Validation of Spatial Prediction Models for Landslide Hazard Mapping

Presenter: Huang Chih-Chieh

Reference

- Chung, C. J. F. and Fabbri, A. G.: 2003, Validation of spatial prediction models for landslide hazard mapping, Natural Hazards 30, 451–472.

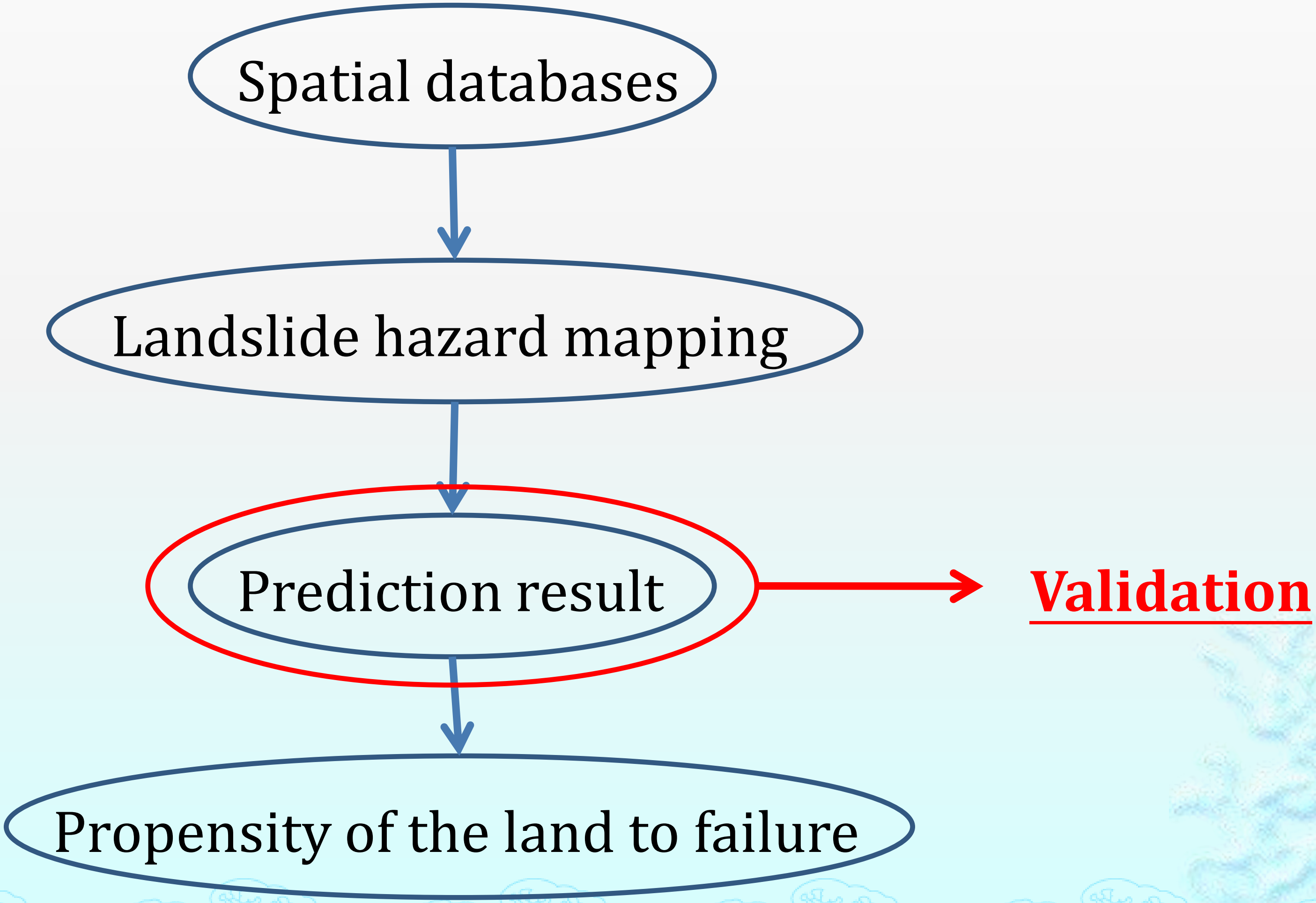
- Chung, C. J. F. and Fabbri, A. G.: 2002, Modelling the conditional probability of the occurrences of future landslides in a study area characterized by spatial data, Proceedings of ISPRS 2000, Ottawa, Canada, July 8-12, 2002.

Outline

1. Introduction
2. Traditional Models
3. Quantitative Models
4. Validation
5. Prediction Rate and Success Rate
6. Concluding Remarks

Introduction

To generate predictions for landslide hazard mapping:



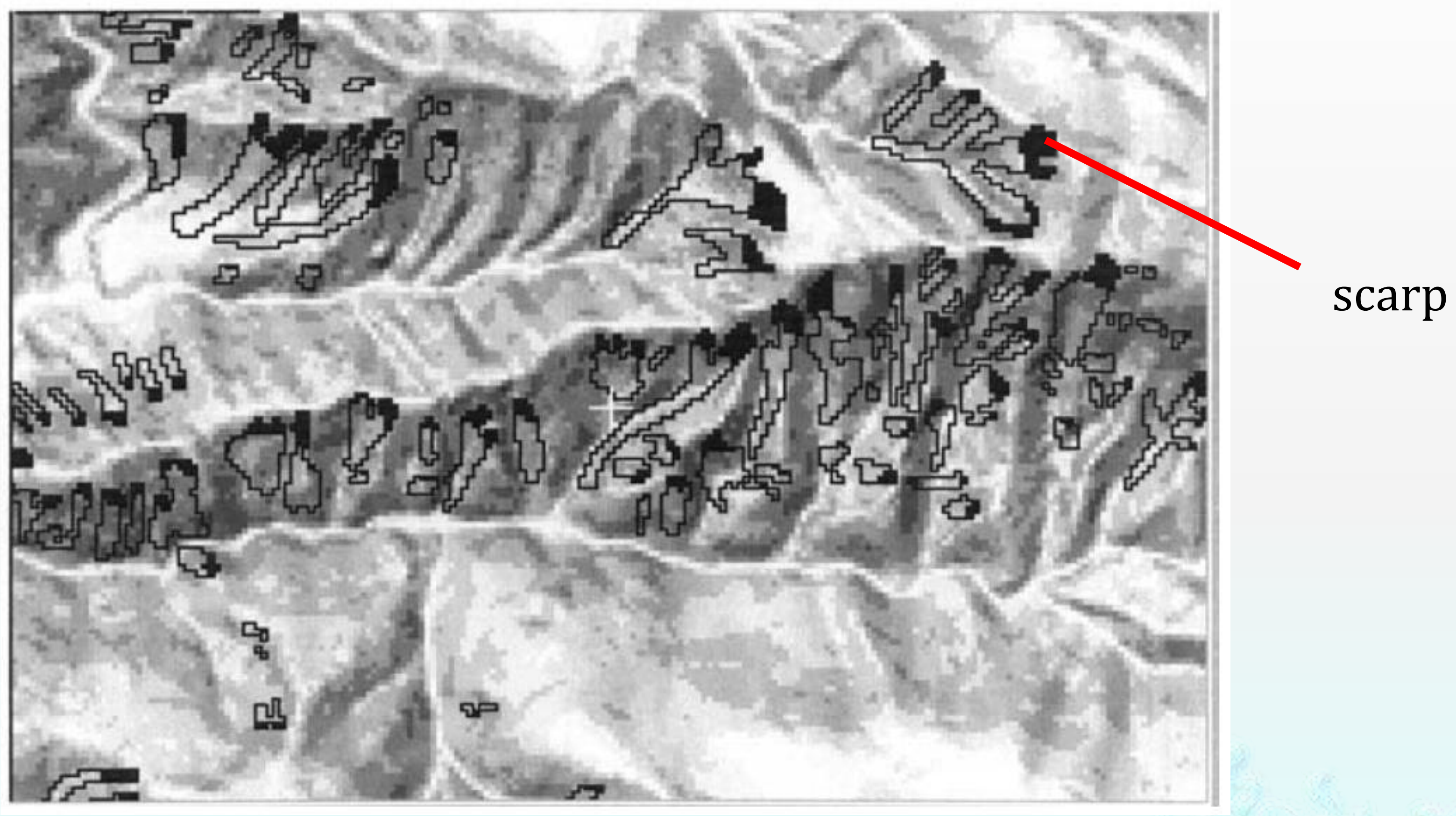
Definition

Study area:

"The area where we wish to have information on the target pattern."

Target pattern:

"The spatial distribution of the areas to be affected by future landslides."



Scars of the past landslides induced by the 1994 Northridge Earthquake in California, U.S.A.

Traditional Models

"Hazard levels were constructed by classifying the observed landforms into gravitational deposits and eroded features."

"It is difficult to assign quantitative scores or values to these qualitative hazard levels."

Two main weaknesses of the hazard maps by experts:

(1) The interpretation of the hazard levels of the maps.

(2) The "independent" verification of the hazard maps.

