MODELING THE CONDITIONAL PROBABILITY OF THE OCCURRENCES OF FUTURE LANDSLIDES IN A STUDY AREA CHARACTERIZED BY SPATIAL DATA

Chang-Jo Chung[a]* and Andrea G. Fabbri[b]

a: Geological Survey of Canada, 601 Booth Street, Ottawa, Canada K1A 0E8
E-mail: chung@gsc.nrcan.gc.ca

b: ITC, Hengelosestraat 99, 7500 AA Enschede, The Netherlands
E-mail: fabbri@itc.nl

Commission IV, WG IV/1

KEY WORDS: Landslide hazard, conditional probability, cross-validation, likelihood ratio function

ABSTRACT:

The most crucial but difficult task in the analysis of the risk due to landslide hazard is the estimation of the conditional probability of the occurrence of future landslides in a study area within a specific time period given the presence of spatial and geomorphologic features. This contribution explores a modeling procedure for estimating that conditional probability. The procedure proposed consists of two steps. The first step is to divide the study area into a number of "prediction" classes according to the hazard level for the likely occurrence of future landslides. "Favourability Functions" based on the spatial and geomorphological data in the study area were used for the sub-division. The number of the classes is dependent on the quantity and quality of the input data. Each class represents a level of hazard with respect to the future landslides. We term it the "hazard-mapping step". For this step, several quantitative models have been developed and the strategy is to reconstruct the typical settings in which the future landslides are likely to occur. The second step is to empirically estimate the conditional probability in each prediction class given the spatial and geomorphologic data based on cross- validation techniques. For the second step, termed the "probability estimation step" the basic strategy of the cross-validation is to construct the prediction classes in the first step using the occurrences of the landslides from the first time-period and then to compare the prediction classes with the distribution of the landslide occurrences from the later time period. The statistics obtained from the comparison provides the crucial quantitative measure to estimate the conditional probability. We illustrate the modeling procedure using a case study, La Baie, Quebec in Canada.

1. Introduction

For a given study area, geomorphologists, experts in surficial earth processes have traditionally constructed a landslide hazard map identifying areas likely to be affected by future landslides. It has been achieved by geomorphological understanding of the area through aerial photographs and field works. The hazard map is usually derived from geomorphological maps containing the basic geomorphological characteristics of landforms and it includes a systematic inventory of the past landslides (Panizza et al, 1998). On the other hand, quantitative geomorphologists and civil engineers have constructed a slope stability map based on deterministic models by studying and interpreting the physical processes of landslides using slope angles, soil cohesion, water saturation capacities, shearing resistance and etc. Each point in the stability map shows a level for "the safety factor of slope failure" of the unit area surrounded the point (Terlien et al, 1995).

While the hazard maps from geomorphological maps usually show three or five levels of hazard, the slope stability maps are shown the level for the safety factor in a continuous scale. These prediction maps representing both the hazard and the slope stability maps are generated for guiding the decision makers for land-use planning. The difficulty facing the land-use planners is how to interpret the hazard levels. For example, if only a small sub-area has been assigned as "extreme hazard class" in a hazard map or has consistently extreme values for the safety factors of slope failures in slope stability map, then it may be relatively easy to make a decision not to allow any types of economic and human activities, the economic sterilization by the ban may outweigh the possible future damage due to the occurrences of future landslides in that small sub-area. However, if a sub-area is classified as "high hazard class" or has a high value for the safety factor in a relatively large sub-area, then although it obviously indicates that the sub-area is possibly be affected by a future landslide, the decision of what to do with the sub-area becomes much more difficult, because the decision makers must compare the economic sterilization with the possible damage.

What the decision makers want to have from the hazard maps or the slope stability maps is not only the relative levels of hazard but also the estimates of the probabilities of the occurrences of future landslides in any given points under certain future scenarios such as a number of future landslides are going to be occurred in the study area within the next 30 years. If we have such estimates of the probabilities, then based on a cost-benefit analysis the decision makers can quantitatively compare the economic sterilization with the possible damage under the assumptions of the scenarios, and hence make a learned and an informed decision, rather than an emotional or a "gut-feeling" decision.

We have adapted a two-step approach proposed by Chung (2002) to tackle the problem of estimating the