Snowmelt Influence in Shallow Landslides

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ABSTRACT

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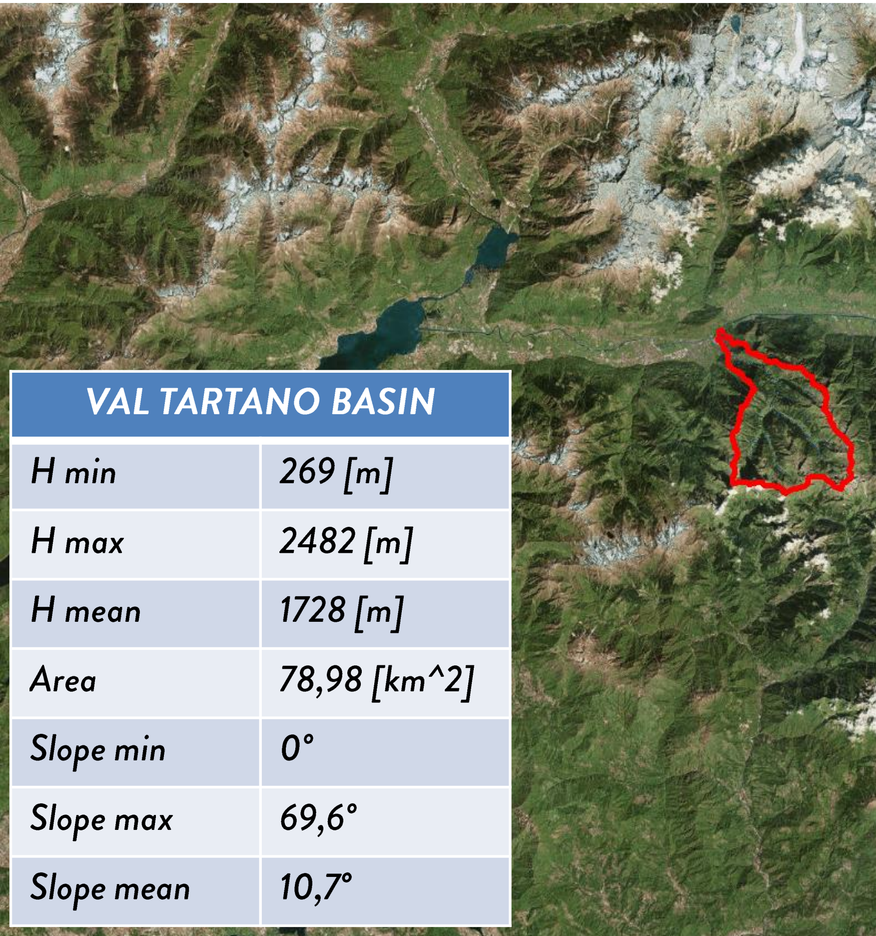
Mass wasting is the major landform shaping process in mountainous and steep terrain, and Italy is among the most affected countries in Europe. Lombardia region shows 130.450 landslides, covering an area of 3.300 km2 (i.e. 7.2% of region's area). The 41% of landslides in Lombardia are rapid mass movements involving shallow soils, occurring mainly in the Alps and Fore-Alps. Many shallow landslides (SLs) result from infrequent meteorological events, inducing unstable conditions on otherwise stable slopes, or accelerate movements on unstable slopes. However, in mountainous areas, such as the Alps of Lombardia region, snowmelt concurs with rainfall intensity and duration in setting the hydrologic conditions favorable to the occurrence of SLs. However, snowmelt contribution to SLs triggering is little investigated. In regions experiencing snow precipitation during winter and snowmelt during spring and summer could decrease the intensity and duration of rainfall needed for SL initiation. Thus, in compliance with the project Mhyconos, a project founded by Fondazione CARIPLO, we aim to develop a robust and parameter parsimonious model that accounts for the combined effect of precipitation duration and intensity in the triggering mechanism of shallow landslides coupled with snowmelt. The model is applied to the case study of Tartano basin, paradigmatic of SLs in the Alps of Lombardia where in July 1987 a SL event produced 30 fatalities.