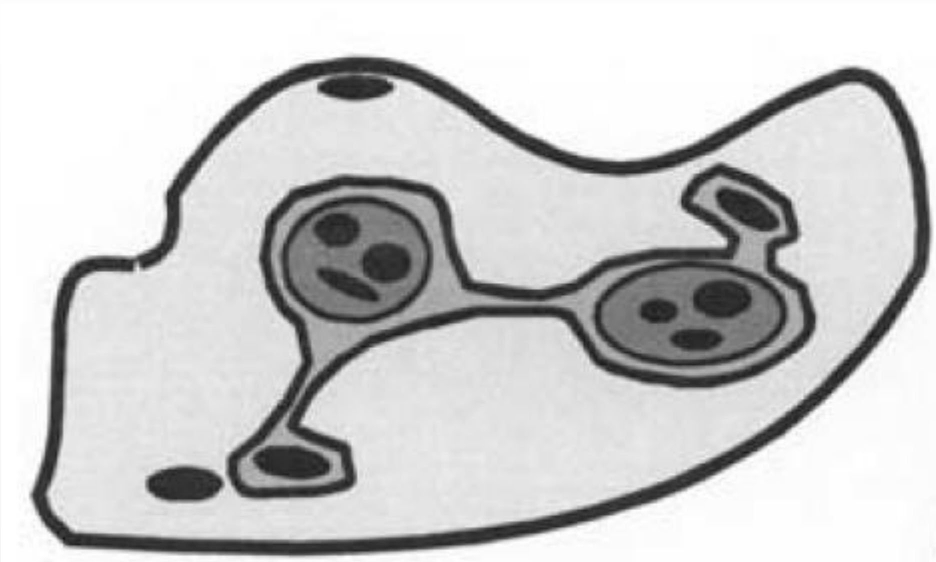
Quantitative Models

"ratio of effectiveness": $$\frac{qt}{r\alpha}$$

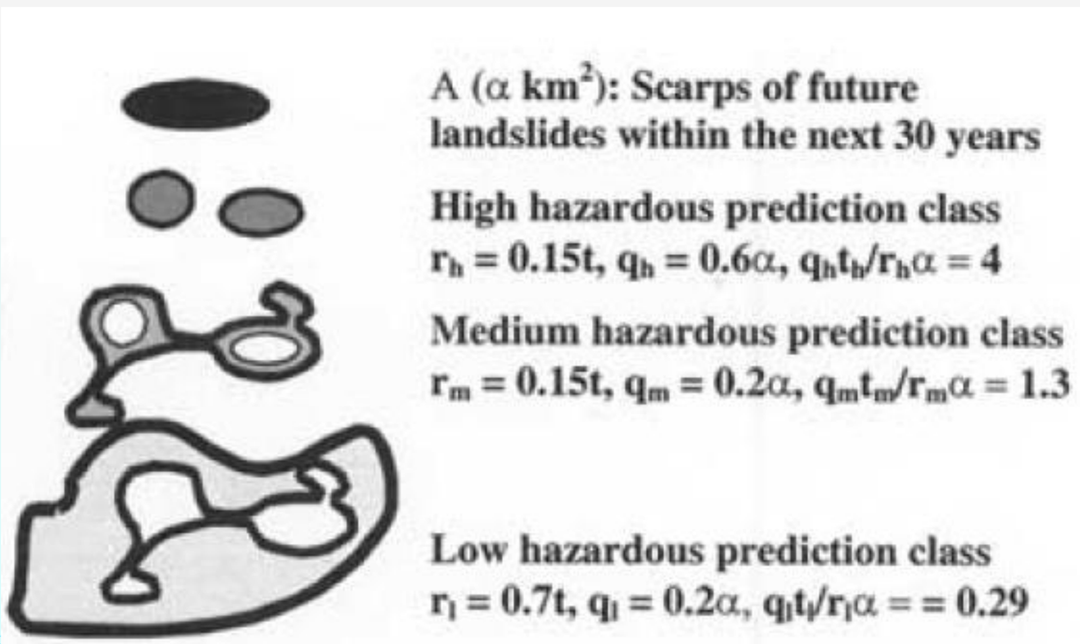
- *α/t:* The probability of any pixel in the study area to be affected by a future landslide.
- *q/r:* The probability that a pixel within the class will affected by a future landslide.

Assume:

1. *The target area, A to be affected by future landslides is **α** km^2*
2. *The portion of future landslides of **α** km^2 that has occurred within that class is **q**.*



The study area, T of the size of **t** km^2, includes three prediction classes, high, medium and low of a prediction pattern and the target area.



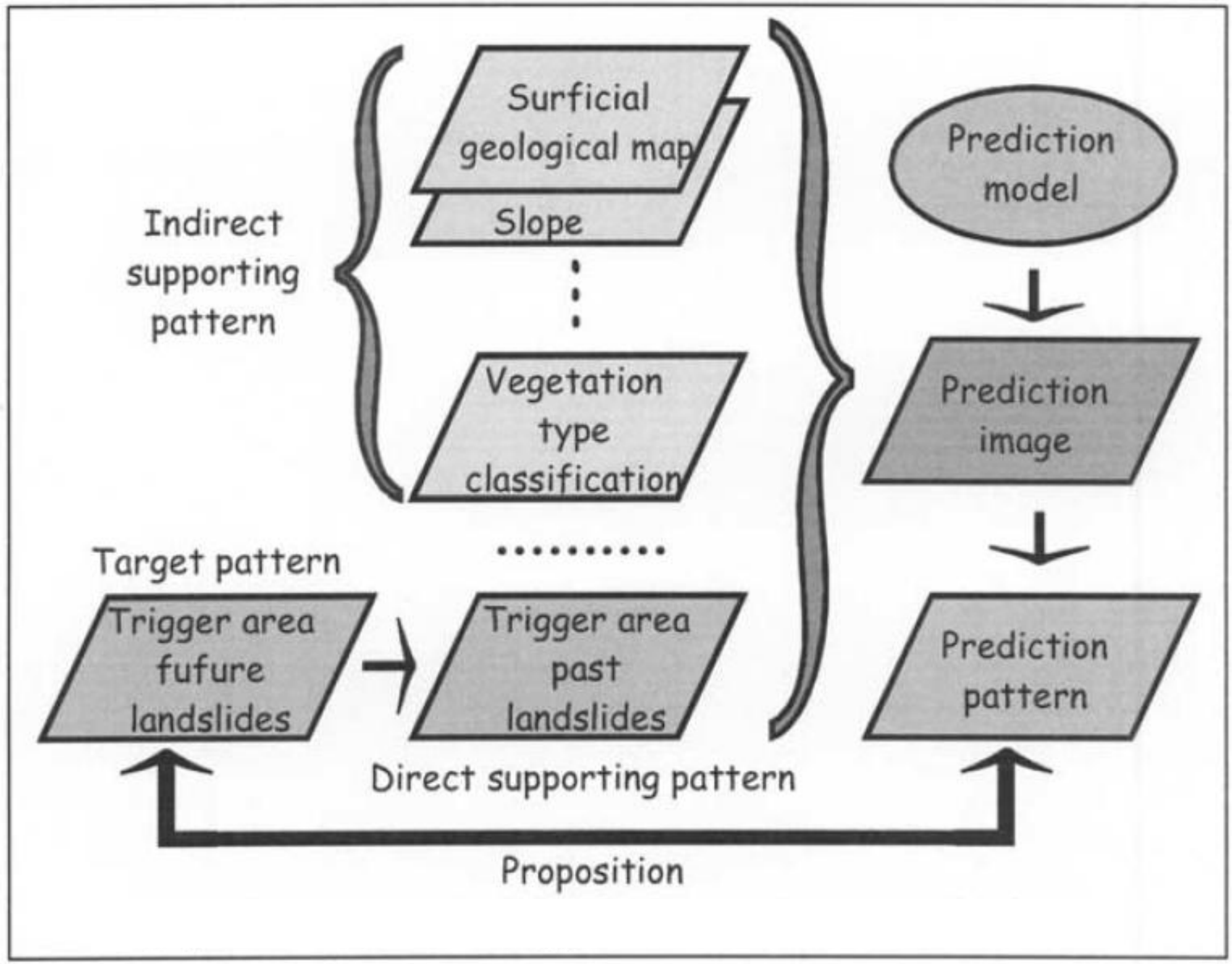
Ratio of effectiveness

Significant:

