Phoenix: development and application of a bushfire risk management tool

Tolhurst, Shields and Chong discuss the bushfire risk management model being developed by the Bushfire CRC.

Abstract

The need for an independent and comprehensive risk assessment system for all natural disasters in Australia was recognised by the Council of Australian Governments (COAG). The Australian/New Zealand Standard for Risk Management provides a framework for this consistent and comprehensive approach, but this system needs to be applied to each type of disaster taking into account the unique facets of each. The Bushfire Risk Management Model being developed by the Bushfire CRC is one application of this framework. This model goes further than previous models and developed internationally because it directly relates the impact of various management strategies to changes in fire characteristics across the landscape, using PHOENIX, and then to the nature of the impact on various values and assets in the landscape. This model is intended for use by fire agencies, land managers, town and land planners, and policy makers.

Introduction

State and federal governments need consistent and comparative measures on all types of natural disasters (DOTARS 2004) to allocate resources and formulate policies. Fire managers, land managers, policy makers and land use planners need decision support tools that can assess the level of bushfire risk to a wide range of values and assets, and also demonstrate the benefits or otherwise of alternative management strategies.

The traditional approach to fire management has been based on fire suppression using “Standards of Fire Cover”. This methodology has been used at least since World War II (Home Office 1985) and has been adopted in many countries of the world, including Australia. The underlying theory of fire cover is that across an agency’s management area, like-risk receives like-cover. As an example, the Victorian public land Model (standard) of Fire Cover (NRE 2000, CFA 2001, OESC 2001) classifies the threat from each identified problem element and mitigation limitation (e.g. travel time) into low, medium or high risk categories. These elements are then assessed in combination to obtain an overall level of threat.

A more spatially explicit approach, using Geographic Information Systems (GIS) technology, is Wildfire Threat Analysis (WTA) (e.g. Hawkes & Beck 1997, Vakalis et al. 2004, Daniel & Tunstead 2004). This process attempts to quantify the spatial distribution of wildfire risk. The typical output of WTA is a map depicting the different levels of “threat”. “Threat” is determined using various mathematical summations of the specified input elements from GIS layers. WTA has been widely applied in Australia, New Zealand and elsewhere with probably the best developed systems being in Western Australia (Sneeuwjagt 1998) and New Zealand (Leathwick & Briggs 2001). However, WTA takes a relatively static view of fire.

In some places, Wildfire Threat Analysis has lead to more detailed wildfire risk assessments. These tend to be either quite complex, using detailed spatial data, or quite simple, relying on simple questionnaire material. The spatial models are used by governments or fire agencies and at a landscape scale. The simpler models tend to be developed and used by a local community or individual home owners and are used at a community and home scale.

Examples of complex models application include:

- the Fire Program Analysis in USA using FSPro (Finney 2007);
- Wildland Fire Situation Analysis using FSPro and the “Rapid Assessment of Values at Risk” (RAVAR) in the USA (McDaniel 2007);
- wildfire susceptibility mapping with Burn-P3 in Canada (Parisien et al. 2005);

- the Spatial Fire Management System in Canada (Canadian Forest Service, http://cwfis.cfs.nrcan.gc.ca/);
- the Greater Vancouver Water Catchment in Canada (Blackwell 2003); and
- the NSW Rural Fire Service, Bushfire Risk Management Planning Guidelines for Bushfire Management Committees (RFS 2007).

All of these examples are landscape scale models and rely strongly on developing large underlying datasets and use a matrix overlay to combine the notions of likelihood and consequence. The value of these complex models is undermined when different users subjectively weight impacts, thus manipulating the results of what otherwise would be an objective assessment process (Shields & Tolhurst 2003).

Examples of simpler models include the Wildfire Management Overlay, Victoria (CFA 2008) and UC Berkeley Fire Toolkit (UC Berkeley 2008). These simple models are designed to allow home owners to assess the risk to their own home and provide guidance on what actions might reduce this level of risk.

The Australian Standard for Risk Management (AS/NZS 4360-2004) was developed to be applicable to a wide range of industries and situations. The standard provides a generic framework for establishing the context, identification, evaluation, treatment, monitoring and communication of risk. A new ISO standard (31000) will update parts of AS/NZS 4360. The ISO standard will hold most of the key process aspects of the AS/NZS 4360, but de-emphasises the use of a risk matrix as the assessment method. Since publication of the Risk Standard (AS/NZS 4360-2004), there have been several attempts to apply the generic risk management framework to the fire management business.