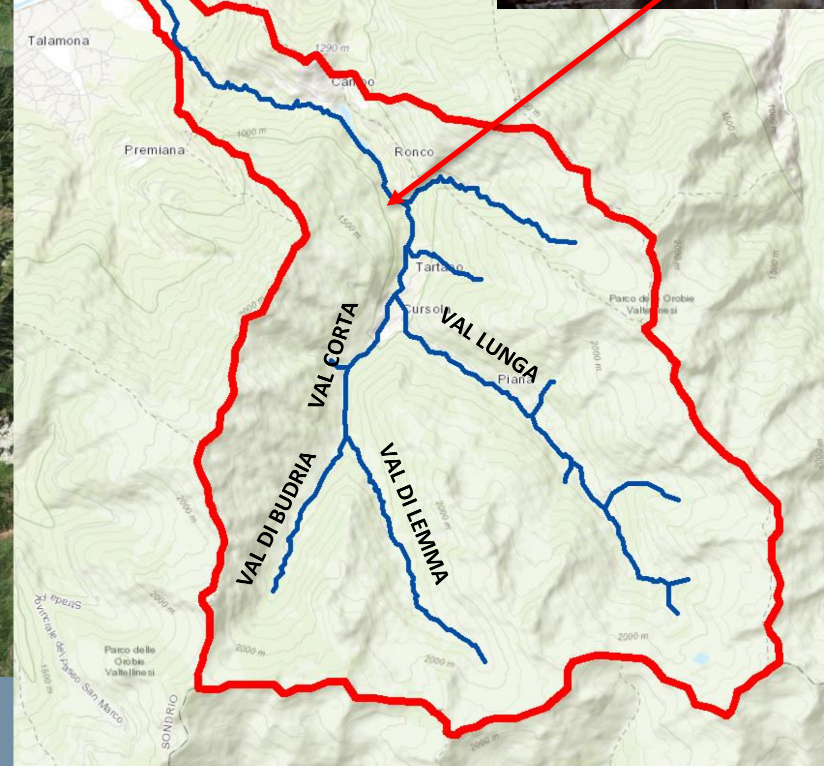
Results show that about 37% of Tartano Basin is under unstable condition of which more than 50% can be influenced by soil moisture variation. Using a traditional approach (i.e.rainfall based), shallow landslide failure is predicted to occur only during the rainy period of October and November. By contrary, including snowmelt the model outputs highlight how potential failure might occur not only in autumn, but also during April and May. Currently, our efforts are aimed to conduct interviews and construct a temporally based dataset where the duality of occurrences can be evidenced. Thus, risk perception by population can change and public authority can be prepared to implement emergency plans in order to prevent injuries, causalities and damages to infrastructures also during spring time.

CASE STUDY

Val Tartano (SO) – Northern Italy



VAL TARTANO BASIN	
H min	269 [m]
H max	2482 [m]
H mean	1728 [m]
Area	78,98 [km^2]
Slope min	0°
Slope max	69,6°
Slope mean	10,7°



MODEL

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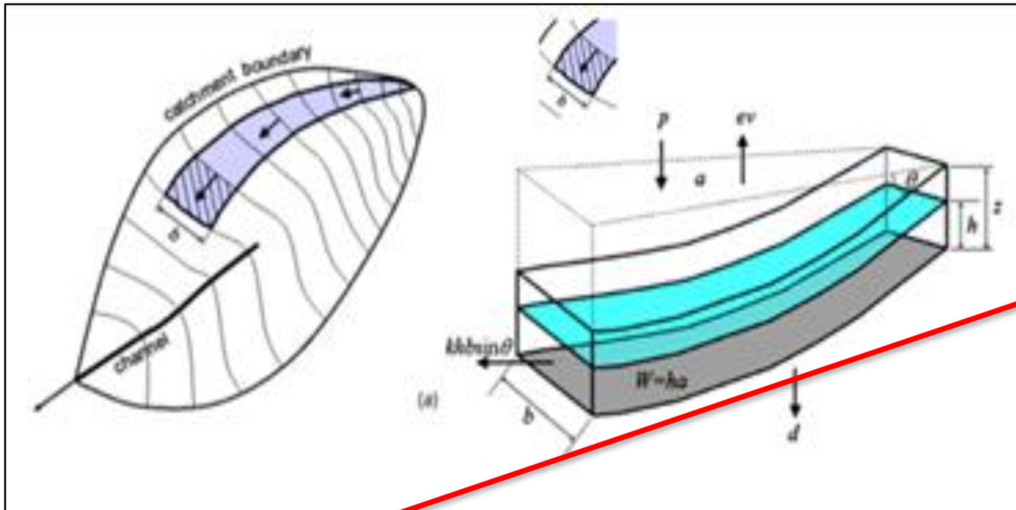

«R. Rosso, M. C. Rulli, G. Vanucchi, 2006»

SNOW MELT is added in the slope stability model proposed by Rosso (Rosso et al., 2006)

$$h = \frac{apz}{Tb \cdot sin\theta}\left[1 - exp\left(-\frac{(1+e)\cdot Tb \cdot sin\theta}{az\cdot(e - eSr)}t\right)\right] + h_i \cdot exp\left(-\frac{(1+e)\cdot Tb \cdot sin\theta}{az(e - eSr)}t\right)$$

$$h_{CR} = \frac{z\cdot(G_s + e\cdot S_r)\cdot\left(1 - \frac{\tan\theta}{\tan\phi'}\right)}{1 + e - e\cdot(1 - S_r)\cdot\left(1 - \frac{\tan\theta}{\tan\phi'}\right)}$$

