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Comment on “The new assessment of soil loss by water erosion in Europe” by Panagos et al. (Environmental Science & Policy 54 (2015) 438–447)

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The newly published European map of sheet and rill erosion by Panagos et al. (2015a) represents a great effort to produce a homogenized basis for administrative and political decisions regarding soil conservation in Europe. The ambition to set a new benchmark is clear from the title of the publication and based on the general mandate of the Joint Research Centre JRC in Ispra (Italy), the European Commission’s in-house science service, where most of the authors of the Panagos et al. (2015a) publication are affiliated.

This European erosion map will potentially have tremendous effects on political and administrative decisions and allocation of funds, and should therefore represent the best we – the soil erosion community – can provide for Europe. We acknowledge that for some European countries little information about soil erosion is available and Europe-wide modelling based on (R)USLE technology could overcome these deficits. However, in other countries, e.g. Germany, which for brevity we will use as a case in point, there has been an enormous body of research on the adaptation, parameterization, implementation, improvement and validation of the (R)USLE since the late 1970s. The application of the (R)USLE thus has reached a high degree of maturity and relevant gaps that would show up in current scientific literature are scarce. The (R)USLE is widely accepted and used within all relevant bodies of administration (agriculture, environment, hydrology, justice etc.). This may be illustrated by the fact that an adapted version of the (R)USLE was developed into a national standard (DIN, 2005), which was recently updated (DIN, 2015). Maps on different scales from 1:5000 to 1:1 000 000 are daily tools in administration, which – where necessary – are annually updated to include current cropping information for all individual fields within Germany. It would have been useful to make use of this large body of expertise, e.g. for verifying and validating the European map.

It may not be possible to reach the same degree of maturity in erosion modelling on the European scale. Even so, basic modelling principles, like validation, and the basic principles of the (R)USLE in particular, should not be disregarded.

A characteristic property of the (R)USLE is that, due to the multiplication of factors, any error in one of the factors will produce an error of the same magnitude in the final result. Unfortunately, it has been shown for two factors (soil erodibility factor *K* see Auerswald et al., 2014 and rain erosivity factor *R* see Auerswald et al., 2015) that the approach taken in previous work by Panagos and coworkers, and which was incorporated into this current erosion map, carries considerable error. E.g., for a total of about 20,000 soil analyses from Central Europe, it has been shown (Auerswald et al., 2014) that the approach taken by Panagos et al. (2015a) will fail in about 45% of all cases. The failure can be large and may over or underestimate the *K* factor by up to 50%. It has also been shown that for different landscapes, the error will be in different directions. Hence, it does not level out on a map but it will distort the relation between different landscapes (Auerswald et al., 2014). Moreover, it is unclear how Panagos et al. (2015a) calculated soil erosion for Bulgaria, Romania and Croatia, which were not included in the calculation of the referenced K factor map (Panagos et al., 2014). Similarly large errors on the landscape level can be expected for the *R* factor (see Auerswald et al., 2015).

The approach of Panagos et al. (2015b) to estimate the crop and cover factor (*C* factor) has not yet been critically evaluated, but is an even larger source of error than the *R* and *K* factors. The *C* factor essentially quantifies the interaction of the seasonal variation of soil cover with the seasonal variation in rainfall erosivity, averaged over a crop rotation. The seasonal *C* factor will be low even in a period with little soil cover if there is little rain erosivity, while the seasonal *C* factor will reach high values in this case if rain erosivity is high. Due to the facts that seasonal variation of soil cover changes regionally following changes in ambient temperature and that seasonal erosivity also changes regionally, the *C* factor, even for one crop, will differ greatly between regions. Especially under Mediterranean climate where a high percentage of rain erosivity can be expected to occur during winter months (e.g., 43% in mid Italy, Fig. 1), crops which provide little cover during winter will be particularly susceptible to erosion. In contrast, for regions under more continental climate, where most erosive thunderstorms occur during the summer months, crops with little cover during winter are less critical. For instance, in Austria only 7% of the

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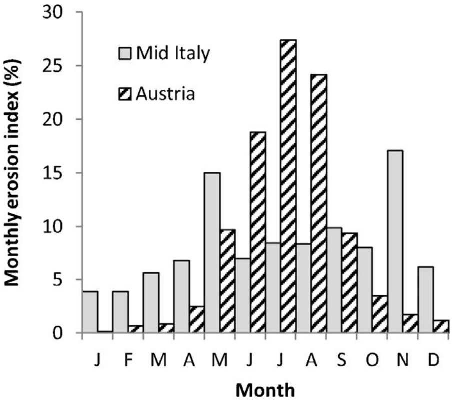

Fig. 1. Monthly distribution of annual erosivity (*R* factor) for mid Italy (Mediterranean climate) and Austria (subcontinental climate); data for Italy were taken from Diodato (2005) and for Austria from Strauss et al. (1995).

annual erosivity is expected to fall in the winter half year (November to April; Fig. 1). In consequence, winter small grain, which has its most susceptible seedbed during the winter half year, will be highly prone to erosion in mid Italy while it can be regarded as rather safe in Austria. Thus, large contrasts can be found between neighboring countries or even within countries like Italy (Diodato, 2005), due to the interlacing of Mediterranean, continental, maritime and Nordic climates on rather short distances within Europe. Taking *C* factors from different studies without accounting for climate and averaging them to yield a "European" average for a certain crop, as done by Panagos et al. (2015b), will produce numbers that will certainly not be applicable everywhere, and may not be relevant at the vast majority of sites.

