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The new assessment of soil loss by water erosion in Europe. Panagos P. et al., 2015 Environmental Science & Policy 54, 438–447—A response

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ABSTRACT

We respond to an article by Panagos et al.—'The new assessment of soil loss by water erosion in Europe' in Environ. Sci. Policy, 2015, 54, 438–447. It is aimed at helping policy makers make better decisions. The assessment uses a Geographical Information Systems approach based on the Revised Universal Soil Loss Equation. RUSLE is based on data gained from plot experiments. The authors assume RUSLE is the only way to assess erosion and ignore critiques of erosion models and other ways of assessing erosion. A different way of assessing water erosion, based on collecting information on extent, frequency and rates, mainly from farmers' fields but also grazed uplands, has been carried out over recent decades in Britain. The two ways of assessing erosion, one largely theoretical, the other based on reality, evolved in response to particular situations. However, they should relate well to each other. We show that the model is inappropriate to assess soil loss by water erosion in Britain, not only for agricultural land but also for uncultivated land. Predicted high rates of erosion do not relate well to where erosion actually occurs and are too high, and the model takes no account of the spatial extent of erosion on the ground. In other words, the model does not reflect reality. Policy decisions should not be taken based on such a model. Erosion must be assessed in a better way with a large field-based element.

1. Introduction

A new assessment of soil loss by water erosion in Europe has recently been published (Panagos et al., 2015a), aimed at policy makers. The assessment is based on a model, the Revised Universal Soil Loss Equation (Laflen and Moldenhauer, 2003). Here, we respond to this assessment. Our response, based on fieldwork to assess if erosion was a problem in Britain reflects a difference in attitude as to how water erosion should be assessed. We think it should be based on assessments made in the field, by locating eroded fields (Evans and Boardman, 1994; Evans, 2002a) or eroding upland landscapes (Evans, 1996) and estimating how much soil has been eroded. The paper by Panagos et al. (2015a) considers it should be done using a model based on plot experiments to estimate the rate of soil erosion. As Panagos et al. (2015b,c) note this is the most frequently used way to assess erosion and has been used in many countries. Because this is the most used method to assess erosion, there is a multitudinous literature on it, as a corollary there are many fewer references to field assessment as most of the research has been carried out in Europe, especially Britain (Evans, 2002a) and Switzerland (Prasuhn, 2011, 2012).

However, that a particular technique is most frequently used does not necessarily mean it is the best, or indeed, the only way. The RUSLE based model assumes estimated rates of erosion apply across the landscape. In our research we have found that rill erosion, which accounts for much of the erosion (Evans, 1990a), often occurs in isolated fields, does not happen in that field every year and that the severity of erosion can vary greatly from field to field and year to year (Evans et al., 2015). Here, we will not argue whether the value of the factors which comprise RUSLE are correct, we are sure others more qualified to make those criticisms will do that, what we are concerned with is how the RUSLE based model predicting soil erosion by water compares with results of field-based assessment in Britain. The policy makers whom Panagos et al. (2015a) are hoping to influence would hope that the two ways of assessing water erosion would relate to each other, the field assessment verifying and validating the model assessment, or at the least the two should compare well, for example, where erosion occurs and the relative magnitudes of rates of erosion.

As Sterman (2010, pp. 846) notes "no model can ever be verified or validated. Why? Because all models are wrong . . . . .all models, mental or formal, are limited, simplified representations of

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the real world. They differ from reality in ways large and small, infinite in number." Further, he goes on to note (Sterman, 2010, pp. 850), "Experienced modellers likewise recognise that the goal is to help their clients (*or policy makers, our italics*) make better decisions, decisions informed by the best available model. Instead of seeking a single test of validity models either pass or fail, good modellers seek multiple points of contact between the model and reality by drawing on many sources of data and a wide range of tests. Instead of viewing validation as a testing step after a model is completed, they recognise that theory building and theory testing are intimately intertwined in an iterative loop. Instead of presenting evidence that the model is valid, good modellers focus the client (*policy maker*) on the limitations of the model so it can be improved and so clients will not misuse it." We argue here that for Britain this new assessment of water erosion does not reflect reality as seen in the field, and should not be used by policy makers as the only source of information regarding soil erosion.

