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Accuracy of methods for field assessment of rill and ephemeral gully erosion

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Abstract

To properly assess soil erosion in agricultural areas, it is necessary to determine precisely the volume of ephemeral gullies and rills in the field by using direct measurement procedures. However, little information is available on the accuracy of the different methods used. The main purpose of this paper is to provide information for a suitable assessment of rill and ephemeral gully erosion with such direct measurement methods. To achieve this objective: a) the measurement errors associated to three methods used for field assessment of channel cross sectional areas are explored; b) the influence of the number of cross sections used per unit channel length on the assessment accuracy, is analysed and; c) the effect of the channel size and shape on measurement errors is examined. The three methods considered to determine the cross sectional areas were: the micro-topographic profile meter (1); the detailed measurement of section characteristic lengths with a tape (2); and the measurement of cross section width and depth with a tape (3). Five reaches of different ephemeral gully types 14.0 or 30.0 m long and a set of six 20.4 to 29.4 m long rill reaches were selected. On each gully reach, the cross sectional areas were measured using the three above mentioned methods, with a separation (s) between cross sections of 1 m. For rills, the cross sectional areas were measured with methods 1 and 3, with $s = 2$ m. Then, the corresponding total erosion volumes were computed. The volume calculated with method 1 with $s = 1$ m for gullies and $s = 2$ m for rills was taken as the reference method. For each channel, and for each one of the possible combinations of s and measurement method (m), the relative measurement error and the absolute value of the relative measurement error (E^r_{sm} and $|E^r_{sm}|$), defined with respect to the reference one, was calculated. $|E^r_{sm}|$ much higher than 10% were obtained very easily, even for small s values and for apparently *quasi* prismatic channels. Channel size and shape had a great influence on measurement errors. In fact, the selection of the more suitable method for a certain gully shape and size seemed to be much more important than s, at least when $s < 10$ m. Method 1 always provided the most precise measurements, and its results were the less dependent on s. However, s must be <5 m to guarantee an error smaller than 10%. Method 2 is not recommended, because it is difficult, time consuming and can lead to large errors. Method 3 seems to be enough for small, wide and shallow gullies, and for small rills, but only if s is shorter than 5 m. Results obtained after the analysis of rill measurement errors were similar to those of gullies. The analysis of E^r_{sm} and $|E^r_{sm}|$ when calculating channel volumes using a unique representative cross section highlighted the importance of correctly selecting the adequate cross section. Due to the high error values that this method can entail, it is not considered as advisable whenever accurate erosion measurements are pursued.

Keywords: Ephemeral gully erosion; Rill erosion; Field assessment; Assessment methods; Accuracy of methods

1. Introduction

Ephemeral gullies are channels of various sizes, formed by the scouring of concentrated surface runoff flowing on agricultural soils during rain events, refilled by the farmers usually shortly after the rains, but often reappearing in the next rainy season (Foster, 1986; Thorne et al., 1986; Zheng and Huang, 2002). Rill erosion (Foster, 1986; Bryan, 1987; Flanagan, 2002) consists on the development of numerous minute closely spaced channels resulting from the uneven removal of surface soil by running water that is concentrated in streamlets of sufficient discharge and velocity to generate cutting power. It is an intermediate process between sheet

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erosion and gully erosion (Jackson, 1997). While the presence of rills is restricted to planar elements of watersheds, ephemeral gullies occur on valley bottoms, within swales. Ephemeral gullies and rills are common in cultivated soils in many areas around the world, and can cause large soil losses (Bryan, 1987; Govers and Poesen, 1988; Benito et al., 1992; Auzet et al., 1993; Bennett et al., 2000; De Alba and Benito, 2001; Zheng and Huang, 2002; Poesen et al., 2003; De Santisteban et al., 2004).

Considering the importance of this erosion types, measurement methods to precisely determine the volume of rills and ephemeral gullies are required. Methods based on the assessment of a number of cross sectional areas with micro-topographic profilers, or with a tape or ruler along the channels, have been, and still are, widely used (Spomer and Hjelmfelt, 1986; Govers, 1987; Govers and Poesen, 1988; Govers, 1991; Auzet et al., 1993; Smith, 1993; Ludwig et al., 1995; Vandaele and Poesen, 1995; Casalí et al., 1999; Bennett et al., 2000; Nachtergaele et al., 2001a,b; De Santisteban et al., 2004). In fact, direct assessment is often essential, because it can be very precise, simple and low-cost compared with other methods, which in turn require direct assessments for validation purposes. Accurate ground measurements are difficult, costly and time consuming. Therefore, authors have been forced to use approximated cross section and/or volume measurement methods. Authors very rarely provide information on probable errors that can be associated to each method.

