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Soil erosion in the Swiss midlands: Results of a 10-year field survey

Volker Prasuhn *

Research Station Agroscope Reckenholz-Tänikon ART, Reckenholzstrasse 191, CH-8046 Zurich, Switzerland

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ABSTRACT

Long-term field monitoring of soil erosion by water was conducted on arable land in the Swiss midlands. All visible erosion features in 203 fields were continuously mapped and quantified over 10 years. The eroded soil volume associated with linear erosion features was calculated by measuring the length and cross-sectional area in rills at representative positions and the extent of interrill erosion was estimated. Averaged across the 10 study years, just under one-third (32.2%) of the fields exhibited erosion. With 0.75 t ha^{-1} yr^{-1} (mean) and 0.56 t ha^{-1} yr^{-1} (median), the average annual soil loss of the region was relatively small. The year-to-year variation in soil loss of the region was great and ranged from 0.16 to 1.83 t ha^{-1} yr^{-1}. The maximum annual soil erosion in a single field was 96 t yr^{-1} or 58 t ha^{-1} yr^{-1}, thus demonstrating that only a few erosion events on a few fields may decisively contribute to the total extent of soil erosion in a region. Linear and interrill erosion accounted for 75% and 25% of total soil loss, respectively. Wheel tracks, furrows, headlands, and slope depressions were important on-site accelerators of erosion. Run-on from adjacent upslope areas was an important trigger of erosion. Of the soil moved by erosion, 52% was deposited within the field of origin. A high proportion (72%) of the linear erosion features caused off-site damage. Part of the total eroded soil (20%) was transported into water, thereby contributing to their contamination. The long-term field assessment of soil erosion helps to fill existing knowledge gaps concerning temporal and spatial variability of soil erosion on arable land, the extent and severity of soil erosion and its sources and causes, as well as subsequent off-site damage.

1. Introduction

Soil erosion is the most widespread form of soil degradation in Europe and is one of the major environmental threats (Van Camp et al., 2004). Currently, modeling is the most popular method for evaluating soil erosion (Van Dijk et al., 2005), but most soil erosion models are based on results from test plot experiments and have not been validated by soil erosion data from farmers' fields. Cerdan et al. (2006) reviewed data from 208 test plots at 57 experimental sites in 13 European countries, on which the extent of rill and interrill soil erosion was assessed, and found a mean erosion rate of 8.8 t soil ha^{-1} yr^{-1}. Auerswald et al. (2009) analyzed results from all available test plot experiments conducted in Germany under natural rainfall conditions (416 plot-years) and found a standardized soil loss of 15.2 t ha^{-1} yr^{-1} for arable land. However, erosion rates determined on test plots have been reported to be two to ten times higher than those measured in farmers' fields (Poesen et al., 1996; Boardman, 2006). Test plot studies only provide limited information on the frequency and intensity of rill erosion and the factors controlling the between-field and within-field variations (Govers, 1991; Evans, 2002). Therefore, soil erosion rates measured on test plots do not realistically reflect total erosion in a catchment or landscape and they do not satisfactorily indicate the redistribution of eroded soil within a field (Poesen et al., 2003).

Verheijen et al. (2009) reviewed measured erosion rates in Europe for different types of erosion (water, wind, tillage, crop harvesting, and slope engineering). Even though various authors (Evans, 1993, 2005; Boardman, 2003, 2006) have pointed out the importance of large-scale field studies for determining soil erosion precisely, most estimates are still based on test plot measurements or models. One reason for this may be that many researchers consider this method to be “not scientific” (Boardman, 1996) or an “out-of-fashion inductive approach” (Boardman, 2003). On the other hand, it is undisputed that gully and ephemeral gully erosion, which are of great importance in the Mediterranean area, can be assessed with the help of field surveys, which may be supplemented by high-resolution aerial photographs (Vandaele et al., 1997; Vandekerckhove et al., 1998; Valcárcel et al., 2003; Zucca et al., 2006).

Table 1 shows results from some of the recent European erosion monitoring studies. Although indicated so in the table, the figures are not fully comparable due to different methods applied, missing information, unique situations, and considerable variability in space and time (Boardman, 1998). It should be noted that most measurements are volumetric and the results were converted to mass units using a single value of dry bulk density of the soil, which was not measured. Evans (2005) showed that estimates of average erosion rates are highly dependent on the method used. Poesen et al. (1996)

* Tel.: +41 44 3777145; fax: +41 44 3777201.
E-mail address: volker.prasuhn@art.admin.ch.

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Table 1
Soil erosion rates from field monitoring schemes in European countries in alphabetical order.

