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Non-market values in economic analyses of bushfire mitigation

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Abstract: Economic analysis of bushfire mitigation options requires a range of information, such as the risk of bushfire, effectiveness of mitigation in reducing damage as well as cost and benefit estimates. Intangible or non-market benefits are likely to be a significant component of the latter as mitigation activities are designed to protect environmental, social and economic assets and services. Yet it is not clear whether these types of benefits have been given much consideration in economic analyses. In this paper, we review the studies that estimate the value of non-market benefits from bushfire mitigation and investigate to what extent non-market values have been incorporated in economic analysis. We find a small proportion of non-market valuation studies within the bushfire mitigation literature. About half of the studies on bushfire mitigation included non-market values but the values included were predominately environmental. We provide some possible explanations as to why non-market values are not used in economic analyses more widely and make recommendations to improve future use.

Key words: bushfire, mitigation, economic analysis, non-market valuation, intangibles

Introduction

In countries like Australia, policy makers face the challenge of allocating the right amount of funds to programs such as mechanical vegetation removal, prescribed burning and education to reduce the impact of bushfires to communities. The efficient allocation of funds requires the use of economic frameworks like benefit-cost analysis (BCA) (Ganewatta and Handmer 2006). When evaluating alternative bushfire mitigation actions, a range of factors should be taken into account, including the risk of bushfire, effectiveness of mitigation in reducing damages, cost of mitigation and benefits (or reduced bushfire damages) from mitigation. Further, the non-market or intangible impacts from bushfires should also be taken into account, as they can be significant. For example, statistics for the United States show that there were over 3000 fire related deaths per year between 2004 and 2013 (US Fire Administration, 2015). Stephenson et al. (2012) estimate that environmental losses from two of Australia's high impact fires accounted for 9% (1983 Ash Wednesday Fires) and 71% (2005/06 Grampians Fires) of the total losses. But, for some vegetation communities, fire improves ecological values (Maynard et al., 2013). Bushfires can interrupt, diminish or improve ecosystem services from the time the bushfire takes place through to the full recovery of the system to its pre-fire condition (Lee et al. 2015).

These non-market values need to be quantified in dollars for inclusion in BCA. There is a substantial body of literature that provides estimates of non-market values, using a group of methods termed non-market valuation. For example, Carson (2012) provides a list of over 7,500 applications of just one non-market valuation method applied to estimate non-market values for culture, the environment, and health. But, it's unclear as to how many of these applications are relevant to the non-market impacts from bushfire mitigation. Venn and Calkin (2011) reported on a small, but growing, non-market valuation literature in the

bushfire mitigation context. Milne et al. (2015) recently commented that economic studies of bushfire risk mitigation tend to focus on financial costs.

The purpose of this review is to improve the awareness of non-market values affected by bushfires so that these values can be accounted for in decision making. The review uses a qualitative approach to identify non-market values impacted by bushfire mitigation and the extent to which these values are currently used in economic analyses of bushfire mitigation. In the next section we provide a description of the non-market valuation methods available to estimate non-market values. This is followed by a description of the methods used in this study to identify the relevant non-market values and the economic analyses. The results are the non-market valuation studies available within the bushfire mitigation context and an assessment of the use of these values in each economic analysis. We conclude with a discussion of key issues identified and recommendations for future research.

Measuring non-market values

Non-market values are typically things that are not traded in a market, meaning their economic value is unobserved. To estimate these values economists have turned to a group of methods that uses people's actual or hypothetical behaviour to infer the economic value of the good. There are two main approaches to non-market valuation: revealed preference and stated preference.

Revealed preference methods estimate the relationship between a marketed good and its characteristics, which could include public goods or services. For example, Donovan et al. (2007) estimate the value of bushfire risk using a revealed preference method known as hedonic pricing. This method uses the variation in housing sales data to infer values for the characteristics of homes, such as location, number of bedrooms and proximity to natural amenities. In this analysis, a number of fire risk related variables were used to explain

property sales data: property fire risk rating, distance to dangerous topography, home building materials and vegetation density surrounding the house.

