer, Cary, Dovers (in press), *International Journal of Wildland Fire*, generated new insights into the research needs and barriers to the use of economic information, from a survey of managers and policy professionals employed in the fire and emergency services industry across Australia. Part of the survey asked respondents to indicate how often they use information about the changing cost-of-impact of bushfires under climate change, the level of support that their organisation provided to facilitate the use of this information, and their perception of the usefulness of this information. Respondents generally indicated 'the lowest level of organisational support related to projections about changing cost-of-impact from bushfire under future climate change scenarios. Higher levels of support were reported for the evaluation of bushfire risk to assets, evaluation of the benefits of bushfire management activities, and assessment of where the highest impacts (costs) were likely to occur' (**Clayton et al.** in press).

➤ Read the full abstract for this research at:

http://www.publish.csiro.au/view/journals/dsp_journals_pip_abstract_Scholar1.cfm?nid=114&pip=WF13140

Schirmer, Clayton, Mylek, Cary and Dovers (The Australia New Zealand Society for Ecological Economics (ANZEE) Conference 2013, Canberra, Australia, 11 to 14 November) explored the implications of failing to integrate economic evaluation effectively into complex, multi-objective and politicised decision-making processes, using the case study of bushfire management. This aspect investigated the challenges of integrating economic evaluation into complex policy arenas, like bushfire management.



Costs, benefits and losses associated with bushfires can be tangible or intangible, and direct or indirect (Photo: Geoff Cary).

Clayton, Dovers and Cary (2011), and Mylek, Clayton, Schirmer, Dovers and Cary (2012) presented aspects of these findings to the AFAC and Bushfire CRC conferences in 2012 and 2013.



What Does Economics Have to Offer?

Linking economic analysis to fire management & policy

Helena Clayton, Stephen Dovers and Geoff Cary
Fenner School of Environment and Society, The Australian National University, Canberra

Increased demand for economics

- Integration of economic information: Increased occurrence of damaging bushfires, and the prospect of climate change worsening this situation, has heightened discussion of bushfire policy and management decision-making, with calls for increased integration of economic information to help inform decisions.
- Multiple approaches: Our research suggests multiple roles for economic analysis on top of those often promoted (i.e. costing of fire impact and cost-benefit analysis of fire programs or fire-fighting technology) need to be matched carefully to the context and the decisions to be made.

What we aim to achieve

- Review and appraise: The aim is to advance understanding of bushfire economics, and identify where different methods can be brought to bear on policy and management problems faced across diverse decision-making contexts.

Linking decisions to policy & method

We have developed a review framework to link fire management and policy challenges with relevant economic modes of analysis. This combines three perspectives:

- 1. Locating decisions**
Identifying where decisions are made across the policy-institutional system.
 - I. Decision scale:** Macro, Meso, Micro, Multi-scale
 - II. Policy/institutional system:**
 - Government: Central executive (federal & state), local, agency-level, judiciary
 - Legislature: Parliament, parliamentary inquiries
 - Private sector: industry (e.g. insurance, developers, commercial forestry), utilities
 - Community: Community groups, charities, unions
 - Individual: Individuals, households, small business
- 2. A typology of decisions**
Fire management and policy challenges:
 - I. Allocating public resources across competing:**
 - Public interest portfolios (e.g. fire, education, defence)
 - Activities within a fire management program (e.g. research, risk modification, response)
 - Technologies and strategies to meet management objectives (e.g. prescribed burning for protection of lives, built assets and biodiversity)
 - II. Policy and institutional considerations within public allocation decisions:**
 - Fire budget and decision support policy
 - Asset management and land use policy
 - Individual risk aversion behaviour in relation to public policy
- 3. Areas of economic analysis**
Distillation of four different modes of analysis, from economic theory and theoretical review of the literature:
 - I. Benefit-cost analysis:** Evaluating net benefits from investments in fire programs, management responses, technology, policy (e.g. research, risk modification, response)
 - II. Decision-support systems:** accounting for multiple objectives, priorities, and tradeoffs in fire management and policy decisions.
 - III. Institutional/behavioural economics:** evaluation of institutional dimensions of human behaviour, and related policy implications.
 - IV. Political economy:** Evaluation of incentives within political and governmental systems that influence fire management and policy decisions.



Bushfire Management & Economics – What's the Connection?

Helena Clayton, Stephen Dovers and Geoff Cary
Fenner School of Environment and Society, The Australian National University, Canberra

“Understanding the use and usefulness of economic evaluation in bushfire management decision-making”
Andrew Stark*

Economics in bushfire management

Economic decisions impact the fire and emergency services sector every day. But not enough is known about how to use economics to best support decisions on competing priorities, efficiencies and the broader values and preferences in our society (Johnson et al. 2006, Cary et al. 2012).