Location	Year	Period	Area (ha)	Number fields observed per year	Soil loss total amount (t)	Soil loss mean (t ha^{-1})	Soil loss median (t ha^{-1})	Soil loss max. (t ha^{-1})	Reference
Austria	2002	1 event	290	16	734[*1]	2.5[*1b]		226[*]	Strauss and Klaghofer, 2004
Belgium, loam belt	1982–85	3 winter		86		3.6[1]			Govers, 1991
Belgium, loam belt	1989–91	2 years	170, 2 locations		104[*1]/380[*1]	1.04[*1]/1.58[*1]			Vandaele, 1993
Belgium, loam belt	1989–92	3 years	50, 2 locations		1300[*]	8.7[*]			Vandaele and Poesen, 1995
Belgium, loam belt	1996/97	1 event	269		11,256[3]	41.9[3]		194	Takken et al., 1999
Belgium, loam belt	1997	1 event	250		4160[3]	16.6[3b]			Steegen et al., 2000
Belgium, loam belt	1997–99	2 years		58	4640[*2]	80.0[*2a]			Nachtergaele et al., 2001
Denmark	1994–99	6 years	20 locations	189		0.6[*1b]	0.7[1a]	37	Schjønning et al., 2009
Germany, Lower Saxony	2000–08	9 years	400, 7 locations	72	4680[*]	1.3[1b] 2.2[3b]	0.75[3b]	52.2	Mosimann et al., 2009
France, Normandy	1999/2000	2 events	94		1066[*3]/216[*3]	11.3[3]/2.3[3]			Cerdan et al., 2002
France, Alsace	2001	1 event	420	80	15,000[3]	36.0[b]			Van Dijk et al., 2005
France, northern	1988/89	1 winter	680, 20 locations		1560[*1]	3.4[*1] (range 0–9.1[*])			Auzet et al., 1993
France, northern	1988/91	3 winter	680, 20 locations	600	4862[*1]	2.4[*1] (range 0–15.2[*])			Auzet et al., 1995
France, northern	1989/92	3 winter	1130, 35 locations	470	5540[*1]	1.6[*1] (range 0–15.3[*])			Ludwig et al., 1995
Italy, Tuscany	1984–87	3 years	450	22		18.8[1]		192	Herweg, 1988
Norway, south-eastern	1990	1 event	71, 3 locations	23	3228[1]	56.0[1a]	25.5[1a]	411	Øygarden, 2003
Portugal, north-east	1995/96	5 month	0.5–4.1, 4 locations			10.3–54.0[*2]			Vandekerckhove et al., 1998
Spain, north-west	1997–99	2 years	36.8, 13 locations	39		0.05–4.2[*2b]		64.9[*]	Valcárcel et al., 2003
Sweden, south	1986–89	3 winter	ca. 900, 3 locations	935		0.04[3b]	0.83[1a]	120	Alström and Bergman Åkerman, 1992
Switzerland, Jura	1987–99	12 years	64.6	128	249	0.4[*3b]		22.5	Ogermann et al., 2003
Switzerland, pre alps	1981–82	2 years	148, 2 locations		151[*]	0.4		20	Rohrer, 1985
Switzerland, loess/gravel	1975–87	12 years	185, 2 locations			5.0/0.3[3b]		95	Schaub, 1989
Switzerland, Jura	1978–90	12 years	29.5	60	440[3]	1.45[3b]		15.9	Prasuhn, 1991
Switzerland, central	1986–89	3.5 years	680	716		2.7[1a]		400	Mosimann et al., 1990
Switzerland, west	1987–88	2 years	378	189		2.4[1a] 0.43[3b]		13	Mosimann et al., 1990
Switzerland, central	2005–06	1 year	734, 3 locations	780		0.7–2.3[3b]			Ledermann et al., 2008
Switzerland, central	1998–2007	10 years	265	203	1969[3]	0.75[3b]	0.56[3b]	58	this study
UK, England and Wales	1982–84	3 years	70,900, 17 locations	298			1.0[*2] (range 0–10.3)		Boardman, 1998
UK, England and Wales	1982–86	5 years	70,840, 17 locations	340	ca. 1700	0.7–6.2[*a] 0.003–0.45[*b]	0.26–4.7[*a]	225[*]	Evans, 1993, 2002, 2005
UK, England and Wales	1982–86	5 years	11 locations	240		0.61–6.27[a] 0.013–0.330[b]			Evans and Brazier, 2005
UK, England and Wales	1989–94	5 years	1130, 13 locations	77		17.0[1a]	<0.01–6.3[1b]	186[*]	Chambers et al., 2000; Evans, 2005
UK, England and Wales	1990–94	3.5 years	1131, 13 locations	92		4.2[1b] (range 0–11.0)	0.41[1b] (range 0–6.3)	143	Chambers and Garwood, 2000
UK, South Downs	1982–91	10 years	3600		24,553[*2]	2.1[2]	1.98[*2] (range 0.65–6.5)	263	Boardman, 2003; Boardman and Favis-Mortlock, 1993
UK, West Sussex	2006/07	1 winter	1620	54				234[*]	Boardman et al., 2009
UK, Scotland, north-east	1985–86	1 winter		11	654[*1]	8.7[*1]	3.2[*]		Watson and Evans, 1991

[*] = recalculated, soil volume multiplied with an assumed bulk density of 1.3 Mg m^{-3}.
[1] = rill erosion.
[2] = rill and gully erosion.
[3] = rill and interrill erosion.
[a] = fields with erosion.
[b] = all fields.