Understanding Disaster Risk on Volcanic Islands: a Research Agenda

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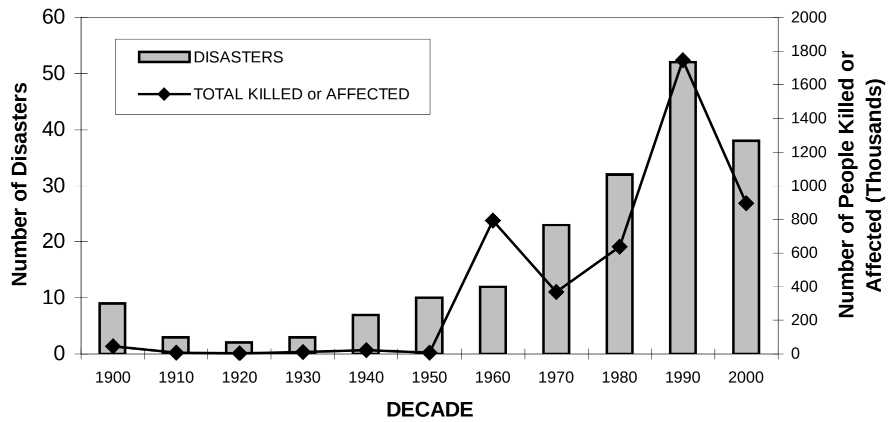
1. The significance of natural disasters

Disasters as a result of natural hazards are increasing in frequency and having a greater impact on populations and economies worldwide (World Bank, 2005, ISDR, 2004, Emergency Disasters Data Base). Therefore it is imperative for scientists and practitioners in hazardous areas to have a better understanding of the causes of disaster risk, and improved tools for assessing its impact on vulnerable populations.

This paper describes the creation of an operational tool for improved volcanic vulnerability and risk assessment. The research takes a multi-disciplinary approach creating a more comprehensive assessment of risk, taking into account the physical exposure of buildings and infrastructure to volcanic hazards, in addition to the social, economic and cultural characteristics of the population living in the hazardous areas. This research is being carried out in partnership with the emergency managers and planning officials at two study sites, in an explicit attempt to involve the end-users of risk assessments and to accommodate their views as to what information may be practical and useful.

According to CRED (Centre for Research on the Epidemiology of Disasters, 2004) over the last 30 years more than 5.1 billion individuals have been affected, of which 182 million were made homeless, and more than two million people have been killed by 6,367 natural disasters. These disasters have led to accumulated losses of US$1.38 trillion, all arising from interaction of natural hazard events with the human and economic elements exposed to the damage. Given that the frequencies with which events arising out of geological natural hazards appear to be constant, the increase in the numbers of disasters is attributed to people and places becoming more vulnerable (ISDR, 2004). This trend in increasing numbers of disasters is evident when considering volcanic eruptions, illustrated in figure 1.



Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium"

Figure 1: Number of Volcanic Disasters and People Affected 1900-2006

2. Disasters and risk

A disaster is the materialisation of risk: however, there is little consensus as to how to define risk and what elements should be included in its calculation. There are two main schools of thought with regards to studying disasters and risk– the technocratic approach and the vulnerability approach. The technocratic approach, according to Hewitt (1983), seeks to manage risk in three ways:

1. to anticipate and hence contain the extremes of nature through environmental engineering works (e.g. flood embankments);
2. to monitor and model extreme geophysical events; and
3. to create disaster plans and emergency responses.

The technocratic approach is hazard-focused, and aims to reduce disaster losses through control of the natural environment. In contrast, the vulnerability approach is people-focused and concentrates on the social, economic, political and cultural characteristics of people that make them more *vulnerable* to loss from a natural hazard event. The vulnerability view emerged in the 1970s from social scientists, particularly those working in developing countries, who had become frustrated at the slow progress in reducing disaster losses through the then dominant, technocratic approach.

The technocratic approach is evident in many national and international policies on natural hazards and disasters. For example the 1990s United Nation's International Decade for Natural Disaster Reduction (IDNDR) was very techno-centric in its approach during the early years. This is perhaps unsurprising as the initiative was the work of natural scientists from the outset. The initial focus of the IDNDR was to reduce disaster losses through the transfer of technology and methods from developed to developing countries (Chester et. al., 2002).

In addition, individual volcanic risk and vulnerability assessments have traditionally followed the technocratic approach. If vulnerability measures are included at all, they represent the physical vulnerability of buildings and people (e.g. Pomonis et. al., 1999 and Spence et. al., 2005). More recently, the principles of a bottom-up, societal approach have been integrated into volcanic disaster management. For example Dibben and Chester (1999) complemented the physical vulnerability assessment of Furnas Volcano in the Azores (Pomonis et. al., 1999) with a human vulnerability assessment.

