CHANGES meeting in Poland
Course on probabilistic risk assessment
22-23 September, Stryszawa near Krakow, Poland

LANDSLIDE SUSCEPTIBILITY AND HAZARD ASSESSMENT

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CHANGES Risk=HVA

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MARIE CURIE ACTIONS

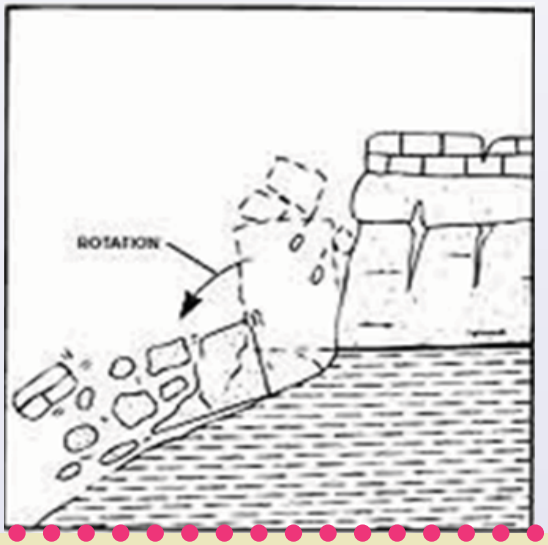
SEVENTH FRAMEWORK PROGRAMME

- DEFINITION OF THE PROBLEM
- LANDSLIDE SUSCEPTIBILITY
- PROBABILITY OF LANDSLIDE SIZE
- TEMPORAL PROBABILITY
- LANDSLIDE HAZARD
- FINAL REMARKS

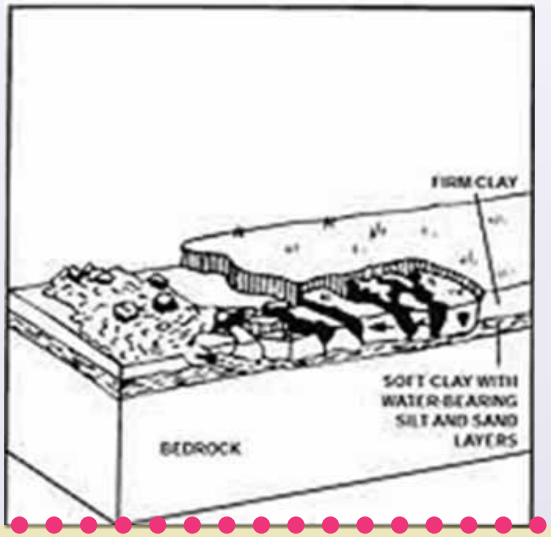
OUTLINE

ROCK FALL

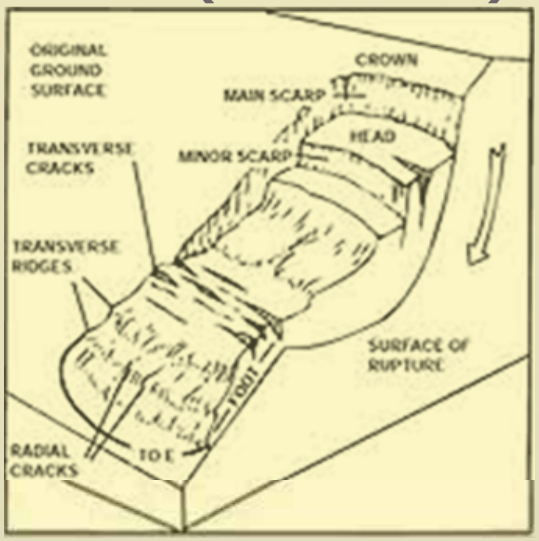
TOPPLE



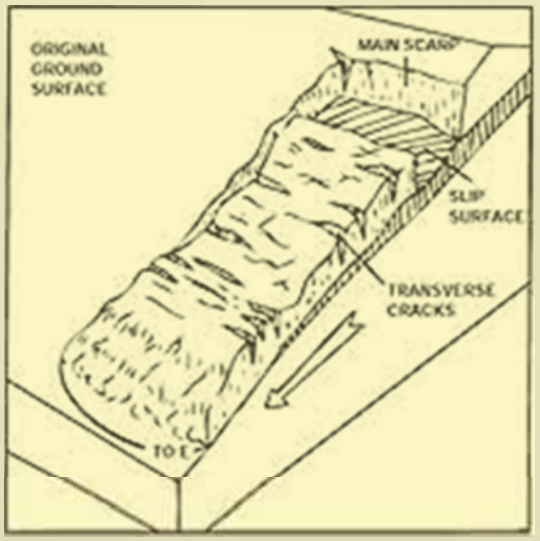
LATERAL SPREAD



SLIDE (Rotational)



SLIDE



(Varnes 1978, Cruden and Varnes, 1996)

