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Methodological and Ideological Options

A structured war-gaming framework for managing extreme risks

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ABSTRACT

Extreme risks are challenging to learn from, prepare for and protect against, and they invite the development of new approaches to complement existing methods of risk management. We describe a systematic ex ante approach to support the strategic preparedness of risk management and apply it to a biosecurity case study. Our framework integrates a war-game model and a structured decision making approach. The model provides interactive maps that help stakeholders in visualizing the economic impacts of the extreme risk under different management scenarios, and it facilitates adaptive management by translating science-based results into stakeholder perspectives. The structured decision making approach not only offers an analytical structure to organize the multiple objectives of risk management, but also functions as a platform for group deliberation among alternative courses of management action with uncertain consequences. We found that this integration helped stakeholders develop a better understanding of the complexities and interconnectedness of the extreme risk management and reached a consensus regarding the most preferred management option.

1. Introduction

The risks posed by epidemics, stock market crashes, and massive avalanches are characterized by losses of huge magnitude but infrequent occurrence (Cox, 2012). Analyzing and managing such extreme risks are inherently difficult. The limited data we collect on these rare events is unlikely to be representative (Franklin et al., 2008). This lack of data often results in a tendency for policymakers to under-invest in protecting against these risks. When these disastrous events finally eventuate, people are likely to over-invest in response due to their lack of experience and cognitive errors (Noll, 1996).

Extreme risks pose challenges for conventional models of risk analysis and risk management, and they invite development of new approaches to complement existing methods (Buchholz and Schymura, 2012). Historically, these risks have usually been managed on a piecemeal and ad hoc basis (Scott, 1996). But researchers are now beginning to develop systematic and ex ante approaches to improve the efficiency and effectiveness of managing extreme risks (Ermoliev et al., 2000). Strategic preparedness is an example of such an approach.

Strategic preparedness is a decision-making process aimed at reducing consequences and controlling their likelihood to a level considered *acceptable* though decision makers' implicit and explicit acceptance of various risks and tradeoffs (Crowther et al., 2007). Having a multi-faceted and multi-objective nature, strategic preparedness not only has to address the inherent interconnectedness and interdependencies among the sub-systems of an affected system, but also government agencies, the private sector, and communities must negotiate a host of conflicting and competing goals and objectives (Haimes, 2012). The success of this negotiation, however, might be hampered because multiple participants are likely to have disagreements over extreme risks due to knowledge gaps in understanding the affected system and in quantifying consequences (Bristow et al., 2012).

To address this problem, the state of the art in decision science calls for a process of group deliberation that is important for building resilient communities (Cox, 2012). For extreme risks that have not yet eventuated, reasoned imagination is also critical, because it not only implies anticipating by systematic analysis scenarios but also recognizing and communicating potential impacts in a graphical format (Pate-Cornell, 2012). To our knowledge, there is no existing framework featuring a process of integrated group deliberation and graphical scenario planning in the arena of environmental risk management. In this paper, we fill this gap by developing such an integrated framework to support

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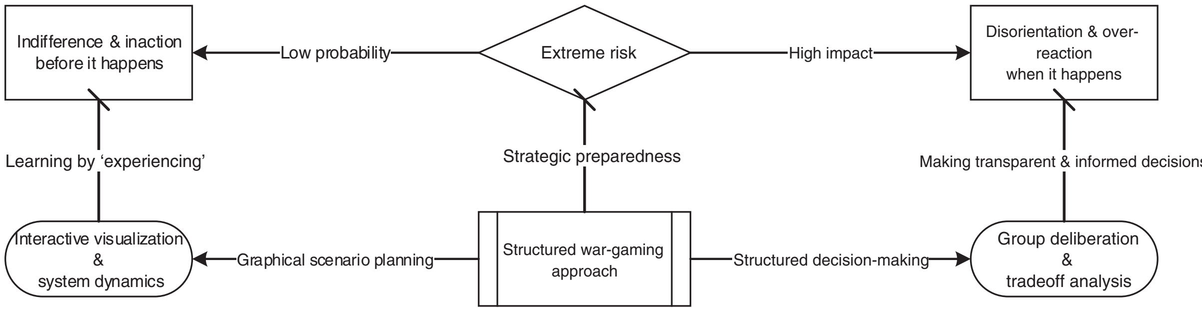

Fig. 1. Using the structured war-gaming approach to tackle the challenges of extreme risks.

strategic preparedness for managing extreme risks, and we apply it to a biosecurity case study.