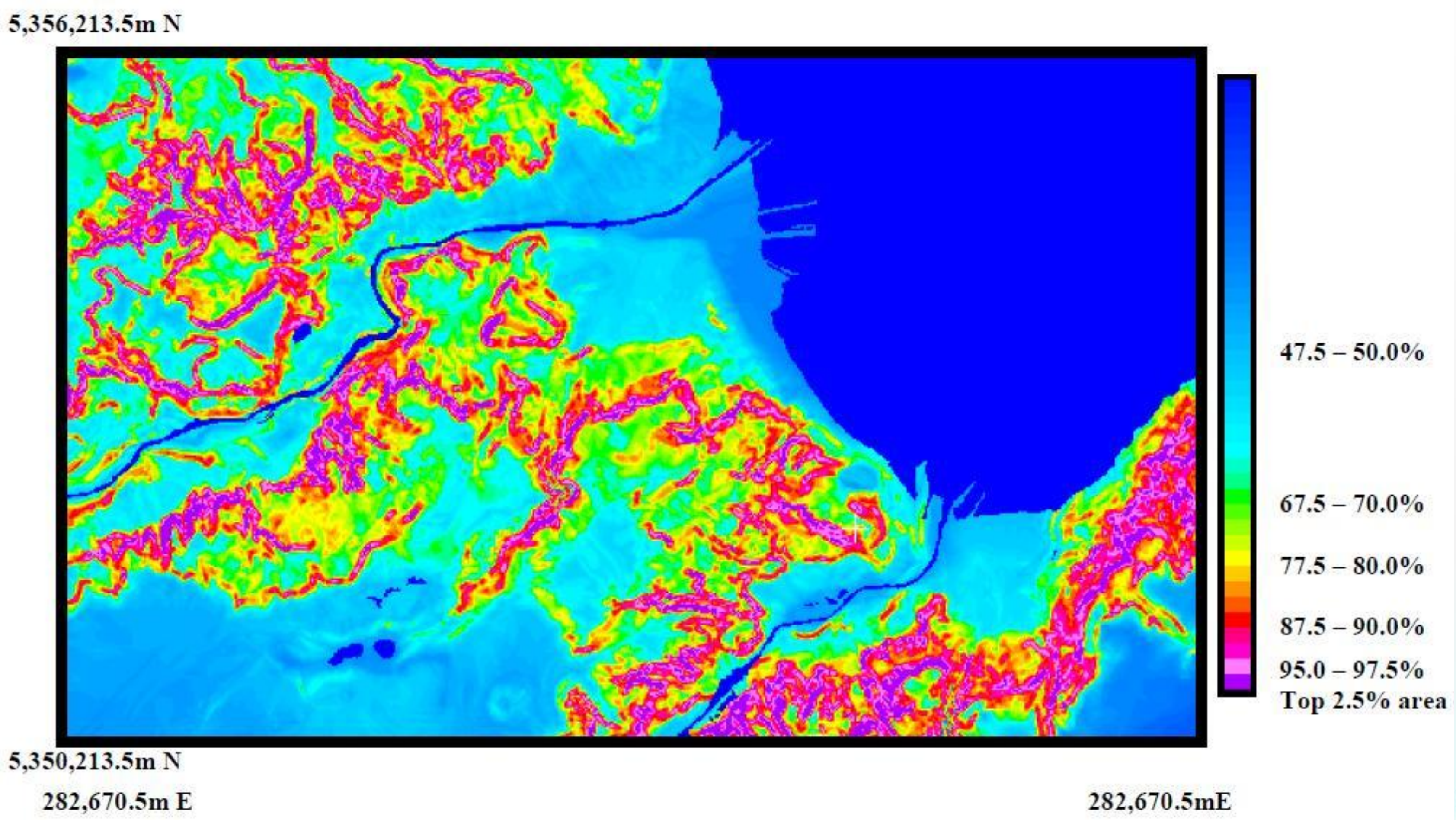
> 3 , or < 0.2

Significantly effective:

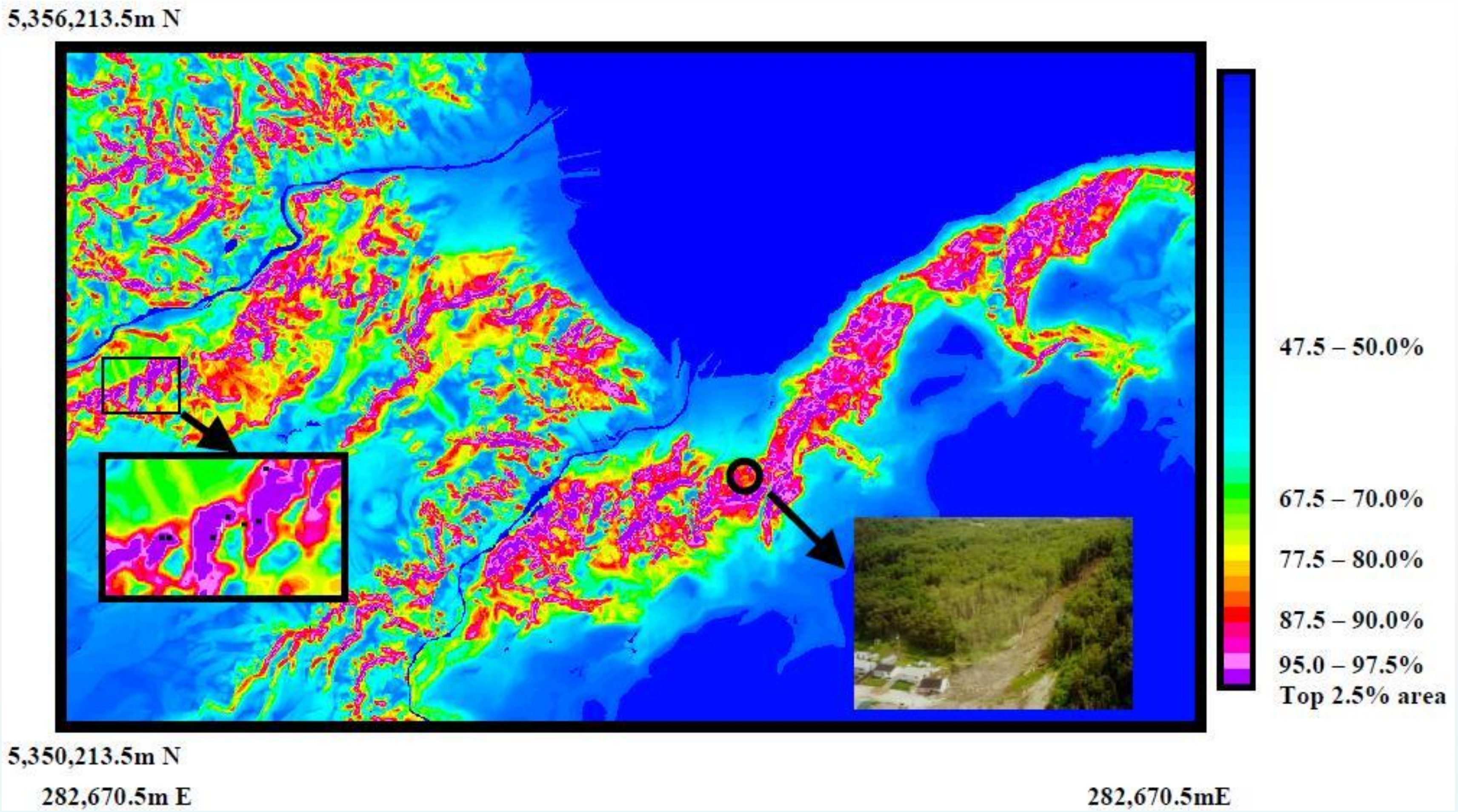
> 6 , or < 0.1



The construction of a prediction map for future landslide hazard.



Landslide hazard prediction map based on 73 landslides (22 in 1967, 51 landslides in 1976 and 1996) and five layers (bedrock geology, forest coverage, elevation, aspect angle, slope angle maps) of geomorphological map information using likelihood ratio function model.



Landslide hazard prediction map based on 22 landslides occurred in 1967 and five layers (bedrock geology, forest coverage, elevation, aspect angle, slope angle maps) of geomorphological map information using likelihood ratio function model. The 51 black dots represent 51 landslides occurred in 1976 and 1996. The left side inset is an enlargement of a small area in black rectangle area in the middle left side. The right side inset with “Year 1996” is an image showing a photograph of a landslides occurred in 1996 at the black circle area in the middle area.

Visualization

There are two ways of making the prediction classes for a prediction pattern from the pixel values:

"Equal-interval classes"

