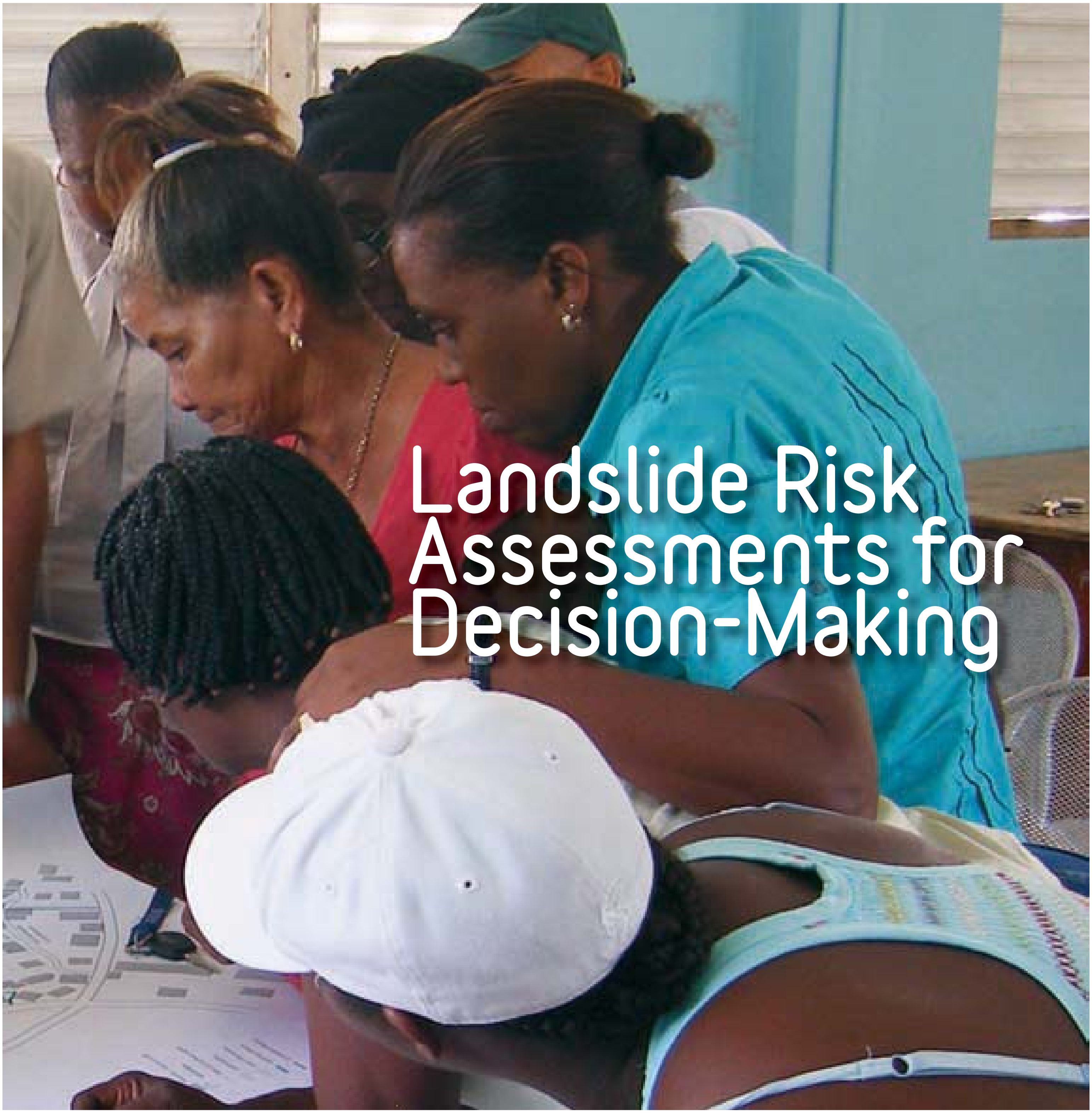

Landslide Risk Assessments for Decision-Making

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Landslide risk is an incredibly multidisciplinary problem: it's a social problem, a technical engineering problem, a water problem, and a housing problem.

Landslides are a relatively underestimated type of hazard and do not seem to show up prominently in disaster statistics. Individual landslides might not cause such extreme losses as other types of hazards do, but since they occur more frequently the cumulative effect might be more than one would expect. Furthermore, other processes often trigger landslides; such as earthquakes or extreme rainfall events and the resulting landslide losses are often grouped under the main triggering events.

Studies done by the landslide research center of Durham University on the actual death toll of landslides in the past decade revealed that in the EM-DAT database the death toll was less than 10,000 whereas the actual number was about eight times as high.

Landslides pose an increasing risk to many countries, closely related to both demographic pressures and territory mismanagement, such as illegal settlements, deforestation and lack of appropriate wastewater management.

