Evaluating risk in a rural environment; a case study; Sorbas, SE Spain

M. R. Z WHITWORTH[1], J. S. GRIFFITHS[2] & E. M. LEE[3]

[1] *University of Plymouth. (e-mail: michael.whitworth@plymouth.ac.uk)*
[2] *University of Plymouth. (e-mail: j1griffiths@plymouth.ac.uk)*
[3] *Consultant-Engineering Geomorphologist. (e-mail: emarklee@compuserve.com)*

Abstract: Rural environments in Europe are occupied by over 30% of the total population. The population of Spain is 40 Million with over 20% residing in rural areas, which is lower than the UN global estimate of 50%. The Sorbas Area of SE Spain is a typical rural environment having a population density of approximately 10 per km^2, with the majority of the population residing in small towns and villages. Except on the coastal areas the main employer is non-intensive pastoral agriculture, and quarrying. On the coast more intensive farming is found along with a tourist industry.

Natural hazard and risk investigations have concentrated on the interaction between the process, such as landslides or floods, and infrastructure development, notably in urban environments. Here the consequences can be easily quantified in terms of lives lost, the value of property and the land affected. However, little work has been published describing the main risks to rural environments were the adverse consequences cannot so easily be identified or quantified. If the likely potential consequence cannot be identified and evaluated effectively then the consequence-benefit analysis for mitigation measures would skew the measures in favour of areas of higher population, thus potentially ignoring the effects on smaller rural communities.

This paper aims to evaluate the consequences of a landslide event on a rural area and tries to answer the fundamental questions:

- What is there to be affected?
- How will it be affected?
- What is the likely potential for secondary hazards?
- And how will the adverse consequences be valued?

A method is then put forward to allow the evaluation of the potential consequences of natural hazards in rural areas as part of a broader study on landslides in the Sorbas area.

Résumé: Des environnements ruraux en Europe sont occupés près plus de 30% de la population totale. La population de l'Espagne a 40 millions ans avec plus de 20% résidant dans des secteurs ruraux, qui est inférieur à l'évaluation globale de l'ONU de 50%. La région de Sorbas de Se Espagne est un environnement rural typique ayant une densité de population approximativement de 10 par km2, avec la majorité de la population résidant dans de petits villes et villages. Excepté sur les secteurs côtiers l'employeur principal est agriculture pastorale non-intensive, et extraction en carrière. Sur la côte l'affermage plus intensif est trouvé avec une industrie du tourisme.

Les investigations de risque se sont concentrées sur l'interaction, par exemple entre les éboulements et le développement d'infrastructure, notamment dans les environnements urbains. Ici les conséquences peuvent être facilement mesurées en termes de vies perdues et valeur de la propriété et de la terre détruites. Cependant, peu travail a été édité décrivant les risques principaux aux environnements ruraux étaient les conséquences défavorables ne peut pas aussi facilement être identifié ou mesuré. Si la conséquence potentielle probable ne peut pas être identifiée et n'évaluait pas efficacement alors l'analyse d'conséquence-avantage pour des mesures de réduction biaiserait les mesures en faveur des secteurs d'une plus haute population, de ce fait potentiellement ignorant les effets sur les plus petites communautés rurales.

Cet article vise à évaluer les conséquences d'un événement d'éboulement dans un environement rural et essaye de répondre aux questions fondamentales :

- qu'y a-t-il pour être affecté ?
- comment sera-t-il affecté ?
- quel est le potentiel probable pour des risques secondaires ?
- et comment les conséquences défavorables seront-elles évaluées ?

Une méthode est alors proposée pour permettre l'évaluation des conséquences potentielles des risques normaux dans des secteurs ruraux en tant qu'élément d'une plus large étude sur des éboulements dans la région de Sorbas.

Keywords: risk assessment, geological hazards, landslides.

INTRODUCTION

Recent natural hazard events, e.g. the 2005 Pakistan Earthquake, have highlighted the risk to rural communities from natural disasters including the problems encountered with emergency relief and the length of time it takes for a community to recover. Underestimating the level of risk is a contributory factor in failing to deliver relief and minimising the time to recovery.