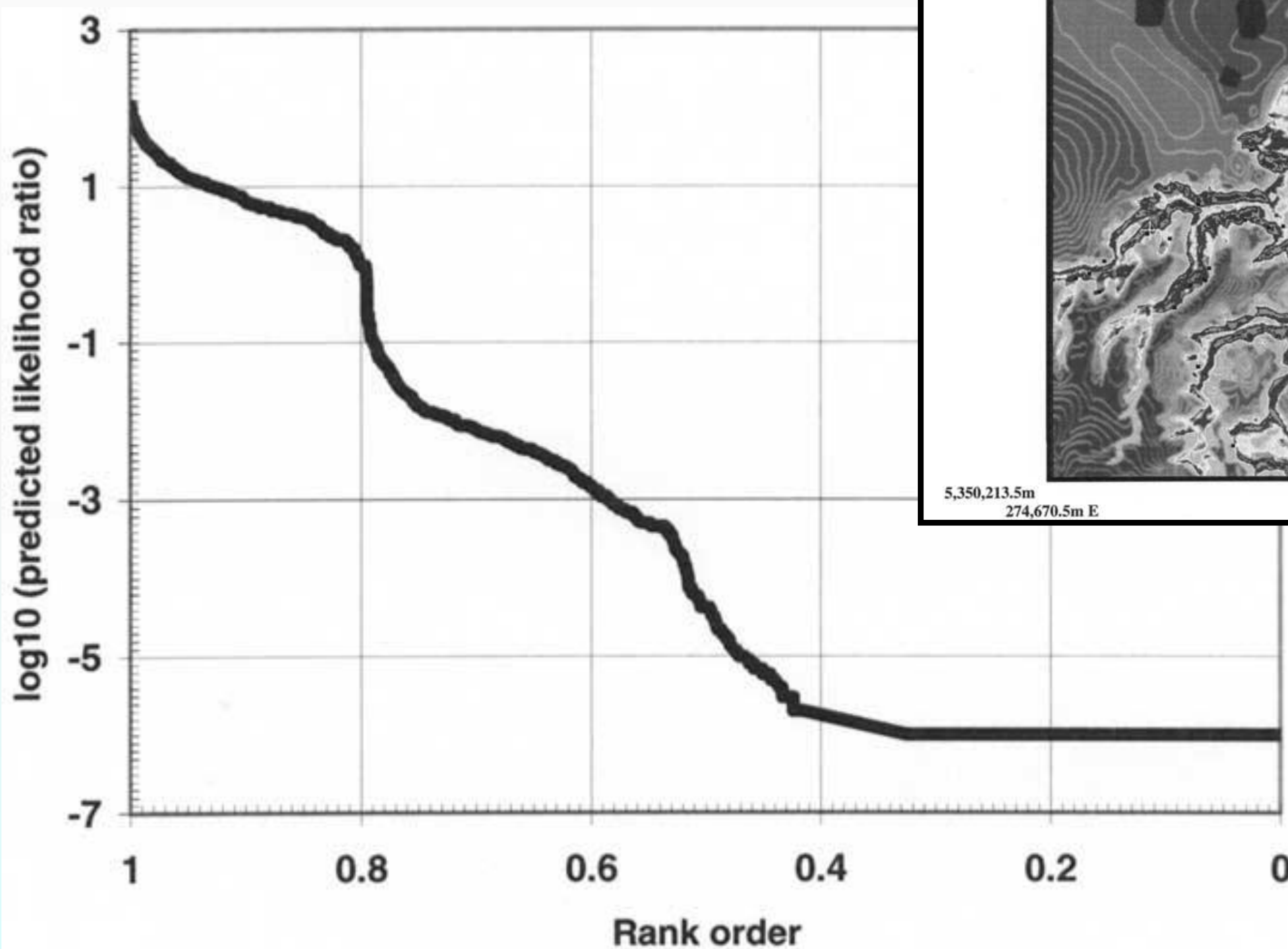
The range of all the pixel values is divided into a number of equal intervals.

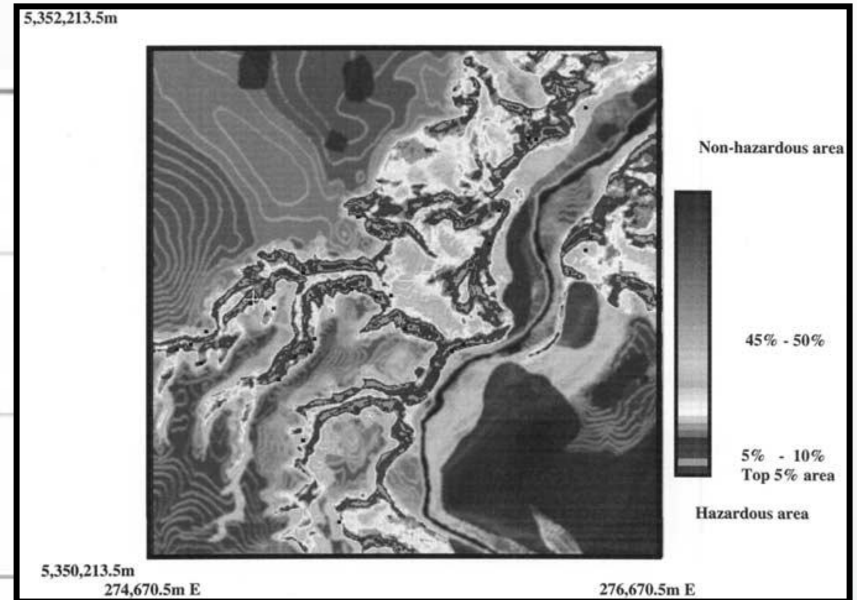
"Ranking equal-number Classes"

All pixels are sorted according the pixel value in descending order.

GOOD!!

Ranking Procedure





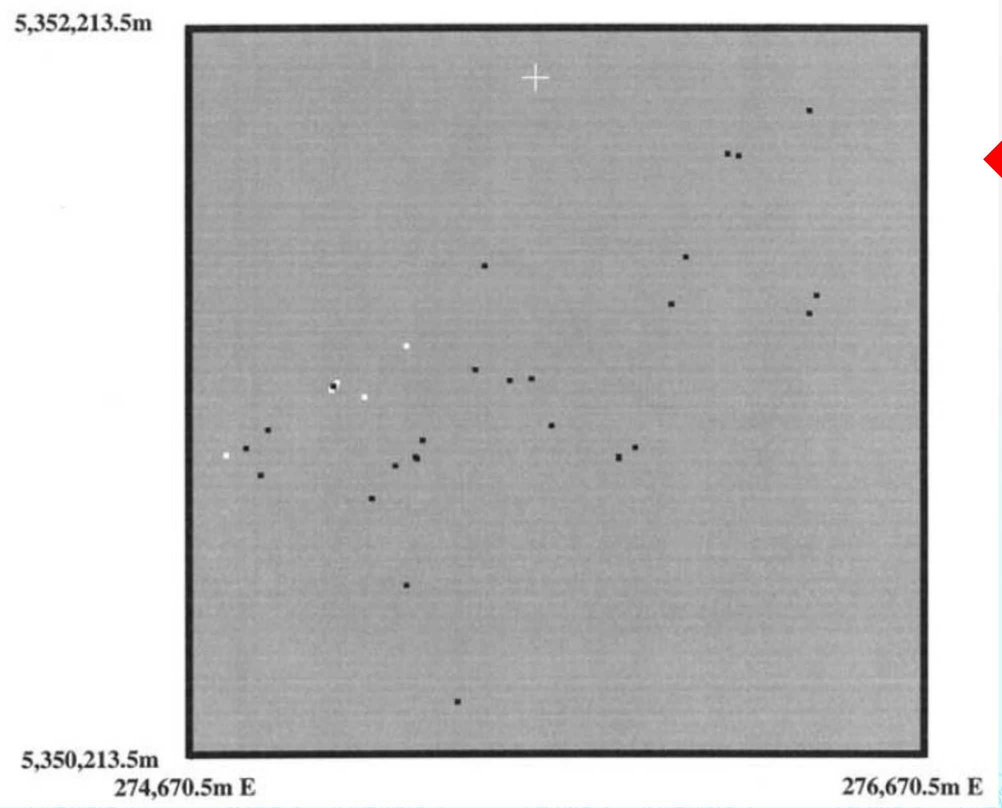
La Baie area, Quebec

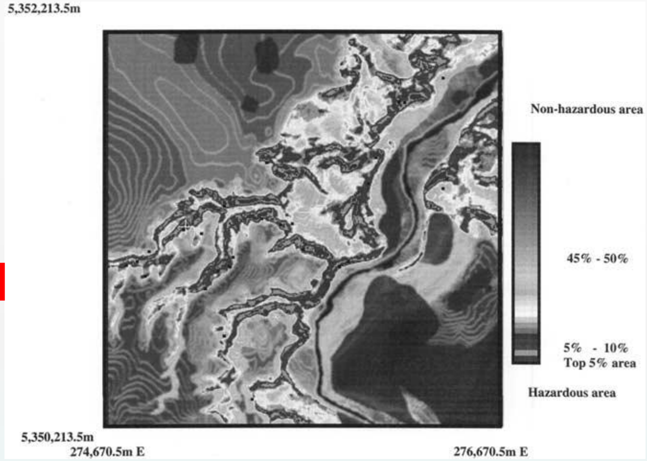
Relationships between the rank order of predicted value pixels in the image.

Validation

The next best thing to do is to mimic the comparison by using a part of the past landslides as if it represents the target pattern.

