A DATA-DRIVEN METHOD FOR ASSESSING THE PROBABILITY FOR TERRAIN GRID CELLS OF INITIATING ROCKFALLS ON A LARGE AREA

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THE PROBLEM

A common requirement for rockfall susceptibility approaches is the need to locate the potential point locations of source areas.

Challenging for large areas (i.e. national scale)

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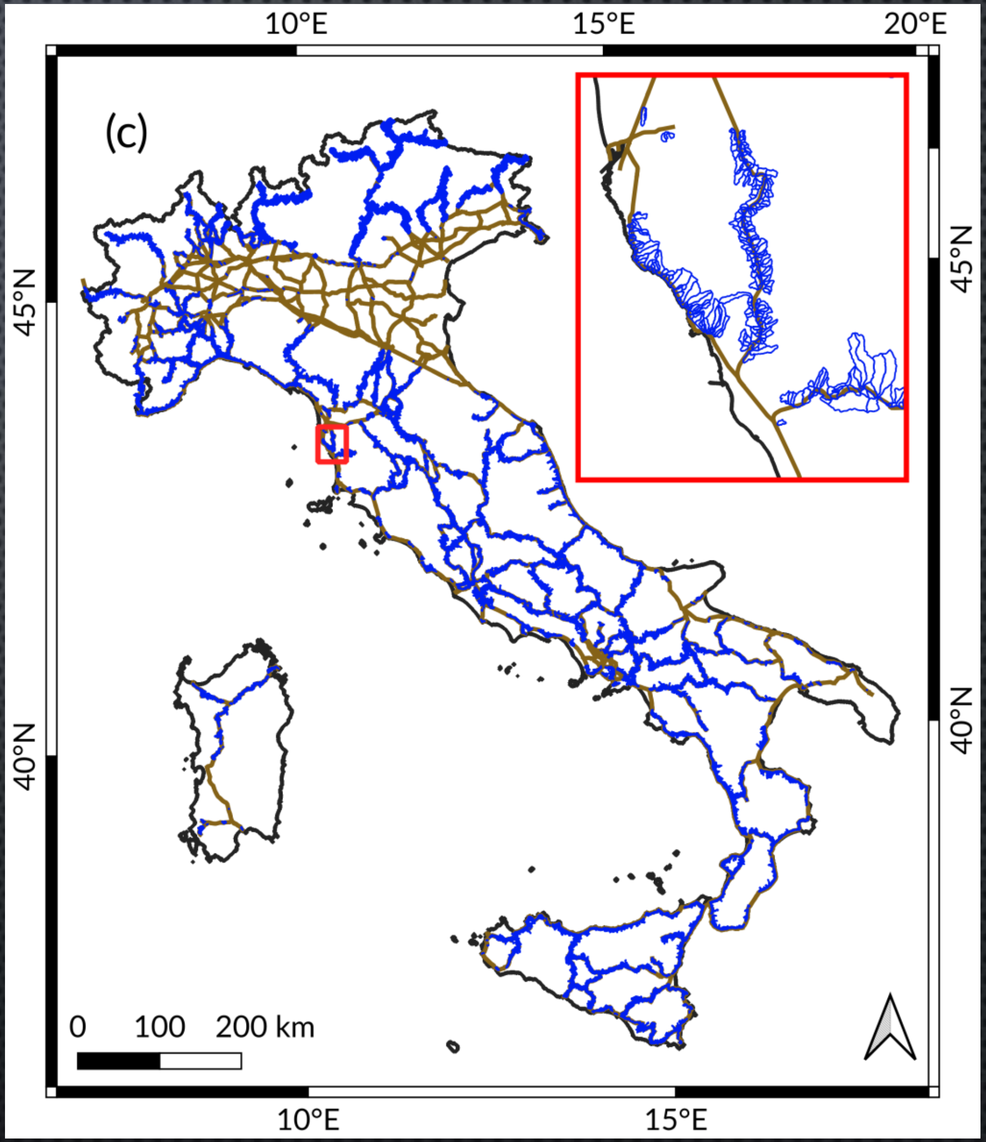
STUDY AREA

Railway track depicted in brown, over 17,000 km

Slope units intersecting the buffer are in blue

The selected slope units are 32,200, out of the over 330,000 polygons in Italy, for a planimetric area of 25,400 km^2

