European Geoscience Union
General Assembly 2012

Vienna, Austria, 22-27 April 2012

Probabilistic rainfall thresholds for landslide occurrence using a Bayesian approach

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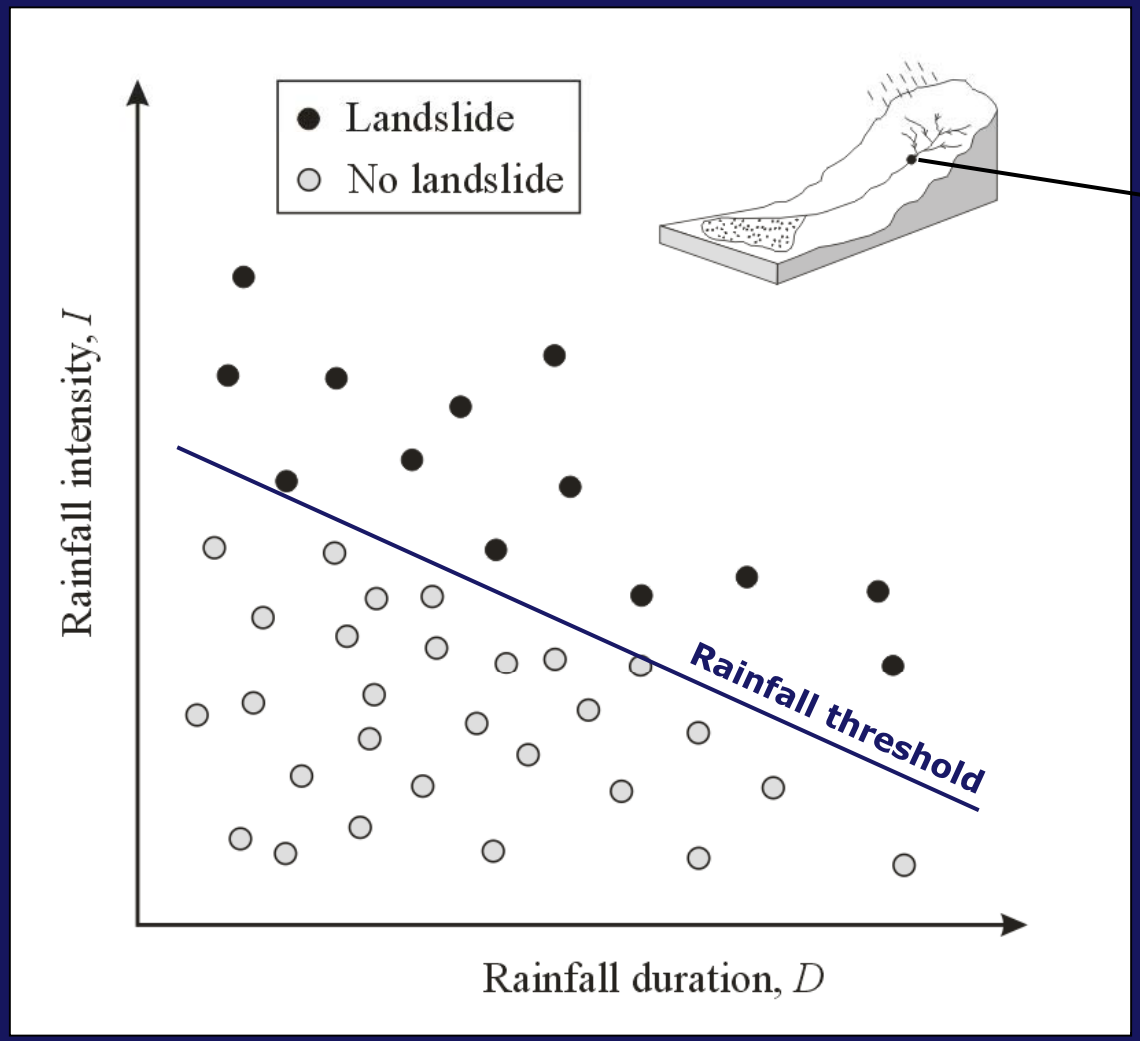
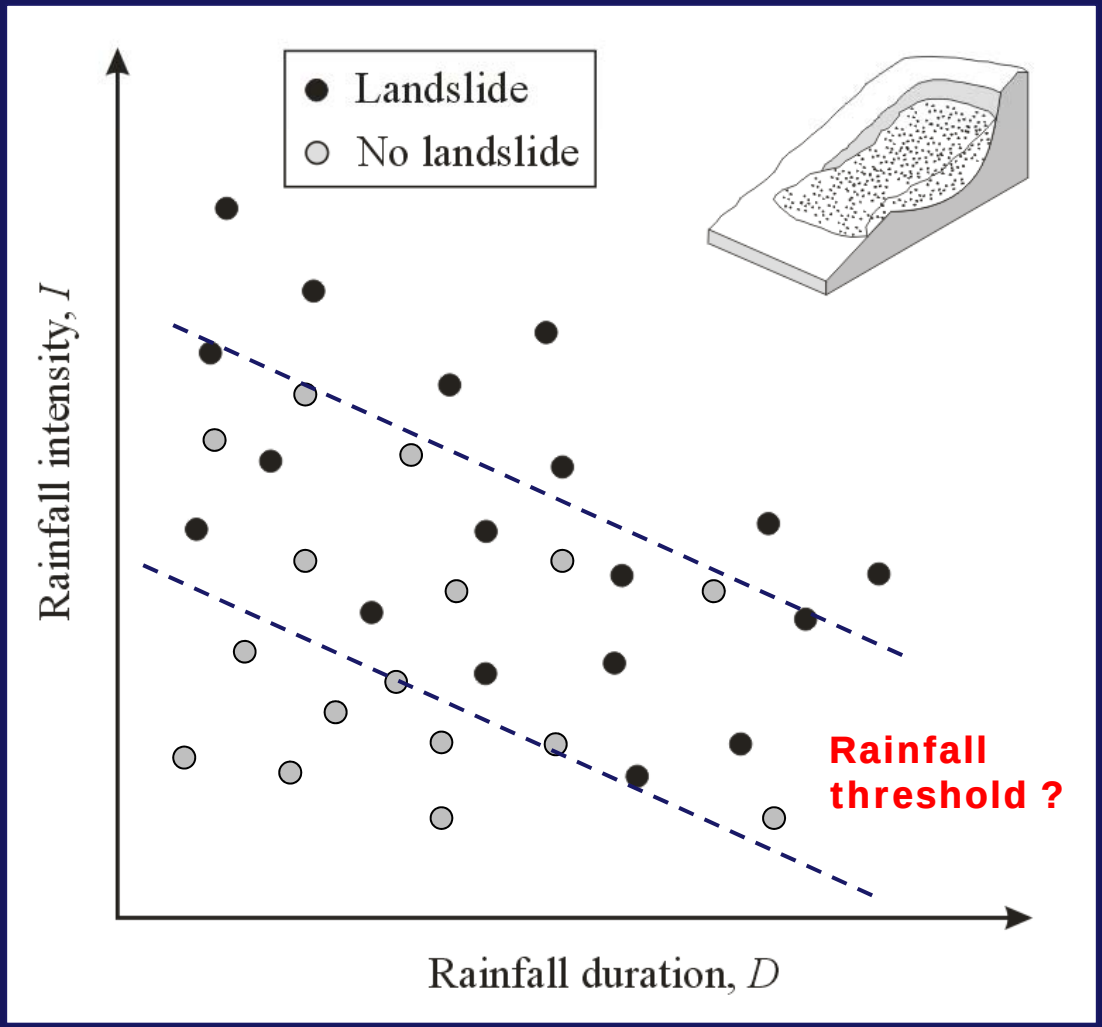
Problem statement (1)