2. Differences in approach to assessing soil erosion by water

The differences in approach to assess soil loss by water erosion probably arise from the different circumstances pertaining at the time. Thus in the 1930s soil erosion was high on the agenda in the USA and was widespread (Bennet, 1939), and an understanding of processes driving erosion was needed. Plot experiments were set up at experimental stations to measure water erosion on different soil types, under different crop types, with differing plot lengths and with both natural and simulated rainfall. It was assumed that erosion risk based on the factors derived from plot experiments, **R**ainfall erosivity, **K** soil erodibility, **LS** slope factors, **C** crop cover and **P** practices to inhibit erosion, could be modelled using the Universal Soil Loss Equation to predict erosion risk (Laflen and Moldenhauer, 2003) and identify localities where erosion should be tackled. In Britain, on the other hand, where it was considered water erosion was not a problem, primarily because rainfall intensities were low (Hudson, 1967), when erosion in arable fields first started to be reported (Evans, 1971) information was sought on the extent of erosion (where and how many eroding fields) to see if it was a problem (Evans, 1996). It was quickly realised that erosion was most extensive in particular soil landscapes and needed to be assessed in a more methodical way. Measurements of severity of erosion could be made easily and quickly in arable fields of rill and gully erosion by measuring length of channels and their cross sectional areas at points down the channels and estimating volumes of soil deposited by measuring area and depth of deposits. Erosion in the uplands was less easily assessed (McHugh et al., 2002; McHugh, 2007). Evans (1996, 2002a, 2010) outlines the evolution of the assessment of water erosion in Britain and how erosion and runoff could be mitigated. In other words, one method of assessing erosion was to model erosion risk, the other was to find out where erosion occurred, its extent, frequency and severity. One way was largely experimental and theoretical, the other pragmatic and based on what was actually happening on the ground, i.e. reality. The modelled approach takes a more long-term view of risk, field-based the shorter term.

Estimates of rill and gully erosion in England were found to be within a range of one-half to twice the average value estimated by a number of researchers (Evans and Boardman, 1994) and compared well when estimated both on the ground and from photographs of the field (Watson and Evans, 1991). At that time, and still, that was considered a reasonable estimate of error, as it was obvious, for example, that an estimate 10 times the average would appear excessive, i.e. would need 10 times the length of rills estimated or deeper rills than measured, or enormous areas of fields covered by deposits or much deeper deposits than measured. Evidence for interrill erosion, better defined as wash or sheet erosion as wash can occur without rilling, was/is rare except on silty soils or the reworking of already deposited material from rills and gullies. It may occur widely across landscapes, but rates of erosion are low (Evans et al., 2015).

Because of the differing approaches to assessment, rarely have either set of researchers referred to each other's work. Criticism of field-based assessments are related to whether rates of erosion can be related to topographical factors and rainfall. Clear cut relationships do not emerge between slope angle, slope length and relief within the field and erosion (Evans, 1990a). Maps of rainfall erosivity of England and Wales (Morgan, 1980; Davison et al., 2005) do not relate well to where from field-based assessment land is most at risk, especially in lowland England (Evans et al., 2015; Fig. 1, pp.3). However, within the modelling fraternity there is debate too as to what the importance or weighting of the factors should be, e.g. in the European context, for erosivity (R), (Panagos et al., 2015b), topography (LS) (Desmet and Govers, 1997; Panagos et al., 2015c), crop cover factor (C) (Panagos et al., 2015d) and mitigating factors (P) (Panagos et al., 2015e). Data from plot experiments show that topographical factors may correlate significantly with erosion rates, but not always especially for slope gradient, but the correlations are weak (Cerdan et al., 2010). Hence, with regard to topographical factors similar criticisms can be made of both types of assessment, i.e. they do not relate well to plot or field data. Also it can be envisaged that other modellers could be critical of Panagos et al. (2015a) in that with different RUSLE factors the erosion risk map would be different and more like the results expected, i.e. reality, what is seen on the ground.