We used 10 m-cell size grid TIN ITALY



THE WORKFLOW

Selection of the set of slope units intersecting the railway

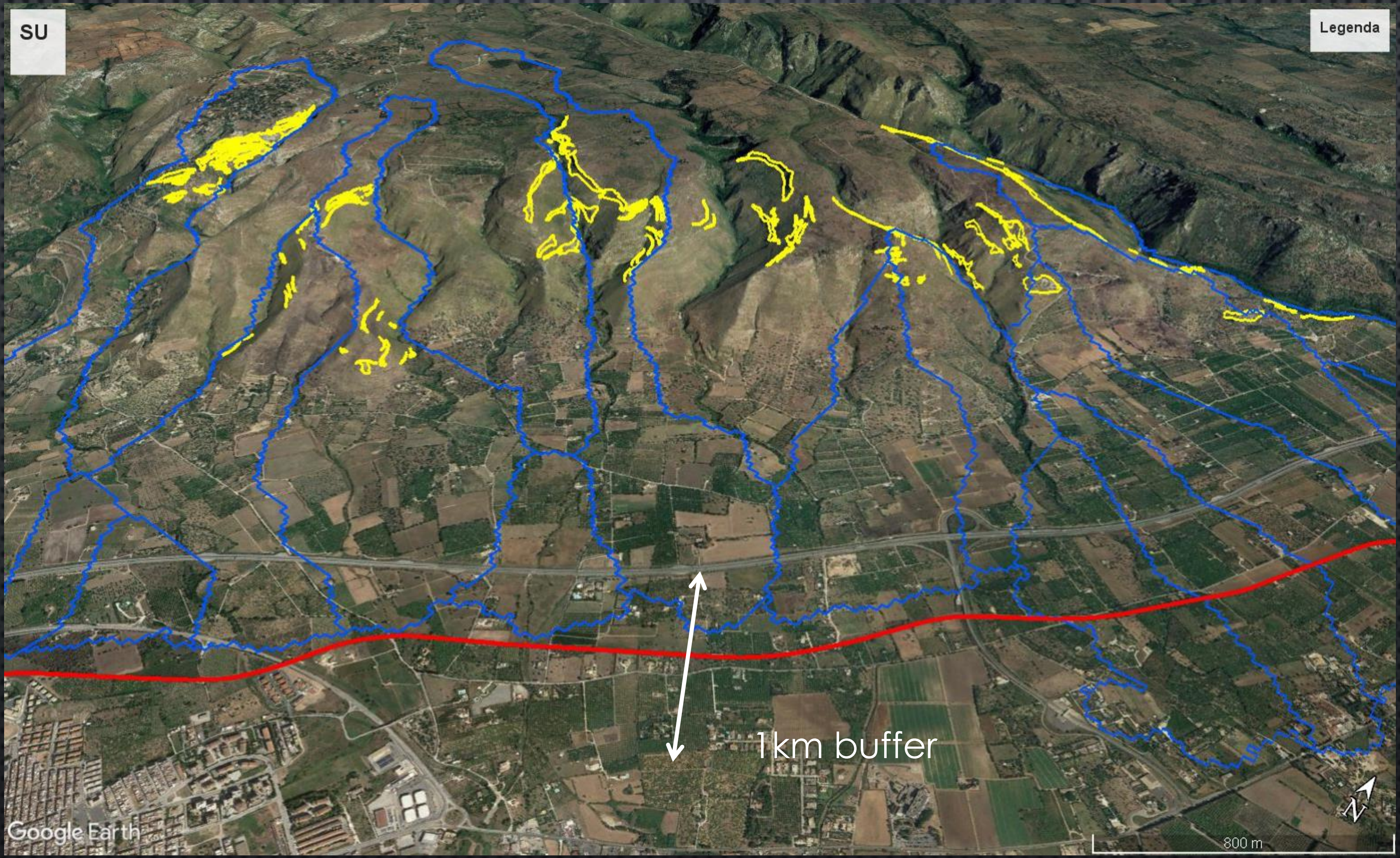
↓

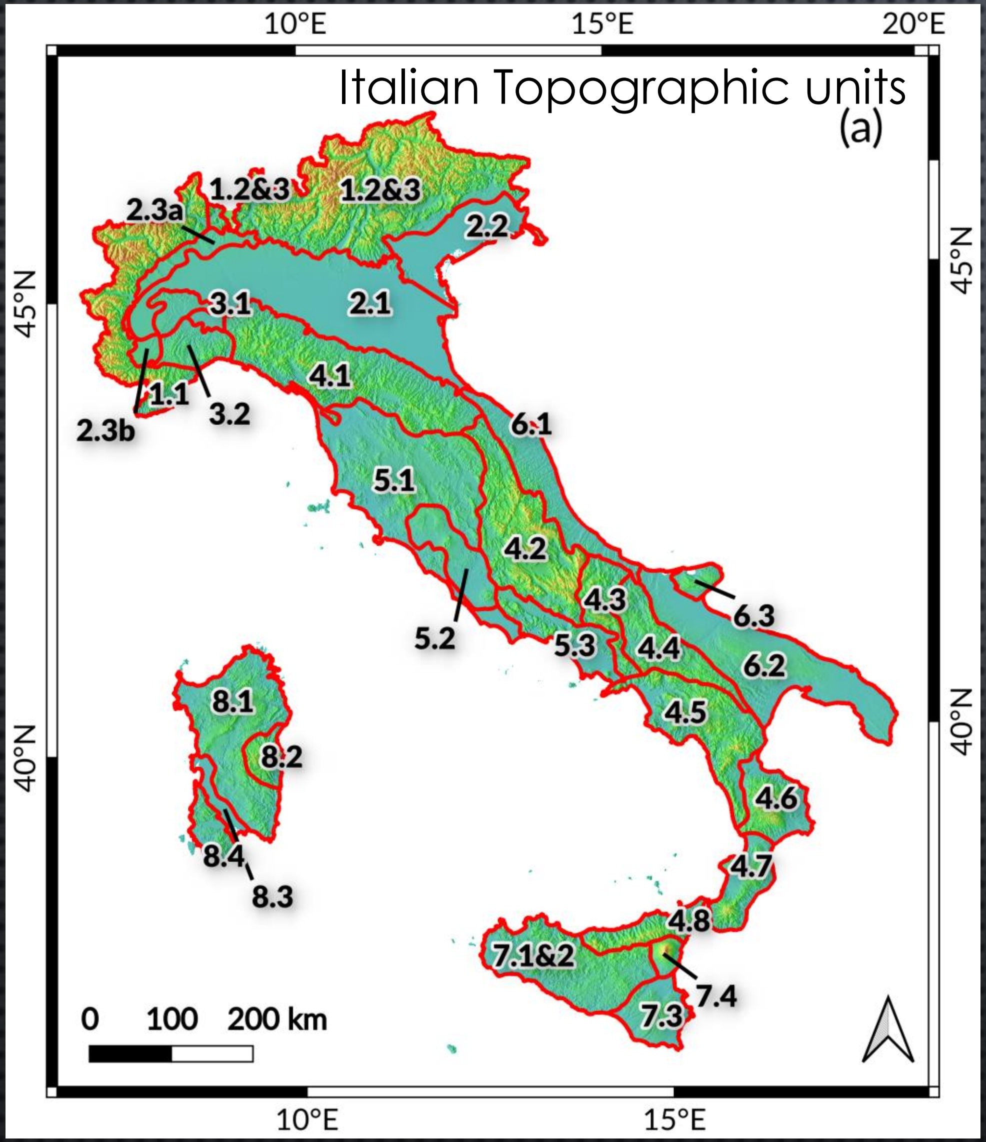
Expert mapping of a subset rockfall source areas within representative SUs in each Topographic Unit

↓

