Derivation of landslide triggering thresholds in Sicily through artificial neural networks

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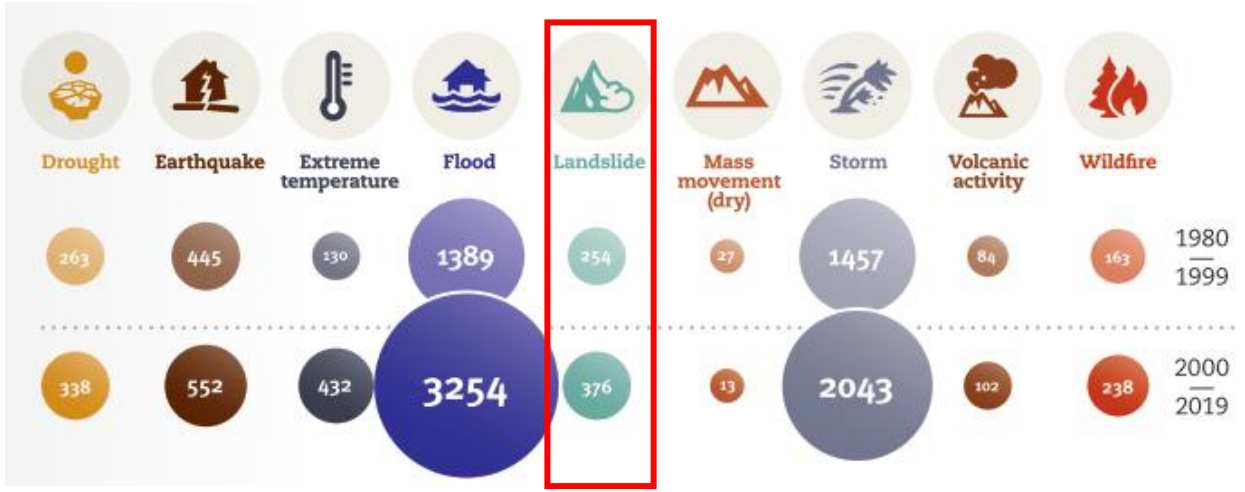
Introduction

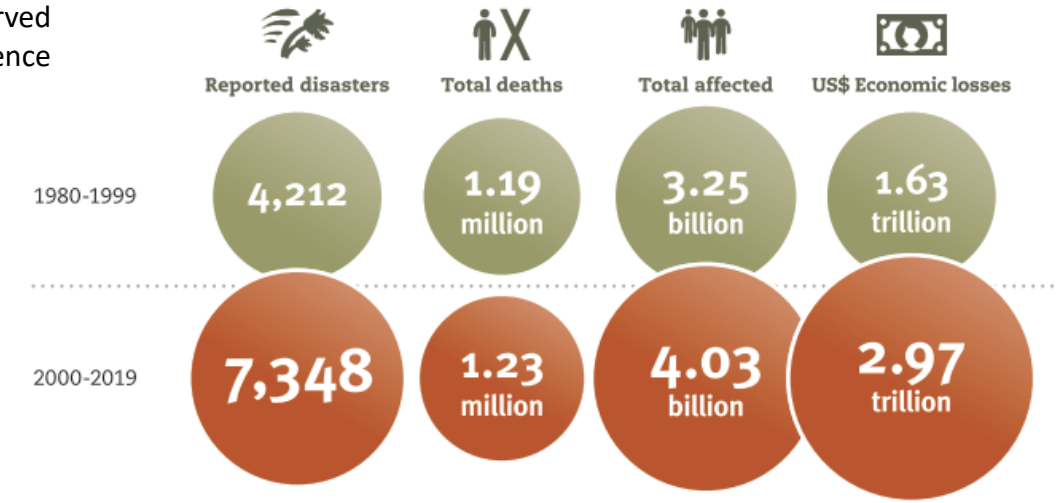
The recent report presented in 2020 by the United Nations (UNDRR, 2020) on the reduction of natural disasters highlighted how disasters have increased globally.

