Suppl. Geogr. Fis. Dinam. Quat.
III, T. 3 (1999), 185-188, 3 figg.

FOURTH INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY - Italy 1997
Round Table: «Geomorphological Hazards: a European Strategy»

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NEW TECHNOLOGIES FOR LANDSLIDE HAZARD ASSESSMENT AND MANAGEMENT IN EUROPE (NEWTECH)

INTRODUCTION

The perception of the natural hazards by the society of the developed countries has experienced noticeable changes during the last decades. Traditional strategies in landslide hazard management were oriented basically to the avoidance of the dangerous sites and to the stabilisation of the unstable slopes. Regional and urban planning have been very effective instruments to direct the growth to the safest places. To this purpose, planners and decision-makers have benefited with the information provided by hazard and risk maps. However, the development in many mountain regions has occurred before hazard maps were available in these regions. As a result of this development, numerous village neighbourhoods and facilities are nowadays settled either on active and dormant landslides or close to them. In such cases, moving the population is often a social and economical problem. Therefore, present hazard management strategies should also consider the co-existence of hazards with human activities. The main challenge is, thus, learning how to live together with natural hazards.

In landslide threatened areas, research needs are directed to the search of mitigation measures that could effectively avoid the slope failure or to divert the moving mass towards other places. When this is unfeasible, we have to consider the implementation of alert systems in order to avoid the loss of human lives. All these measures require a sound knowledge of how do landslides work. Specifically, the landslide mechanism and dynamics, the landslide triggers, the possible thresholds (rainfall intensity and duration) and the expected time of failure or reactivation.

Alert systems are based on the temporal prediction of the landslide failure or reactivation. The prediction may be undertaken on a short or long term bases. The purpose of the short term prediction is to determine the exact moment of the failure or reactivation while the long term prediction is directed to the knowledge of the probability of future occurrence. So far, the basic principle of the long term prediction is that the past is the key of the future. We know now that because the changing conditions of the climate, we can not expect that landslides will follow similar degree of activity in the future that we have observed in the recent past. Climatic scenarios and their rainfall regimes have therefore to be considered for the assessment of the future stability of the natural slopes in different regions.

The short term prediction may be tackled using physically based models. However, these models require large quantity of data of high quality to validate them. This can be achieved only by installing instruments in selected landslides to monitor their response to external factors and by continuously recording the variables needed for running the models. Different rainfall intensity and duration events result in different landslide susceptibility. To establish an alert threshold we need to reproduce the response of the landslide in front of different rainfall intensity-duration events. Consequently, it is necessary the knowledge of the infiltration rate and the subsequent change of the hydraulic head at the failure surface and its effects on the stability of the landslide. Is therefore necessary to prepare models linking the rainfall distribution, the hydrological response of the slope and the subsequent change in stability. This is the purpose of the coupling hydrological and mechanical models.

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These models have to overcome important challenges in terms of reproducibility of the landslide behaviour. For example, large landslides usually have complex geometry, different soil or rock properties, and hydraulic conductivity. It may also occur that the instability conditions are not reached in the whole landslide mass. That means that only parts of the landslide may be active and consequently, displacements and damage can only be expected in local areas of the landslide mass. Thus, to feed the models it is necessary to have a well instrumented landslide providing continuous record of displacements, groundwater fluctuations. This has induced the development of new and sturdy field equipment and procedures for landslide monitoring.

OBJECTIVES OF THE NEWTECH PROJECT

The NEWTECH is a research project which aim is to develop different approaches for landslide hazard assessment. It is a combined effort of a network of several european research institutes and universities. The main partners involved are the Université Louis Pasteur of Strasbourg, the Rheinische Friedrich-Wilhems Universität in Bonn, the Università degli Studi of Modena, the International Institute for Aerospace Survey and Earth Sciences of Enschede, The University of Utrecht, the Universidade de Lisboa, the King's College of London the Universidad de Cantabria in Santander, and the Universitat Politècnica de Catalunya of Barcelona.

The goal of the project is to improve landslide hazard assessment using two different approaches and scales: (a) the analysis of landslide occurrence over large areas by means of both detailed field work and the use of computer based maps implemented on Geographical Information Systems (GIS); and (b) predicting the behaviour of individual slopes by means of physically based models of slope stability conditions. Linkeage between both approaches will be searched as well.