A sound landslide risk management is based on a landslide risk assessment. Risk assessments provide critical information required to identify suitable strategies and mitigation measures.

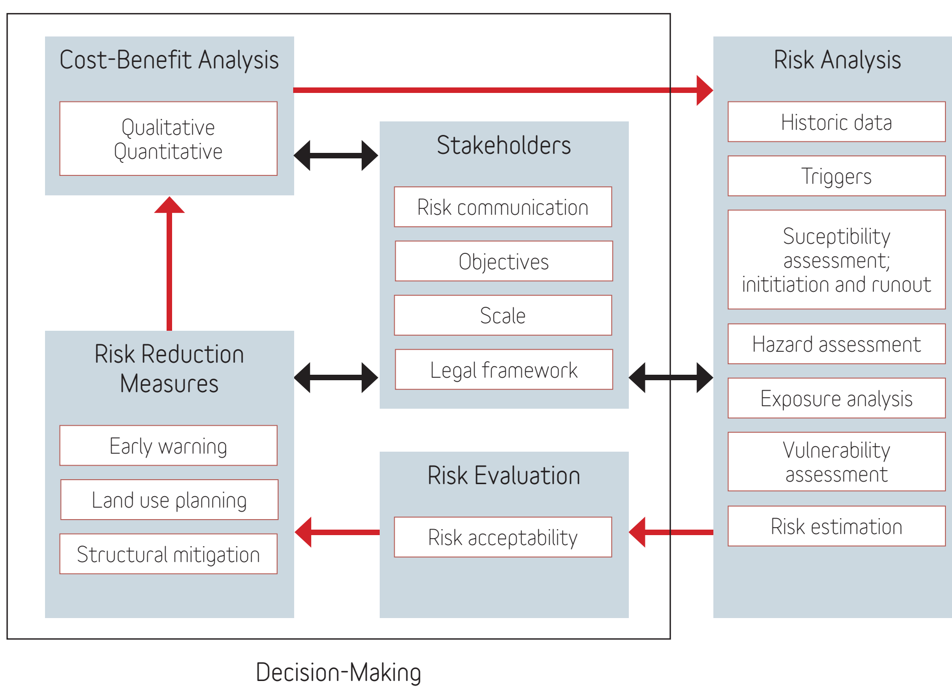
Assessing Landslide Risk

Quantitative landslide hazard and risk assessment is quite a challenge as it involves a number of uncertainties. In order to implement a landslide risk assessment, it is necessary to have the following information, outlined in Figure 1.

For landslide risk analysis, historical data on past landslides is indispensable for generating landslide susceptibility maps for initiation; as is an analysis of the triggering factors of landslides, which include earthquakes, rainfall, snow melt, anthropogenic activities etc. The main difficulties are that input datasets have a large degree of uncertainty.

Landslide susceptibility maps indicate the zones where landslides may occur and the areas that may be affected by landslide runout (debris). The terrain is divided into zones that have different likelihoods of landslides occurring.[27]

FIGURE 1: Framework for landslide risk assessment and decision-making



[27] The likelihood may be indicated either qualitatively (as high, moderate low, and not susceptible) or quantitatively (e.g. as the density in number per square kilometers, area affected per square kilometer, safety factor, height or velocity of runout).

Susceptibility maps can show the potential initiation areas (initiation susceptibility) and theses maps can form an input into the modeling of potential runout areas (runout susceptibility).

A landslide susceptibility assessment can be considered as (i) the initial step towards a quantitative landslide hazard and risk assessment; (ii) an end product in itself, or (iii) used in qualitative risk assessment if there is insufficient information available on past landslide occurrences in order to assess the spatial, temporal and magnitude probability of landslides[28].

Converting susceptibility into hazard requires information on temporal, spatial and intensity probabilities. In most of the methods that convert susceptibility to hazard, triggering events play a major role, hence the importance of obtaining event-based landslide inventories to determine (i) the temporal probability of the trigger; (ii) the spatial probability of landslides occurring within the various susceptibility classes; and (iii) the intensity probability.

Intensity probability is the probability of local effects of the landslides (such as height of debris, velocity, horizontal or vertical displacement, or impact pressure). For estimating landslide magnitudes, the area of landslide can be considered as a proxy to the volume, which is often difficult to collect from inventories. The frequency / size analysis of landslide area can be carried out by calculating the probability density function of the landslide area.

Temporal probability assessment of landslides is either done using rainfall threshold estimation, through multi-temporal data sets in statistical modeling, or through dynamic modeling.

The next step is exposure and vulnerability assessment. Exposure assessment analyzes the number of elements at risk and can be carried out by counting the number of elements exposed (e.g. number of buildings), or by expressing them in monetary values (e.g. replacement costs); vulnerability assessment analyzes the degree of loss to elements with a given intensity. The limited availability of historical landslide damage data makes it difficult to construct vulnerability curves. Therefore at a medium scale, expert opinion and the application of simplified vulnerability curves or vulnerability matrices are used.