DEFINITION AND CLASSIFICATION

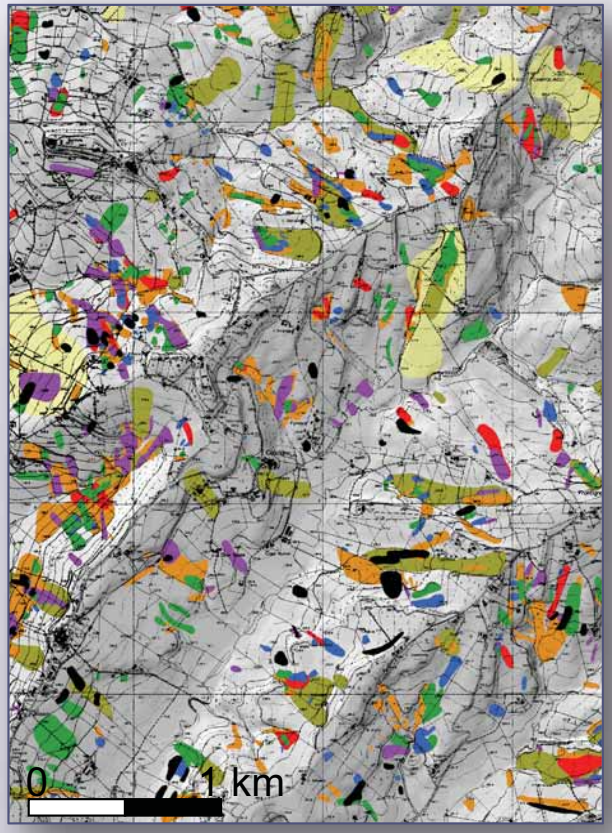
Engineering Geology

Predicting single landslides

La Conchita, California
Photo: Robert L. Schuster, USGS

Applied Geomorphology

Predicting multiple landslides



Inventory map for a portion of the Collazzone area, Umbria. CNR-IRPI

SINGLE vs. MULTIPLE LANDSLIDES

***Landslide hazard** is the probability of occurrence in a specified period and within a given area of a potentially damaging landslide of a given magnitude.*

The definition incorporates the concepts of location (**where?**), time (**when, or how frequently?**) and magnitude (**how large?**).

(Guzzetti et al. 1999, 2005)

LANDSLIDE HAZARD

$$H_L = P\,[A_L \geq a_L \text{ in a time interval } t, \text{ given } \{ \text{morphology, lithology, structure, land use, ... } \}.$$

$$H_L = P(A_L) \times P(N_L) \times S$$

- Probability of landslide **size**, a proxy for magnitude
- Probability of **temporal** occurrence of landslides
- Probability of **spatial** occurrence of landslides (landslide **susceptibility**)

LANDSLIDE HAZARD ASSESSMENT

Landslide susceptibility is the likelihood of a landslide occurring in an area on the basis of local terrain conditions. *(Brabb, 1984)*

It is the degree to which a terrain can be affected by slope movements, i.e., an estimate of "**where**" landslides are likely to occur.

Susceptibility does **NOT** consider the **temporal** probability of failure (i.e., when or how frequently landslides occur), nor the **magnitude** of the expected landslide (i.e., how large or destructive the failure will be).

LANDSLIDE SUSCEPTIBILITY

The spatial probability of landslides, also known as **susceptibility**, is the probability that a region will be affected by landslides given a set of terrain conditions

$$S = P\,[F \text{ is true, given } \{ \text{morphology, lithology, structure, land use, ... } \}]$$

$$S = P\,[F \mid v_1(r), v_2(r), \ldots, v_m(r)]$$

SPATIAL PROBABILITY

Several methods and techniques for evaluating landslide susceptibility have been proposed in the literature. Difference are mainly due to:

- THE GENERAL ASSUMPTIONS
- THE TYPE OF MAPPING UNIT SELECTED FOR THE INVESTIGATION
- THE TECHNIQUES, METHODS AND TOOLS USED FOR THE SUSCEPTIBILITY ASSESSMENT

