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Soil erosion by water in Northern Germany: long-term monitoring results from Lower Saxony

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ABSTRACT

Soil erosion caused by water has been monitored for 17 years on 465 ha cropland in Lower Saxony (Northern Germany). The 86 monitored fields are representative for three different typical agricultural landscapes with an intermediate to high water erosion risk in Northern Germany. The monitoring scheme included regularly conducted erosion damage mapping and cultivation surveys. The collected data encompasses 1275 field years and 1355 mapped erosion systems, giving evidence on the extent, frequency and rate of soil erosion by water. Mean mapped soil loss for all fields was relatively small at 0.85 t ha^{-1} a^{-1}. The highest rate for a single field amounted to 7.02 t ha^{-1} a^{-1}. Variability of soil loss in time and space was high: annual losses (mean of all fields) ranged between 0.04 and 2.81 t ha^{-1} a^{-1}. The highest annual loss on a single field was 53.07 t ha^{-1}. Every year, at least 24% of the monitored fields were not affected by erosion, only 1.3% of the monitored area eroded at least once a year. Spatial analysis of mapped erosion features shows that the highest soil loss is located in topographically-defined flow paths and in wheel tracks oriented in line of the steepest slope. Cultivated crops and tillage management have a high influence on loss rates ranging from 0.07 for catch crop to 2.78 t ha^{-1} a^{-1} for potato. Additionally, the results prove that farmers in the investigation areas were able to significantly reduce soil loss rates of the five most important crops from 0.6 to 0.37 t ha^{-1} a^{-1} by using conservation tillage measures. The annual variability in the collected data emphasises the importance of appropriate long-term monitoring programmes to create sound data on the extent, frequency and rate of soil erosion by water at a field to landscape scale.

1. Introduction

Soil erosion by water accounts for the biggest share of soil loss in Central European agricultural ecosystems (Panagos et al., 2015b). The loss and degradation of soils have negative impacts on a wide bundle of soil-related ecosystem services including crop production, water purification, nutrient cycling and carbon stocks (Dominati et al., 2010). Therefore, scientists and European authorities recognize soil erosion by water as a major problem in soil conversation (Boardman and Poesen, 2006).

Most European, national and regional assessments of soil loss use models, usually a derivate of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), to estimate long-term averages of annual soil loss by water through small rill and sheet erosion. The USLE is based on test plot evaluations in the USA that assess soil loss by five main factors: precipitation, soil type, topography, land use and land management. USLE cannot, however, predict soil loss from gully erosion, which is known to play an important part in soil loss by water, especially in the Mediterranean region (Poesen et al., 2003). Despite the lack of validation by data collected from farmers' fields (Evans, 2013) and other known limitations, the application of USLE is widely accepted. In Germany, USLE is the national standard method for predicting soil erosion by water (DIN, 2005) and has recently been updated (DIN, 2017). Panagos et al. (2015b) use a modified version of the USLE (RUSLE2015) to assess soil erosion by water in Europe. Mean soil loss rates of 2.67 t ha^{-1} a^{-1} for arable land in the European Union and 1.75 t ha^{-1} a^{-1} for arable land in Germany were estimated based on RUSLE2015 (Panagos et al., 2015b). These values are seriously questioned: Fiener and Auerswald (2016) remark that the approaches for calculating some of the RUSLE2015-factors carry substantial errors. Evans and Boardman (2016) criticise the disregard of critiques on erosion models and state that the approach is inappropriate to assess soil erosion in Britain and call for assessments based on fieldwork.

Besides modelling approaches, plot experiments provide small-scale data on soil loss and are helpful for analysing the process of soil erosion under controlled conditions. However, plot measurements are not able