Survey of bushfire managers & policy professionals

We surveyed bushfire managers and policy professionals employed in the fire and emergency services industry across Australia. The objectives of the survey were to:

1. Improve understanding of the **value of, and priorities for, economic information**
2. Identify where agencies could benefit from economic information to **guide and prioritise investment, defend budgets and influence policy**
3. Identify industry needs and priorities for economic **support and training**
4. Improve the understanding between end-users and economics researchers

Survey sections – containing further detailed questions

1. Economics role in bushfire management
2. A role of economics in support bushfire management decisions
3. Factors that encourage and motivate the use of economic information
4. Confidence and relevance of economic information
5. Factors that encourage and motivate the use of economic information
6. Economics training and background

Preliminary survey results

- 59 respondents across all Australian states and territories, and New Zealand.
- 43% of respondents had participated in training courses, seminars or workshops on economics in the past.
- 66% of respondents feel that bushfire management requires economic evaluation, but 78% feel that decisions about bushfire management investment should not be based solely on economic evaluation.
- 78% of respondents feel that a lack of expertise & knowledge about economic evaluation represents a barrier to greater use of economic evaluation in their organisation.
- Respondents feel that the current level of funding from State Governments (72%) and Federal Government (89%) is not adequate given risks posed by bushfires.
- 93% of respondents feel that the public should take greater responsibility for mitigating bushfire risk to their own life and property.

Conclusions

Although economic evaluation is used in bushfire management decision-making (both formally and informally), it is not ranked highly in decision-making processes. However, it is considered an important tool in bushfire management decision-making, provided it is not used in isolation. Lack of expertise and knowledge about economic evaluation is the largest barrier to the use of economic evaluation, indicating a greater need for industry-wide training in economic evaluation techniques. The use of economic evaluation studies showing direct benefits to organisations, as well as better access to these results would help encourage the use of economic evaluation.

Integration

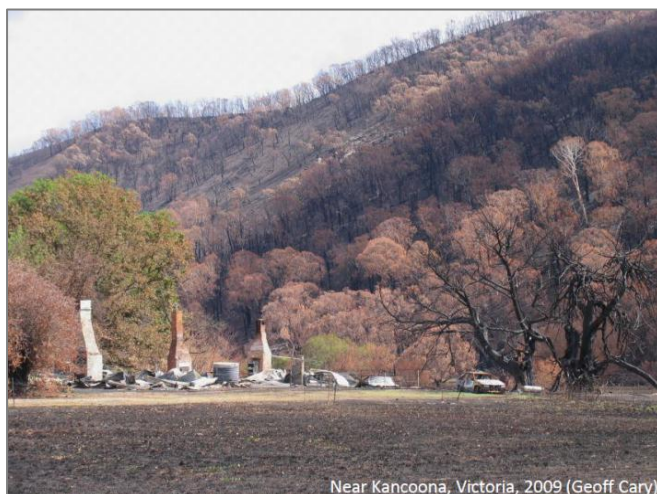

Cary, Collett, Gill, Clayton and Dovers (2012), *Australian Journal of Emergency Management*, convened a workshop on ‘Future Scenarios of Bushfires in Australia’, at the Australian National University, Canberra, in November 2011. At the workshop, ‘Seventeen researchers with expertise in bushfire dynamics and effects, bushfire management, land planning, economics and bushfire law, explored: (i) the effect of global change on fire regimes; (ii) implications for a range of socio-economic and environmental assets; (iii) potential mitigation strategies; and (iv) society’s response in relation to law and planning. The workshop agenda extended discussion on future bushfire scenarios significantly beyond recent syntheses, and captured relevant research from outside the future scenarios project’ (Cary et al. 2012).

➤ Read the full article for this research at:

<http://www.em.gov.au/Publications/Australianjournalofemergencymanagement/Pastissue/Pages/AJEM27THREE/FuturescenariosforAustralianbushfiresReportonaBushfireCRCworkshop.aspx>

Outcomes from the future scenarios workshop were also presented at the 2012 Bushfire CRC/AFAC Conference:

Cary, Collett, Gill, Clayton and Dovers (2012) ‘Future Bushfire Scenarios’, Conference Poster presented at AFAC 2012 and Bushfire CRC conference: *Diverse Country, Common Ground*. Perth, 28-31 August 2012.

