GULLY EROSION IN CENTRAL ITALY: DENUDATION RATE ESTIMATION AND MORPHOEVOLUTION OF *CALANCHI* AND *BIANCANE* BADLANDS

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1. Introduction

Long lasting geomorphological researches (Ciccacci et al., 1981, 1986, 2003; Del Monte et al., 2002; Del Monte, 2003; Della Seta et al., 2006) allowed the evaluation of denudation rates in some of the major catchments of Central Italy. It was observed a noticeable spatial variability of the *denudation index* (*Tu*) values (Ciccacci et al., 1981, 1986) and field monitoring suggested that gully erosion at badlands is likely to afford the major contribution to overall denudation at catchments scale.

This paper summarizes the original results of the last three years of researches, performed on Tevere, Paglia and Ombrone river basins. By thickening field monitoring, it was evidenced as well a variability of denudation rates among sharp- and rounded-edged badlands (*calanchi* and *biancane*), according to their different morphoevolution.

2. Denudation rate estimation

Denudation rates were indirectly estimated at the catchment scale in terms of suspended sediment yield (*Tu*). *Tu* was calculated using the equations (1) and (2) computed by means of morphometric parameters (Horton, 1945; Strahler, 1952; 1957; Avena et alii, 1967; Lupia Palmieri, 1983):

$$\log Tu = 1.05954 + 2.79687 \log D + 0.13985\Delta a \qquad (1)$$

with $D \geq 6$

$$\log Tu = 1.44780 + 0.32619D + 0.10247\Delta a \qquad (2)$$

with $D < 6$

Ciccacci et al. (1981, 1986) experimentally derived these equations: they found that values of measured suspended sediment yield at the outlet of several Italian catchments showed the best simple statistical correlation with *drainage density* (D) and even better multiple correlations with D and *hierarchical anomaly index* (Δa). On the contrary, measured *Tu* values didn't correlate with climatic parameters p^2/P (Fournier, 1960) and $P \times \sigma$ (Ciccacci et al., 1977).

The *denudation index map* of Fig. 1a shows the strong spatial variability of the indirectly estimated *Tu* values, which range between 100 e 6000 t/km?/year. The highest values pertain to small catchments widely affected by *calanchi* and *biancane* badlands. As shown in Fig.1b, field monitoring at the hillslope scale was performed using iron pins (Del Monte, 2003; Della Seta et al., 2006) suitably placed to record sheet, rill and gully erosion on clayey deposits. Earth micro-pyramids (naturally formed or induced by placing coins on the soil surface) provided further data. Uphill and downdale differences in the topographic surface measured at each station provided denudation plots showing a step-like trend (example given in Fig. 1c), with critical denudation periods triggered by rainfall events several days long. We identified a rough minimum rainfall threshold of *70 mm per 6 consecutive days* as possible trigger of critical soil losses (higher than 2 cm). On the contrary, even strong, single-day events were not followed by drops in the denudation graph.

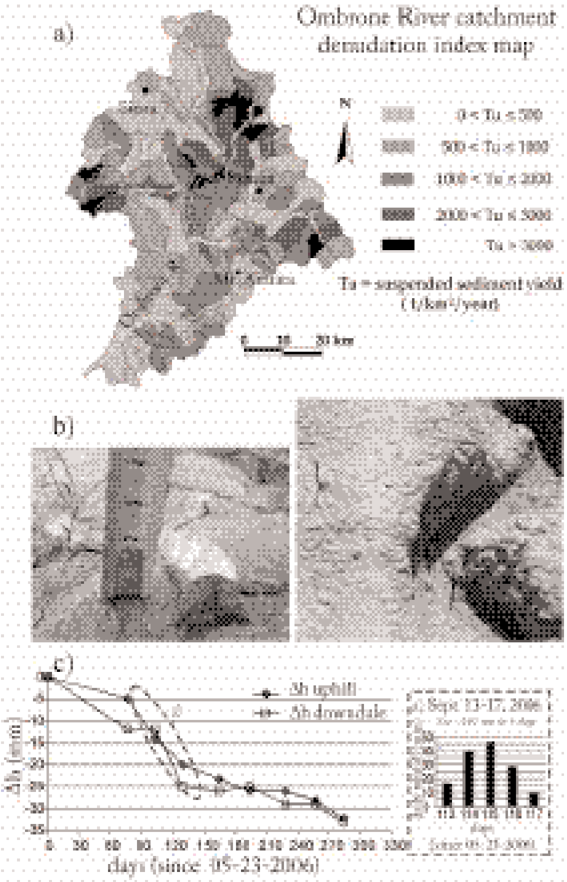

Fig. 1. Denudation rate estimation. Indirectly estimated *denudation index* (*Tu*) (a) and direct field monitoring (b). The sample plot shows the monitored denudation trend within the above gully, compared to a critical rainfall event (c).