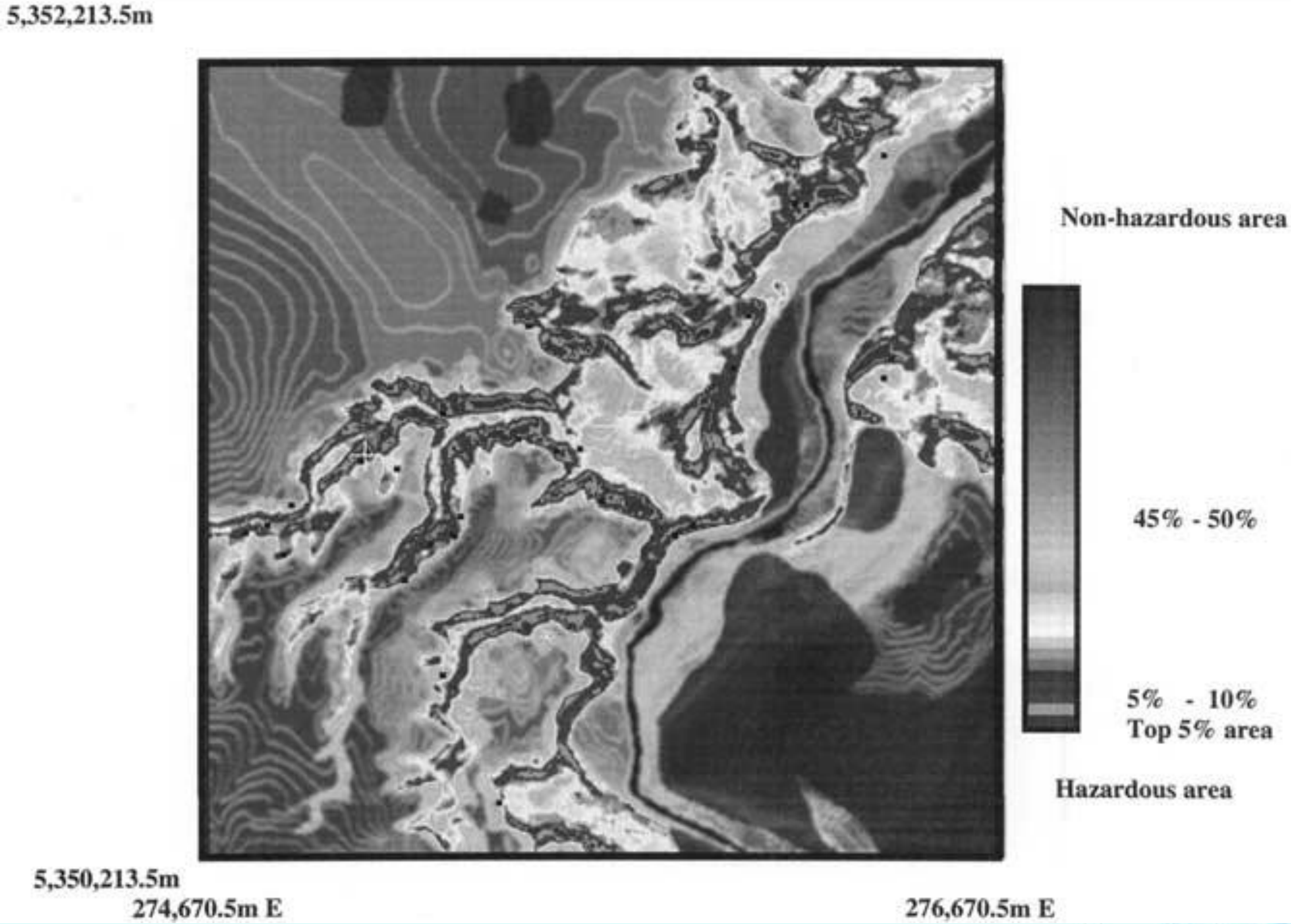
"TIME PARTITION"



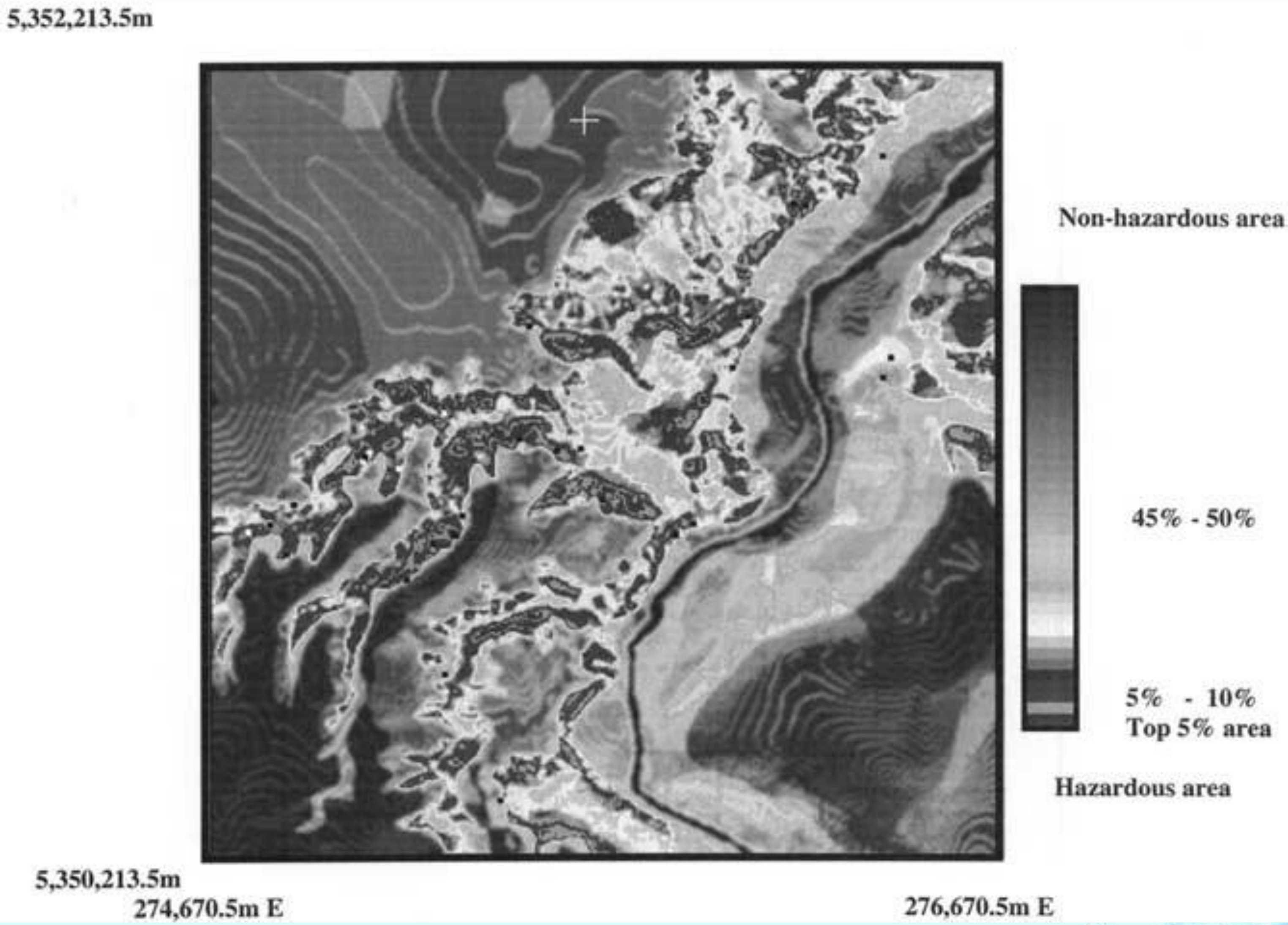


The distribution of landslides in part of the La Baie study area in Quebec, Canada.

The 5 white dots locate the landslides of the year 1964; the 24 black dots those of 1976 and 1996.

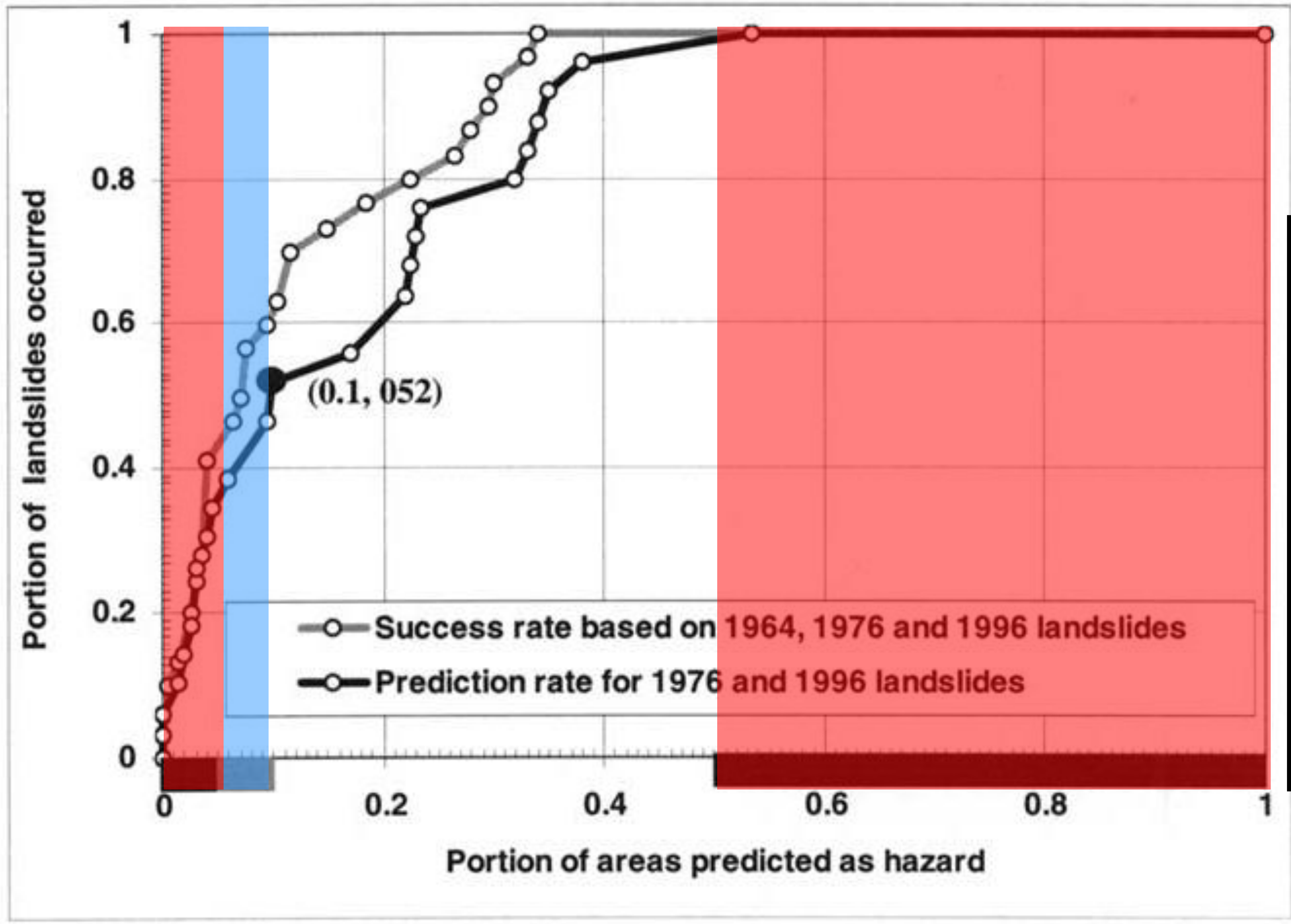


Prediction pattern in the La Baie area, Quebec, obtained by the likelihood method using all the 29 landslides (both white and black dots) of 1964, 1976 and 1996.