Problem statement (2)



The Bayes theorem

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}$$

A = Landslide event

B = Rainfall event

$P(A)$ = Prior probability of A

$P(B)$ = Marginal probability of B

$P(B|A)$ = Conditional probability of B given A

$P(A|B)$ = Conditional probability of A given B

A simple example

N	Duration (day)	Intensity (mm/day)	Landslide
1	0.2	12	○
2	0.5	30	○
3	0.6	21	○
4	0.7	15	○
5	0.8	65	○
6	0.5	78	●
7	0.7	85	○
8	0.2	90	●
9	0.9	33	○
10	0.3	25	○
11	1.3	22	○
12	1.5	36	●
13	1.8	35	○
14	1.8	10	○
15	1.6	60	●
16	1.7	75	●
17	1.2	70	○
18	1.2	40	○
19	0.4	45	○
20	0.2	10	○

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}$$

Number of rainfall events, $N(B)$=20
Number of landslides, $N(A)$=5

What is the probability to have a landslide IF an intense rainfall (I>40 mm/day) occurs?

Conditional probability of the critical rainfall:
$P(B|A)$=4/5=0.80

A simple example

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18	1.2	40	○
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$$P(A \mid B) = \frac{P(B \mid A) \cdot P(A)}{P(B)}$$

Number of rainfall events, $N(B)$=20
Number of landslides, $N(A)$=5

What is the probability to have a landslide IF an intense rainfall (I≥40 mm/day) occurs?

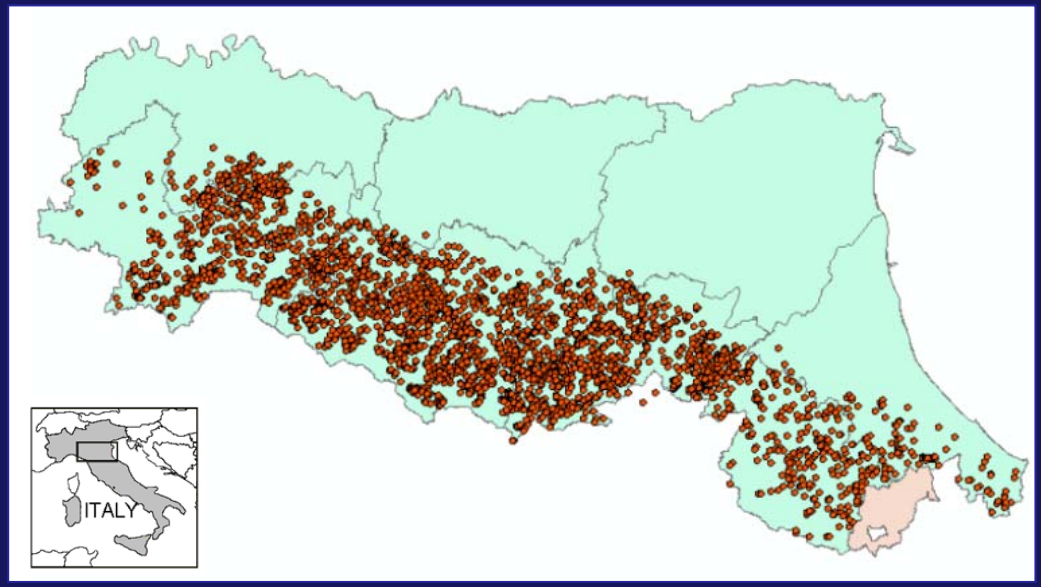
Conditional probability of the critical rainfall:
$P(B|A)$=4/5=0.80

Marginal probability of the critical rainfall:
$P(B|A)$=9/20=0.45

Prior landslide probability:
$P(A)$=5/20=0.25

Landslide probability:
P(A|B)=(0.80·0.25)/0.45=0.44

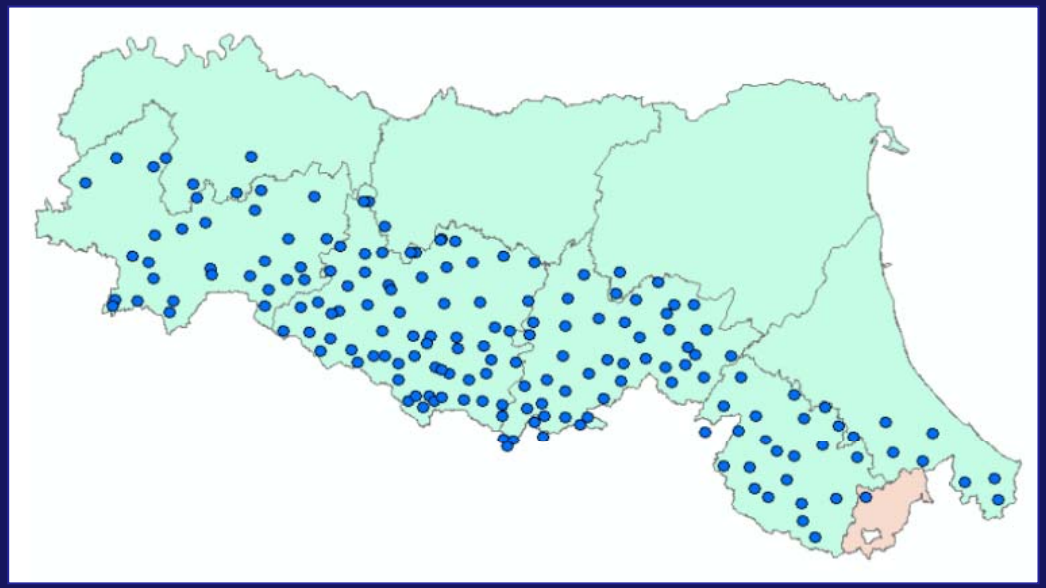
Application to the Emilia-Romagna dataset (Italy)