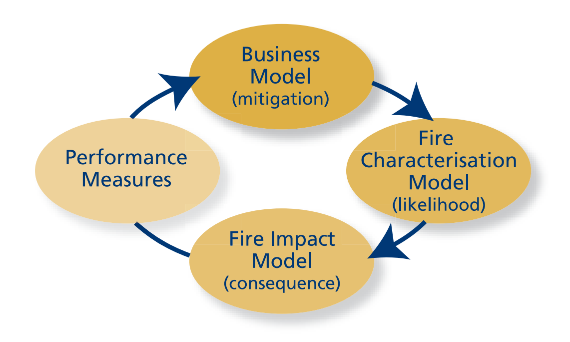
Although new risk assessment frameworks attempt to systematically address or calculate risk, they are suboptimal when it comes to assessing management options. A critical element in any performance management framework is the need to make explicit, the logic that connects treatment delivery and outcomes. Many performance measurement frameworks simply assume implicit relationships between these two elements. A risk management model needs to incorporate the way various risk treatments contribute to the achievement of risk outcomes, and to be able to determine what the best or most cost effective treatment options are.

To achieve this, the Bushfire Risk Management Model, being developed as part of the Bushfire Cooperative Research Centre (CRC), draws together three separate by inextricably linked processes. Firstly, the bushfire management "business" needs to be modeled. Secondly, the implication of various management options then needs to be quantified in terms of the changed fire characteristics in the landscape. And finally, the impact and consequence of these changed fire characteristics needs to be quantified and presented to the fire manager as an aid for decision making.

Method

PHOENIX is one component of a bushfire risk management model, being developed by the Bushfire CRC, for southern Australia. There are three components to the risk management model – a fire management business model, a fire characterization model and a fire impact model (Figure 1). These three elements in combination with the use of performance measures for monitoring and review make up the risk management process as outlined in the Australian/New Zealand Standard of Risk Management (AS/NZS 4360:2004).

Figure 1. The three main components of the Bushfire Risk Management Model.



PHOENIX is a scenario based model where particular scenarios must be created by the fire manager and the risk management model will describe the likely consequences of each scenario in term of the degree of impact each management scenario will have on specified values and assets.

Business model

The Bushfire Business Management Model establishes the context of the risk management process and within that context; the model can be used to explore the strength and types of interactions between the various elements of bushfire management.

The Business Model was based on 54 elements of bushfire management and these elements were grouped into five strategies – prevention, preparedness, response, recovery and fire regime management (Tolhurst et al. 2006). The 54 elements cover a spectrum of fire management activities including: legislation, planning, public education, firefighter training, equipment

Figure 2. PHOENIX is a tool to explore the relationships between the Bushfire Business Model and the impacts and consequences of bushfires in the landscape. PHOENIX quantifies the changes in fire characteristics resulting from changes or potential changes in fire management.

