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Monitoring of erosion on two calanchi fronts – Northern Sicily (Italy)

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Abstract: In the present research, two neighbouring *calanchi* fronts have been monitored by means of repeated readings on erosion pins, that were carried out between November 2006 and October 2008. During the monitoring period, a gauge station has been recording rainfalls, allowing us to compute the Rainfall-Runoff Erosivity Factor of the USLE model. The research highlighted: i) a general correspondence between rainfalls temporal trends and surface variation rhythms; ii) alternating erosion and deposition phases result in a retreat of the "calanchi" fronts.

Keywords: water erosion, calanchi, monitoring; Sicily

Introduction

Erosion by water constitutes both one of the main slope modelling process and a problem of great relevance for agriculture activities in arid to semi-arid regions. The Mediterranean areas in particular are affected by severe water erosion phenomena that are favoured by environmental conditions such as irregular rainfalls, strong seasonal climate changes, spare vegetation cover and the frequent outcropping of clayey deposits. Water erosion effects imply also social and economic damages on cultivated lands where high soil loss rates are observed in particular where erosion-control practises are not carried out; the effects of water erosion can be so strong and specific to cause the acceleration of the processes and the development of typical badlands landscapes, like the ones that in the Italian Apennines are site of the "calanchi" landforms.

A quantitative evaluation of water erosion effects can be obtained by means of field observations of soil loss on slopes (direct measures) or by applying models able to remotely assessing erosion rates (indirect methods). Due to their costs, the first methods are not applied at regional or watershed scale and the evaluation of soil loss in these cases is usually made by applying indirect erosion models (empirical or physically-based). At hillslope scale , water erosion evaluation can be carried out by means of direct measurements which can be done by exploiting moderate time- and cost-consuming approaches. Test plots or sample areas can be easily equipped with unexpensive instruments as erosion pins or sediment traps, especially where high erosion rates are expected; moreover, sediment yield can be evaluated by analyzing the temporal evolution of morphometric features of erosion landforms such as rills or gullies, measured in the field by using simple instruments as profilometers, or quantified by means of remote sensing techniques.

In the present research, two neighbouring calanchi fronts have been studied and monitored by means of repeated readings on erosion pins, that allowed describing the point relative height (PRH) of the topographic surface in a time span of two years. Also, during this period, a rain gauge station has been working, collecting precipitation time series, that have been processed to characterize the USLE Rainfall-Runoff Erosivity Factor *R* (Wischmeier & Smith 1965).

Setting of the study area

The investigated area, named "Scillato basin", is a sector of the Madonie Mountains located in north-