SPATIAL DISTRIBUTION OF SNOW COVERAGE

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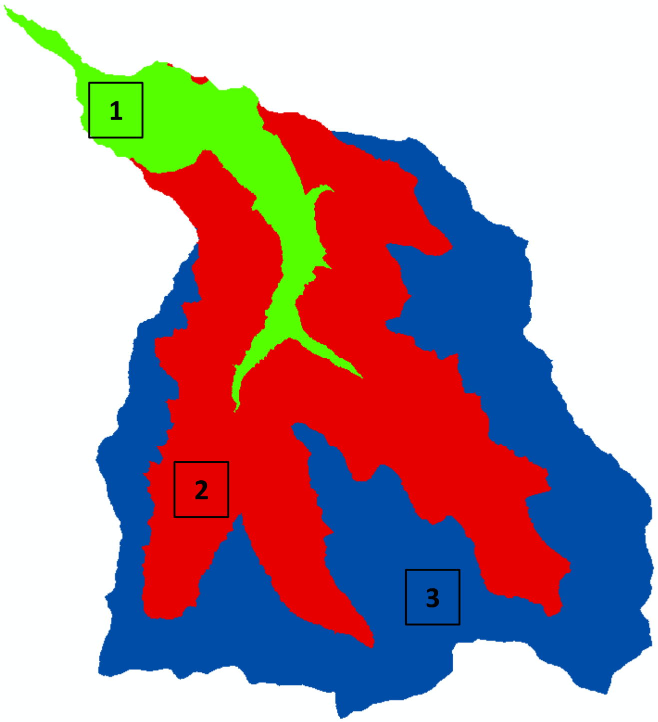
In every cell of every elevation band the amount of water at time t will be:

$$A_1(t) = a_{11} \cdot p_1(t) + a_{12} \cdot p_2(t) + a_{13} \cdot p_3(\mathrm{t})$$

$$A_2(t) = a_{22} \cdot p_2(t) + a_{23} \cdot p_3(t)$$

$$A_3(t) = a_{33} \cdot p_3(t)$$



Where:

a_{11}*= Flow accumulation*cell size in band 1 given by band 1*

a_{12}*= Flow accumulation*cell sizw in band 1 given by band 2*

Etc….

HYDROLOGICAL MODEL: INCLUSION OF SNOW MELT

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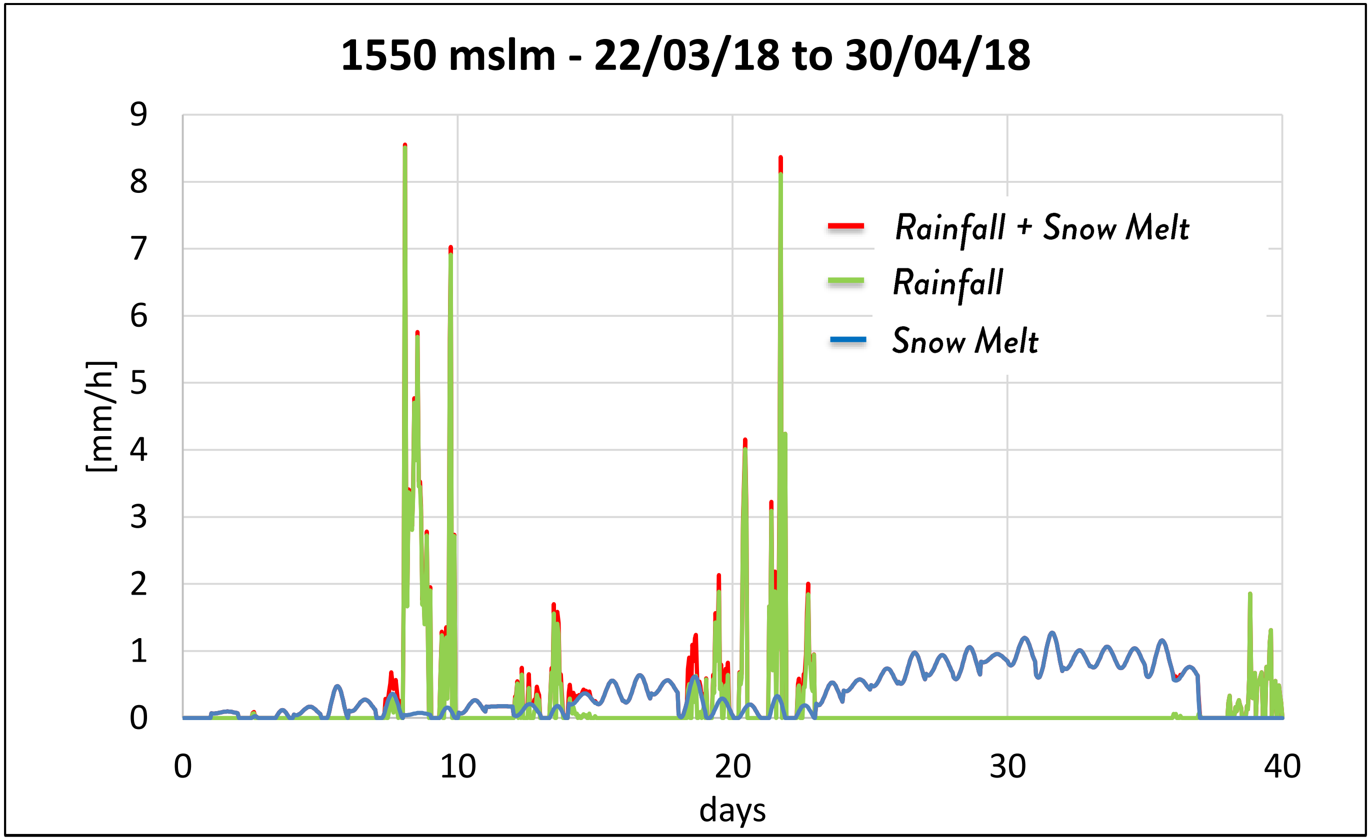
Precipitation and Snow Melt