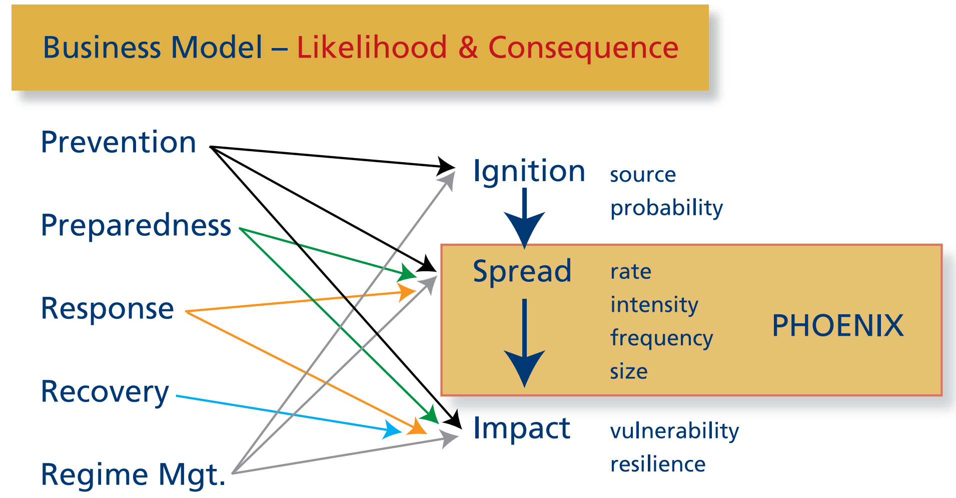
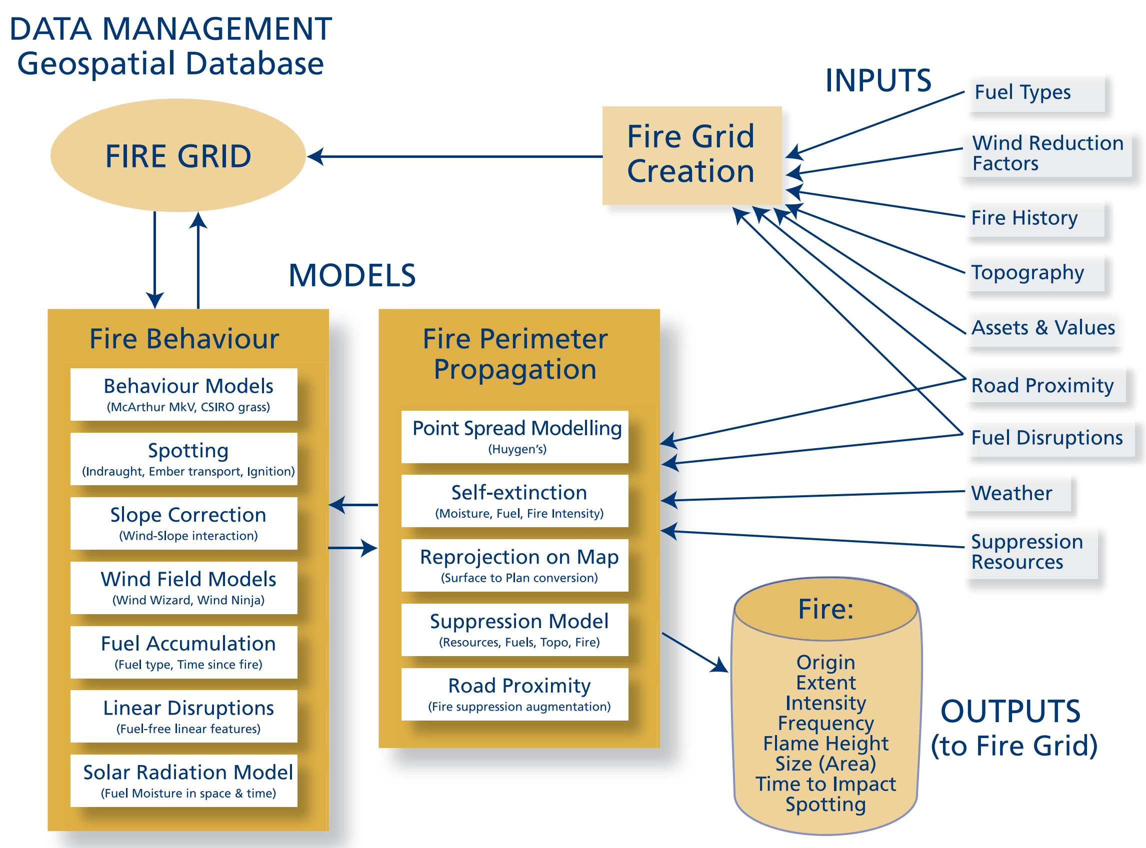


Figure 3. Schematic diagram of PHOENIX showing the inputs, outputs and data storages.



development, prescribed burning, fuel management, fire detection, firefighting, use of aircraft, post-fire recovery, environmental rehabilitation and others. The Business Model quantifies the relationship between the 54 elements of the bushfire management business and gives a relative measure of any combination of these elements in terms of the level of residual bushfire risk. The two types of interaction included in the model are the interchangeability of the elements and the interdependence between the elements. The strengths of these relationships are measured in terms of the resource cost (budget) and their ability to reduce the overall level of bushfire risk. The Business Model provides a means of optimizing the combination of management options to result in the greatest level of risk mitigation. The business model is therefore a non-spatially explicit bushfire risk mitigation model.

The effect of changing different elements of the bushfire management business can be explored spatially through the use of PHOENIX, a spatially and temporally explicit fire characterization model (Figure 2).

