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Reply to “The new assessment of soil loss by water erosion in Europe. Panagos P. et al., 2015 Environ. Sci. Policy 54, 438–447—A response” by Evans and Boardman [Environ. Sci. Policy 58, 11–15]

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ABSTRACT

The new assessment of soil loss by water erosion in Europe (Panagos et al., 2015a) was commented by Evans and Boardman (2016), who raised not only concerns related to the spatial differences outlined by our work compared to their visual semi-qualitative assessment conducted in Britain during the late eighties, but also generally to the suitability, validity and scientific robustness of the applied modelling approach. The objective of the pan-European assessment using the Revised Universal Soil Loss Equation (RUSLE) was not to outcompete any regional- or national-scale modelling, but to harmonize and improve our knowledge and our understanding of current soil erosion rates by water across the European Union. The focus of such a modelling project is on the differences and similarities between regions and countries beyond national borders and nationally adapted models. In order to do so, a state-of-the-art large-scale spatially distributed modelling exercise using harmonized datasets and a unified methodology to suit the pan-European scale was carried out. We reply that the semi-qualitative approach proposed by Evans and Boardman (2016) is not suitable for application at the European scale because of work force and time requirements, input data accessibility issues, accuracy of field-based estimates, subjectivity of soil loss estimates during the aerial and terrestrial photo interpretation, impossibility of upscaling or downscaling, inadequate representation of sheet erosion processes, lack of spatial and temporal representativeness, and lack of detailed description expressing the risk level. As such, their methodology has limited applicability, with today’s financial resources it is not feasible at European or at national scale and, most important, cannot respond to policy requests regarding scenarios of climate and land cover/use change. In contrast to Evans and Boardman (2016), we do know that RUSLE, like probably any other approach, is not able to reproduce “reality”. The latter is actually a misjudgment which has been extensively discussed 20 years ago. Modelling in general and large-scale modelling specifically can per se not aim at an accurate prediction of point measurements, but tests our hypothesis on process understanding, relative spatial and temporal variations, scenario development and controlling factors (Oreskes et al., 1994). As such, our approach can be offered as a helpful tool to policy makers at pan-European scale. We are confident that the simple transparent structure of RUSLE as well as the discussion of the uncertainties of each modelling factor will help to supply objective guidance to policy makers.

1. Assessment of soil erosion by water at European scale: necessity and usefulness

The request of developing a pan-European assessment for soil loss by water erosion comes from policy makers who aim to have dynamic tools to monitor the impact of various policies such as the Soil Thematic Strategy, Common Agricultural Policy, and Climate Action on Land use and to develop indicators on the state of soils in Europe (SOER, 2015; Eurostat, 2015; CAP, 2015). To meet these

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policy needs, the Joint Research Centre (JRC) conducted research over the last 15 years developing a series of pan-EU soil erosion assessments based on modelling studies such as USLE (van der Knijff et al., 2000), MESALES (Le Bissonnais et al., 2002), PESERA (Kirkby et al., 2008), and RUSLE2015 (Panagos et al., 2015a). As the mandate of the JRC is to provide independent scientific advice and support to the EU policy, the development of a harmonised, widely applicable and scientifically sound pan-European soil erosion risk assessment is not only essential but, as outlined in detail by Panagos et al. (2015a), very useful.

Besides modelling approaches, the JRC utilized the knowledge provided by experts of the Member States through the European Environment Information and Observation Network (EIONET). In 2009–2010, we followed a bottom-up approach by asking the Member States for their available data on soil erosion rates. Unfortunately, the result obtained following this approach was far from being a pan-European map of soil erosion as only eight countries supplied data (please note that the United Kingdom was unfortunately not among them Panagos et al., 2014a). Even though all involved countries adopted a RUSLE-based modelling scheme, a wide spectrum of research methodologies on the estimation of the input model parameters was applied. This fact limited the inter-comparability of the modelling outcomes between countries.

Due to the incomplete and methodologically heterogeneous picture obtained through the EIONET project, the JRC researchers decided to further refine the input factors of a widely-accepted model such as the RUSLE to run a new pan-European modeling approach. Several methodological and conceptual improvements were included with respect to previous JRC modelling assessments and the EIONET data collection such as (i) the modelling of rainfall erosivity (R factor) based on rainfall intensity, frequency, amount and duration (Panagos et al., 2015b), (ii) using the harmonized field-based soil surveys of LUCAS-topsoil to improve predictions of soil erodibility (K factor; Panagos et al., 2014b), (iii) using a Digital Elevation Model with the highest available resolution to improve topographic factors (L and S; Panagos et al., 2015d) and (iv) incorporating cropping statistics, vegetation density and management practices to refine the cover management factor (C-factor; Panagos et al., 2015c) and the support practice factor (P-factor; Panagos et al., 2015e).