Risk assessments have in the past normally assessed the consequence of an event in terms of human life and property loss. This approach means that emergency plans have been centred on the more urbanised centres with little consideration for smaller mainly rural communities. To address the balance a more thorough risk assessment is needed that incorporates the variety of risks posed to a rural environment. This has to include a time factor that takes into account the ability of a community to recover.

This paper proposes the use of an event sequence or event tree to establish the effect of a hypothetical event on a rural community using an area of the Sorbas Basin in South East Spain as a case study to establish the possible consequences.

BACKGROUND

The Sorbas Area of South East Spain (Figure 1) has a population density of approximately 10 per km^2 (Institute Of Statistics of Andalusia, 2005). The main employment and economy is based around non-intensive farming (mainly olives but also goat herding), quarrying and an increasing level of tourism. This area of Spain is semi-arid with an annual rainfall of less than 210mm (Estaban-Para et al., 1998), the majority falling in large rainfall events, potentially causing flash floods in generally ephemeral rivers. Temperatures range from -3^{o}C to 52^{o}C (weather Station records Cortijo field centre). Hart et al. (2000) and Griffiths et al. (2002) identified over 300 landslides within the Rio Aguas catchment (part of the Sorbas basin) with a distribution of 0.74 landslides per km^2; size varying from a few m^3 to several million m^3.

Geology and Tectonic History of the Sorbas Basin

The Sorbas basin is part of the Trans-Alboran shear zone (Larouziere et al. 1988) a zone dominated by left lateral movement within the internal zone of the Betics. The metamorphic basement units are made up of mica-schists and dolomites (Alpujarride nappe) and various mica-schists and also tourmaline gneiss (Nevado filabride nappe) (Mather, 2000). The sedimentary cover of the Sorbas area is made up of Pleistocene conglomerates and Messinian carbonates and marls. The area is still seismically active with Mercalli intensity X magnitude in 1884 (Lopez-Arroyo et al., 1980) with more regular activity in the region of Richter magnitude 3-4.