Fire Characterisation model

PHOENIX is a dynamic fire behaviour and characterisation model. Unlike many standard fire behaviour models, PHOENIX runs in an environment where it can respond to changes in conditions of the fire in addition to changes to fuel, weather and topographic conditions as a fire grows and moves across the landscape. Two specific examples of this dynamic nature is how spotfires ahead of the main fire front increase the rate of spread of the fire, a second example is how different strata of the fuel are included or excluded in the fire behaviour calculations as the fire changes in intensity around the fire perimeter and over time.

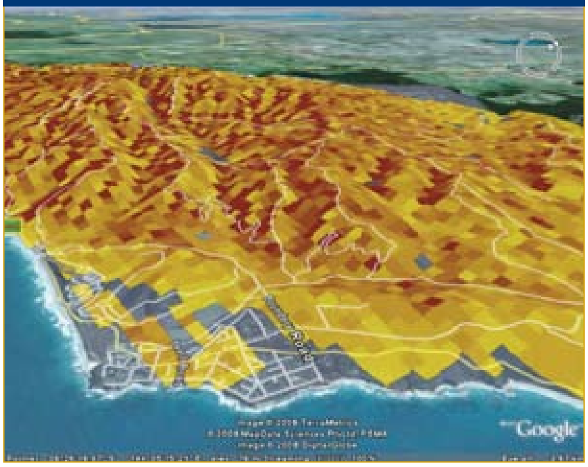
Two basic fire behaviour models underpin PHOENIX. These are the CSIRO southern grassland fire spread model (Cheney & Sullivan 1997, Cheney et al. 1998) and the McArthur Mk5 forest fire behaviour model (McArthur 1962, 1967, 1973, Noble et al. 1980). However, some important modifications were made to both models for inclusion in PHOENIX, to make them respond to the dynamic nature of the interaction between fire and its environment.

The fire behaviour models are used to calculate the point rate of spread, flame height, and fireline intensity. To translate how the fire behaviour at each point around the perimeter of the fire then moves across the landscape, a spread algorithm is used.

The fire spread algorithm used in PHOENIX is Huygen's (Richards 1995). Huygen's approach is used by FARSITE (Finney 2004), PROMETHEUS (Tymstra 2004, Tymstra & Bryce 2007) and SIROFire (Coleman & Sullivan 1995). Each implementation of Huygen's approach varies (e.g. Richards & Bryce 1995, Finney 2004, Coleman & Sullivan 1995, 1996) and PHOENIX used the approach most like that used in SIROFire (Knight & Coleman 1993).

PHOENIX operates in a landscape divided into uniform-sized square cells. Each cell has many attributes (currently 31) which are either used as inputs or outputs to the simulation (Figure 3). These attributes are stored in a personal geodatabase (MS-Access). These data can be analyzed externally to PHOENIX as with any other data stored in a spreadsheet or database. The size of each cell is specified by the user during the creation of the grid. Grids as small as 5 m have been used for very detailed analysis of a small area, but a grid size of 100m or 200m is usually found to be sufficient for most operational purposes.

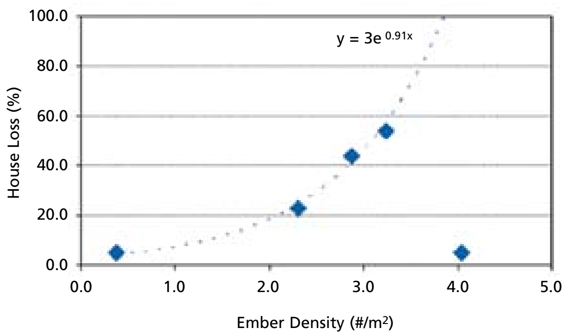
Figure 4. Fire intensity as simulated by PHOENIX in each 200m block near Airey's Inlet, Otways Ranges, Victoria, based on fuel, topography and weather conditions on Ash Wednesday 1983. Darker colours indicate higher intensity fire. The fire was spreading from the top-left to bottom-right in this image.



PHOENIX incorporates a number of models apart from the basic fire behaviour models. Models involved in modifying the inputs or outputs from the fire behaviour models deal with the effect of spotfire induced indraughts at the fire front, ember transport and distribution, spotfire ignition, wind-slope interactions, linear disruption to fire behaviour, fuel accumulation rates, solar radiation, and fuel moisture models. A second set of models is used to describe the spread of fire across the landscape given the general fire behaviour conditions. This is done by considering the conditions at each point on the fire perimeter so that the movement or extinction of that point can be determined from one time period to the next. These models include Huygen's perimeter growth, point self-extinction, surface-to-plan reprojection and fire suppression modelling. The time interval between perimeter spread calculations varies from one minute for fast moving fires to 15 minutes for slow moving fires.