2. Field mapping an option at pan-European scale?

Evans and Boardman (2016) propose a method to map soil erosion based on collecting information on the extent, frequency and rates of erosion from farmers' fields, but also from grazed uplands, by using photointerpretation and direct field observations. Evans and Boardman (2016) believe that their method provides soil erosion estimates close to reality and propose to use this method or at least to use it as validation for RUSLE2015. In the following we will detail why we cannot follow their advice.

The application of the field mapping approach at a pan-European scale to monitor rates of soil erosion by water would require a large-scale project by far exceeding the size of previous pan-European soil projects (e.g. LUCAS, Biosoil, etc.) since it would require substantial European financial investments, work force and a period of several decades. The product of field mapping approach would have an inevitable high degree of subjectivity, if not very carefully designed and structured across all countries and landscape units. An overall danger of such an assessment would be the bias towards incisive erosion processes that can be clearly observed in the field (i.e. rills and gullies). In many European regions, however, the almost invisible process of sheet erosion (also referred to as interrill erosion) occurs as well, which will be very difficult, if not impossible, to document at pan-European scale using the proposed methodology by Evans and Boardman (2016). This soil erosion process will hardly show up on the map of Boardman and Evans (2006).

In addition, we wonder if the methodology proposed by Evans and Boardman (2016) might be biased due to:

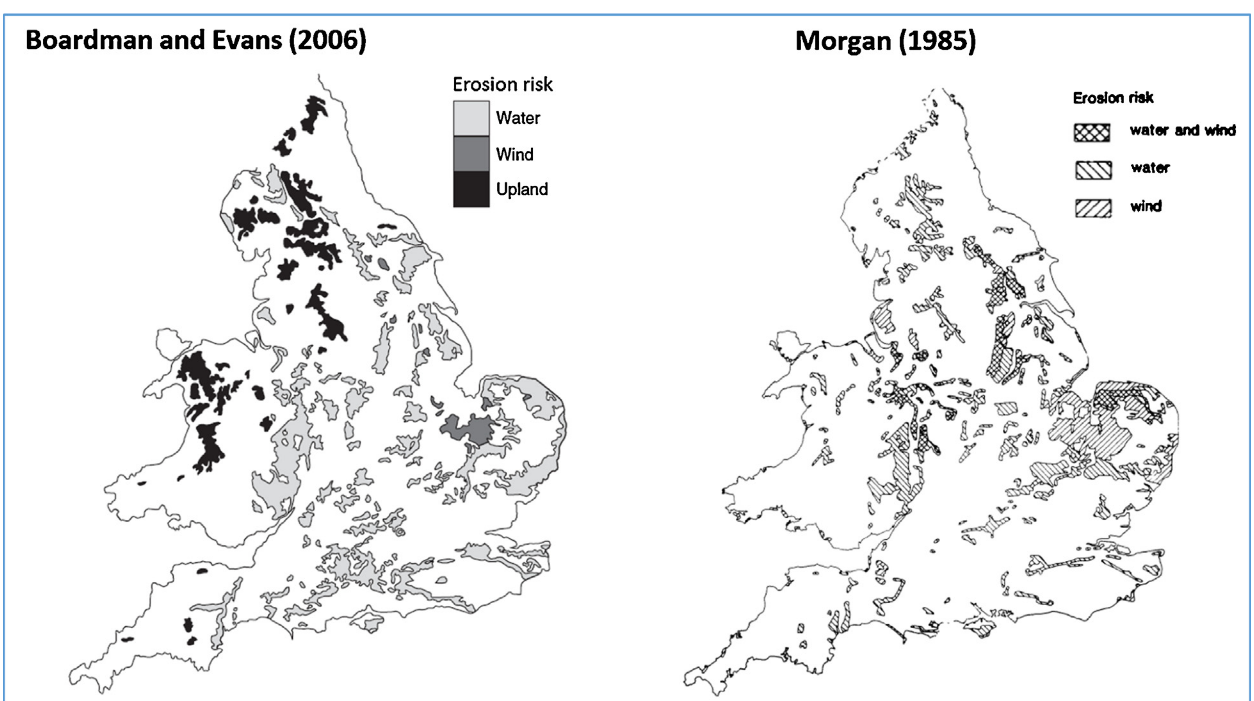

Fig. 1. Comparison of two soil erosion risk maps for England and Wales produced by Boardman and Evans (2006); (originally from Evans, 1990) and Morgan (1985).

