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On-farm effects of tillage and crops on soil erosion measured over 10 years in Switzerland

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ABSTRACT

The positive effects of soil conserving farming methods have mostly been demonstrated using small test plots. The present study is aimed at confirming that they also occur on the catchment scale. The impact of crops and soil tillage practises on the extent of soil erosion was determined in 203 crop fields over 10 years in the Swiss Midlands. Soil erosion totalled 1969 t or 0.75 t ha^{-1} yr^{-1}. Most erosion took place in winter wheat fields (33%), which accounted for 22% of the crop area. Second and third most erosion was observed in potato (26%) and fallow (14%) fields. By far the highest mean soil loss was found for potatoes, at 2.87 t ha^{-1} yr^{-1}. Fallow (1.06 t ha^{-1} yr^{-1}) and winter wheat (1.05 t ha^{-1} yr^{-1}) fields were also relatively susceptible to soil erosion. In contrast, values for soil loss below mean were observed for maize (0.44 t ha^{-1} yr^{-1}), sugar beet (0.27 t ha^{-1} yr^{-1}), and rape seed (0.39 t ha^{-1} yr^{-1}). 88% of soil erosion took place on plough tilled land (PT), 9% on non-ploughed land with less than 30% surface residue cover (RT), 1% on mulch-tilled land with more than 30% surface residue cover (MT), and 2% in non-tilled or strip-tilled land with >30% soil cover (NT). At 0.07 and 0.12 t ha^{-1} yr^{-1}, respectively, the mean soil loss in MT and NT fields was more than an order of magnitude lower than that under PT (1.24 t ha^{-1} yr^{-1}). Field mappings confirmed the positive effects of the soil conserving soil tillage practises. The risk of soil erosion was significantly influenced by crop rotation. The carry-over effects should be taken into account when studying the effects of cropping methods on soil erosion.

1. Introduction

Erosion has been considered to be one of the greatest threats to the world's agricultural soils (Montgomery, 2007a). Soil erosion may have adverse effects on the environment (i.e. water pollution, organic matter loss, reduction in water storage capacity) (Boardman and Poesen, 2006) and cause depressions in crop yield (Bakker et al., 2007). The extent of soil erosion is determined by numerous factors such as relief, soil type, precipitation, farming practises, etc. (Evans, 2002). While soil and relief characteristics of fields show little change from year to year, precipitation and farming practises may vary strongly over time. The time-dependent combined effects of precipitation and state of the crop fields with regard to the crop planted, soil cover, soil tillage, and soil looseness are crucial for soil erosion in any given area (Fiener et al., 2011).

Soil conserving tillage practises have been recognised as effective methods for controlling soil erosion (Derpsch et al., 2010; Lal et al., 2007). There is a great body of literature dealing with the effects of crops and farming practises on soil erosion. However, reports vary considerably with regard to the actual quantitative effects of management practises. Strauss et al. (2003) analysed 68 papers with 160 comparable results from plot trials in which soil erosion and runoff were determined under different soil tillage practises. On average, application of conservation tillage resulted in a reduction of soil loss of 60% (arithmetic mean) and 76% (median). Montgomery (2007b) summarised results from 39 experiments in which conventional tillage and no-till methods were compared directly and found that no-till practises reduced soil erosion 2.5 to >1000 times, with median and mean values of 20 and 488 times, respectively. Moreover, in his review of 153 publications, Evans (2006) showed that soil erosion can be strongly reduced by soil conserving tillage. Holland (2004) reviewed the literature about soil conservation tillage in Europe and concluded that there is considerable evidence that conservation tillage can provide a wide range of benefits to the environment.

It is possible to achieve satisfactory yields when soil conservation tillage methods are applied. Van den Putte et al. (2010) found that, on average (47 European studies, 563 observations), conservation tillage reduced crop yield by 4.5%. However, there is considerable variability in findings, with some studies reporting increased crop yields. There are great differences in the effects of tillage practises in the various studies. This is due to different methodological approaches, soil and site properties, and land

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management methods as well as a high degree of experimental error and the complexity of the processes involved.

For the sake of practicability, most experiments were carried out on relatively small test plots (Cerdan et al., 2010). This raises the question as to whether the results from such studies can be extrapolated to larger areas such as fields or catchments (Fiener and Auerswald, 2007; Leys et al., 2010). Holland (2004) also stated that, thus far, no detailed studies have been undertaken in Europe at the catchment scale. He concluded that some findings should be treated with caution until they are verified at larger scales. At the same time, there is a great need for experiments on larger areas, making it possible to till the soil with normal farm machinery. Furthermore, farmers' fields and homogenous small test plots may differ in runoff patterns because of tillage-induced surface roughness and complex relief situations (Takken et al., 2001).