4141 Historical landslides

Years: 1939-2009

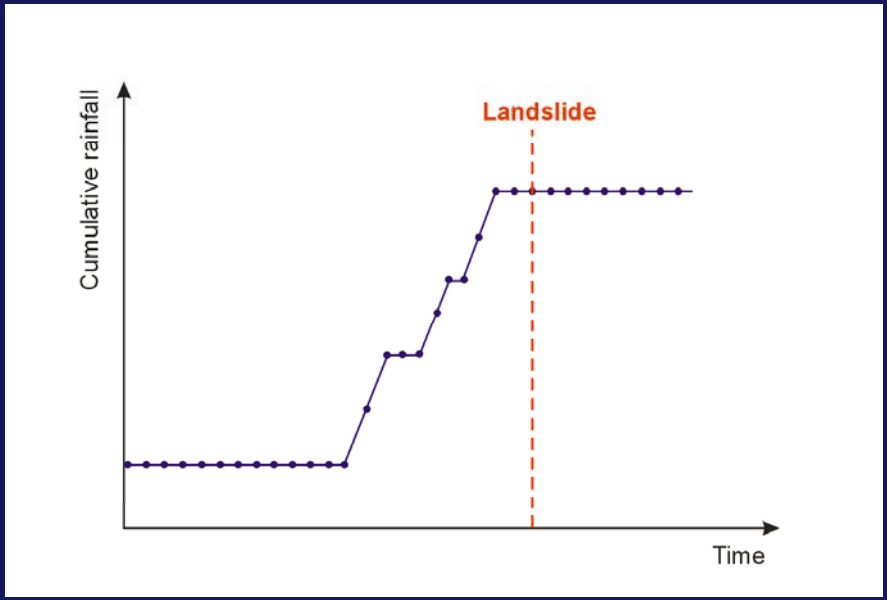
Triggering date known with daily accuracy

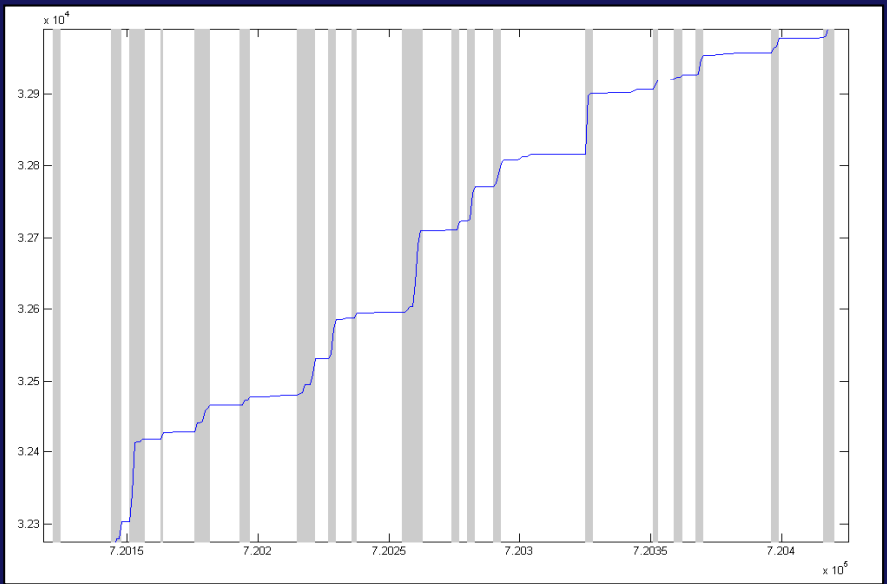


176 Raingages

Years: 1931-Present

Data preparation





For each historical landslide we:

1. Compared the cumulative rainfall of the 3 closest raingauges
2. Manually identified the triggering rainfall

↓

Rainfall detection algorithm

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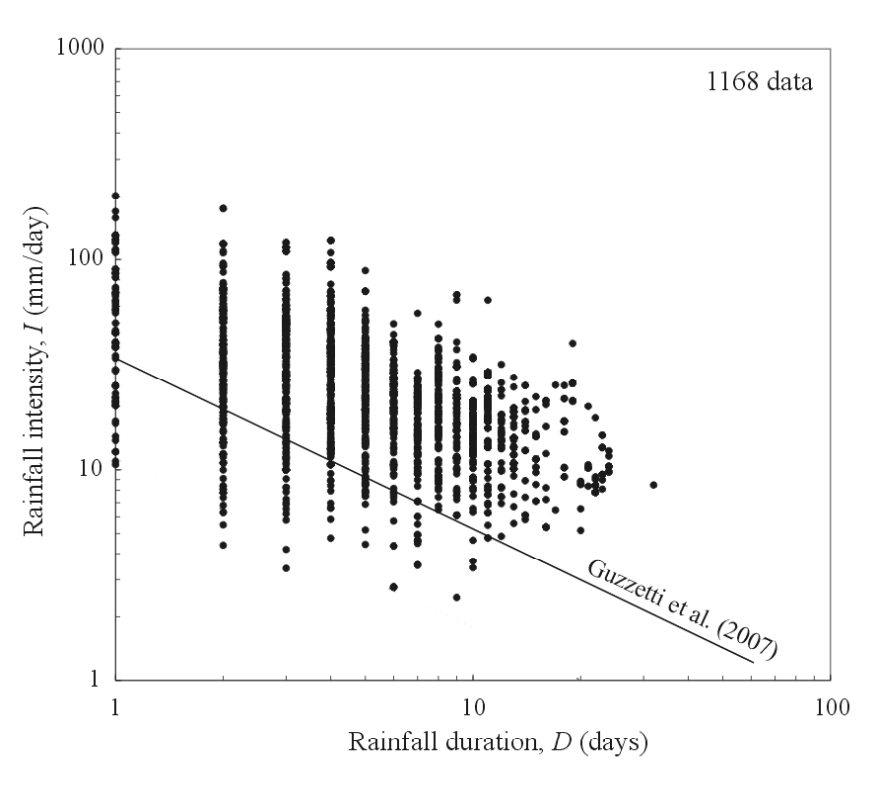
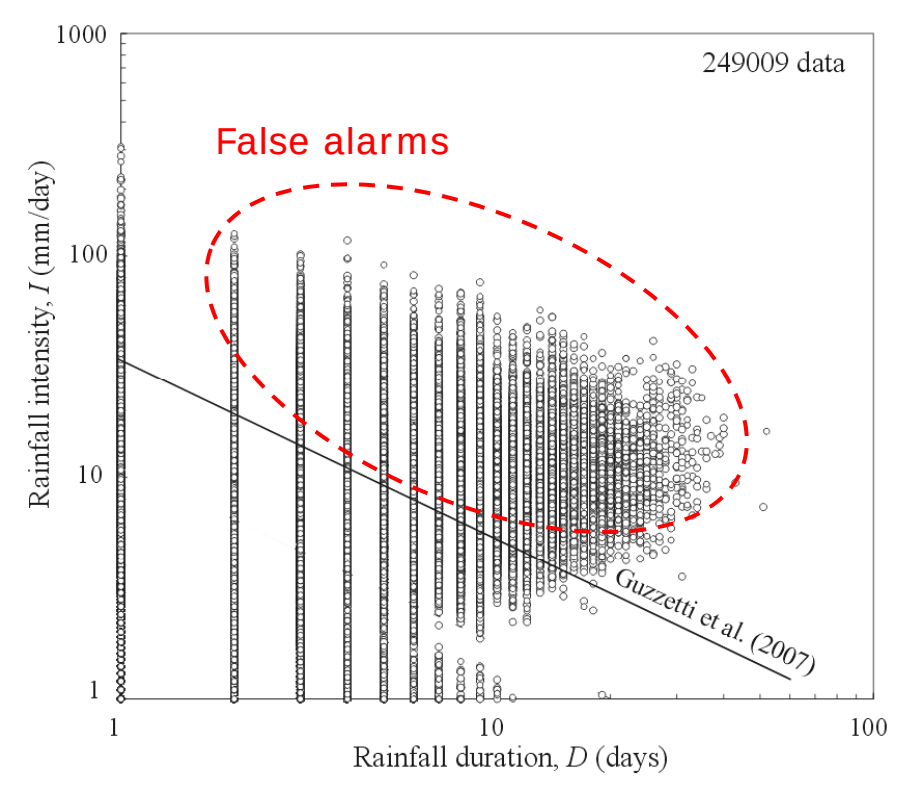
Identification of the rainfall events for all the 176 raingauges