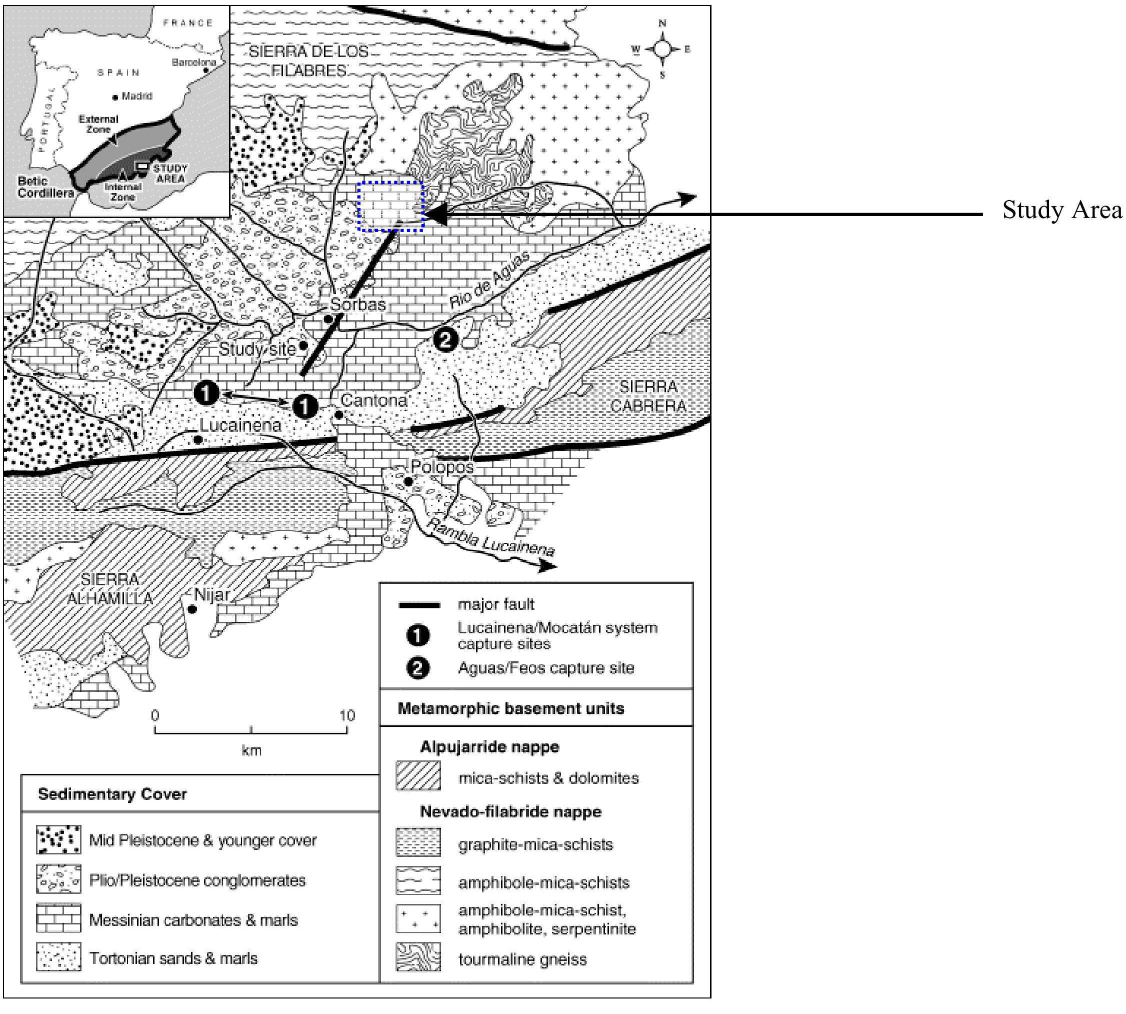


Figure 1. Regional setting and geology of study area showing location of the study site in dotted lines (Modified from Mather, 2000).

STUDY AREA

The study area (approximately 4km^2), is located 6km north of the main town of Sorbas in the Almeria region of Southern Spain (Figure 1). It is part of the ephemeral river system of Rambla Costanos. The local population is approximately 100, mostly residing in the villages of Los Alias and Cariatiz. This gives a population density of 25 per km^2; above the average for the Sorbas Area. The geology of this section is predominantly a Neogene sequence of moderately strong reef limestone overlying moderately weak marls. The erosion of the underlying marls by flash flood events, rapid localised increases in water pressure at the limestone-marl boundary, denudational unloading, plastic deformation of the marl, and freeze-thaw weathering of the limestone are the predominant causes for the landsliding in this study area. Local tectonic activity may also have an influence on the landslide activity observed, although this remains unproven.

Aerial photographic interpretation and field surveys using geomorphological mapping has shown that the area affected by landslides is approximately 6% of the total. The landslide type is mainly large rock falls, an example is shown in Figure 2. This shows a large rock fall that at some point probably dammed the river for a short period.

The economic basis of this 4km^2 study area is made up of semi-intensive to non-intensive farming, amounting to approximately 50% of the study area. The villages are supplied by one major road along which the electricity and telephone lines run. Access to farm lands is by way of unsurfaced tracks.

Figure 3 is a panoramic view looking north of the study area showing the reef limestone, rock falls and the large percentage of farmed area.

Figure 2. Large rock fall that probably dammed the Rambla Costanos, flowing towards the camera. N.B. The gradient of the river increases on the downstream side the rock fall

HAZARD, RISK, SOCIETAL VULNERABILITY AND RECOVERY

For the purpose of this paper:

Hazard is a situation that could occur during the lifetime of a person, product, system or plant that has the potential for human injury, damage to property, damage to the environment, or economic loss.

Risk is the combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence (Royal Society, 1992).