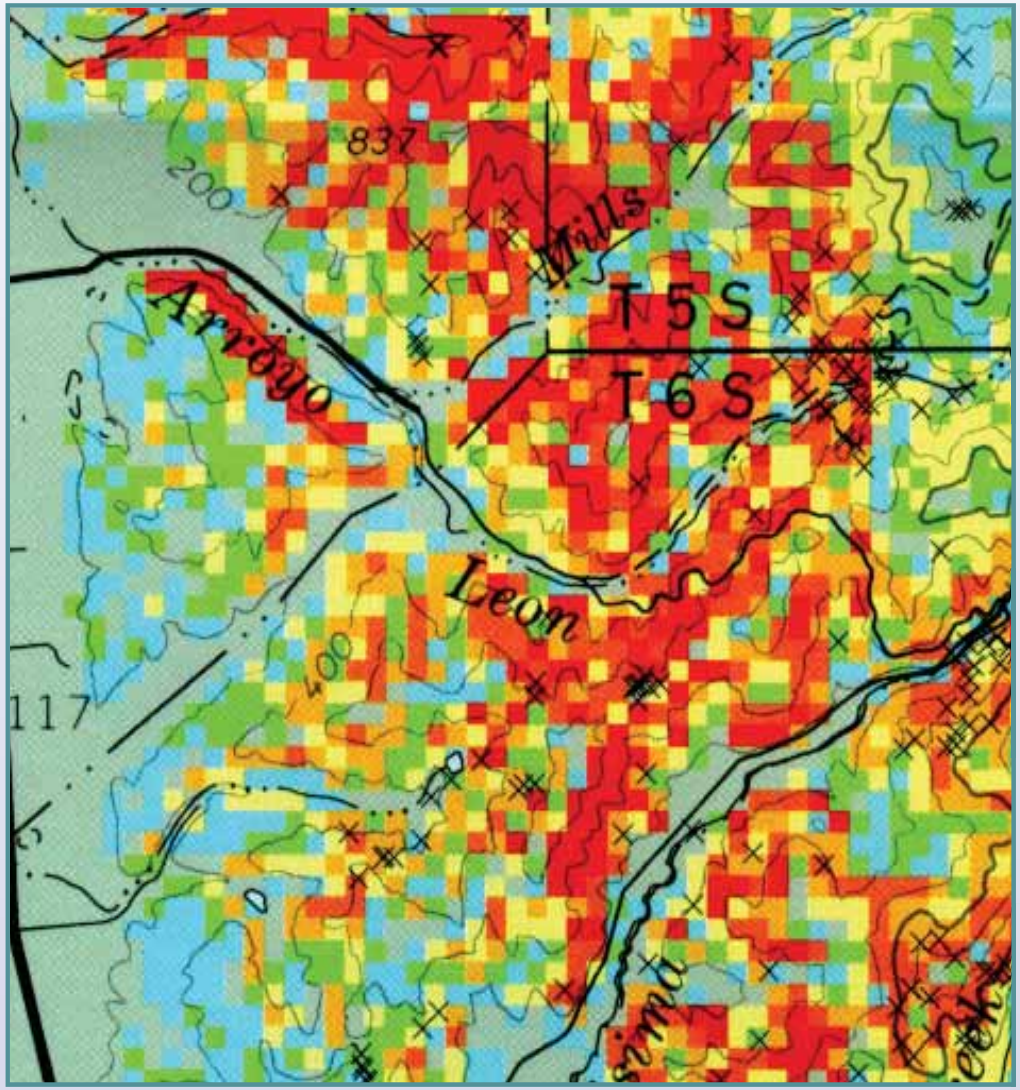
LANDSLIDE SUSCEPTIBILITY

A mapping unit is a portion of the land surface containing a set of ground conditions which differ from the adjacent units across definable boundaries

A domain that maximizes internal homogeneity and between units heterogeneity

- GRID CELL
- TERRAIN UNIT
- SLOPE UNIT
- UNIQUE CONDITION UNIT
- ADMINISTRATIVE BOUNDARY
- TOPOGRAPHIC UNIT

MAPPING UNITS



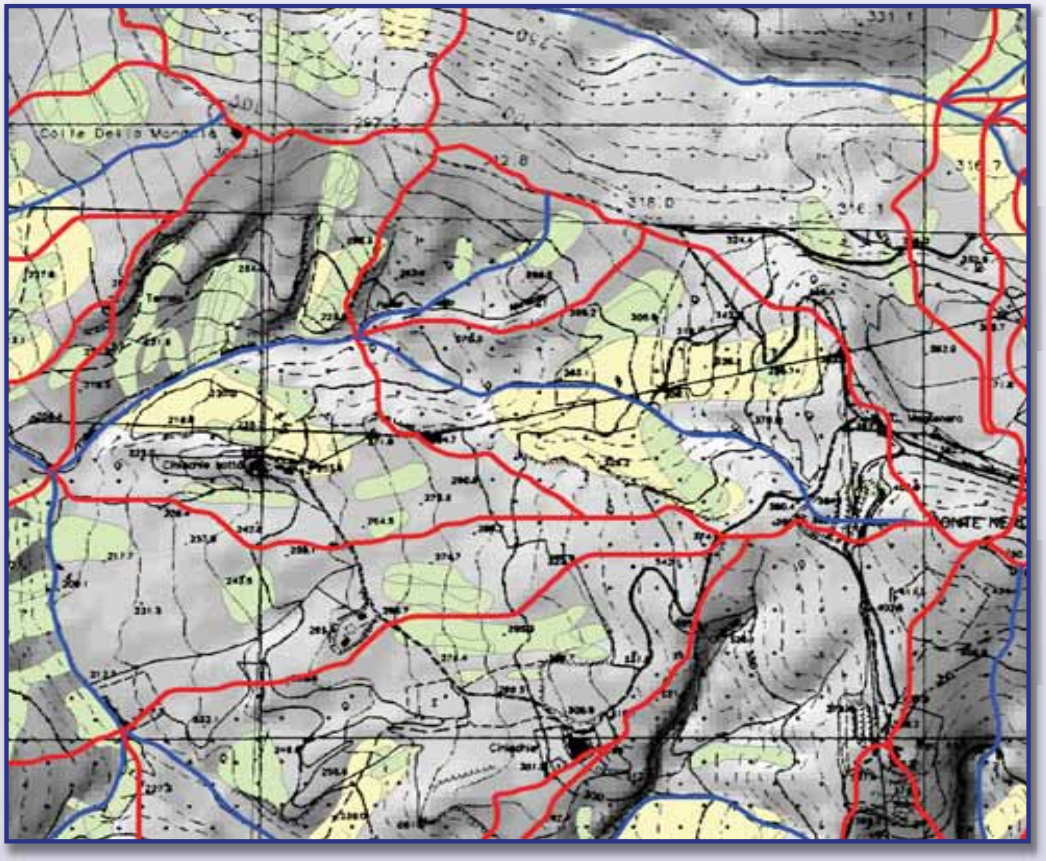
A grid-based debris flow map for the San Mateo County, California, Mark R.K., 1992