Statistical procedure to generalize the source areas to different grid cells

-> **Map of source areas**

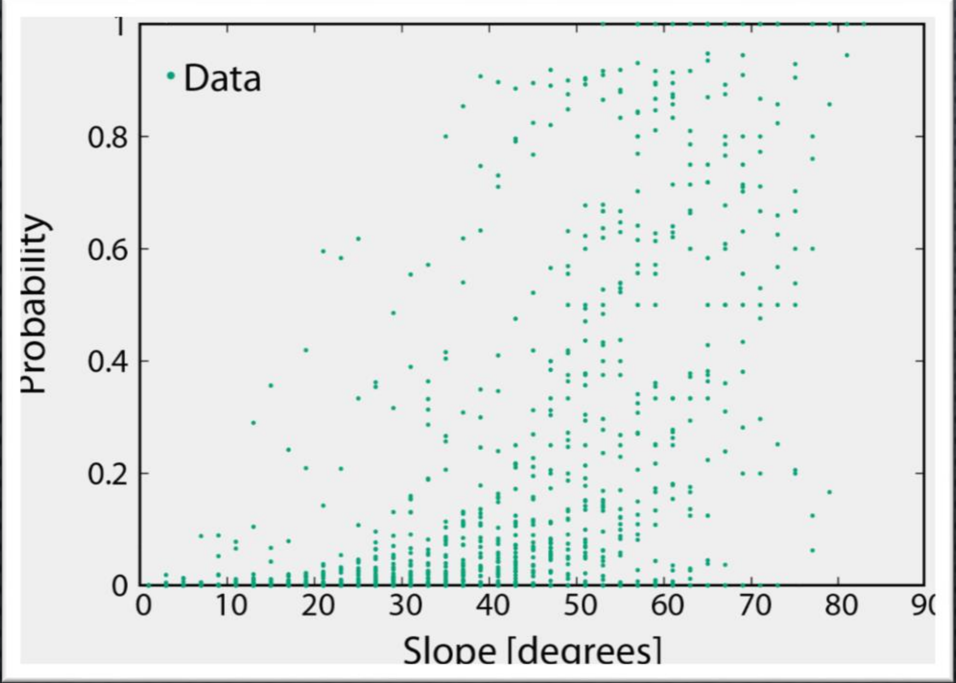

SU
Legenda
1km buffer
800 m
Google Earth



Here, we introduce a method to **assign a probability to any grid cell of representing a source**. Thus, we end up with a probabilistic map.