RESULTS

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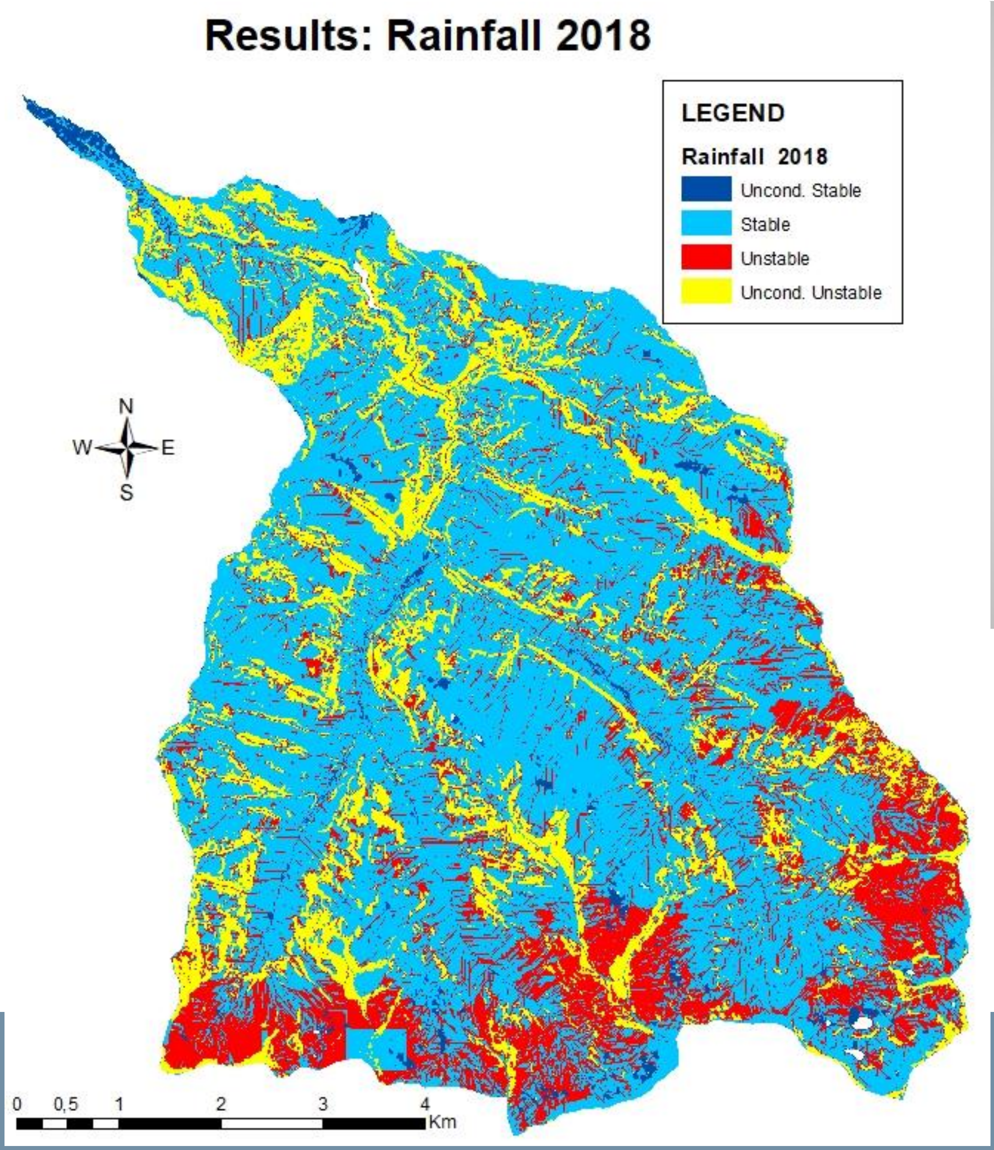