GRID CELL

- GRID-CELLS DEVIDE THE TERRITORY INTO REGULAR SQUARES OF PRE-DEFINED SIZE
- EACH GRID-CELL IS ASSIGNED A VALUE FOR EACH THEME
- PREFERRED BY RASTER-BASED GIS USERS

MAPPING UNITS

SLOPE UNITS

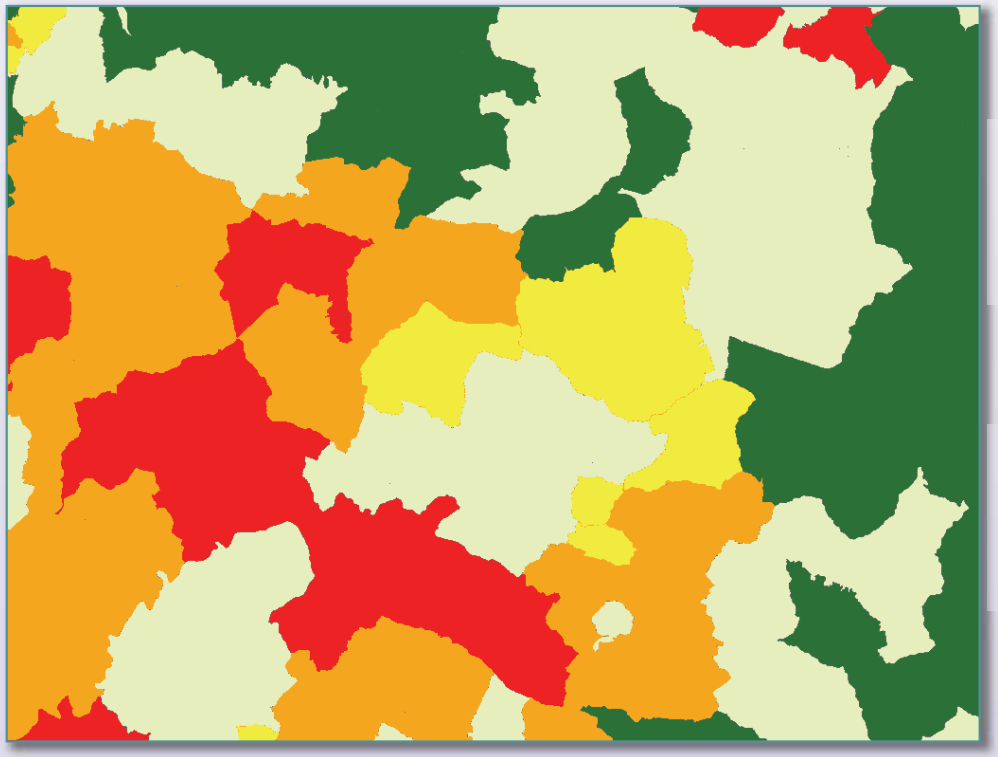


From: Carrara and others, 1991

- SLOPE-UNITS PARTITION THE TERRITORY INTO REGIONS BETWEEN DRAINAGE AND DIVIDE LINES
- AUTHOMATICALLY DERIVED FROM DTM
- BEAR A PHYSICAL RELATIONSHIP WITH SLOPES, WHERE MASS MOVEMENTS TAKE PLACE

MAPPING UNITS

ADMINISTRATIVE BOUNDARIES



Italian Municipality boundaries

ADMINISTRATIVE BOUNDARIES (REGIONS, PROVINCES, MUNICIPALITIES)

USED IN A SMALL SCALE EVALUATION

MAPPING UNITS

Methods can be **qualitative** if they portray the susceptibility zoning in descriptive terms; or **quantitative** if they produce numerical estimates.