FUTURE BUSHFIRE SCENARIOS

Geoff Cary, Eddy Collett, Malcolm Gill, Helena Clayton, and Steve Dovers
The Fenner School of Environment and Society, The Australian National University, ACT

1. Bushfire CRC workshop
A workshop on 'Future Scenarios of Bushfires in Australia' was held at the Australian National University, Canberra. Seventeen researchers with expertise in bushfire dynamics and effects, bushfire management, land planning and bushfire law, explored: (i) the effect of global change on fire regimes; (ii) implications for a range of socio-economic and environmental assets; (iii) potential mitigation strategies; and (iv) society's response in relation to law and planning.

2. Global change drivers
Fire regimes are governed by climate, fuel, ignition rates, suppression efforts and terrain. Greenhouse gas emissions are close to the IPCC A2 scenario, indicating global warming will likely be near upper estimates of 3 to 4°C by 2070. Increasing bushfire danger in many Australian ecosystems. New research indicates, however, the effects of climate and atmospheric CO₂ may result in lower fuel loads in temperate grassy ecosystems (Figure 2, Gill et al. 2012). Although outcomes for other fuel types (woodland/forest) are more speculative. Fire ignitions are correlated with human population size. Indicating increases for areas of future population growth, although high population density will likely remain a strong controlling influence. Evidence indicates that changes in land-use, rural urban plant communities, and wildland-urban interface will influence fire regimes significantly, presumably involving complex interactions.

3. Management
Increased rates of high-contrast prescribed burning could conceivably mitigate future increases in unplanned fire, although total area burned will increase significantly. Insurance programs aimed at reducing rates of bushfire ignition, along with rapid critical effects of fires will also remain critical. Fire managers are likely to face increasingly difficult conflicts in allocation of resources to address the complex and interacting facets of fire management.

4. Implications for assets
The management of bushfire protection and enhancement of natural and built assets, depending on sector and regional priorities. Particular areas and the urban fringe (see photo) are at greatest risk. Future scenarios range from continued development, with little change in the fire prone area, to one that is highly regulated effectively prohibiting further development. Changed fire regimes will also affect Australia's flora and fauna, which at the same time, could be directly affected by climate change, underlining the urgency of present conservation measures in this context will be important. Carbon stocks are increasingly viewed as key assets. Higher (discounted) fire frequency is expected to cause a 50% reduction in carbon stocks in SE Australian forests under an A2IP climate projection. Fire-induced effects on vegetation will influence water cycles, although ecosystem models are required to fully understand dynamics and make reasonable projections for the future.

5. Law and planning
Bushfire policy is significantly influenced by the particular circumstances of the most recent events, rather than necessarily forecasting future requirements as time evolves in response to global change. Therefore, society tends toward becoming reactive to respond to the last disaster, not the next one, and this encourages agencies to prepare adequately for the future. There is an increasing tendency for land management agencies to be deferential to bushfire litigation, and this may be a trend that continues in the future.

6. Ongoing research
2006-2070 fire regime projections will be derived from the A2IP scenario for key regions. The analysis will draw on some aspects of use case planning but will not take the form of a traditional scenario planning exercise. Future scenarios will focus on urban assets and built assets in particular environments. Insights will provide critical input into economic evaluation of bushfires in Australian society, both currently and in the future.

Figure 1. Conceptual framework for future bushfire scenarios. Climate change will affect the regime that will influence assets directly, as well as indirectly via the management effects. Directly, increasing greenhouse gas emissions will increase fire frequency, intensity and area burned, which will in turn affect assets. Indirectly, climate change will affect management through changes in fire regimes, which will then affect assets.

Figure 2. Increased costs of bushfire risk under A2IP scenario. The graph shows the increase in bushfire risk under the A2IP scenario compared to the current situation. The x-axis represents the year (2000-2070) and the y-axis represents the cost of bushfire risk (in \$/ha/yr). The graph shows a significant increase in risk over time, particularly after 2050.

Figure 3. Bushfire risk under A2IP scenario. The graph shows the bushfire risk under the A2IP scenario compared to the current situation. The x-axis represents the year (2000-2070) and the y-axis represents the bushfire risk (in %/ha/yr). The graph shows a significant increase in risk over time, particularly after 2050.

Figure 4. Bushfire risk under A2IP scenario. The graph shows the bushfire risk under the A2IP scenario compared to the current situation. The x-axis represents the year (2000-2070) and the y-axis represents the bushfire risk (in %/ha/yr). The graph shows a significant increase in risk over time, particularly after 2050.