Traditional approach

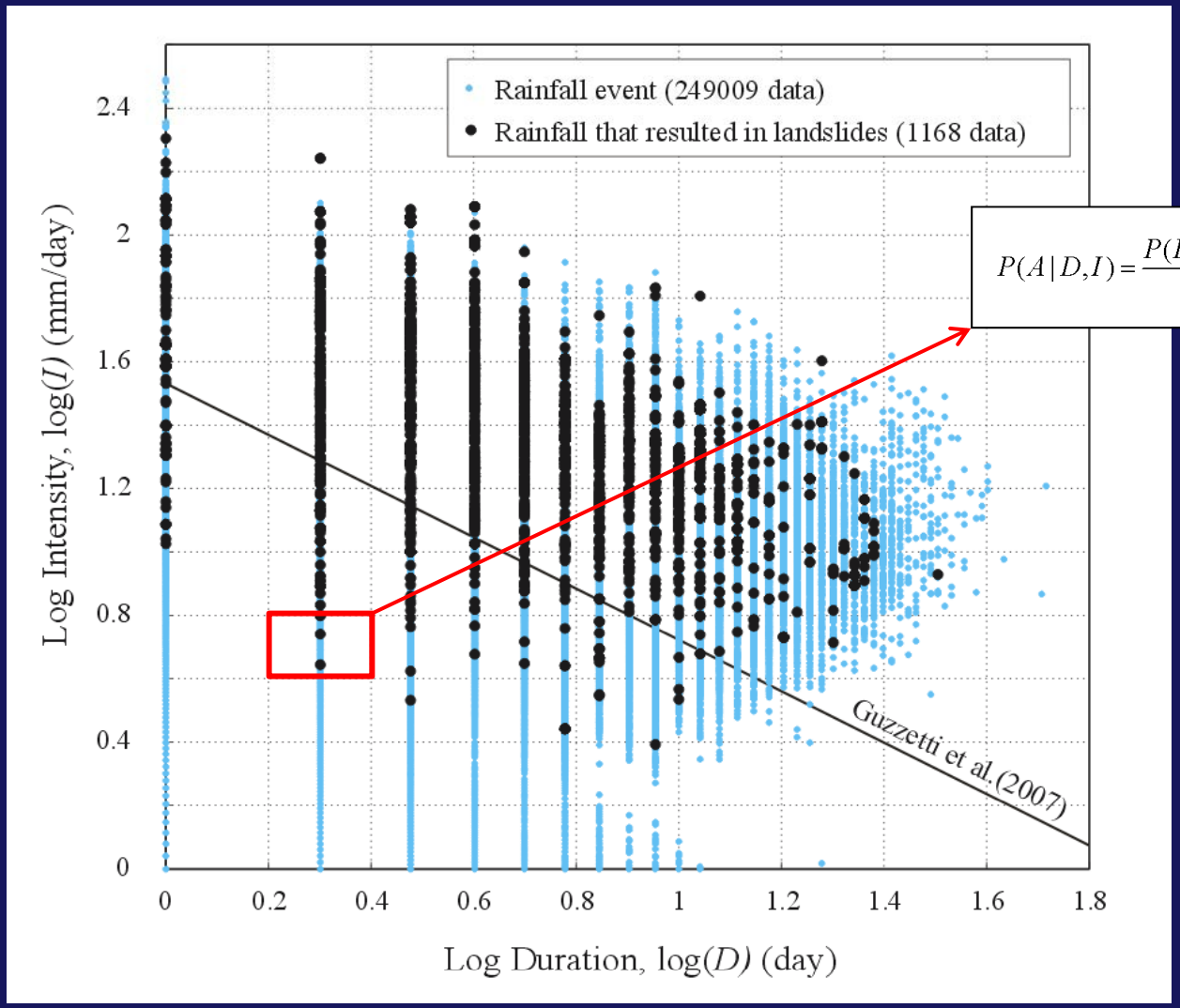
Rainfall that resulted in landslides