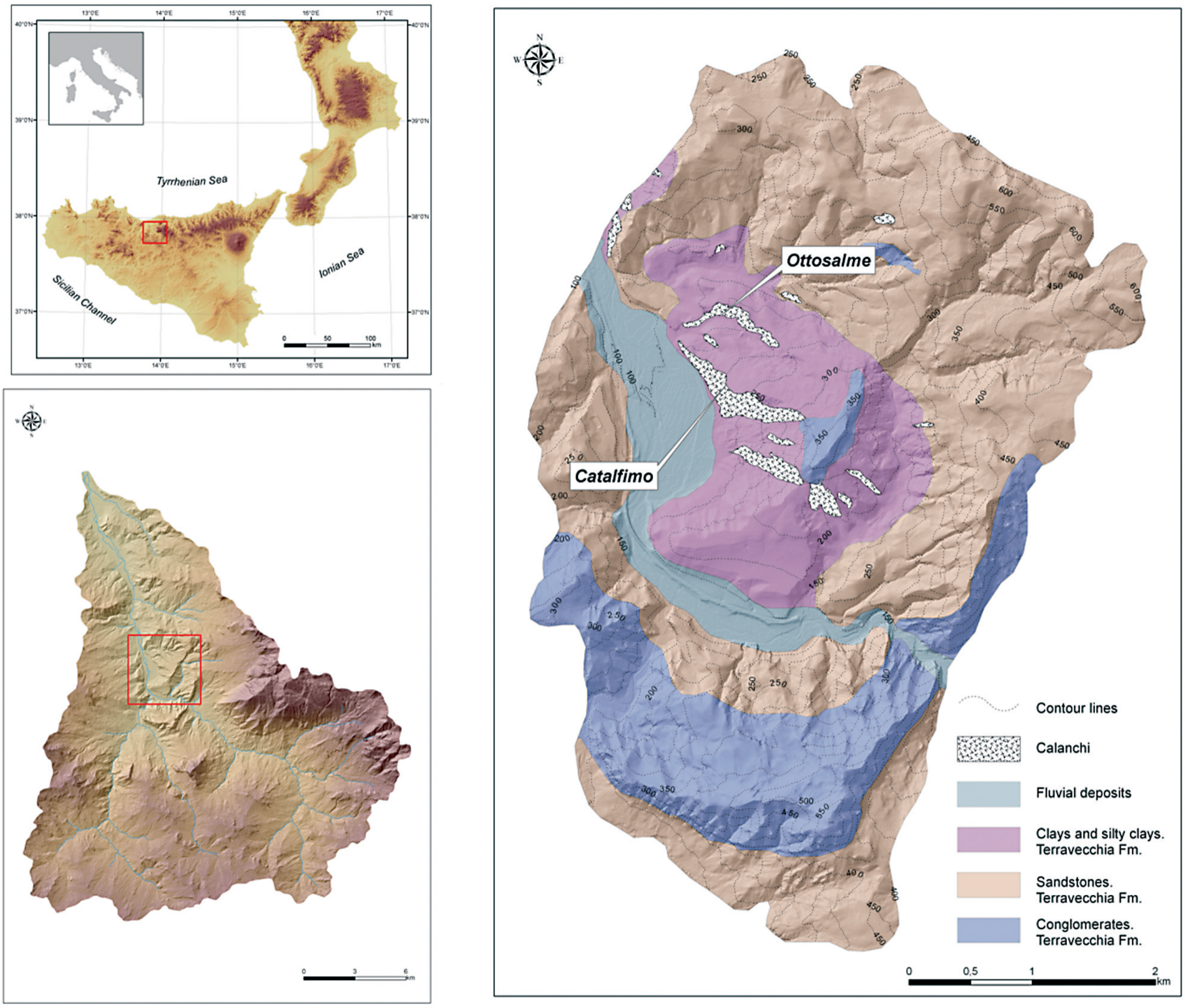

Fig. 1. Geographical and geological setting and calanchi fronts of the "Scillato basin" area

ern Sicily, along the Apennines chain sector (Fig. 1); particularly, this area coincides with the central sector of the drainage area of the Imera Settentrionale river. The study area belongs to the meso-mediterranean type of climate, characterized by hot dry summers and mild wet winters, with bimodal rainfall distribution. Rainfall data, referred to the 1956–2000 period, indicate a mean annual value of about 620 mm, with a maximum of near 90 mm in January and about 5 mm in July.

The "Scillato" is a small piggy-back basin (Abate et al. 1999) extending for about 24 km^2, having a syncline structural setting and being infilled with fluvio-delta and marine deposits of Terravecchia Fm. (Upper Tortonian – Lower Messinian). The Terravecchia Fm. is constituted by conglomerate, arenitic and silty clays facies, forming a multi-cycles sequence from alluvial clastic sediments to marine pelites. Their sedimentation was generally controlled by synsedimentary tectonic movements and migration of basement subsidence towards the north (Abate et al. 1999).

The geologic setting is responsible for structurally controlled slopes that, where the strata outcrops, are densely marked by linear water erosion landforms (both rills and gullies) which are ordered to form typical calanchi fronts, two of which are the sites of the monitoring stations hereafter called "Catalfimo" and "Ottosalme" (Fig. 1).