Expert–mapped sources were used to **infer** the **probability** of **any grid cell to be a source**

We calculated histograms of the distribution of values of **slope angle** in the cells within the mapped polygons, and within the whole slope unit.
In each bin of 2° width we took the ratio of the two histograms:

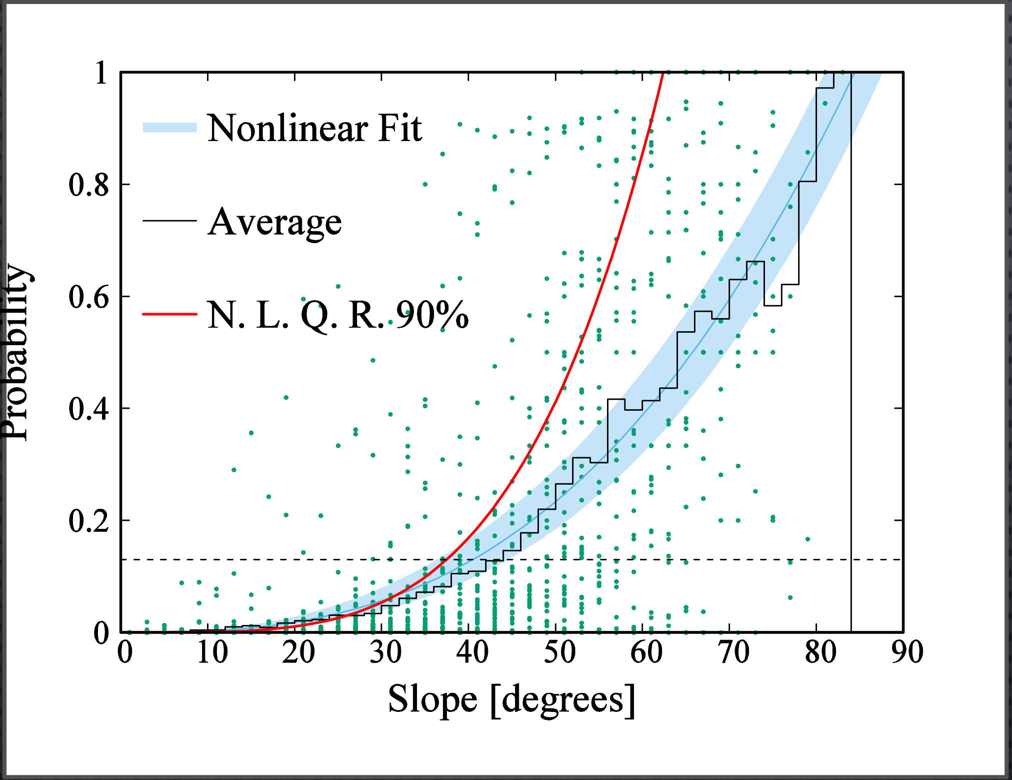


$$0 \leq \frac{\textbf{values of slope within the sources}}{\textbf{values slope within the whole slope units}} \leq 1$$

We have a **probability point (green dots)** for each 2° slope bin.

Procedure repeated for all of the sampled SUs in the given topographic unit.

We used the values of the histogram ratios (green points) to **build a model** P for the probability of a grid cell to be a source, as a function of slope *s* -> P(s)



The **black histogram** is the simple **average**, in each slope bin, of the observed probability values.