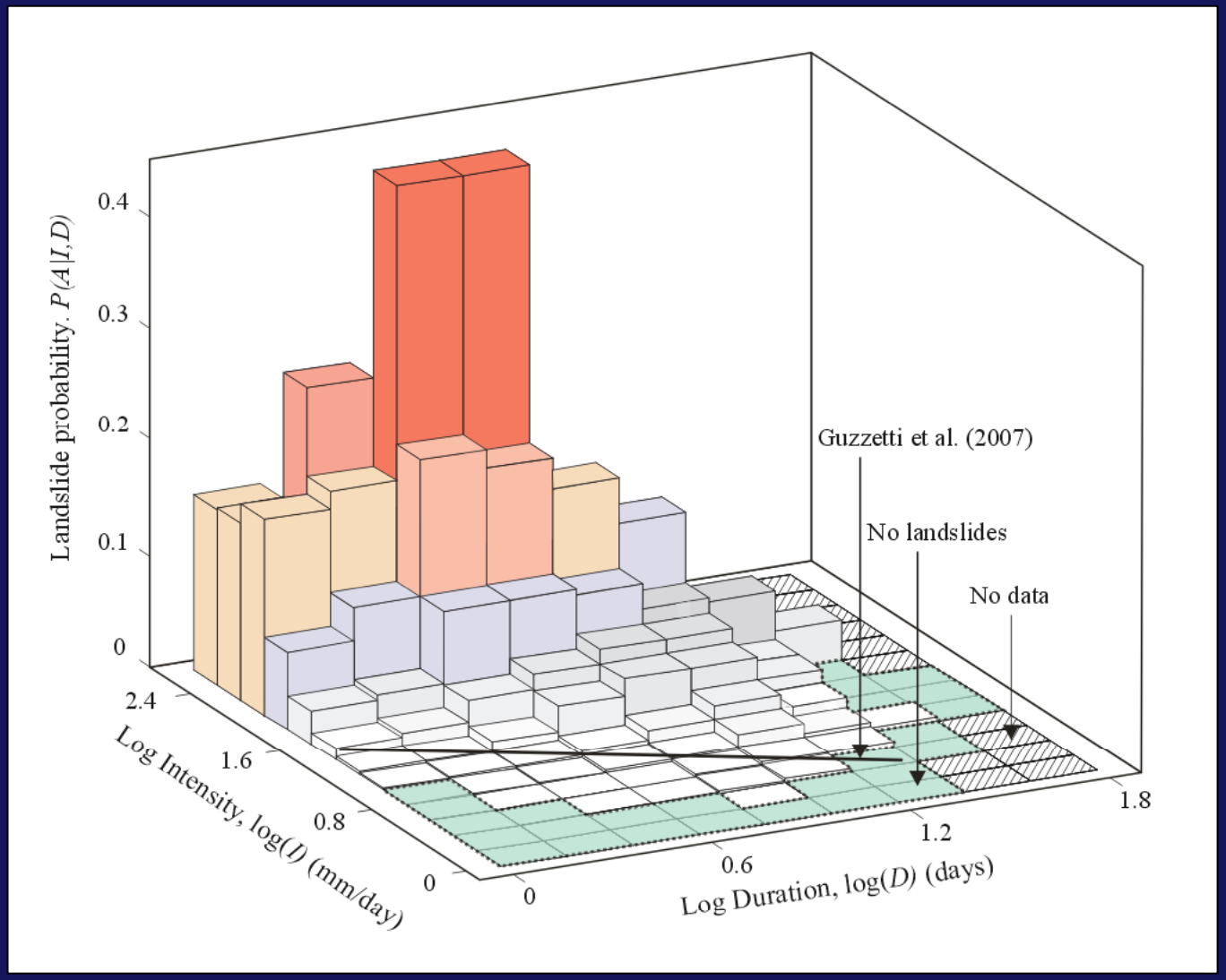
Rainfall that NOT resulted in landslides