- field accessibility (e.g. certain land parcels or remote areas might not be accessible);
- spatial and temporal representativeness of selected measurement points;
- Interpretation and transparency (e.g. how accurately can rill or gully or even more challenging sheet erosion be identified through terrestrial and aerial photo interpretation and how to assess the accuracy and the bias of the individual surveyors?);
- Timing (e.g. there might be only a limited time window for the field observations of erosion features which is shortly after an erosive event; if this time window is missed erosional features remain undetected).

In addition, issues of statistical upscaling, availability of soil maps at 1:250,000, availability of aerial photos at 1:10,000 (conditions according to Evans, 2013) are still to be solved in order to make the methodology operational at European scale. Moreover, Evans (2013) suggests to visit the sites after each 10-mm rainfall event. According to the Rainfall Erosivity Database at European Scale (REDES) (Panagos et al., 2015b), most of the 38 rainfall stations in United Kingdom show erosive events with a rain depth >10 mm ca. 15 times per year.

In case we could ever accomplish this task we might still question if the assessment of soil erosion rates in Europe using the method proposed by Evans and Boardman (2016) would serve the needs of the end user (policy maker) since it is neither harmonized, nor transparent. Moreover, it cannot be used to assess the impact of various policy scenarios and it is misleading. The latter is due to the fact that Boardman and Evans (2006) only define areas at "risk" in a dichotomous way, which makes it impossible to characterize areas at higher or lower "risk" (Alexander, 2000) and this implies that areas not marked at "risk" are "immune" to soil erosion.

Nonetheless, as a future vision, and with the belief that the limitations of an experimental approach would be overcome and the costs of soil erosion monitoring for an area of more than 4.3 million km^2 (covering the European Union) could be provided, such a project would indeed be worth striving for.

3. The case study of Evans and Boardman

As Evans and Boardman (2016) base their critique of Panagos et al. (2015a) mainly on the lessons learned from the their past studies (Evans, 1990; Boardman and Evans, 2006; Evans, 2013; Evans et al., in press), we would like to demonstrate why it is not possible to extrapolate their methodology and experience to a pan-European assessment of soil erosion by water.

Even though Evans (1990) used field-based surveys from 1982–1986 which aimed to improve the map of Morgan (1985) (which in his opinion had the limit to "*portray only two categories of soil erosion risk*": risk/no risk), the newly proposed map of soil erosion in England and Wales, 16 years later, by Boardman and Evans (2006) still portrays two categories of risk only. Only in 2015, Evans et al. (in press) presented a map of water erosion with more than two classes of risk (i.e., moderate, high, very high). This semi-qualitative approach suggested by Evans and Boardman (2016) took almost 30-years to be accomplished solely for Britain. Nonetheless, the maps of Boardman and Evans (2006) (after Evans, 1990) and Morgan (1985) remain rather semi-quantitative, and significant differences in the spatial pattern of soil erosion risk by water between their maps can be observed (Fig. 1).

The situation about soil erosion in England and Wales becomes even more complex as we noted recent assessments carried out by the Department for Environment Food & Rural Affairs (DEFRA, 2011; DEFRA, 2005) and the UK's Environmental Agency Report (Environment Agency, 2004) which portray soil erosion risk by water considerably different from Boardman and Evans (2006).

The United Kingdom is one of the European countries with the highest number of plot studies, field-based surveys and monitoring schemes of soil erosion (Brazier, 2004) which have been extensively financed in the 80's and 90's. Contrary to Evans and Boardman, Brazier (2004) stated that soil erosion occurs to significant levels throughout the United Kingdom and recognized that even though a large number of datasets are available from various studies, they are not ideally suited for model validation and development, as they are in a way qualitative and not compatible with model outputs. Soil erosion models should incorporate, and should certainly be validated by, field-based assessments of erosion (Gobin et al., 2004), but plot data must be collected in a way that is suitable to be compared with model outputs that, mostly, express erosion rates in terms of physical quantities (Brazier, 2004). Also in contrast to what Evans and Boardman (2016) stated, soil erosion takes place more frequently than once in 5 years and we wonder if sheet erosion totally slipped their attention since this is often a more continuous process. The fact that soil erosion happens to a larger extend than claimed by Evans and Boardman is supported by the recent heavy rains resulting in floods in December 2015 and in February 2014 caused significant soil erosion and sediment production and transport processes as shown in Fig. 2. In addition, a national assessment of soil erosion in England and Wales based on Cesium 137 (Walling and Zhang, 2010; Walling et al., 2014), which provides an assessment of soil erosion magnitude shows a different spatial pattern of soil erosion compared to the assessment of Boardman and Evans (2006).

