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The new assessment of soil loss by water erosion in Europe

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ABSTRACT

Soil erosion by water is one of the major threats to soils in the European Union, with a negative impact on ecosystem services, crop production, drinking water and carbon stocks. The European Commission's Soil Thematic Strategy has identified soil erosion as a relevant issue for the European Union, and has proposed an approach to monitor soil erosion. This paper presents the application of a modified version of the Revised Universal Soil Loss Equation (RUSLE) model (RUSLE2015) to estimate soil loss in Europe for the reference year 2010, within which the input factors (Rainfall erosivity, Soil erodibility, Cover-Management, Topography, Support practices) are modelled with the most recently available pan-European datasets. While RUSLE has been used before in Europe, RUSLE2015 improves the quality of estimation by introducing updated (2010), high-resolution (100 m), peer-reviewed input layers. The mean soil loss rate in the European Union's erosion-prone lands (agricultural, forests and semi-natural areas) was found to be 2.46 t ha^{-1} yr^{-1}, resulting in a total soil loss of 970 Mt annually.

A major benefit of RUSLE2015 is that it can incorporate the effects of policy scenarios based on land-use changes and support practices. The impact of the Good Agricultural and Environmental Condition (GAEC) requirements of the Common Agricultural Policy (CAP) and the EU's guidelines for soil protection can be grouped under land management (reduced/no till, plant residues, cover crops) and support practices (contour farming, maintenance of stone walls and grass margins). The policy interventions (GAEC, Soil Thematic Strategy) over the past decade have reduced the soil loss rate by 9.5% on average in Europe, and by 20% for arable lands. Special attention is given to the 4 million ha of croplands which currently have unsustainable soil loss rates of more than 5 t ha^{-1} yr^{-1}, and to which policy measures should be targeted.

1. Introduction

The land degradation process due to the rate of soil loss exceeding that of soil formation has helped shape today's physical landscape (Alewell et al., 2015). Soil erosion is among the eight soil threats listed within the Soil Thematic Strategy of the European Commission (EC, 2006). During the past decade, the problem of soil erosion has become part of the environmental agenda in the European Union (EU) due to its impacts on food production, drinking water quality, ecosystem services, mud floods, eutrophication, biodiversity and carbon stock shrinkage (Boardman and Poesen, 2006). Soil erosion by water accounts for the greatest loss of soil in Europe compared to other erosion processes (e.g. wind erosion). Recent policy developments in the European Commission (the Soil Thematic Strategy, the Common Agricultural Policy, Europe 2020, and the 7th Environmental Action Programme) call for quantitative assessments of soil loss rates at the European level. As the measurement of actual soil loss rates at the continental scale (by means of e.g. experimental plots, Caesium-137 measurements, the sampling of sediment loads in the runoff from small catchments) is not financially feasible, soil erosion modelling approaches are used to make such assessments. Besides the policy requests, a continental assessment of soil loss may help to: (a) quantify the impacts of soil loss at such a large scale, (b) assess the main effects of climate, vegetation and land use changes on soil erosion rates, and (c) prioritise effective remediation programmes (Lu et al., 2003).

The main factors affecting the rates of soil erosion by water are precipitation, soil type, topography, land use and land management. In a recent inventory, Karydas et al. (2014) identified 82 water-erosion models classified on different spatial/temporal

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scales with various levels of complexity. The most commonly used erosion model is the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and its revised version (RUSLE) (Renard et al., 1997) which estimates long-term average annual soil loss by sheet and rill erosion. It should be noted that soil loss caused by (ephemeral) gully erosion is not predicted by RUSLE (Poesen et al., 2003). Despite its shortcomings, RUSLE is still the most frequently used model at large scales (Renschler and Harbor, 2002; Kinnell, 2010) as it can process data input for large regions, and provides a basis for carrying out scenario analysis and taking measures against erosion (Lu et al., 2003). In addition, a recent collection of soil loss data in Europe by the European Environmental Information and Observation Network (EIONET) found that all participating countries used USLE/RUSLE (Panagos et al., 2014a) to model soil loss.

The objective of this study is to provide an up-to-date soil loss map of the European Union using the RUSLE model. This map aims to:

(a) use the most updated input layers of precipitation, soil, topography, land use and management,
(b) help predict the effects of policy scenarios,
(c) be replicable, comparable and utilised at a broader scale (other than soil erosion modelling).

2. Methodology

This study uses a modified version of the RUSLE model (RUSLE2015, based on Renard et al., 1997), which calculates mean annual soil loss rates by sheet and rill erosion according to the following equation:

$$E = R \times K \times C \times \mathrm{LS} \times P \quad (1)$$

where E: annual average soil loss (t ha^{-1} yr^{-1}), R: rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}), K: soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}), C: cover-management factor (dimensionless), LS: slope length and slope steepness factor (dimensionless), and P: support practices factor (dimensionless).