The observed data were considered with reference to two time windows 1980/1999 and 2000/2019.

Data shows how number of victims, populations affected and funds to deal with these emergencies have increased.



Disasters observed in the two reference time windows



Motivation of the study

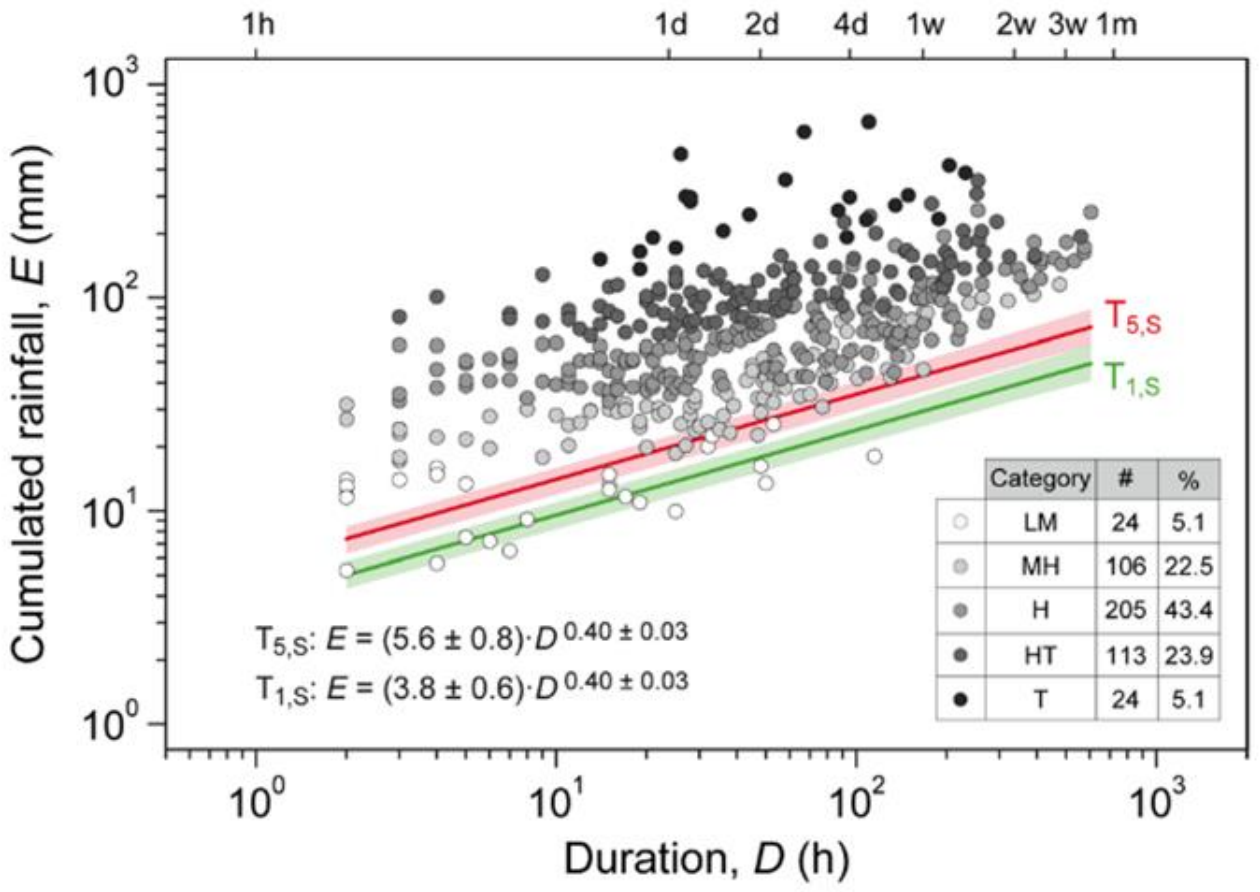
Landslides are among the phenomena that can cause casualties among the population and provoke considerable damage to infrastructures, and public and private assets.