Other Bushfire CRC research affiliated with the Future Scenarios and Economics project

The *Future Scenarios and Economics* project has contributed significant other peer-reviewed publications, originating from an earlier Bushfire CRC project, but benefiting significantly from efforts by researchers in the future scenarios project during the life of the current project. These include:

Leavesley and **Cary** (2013) The effect of patch area on birds in central Australian mulga (*Acacia aneura*) woodland of different times-since-fire. *Pacific Conservation Biology* **19**: 28 – 38. This research investigated the effect of patch area on bird communities in mulga (*Acacia aneura*) woodland in central Australia. The research concluded that patch area did affect the distribution of some birds in mulga woodland, 'However, patch area was not a mechanism of the fire mosaic hypothesis because the effects of patch size tended to increase avian diversity in larger patches rather than small' (Leavesley and **Cary** 2013).

- Read the full abstract for this research at: <http://search.informit.com.au/documentSummary;dn=431001814188300;res=IELHSS>

Vivian and **Cary** (2012) Relationship between leaf traits and fire response strategies in shrub species of a mountainous region of south-eastern Australia. *Annals of Botany* **109** (1): 197-208, noted that 'The results suggest that facultative resprouters may require a strategy of rapid resource acquisition and fast growth in order to compete with species that either resprout, or recruit from seed'. See <http://aobblog.com/2013/01/the-botany-of-bushfires/>

- Read the full abstract for this research at: <http://aob.oxfordjournals.org/content/109/1/197.abstract?sid=0dc177b1-f410-4383-a8d9-3e81aa18b198>



Plant community regeneration in the Brindabella Range after the 2003 Canberra region fires. Predicting the effects of altered fire regimes on natural assets requires ongoing ecological research. (Photo: Lyndsey Vivian).

Other new insights from collaboration with other bushfire researchers

Researchers in the *Future Scenarios and Economics* project collaborated with colleagues from current and former Bushfire CRC projects and published new findings highly relevant to the core activities of the project. These findings have contributed significantly to our understanding of future bushfire scenarios and land management, and the resultant publication indicates strong collaboration with these external researchers. We are grateful to our colleagues for including us in this collaboration, reciprocating similar collaborations that we have led.

Bradstock *et al.* (2012), including **Cary** and **Gill**, investigated the potential for prescribed burning to mitigate emissions from fire-prone Australian ecosystems in the *International Journal of Wildland Fire*. Simulation modelling of fire activity in south-east Australian eucalypt forest indicated that (i) significant prescribed burning is required to reduce area burned by unplanned fire, and (ii) the potential for minimising carbon emissions from unplanned fires via prescribed fire is limited.

- Read the full abstract for this research at: <http://www.publish.csiro.au/paper/WF11023.htm>

State of knowledge now

Adaptation to climate change will be an ongoing issue for Australian bushfire management agencies, and economics is likely to provide much-needed guidance for fire management decisions into the future. The outcomes of this research have: (i) contributed to our understanding of the future scenarios for Australian bushfires, and (ii) provided insights into the emerging role of economics in bushfire management and policy. Our results have reduced uncertainty concerning the areas that are most likely to face increases, and in some cases decreases, in fire activity with global change. Adapting to these changes will require management and policy agencies to refine current approaches or explore alternative management responses and investment priorities. Economics can play a role in informing these kinds of decisions, and encouraging wider use of economic evaluation within land and fire management agencies is likely to increase the capacity of these organisations to deal with the challenges posed by climate and other changes. We found the relevance of economics extends beyond evaluation of the benefits and costs of bushfire impact and management to evaluation of policy, institutional and political responses to changing bushfire activity. However, our research indicated that despite information about the changing cost-of-impact of bushfires under climate change being considered useful by bushfire managers and policy professionals, currently it is not widely used, and there is little support within organisations to facilitate its use. The survey also showed that the largest barrier to the use of economic evaluation was respondents' lack of knowledge of economic evaluation. These findings suggest that one avenue for increasing support and encouraging wider use of economic information is to increase the training of managers and policy professionals in economic evaluation methods.

Future fire management and policy priorities will be affected by a number of interrelated considerations including changes to (i) bushfire activity, (ii) consequential risk to social, economic and environmental assets (Gill *et al.* 2013), (iii) the influence of macro-level changes such as changing land use or demographics on the assets at risk, and (iv) the benefits and costs of management responses. While integrated economic assessment is likely to be useful for supporting the prioritisation of adaptation responses to the anticipated changes in fire activity, our research shows that information about potential economic impacts of these changes is not widely used. We have suggested that broader use of economic information in bushfire management decision-making now and into the future will require increased training across the bushfire management and policy sectors, and increased accessibility to appropriate economic evaluation. We suggest that accessibility will require economic researchers and the bushfire industry to work collaboratively in the early design stages of research to ensure the economic evaluations developed and applied are appropriate to the decision-problem and context at hand.

