Geological, geometrical, and statistical analysis of the Ticino landslide inventory

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Image: https://visibleearth.nasa.gov/images/65659/western-europe

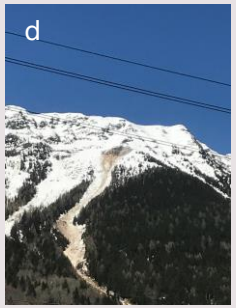
Introduction

- **Ticino**: south of Switzerland, Alpine topography (pre-Alpine vs Alpine), humid climate.
- Inventory: + 2000 mass movements [rockfalls (43 %), debris flows (28%), landslides (17%), and avalanches (12%)] complete starting in the year 2000.

Preonzo (Roscioro) 2012 (R-00001 and S-00019)

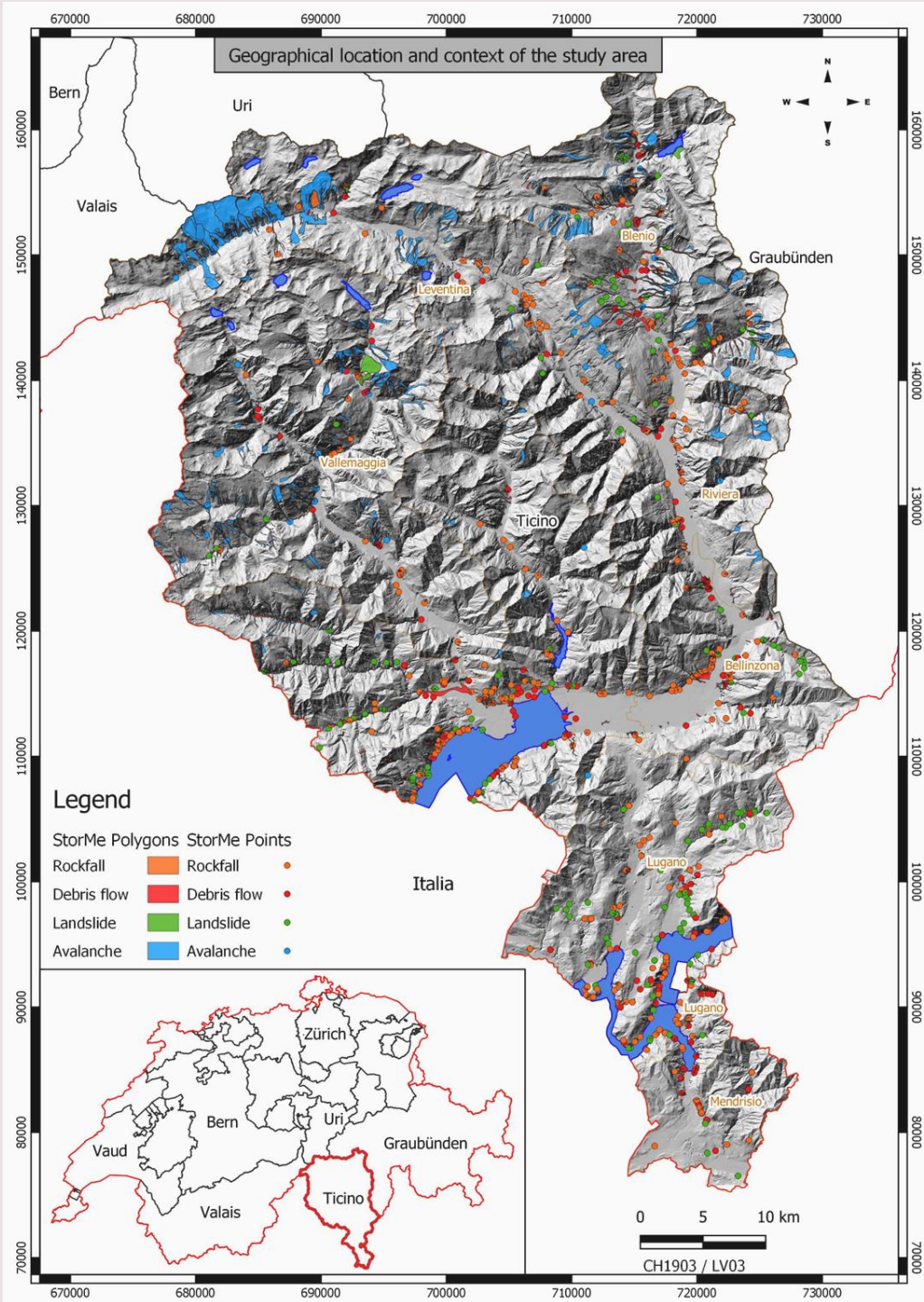
Pollegio, 2016-S-0006

Visletto, 2012-S-0033



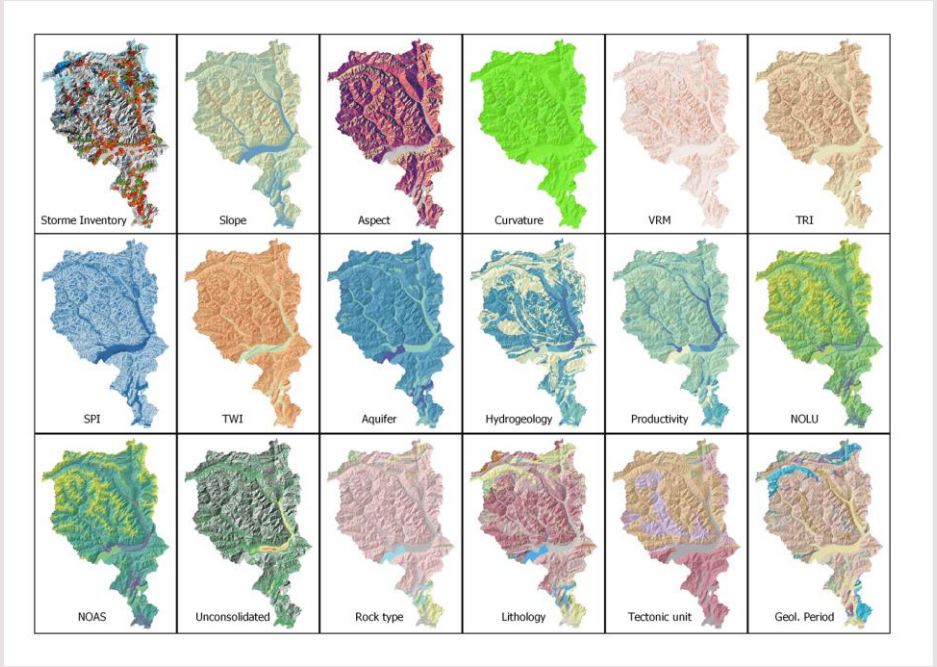