Using Geographical Information Systems models can predict erosion risk, based on severity (rates) of erosion at a variety of scales, but field-based assessments can also bring out the different rates of erosion occurring within fields (=plot scale) (Evans, 1992), fields and soil landscapes (Evans, 2002a) and has been done nationally for lowland soil landscapes in England and Wales (Evans, unpublished). A number of models used to predict soil erosion and sediment at regional scales use plot-based data, and after comparing the results from these and other models, 14 in all, de Vente et al. note (2013, pp. 26) "..understanding and predicting the sediment delivery process at the catchment scale, under present and future land use and climate conditions, is still a major challenge in soil erosion and sediment yield research." Field assessment could be a useful tool to aid in this challenge (Evans, 2006a).

However, regardless of how erosion is assessed whether by modelling or using information gained in the field, the two ways of assessment should relate well to each other, as they do for example in showing that plots or fields planted to maize erode much more than plots or fields planted to cereals (Evans, 1995a).

3. A critique of the RUSLE assessment of soil loss, with especial reference to Britain

This new assessment of soil loss by water erosion in Europe (Panagos et al., 2015a) is based, as noted above, on a prediction of erosion rates using a modified version of the Revised Universal Soil Loss Erosion Equation. RUSLE predicts long-term average erosion rate for a parcel of land. The equation was originally devised to predict average erosion rates only for cultivated land and is based on plot experiments and rainfall simulation studies (Laflen and Moldenhauer, 2003). RUSLE applies to rangeland where mechanical practises can be used to mitigate erosion (Renard et al., 1997). It is noteworthy that a high-resolution erosion risk map of Switzerland based on a USLE approach only applies the model to agricultural land (Prasuhn et al., 2013). There were sound reasons for restricting the USLE to cultivated land. Thus, cultivating the land to expose soil is a very different process to animals or fire initiating bare soil or heavy rainfalls triggering mass movements (Evans, 2006b). Also, animals, frost and wind, as well as rainfall are at work on bare soil exposed on uncultivated land. For much of the uncultivated land of Europe therefore the RUSLE approach may not be appropriate, as it does not reflect the major erosional processes at work, only rainfall.

RUSLE assessments have not, as far as we know, been compared with field-based assessments. That is understandable as there are few countries where there is sufficient information from field-based assessments to make the comparison. It is assumed by modellers that predicted high erosion rates equate with severe and extensive erosion on the ground. But do these modelled predictions have any relationship to what is actually happening on the ground? As the authors point out, the model does not include ephemeral gullying and gullying, which can form a substantial proportion (10–80%) of total erosion on cultivated and grazed land (Boardman and Poesen, 2006). However, it has been drawn to our attention (Verstraeten, pers. comm., 2015) that in fact the runoff model incorporated, based on Desmet and Govers (1997), does take into account gully erosion in valley floors. Regardless, Panagos et al. (2015a) maintain the assumption that the rates of erosion predicted and mapped in the paper reflect reality. It is highly probable that the rates of erosion predicted and mapped do not reflect reality (Boardman, 1998a,b), they do not in Britain.

The paper also implies, as no other type of assessment is discussed, that RUSLE is the only way of assessing erosion. It is not (Herweg, 1996; Stocking and Murnaghan, 2001). Indeed, criticisms of the USLE approach to assessing erosion have been ignored, even though they have been made for over two decades (Boardman, 1998a,b, 2006; Evans, 1993, 1995a, 1998, 2002a,b; Favis-Mortlock et al., 2001; Trimble, 1999; Trimble and Crosson, 2000a,b), time enough for criticisms to be acknowledged. A recent critical article has been ignored (Evans, 2013) even though it was brought to the attention of the authors. Erosion can be assessed in the field, most easily for cultivated land (Boardman, 2007; Evans and Boardman 1994; Evans, 2002b) but also for grazed land (McHugh et al., 2002; Evans, 2005). There is also the assumption that predicted rates are correct and representative – they are probably too high (Risse et al., 1993) with a great range in values around the mean (Boardman and Favis-Mortlock, 1999; Burrough and McDonnell, 1998) and are not representative (Boardman, 1998a).

Although the authors say the inputs for the model have been peer-reviewed, if the inputs are to an unsatisfactory model, peer review of the inputs is of little relevance.

Soil erosion models have been critically reviewed in several publications and their strengths and weaknesses are well known e.g. De Roo, 1993; Jetten et al., 1999; Favis-Mortlock et al., 2001; Jetten and Favis-Mortlock, 2006. It is unfortunate that the authors do not refer to this literature, in particular to the GCTE soil erosion model comparison exercise using common datasets (Favis-Mortlock, 1998).