Outputs from PHOENIX characterize the fire in each cell across the landscape in terms of the origin of the source fire, the size of the fire at the time of impact, fireline intensity, flame height, time to impact the cell from ignition, and ember density falling in the cell. An example of the spatial variation in fire intensity from a wildfire is given in Figure 4. Other outputs from PHOENIX could be displayed in a similar fashion. Where there is a multi-fire simulation, the number of fires affecting each cell is also recorded to help calculate the likelihood of fire at that location. It is possible to determine the probability of a fire starting at the point of ignition from historic fire probability data and this can be included in the calculation of fire likelihood.

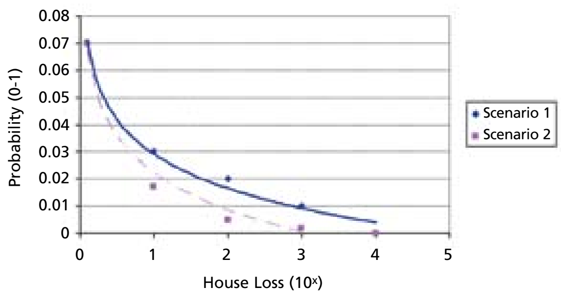
Figure 5. Relationship between estimated ember density (PHOENIX) and proportion of house loss in the Dean's Marsh fire on Ash Wednesday 1983. The data points from left-to-right are for Lorne, Airey's Inlet, Fairhaven, Moggs Creek and Anglesea respectively.



Impact and consequence model

The approach taken in the Bushfire Risk Management Model is to calculate the estimated physical "impact" of the fire on specified values and assets and then to provide this information in a form that can be used to assess the consequence of these impacts. We consider "consequence" to be a relative term which must be considered in the context of the scale of the impact, the importance of the value or asset to its community at the time of the fire, the level of vulnerability of the value or asset at the time of the impact, and the ability of that value or asset to recover or be replaced following the fire. Because "consequence" is a conditional term, the Bushfire Risk Management Model only goes as far as quantify the degree of impact from which the consequence can be assessed.

Figure 6. A hypothetical demonstration of the type of data that will be produced from impact evaluations in PHOENIX. The difference between the two impact curves is due to different management scenarios.

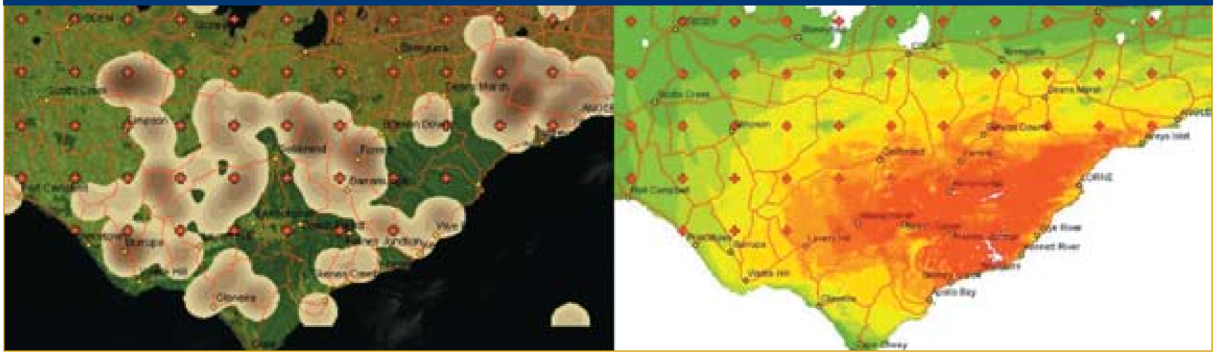


The spatially and temporally explicit output from PHOENIX can be used to estimate the nature and extent of the impact of the fire on specified values or assets. In the case of the township of Airey's Inlet, shown in Figure 4, 196 homes were destroyed there in the Ash Wednesday fires. The re-creation of this event in PHOENIX produces modelled estimates of fire intensity, ember density, flame height, fire size and various other fire characteristics that can be used in an impact model.