Prediction pattern in the La Baie area, Quebec, obtained by the likelihood method using only the 5 landslides (white dots) of 1964.

The landslides of 1976 and 1996 (black dots) are used to evaluate the prediction.



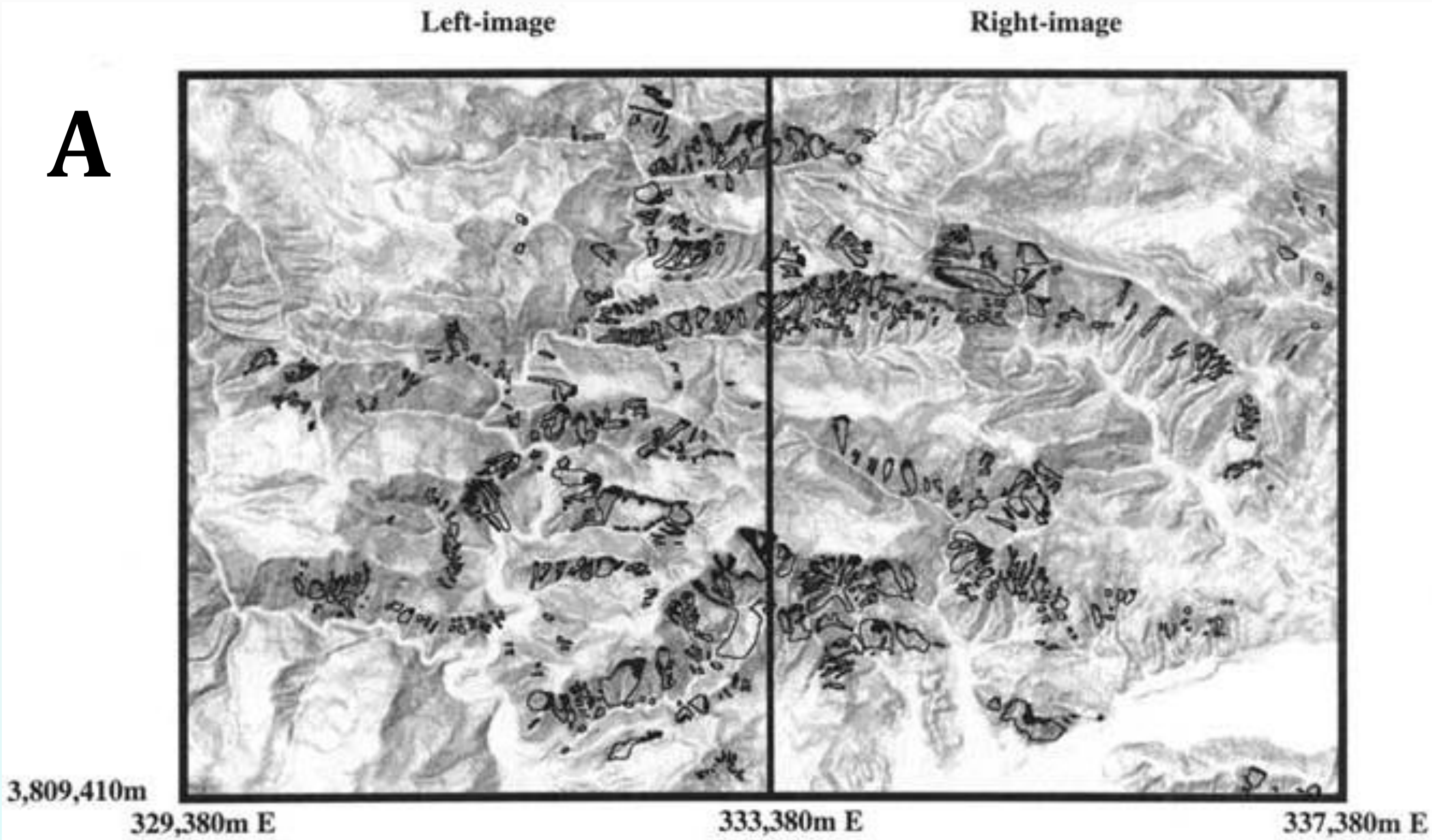
Classes	Ratio of effectiveness: qt/rα
0–0.025	7.32
0.025–0.05	6.96
0.05–0.1	3.22
0.1–0.2	0.72
0.2–0.3	1.99
0.3–0.4	1.73
0.4–0.5	0.28
0.5–1.0	0.02

Prediction- and success-rate curves for the La Baie study area, Quebec.

"SPACE PARTITION"