Direct methods map landslide susceptibility, in the field, from the aerial photographs or from satellite images. (Most commonly it is associated with the production of a landslide inventory map).

Indirect methods are essentially stepwise. They require: **(i)** the recognition and mapping of landslides over a target region or a subset of it **(ii)** the identification and mapping of the physical factors which are directly or indirectly correlated with slope instability **(iii)** an estimate of the relative contribution of the instability factors in generating slope failures, **(iv)** the classification of the land surface into domains of different levels of susceptibility, and **(v)** the assessment of the model performance.

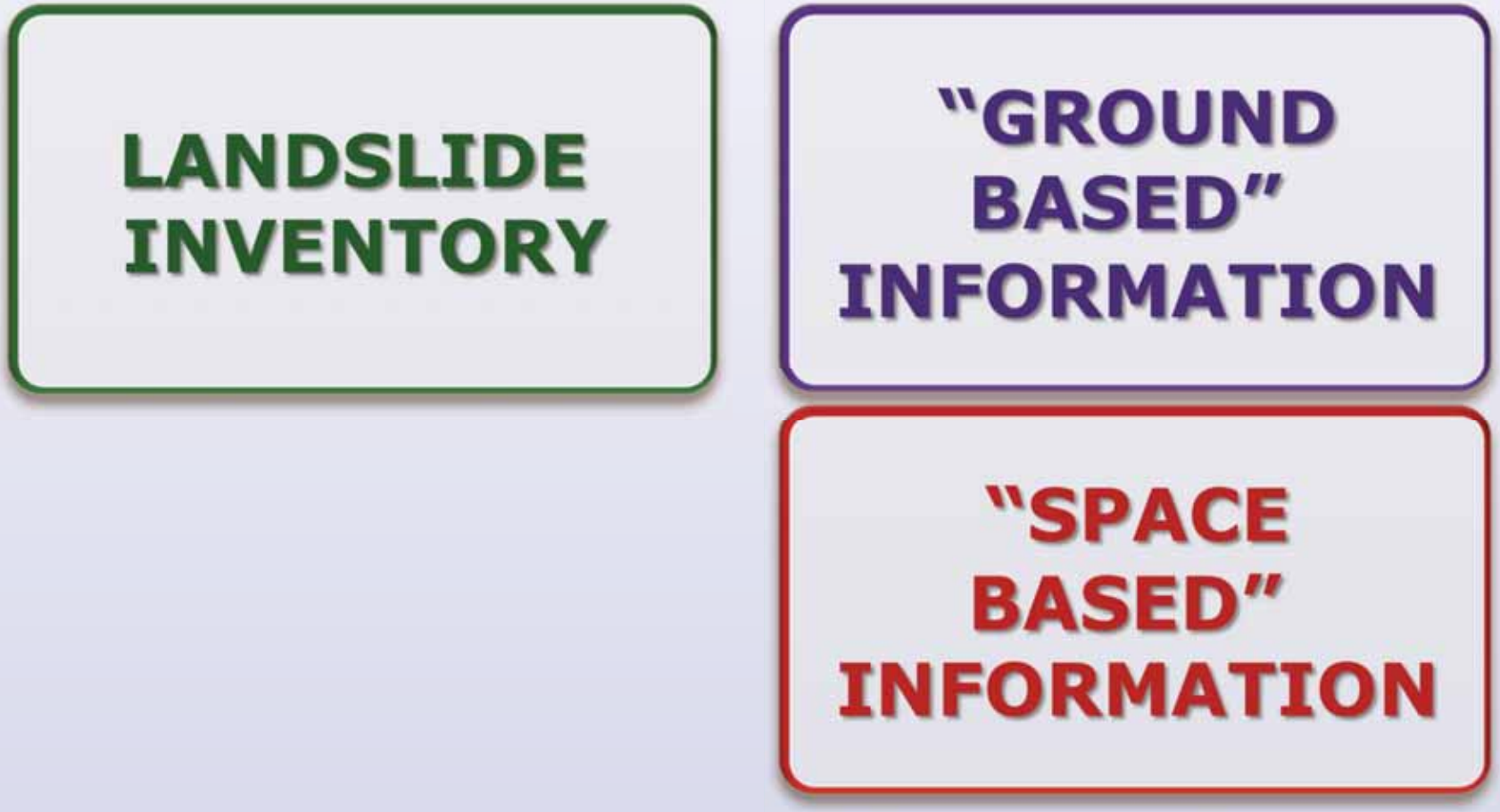
LANDSLIDE MODELLING

	Direct	Indirect	Qualitative	Quantitive
Geomorphological mapping	✓		✓	
Heuristic (index-based)		✓	✓	
Analysis of inventories		✓		✓
Statistical modelling		✓		✓
Process based (conceptual)		✓		✓