Understanding the economic implications of future scenarios will also require thinking through emerging challenges regarding how individual and social preferences and formal and informal institutions will evolve and respond over time to future fire regimes and global changes more broadly. Flannigan *et al.* (2009) have suggested that future fire scenarios under climate change will trigger social shifts around the current tolerances to unplanned fire, suggesting that there will be *'...a gradual reassessment and realignment of protection priorities wherein natural fire is permitted over larger areas, while intensive protection efforts will focus more narrowly on high-value areas and resources'*. The need to reassess tolerances to fire in the urban and natural landscape has also been raised by others, particularly in the context of the upward trend in suppression costs (e.g. Donovan *et al.*, 2011). Whether or not such re-assessments will occur will depend on social, political, economic and institutional change and the pathways for such change are uncertain but warrant investigation.

It is possible that any increased risk arising from changing bushfire activity will at least partially be addressed through market mechanisms, such as through the insurance or real estate market. However, it is also possible that there will be an expanding (and economically justified) role for regulatory policy mechanisms to reduce the burden of changing fire regimes on public fire management agencies. This could include regulations around the design and location of urban and peri-urban housing developments and the use of fire-resistant housing materials. Economics could help to guide future public policy responses by evaluating and comparing the economic efficiency and effectiveness of markets, private investment and public investment in fire risk management as well as other public policy responses (e.g. regulations or education) for meeting social objectives.

More broadly, Gill and Cary (2014) outline ten key tasks concerning research and society understanding of bushfires in Australian life and landscape, including: improve probability (risk) analysis; achieve effective management for multiple objectives – especially when there are multiple agencies involved; address global warming issues; understand the implications of the trend to domesticate/control fire regimes.

Journal articles and book chapters

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- King KJ, Cary GJ, Bradstock RA, Marsden-Smedley J (2013) Contrasting fire responses to climate and management: insights from two Australian ecosystems. *Global Change Biology* **19** (4): 1223-1235 (**Peer-reviewed journal article**)².
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- Vivian LM, Cary GJ (2012) Relationship between leaf traits and fire response strategies in shrub species of a mountainous region of south-eastern Australia. *Annals of Botany* **109** (1): 197-208 (**Peer-reviewed journal article**)³.

¹ Publication resulting from collaboration between the current project and other Bushfire CRC projects (including previous 2003 – 2010 projects) or other external projects.

² Publication initiated in an earlier Bushfire CRC project but which relied on significant effort from the current project.

³ Publication on fire ecology arising from an earlier Bushfire CRC project (2003 – 2010).

Fire Notes

- Clayton H, Dovers S, Cary G (2013) 'Economic contributions to bushfire management and policy'. Bushfire CRC Fire Note 105.
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- Cary G, Bradstock R, Gill M, Williams R, Collett E (2011) 'Future Scenarios for Australian Bushfires'. Poster presented at the *AFAC and Bushfire CRC 2011 Conference*, Sydney, August.
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- Clayton H, Dovers S, Cary G. (2012) 'What does economics have to offer bushfire management & policy decision-makers?' Poster presented at the *56th Annual Agricultural and Resource Economics Society Conference*, Fremantle, February 2012.
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Conference Abstract

- Schirmer J, Clayton H, Mylek M, Cary G & Dovers S (2013) 'Using economics to support complex, multi-objective and politicised decision making: insights from the Australian bushfire sector'. The *Australia New Zealand Society for Ecological Economics (ANZEE) Conference 2013*, Canberra, Australia, 11 to 14 November.

Quarterly reports

1. Cary, Dovers, Gill (2011) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 1: April – June 2011.
2. Cary, Dovers, Gill, Clayton, Collett (2011) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 2: July – September 2011.
3. Cary, Dovers, Gill, Clayton, Collett (2011) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 3: October – December 2011.
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5. Cary, Dovers, Gill, Clayton, Collett (2012) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 5: April – June 2012.
6. Cary, Dovers, Gill, Clayton, Mulvaney (2012) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 6: July – September 2012.
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8. Cary, Dovers, Gill, Clayton, Mulvaney (2013) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 8: January – March 2013.
9. Cary, Dovers, Gill, Clayton, Mulvaney (2013) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 9: April – June 2013.

10. Cary, Dovers, Gill, Clayton, Mulvaney (2013) Quarterly Report for CRC Extension Projects. Future Scenarios and Economics. Quarter 10: July – September 2013.

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