In spite of the lithological homogeneity, the two calanchi areas are characterized by different geomorphologic conditions: the "Catalfimo" site is mainly controlled by piping and gravitative surface processes, responsible for less shaped valleys and divides, where gullies trigger as a consequence of the roof pipe falling (Fig. 2); the "Ottosalme" site is a typical A-type calanchi area (Moretti & Rodolfi 2000) dominated by rill and pure gully erosion processes.

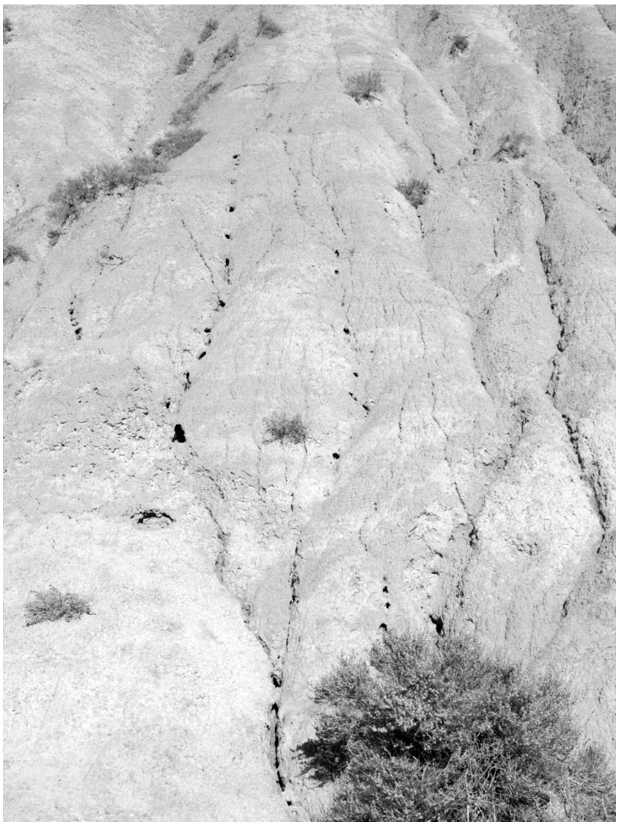

Fig. 2. Catalfimo area: example of linear water erosion landforms (rill and gully) and evidences of piping

Monitoring data – erosion pins

The erosion pins (Fig. 3) graded iron stakes 100 cm long, with a circular section having a diameter of 1.6 cm. Two grids of randomly distributed erosion pins were installed, one for the "Catalfimo" site made of 41 nodes, and one for the "Ottosalme" site made of 13 nodes (the "Ottosalme" site is characterized by a general homogeneity of the geomorphologic conditions). Readings at the erosion nodes, consisting in the estimation of the distance between the ground surface at the base of the erosion pin and a reference level marked on its points, so that errors produced by view top, have been remotely made by acquiring high resolution photographs from fixed view perspective changing effects could be neglected.

Measurements at the erosion pins have been carried out for 18 surveys, starting from the "zero measurement", on October 2006 up to the final survey on September 2008, and allowed to build a dataset of 972 readings.

By comparing the measurements acquired, for the same erosion pin, in different field surveys (Fig. 4), estimations of the point relative height (PRH) of the topographic surface have been derived.