La Sacca, 2018-L-0053

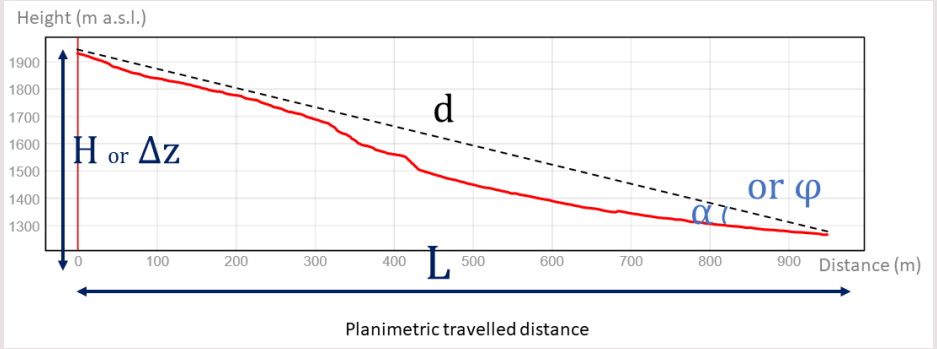
Preonzo, 2012-W-0010



Data collection and pre-processing

- Pre-existing data, for each event: ID, year, date, name, type, location, and district.
- Pre-processing (spatial data) : verification of geometries & calculation of perimeter, area, and bounding box dimensions.
- GIS: extraction of highest and lowest point.
- Additional data : topography (7 layers), hydrography (6), land use (4), and geology (8).
- Access Database: start and end coordinates, travelled distance, thickness volume + specific attributes by movement type (ex. number of blocs for rockfall).
- Estimation of the **angle of reach** (2 methods).