Societal vulnerability determines the variable impact of landslides on different sections of a society (i.e. poorer neighbourhoods and cheap or shanty housing tend to be more vulnerable) and the ability of a community as a whole to withstand a landslide impact. To many social scientists and planners the vulnerability of groups within a society may be of greater importance in determining the impact of a landslide than its intensity.

Recovery is the time taken for a habitat or environment to return to its original state; it includes three inter-related factors:

- *Resilience*, or the ability to maintain a system and to recover after impact, is used in the context of communities as well as the of the economic or wealth generating systems within an area. An economy dependent on a limited number of transportation routes or a single industry may be highly vulnerable to landsliding;
- *Robustness*, or the ability to respond to a spectrum of uncertainties or actual physical threats, is applied to organisations, communities and individuals within a group, reflecting social, health and economic strength. Insurance, for example, can make individuals more able to recover from the losses incurred in a landslide;
- *Preparedness*, which can reflect both the protection provided to a group and their willingness to act on their own behalf.

STUDY AIMS, OBJECTIVES AND METHOD

During a field visit to the Sorbas area the research question was posed; what is the risk from landsliding in this area? Initial reconnaissance indicated that this was not easily assessed and during the field mapping information was gathered on infrastructure, agriculture, populations, that is all the elements that could potentially be at risk. To effectively assess the risk a technique was required that would allow the evaluation in a systematic and visual manner that could also provide a tool for future work and later to enable the information to be evaluated in a GIS format. For this an event sequence or event tree was constructed starting from an initiating event through to the evaluation of the worth or value of a specific element at risk. The findings of the event sequence analysis are described in the next section with the event tree shown in Figure 4.

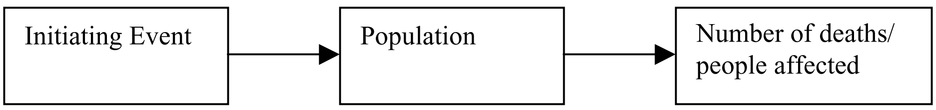
Figure 3. Panoramic View looking North of the Study Area and Rambla Costanos valley. The river runs approximately left to right. The escarpment is made up of limestone reefs. It is possible to see the rock falls and the large amount of agricultural developments

EVENT SEQUENCE ANALYSIS

An event sequence starts with an initiating event e.g. earthquake or high rainfall and considers the following based on Lee & Jones, 2004:

1. What is there to be affected? (e.g. Population infrastructure and services)
2. How will it be affected? (e.g. deaths, building collapse etc)
3. Are there any secondary hazards? (e.g. famine - this result feeds back to the first stage)
4. How will the adverse consequences be valued? (e.g. monetary value, environment, opportunity cost)

Primarily when risk assessments have been carried out they have focussed on a small section of an event sequence as shown below:



This level of risk assessment will favour urbanised areas e.g. large towns and cities. This means prioritisation of remedial action as well as emergency response will be largely focussed on these areas.

To allow a more effective evaluation of risk the event sequence needs to be developed as shown in figure 4.

If as above you start with an initiating event and broaden the possible consequences, it can be rapidly expanded to take into account not only the affect on populations, infrastructure and industry but also the affect on the environment and the regional heritage. Then the consequence on each of these can be considered e.g. for a given population an estimation of the number of deaths and injuries as well as a consideration of the emotional and physiological affects can be attempted. At this point the potential for secondary hazards can be evaluated and can be fed back into the event sequence to establish the consequences. Once all consequence have been established a value or worth can be assigned to each, either by unit i.e. cost per km^2 of agricultural land destroyed or as a total value estimation. The authors acknowledge that a value is difficult to attribute to some consequences. This event sequence can be further expanded to include the time for relief to arrive, the ability of the environment to adapt to the change or recover to its original state. These are all factors that need to be taken into account if an effective and fair risk assessment is to be carried out. An effective and fair risk assessment would need to consider:

- scenarios of landslide development in terms of physical characteristics and intensity;
- estimations of patterns and intensities of damage/destruction to buildings and infrastructure;
- estimations of the likelihood, nature and severity of secondary hazards;
- estimations of the number of people expected to be within the area affected by primary and secondary hazards, after consideration of timing and the possibility of warning/evacuation;
- estimation of relevant characteristics of people and activities within the danger area (e.g. resilience, robustness and preparedness);
- estimation of survival rates based on anticipated nature of destruction and likely efficiency of emergency response.