As a consequence of this averaging over regions, the *C* factors for different crops do not differ much, because their interactions with seasonal rainfall distribution has been lost. It is thus not surprising that the *C* factors of wheat and maize differ only slightly in Panagos et al. (2015b) (0.20 vs. 0.38), while in reality they may differ considerably. For instance, in Germany they differ by a factor of eight (0.04 vs. 0.33) (Table 11 in Schwertmann et al. (1990); see also DIN (2005, 2015),) and Auerswald et al. (2003).

Importantly, the *C* factor has to be calculated for rotations and not for individual crops because large carry over effects may occur between crops (especially in the case of ley crops, see Wischmeier and Smith, 1978, but also with other crops, e.g. potato, maize and wheat see Fiener and Auerswald, 2007) and because the period between two main crops differs largely depending on which crop follows the other. As an example, this period may last only a few weeks after winter barley if canola follows, while it may last almost three quarters of a year if maize follows. As a consequence, the *C* factors of rotations differ from the average of *C* factors of their individual crops. Further, if the *C* factors has to be estimated from cropping statistics that average over different farms, although the crops do not rotate between farms, another bias appears that leads to an underestimation of the true average *C* factor (Auerswald, 2002; Auerswald et al., 2003). Both effects can be accounted for (Auerswald, 2002; Auerswald et al., 2003) but this was not done by Panagos et al. (2015b). It is thus not surprising that the estimated *C* factors by Panagos are largely misleading. For Bavaria, which is 71,000 km^2 in size, Panagos et al. (2015b) report only one *C* factor on arable land without further differentiation (0.27). In fact, the *C* factor on arable land (excluding hops) in Bavaria differs between 0.01 and 0.45 for different area municipalities and thus exhibits a pronounced regional variation (Auerswald et al., 2003). Needless to say that peculiarities, like the cultivation of hops, which has an exceptionally high *C* factor (0.4–1.0, depending on cultivation method, Schwertmann et al., 1990) and which is the dominant arable crop within a particular 2400 km^2 landscape (Hallertau), is not considered in Panagos et al. (2015b). Furthermore, the Bavarian average on arable land (0.13; without hops) differs by a factor of two from the estimate by Panagos et al. (2015b). Similarly, the spatial variation of the *C* factor within Germany is greatly misleading. According to Panagos et al. (2015b), Bavaria has the lowest average *C* factor on arable land within Germany, while in fact, aside from the north-western corner of Germany (Cloppenburg-Vechta), Bavaria is actually considered to have the highest C factor due to the extraordinarily high contribution of maize (Schwertmann and Vogl, 1985; Wurbs and Steininger 2011).

The problems in the map of Panagos et al. (2015a) should become clear when compared with other maps. Indeed, the correlation with predictions based on 2741 plot-years of erosion measurement under natural rainfall (Cerdan et al., 2010) is poor and insignificant ($p = 0.41$; data taken from Table 2 of Panagos et al., 2015a). Furthermore the mean of the Panagos map (2015a) for nine countries listed in his Table 2 is about twice as high as the mean of the same countries in Cerdan et al. (2010), which suggests a large bias. The bias of individual countries is even larger. In some countries the bias can be factor 5 or larger. Panagos et al. (2015a) blame Cerdan et al. (2010) for this discrepancy because, according to Panagos et al. (2015a), "rainfall intensity was not included in the soil erosion map of Europe" by Cerdan et al. (2010). They fail to explain how soil erosion measurements under natural rain can exclude the influence of rain intensity.

It is good scientific modelling practice to complement modelling by rigid validation, sensitivity and uncertainty analyses (e.g. Refsgaard and Henriksen, 2004; Mulligan and Wainwright, 2004). These practices are even more necessary as Panagos et al. (2015a) modified the original, well tested (R)USLE approach and also included mountain areas such as the high Alps, which fall beyond the secured range of the (R)USLE. The model validation in Table 2 of Panagos et al. (2015a) is rough and incomplete. It only shows nine selected countries, while data for 17 countries based on plot measurements and another 25 countries without measurements would have been available (Cerdan et al., 2010). In addition, the comparison to Cerdan et al. (2010) does not support the map by Panagos et al. (2015a) ($p = 0.41$; see above), but no further analysis was carried out to elucidate the large differences. Moreover, the large number of available national datasets and maps could have been used for an analysis of the performance of the new map.

Apart from a missing rigid validation, one could also expect some analysis of uncertainties in the modelled erosion rates, as they relate to uncertainty in model structure, parameter values etc., which would have given the decision maker using such a map some estimate of the risk associated with quality of the predictions (e.g. Beven, 2007). This would be especially important for scenarios of future erosion, where Panagos et al. (2015a) only used climate (WorldClim; Hijmans et al., 2005) and land use (LUMP; Lavalle et al., 2013) projections for the year 2050, while ignoring observed climate driven shifts in the seasonality of erosivity (e.g. Fiener et al., 2007) and crop phenology (Menzel and Fabian, 1999; Estrella et al., 2007), as well as potential future changes in crop management (Hatch et al., 1999; Bacenetti et al., 2014).

We conclude that still more effort should be taken by the European soil erosion community to derive a homogenized soil erosion map of Europe, which can be used as a basis for political and economic decisions on the European level. If a (R)USLE approach is used for an European erosion map, it is essential to utilize existing data, knowledge and procedures already operational in different European states. Soil erosion has been named as one of the major environmental threats in the European Union. As such, we believe that a more concerted effort to deal with (future) soil erosion in Europe is needed, especially in light of the projected changes in future land use, land management and climate. Until then, the map by Cerdan et al. (2010), synthesized from 2741 plot-years under natural rainfall, clearly remains the best estimate of soil erosion by sheet and rill flow in Europe and we recommend its use.

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