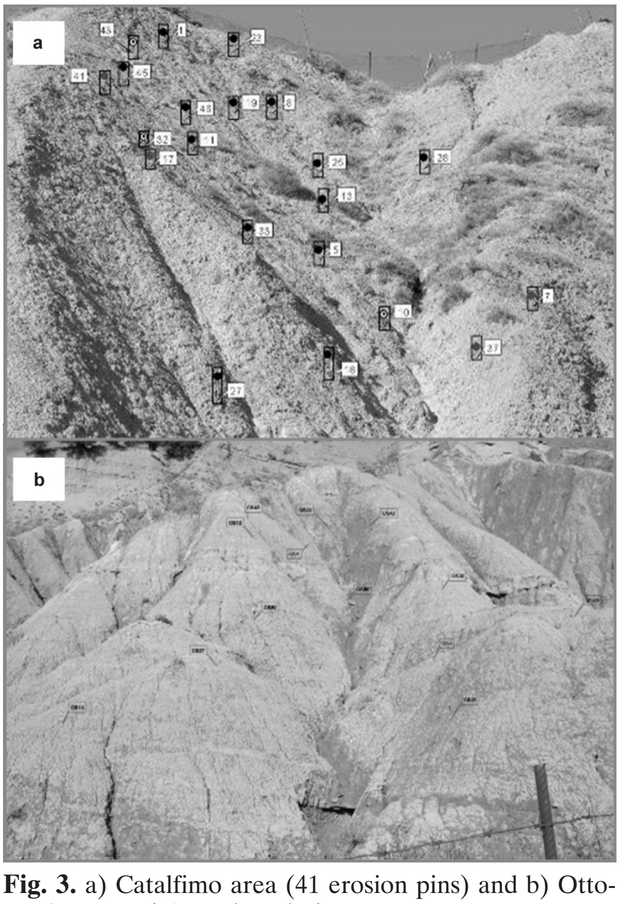

Fig. 3. a) Catalfimo area (41 erosion pins) and b) Ottosalme area (13 erosion pins)