Our framework integrates a war-game model and a structured decision making approach (Fig. 1). The war-game model demonstrates the interconnectedness and interdependencies of system dynamics and enables users to visualize the outcomes of the simulated management scenario in an environment that is easy to explore and understand. Using an interactive map-based interface, the model helps decision makers in "learning by experiencing" the extreme risk before it happens. The structured decision making provides an analytical structure to assess conflicting objectives with the benefits of stakeholder participation and group deliberation (Proctor and Drechsler, 2006). Based on explicit tradeoff analysis, this approach is effective in facilitating groups to make transparent and informed decision (Hajkowicz, 2009) and helping them avoid disorientation and over-reaction when extreme risk happens (Liu et al., 2012). Even though only documenting a biosecurity case in this study, we believe this integrated framework can be applied to manage other type of extreme risks.

2. Background

Biological invasions and natural disasters are similar phenomena in that their occurrences are too rare to be predictable and they can generate considerable damage (Ricciardi et al., 2011). These characteristics of extreme risks present challenges for using standard risk assessments that usually require prior estimates of model parameter. For example, there are often no or very limited existing data for parameterization, and when asked for subjective estimates of prior distributions, even experts tend to be overconfident (Burgman, 2005) and disagree with each other (Humair et al., 2014). As a result, these risk assessments are likely to be too inaccurate to be useful (Hulme, 2012).

Our case study concerns fire blight, a disease caused by the bacterium *Erwinia amylovora*, which principally affects plants of the *Rosaceae* family (CABI and EPPO, 1997). It can cause considerable damage to both apples (*Malus domestica*) and pears (*Pyrus communis*), and since it is not currently found in Australia, the disease is considered a high priority threat to the Australian apple and pear industries (Biosecurity Australia, 2004).

We applied the integrated framework to analyze the risk posed by fire blight to Victoria's Goulburn Valley (Fig. A.1 in Appendix A), one of Australia's major apple and pear production areas where approximately 60% of the nation's apple and 80% of the pear production takes place (HAL, 2004). The aim was to better prepare both industries for an incursion of fire blight by using a mock incursion scenario. Our decision question was "In the event of a fire blight incursion in the Goulburn Valley, is "Eradication", "Containment" or "Live with it" the preferable management option, given the size of the incursion upon detection?"

Table 1 below summarizes the differences and similarities of the three policy options. We elicited the information from a group of experts on fire blight or incursion management during a workshop and following face-to-face interviews with those who could not make it to the workshop. These characteristics of the three options function as the assumptions for both the war-game model and the structured decision making approach.

In the Live with it option, major investment was made in activities to mitigate the effects of the fire blight. Under this alternative, we assumed that the disease could not be eradicated. Therefore, any attempts to locate and destroy it were minimized. For the Containment option, we also assumed that it was impossible to eradicate the fire blight. Most efforts focused on reducing the rate of its expansion from the infected orchards to surrounding areas with intensive surveillance and movement control (e.g. by stopping bees, the main vector of the fire blight, from flying out of a quarantine zone). In the Eradication option, management activities focused on searching for, destroying, and preventing the expansion of the disease.

Table 1
The differences and similarities among the three policy options.

	Eradication	Containment	Live with it
Organized response program in place?	Yes	Yes	No
Orchardists apply antibiotic treatment?	No	No	Yes
Infested fruit trees being destroyed?	Yes	No	No
A quarantine zone being established to stop bees[a] from flying out of it?	Yes	Yes	No

[a] Bees are the main vector for the spread of fire blight.

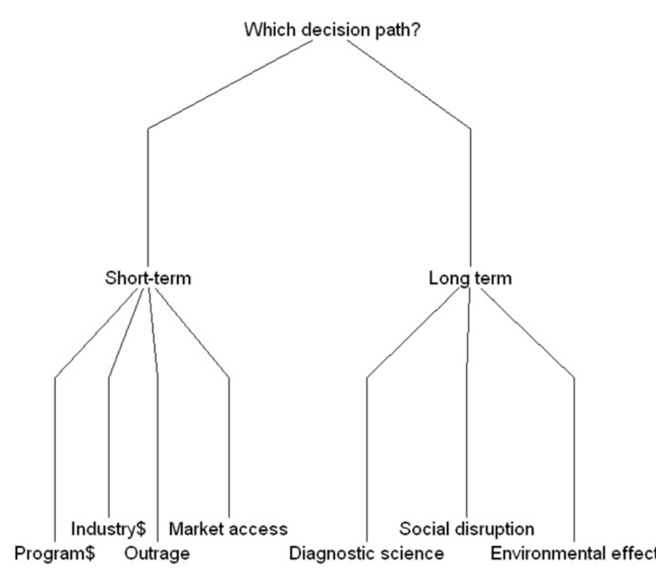

Fig. 2. The value tree developed for managing a fire blight incursion (Program$: saving taxpayers' money; Industry$: decreasing cost to the apple and pear industries; Outrage: minimizing public outrage; Market Access: enhancing the industries' competitiveness; Diagnostic science: advancing science; Social disruption: minimizing social disruption; Environmental effect: minimizing side effects of control treatments).