A simple demonstration of this is given in Figure 5, where the proportion of houses destroyed in five townships is shown as a function of ember density, as calculated in PHOENIX. The data point for Anglesea (far right) is an outlier of this dataset indicating that factors other than just ember density are important. With enough data, impact relationships for a range of values and assets and various fire characteristics can be developed.

Having determined the likely impact of a fire event, it is then possible to develop a set of potential impact curves for each fire event or suite of fire events in a multi-fire scenario. For example, under one management scenario, the probability of house loss might be represented by a curve similar to that in Figure 6, where the probability of one, ten, 100, or 1000 houses being lost can be shown graphically. The probability of different levels of loss will be determined as a function of the probability of a fire starting and the number of times fires may be expected to reach a particular value or asset (Figure 7). With a change in the elements of the Bushfire Business Management Model (Figure 2), the change in the potential impact curve can be seen. Such a set of curves can then be used by the fire manager to decide on the most desired management strategy to reduce the level of risk to an acceptable level or achieve the lowest level of risk for the level of resources available.

Figure 7. Fire ignition probability for Otways region (left) based on historic lightning fire records and fire frequency map (right) resulting from a grid of ignition points across the region under a single set of weather and ignition times.



The acceptable level of risk can be described in terms of the consequence. Frequently used terms of consequence such as "catastrophic", "fatal", and "serious" would imply unacceptable levels of risk, whereas "minor" and "negligible" consequences are more likely to be acceptable levels of risk. However, the potential consequences are always considered with reference to the context of the managed environment and the overall management objectives.

Discussion

The strengths of the Bushfire Risk Management Model are that it provides an objective basis for evaluating various fire management options in a real-to-life situation and quantifies the level of impact on a range of values and assets without making a priori value judgements. The complexity of this process has resulted in many previous wildfire risk models resorting to weightings of critical input factors and weighting of relative impacts to simplify the information presented to the fire manager.

A further strength of the Bushfire Risk Management Model is the need for the fire manager to explicitly specify the conditions of the scenarios being tested, including the range of management options, the design weather conditions, and the identification of critical assets and values in the area of interest.

The results from the Bushfire Risk Management Model encapsulate the complex interaction of ignition, spread, suppression, terrain, weather, fire history, fire protection measures and a range of other factors affecting the final impact of fire across the landscape. Unlike Wildfire Threat Analysis, it is not based on static inputs or subjective weightings.

Some of the weaknesses of the Bushfire Risk Management Model include the reliance on good quality input data such as fuels and weather at a spatial and temporal accuracy as good as or better than the required output accuracy. The model also requires the users to have a range of skills including knowledge of Geographic Information Systems (GIS), fire behaviour models, database management skills and a good appreciation of the fire management process.

Some of the powers of this modelling process include the ability to produce repeatable results, provide good graphic material for presentation to various stakeholders and managers, and deal with very complex situations and interactions in a relatively simple fashion.

Conclusions

The Australian/New Zealand standard on risk management (AS/NZS 4360:2004) provides a consistent terminology and framework for risk management. This standard is well suited to bushfire risk management.

The fire characterization model, PHOENIX provides a critical tool to describe the interaction of weather, topography, the fire itself, suppression actions and fire protection measures across the landscape. In the context of the Bushfire Risk Management Model, PHOENIX provides a platform for exploring the impact of various management options in terms of their impact on specific values and assets.

Spatially and temporally explicit modelling is critical in a wildfire environment because many of the impact factors result from fire attributes such as fire size, number of fires in the landscape, suppression resource effectiveness, time from ignition to impact, fire intensity, spotting activity, ember production and local weather factors. Without these interactions, it is not possible to make a realistic assessment of the true wildfire risk, nor the effectiveness of mitigation measures. Most existing wildfire risk models only show the area of assets or values potentially impacted by fire rather than quantifying the impact as affected by the nature of the fire and the vulnerability of the assets or values.

We believe that the "consequence" of particular wildfires will be dependent on factors such as scale (local, regional, national, international), periods of economic stress (recessions, droughts), periods of political uncertainty, times of multiple disasters (e.g. storms and wildfire), and other recent events affecting vulnerability and resilience of a community. Therefore, this risk management model only goes as far as producing data on wildfire impacts in terms of risk curves rather than specifying a level of consequence. "Consequence" is very scale and time dependent and thus cannot be objectively incorporated into a single model.