GIS approach includes the improvement of data capture and mapping techniques for landslide hazard assessment and standarization procedures. New landslide mapping procedures are being tested. An evolutive mapping of the Corvara landslide evolution since 1954 to present days (fig. 1) has been prepared using qualitative-quantitative methods based mainly on the analysis of the overall morphological, morphometrical, hydrological, geomechanical and geothecnical characteristics of the ground (Panizza & *alii*, 1997). Systematic description of field observations are used to generate databases at each field station utilising geo-referenced cartographic symbols. The data base is interfaced with a Computer Aided Drafting (CAD) and Geographical Information Systems (GIS) for data processing. The accuracy of computerized data capture is checked in the field. GIS based landslide hazard maps at three study areas (Corvara in Italy, Lisbon in Portugal and Cantabrian Range in Spain) are under preparation by means of an statistical analysis (multivariate statistical techniques and favourability functions) of both automatic data captured and field work data.

Physically based models approach includes several steps. First of all, new low-cost equipment (wire extensometers and tilt meters) and new techniques for the monitoring of ground movement (GPS) and for landslide geometry definition (ground penetrating radar), is being tested at

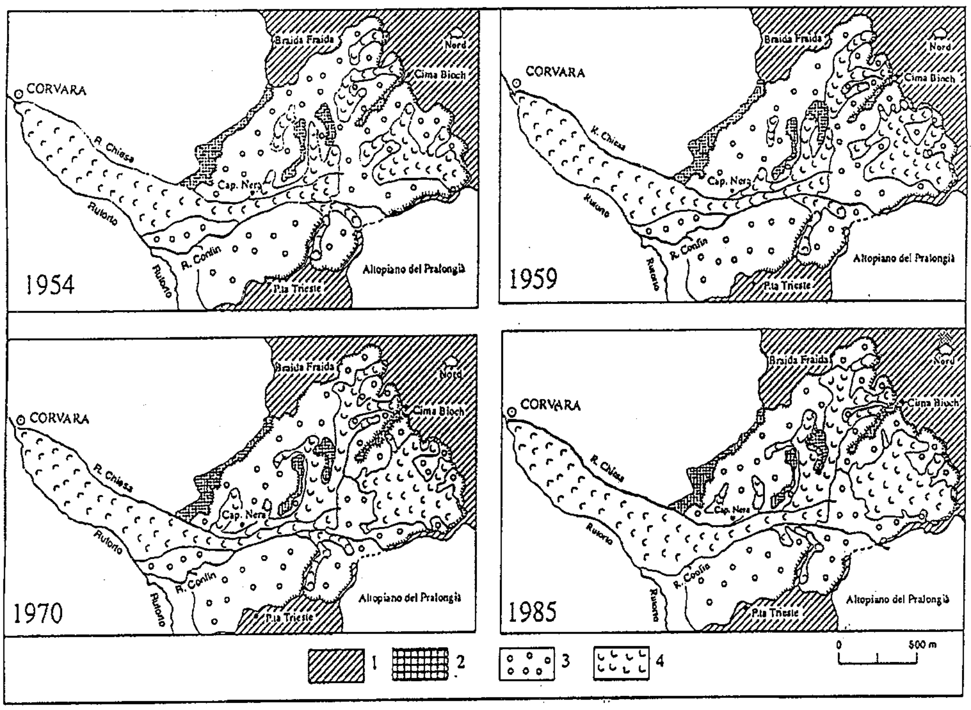
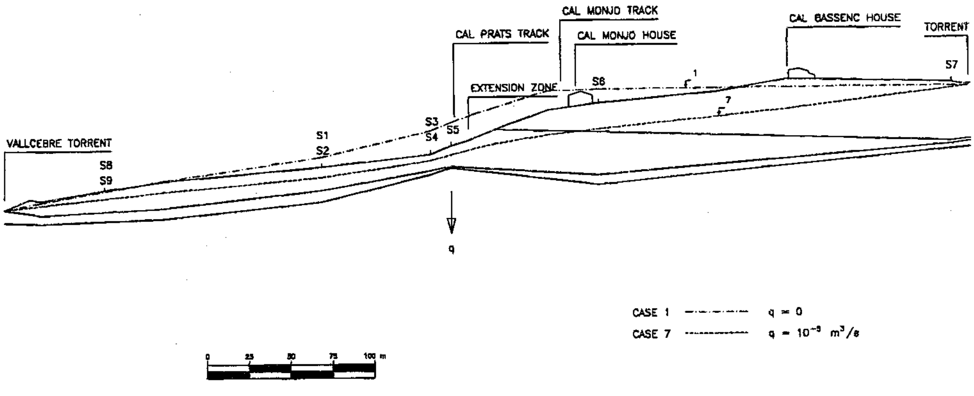


FIG. 1 - Evolutive map of the Corvara landslide (Panizza & *alii*, 1997). Legend: 1) bedrock (La Valle and San Cassiano formations); 2) misplaced rock mass; 3) dormant landslide; 4) active landslide.