Stated preference methods such as contingent valuation and choice experiments create a hypothetical market in a survey and ask individuals for their willingness to pay for the non-market good if it were available in this market. For example, Loomis and Gonzalez-Caban (1998) use the stated preference method, contingent valuation, to determine the willingness to pay to reduce fire intensity and acres of burned spotted owl habitat in old growth forests in California and Oregon.

In many cases, it would not be practical to undertake original valuation studies because of cost (financial and time) considerations. Benefit transfer relies on the use of stated or revealed preference research results from pre-existing primary studies at one or more sites or policy contexts (often called study sites) to predict welfare estimates or related information for other, typically unstudied sites or policy contexts (Rolfe et al. 2015). Benefit transfer is advocated for use in policy making, particularly for non-market values, because it is usually cheaper, takes less time and is more straightforward than conducting primary studies.

There has been a limited application of benefit transfer in bushfire mitigation economic analysis. Mason et al. (2006), for example, use benefit transfer for the value of fire risk reduction. In the natural disaster economic analysis literature, Whitehead and Rose (2009) use benefit transfer to evaluate the environmental and historical value of actions funded to mitigate against earthquake, wind and flood events. The mitigation actions generally targeted one impact from the natural disaster, such as reducing the risk of drinking water contamination from a flood. Some of the mitigation actions targeted multiple impacts, such as recreational fishing, drinking water, wildlife watching, hiking and historic benefits. The benefits were calculated by applying a per unit benefit measure from previous studies to the

size of the affected population. Other characteristics of the natural disaster, like time lags and duration of effect seem to have been accounted for in the benefit measure. Lower, middle and upper estimates of benefits were determined through sensitivity analysis. They found that the environmental and/or historical benefits from the funded mitigation efforts accounted for less than 1% of the total mitigation benefits.

Methods

Classification and identification of non-market valuation studies

First, we classify the different types of non-market values affected by natural hazards. We use two approaches: a literature review and consultation with bushfire managers and policy makers. For the review, we collated the relevant studies through a key word search in Web of Science. The combinations of the key words used include ‘willingness to pay’, ‘choice modelling’, ‘choice experiment’, ‘contingent valuation’, ‘preferences’, ‘non-market valuation’, ‘valuation’, ‘bushfire’ and ‘wildfire’. This search produced 35 relevant studies. Milne et al. (2015) and Venn and Calkin (2011), amongst others, list the types of non-market values that are effected by improved bushfire mitigation. Our consultation with policy makers and managers from emergency management committees across Australia produced a broader range of impacts, including: mortality, morbidity, injury, psychological, amenity, animal welfare, memorabilia and social disruption (service provision, daily activities). A list of bushfire related non-market values and their categories are presented in Table 1.

Classification and identification of economic analysis studies

The economic analysis studies included in the review are similar to those described by Milne et al. (2015) as evaluations of investment in wildland fire management programmes. These were identified through a key word search in Web of Science using the key word

combinations ‘economic analysis’, ‘benefit: cost analysis’, ‘bushfire’ and ‘wildfire’. The search produced 15 studies, which were then reviewed and assessed in relation to the use of non-market (and market) values in the analysis of bushfire mitigation options.

Results

Non-market value estimation in the context of bushfires

The data in Table 1 show that the most commonly available non-market value estimates are for perceived bushfire fire safety (19). There are eight relevant recreation studies, five amenity studies, four water quality studies, three morbidity studies, two threatened species studies, one mortality study and one ecosystem degradation study. There are no relevant studies for the remaining value types, namely, injury, stress/anxiety, pain, grief, invasive species, carbon storage, social disruption, cultural heritage, animal welfare and memorabilia.

Table 1 Non-market values impacted by bushfires, with the number of relevant studies in parenthesis.