LANDSLIDE MODELLING

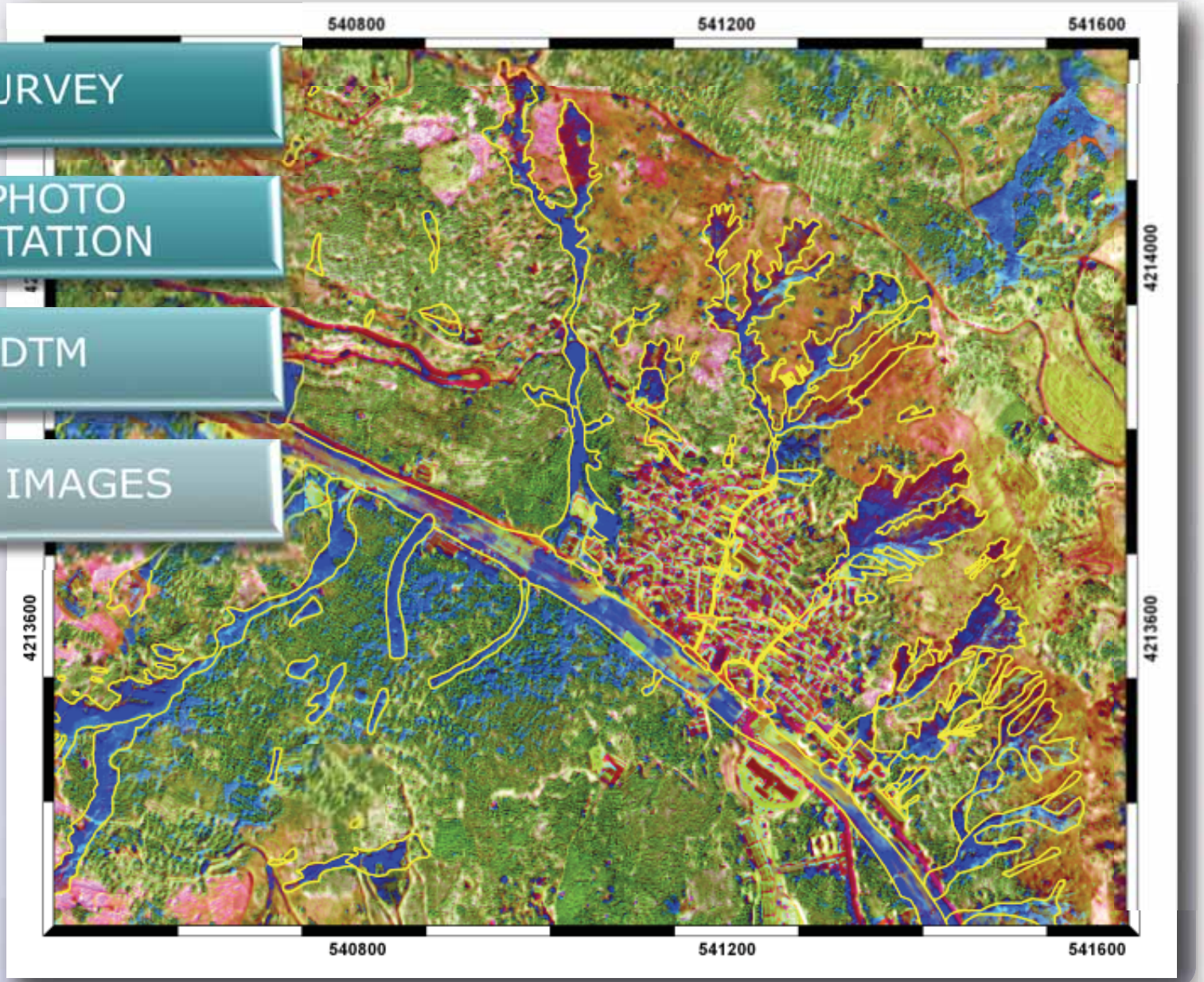
	Geomorphologic mapping	Analysis of inventories	Index based	Statistically based	Physically based
Grid cell		✓	✓	✓	✓
Terrain units	✓			✓	
Unique condition units			✓	✓	
Slope units				✓	
Topographic units					✓
Administrative boundary		✓	✓	✓	