FIG. 2 - Computed water tables at the Vallcebre landslide for two analysis, using different outflow values. Case 1): lack of outflow in the landslide. The computed location of the groundwater table (-above the ground surface) does not correspond to the observed data in piezometers. Case 7): outflow of 10^{-5} m^3/s through a landslide crack. The location of the groundwater table is in agreement with the observed piezometric readings (Corominas & *alii*, 1997).



four landslide sites in Vallcebre (Eastern Pyrenees), Alverà (Dolomites), Roughs (British Coast) and Super-Sauze (French Alps).

The second step includes the analysis of the performance of different hydrological and slope stability models in predicting groundwater fluctuations and landslide behaviour at each landslide site. Existing hydrological models are being improved by investigating the effect of vegetation and the significance of unsaturated and fast flow bypassing conditions (macropores and vertical fractures) in triggering or reactivating landslides. Preliminary results of the position of the groundwater table has been obtained in Vallcebre, using a 2D saturated flow finite element code (Corominas & *alii*, 1997). It has shown that the only way to keep the groundwater table below the ground surface, as shown by the piezometric readings, was by considering outflow through landslide crack (fig. 2). Coupled hidrology-stability models will be prepared and validated with monitored data.

The third step corresponds to the downscaling of General Circulation Models (GCM's). Since climate is an important forcing parameter of many landslides, it is clear that climate change is of high concern for landslide research, specifically in a project like NEWTECH. The importance of the climate on landslide activity has been evidenced by the Intergovernmental Panel on Climate Change (IPCC). Beniston & Douglas (1996), stated that, a future climate in which both the mean and the extremes of precipitation may increase in certain areas, the number of small and large slides would correspondingly rise. However, nearly no quantitative assessments of projected climate change on landslides have been made up to our knowledge. Downscaling of GCM's in NEWTECH is carried out by means of an statistical treatment which interrelates the characteristic patterns of observed simultaneous variations of regional climate parameters and the large-scale atmospheric flow. Mean monthly air temperature of the 4 test sites for July simulated in the Hadley Centre Coupled Model (HadCM2) is shown in fig. 3. Temperature and rainfall occurrence obtained by this procedure will be used as a data input of hydrological-slope stability models in a climatic scale.

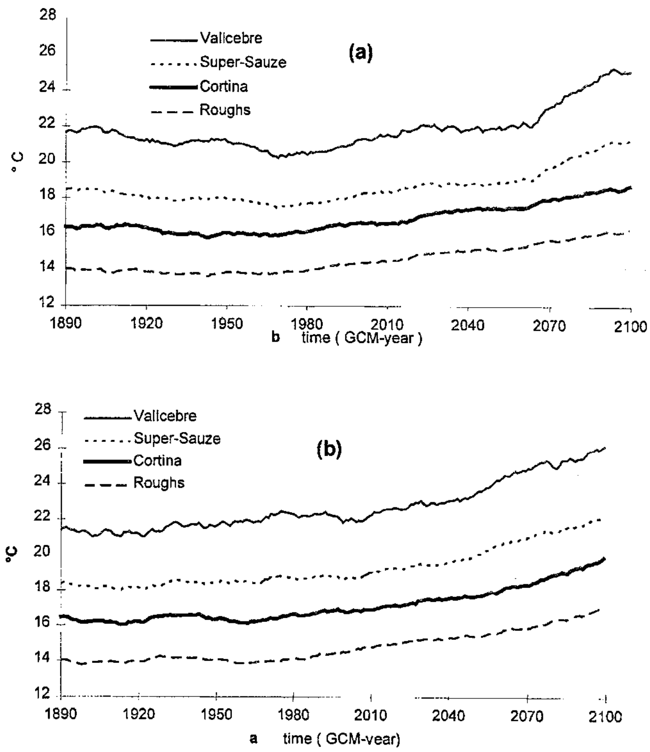


FIG. 3 - 30-years moving averages of mean July temperature interpolated from the 6 GCM grid points next to the NEWTECH test sites from HadCM2. a) greenhouse gases only; b) greenhouse gases and sulfate aerosols (from Dikau & *alii*, 1997).

Finally, the linkage between the GIS approach to landslide stability assessment and the physically based models is being carried out in the Roughs landslide (Collison & *alii*, 1997). A relatively simple hydrological modelling has been coupled to an infinite slope stablity model (Selby, 1993) and represented in a GIS. The models have been written using a combination of C++ programming, ArcGrid GIS functionality and Idrisi GIS macros. A 1:10000 DEM has been used to reproduce the topography of the site and validation of the piezometric response is currently made using different storm events.

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