Landslide early warning systems (LEWS), aiming at reducing the exposure of the population, have been developed based on rainfall thresholds derived mostly by empirical methods, i.e. on finding a statistical link between the characteristics of precipitation and the occurrence of landslides.

Aim of the study

Commonly the proposed thresholds have the form of a power law linking rainfall intensity (or cumulated rainfall) to duration.

One of the limitations of this approach is that using a predetermined form of threshold equation may potentially reduce the predictive performances.



Melillo et al., 2016, Landslides.

Methodology

Commonly, Machine Learning Techniques are used to remove such a limitation. Among the many available techniques, that fall into this category, we propose the use of Artificial Neural Network (ANN).

Artificial neural networks are data-driven self-adaptive methods in that there are few a priori assumptions about the models for problems under study.

After being trained on the basis of a sample data submitted to them, ANNs can often correctly infer the unseen part of a population even if the sample data contain noisy information (Khashei & Bijari, 2010. Expert Systems with applications).

Methodology

1. Data processing;
2. Create the neural network;
3. Data enter;
4. Choose the network architecture;
5. Evaluate the performance .

Use of Matlab's Neural Net Pattern Recognition app in the 'Machine Learning and Deep Learning' category.

Input data	Numbers of neurons
I – D	1÷20
E – D	1÷20
Ipeak - D	1÷20
I – E – D	1÷20
Ipeak – E – D	1÷20
I – Ipeak – E – D	1÷20

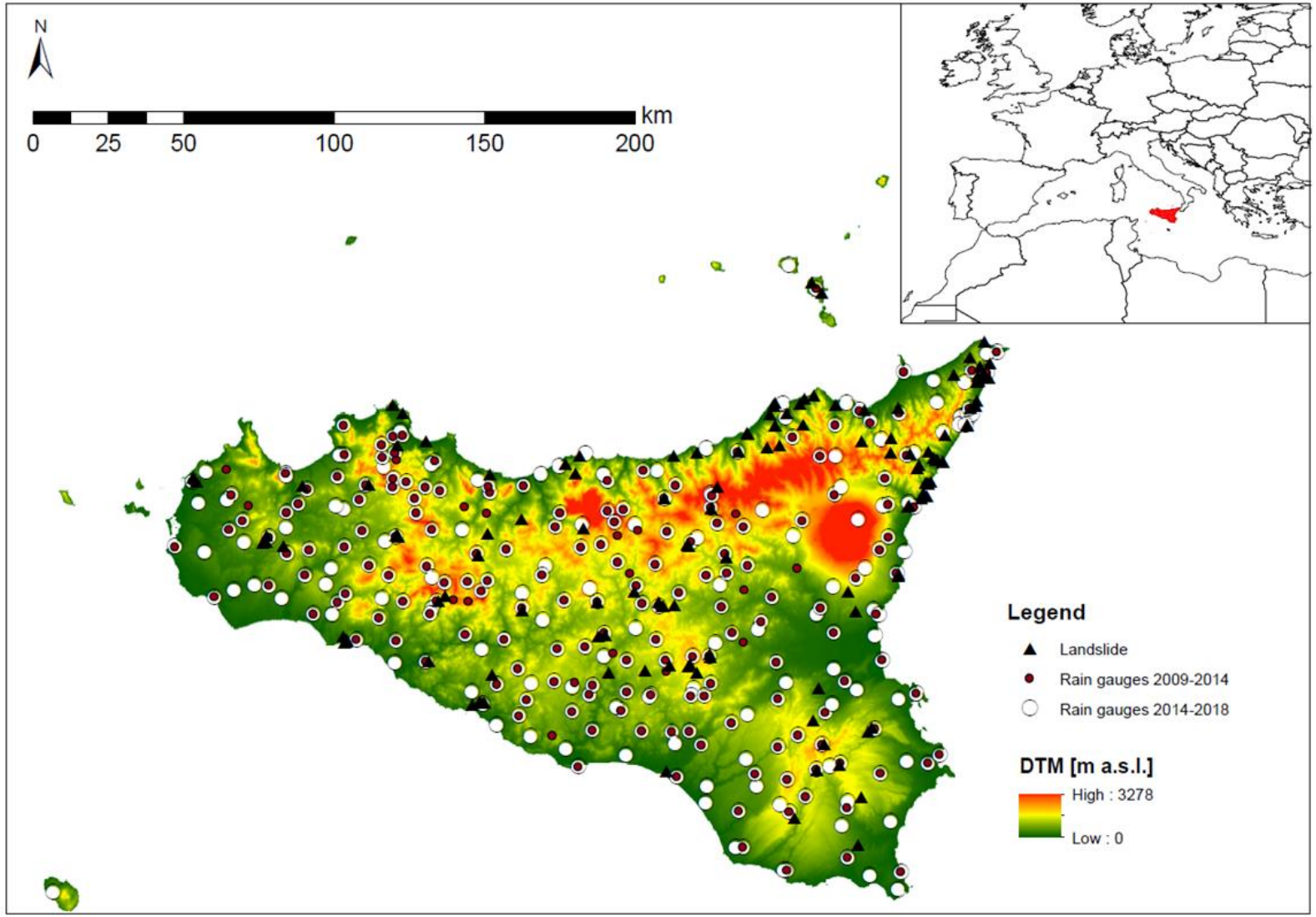
D = duration ; E = cumulated rainfall
I = intensity ; Ipeak =peak intensity