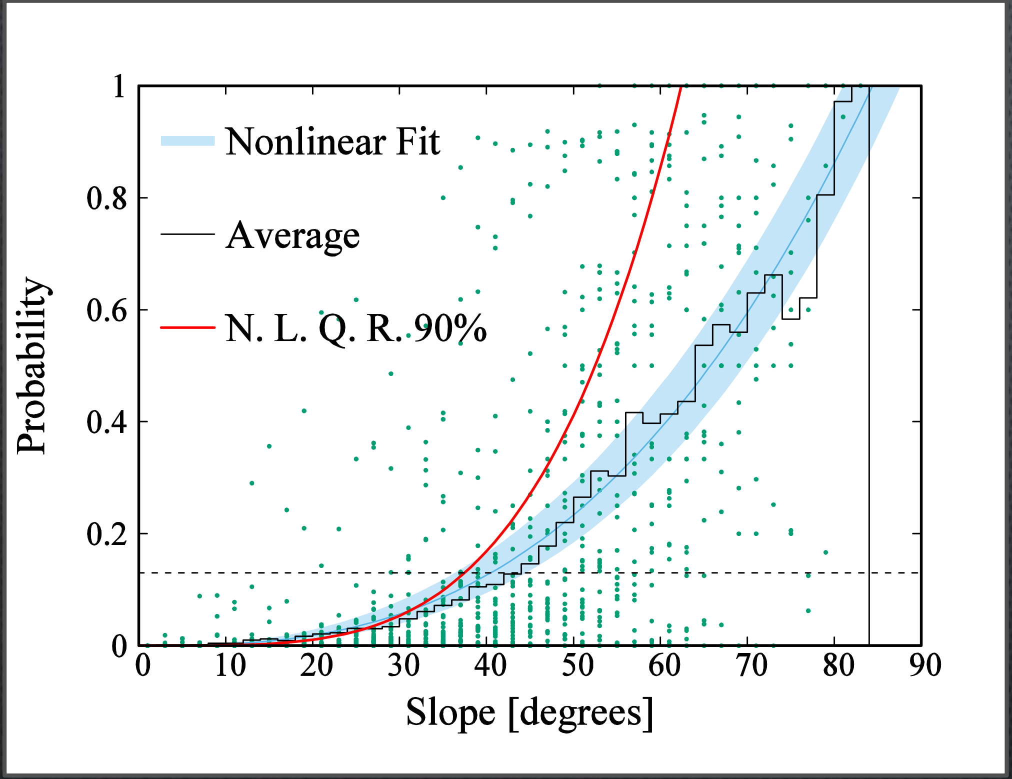
The **blue curve** is a **non—linear fit** of the values estimated from observed data, with a function of the following form:

$$P_{FIT}(s) = a\left(\frac{s}{90}\right)^{b}$$

The **red curve** is a **non—linear** quantile regression with the **90th percentile**, with a function containing a single parameter, c:

$$P_{FIT}(s) = c\left(\frac{s}{90}\right)^{4}$$

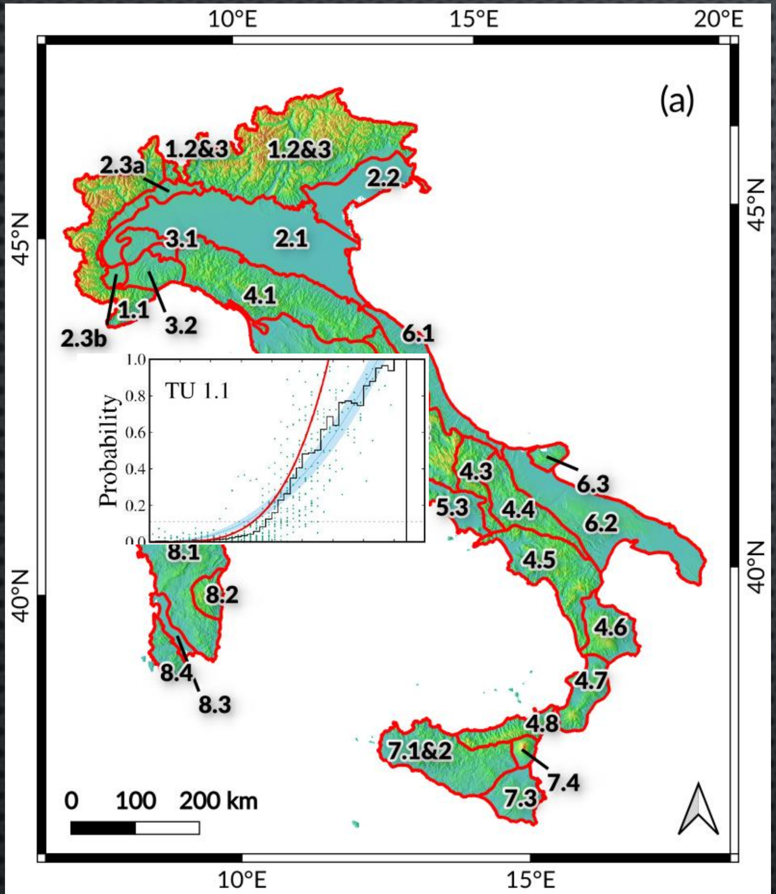
$$P_{FIT} = c\left(\frac{s}{90}\right)^4$$