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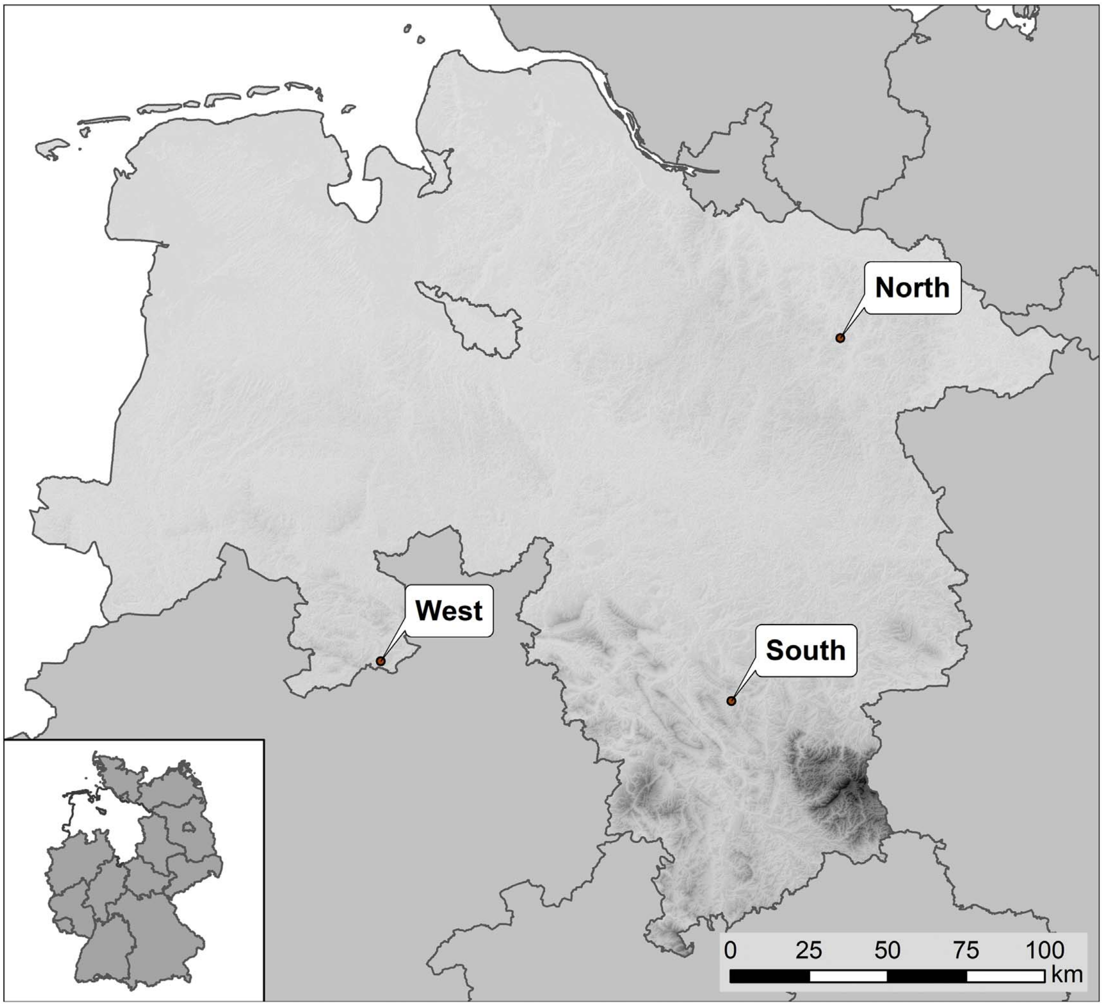

Fig. 1. Location of the monitored regions in Lower Saxony (Northern Germany).

to consider the effects that are important on the landscape scale such as complex topography and flow paths that spread to neighbouring fields. Evans (1995) states that soil loss rates from plots are 2–10 times higher than those measured directly on fields. Accordingly, plot data cannot be extrapolated directly to a regional scale (Evans, 2013; García-Ruiz et al., 2015, 2017). Cerdan et al. (2010) compiled erosion plot data from 81 experimental sites in Europe. The soil losses on these plots amount to an average of 8.8 t ha^{-1} a^{-1}. Based on these plot data, the estimated mean soil loss rate from rill and sheet erosion for arable land in Europe is ca. 3.6 t ha^{-1} a^{-1}. In a similar study, Auerswald et al. (2009) assessed 27 German plot measurement studies with a standardized soil loss rate of 15.2 t ha^{-1} a^{-1}, resulting in an average soil loss rate of 5.7 t ha^{-1} a^{-1} for arable cropland in Germany.

García-Ruiz et al. (2015) compared published soil erosion rates in a meta-analysis, obtained by different methods. They identified a large variability in loss rates depending on scale, method and observation period and emphasised the selection of appropriate designs to obtain erosion rates at different scales. In line with this statement, Boardman (2006), Evans (2013) and Evans and Boardman (2016) called for long-term and large-scale field studies at the landscape scale to assess and monitor soil losses by erosion directly on farmers' fields. de Vente et al. (2013) stressed the need of measurements at the regional scale. In other words: ground-truth data from farmers' fields is needed to build up a realistic picture of the extent of soil erosion at the landscape to regional scale. Soil erosion by water is a highly discontinuous process. Hence, long investigation periods are essential to reduce the effects of high magnitude events that shift results to unrealistic high loss rates (García-Ruiz et al., 2015). Accordingly, sufficiently lasting long-term monitoring studies, best carried out on an event basis (Evans, 2013), are required to obtain a realistic view of the frequency, extent and magnitude of soil erosion by water.

Prasuhn (2011) has listed 35 different field monitoring studies at a landscape scale from 12 European countries. The results are, however, often not directly comparable because different methods were used. Additionally, the observation periods were too short in most cases for valid statements on mean annual soil loss rates. Only 5 listed studies (4 from Switzerland, 1 from the United Kingdom) lasted at least 10 years, minimizing the impacts of occasional erosion events and reducing the bias in the recorded soil losses (Prasuhn, 2011). An additional study summarizes field-based surveys in lowland Britain (Evans et al., 2016). The mean soil loss rates calculated in these studies ranged from 0.3 to 5 t ha^{-1} a^{-1} (Boardman, 2003; Boardman and Favis-Mortlock, 1993; Ogermann et al., 2003; Prasuhn, 1991, 2011; Schaub, 1989 re-calculated in Prasuhn (2011).

In this study, we present results from a long-term erosion monitoring programme started in the year 2000. This programme combines event-based mapping of soil erosion damages with land management surveys. As part of the Lower Saxonian soil monitoring programme, it is funded by the Lower Saxonian State Authority for Mining, Energy and Geology (LBEG). The objectives of the programme are to generate information on the extent, frequency and rate of soil erosion by water in potentially vulnerable areas of Lower Saxony (Northern Germany). Using the resulting monitoring data, the objectives of this study are (1) to evaluate the temporal and spatial variabilities of soil loss in Lower