TERRAIN UNITS vs MODELS

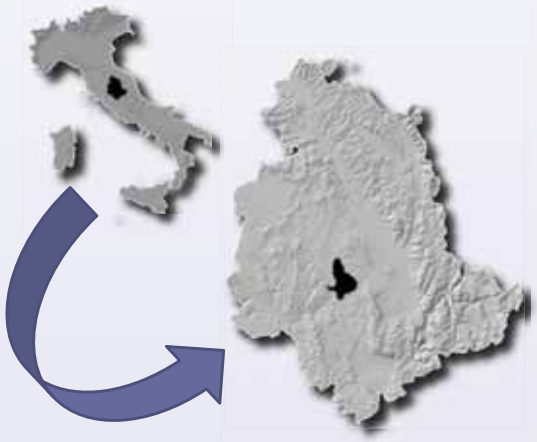


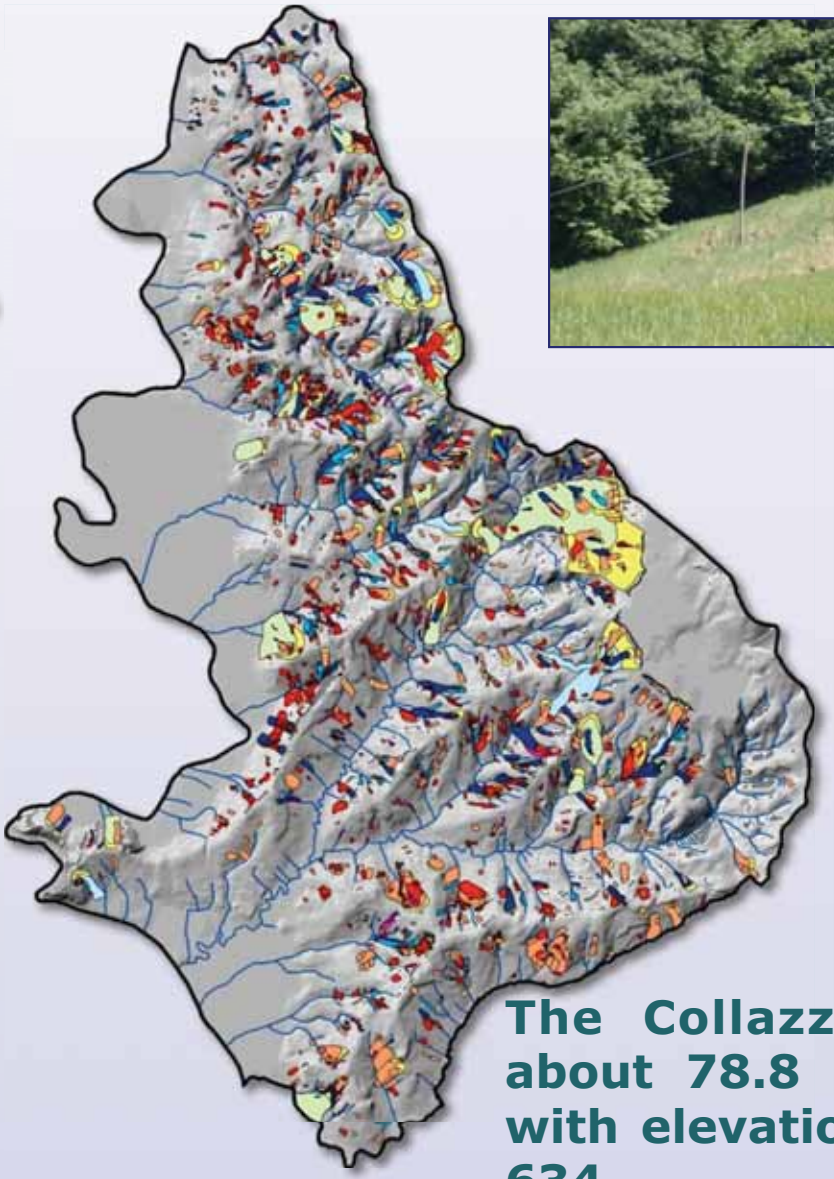
THEMATIC INFORMATION

- FIELD SURVEY
- AERIAL PHOTO INTERPRETATION
- LIDAR DTM
- SATELLITE IMAGES



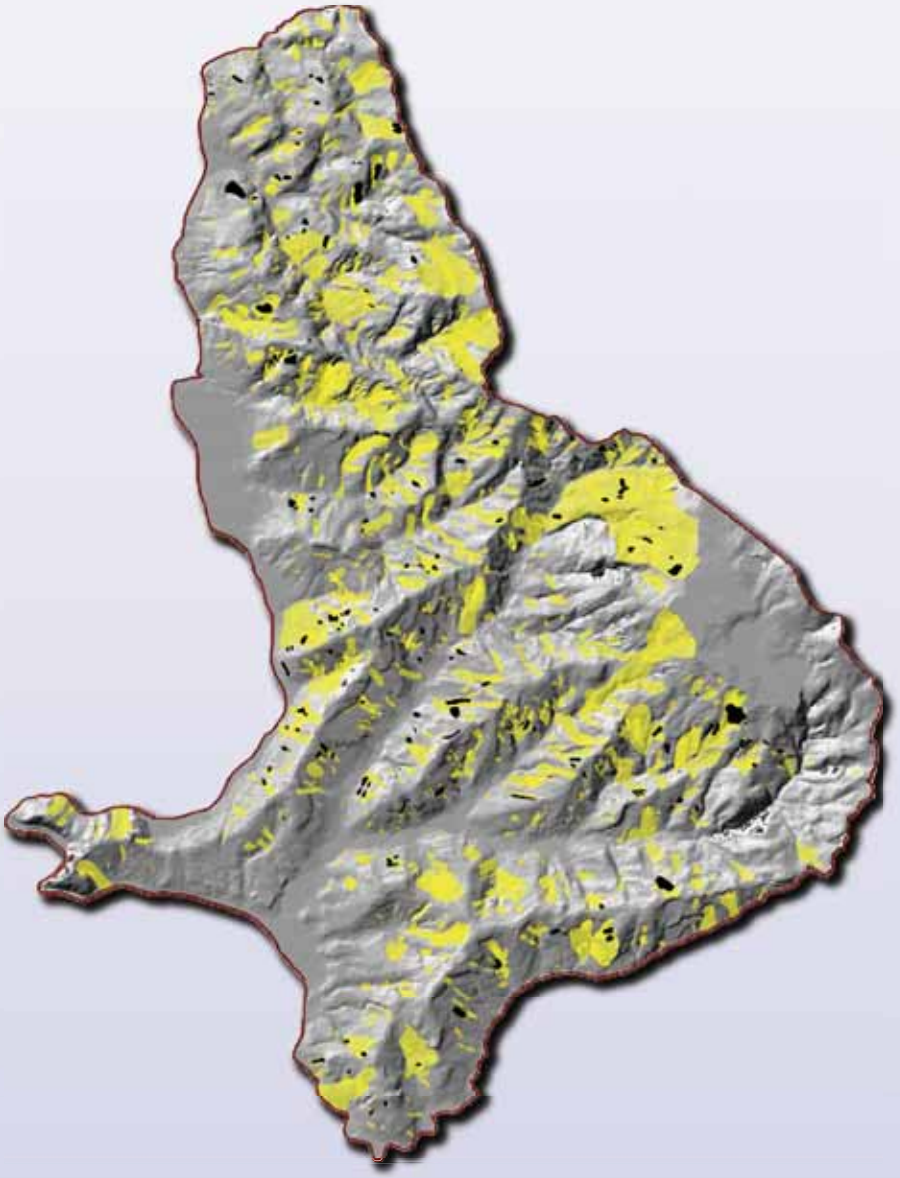