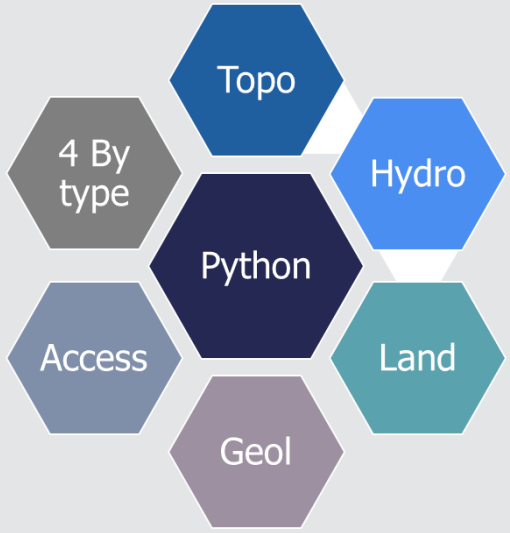




Methodology - Workflow

1. Distribution & selection of **controlling parameters** : MATLAB.
2. **Spatial distribution** of events: ArcGis Pro (Model Builder).
3. **Main analysis**: Python (Jupyter Notebooks).

Main analysis



Shapefile → Pandas dataframe → Pandas profiling → Indicative data

Descriptive Statistics	Correlation coefficients	Pairplots
• Mean • Mode • St. Deviation • Etc.	• Spearman • Pearson's	• Numerical variables • Log-log for non-null

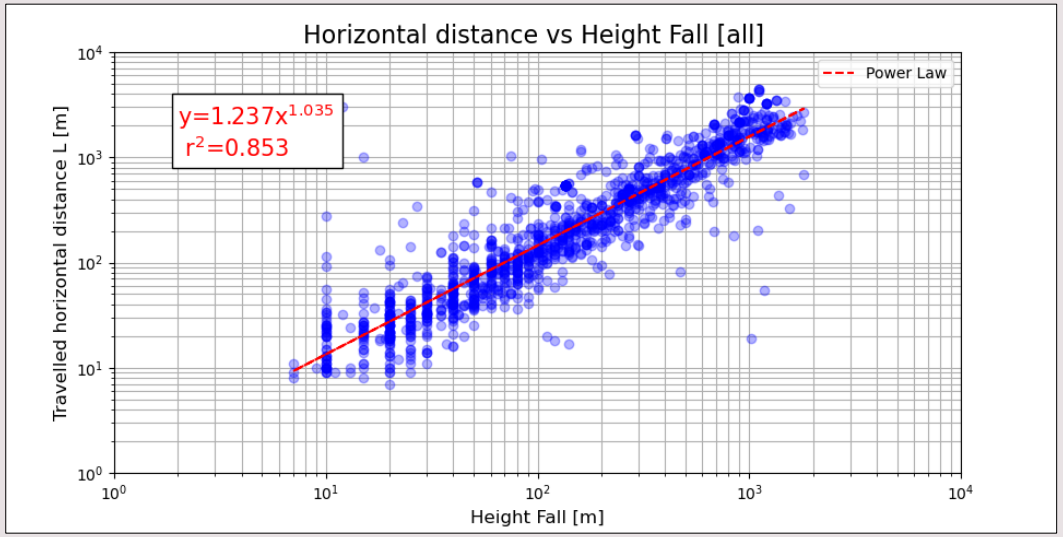
Variables of interest	Dropped values	Discarded variables	Specific relations
• Plots • Diagrams • Histograms • Pairplots	• Null • NaN • -Inf, Inf	• Self-correlation • Non representative • Non-specific behaviour	• Linear Regressions • Power Laws • Models