Health	Environment	Social
Non-market good or service		
<i>Mortality</i> [1]	<i>Threatened species</i> [2]	<i>Recreation</i> [8]
<i>Morbidity</i> [3]	<i>Ecosystem degradation</i> [1]	<i>Amenity</i> [5]
<i>Injury</i> [0]	<i>Water quality</i> [4]	<i>Safety</i> [19]
<i>Stress/ anxiety</i> [0]	<i>Invasive species</i> [0]	<i>Social disruption</i> [0]
<i>Pain</i> [0]	<i>Carbon storage</i> [0]	<i>Cultural heritage</i> [0]
<i>Grief</i> [0]		<i>Animal welfare</i> [0]
		<i>Memorabilia</i> [0]

Source: Based on Venn and Calkin (2013), Milne et al (2015) and own non-market valuation literature review.

Economic analysis of bushfire management

In Table 2, we summarise the 15 studies that received the focus of this review. Seven of these studies included some non-market values in the economic analysis. There was a general lack of transparency in the explanation of the value measure given in each study and therefore it was difficult to determine which value types were included in the analysis. For the seven studies that did use some measure of non-market value, only Huang et al. (2013) and Mason et al. (2006) used data from a non-market valuation study. The use of the Value of a Statistical Life (VSL) estimates by Huang et al. (2013) and Mason et al. (2006) illustrates the ease with which these values can be incorporated into economic analysis. A large body of literature exists on VSL. The remaining studies used proxy variables, such as government expenditure on a program to protect the non-market asset or the replacement costs, as estimates of non-market value.

Overall, there was a range of non-market values included in the economic analyses we reviewed: environmental values (five studies), mortality (two studies) and amenity (two

studies) and cultural sites (one study). However, in almost all cases, studies manage to include only a subset of the relevant values. Huang et al. (2013) include the most comprehensive set of non-market values: mortality, forest restoration, forest health, water supply, stored carbon and safety. Mason et al. (2006) acknowledge the broad set of values that should be included, but fail to provide quantitative estimates for all.

Table 2 A review of economic analyses of bushfire mitigation and the use of non-market values.

Reference	Study site	Description	Method of analysis	Mitigation action(s)	Non-market values included	Market values included
Abt et al. (2015)	Tribal managed land, United States	Evaluating benefit cost ratios of wildfire prevention education and law enforcement officers	Cost-effectiveness analysis	Wildfire prevention education; law enforcement officers	None	None
Busby et al. (2012)	Harney County, Oregon	Optimal location of fuel treatment on public and private land	Minimise public and private cost	Prescribed burning	Amenity; other public goods	Residential property
Busby et al. (2013)	Eastern Cascade forest, Oregon and Washington	Optimal location of wildfire risk management with homeowner and spatial externalities	Simulation of socially optimal fuel treatment path	Prescribed burning; fuel stock regulation	Amenity	Residential property
Butry et al. (2010)	Florida	Spatial allocation of wildfire prevention policies	Optimisation; benefit: cost analysis	Prescribed burning; wildfire prevention education	None	None
Butry and Donovan (2008)	Not specified	Evaluation of direct and spill over damage from wildfire under different homeowner spatial risk patterns	Simulation	Homeowner mitigation	None	Residential property
Dyer and Smith (2003)	Northern Australia	Evaluation of the economic impact on pastoral	Benefit: cost analysis	Prescribed burning	None	Livestock

		companies from prescribed burning				
Heckbert et al. (2012)	Northern Australia	Evaluation of alternative savanna burning regimes to provide carbon offsets	Benefit: cost analysis	Prescribed burning	Stored carbon	None
Huang et al. (2013)	Northern Arizona	Economic value of carbon storage and release from fuel reduction	Carbon accounting	Fuel treatment (thinning and prescribed fire)	Mortality; forest restoration; forest health; water supply; stored carbon; safety	Timber; suppression costs avoided; infrastructure; regional development
Mason et al. (2006)	National forests, Oregon and Washington	Evaluate benefits and costs of fuel treatment	Benefit: cost analysis	Forest thinning	Mortality; forest regeneration; safety	Timber; infrastructure; regional economy
Mercer et al. (2007)	Volusia County, Florida	Optimal amount of prescribed burning on across public and private land that minimises net economic loss from wildfire	Optimisation	Prescribed burning	None	Timber; property; tourism
Penman et al. (2014)	Sydney Basin, Australia	Cost-effectiveness of landscape or close to asset prescribed burning in reducing house loss risk	Cost-effectiveness analysis	Prescribed burning	None	None
Prestemon et al. (2010)	Florida	Value of wildfire prevention education in	Benefit: cost analysis	Wildfire prevention education	None	None