Bayes approach



Landslide probability in the rainfall duration-intensity plane



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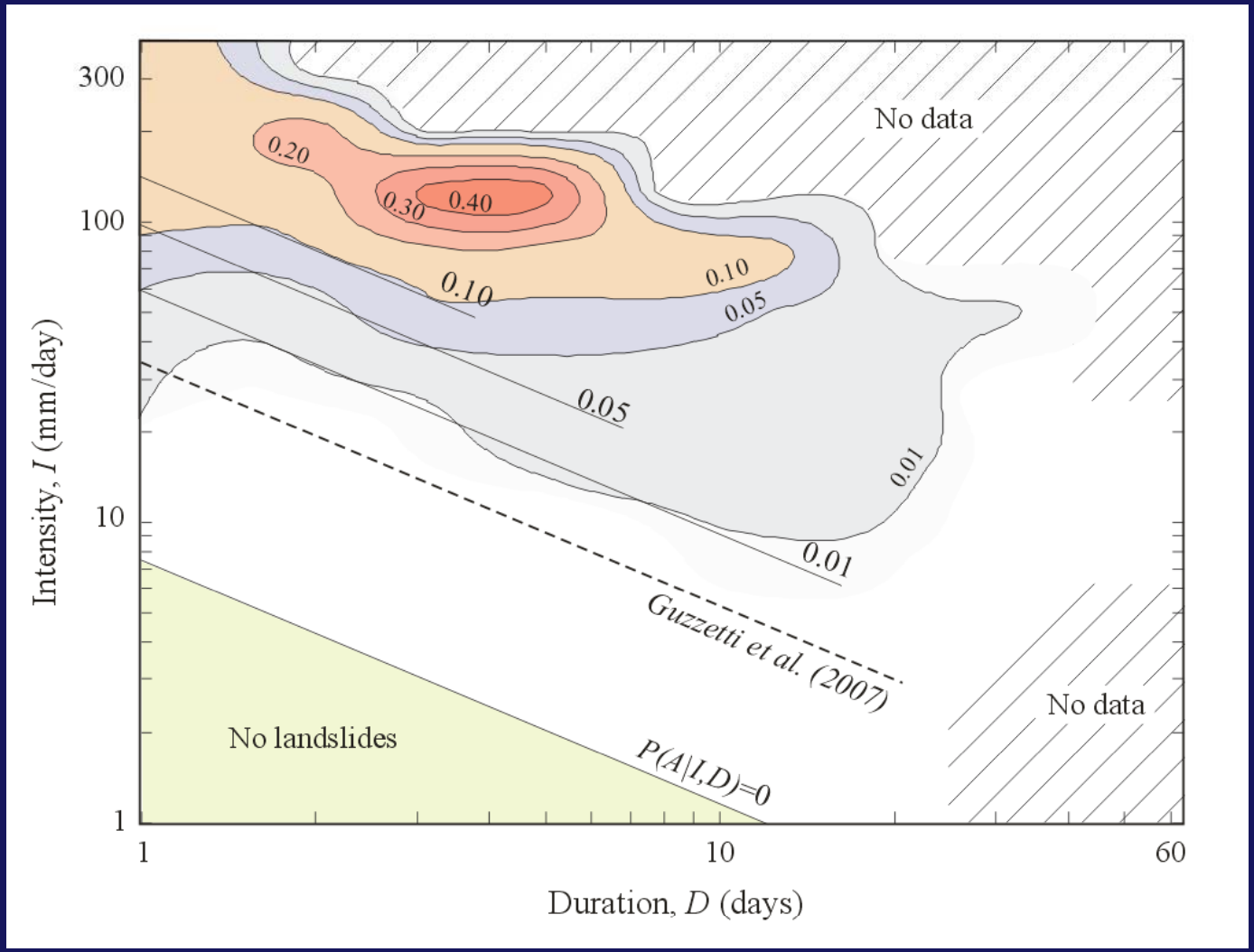

Conclusions

- A probabilistic approach is required to define rainfall thresolds in complex geological conditions
- Both the rainfall that resulted and NON resulted in landslides should be considered
- Bayes theory is suitable to define probabilistic rainfall threshold
- In our test area, there is a good agreement between the probabilistic approach and the traditional methods