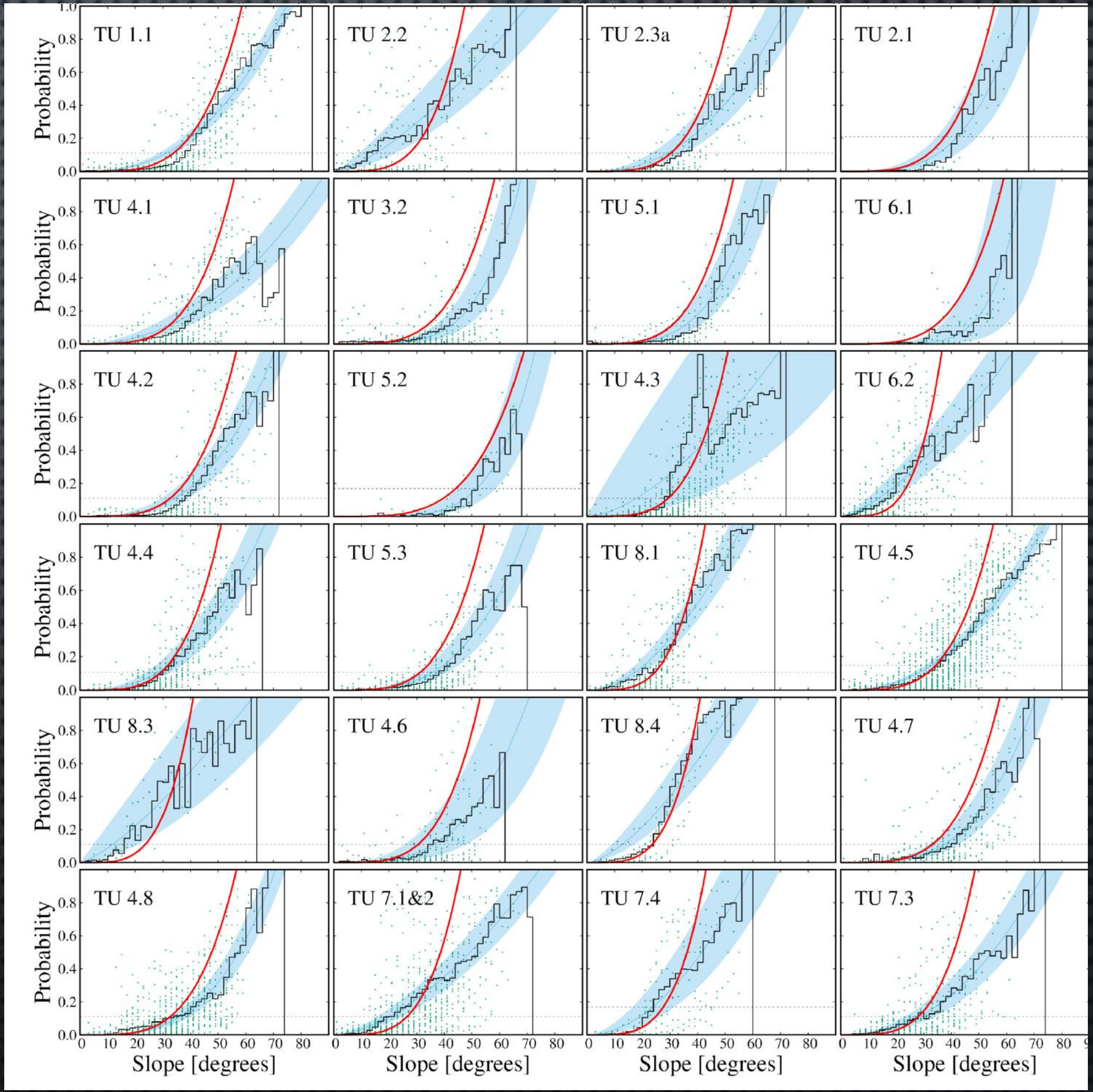
We decided to use the method of **quantile regression**, to assign the probability of a grid cell to represent a source area.

We believe that it **maximizes the information extracted from observed data**.

Moreover, we used a function with **a fixed exponent** (the 4th power of S/90) because using **a parametric exponent** the resulting curves **systematically underestimated the probability** of source presence for **large** values of **slope.**