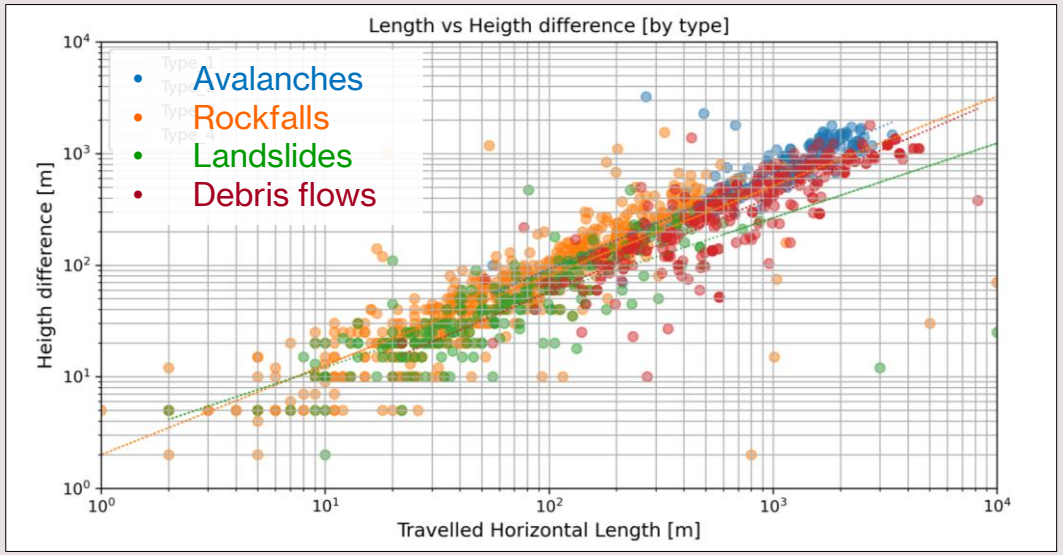
Results

- Initial **statistical analysis**:
  - Relevant controlling parameters: slope, aspect, terrain roughness index, topographic wetness index, and general lithology.
  - Important geometrical aspects: area, length, height difference, volume, and angle of reach.
- Most affected **districts**: Blenio (DF + A), Mendrisio (DF), Locarno (R) and Bellinzona (R).

- Aspect: snow avalanches mainly on S-SW slopes and debris flows on E-W slopes.
- Land use: majority of events on wooded areas.
- Area & perimeter : rockfalls < landslides < avalanches < debris flows.
- Calculation of the angle of reach with database coordinates.
- **Angle of reach** by movement type: debris flows 22/26º, avalanches 29/34º, landslides 34º/35° , and rockfalls 41º/45°.

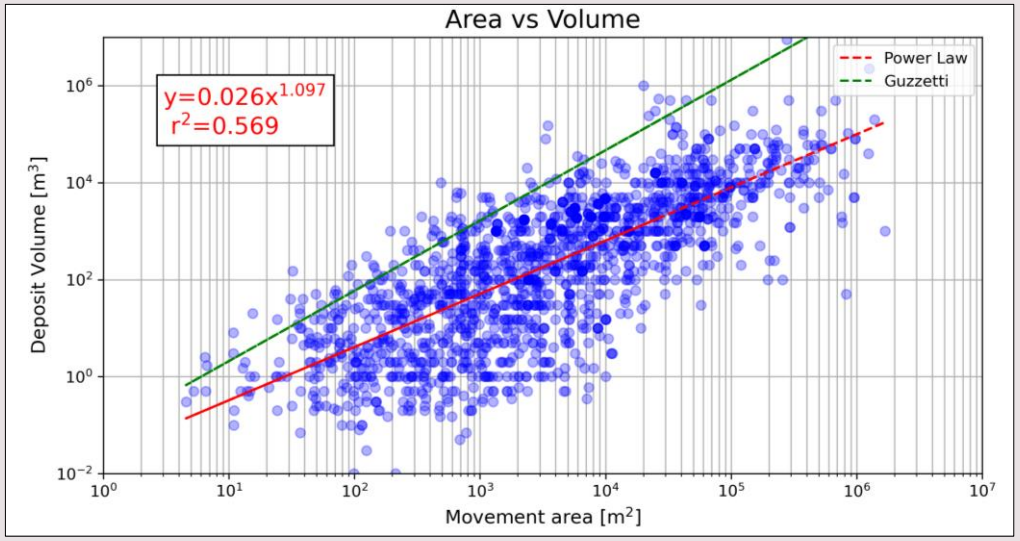
Length vs height fall (Corominas, 1996)