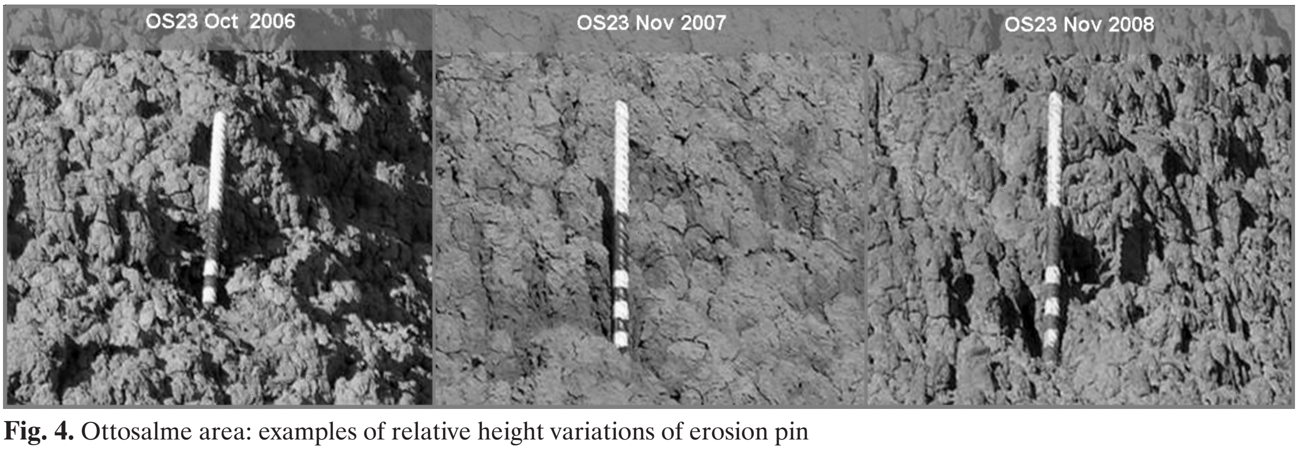

Fig. 4. Ottosalme area: examples of relative height variations of erosion pin

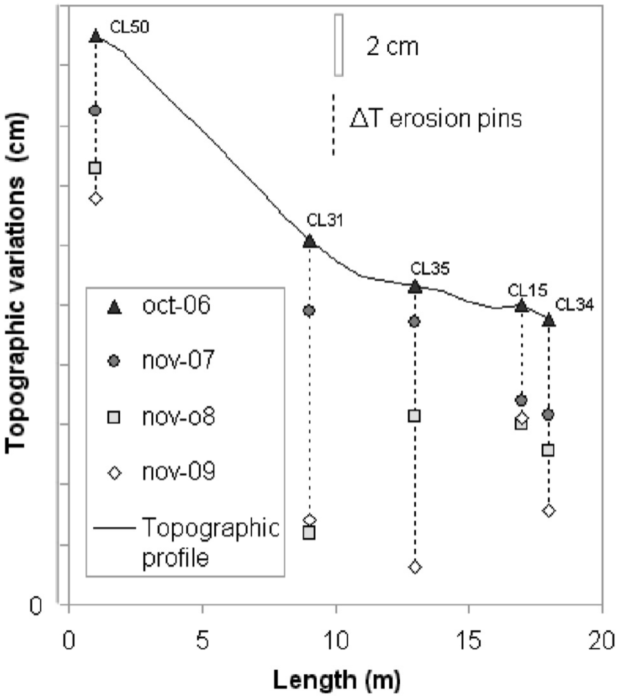

Fig. 5. Ottosalme area: examples of relative height variations of erosion pin

Generally, the PRH signals from the erosion pins (Fig. 5) are characterized by at least two components: a seasonal component, showing an unambiguous trend (erosion, lowering of the ground surface, i.e. negative seasonal PRH, or accumulation, raising of the ground surface, i.e. positive PRH); a higher frequency (in same cases, half-seasonal) component, describing erosion and accumulation morphodynamic phases.

Although during a single season, erosion pins can be affected by erosion and accumulation (Table 1), "negative" and "positive" pins have been distinguished, depending if the annual balance was a loss or gain of soil. Erosion and accumulation annual trends have been evaluated separately for the top, medium and foot portions [better segments] of the slopes.

During the first period (Oct 06–Nov 07), a number of erosion and accumulation cycles have been observed, producing a negative (erosion) final balance of 1.93 cm for "Catalfimo" station and 1.72 cm for "Ottosalme" station; the latter didn't show pins characterized by accumulation at the end of this season.

The second period was characterized by a more enhanced erosion trend, expressed by final more enhanced negative values of 3.5 cm and 3.77 cm, respectively). Again, any of the "Ottosalme" pins showed a "positive" balance.

Monitoring data – rainfall

During the monitoring period, a gauge station has been recording rainfall (Fig. 6). A total number of 27 erosive events has been distinguished, for which *Re* values have been computed by adopting the equation (Bagarello & Ferro 2006):

Table 1. Synthetic data for "negative" (erosion) and "positive" (accumulation) pins

Nov 06–Oct 07			Nov 07–Oct 08		
Location and portions of the slopes	Mean erosion rate (cm)	Overall mean erosion rate (cm)	Location and portions of the slopes	Mean erosion rate (cm)	Overall mean erosion rate (cm)
Catalfimo (Top)	1		Catalfimo (Top)	3.02	
Catalfimo (Medium)	1.25	1.93	Catalfimo (Medium)	2.68	3.5
Catalfimo (Foot)	2.12		Catalfimo (Foot)	4.11	
Ottosalme (Top)	1.64		Ottosalme (Top)	4.61	
Ottosalme (Madium)	1.6	1.72	Ottosalme (Medium)	3.47	3.77
Ottosalme (Foot)	1.52		Ottosalme (Foot)	3.12	
Nov 06–Oct 07 Accumulation trend			Nov 07–Oct 08 Accumulation trend		
Location and portions of the slopes	Mean accum. rate (cm)	Overall mean accum. rate (cm)	Location and portions of the slopes	Mean accum. rate (cm)	Overall mean accum. rate (cm)
Catalfimo (Top)	1.88		Catalfimo (Top)	2.63	
Catalfimo (Medium)	1.45	1.67	Catalfimo (Medium)	0.4	2.07
Catalfimo (Foot)	1.27		Catalfimo (Foot)	0	
Ottosalme (Top)	0		Ottosalme (Top)	0	
Ottosalme (Madium)	0	0	Ottosalme (Medium)	0	0
Ottosalme (Foot)	0		Ottosalme (Foot)	0	