4. The paradigm of RUSLE critique

USLE type models are the most widely used for predicting soil loss by sheet and rill erosion and as such are also the most widely criticized soil erosion models. The main advantages of these models are their simplicity in structure and their non-complexity of model input parameters. Discussion and critical evaluation of model results is absolutely necessary to improve our understanding of processes and input factors and might be especially necessary for USLE-type models to avoid the risks of oversimplification. However, as with any scientific debate, arguments raised should be justified and based on scientific evidence.

Evans and Boardman (2016) raise concerns regarding the comparison of our assessment of soil loss by water erosion in

Fig. 2. Satellite image taken on 16 February 2014 showing sediment plumes along the coast, indicating where Britain's sediments are transported to the sea (Guardian, 2014; Dundee Satellite, 2014).

Europe with results of their field experiments carried out in Britain during the eighties. The burden of proofs is theirs, to demonstrate that climate, land use and soil structure was stable over the last 30 years in the discussed regions. Without this proof their argument is not based on scientific evidence.

Evans and Boardman (2016) try to discredit our work stating that the soil loss rates were modelled using rainfall amounts (instead of rainfall erosivity), that the topographic factors have been overestimated, and that "*scant attention has been paid to crucial issues of vegetation and land management*". We assume they are not aware of the extensive literature on which the soil erosion map of Europe is based upon (Panagos et al., 2015b; Panagos et al., 2015c,d,f,e,g; Panagos et al., 2016).

Evans and Boardman (2016) repeatedly criticize the basic principles of USLE and RUSLE models, questioning the input factors, their relationships and the overall model structure. This is an old discussion and, as said above, might serve an important scientific purpose: i.e. to avoid oversimplification. However, intensive discussion on ecosystem modelling 20 years ago (Oreskes et al., 1994) came repeatedly to the overall conclusion that simple, lumped modelling structures work best not only for description of ecosystems processes and controlling factors but even for scenario development. The latter is due to the fact that complex model structures are mostly over parameterized (which imply the non-uniqueness of the calibration process) and simply not suitable because of the non-availability of required input-parameters for such models.

The RUSLE model is based on more than 10,000 plot-years of experiments, its factors have been developed and weighted according to a large number of field experiments and this model was more or less successfully applied all over the world (e.g. Wischmeier and Smith, 1978; Renard et al., 1991; Renard et al., 1997). Moreover, one has to recall that the intention of RUSLE is to assess average long-term soil loss rates by sheet and rill erosion and as such it cannot directly be compared to field assessments of soil loss caused by a particular rain event or a rainy season.

5. Conclusions

We conclude that a scientific discussion of modelling results and their implications is absolutely necessary and will help to improve our understanding of soil erosion by water at continental scale. It is unfortunate that Evans and Boardman, who collected many field data through soil erosion mapping in the field, disregard the recent modeling developments and the important improvements of RUSLE application at European scale presented by Panagos et al. (2015a) and therefore miss the opportunity to improve our understanding of the erosion processes that are among the most threatening to the valuable soil resource.

Evans and Boardman (2016) proposed field methods for assessing soil loss by water erosion combined with visual interpretations of aerial and terrestrial photos, and statistical upscaling to quantify soil loss rates at pan-European level. As such, a pan-European assessment and approach might be an important step towards a future long-term monitoring of soil erosion across Europe (following up programs like e.g. ICP-Waters or ICP-Forests; International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes and Forests, respectively). These methods might indeed deliver invaluable data and knowledge far beyond modelling validation, however such an effort would need careful scientific planning and strategy combined with a long-term policy and a serious commitment for substantial funding across Europe (or directly from the EU).

Evans and Boardman (2016) do not improve our scientific understanding of soil erosion. Moreover, their proposed methodology to map soil erosion may even limit the implementation of soil conservation policies at the EU level since local methodologies may suffer from a large heterogeneity, ambiguity, low consistency and, in many regions, a total lack of information. In contrast, a quantitative approach based on consistent and harmonized spatial data, guarantees that the relative differences in mean predicted soil loss rates among regions and countries are less biased by national methodologies. This is a fundamental aspect for implementing fair policies like the Agricultural Policy (CAP), governing the agricultural sector of the EU.

Moreover, many modelling applications that are in place to assess land use and climate change effects on soil ecosystem services and/or their economic impacts (e.g. Panagos et al., 2015g; Borrelli et al., 2016; Lugato et al., in press) need quantitative soil loss data. We wonder how the best remedial actions can be planned in a changing world, without using dynamic and quantitative approaches.

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