This paper describes a new approach to assessing the risk factors that underlie volcanic emergency management. Key to this task is our ability to quantify risk in potential disaster settings. The Royal Society (1992) specifically define risk as *"the chance in <u>quantitative</u> terms of a defined hazard occurring"* (p. 4: emphasis added). The problem lies in devising methods of assigning values to a risk – e.g. driving above the speed limit – and the rewards associated with accepting this risk – e.g. arriving somewhere on time. In addition to this, how are risks compared? The example Adams (1995) uses is for road traffic accidents. How many dented bumpers equal one death on the road? (p. 22). Despite these limitations, scientists and policy makers continue to quantify risk, often to provide information for decision-making. For example, Soufriere Hills volcano on the island of Montserrat in the eastern Caribbean has been erupting since 1995, and scientists quantify risk using a combination of expert elicitation methods for probabilities of hazard occurrence with Monte Carlo simulations of risk to the population (MVO, 2006). The levels of risk to an individual living in different areas of the island are expressed in terms of the Chief Medical Officer's Risk Scale, which was originally devised for use in the health sector in the UK. Risk exposure levels are described by seven categories ranging from negligible to unknown, each with a numerical estimate attached, such as *High Risk - greater than 1 in 100 chance of event occurring* (p. 37).

The methods of quantitative risk assessment described above deal only with the likelihood of death, and do not answer the question of why people in certain areas suffer greater losses in a disaster than other areas despite apparently having equal risk exposure. To address this, one needs to examine individual houses or communities through some kind of vulnerability analysis. There is a vast amount of work by NGOs undertaking vulnerability and capacity analysis (VCA) at community level (e.g. Davis et al., 2004). These identify the characteristics of a community that increase their vulnerability to a natural hazard event, for example, seasonal employment in agriculture, and the factors that increase their ability to adapt and cope in a disaster, such as social networks.

3. GIS and quantitative risk assessment

Despite a large number of individual VCAs in a variety of locations there is still no consensus as to what characteristics of populations and places make them vulnerable, no standard methodology for undertaking VCAs and little with respect to how to quantify vulnerability indicators to be included in a risk assessment. This is where GIS is emerging as a useful tool.

One example of where GIS is key to a methodology to quantify vulnerability is the Social Vulnerability Index (SoVI) (Cutter et al., 2003). The authors used county-level census data in the United States to construct an index of vulnerability to environmental hazards and mapped the results to show counties with higher or lower vulnerability relative to a country average. Additional studies have combined social vulnerability data with hazard data to understand the geography of 'place vulnerability' (Cutter et al., 2000).

The research described in this paper has adapted these methodologies outlined by Cutter and tested the feasibility of using a GIS to map vulnerability and risk on the volcanic island of St. Vincent in the eastern Caribbean. A similar method to SoVI was adopted where the 2001 census was used to create 14 vulnerability indicators, which were mapped by census division. This vulnerability map was combined with volcanic hazard data for the island to produce a risk map using raster math and the simple equation *risk = hazard x vulnerability*. Further work is refining the vulnerability indicators and designing a risk equation based on the views of stakeholders at the two study sites.

A GIS has been chosen for this work for a number of reasons, specifically:

1. hazard, vulnerability and risk all have strong spatial components that can be displayed in a GIS; and
2. disasters are multi-dimensional, multi-disciplinary phenomena; therefore GIS techniques such as overlay are well suited for the analysis that is needed when combining a variety of data – what Hewitt (1997) calls "*the map of risk*" (p. 40).

In addition, the uniqueness of volcanic hazards in particular lends themselves to display and analysis in a GIS:

1. as the extents of hazards are often known providing mapable locations that can be used to overlay with vulnerability; and
2. as a volcanic crisis unfolds, and hazard maps are altered in response to changing activity, so use of a GIS allows new data to be input and an updated risk assessment to be created with ease.

GIS have previously been used for volcanic hazard and risk mapping (Lirer and Vitelli, 1998, Pareschi, 2002, Paleo and Trusdell, 2002, Gomez-Fernandez, 2000, Pareschi et. al., 2000). However, there are few methods for including the socio-economic vulnerability data into these maps that are crucial to a comprehensive analysis and decision-making tool. These studies highlight an additional problem - that of GIS use being largely restricted to wealthier countries (Davis, 2004). GIS software is becoming more widely available in developing countries, yet it is not utilised fully due to problems of a lack of time, training and expertise. Many tasks utilising a GIS are contracted out to external consultants. This research is addressing this problem by creating a simple tool designed around the user that takes into account:

1. the stakeholders understanding of hazard, vulnerability and risk;
2. the data available on the island; and

3. the purpose of undertaking the risk assessment – i.e. decision making for emergency management and planning.

The two study sites where this tool is being developed are the volcanic islands of St. Vincent and Dominica in the eastern Caribbean.