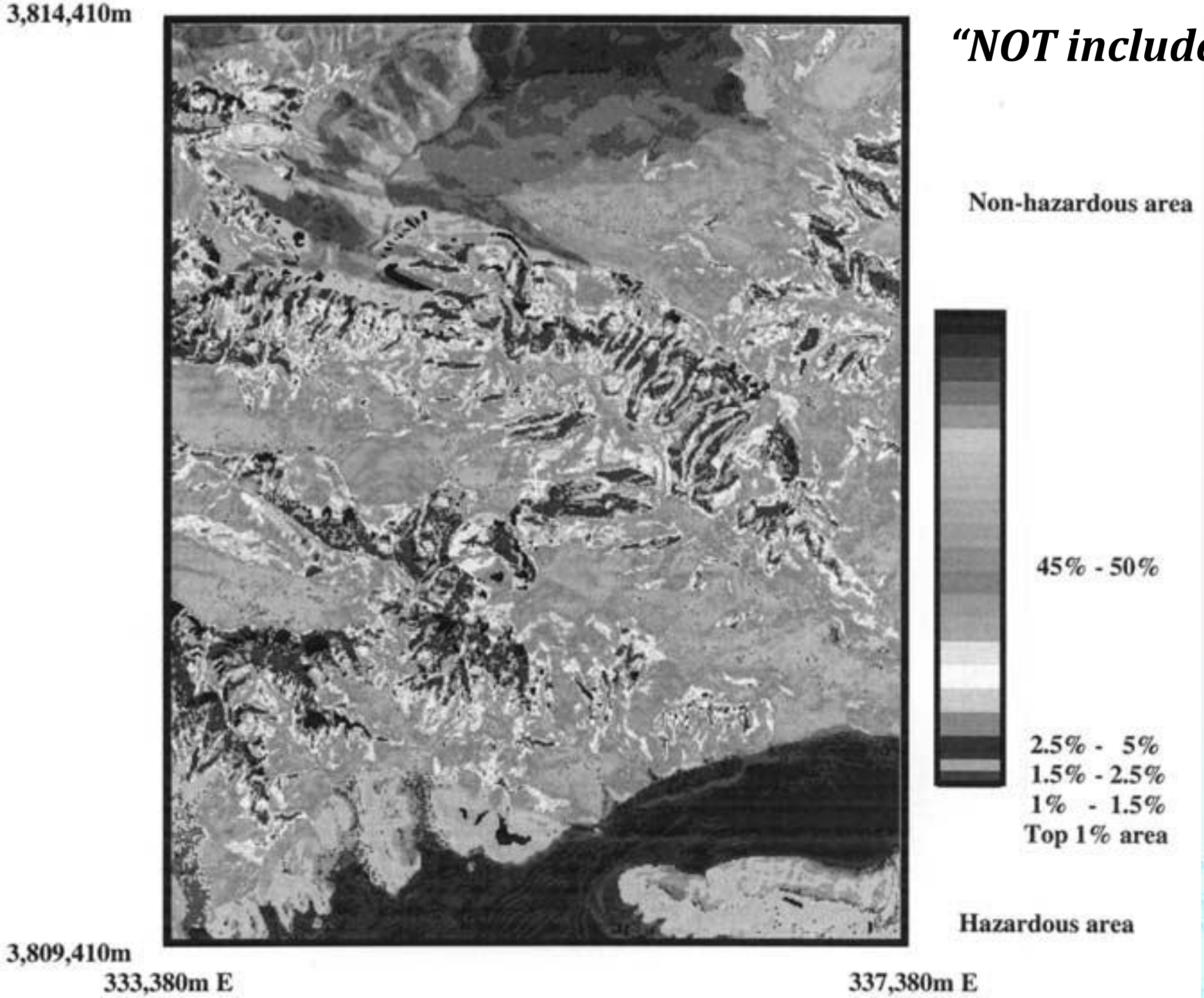
Landslide :331 **Landslide :314**

A **B**



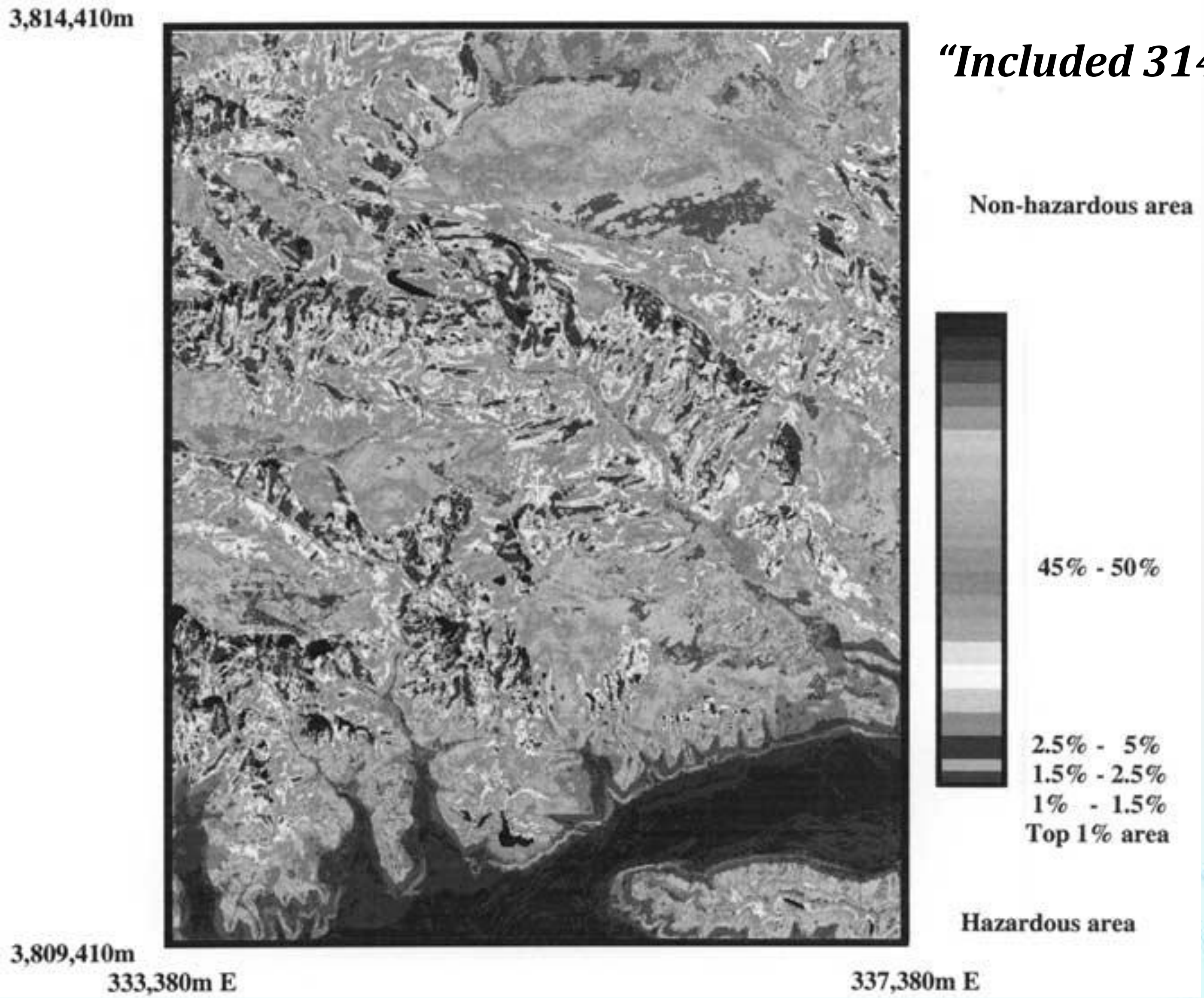
Distribution of landslide scars (bodies) and scarps (trigger areas) in part of the Northridge study area of California (USA).
The background is a shaded relief image.

“NOT included 314 landslides”

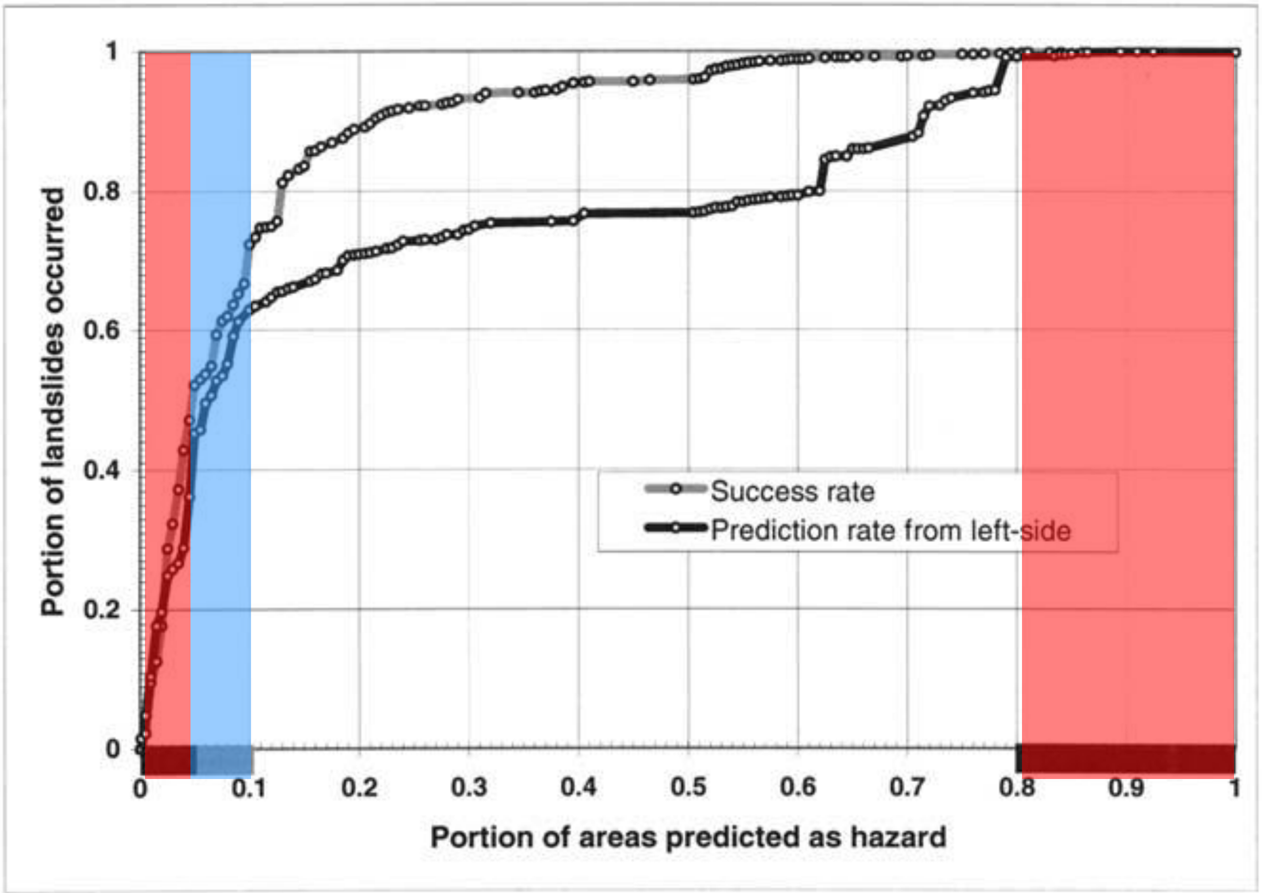


Landslide hazard prediction pattern in the right sub-area obtained by the likelihood ratio method using the data from the left side sub-area in the Northridge study area, California.

"Included 314 landslides"



Landslide hazard prediction pattern in the right sub-area obtained by the likelihood ratio method using the data from the right side sub-area in the Northridge study area, California.