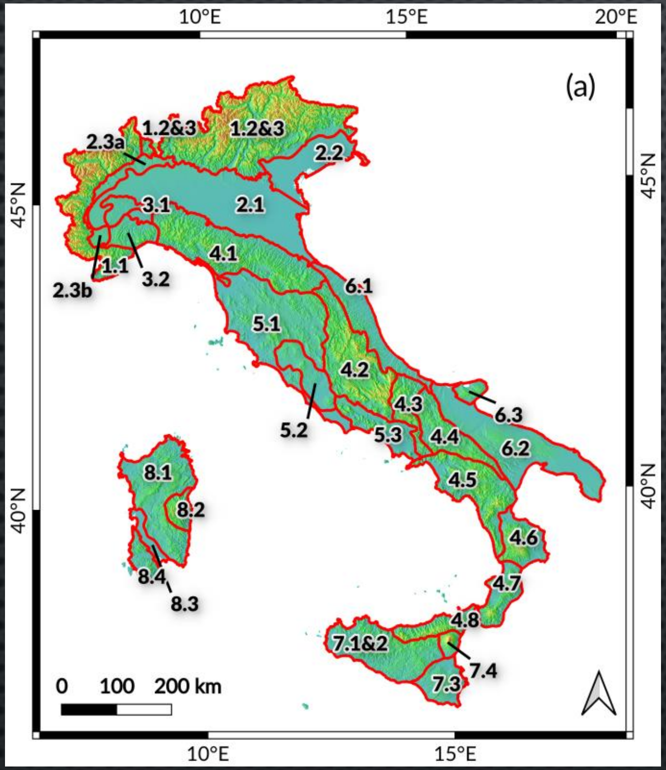


10°E
15°E
20°E
45°N
40°N
(a)
1.2&3
1.2&3
2.3a
2.2
2.1
3.1
4.1
1.1
3.2
2.3b
6.1
TU 1.1
Probability
4.3
6.3
5.3
4.4
6.2
8.1
4.5
8.2
4.6
8.4
8.3
4.7
4.8
7.1&2
7.4
7.3
0 100 200 km



TU 1.1
TU 2.2
TU 2.3a
TU 2.1
TU 4.1
TU 3.2
TU 5.1
TU 6.1
TU 4.2
TU 5.2
TU 4.3
TU 6.2
TU 4.4
TU 5.3
TU 8.1
TU 4.5
TU 8.3
TU 4.6
TU 8.4
TU 4.7
TU 4.8
TU 7.1&2
TU 7.4
TU 7.3
Probability
Slope [degrees]

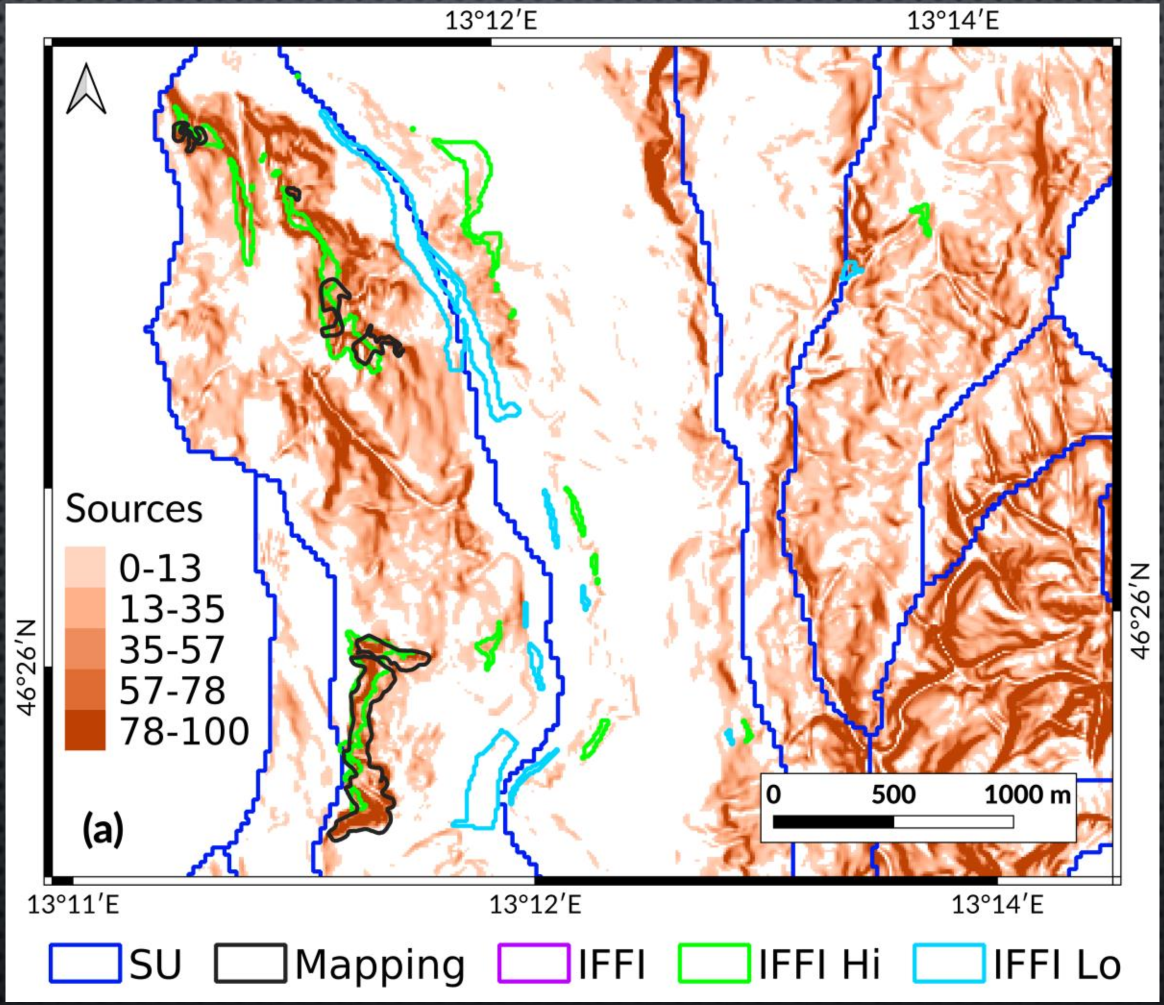
QUANTITATIVE COMPARISON



Evaluation of the Agreement HR=TP=(TP+FN)