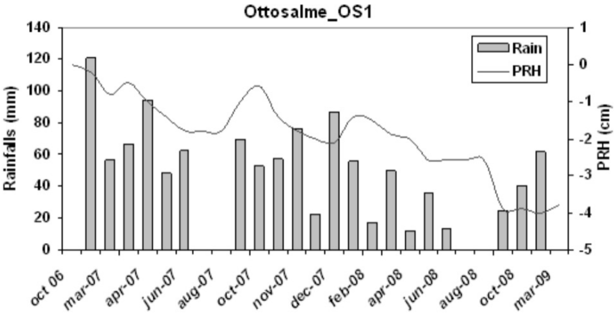

Fig. 6. Rainfall data from the rain gauge station and PRH of an erosion pin (OS1) of Ottosalme area

$$R_e = E_{I30} \text{ (MJ mm ha}^{-1}\text{ h}^{-1}) \quad (1)$$

The 27 R_e data obtained (Fig. 7) are quite similar to values observed in Sicily (Bagarello & Ferro 2006), with the exception of a few peak events occurred in June, October and November. In order to estimate annual R_e values, the rainfall data have been divided in two hydrological seasons (Nov 06–Oct 07 and Nov 07–Oct 08) and the R_e values of events falling inside the two periods were added, obtaining respectively: 943.2 MJ mm ha^{-1} h^{-1} (Nov 06–Oct 07) and 1,471.9 MJ mm ha^{-1} h^{-1} (Nov 07–Oct 08).

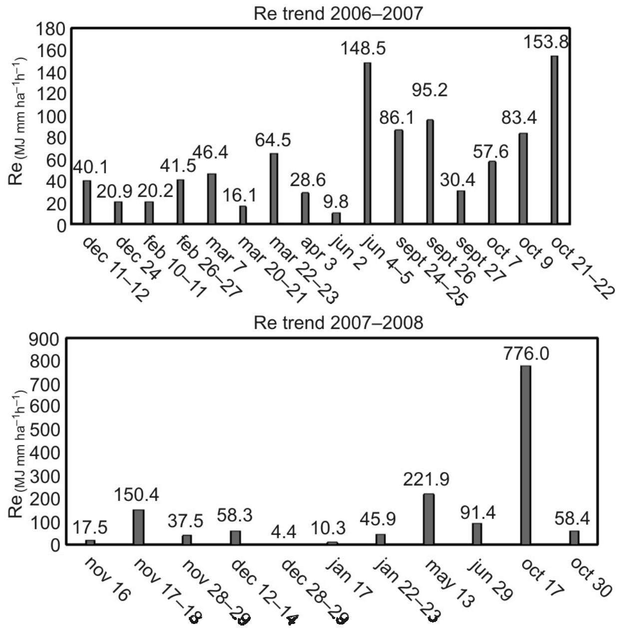

Fig. 7. R_e values from the rain gauge station

Results and discussion

The research has pointed out how, on a short temporal scale, the evolution of the monitored calanchi slopes is characterized both by erosion and deposition phases, whose final net result is congruent with a general erosive re-treatment trend (more than 2.5 cm yr^{-1} at the head of the front).

The morphodynamic phases and the whole evolution of the slopes are controlled by rainfall temporal trend, mineralogical and geotechnical properties of the outcropping rocks, topographic features of the slopes and superimposition of phenomena like and piping.

In conclusion, the applied monitoring method allowed to quantify punctual relative height variations of the calanchi surface, characterized by similar physiographic features and mineralogical properties that weakly change; and general correspondence between rainfalls temporal trends and surface variation rhythms has been observed.

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