The most serious problem is that the model and maps showing erosion losses due to water erosion have not been compared to other assessments of erosion. In Britain (Boardman, 1990, 2003; Boardman and Evans, 2006; Evans, 2005; Evans et al., 2015), as well as Switzerland (Prasuhn, 2011, 2012) field-based assessments of arable land have been carried out. The findings in the two countries compare well (Evans, 2013). In Switzerland, model predicted erosion rates do not relate well to field based assessments (Evans, 2013). Perhaps it is fortunate that soil losses have not been modelled for Switzerland (there are blanks on the maps, although a potential erosion risk map of agricultural land in Switzerland has been produced using a USLE approach; Prasuhn et al., 2013) as it can be shown there that not only are rates of erosion much lower than predicted, erosion of cultivated fields does not take place uniformly across the landscape, because not every field erodes every year (Evans, 2013). When the total amount of erosion is averaged across the whole landscape the mean value of erosion/ha for all the fields in the landscape is much lower than the mean value per cultivated field (Evans, 2002a).

Maps showing land most at risk of erosion in Britain (Fig. 1.33.1; Boardman and Evans, 2006; arable land in England and Wales, Evans, 1996 pp. 61; upland and pasture, Evans, 1996, pp. 63) do not compare well with Fig. 2 in Panagos et al. (2015a), high rates of erosion predicted by RUSLE do not relate well to actual erosion risk. The map in Boardman and Evans (2006) reflects field-based assessments of erosion and most erosion in the lowlands is found in arable areas where soils (sandy, coarse loamy and silty) are most vulnerable to erosion and where a wide range of crops is sown in both autumn and spring (Evans, 1990b; Evans et al., 2015, Fig. 1), and in the uplands where grazing lands are too highly stocked and where peat soils occur on flat crests and gentle slopes. However, all evidence for Britain suggests that rates of erosion are higher on arable land than in generally well-vegetated uplands, contrary to what Panagos et al. (2015a) claim. The map in Panagos et al. (2015a) reflects relief and rainfall amounts (and by implication, rainfall intensity), and hence it is the higher ground and wetter parts of Britain predicted to be most at risk of erosion. The map pays scant attention to the crucial issues of vegetation cover and how the land is managed. Predicted rates of erosion do not indicate where erosion is most extensive, thus predicted rates of erosion can be low but erosion extensive (see below) affecting a considerable portion of the land, a factor taken into account in England and Wales in assessing risk of erosion (Evans, 1990b; Evans et al., 2015). In other words, one map reflects reality (Boardman and Evans, 2006), one does not (Panagos et al., 2015a). This discrepancy between predicted erosion and actual erosion has also been noted for a number of localities in lowland England and Wales (Evans and Brazier, 2005). This lack of correspondence is due to the model being mainly driven by rainfall and slope factors whereas in actuality in Britain the occurrence of erosion is largely determined by soil type and land use.

Perhaps more seriously, – because high rates of soil loss imply severe and extensive erosion with the accompanying costly impacts of flooding and pollution of water courses and especially the loss of what is best considered a non-renewable resource, the soil, – if the predicted rates of soil loss are too high the problem of erosion as the loss of a resource is overstated. There is also the implication (to the researcher and policy maker) that erosion will be sufficiently severe that the land manager will see it and act accordingly. The history of tackling erosion shows that assumption is not true. In Britain severe erosion is rare, most erosion of cultivated land does not seriously impede the farmer or result in loss of crop. It is the off-farm costs which are severe (Boardman et al., 1994; Boardman, 1995, 2003; Boardman et al., 2006; Evans, 1995b). There is a need for a different approach or model to deal with the acknowledged western European problem of off-site impacts of runoff and erosion, RUSLE is not helpful.