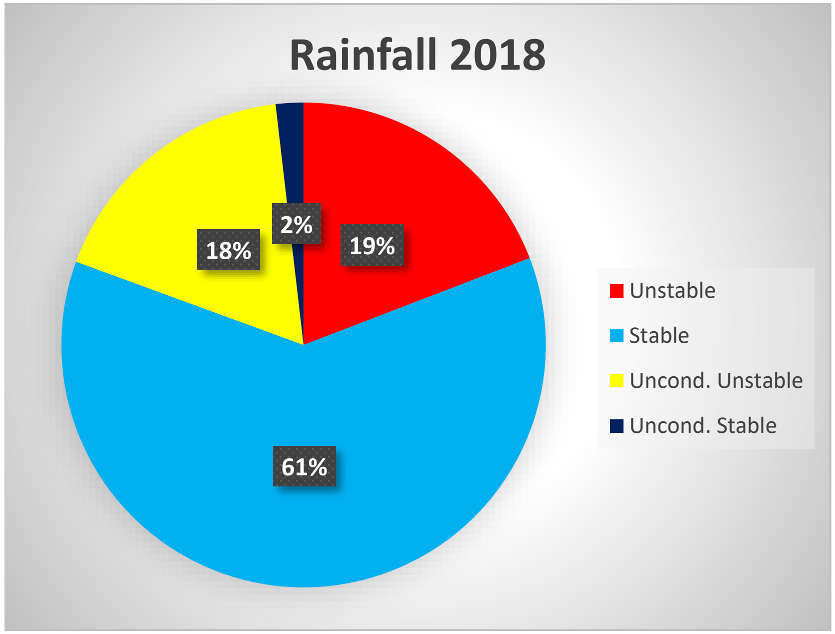
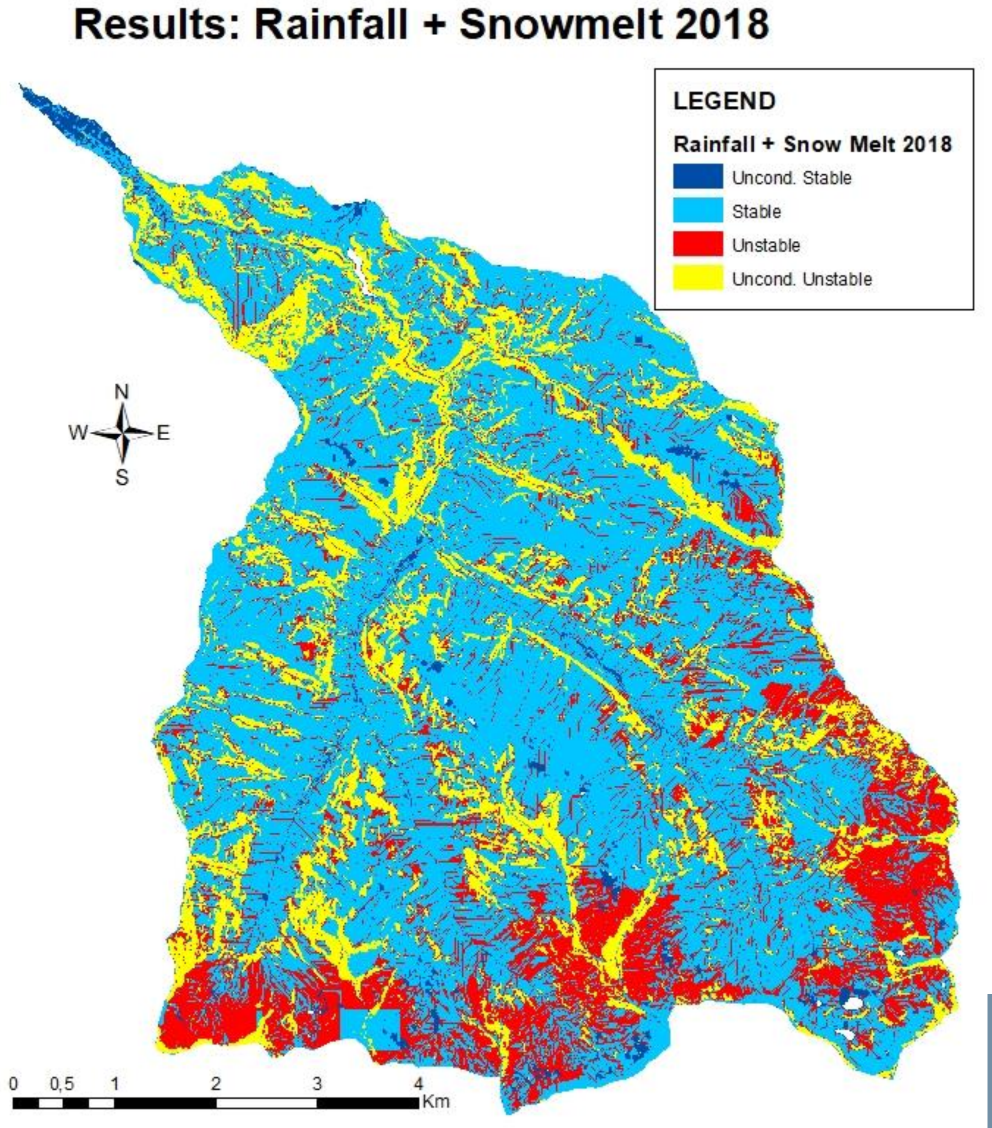
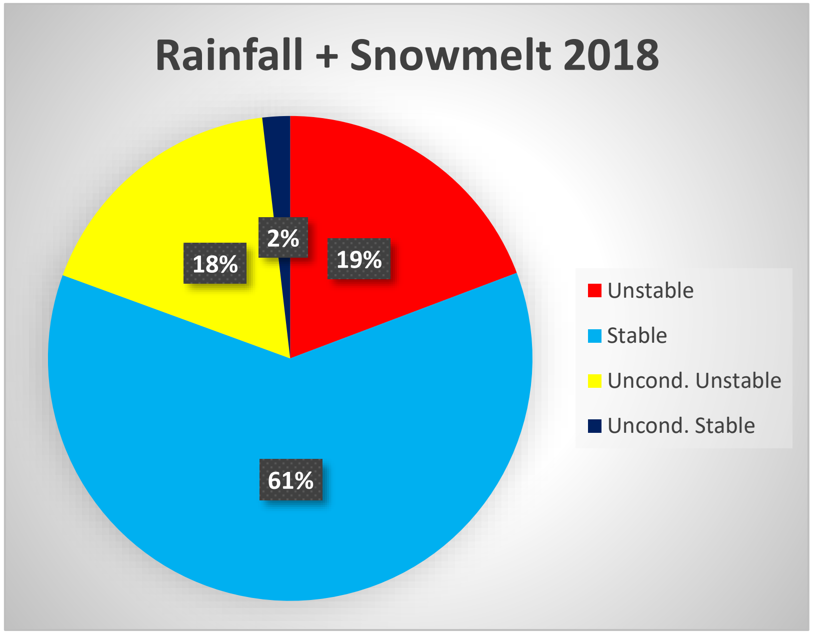