Section ID	Total Area [km^2]	SU Area [km^2]	Mapped Polygons (#)	Mapped Area [km^2]	HR (Mapped) (Total)	HR (Mapped) (P > 80%)
1.1	16,274	1590	152	3.2	77%	13%
1.2&1.3	35,735	2620	78	2.2	80%	19%
2.1	32,702	373	11	0.039	80%	27%
2.2	9426	164	38	0.58	11%	6%
2.3a	3103	458	58	0.34	75%	16%
2.3b	1298	88	2	0.001	–	–
3.1	2322	332	39	0.027	16%	0%
3.2	3991	1778	225	0.84	51%	4%
4.1	22,393	2067	151	0.84	78%	7%
4.2	16,835	1894	105	1.5	79%	9%
4.3	4920	457	89	1.9	77%	13%
4.4	8097	1585	102	1.6	75%	14%
4.5	12,890	1379	200	7.2	79%	18%
4.6	6203	383	62	0.34	50%	3%
4.7	5337	598	70	0.57	59%	9%
4.8	4262	511	127	1.6	48%	3%
5.1	25,346	2086	80	0.19	58%	12%
5.2	6136	972	11	0.013	79%	5%
5.3	6375	859	81	0.081	62%	4%
6.1	9023	930	46	0.035	78%	10%
6.2	20,236	706	107	1.2	44%	11%
6.3	1731	–	0	–	–	–
7.1&7.2	14,285	2195	121	3.5	56%	12%
7.3	5321	691	561	0.97	46%	9%
7.4	1499	210	31	0.37	80%	28%
8.1	16,404	428	80	1.4	63%	14%
8.2	258	–	–	–	–	–
8.3	1946	4	6	0.061	58%	21%
8.4	2844	42	11	0.66	76%	22%

QUANTITATIVE COMPARISON



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Rockfall susceptibility and network-ranked susceptibility along the Italian railway

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ABSTRACT

Rockfalls pose a substantial threat to ground transportation, due to their rapidity, destructive potential and high probability of occurrence on steep topographies, often found along roads and railway routes. Approaches for the assessment of rockfall susceptibility range from purely phenomenological methods and statistical methods, suitable for modeling large areas, to purely deterministic ones, usually easier to use in local analyses. A common requirement is the need to locate potential detachment points, often found uphill on cliffs, and the subsequent assessment of the runout areas of rockfalls stemming from such points.

Here, we apply a physically based model for the calculation of rockfall trajectories along the whole Italian railway network, within a corridor of total length of about 17,000 km and varying width. We propose a data-driven method for the location of rockfall source points based on expert mapping of potential source areas on sample representative locations. Using empirical distributions of gridded slope angle values in source areas mapped by experts, we derived probabilistic maps of rockfall sources in the proximity of the railway network, regardless of a particular trigger.

Source areas act as starting points of simulated trajectories within the three-dimensional model STONE. The program provides a pixel-by-pixel trajectory count, covering 24,500 km^2 and representing the largest homogeneous application of the model to date. We classified the raster map into a vector susceptibility map, analyzing the railway track as a collection of segments, for which we provide segment-wise rockfall susceptibility.

Eventually, we considered an equivalent graph representation of the network, which helps classifying the segments both on the basis of rockfall susceptibility and the role of each segment in the network, resulting in a network-ranked susceptibility. Both maps are useful for subsequent hazard assessment, and to prioritize safety improvements along the railway, at national scale.

1. Introduction

Rockfall susceptibility along a transportation corridor is a recurring

mobilization of individual blocks or rock masses at the local scale. The input to prepare a susceptibility map is less demanding, though it would still not be trivial to gather the required data homogeneously over a

Alvioli, M., Santangelo, M., Fiorucci, F., Cardinali, M., Marchesini, I., Reichenbach, P., Rossi, M., Guzzetti, F. and Peruccacci, S., 2021.

Rockfall susceptibility and network-ranked susceptibility along the Italian railway.

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https://doi.org/10.1016/j.enggeo.2021.106301

OTHER KEY PAPERS

Topographic Units

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Stone Software for rockfall simulation

- Guzzetti, F., Crosta, G., Detti, R., Agliardi, F., 2002. STONE: a computer program for the three-dimensional simulation of rock-falls. Comput. Geosci. 28, 1079–1093. https:// doi.org/10.1016/S0098-3004(02)00025-0.

Thank you for watching, listening and getting over the time difference

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