The last component of landslide risk assessment is to integrate the hazard, exposure, and vulnerability components into an estimation of risk. For each hazard scenario with a given temporal probability the losses are calculated by multiplying the vulnerability (V) and the amount of exposed elements at risk (A). The result is a list of specific risk scenarios, each one with its annual probability of occurrence and associated losses (V*A). The specific risk is calculated for many different situations, related to hazard type, return period and type of element at risk.

Given the large uncertainty involved in many of the components of the hazard and vulnerability assessment, it is best to indicate the losses as minimum, average, and maximum values for a given temporal probability.

Using Landslide Risk Assessments in Decision-Making

Landslide risk assessments provide the critical information required to identify suitable strategies and mitigation measures. Such strategies, such as the integration of landslide hazard zones into land-use planning, structural measures to stabilize slopes, development of drainage systems or the establishment of early-warning systems, are all critically dependent on reliable information. However, the complexities associated with gathering this information present the broad challenges indicated above.

Based on the estimated risk, evaluations should be carried out according to pre-defined standards. However, in many countries a

[28] Many methods have been proposed for landslide susceptibility assessment, ranging from expert weighting, statistical modeling towards the application of physical models, which require much more input data. Methods for assessing landslide runout may be classified as empirical and analytical/rational. For hazard zoning purposes both methods are widely used given their capability of being integrated in GIS platforms. However, they vary a lot depending on the type of process modeled, the size of the study area (modeling individual events or modeling over an entire area), availability of past occurrences for model validation, and parameterization.

standard for risk acceptability does not exist, leading to unbalanced decisions. The implementation of the most optimal risk reduction measures should be based on cost/benefit analysis or cost/effective analysis. For such informed decision-making a reliable estimation of the landslide risk is essential.

Stakeholders play a crucial role in this process, but their participation can be problematic when there are many perspectives and agendas. In addition, communicating risk and the role of uncertainty is a major challenge.

Landslide Susceptibility Assessment in the Caribbean

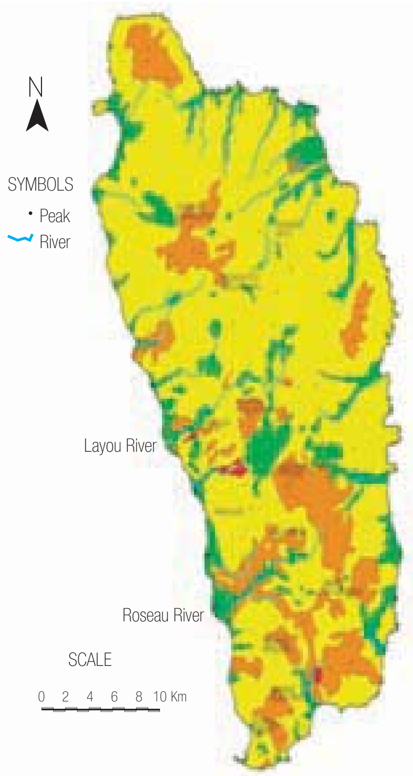
In many of the lesser-developed areas of the world, regional development planning is increasingly important for meeting the needs of current and future inhabitants.

Expansion of economic capability, infrastructure, and residential capacity requires significant investment, and so efforts to limit the negative effects of landslides and other natural hazards on these investments are crucial.

Many of the newer approaches to identifying and mapping landslide susceptibility within a developing area are hindered by insufficient data in the places where it is most needed.

An approach called matrix assessment was originally designed for regional development planning where data may be limited. Its application produces a landslide-susceptibility map suitable for use with other planning data in a Geographic Information Systems (GIS) environment. Its development also generates basic landslide inventory data suitable for site-specific studies and for refining landslide hazard assessments in the future (Map 1).

This example demonstrates how this methodology can be applied in a geologically complex setting. A validated approach to mapping landslide susceptibility, which does not require extensive input data, offers a significant benefit to planning in lesser-developed parts of the world.



Map 1: Dominica, West Indies

Landslide Susceptibility

Low Moderate
High Extreme

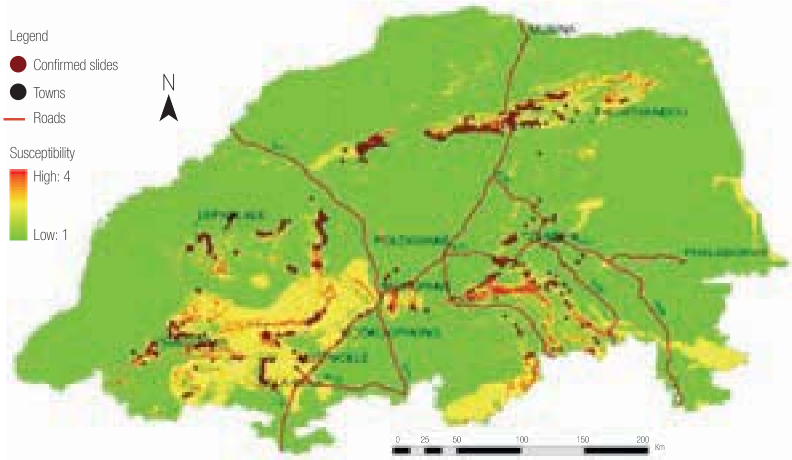
Dealing with Incomplete Landslide Inventories for Landslide Susceptibility Mapping in South Africa