Data

The study area is the Region of Sicily (southern Italy).

Precipitation data from more than 300 rain-gauges were used for processing in 2009÷2018 time frame

The landslide events came from “FraneItalia” database (Calvello & Pecoraro, 2018).



Data

The CRTL-T (Melillo et al.,2018, Environ Modell Softw) code was used for processing rainfall data.

1. Algorithm managed to reconstruct 144 landslide events out of 207 landslide events triggered by rain (from 255 total landslides in the database for the study area).
2. Threshold equation with probability of not exceeding 5%:

$$E_{5\%} = (4{,}9 \pm 1{,}1)D^{(0{,}26 \pm 0{,}06)};$$

3. Threshold equation with probability of not exceeding 1%:

$$E_{1\%} = (2{,}9 \pm 0{,}7)D^{(0{,}26 \pm 0{,}06)};$$

4. Total of 47398 non-triggering rainfall;
5. Distinction of data, by binary encoding, between triggers (1) and non-triggers (0) events.

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Results

Imput data:

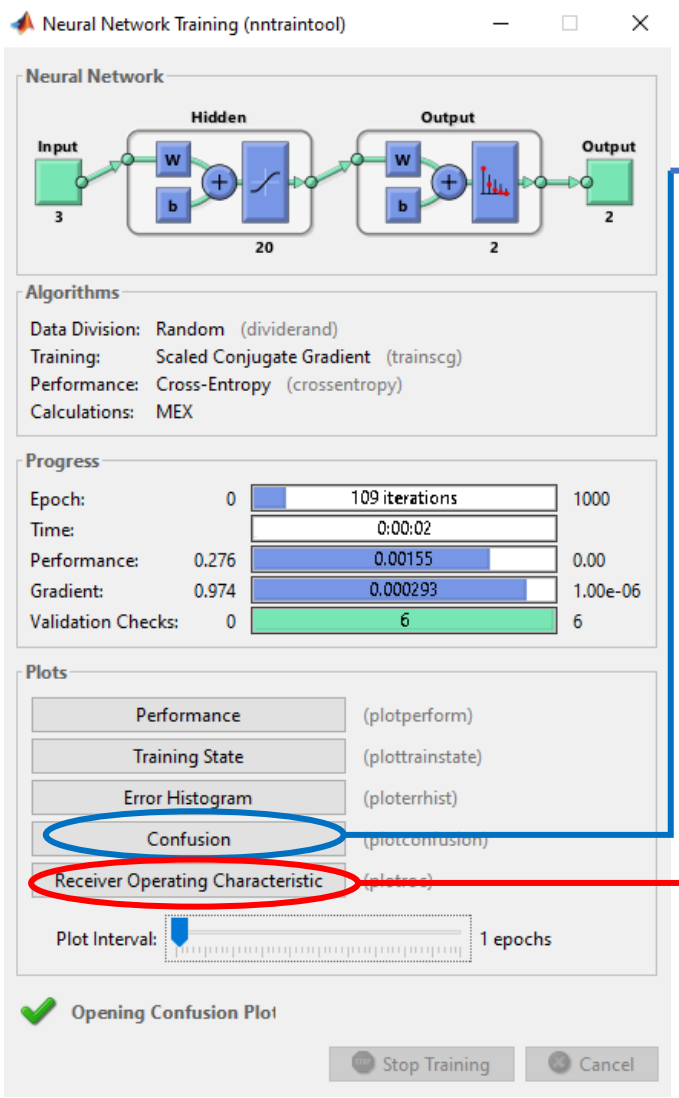
Duration D;