4. Consolidation

The importance of this research lies in the way in which it integrates the traditional natural science view of risk with the social science view that takes into account population characteristics, and in the design of a tool that is based around the user. This paper describes how this is likely to lead to the creation of more comprehensive risk assessment on small volcanic islands. In addition, this should allow local officials to be self-sufficient, both in pre-disaster planning and in crisis management, and allow realisation of the advantages that many wealthier countries already have in using GIS for vulnerability and risk assessment.

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6. References

ADAMS, A, 1995. Risk (London: UCL Press).

CHESTER, D.K., DIBBEN, C.J.L. AND DUNCAN, A.M., 2002. Volcanic hazard assessment in Western Europe. Journal of Volcanology and Geothermal Research, 115, pp. 411-435.

CRED (2004) Thirty years of natural disasters 1974-2003: The numbers. (Belgium: Presses universitaires de Louvain).

CUTTER, S.L., MITCHELL, J.T. AND SCOTT, M.S., 2000. Revealing the Vulnerability of People and Places: a case study of Georgetown County, South Carolina. Annals of the Association of American Geographers 90(4) pp. 713-737.

CUTTER, S.L., BORUFF, B.J. AND SHIRLEY, W.L., 2003. Social vulnerability to environmental hazards. Social Science Quarterly, 84(2), pp. 242-261.

DAVIS, I., 2004. Progress in Analysis of Social Vulnerability and Capacity. In Bankoff, G., Frerks, G. and Hilhorst, D (ed) Mapping Vulnerability: disasters, development and people (London: Earthscan) pp. 128-144.

DAVIS, I., HAGHEBAERT, B. AND PEPPIATT, D., 2004. Social Vulnerability and Capacity Analysis Workshop (Geneva: ProVention Consortium).

DIBBEN, C. AND CHESTER, D.K., 1999. Human vulnerability in volcanic environments: the case of Furnas, Sao Miguel, Azores. Journal of Volcanology and Geothermal Research, 92, pp. 133-150.

EM-DAT: The International Disaster Database [online]
Available from: http://www.em-dat.net [Accessed 21st August 2006]
GOMEZ-FERNANDEZ, F., 2000. Contribution of geographical information systems to the management of volcanic crises. Natural Hazards, 21, pp. 347-360.
HEWITT, K. (ed), 1983. Interpretations of Calamity: from the viewpoint of human ecology (London: Allen and Unwin Inc.).
HEWITT, K., 1997. Regions of Risk: a geographical introduction to disasters (Harlow: Addison Wesley Longman Limited).
ISDR, 2004. Living with Risk: A global review of disaster risk reduction initiatives (Geneva: ISDR).
LIRER, L. AND VITELLI, L., 1998. Volcanic risk assessment and mapping in the Vesuvian area using GIS. Natural Hazards, 17, pp. 1-15.
MVO, 2006. Assessment of the hazards and risks associated with the Soufriere Hills Volcano, Montserrat: Seventh Report of the Scientific Advisory Committee on Montserrat Volcanic Activity, Part II Technical Report. [online]
Available from: http://www.mvo.ms/SAC/SAC7_Tech.pdf
[Accessed 15th December 2006]
PALEO, U.F. AND TRUSDELL, F., 2002. Volcanic risk assessment and spatial planning policies in the island of Hawaii. In Briggs, D.J. (ed) GIS for emergency planning preparedness and health risk reduction (The Netherlands: Kluwer Academic Publishers), pp. 115-135.
PARESCHI, M.T., CAVARRA, L., FAVALLI, M., GIANNINI, F. AND MERIGGI, A., 2000. GIS and volcanic risk management. Natural Hazards, 21, pp. 361-379.
PARESCHI, M.T., 2002. Evaluation of volcanic fallout impact from Vesuvius using GIS. In Briggs, D.J. (ed) GIS for emergency planning preparedness and health risk reduction (The Netherlands: Kluwer Academic Publishers), pp. 101-114.
POMONIS, A., SPENCE, R. AND BAXTER, P., 1999, Risk assessment of residential buildings for an eruption of Furnas Volcano, Sao Miguel, the Azores. Journal of Volcanology and Geothermal Research, 92, pp. 107-131.
ROYAL SOCIETY, 1992. Risk: analysis, perception and management (London: Royal Society).
SPENCE, R.J.S., KELMAN, I., CALOGERO, E., TOYOS, G., BAXTER, P.J. AND KOMOROWSKI, J.-C., 2005, Modelling expected physical impacts and human casualties from explosive volcanic eruptions. Natural Hazards and Earth System Sciences, 5, pp.1003-1015.
WORLD BANK 2005, Natural Disaster Hotspots: A global risk analysis. (Washington D.C.: The World Bank).

Biography

Catherine Lowe is a PhD student in the Department of Geography and the Benfield UCL Hazard Research Centre at UCL. She holds a BSc (Hons) in Environmental Science from the University of East Anglia and has spent a year at the University of Oregon, USA (Geological Sciences). Having gained experience working at volcano observatories In both Montserrat, and Mexico, she completed an MSc GIS (Distinction) at UCL