Completing the whole of this risk assessment using an event sequence would ensure the probability of an unforeseen event occurring would be reduced and mitigatory measures could be planned in advance, therefore improving the emergency response to an event and reducing the time taken for an environment to adapt or recovery.

EFFECT ON A RURAL COMMUNITY

Although for a sparsely populated environment such as the Sorbas Area of South East Spain, the consequences in terms of deaths/injuries is minimal and in general terms the risk would be categorized as low, the peripheral consequences can be large.

In the study area there is a large probability from historical landsliding that agricultural developments would be heavily affected (i.e. approximately 125m^2 of an area of 4km^2). Expanding this to the whole of the Sorbas area (approximately 500km^2) then 15km^2 of agricultural land could be affected (assuming the landslide density of the study area is indicative of the whole of the Sorbas region).

For a community that relies on a single road for communication, transport and services the consequences of a natural disaster can be dramatic. With the emergency services finding it difficult to respond and longer time periods for the infrastructure to be repaired, communities would find it difficult to adapt, therefore the recovery time would be high in comparison to larger more urban communities.

CONCLUSIONS

To provide a better understanding of the risk from all natural hazards in rural and urban communities, in order that better emergency response planning is put in place and to foresee potential difficulties after an event, it is imperative that a detailed and thorough hazard and risk assessment is carried out. This requires an evaluation of the population densities, infrastructure, industry and the financial risk. However, it is critical to evaluate the effects that a hazardous event might have in the long term by evaluating how long it takes for a community to recover. A more thorough risk assessment that included emergency response and recovery time would permit better long term planning, and would facilitate more effective remedial actions, The particular problems faced by rural populations of slow response of emergency efforts and longer recovery times would allow a more realistic proportion of resources to be allocated to their needs. An event sequence or event tree is just one tool of many that would help facilitate this future process.