Point measures on rapidly evolving slopes provided considerable mean denudation rates ranging from 1-2.5

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cm/year at *calanchi* badlands to 4-5 cm/year at *biancane* badlands.

Differences in the morphoevolution of these two badland types might partly explain this denudation rate variability.

3. Morphoevolution

Data from long lasting slope monitoring suggest that the development of either *calanchi* or *biancane* badlands is strictly connected to slope steepness (S). In particular, sharp-edged *calanchi* badlands develop on scarp slopes (S=30% to 50%) and their growth is supported by caprocks at the summit (Fig. 2a). Rounded-edged *biancane* are small clay domes up to about ten meters high, mostly uncovered on the southern (generally steeper) slope where denudation is particularly strong (Fig. 2b). They are typically located near the hills foot as well as at the summit of steep *calanchi* slopes and their distribution is always associated to gentle gradients (S=15% to 30%). Occurrence of *biancane* at the summit of *calanchi* slopes made us exclude that they could represent residual landforms, as proposed by some Authors (Del Prete et al., 1997).

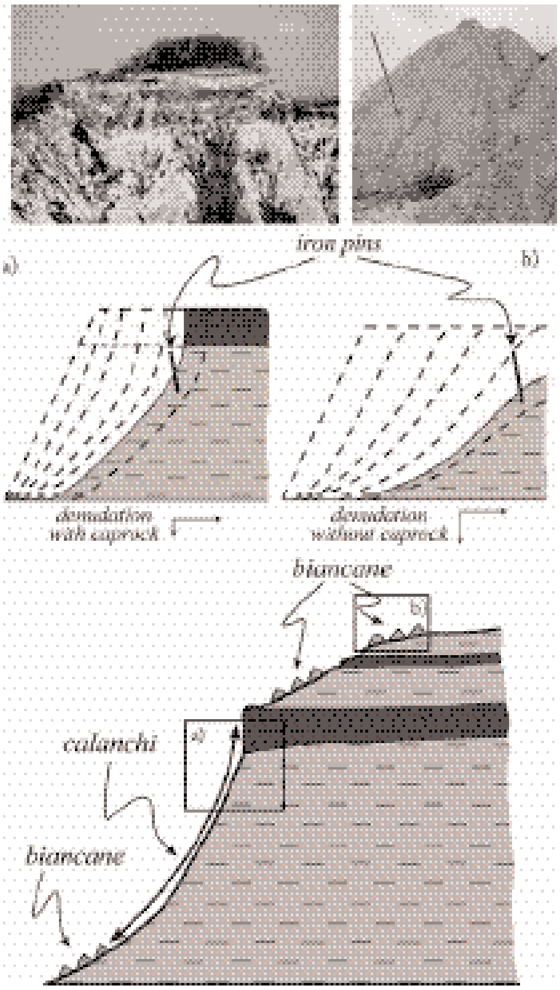

Fig. 2. Distribution of sharp-edged (*calanchi*) and rounded-edged (*biancane*) badlands. Morphoevolutive sketches are shown in (a) and (b) (modified after Scheidegger, 1964).

These two landform types are more probably the results of quite different morphoevolutive trends (Fig. 2a-b): *calanchi* slopes evolve by substantial parallel retreat, helped by caprocks, whereas *biancane* slopes undergo a progressive steepness decrease, according to the Scheidegger's model (Scheidegger, 1961, 1964). The greater vertical component of denudation on *biancane* slopes, with respect to the *calanchi* ones, can partly justify their higher mean denudation rates recorded at pins (up to 5 cm/year; see plot in Fig. 1). Moreover, on steeper *calanchi* slopes, landsliding may contribute to in site effects of denudation (Fig. 2a) by frequent mud flows and earth slides damaging iron pins. On the contrary, on gentler *biancane* slopes sheet, rill and gully erosion processes afford the major input to denudation.

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