Consequently, the major advantage of experiments involving complete fields is that it is possible to conduct measurements at the proper scale with realistic soil, climate, and relief conditions as well as soil and crop management practises (Stroosnijder, 2005). Long-term erosion damage mappings, as conducted by Evans (2002) and Boardman (2003) in Great Britain and Mosimann et al. (2009) in Germany, represent an appropriate tool for recording the temporal and spatial distribution of erosion in a region under real environmental and land management conditions. In Switzerland, erosion mappings have a long tradition that goes back to the early 1970s. Various long-term studies have been conducted since then (Prasuhn, 2011). However, since soil conserving tillage methods have gained popularity quite recently in Switzerland, there is little information about their effects on soil erosion (e.g. Hauert and Liniger, 2008).

Direct seeding has been considered as the most effective soil conservation method (Sturny et al., 2007). Worldwide, no-tillage farming was adopted on about 111 million hectare in 2009 (Derpsch et al., 2010). While no-till farming has widely spread in South America (on 47% of the total arable land), North America (28%), and Australia (11%) (Kassam et al., 2009), it still plays a small role in Europe (1.1%) (Basch et al., 2008). It is somewhat more popular in Switzerland (3% or 12,000 ha) than in the rest of Europe; in some regions of Switzerland, the proportion of untilled cropland is as high as 10–20% (Ledermann and Schneider, 2008). According to Schneider et al. (2010), the expansion of no-till practises in Switzerland from the first half of the last century until today has gone through several phases: (i) occasional abandonment of ploughing to improve agricultural productivity, (ii) method of soil cultivation used by individual farmers, (iii) measure for conserving soil and water, (iv) comprehensive cropping system and (v) way of life. They show that no-tillage development may be regarded as a dynamic process of co-creation of innovation, and that these concepts emerged and varied as a result of network building between various human and non-human actors.

Apart from direct drilling and ploughing, there are further less extreme soil tillage practises. Little is known about their distribution and effect on soil erosion.

The present paper aims at determining the impact of various crops and soil tillage practises on the distribution and extent of soil erosion in farmers' fields. Data from 10 years of monitoring (1998–2007) of soil erosion in 203 crop fields or 263 ha, respectively, were analysed. All types of erosion damage were mapped after precipitation events in 78 cases; the crops grown and the cropping methods were recorded. The temporal variability of the erosion events and the influence of single precipitation events on soil loss have already been dealt with by Prasuhn (2010). Information about the extent, frequency, and severity of soil erosion as well as analyses of the causes, sources, triggers, accelerators, and impacts of soil erosion can be found in Prasuhn (2011).

2. Material and methods

2.1. Region investigated

The region under investigation lies about 20 km northwest of Berne in the Swiss midlands, with altitudes ranging from 475 to 720 m a.s.l. (Fig. 1). The study was conducted in five neighbouring sub-regions (Frienisberg, Seedorf, Suberg, Lobsigen, Schwanden), but for the purpose of this paper the data from these areas were pooled. The land use in this region is typical of the Swiss midlands. It was already investigated in the late 1980s with regard to soil erosion (Mosimann et al., 1990). The present study included 203 arable fields with a total area of 263 ha, i.e. the mean field size was 1.3 ha. 52 farms had at least one field in the area under investigation. Most of them were mixed farms, i.e. they grew crops and kept livestock, with a mean farm size of 16.7 ha. The prevailing soils were permeable cambisols and luvisols over ground moraine. The erodibility of the predominating sandy loams was rated as moderate (Prasuhn and Grünig, 2001).

The long-term annual precipitation ranges from 1035 (Seedorf) to 1150 mm (Frienisberg). Rainfall erosivity values were calculated by rainfall erosion index (*R*-factor) after Schwertmann et al. (1990)

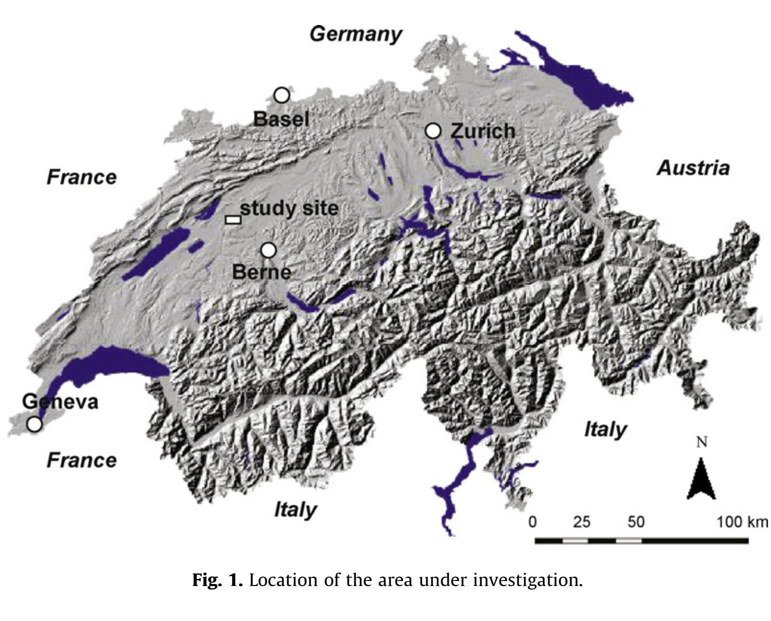

Fig. 1. Location of the area under investigation.