	Area [Km^2]
Unstable	*15,10*
Stable	*48,38*
Uncond. Unstable	*13,85*
Uncond. Stable	*1,45*

RESULTS





	Area [Km^2]
Unstable	*15,17*
Stable	*48,30*
Uncond. Unstable	*13,85*
Uncond. Stable	*1,45*

RESULTS

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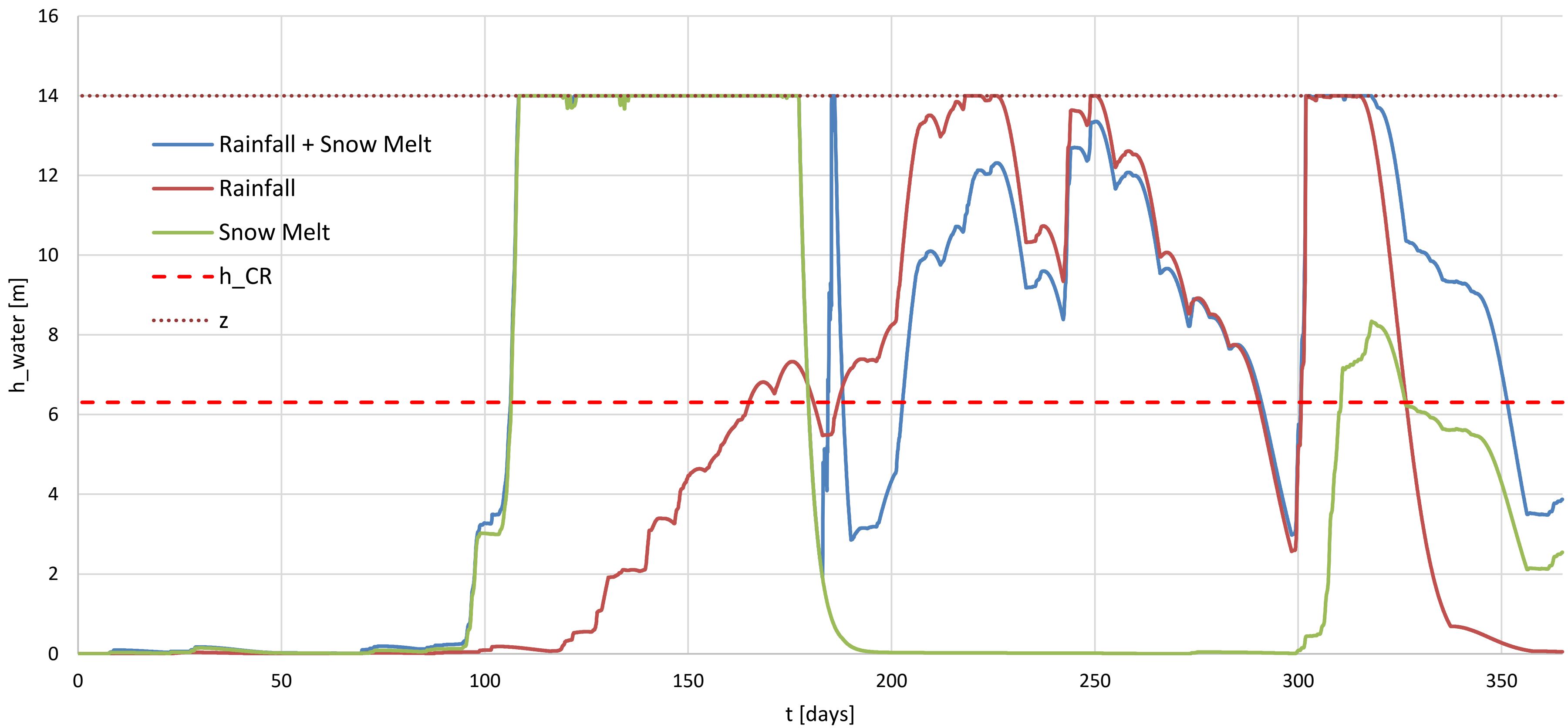
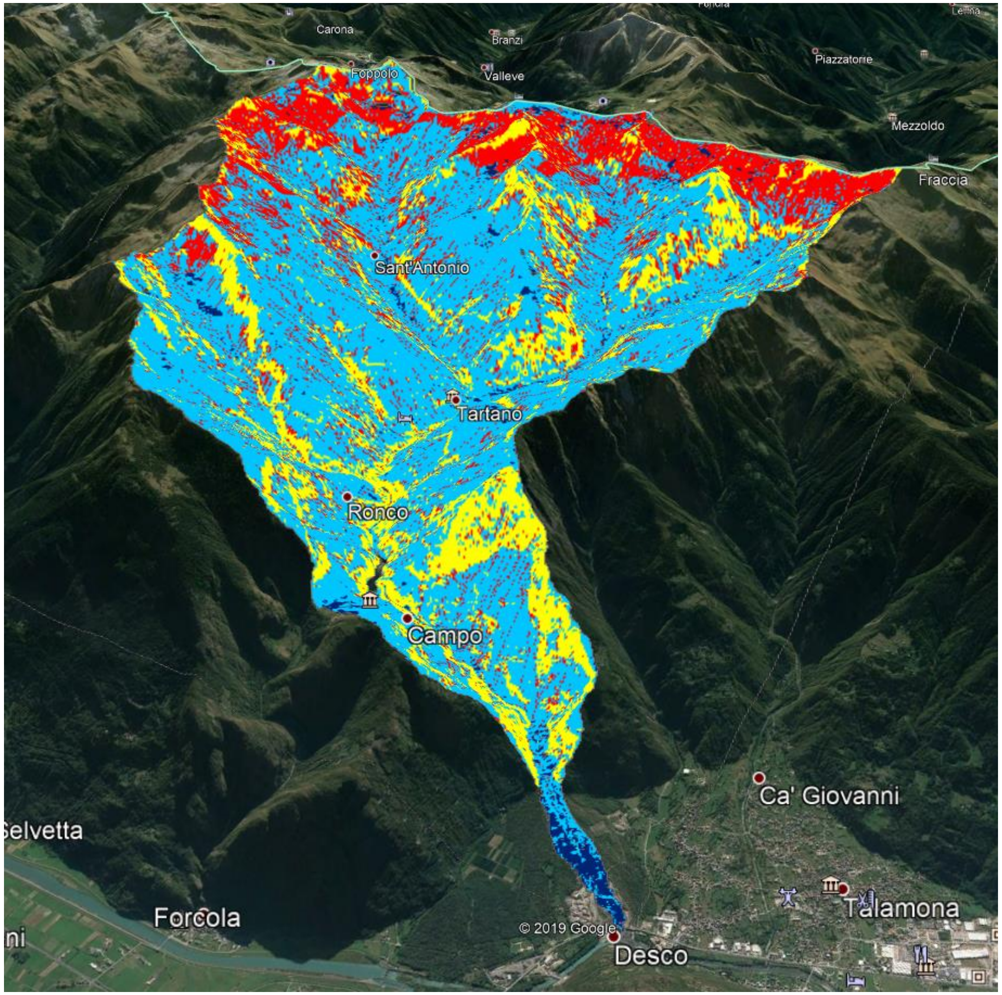
…BUT IT CHANGES THE TIME OF INSTABILISATION



