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Review Article

Navigating scientific uncertainty in wildfire and flood risk mitigation: A qualitative review

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ABSTRACT

Natural hazards are complex events whose mitigation has generated a diverse field of specialised natural science expertise that is drawn upon by a wide range of practitioners and decision-makers. In this paper, the authors bring natural science research, risk studies and science and technology studies together in aid of clarifying the role scientific uncertainties play in the mitigation of natural hazards and their associated risks. Given that uncertainty is a necessary part of scientific practise and method, those engaged in risk mitigation must manage these scientific uncertainties in their decision-making just as, equally, social science researchers, stakeholders and others hoping to understand risk mitigation must understand their character and influence. To this end, the authors present the results of an extensive literature review of scientific uncertainties as they emerge in relation to wildfire and flood risk mitigation in Australia. The results are both a survey of these major uncertainties and a novel categorisation within which a variety of expert and non-expert audiences might discuss and translate the scientific uncertainties that are encountered and managed in risk mitigation.

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1. Introduction

Natural hazard risk mitigation is an exemplar of how, in today's world, we face complex challenges where uncertainty is rife. Natural hazards are complex events encompassing interconnected social, ecological, economic, and political dimensions that inform and influence each other through linear and non-linear feedback loops. Our attempts to manage natural hazards have generated a diverse field of specialised natural science expertise, providing profoundly useful and valuable insights, however uncertainty is also intrinsic to all scientific practises and methods; while further research may diminish some ambiguities, it also may leave others

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untouched, or introduce new uncertainties (see [126]). Individuals, practitioners and institutions engaged in risk mitigation necessarily encounter these scientific uncertainties in their decision-making, without the availability of straightforward solutions, and with the stressful prospects of both a natural hazard event, and the likelihood of having to account for decisions to official inquiries, courts, news media, and other forums.

In this paper, we bring natural science research, risk studies and science and technology studies together in aid of clarifying the role scientific uncertainties play in the mitigation of natural hazards and their associated risks. We do so with reference to two motivating concepts. The first is Ien Ang's notion of 'cultural intelligence': to take complexity seriously as an inherent and irreducible part of our world, whilst also finding conceptual and discursive ways to navigate through it [5]. The important work of simplification (not simplifying) to plot a course through complexity (rather than dispensing with it) is a strategic and enabling response to context. If social and physical science researchers do not diligently work to preserve complexity through simplification the former can, and very likely will, reappear when least welcome to render a schema null [97]. Similarly, while forms of scientific knowledge are crucial to understanding natural hazards, they are neither homogenous nor autonomous; it is not possible to simply defer to scientific authority to 'solve' the complex issues of reducing natural hazard risk, nor is it desirable to abandon the task of translating complexities across scientific and non-scientific contexts.

The second motivating concept is disaster risk reduction, or the identifying, assessing and reducing of disaster risks from a broad range of perspectives. Fostering the role of social resilience in reducing vulnerability is a vital aspect of risk reduction, an end that requires both increasing the range of available knowledge for problem-solving and building cross-scale problem-solving networks [12]. As such, resilience ideally involves the communication of scientific knowledge and its related uncertainties to non-expert groups. In regards to natural hazards, a significant amount of the attention paid to such communication has been within a 'hazard paradigm' (see [50]); that is, it has been focused on messaging, weighing the relative merits of incorporating uncertainty into the design and dissemination of scientific information (e.g. [73,14]). Rather than translating uncertainties 'out' to non-experts, an alternate approach towards resilience would be the production of 'dialogic' or 'middle' terms useful for participatory deliberation and the co-production of knowledge between expert and non-expert groups (see [36]).

As part of plotting the 'navigational' path, the authors have focused on two natural hazards in order to both review a broad selection of scientific methods and their uncertainties and to avoid compressing scientific complexities. Further, in order to maximise the practical applicability of this review we have focused upon uncertainties that emerge in wildfire and fluvial flood risk mitigation in Australia.[1] Australia is a land of marked seasonal variation, world renowned for 'droughts and flooding rains', as well as highly flammable eucalyptus forests. In January 2009, wildfires in Victoria led to 173 fatalities and the burning of 450,000 ha [34]. In December 2010–January 2011, floods in southeast Queensland were responsible for 37 fatalities, approximately $2.38 billion in damages, and an estimated $30 billion in lost revenue [128]. Though low frequency, these high magnitude hazard events have brought renewed public and government attention to their prediction and mitigation, particularly as their occurrence is likely to increase in Australia due to the effects of climate change [70]. Risk is also increasing due to demographic shifts into hazard areas such as floodplains and wildland–urban interfaces, and growing concern over biodiversity loss and rare and endangered species is bringing new dimensions to risk mitigation.

In the development of scientific knowledges around such floods and wildfires, and their application to risk mitigation, the challenges are multi-dimensional. For instance, not only are there issues relating to pure research and implementation—such as current knowledge, funding, institutional priorities, institutional literacy, intellectual property—but also the coordination of multiple scientific practises. Predicting and managing a hazard necessarily involves different methodologies, each attuned to different aspects of that hazard's probable occurrence and behaviour. For example, understanding flood risk in a given area typically involves not only climatological knowledge of the long-term trends in weather events, meteorological knowledge of short-term weather events, hydrological knowledge of rainfall-runoff responses and hydraulic knowledge of flow depth and velocity changes downstream; it also calls upon environmental–geographical knowledges regarding vegetation, topography, land use, population distribution and so on (see [29]). No one methodology can be relied upon to predict the probabilities and consequences of a given hazard, while together these diverse knowledges are more than the sum of their parts.

At the same time, the management of natural hazards in Australia, as in many countries, is conditioned also by institutional diversity. Different government and non-government agencies hold legal responsibility for different aspects of prevention, preparedness, response and recovery (the PPRR spectrum) in relation to different hazards. Historically, this distribution of responsibility has led to major operational issues and preventable losses during natural hazard events (e.g. [46,147]), leading to the recent 'all-hazards-all-agencies' policies [30]. The approach places a high value on technical interoperability between agencies, such as having compatible communication and information management systems and processes, and strategic interoperability, including sharing information, resources and planning exercises. As such, any one scientific methodology cannot and should not be considered the domain of any one individual or any one agency; optimally, knowledges and knowledge practises will pass through the necessary relays and translation between and within agencies efficiently. The assumption of the 'all-hazards' approach is that, as in the case of scientific methodologies more generally, together these diverse agencies are more than the sum of their parts.

Risk mitigation is also shaped by the intersecting public policy discourses of mutual responsibility and deliberative policy production (see [56,92,159]). In multiple ways, and with varying degrees of success, governments in Australia and elsewhere have made efforts to incorporate citizens into different aspects of policy planning and delivery, such as through greater public disclosure, incorporating stakeholders into design processes, conducting public education campaigns, amongst other strategies. The justification for such approaches may derive from normative values, such as democracy or equity, or functional values, such as efficiency and sustainability, and seek a variety of ends; as many commentators note, stakeholder engagement has sometimes been a method for responsibility-shifting by government agents and agencies [143]. Such considerations bring to the fore fundamental issues regarding the relative power and knowledges of those involved, particularly regarding knowledge diversity, public trust in scientific expertise and public understandings of science (see [132]). As the twinned sociological fields of risk studies and science and technology studies have made apparent, the boundaries between scientific research, scientific knowledges and the

[1] For the sake of clarity, we focus on river (fluvial) floods (as against flash floods, urban floods, pluvial floods, sewer floods, coastal floods and glacial lake outburst floods) because they are the dominant hazard in Australia. A significant amount of the scientific practises presented here are nonetheless relevant to other forms of flooding.