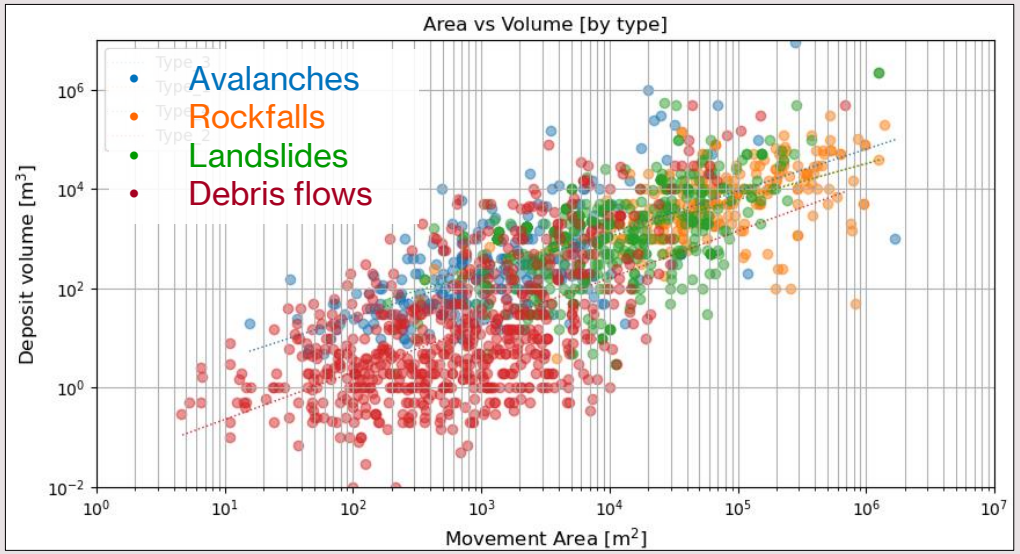




	A	B	Equation	R²
Avalanches	1.758	0.859	H = 1.758 *L0.859	0.790
Rockfalls	1.999	0.803	H = 1.999 *L0.803	0.684
Landslides	2.606	0.669	H = 2.606*L0.669	0.613
Debris Flows	1.109	0.857	H = 1.109 *L0.857	0.719

Area vs volume (Guzzetti et al., 2009)





	A	B	Equation	R²
Avalanches	2.483	0.685	V = 2.483*A^0.685	0.331
Rockfalls	0.026	0.947	V = 0.026 *A^0.947	0.326
Landslides	1.884	0.846	V = 1.884 *A^0.846	0.409
Debris Flows	1.336	0.948	V = 1.336 *A^0.948	0.325

Conclusions

- Large number of **events**, even after separation and elimination: rockfalls (982), debris flows (418), landslides (395), and avalanches (268) → representative.
- Large number of **variables** selected initially (33), narrowed down to the most relevant controlling parameters (5) and geometrical aspects (5).
- Observable differences depending on **movement type** (geometrical parameters), as well as **tectonic context** (sub-alpine vs alpine).
- Importance of **volume estimation** for the inventory and characterization of movements.
- Comparison of 2 methods for batch calculations of the **angle of reach** : most reliable method is using Access database start and end coordinates.

Uncertainties: large study area (zone), large variability in the data, bias in the merging of different data types, bias in some results (ex. mean of the angle of reach for rockfalls).

Thank you for your attention !

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Image: M. Jaboyedoff. 2021

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