The effect of different management scenarios on the level of wildfire risk needs to be displayed graphically so that a wide audience can understand the nature of the impacts. PHOENIX provides a powerful visualization tool as well as being a powerful analytical tool. This is a major benefit of GIS based modelling.

An over-emphasis on GIS tools to model risk has been a limitation of some past risk assessment approaches. The GIS environment does not lend itself to understanding the Fire Management Business, nor does it provide a very efficient platform for modelling complex fire interactions or for complex statistical data analysis. GIS tools are best used in combination with other information and data management tools.

PHOENIX and the Bushfire Risk Management Model provide a decision support tool for land-use planners, land managers, fire agencies and governments. The dynamic nature of this model make it more realistic than many of the past risk assessment techniques. In the future, the Bushfire Risk Management Model could be used to not only explore the value of various management options, but also provide a basis for determining research and data collection priorities.

References

AS/NZS 4360:2004, (2004), Australian/New Zealand Standard – Risk Management, Standards Australia – Standards New Zealand, 32pp.

Blackwell B.A., (2003), Greater Vancouver Watershed Wildfire Risk Assessment, *3rd International Wildland Fire Conference*, Sydney Australia.

CFA, (2008), 'Wildfire Management Overlay', Country Fire Authority, Victoria. Available at: www.cfa.vic.gov.au/residents/buildings, [5 June 2008].

CFA, (2001), 'A model of fire cover for Victoria: CFA's submission to the OESC in response to the Discussion Paper', Victoria, Country Fire Authority.

Cheney, N.P. and Sullivan, A.L., (1997), *Grassfires: Fuel Weather and Fire Behaviour*, CSIRO Publishing, Melbourne.

Cheney, N.P., Gould, J.S. and Catchpole, W.R., (1998), 'Prediction of fire spread in grasslands', *International Journal of Wildland Fire*, Vol. 8, No. 1, pp. 1-13.

Coleman, J.R. and Sullivan, A.L., (1995), 'SiroFire: the CSIRO bushfire spread simulator', in: *Proc. Inst. Foresters Aust. 16th Biennial Conf.*, pp. 309-319, Canberra. Available at: http://ffp.cSiro.au/nfm/fbm/software/Sirofire/home.html, [15 May 2008]

Coleman, J.R. and Sullivan, A.L., (1996), 'A real-time computer application for the prediction of fire spread across the Australian landscape', *Simulation*, Vol. 67, No. 4, pp. 230-240.

Daniel,G and Tunstead, G., (2004), 'The application of GIS based wildfire threat analysis in the Western Australian goldfields', *11th annual AFAC conference and inaugural Bushfire CRC conference*, 7-9 October 2004, Perth, Western Australia.

DOTARS, (2004), *Natural Disasters in Australia – Reforming mitigation, relief and recovery arrangement*, a report to the Council of Australian Governments (COAG), Department of Transport and Regional Services, Commonwealth of Australia, 201pp.

Finney, M.A., (2004), 'FARSITE: Fire Area Simulator – model development and evaluation', Res. Pap. RMRS-RP-4 (revised), Ogden, UT: USDA Forest Service, Rock Mountain Research Station, 47pp.

Finney, M.A., (2007), 'A prototype simulation system for large fire planning in FPA', attachment to the White Paper by National Interagency Fire Center, USA. Available at: www.fpa.nifc.gov/Library/Docs/Science/FPA_SimulationPrototype_0705.pdf 39pp., [25 June 2008]

Hawkes, B. and Beck, J., (1997), *A wildfire threat rating system – McGregor Model Forest*, Technology Transfer Notes No. 1, Forestry Research Applications, Pacific Forestry Centre, Canadian Forest Service, British Columbia, 6pp.

Home Office (1985), *Report on the Joint Committee on Standards of Fire Cover*, United Kingdom.

Knight, I. and Coleman, J.R., (1993), 'A fire perimeter expansion algorithm based on Huygens' wavelet propagation', *International Journal of Wildland Fire*, Vol. 3, No. 2, pp. 73-84.

Leathwick, J.R. and Briggs, C.M., (2001), 'Spatial prediction of wildfire hazard across New Zealand', New Zealand Fire Service Commission, Research Report No.22, 13pp.

McArthur, A.G., (1962), *Control burning in eucalypt forests*, Forest Research Institute, Forestry and Timber Bureau, Leaflet 80, Commonwealth of Australia, Canberra.