RESULTS



LEGEND:

- *Unconditionally unstable*
- *Unstable*
- *Stable*
- *Unconditionally stable*

RESULTS

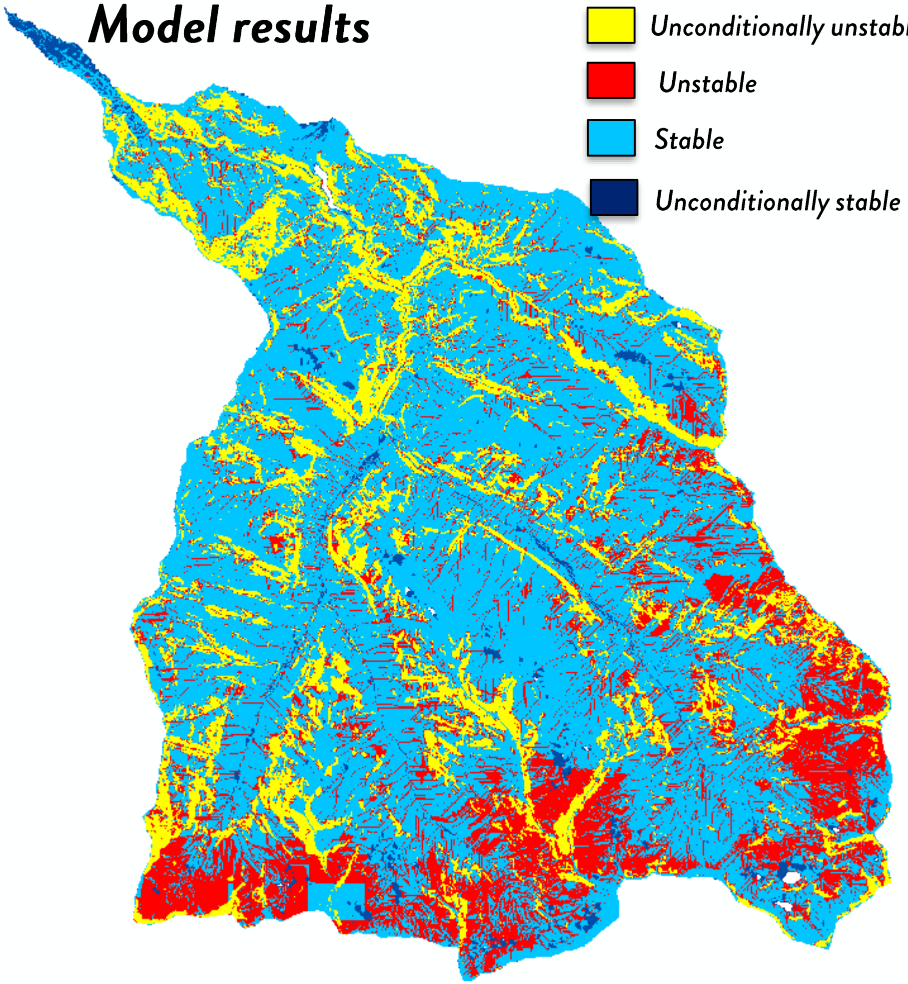
Model results

Unconditionally unstable

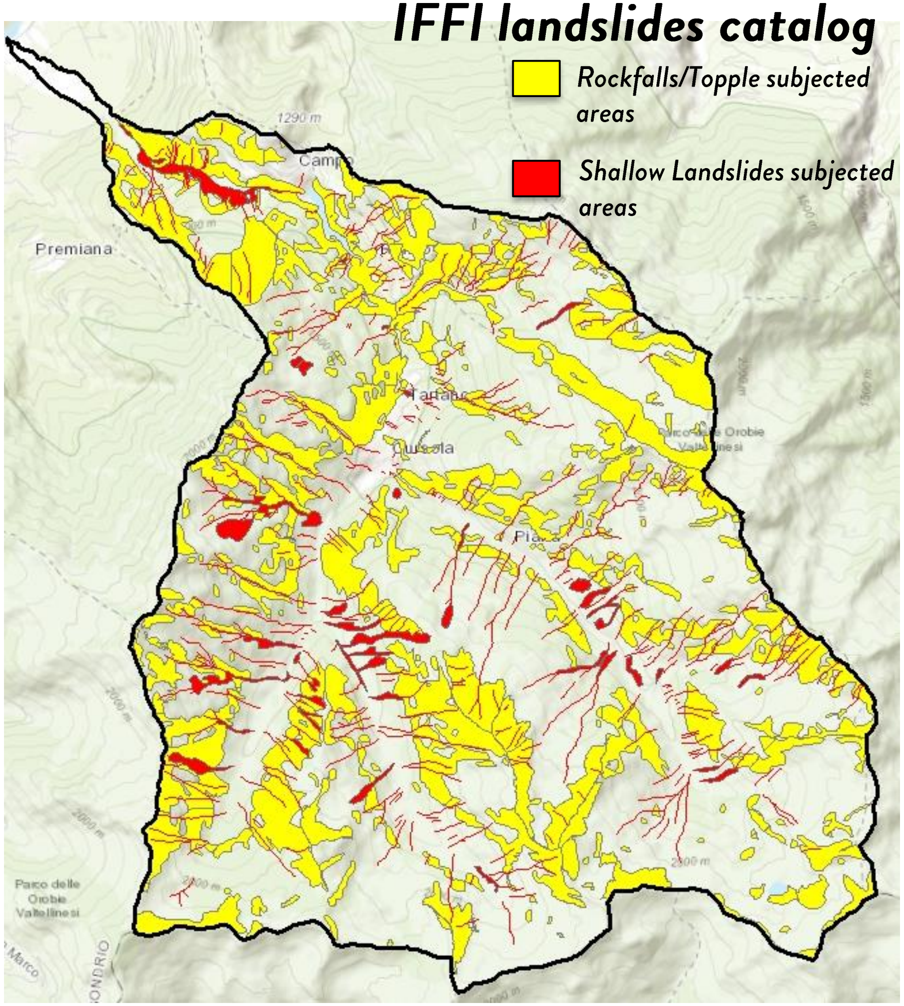
Unstable

Stable

Unconditionally stable



IFFI landslides catalog



CONCLUSION

- *Identification of a further period, coinciding with that of the snow melting, during which landslides can occur.*
- *Delayed detachment: due to the delayed effect of snow melting respect to precipitation, we will therefore have the possibility of having landslide phenomena even with stable and serene weather.*
- *This can increase the risk because landslides can occur at times when the population and authorities do not expect phenomena.*
- *Interesting comparison of the results of the model with the catalogue of landslides: difficulty in defining the period of occurrence of recorded landslides and then distinguishing those caused by the snow melting from those from rainfall*

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Thank you

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