LANDSLIDE MAPPING





The Collazzone area extends for about 78.8 km^2 in central Umbria, with elevations ranging from 145 to 634.

THE COLLAZZONE AREA



1941

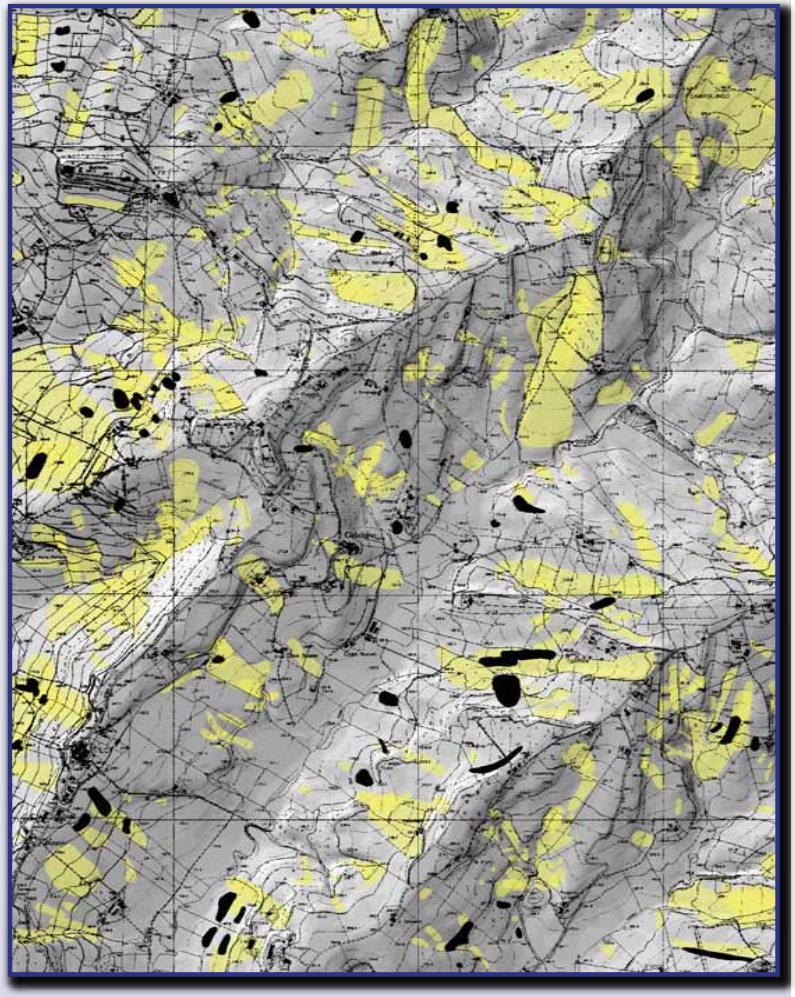
1954

1977

1985

1997

2004



MULTI-TEMPORAL INVENTORY