McArthur, A.G., (1967), *Fire behaviour in eucalypt forest*, Forest Research Institute, Forestry and Timber Bureau, Leaflet 107, Commonwealth of Australia, Canberra.

McArthur, A.G., (1973), *Forest Fire Danger Meter, Mk V*, Forest Research Institute, Forestry and Timber Bureau, Commonwealth of Australia, Canberra.

McDaniel, J., (2007), 'Calculated risk', *Wildfire Magazine*, March/April 2007.

Noble, I.R., Bary, G.A.V., and Gill, A.M., (1980), 'McArthur's fire-danger meters expressed as equations', *Australian Journal of Ecology*, Vol. 5, pp. 201-203.

NRE, (2000), 'Standards of Cover for Fire Suppression: North East Region', Melbourne, Victoria, Department of Natural Resources and Environment, Victoria.

OESC, (2001), 'Discussion Paper: A Model of Fire Cover for Victoria', Department of Justice, Office of the State Emergency Commissioner, Victoria.

Preisler, H.K., Brillinger, D.R., Burgan, R.E. and Benoit, J.W., (2004), 'Probalility based models for estimation of wildfire risk', *International Journal of Wildland Fire*, Vol. 13, pp. 133-142.

RFS, (2007), *Bushfire Risk Management Planning Guidelines for Bushfire Management Committees*, Rural Fire Service, NSW. Available at: www.rfs.nsw.gov.au, [15 May 2008].

Richards, G.D., (1995), 'A general mathematical framework for modeling two-dimensional wildland fire spread', *International Journal of Wildland Fire*, Vol. 5, No. 2, pp. 63-72.

Richards, G.D. and Bryce, R.W., (1995), 'A computer algorithm for simulating the spread of wildland fire perimeters for heterogeneous fuel and meteorological conditions', *International Journal of Wildland Fire*, Vol. 5, No. 2, pp. 73-80.

Shields B.J. and Tolhurst K.G., (2003), 'A Theoretical Framework for Wildfire Risk Assessment', *3rd International Wildland Fire Conference*, Sydney Australia.

Sneeuwjagt, R., (1998), 'Application of Wildfire Threat Analysis in South-Western Forest of Western Australia', *III International Conference on Forest Fire Research and 14th Conference on Fire and Forest Meteorology*, D. X. Viegas (ed.), Portugal, ADAI, Vol. II, pp. 2155 - 2176.

Tolhurst, K.G., Chong, D.M., and Strandgard, M.N., (2006), 'Wildfire risk management model for strategic management', *Proceedings of V International Conference on Forest Fire Research*, ed. D.X. Viegas, Figueira da Foz, Coimbra, Portugal, 27-30 November 2006. 15pp.

Tymstra, C., (2004), *Prometheus fire growth model*. Available at: http://www.firegrowthmodel.com, [10 March 2007].

Tymstra, C. and Bryce, R.W., (2007), *Prometheus – User Manual Version 4.4*, 202pp., Alberta Sustainable Resource Development, Forest Protection Division.

UC Berkeley, (2008), *Fire Toolkit*. Available at: www.firecentre.berkeley.edu/homeassessment/, [15 May 2008].

Vakalis, D., Sarimveis, H., Kiranoudis, C., Alexandridis, A. and Bafas, G., (2004), 'A GIS based operational system for wildland fire crisis management, I. Mathematical modelling and simulation', *Applied Mathematical Modelling*, Vol. 28, pp. 389-410.

About the authors

Dr Kevin Tolhurst is a Senior Lecturer in Fire Ecology and Management at the University of Melbourne. He has over 30 years of fire experience ranging from fire fighting, fire behaviour prediction, fire ecology research and fire education. As part of the Bushfire CRC, Kevin has undertaken to develop a decision support system for fire managers based on risk management.

Brett Shields is a Principal Consultant (Forests and Environment) with GHD based in Sydney. He has had extensive experience in forest fire management in Australia and S.E.Asia and continues to have a passion for taking a social and risk based perspective on wildfire management.

Derek Chong is a software developer based in the University of Melbourne and funded by the Bushfire CRC. Derek's software development background was in the area of tree growth and timber production area before shifting to bushfire modelling in the CRC.

Dr Kevin Tolhurst can be contacted at: kgt@unimelb.edu.au