		reducing damage from wildfire				
Rideout et al. (2014)	Catamount, Colorado	Marginal value of prescribed burning under different treatments	Return on investment	Prescribed burning	Watershed; wildlife habitat	Property; timber
Stockmann et al. (2010)	Western Montana	Cost effectiveness of fire mitigation programs to reduce risk from wildfire damage to these residences	Cost-effectiveness analysis	Home modification; mechanical vegetation thinning; prescribed burning	None	Property (expressed as home ignition probability)
Wei et al. (2008)	Southern Sierra, California	Efficient location of fuel treatment to minimise losses from fire	Mixed integer programming	Prescribed burning	Cultural sites; forest	Wildland urban interface

Discussion

Several key observations can be made based on the review. The first is that, compared to the thousands of publications that estimate non-market values, a very small number are relevant to bushfire mitigation. The second observation is that half of the economic analyses reviewed included non-market values. This is likely to be partly because of the lack of suitable non-market valuation estimates. Venn and Calkin (2011) note the considerable time and cost involved in generating original non-market valuation studies. But there are other important reasons for the limited use of non-market values. Clayton et al. (2014), for example, identify “limited knowledge of values” as a factor that would discourage bushfire manager’s use of economic evaluation tools. Marre et al. (2015) found coastal and marine managers did not perceive information on non-market ecosystem service values to be as important as other sources of information, like ecological indicators.

Benefit transfer has been proposed to get around the issues relating to the availability and cost of non-market value estimates. The method, however, has its own set of problems. As noted by Stephenson et al. (2012), amongst others, one of the key problems with benefit transfer is the validity of using a value estimate from a policy location that differs substantially, in population as well as public good characteristics, from the target policy site for which value estimates are sought. Demographic profiles can vary greatly across geographical areas over which benefits are realised with particular demographic groups being more adversely affected by bushfire than others. A good example in this case is the 2009 Victoria Black Saturday Bushfires, which caused an estimated total loss of AUS\$2.9 billion and where 44% of the fatalities were particularly vulnerable due to and/or had a chronic or acute disability (O’Neill and Handmer, 2012). Age and prior illness make people vulnerable. The VSL was found by Krupnic et al. (2002) to be affected by age and prior illness by

between 10% and 70%. Knowing the socio-demographic profile of the target population for the risk reduction policy is therefore important, especially for estimates being used in benefit cost analysis.

The third observation that can be made from our review is that the majority of studies have leaned towards the inclusion of environmental non-market values, although recreational and perceived safety value estimates tend to be relatively more available. As bushfire management generally falls within environmental or land management agencies, it is perhaps not surprising that there are predominantly environmental related values, such as wildlife and forest regeneration, included. A notable exclusion of non-market values in the economic analyses reviewed were social values. Paveglio et al. (2015) highlight the policy maker's struggle to include impacts to social systems in prioritisation or evaluation tools due to the complexity of the issue and lack of accessible, comprehensive and uniform metrics for assessing social impact. A further complication is that these impacts are likely to vary by population characteristics and also be dependent on the policy environment. For example, McFarlane et al. (2011) found that awareness and previous experience with fire can modify residents' expectations for impact and the efforts they take to reduce future wildfire risk.

In conclusion, non-market values in economic analysis of bushfire mitigation options are underutilised. This poses a problem for policy makers that use economic analysis to inform decisions, as decisions are likely to be biased because of the failure to account for significant non-market benefits from bushfire mitigation. It is recommended that research effort be invested into producing non-market values in the bushfire context. Investment in improved benefit transfer techniques is also recommended as a means to minimising the cost of the valuation effort while improving the coverage of available information on mitigation benefits across bushfire prone areas.

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