# Comment on “Rainfall erosivity in Europe” by Panagos et al. (Sci. Total Environ., 511, 801–814, 2015)

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## ABSTRACT

Recently a rainfall erosivity map has been published. We show that the values of this map contain considerable bias because (i) the temporal resolution of the rain data was insufficient, which likely underestimates rain erosivity by about 20%, (ii) no attempt had been included to account for the different time periods that were used for different countries, which can modify rain erosivity by more than 50%, (iii) and likely precipitation data had been used instead of rain data and thus rain erosivity is overestimated in areas with significant snowfall. Furthermore, the seasonal distribution of rain erosivity is not provided, which does not allow using the erosivity map for erosion prediction in many cases. Although a rain erosivity map for Europe would be highly desirable, we recommend using the national erosivity maps until these problems have been solved. Such maps are available for many European countries.

The Universal Soil Loss Equation USLE (Wischmeier and Smith, 1965, 1978) including its many modifications and successors like the Revised Universal Soil Loss Equation (RUSLE, Renard et al., 1991) has become the most often used model to predict sheet and rill soil erosion by rain in science. Even more importantly, it is the still only erosion model of relevance that is frequently used outside science for planning purposes (e.g. land reconsolidation planning, Ankenbrand and Schwertmann, 1989) or administrative purposes (e.g. in connection with the European Water Directive). In the USLE, the influence of rainfall characteristics on sheet and rill erosion is quantified as rain erosivity. Recently, Panagos et al. (2015) published a map of rain erosivity in Europe. Although such an attempt is highly desirable given the wide relevance of the USLE, the map by Panagos et al. (2015) has significant deficiencies and is therefore likely to misguide users of the USLE for five reasons:

1. For ease of application, the influence of rain erosivity on soil erosion is split within the USLE into two of the six factors that finally have to be multiplied to yield the predicted soil loss. The R factor (rain and runoff factor) quantifies the long-term mean annual erosivity at a site, while the seasonal distribution of rain erosivity (called Erosion index within the USLE, Wischmeier and Smith, 1965) has to be convoluted with the seasonally varying protection of the soil (called Soil loss ratio within the USLE) to yield the convolution integral, which is the so-called C factor (crop and cover factor). The R factor and the Erosion index are derived from the same data and both are needed simultaneously to predict soil loss. This is why usually regional estimates of the R factor also provide the seasonal Erosion index (e.g., Bollinne et al., 1979; Rogler and Schwertmann, 1981; Strauss et al., 1995; Sauerborn, 1994). Panagos et al. (2015) provide a rainfall erosivity (R) map without providing the regionally varying Erosion index. This will likely misguide many users of the USLE, especially outside science, who are not familiar with the theoretical considerations behind the USLE. In an attempt to use the R factor map they are likely to use published C factors that were derived with an Erosion index that may not be applicable at the site of interest. This is especially true for Europe where the Erosion index varies considerably within a few hundred kilometers due to the interlacing areas of Mediterranean, oceanic or continental climate that differ in the seasonal distribution of erosivity.
2. Given the long-lasting and wide relevance of the USLE and the regional character of rain erosivity, many publications on rain erosivity in Europe exist, starting with Bollinne et al. (1979) in Belgium and

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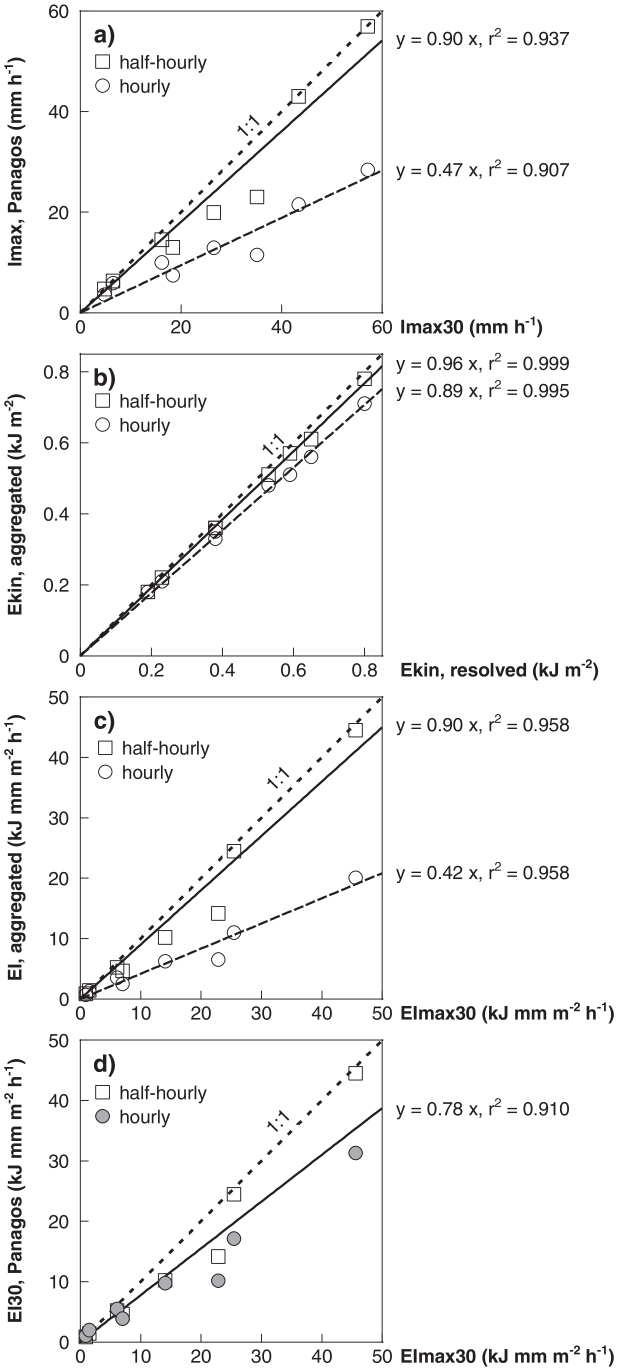

