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Trends in gully erosion as evidenced from repeat photography (North Ethiopia)

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Abstract: Repeat photography offers a valuable tool for assessing gully erosion development over the past 140 years in North Ethiopia. From a dataset of 57 repeated historical photographs that display gully cross-sections, this study demonstrates that a gully incision phase took place in the second half of the 20th century. At present, thanks to the successful implementation of soil and water conservation measures, most gullies are stabilizing.

Keywords: gullies, North Ethiopia, repeat photography

Introduction

In the semi-arid highlands of North Ethiopia, dense gully networks dissect the landscape, with gully depth and width frequently exceeding 5 and 15 m respectively (Frankl et al. 2011). Here, gully erosion is linked to the vulnerability of the landscape, the rainfall intensity and variability, and the land use/cover changes induced by high population density. Over the past 140 years – since the time that photography provided the first unequivocal evidence of gullying – gullies became widespread and nowadays present a serious problem to humans and the environment.

Network expansion and channel widening go together with mass wasting acting on the gully channel walls and potentially threaten human live. The channels are an obstacle for agriculture, while the depressed water tables that surround them reduce agricultural production. Severe landscape dissection leads to the disconnection of rural areas and to the destruction of infrastructure. In the valley bottoms, the gully erosion and efficient runoff concentration in the headwaters cause flooding and water pollution by sediment, endangering human live and health.

Understanding trends in gully erosion, and the relation to changes in its triggers, is important for sustainable development in north Ethiopia. This is especially true as most Ethiopians rely on land resources for their livelihood, in a subsistence economy where food security is low and threatened by drought.

Methodology

In order to assess the evolution of gully channels at large spatial units and long time scale, a set of 57 historical photographs taken in Tigray, dating between 1868 and 1994 (Table 1) and clearly displaying gully cross-sections were precisely repeated in 2006–2009: 34 paired photographs were analyzed visually and 22 quantitatively by measuring cross-sections on the photographs and by calibrating these cross-sections with field measurements (Fig. 1).

Table 1. Historical photographs used in the qualitative and quantitative analysis (n = 57)

Year	Authors (and source of the photographs)	Quantitative analysis	Qualitative analysis
1868	Royal Engineers (KingsOwn Museum, Lancaster, U.K.)	1	4
1895	Unknown photographer (Publifoto – Olycom)		1
1935	Unknown photographer (Corbis)		1
1936	Unkown Italian photographer	1	
1939	Maugini (Istituto Agronomico per l'Oltremare, Firenze, I)		5
1942	Unknown photographer (Getty Images)	1	
1944	David Buxton (Cambridge University)		2
1961	Dick Grove (private collection)		1
1970–1971	Ernesto Abbate (Merla et al. 1979)		2
1974–1975	Tigray Rural Development Study group (Neil Munro, Graham Edgeley, Vernon Robertson, Keith Virgo, Rita Ions)	16	15
1994	Francesco Dramis (private collection)	4	3
	Total	23	34