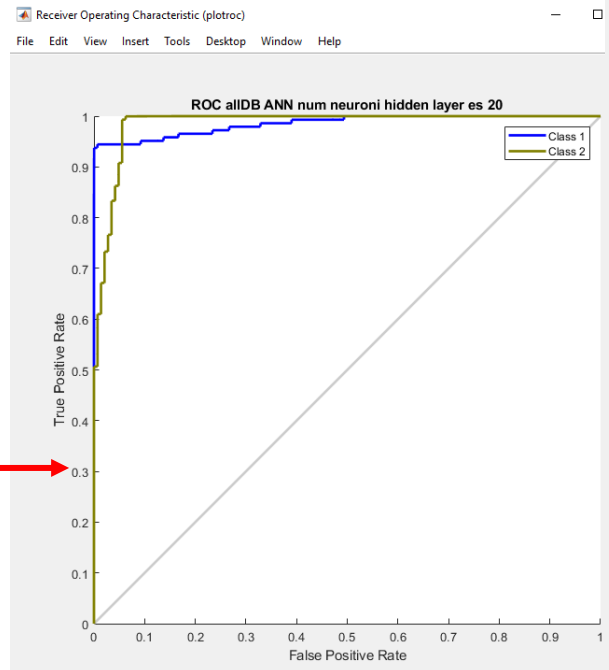
Cumulated Rainfall E;

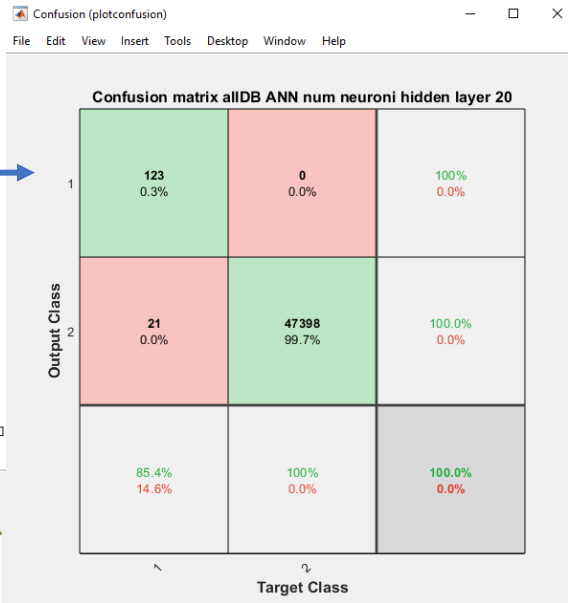
Peak Intensity Ipeak;

Target:

- [0,1] No failure;
- [1,0] Landslide.







Conclusions

Aim of the presented study is to seek a correlation between precipitation characteristics and landslide triggering.

Based on preliminary results, neural networks are able to recognize the characteristics that lead to slope failure.

In the best scenario , 20 neurons in hidden layer, True Skill Statistics is 0.85

Future developments will investigate the role of other input variables regarding initial soil moisture.

References

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