The RUSLE2015 model introduces some improvements to each of the soil loss factors, adapting them to the latest state-of-the-art data currently available at the European scale. The main difference from previous studies that modelled soil loss at the European scale using RUSLE (e.g. Van der Knijff et al., 2000; Bosco et al., 2015) is the improved quality of input layers. Each input factor has been estimated in a transparent way. The assessment procedures for the soil erodibility factor (Panagos et al., 2014b), the rainfall erosivity (Panagos et al., 2015a), the cover-management factor (Panagos et al., 2015b), the topographic factor (Panagos et al., 2015c) and support practices factor (Panagos et al., 2015d) have recently been published, and the corresponding datasets are available from the European Soil Data Centre (Panagos et al., 2012). The 5 factors are described in the supplementary material and the corresponding publications. For the estimation of input factors, RUSLE2015 made use of the most updated and freely available datasets at the European scale (Fig. 1).

The K-factor is estimated for the 20,000 field sampling points included in the Land Use/Cover Area frame (LUCAS) survey (Toth et al., 2013) and then interpolated with a Cubist regression model using spatial covariates such as remotely sensed data and terrain features to produce a 500 m resolution K-factor map of Europe (Panagos et al., 2014b). The R-factor is calculated based on high-resolution temporal rainfall data (5, 10, 15, 30 and 60 min) collected from 1 541 well-distributed precipitation stations across Europe (Panagos et al., 2015a). The C-factor was modelled in non-arable lands using a combination of land-use class and vegetation density while in arable lands C-factor is based on crop composition and land management practices (reduced/no tillage, cover crops and plant residues) (Panagos et al., 2015b). The LS-factor (Panagos et al., 2015c) is calculated using the recent Digital Elevation Model (DEM) at 25 m and applying the equations proposed by Desmet and Govers (1996). The P-factor takes into account a) contour farming implemented in EU agro-environmental policies, and the protection against soil loss provided by (b) stone walls and (c) grass margins (Panagos et al., 2015d).

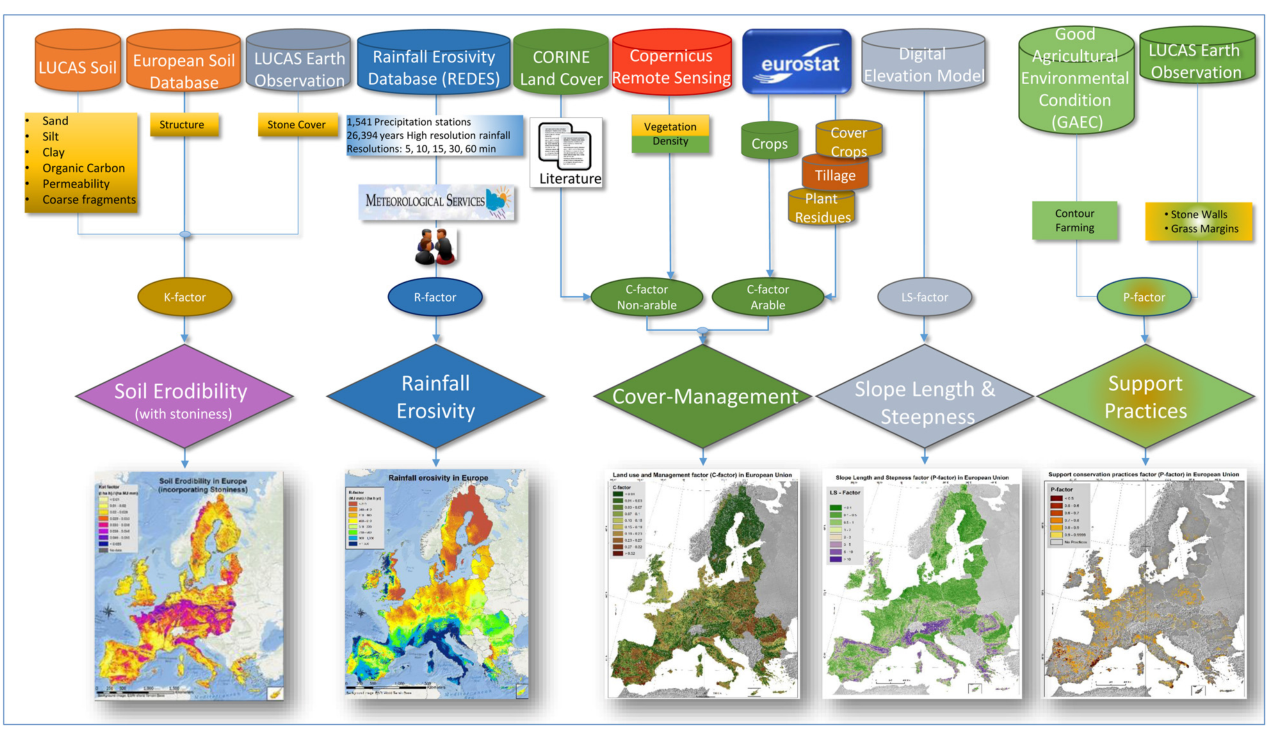

Fig. 1. Input datasets used for the estimation of soil loss factors for Europe in RUSLE2015.