For the United Kingdom the mean overall rate of erosion is predicted by RUSLE to be 2.38 $\text{t ha}^{-1}\text{yr}^{-1}$ and of arable land 1.04 $\text{t ha}^{-1}\text{yr}^{-1}$, these figures reflecting the predicted much higher erosion rates in the uplands. These rates are far too high when related to, for example, suspended sediment loads in streams (Evans, 2006a). Evans et al. (2015) have recently brought together all the field-based assessments of erosion of cultivated land in Britain. Data on rates of soil erosion, extent of erosion within a soil landscape and frequency a field erodes tell a similar story, generally low rates of erosion, usually (much) less than 10% of the landscape erodes by rills or gullies in any year and a field likely erodes no more frequently than once every 5 years. Thus, for example a landscape at very high risk of erosion monitored over

5 years is likely on average to have rilled and gullied fields covering 10% of the landscape and each field will erode once in 5 years at a mean rate of 4 t ha^{-1} i.e. the mean rate of soil loss per year will be 0.8 t $ha^{-1}yr^{-1}$ and over the total landscape 0.08 t $ha^{-1}yr^{-1}$.

It may be that it is more meaningful to qualitatively classify land at risk of erosion based on extent, frequency and severity of erosion, as done for England and Wales (Evans, 1990b), than try to assess risk based solely on rate of erosion. Not only is it difficult to calculate average erosion rates for large areas of land but average rates are not useful and are likely to mislead policy makers. Thus, an initial *ad hoc* field assessment of erosion (Evans, 1980) indicated which lowland soil landscapes were likely to be most at risk of erosion (SSEW, 1983; ENDS, 1984). That assessment, often based on a particular locality, was found to hold elsewhere for the same soil landscape when field work was carried out by other workers, for example by members of the Soil Association (no date) in the later 1980s (unpublished) and Friends of the Earth (Evans and McLaren, 1994; Evans, 1996). The national SSEW monitoring scheme of the mid-1980s confirmed which landscapes were most at risk and the classification of risk refined into 5 classes (Evans, 1990b) and that classification confirmed by a later government funded project (Marks et al., 1997). In other words, landscapes where water erosion was most likely to occur were identified early in the research to assess if erosion was a problem, and confirmed by all the later assessment schemes.

In the uplands much higher rates of soil loss are predicted by RUSLE. However, extensive erosion in the uplands, rarely more than 10% of ground is bare of vegetation, is mainly found on peatlands on gently sloping crests and plateaux (McHugh et al., 2002) where peat losses are probably $<20\,m^3\,yr^{-1}$ (Labadz et al., 1991; Butcher et al., 1993). Peat has a low bulk density (c. 0.3 g kg^{-1}), so such a volume equates to *c.*7 t $ha^{-1}yr^{-1}$. However, this rate is (often much) lower than the high rates (10–> 50 t ha^{-1} yr^{-1},) that are predicted for the wetter and steeply sloping hills and mountains of which the flatter peatlands are a part.

4. Conclusions

In Britain the two ways of assessing erosion do not relate well to each other, field-based assessment does not validate (ratify) model assessment. That a model is widely used does not mean, as is implied here, that it is the way erosion should be assessed. If the predicted rates of erosion do not appear to reflect reality, i.e. where water erosion is actually taking place, as appears to be the case in Britain and seems likely to be true elsewhere, a better way of assessing erosion is needed. If predicted rates of soil loss are too high the problem may well be overstated with regard to loss of the soil. Policy decisions made on grounds such as those expounded by Panagos et al. (2015a) must be problematic. Assessments should be field-based aided by remote sensing techniques (e.g. Evans, 2002a). Remote sensing is likely to be most useful in areas difficult of access, much of which will be grazed by animals (Arnalds et al., 2001).

It is unfortunate that Panagos et al. (2015a) quote without caveats Pimentel et al.'s (1995) value for amount of erosion in Europe. That work (Pimentel et al., 1995) is open to serious criticism (Boardman, 1998a). "Regional or even global estimates have quite wrongly, scaled up measurements made on small plots, arriving at huge masses of eroded soil that would reshape whole landscapes within a few decades" (UNEP, 2007, pp. 95). Excessively high erosion rate figures can be used by politicians/policy makers to advocate measures that may be misguided. Modelled information can be used to suggest that policies to mitigate erosion are successfully tackling soil loss across Europe (Panagos et al., 2015f) when in fact we do not know that. What we can say is that putting land back under grass, for example, will reduce soil loss, but we will not know by how much. It is doubly unfortunate that this work emanates from an EU institution—the Joint Research Centre. As Sterman notes (2010, pp 850) "..good modellers focus the client (*policy maker*) on the limitations of the model so it can be improved and so clients will not misuse it." We consider that in this instance that is not being done.

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