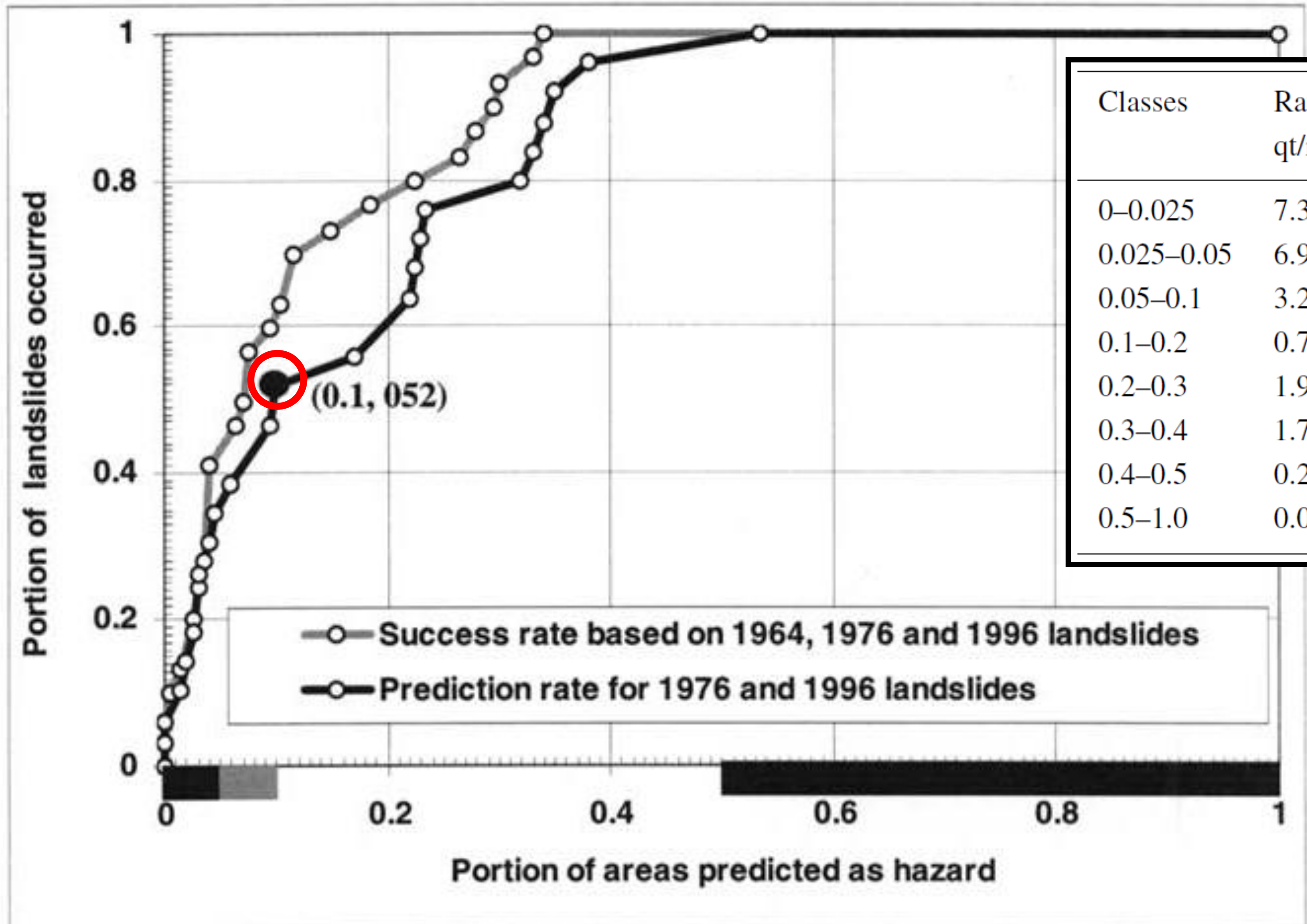


Prediction- and success-rate curves for the right-side sub-area.

Classes	Ratio of effectiveness: $qt/r\alpha$
0–0.025	9.96
0.025–0.05	8.16
0.05–0.075	3.32
0.075–0.1	3.72
0.1–0.2	0.8
0.2–0.3	0.35
0.3–0.4	0.23
0.4–0.5	0.01
0.5–0.6	0.25
0.6–0.7	0.85
0.7–0.8	1.15
0.8–1	0.035

Ratios of effectiveness for several selected prediction classes.

Prediction Rate and Success Rate



Classes	Ratio of effectiveness: qt/rα
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0.2–0.3	1.99
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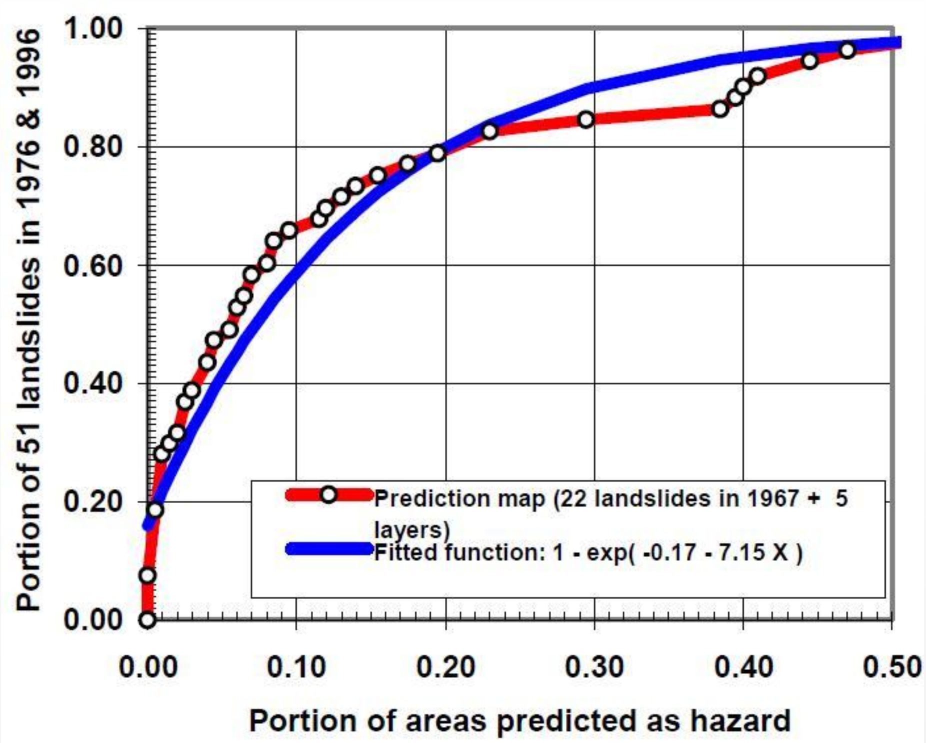
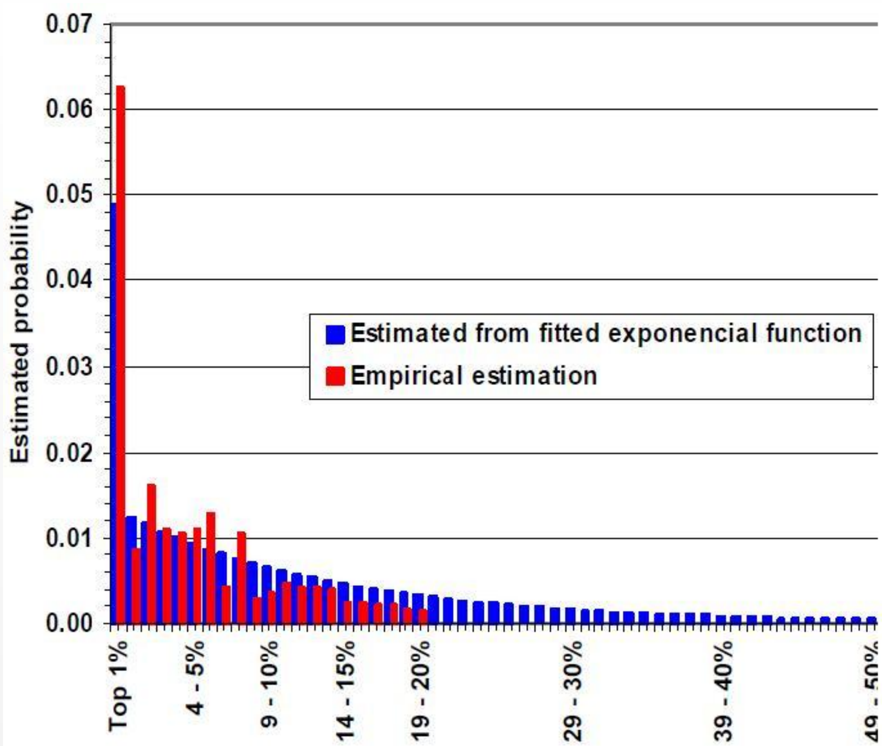
0.4–0.5	0.28
0.5–1.0	0.02

Prediction- and success-rate curves for the La Baie study area, Quebec.

Concluding Remarks

- This contribution has presented strategies for validating the results of models of hazard as functions of a multi-layered spatial database.
- The strategy proposed in this contribution wants to set up the terms to correctly apply quantitative models to generate, visualize and validate predictions by partitioning the database in time or in space.
- Ranking is the analytical technique for assessing and empirically comparing the results of the different predictions.





(a) Prediction rate curve for the prediction map shown in Figure 2. It was obtained by comparing the 1000 hazard classes generated for Figure 3 and the 51 landslides occurred in 1976 and 1996 as discussed in the text. The 20 pairs shown in the second column of Table 1 constitutes 2/5 th of red curve. The fitted function shown in (5.3) is shown as blue curve. (b) It shows, under the assumptions in (5.1), the estimated probabilities that a house of size 10m x 25m (250 m 2 2 or 10 pixels) in the corresponding 1% areas will be affected by a future landslides within the next 35 years using (5.2) and the prediction rate curves shown in (a). Obviously while the red histogram is based in empirical estimates, the blue histogram is based on the fitted prediction rate curve shown as blue curve in The corresponding table values are shown in the 3 rd 5 and 5 th columns in Table 1.