In response to the needs of local and provincial authorities to reduce economic and social losses due to landslides, the systematic creation of inventories and susceptibility mapping of zones prone to slope instability is currently being undertaken for the entire country of South Africa.

Unfortunately, very few research monographs on local landslide and slope instability problems exist in the country and no systematic database on past landslide occurrences is available. As a result, the available landslide maps are generalized and merely highlight qualitatively the relative landslide incidence and thus hazard susceptibility at a regional scale.

In the Limpopo Province, erratic heavy-rainfall events are increasing in frequency and provide an impetus to rapidly map this geohazard in the interests of community safety. A preliminary susceptibility map based on a semiquantitative, bivariate statistical approach and multicriterion fuzzy-set decision theory can now guide planning in the typically hilly areas constraining rural community development (Map 2).

The greatest value of the maps is in raising general public and government awareness of this geohazard.



Map 2: Resulting landslide susceptibility map of Limpopo province

A Community-based Approach for Landslide Risk Reduction in Jamaica

The Management of Slope Stability in Communities (MoSSaiC) methodology, which has been successfully implemented in Saint Lucia, Dominica and Saint Vincent, is a methodology that engages policymakers, community members in particular, managers and practitioners in reducing landslide risk.

The focus of the work is firmly embedded in the communities. It uses existing within-country capacity to reduce urban landslide hazard and identifies hazard drivers to justify interventions.

The project comprises of three components, the first of which involves the development of a toolkit and a short video on MoSSaiC methodology and its application. This outlines the best practices for landslide risk reduction and promotes safer slope management in vulnerable communities. The second entails training on the MoSSaiC methodologies, while the final component involves the implementation of the landslide reduction measures in the selected communities. For more information see: http://www.mossaic.org/

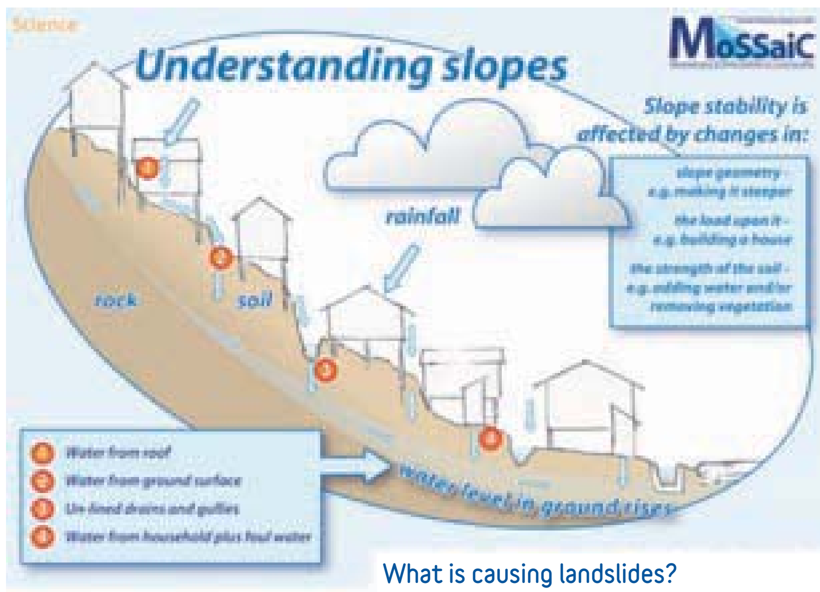


FIGURE 3: Understanding slopes: what causes landslides in urbanized slopes

Contributors to the session

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Further Resources

- Durham University Landslide Research Center: http://www.landslidecentre.org/
- Guidelines and documents from the SafeLand project: SafeLand was a Large-scale integrating Collaborative research project funded by Seventh Framework Programme for research and technological development (FP7) of the European Commission. Thematically the project belongs to Cooperation Theme 6 Environment (including climate change), Sub-Activity 6.1.3 Natural Hazards. The project team composed of 27 institutions from 13 European countries produced a number of very interesting guidelines and documents related to landslide hazard and risk assessment and risk management. The documents can be downloaded at: http://www.safeland-fp7.eu/results/Pages/Summaryreport.aspx