The main purpose of this paper is to provide information and guidance for a suitable assessment of rill and ephemeral gully erosion with methods based on the direct assessment in the field of cross sectional areas with micro-topographic profilers, or with a tape or ruler along the channels. Such information will be also of interest for a better application of other methods, like classical topographic surveys or photogrammetry. To achieve this objective: a) the measurement errors associated to three of the methods frequently used for direct assessment in the field of rill and ephemeral gully cross sectional areas are explored; b) the influence of the cross section density, i. e., the number of cross sections used per unit of channel length, on the assessment accuracy, is analysed and; c) the effect of the channel form (Imeson and Kwaad, 1980) on measurement errors is examined. The three methods considered to determine the cross sectional areas were: the micro-topographic profile meter (1); the detailed measurement, with a tape, of section characteristic lengths (bottom width, top width, heights, bank lengths and slopes, etc.), trying to take into account the complex cross section geometry (2); and the measurement with a tape of cross section width and depth (3).

Table 2
Some characteristics of the rill reaches

Rill number	L (m)	WDR_A	A_A (m^2)	W_A (m)	A_{cv}	Soil type and use
1	20.4	5.67	0.0152	0.25	0.33	Loam, fallow after vineyards
2	21.3	5.43	0.0136	0.24	0.36	Loam, fallow after vineyards
3	23.0	3.93	0.0131	0.20	0.36	Loam, fallow after vineyards
4	29.4	5.03	0.0123	0.23	0.36	Loam, fallow after vineyards
5	29.4	6.21	0.0108	0.22	0.53	Loam, fallow after vineyards
6	22.3	4.93	0.0117	0.22	0.36	Loam, fallow after vineyards

L: rill reach length; WDR_A: average width–depth ratio (Poesen and Govers, 1990) of each rill for a distance s between adjacent cross sections of 2 m; A_A: average cross sectional area of each rill for $s=2$ m; W_A: average cross section upper width of each rill for $s=2$ m; A_{cv}: cross section area variation coefficient of each rill for $s=2$ m.

2. Area descriptions, methods and materials

Five 14.0 or 30.0 m long reaches of different ephemeral gully types were selected for this study, trying to cover a wide range of channel forms (Table 1). The study sites were located in the town councils of San Martín de Unx and Beire, in Central Navarre (Spain) (De Santisteban et al., 2004). On the other hand, a set of six 20.4 to 29.4 m long rill reaches was selected. Rills appeared quite uniformly distributed over a vineyard field located in the town council of Tafalla (Central Navarre). Rill affected area corresponded to a steep slope of approximately 2000 m^2. The main characteristics of the selected rills are summarised in Table 2.

The three methods used for cross section characterization and the procedure to calculate the volume of eroded soil are described below. In all cases, for upper cross section width definition, only points with evidence of recent water erosion were considered.

Micro-topographic profiler (1) (Sancho et al., 1991; Casalí et al., 1999; De Santisteban, 2003). Cross-section

Table 1
Some characteristics of the gully reaches

Gully name and group	L (m)	WDR_A	A_A (m^2)	W_A (m)	A_{cv}	Soil type and use
Navafría 2, I	30.0	12.39	0.0215	1.00	0.43	Loam, fallow after vineyards
Navafría 1, I	30.0	6.82	0.0584	0.70	0.30	Loam, fallow after vineyards
Lakar 1, II	14.0	4.49	0.0604	0.70	0.38	Loam, vineyards
Lakar 2, II	14.0	3.48	0.0477	0.40	0.23	Sandy loam, fallow after vineyards
Beire, II	14.0	2.21	0.1208	0.60	0.27	Not available, not cultivated

L: gully reach length; WDR_A: average width–depth ratio (Poesen and Govers, 1990) of each gully for a distance s between adjacent cross sections of 1 m; A_A: average cross sectional area of each gully for $s=1$ m; W_A: average cross section upper width of each gully for $s=1$ m; A_{cv}: cross section area variation coefficient of each gully for $s=1$ m.