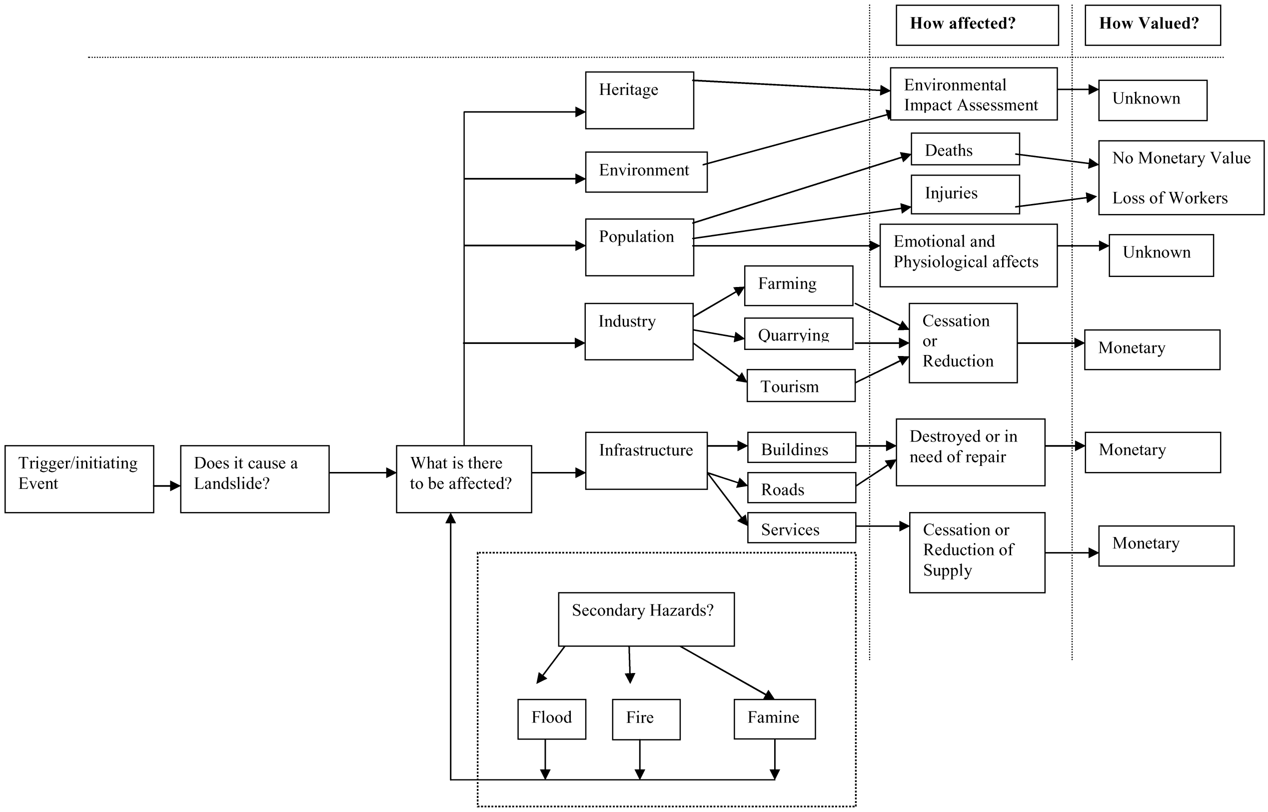


Figure 4. Event sequence analysis evaluating the consequence of a given event on a rural community.

Acknowledgements: Thank you to my co-authors, supervisors and Urra Field Centre.

Corresponding author: Mr Michael Whitworth, University of Plymouth, School of Earth Ocean and Environmental Sciences, Plymouth, Devon, PL4 8AA, United Kingdom. Tel: +44 7886250303. Email: michael.whitworth@plymouth.ac.uk.

REFERENCES

ESTEBAN-PARRA, M.J., RODIGO, F.S & CASRO-DIEZ, Y., 1998. Spatial and temporal patterns of precipitation in Spain for the period 1880-1992. *International Journal of Climatology,* **18**, 1557-1574.

GRIFFITHS, J.S., MATHER,A.M., & HART, A.B., 2002. Landslide sucseptability in the Rio Aguas catchment, SE Sapin. *Quarterly Journal of Engineering Geology and Hydrology,* **35**, 9-17.

HART, A.B., GRIFFITHS, J.S., & MATHER,A.M., 2000. The role of landsliding in landscape development in Bromhead, E., Dixon, N., &Ibsen, M.L, (eds), *Landslides in Research, Theory and Practice,* Thomas Telford, London, 701-706.

LAROUZIERE, F.D. DE., BOLZE, J., BORDET, P., HERNANDEZ, J., MONTENAT, C., OTT D'ESTEVOU, PH., 1988. The betic segment of the lithospheric Trans-Alboran shear zone during the late Miocene. *Tectonophysics,* **152,** 41-52

LOPEZ-ARROYO, A., MARTIN-MARTIN, A.J., MEZCUA-RODRIGUEZ, J., MUNOZ, D., UDIAS, A., 1980 el terromoto de Andalucia de 25 de Diciembre de 1884. *Presidencia del Gobierono Instito Geographico Nacional, Madrid 139 pp.* (in Spanish)

MATHER, A. E., 2000. Adjustments of a drainage network to capture induced base level change. *Geomorphology,* **34**, 271-289.

LEE, E.M., & JONES D.K.C., 2004. Landslide Risk Assessment, Thomas Telford, London

IEA INSTITUTE OF STATISTICS OF ANDALUSIA, 2005. www.juntadeandalucia.es/institutodeestadistica /ingles/iindex.htm

ROYAL SOCIETY, 1992. *Risk: Analysis, Perception and Management*. Report of the Royal Society Study Group, The Royal Society, London