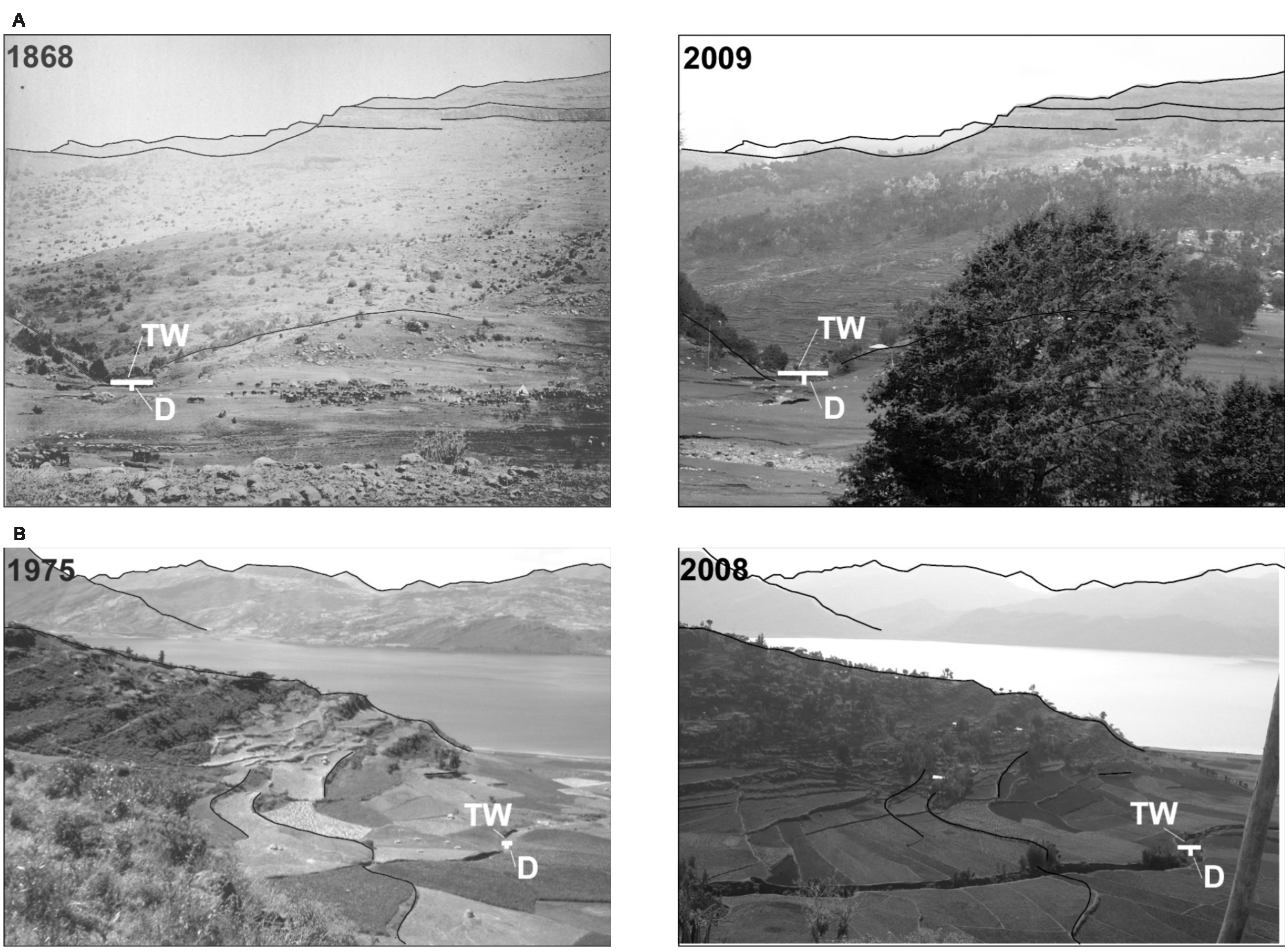

Fig. 1. Examples of gully cross-section quantification using repeat photography: A. View over the valley of Seytan (Bolago), original photograph taken by the Royal Engineers (obtained from the KingsOwn Museum, Lancaster, U.K.); B. View over Lake Ashenge, original photograph taken by Neil Munro. The black lines are stable morphological features that were drawn on the historical photograph and that were used to rotate and rescale the repeated photographs in Adobe IllustratorTM. *TW* = top width and *D* = depth

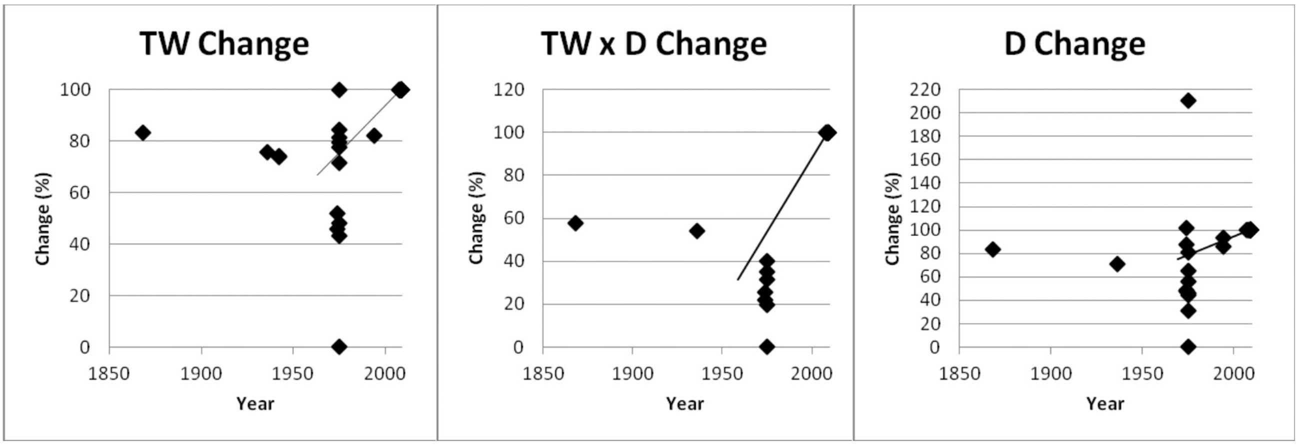

Fig. 2. Trends in gully cross-section properties: *TW* – top width, *D* – depth; Current (2006–2009) channel dimensions are taken as reference values (100%)

Results and discussion

Ninety two percent of the gullies (n = 38) increased in cross sectional area over the studied period. Quantitative analysis indicates that the increase in gully cross sectional area essentially occurred over the past 35 years.

The gullies displayed on photographs of 2006–2009, have cross-sections that have enlarged relative to their present cross-section with a median area of 72.4% as compared to 1974–1975 (n = 6). Twelve gullies out of fourteen have increased in depth relative to their current depth with a median of 34.5% as compared to 1974–1975, while for the median width this increase for 9 widths (out of 10) is 28.6% (Fig. 2).

The findings based on repeat photography were refined with evidence from interviews and geomorphic observations, indicating that the increase in gully cross-sections can mainly be situated before the 1990s (Frankl et al. 2011). Thereafter, gully erosion rates decreased because of the large-scale implementation of soil and water conservation activities (Nyssen et al. 2008). At present, most gullies are stabilizing. For two catchments repeatedly photographed between 1936 and 2009 (see Frankl et al. 2011), the major phases in gully development could be documented in detail. Here, gullies were already common features of the landscape prior to 1963–1965, but no changes occurred in network expansion. From then on, gully networks expanded quickly, reaching a maximum density in 1975 which is similar to the present. Then, the major channel changes occurred though an increase in cross-sectional area which reached a maximum in the 1990s. Over the last two decades, stabilization took place.

Conclusions

Since the second half of the 20th century a gully incision phase took place in the North Ethiopian highlands, which is now reversing into a human-induced gully 'fill' cycle. This research therefore validates previous studies indicating a fast degrading environment in Northern Ethiopia (e.g., Billi & Dramis 2003; Dada et al. 2003; Nyssen et al. 2004), but emphasizes that recent environmental rehabilitation is taking place.

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