**Fig. 1.** Influence of the temporal rainfall resolution on the components of event rain erosivity EImax30 (rain data were taken from Fiener and Auerswald, 2009). a) Comparison of Imax30 and the maximum half-hourly and hourly intensity as used by Panagos et al. (2015). b) Comparison of kinetic energy (Ekin) determined according to Wischmeier (1959) from temporally resolved rain data and from half-hourly and hourly aggregated data. c) Comparison of EImax30 calculated from temporally resolved rain data to EI from half-hourly and hourly aggregated rain data. d) Comparison of EImax30 calculated from temporally resolved rain data to EI from half-hourly (open symbols) and hourly rain data (filled symbols) after correction following Panagos et al. (2015).

Bader and Schwertmann (1980) in Germany. Gabriels (2006) compiled 16 studies from Belgium, Germany, the Netherlands and France but many more exist, e.g., from Finland (Posch and Rekolainen, 1993), from Austria (Strauss et al., 1995), from Germany (Hartmann, 1988; Auerswald, 1996; Sauerborn, 1994; Fiener and Auerswald, 2009), from Poland (Banasik and Gorski, 1992), from Portugal (Loureiro and Coutinho, 1995; Goovaerts, 1999), from Czech (Janeček et al., 2013), or from Italy (Ferro et al., 1991; Arinica and Ferro, 1997). In contrast, Panagos et al. (2015) claim that “Only few studies in Europe have determined the R-factor directly from high-resolution data…” and cite only four studies, which all appeared after 2006 and cover only small areas. This disregards the work of the pioneers of rain erosivity determination in almost all European countries and it ignores the wealth of the existing data, resulting in a map that may be less accurate than would be possible when all available information would have been employed.

3. Panagos et al. (2015) also did not cite the seminal articles by Wischmeier (Wischmeier and Smith, 1958; Wischmeier, 1959). This may explain why they wrongly apply Wischmeier's equations. According to Wischmeier (1959) a rainfall event has to be split into periods of constant intensity. For each period, kinetic energy is calculated from intensity. The sum of the kinetic energy of all periods of constant intensity (E) is then multiplied with the maximum intensity during 30 min (Imax30) of the event to yield the erosivity of the event (EImax30). However, only events with a total rainfall amount exceeding 12.7 mm or an Imax30 exceeding 12.7 mm h$^{-1}$ should be accounted for. Panagos et al. (2015) used the maximum half-hourly intensity rather than Imax30. This will only be correct when Imax30 starts exactly at the full or half hour. In all other cases the maximum half-hourly intensity will be lower than Imax30 (Fig. 1a). Even worse, 38% of Panagos data have only hourly resolution. At hourly resolution, maximum intensity decreases below 50% of Imax30 (Fig. 1a). Panagos et al. (2015) justify their decision to use these data by claiming that “climatic data of high temporal resolution are not easy accessible in Europe or are only available for a fee”. This justification is surprising because usually science is not thought of as being neither easy nor free of costs. Furthermore, high resolution rainfall data sets are available free of costs for scientific purposes in several countries.

   The low temporal resolution influences E to a smaller degree because total kinetic energy mainly depends on the amount of rain and less on drop size distribution that in turn depends on rain intensity. The bias of E (Fig. 1 b) is therefore considerably smaller than the bias of Imax30 but as E and Imax30 are finally multiplied, both biases add up and become larger the larger E and Imax30 are (Fig. 1c).

   Panagos et al. (2015) were aware of the inconsistencies between their data arrays including data of 5-min resolution (1% of their station years), 10-min resolution (17%), 15-min resolution (5%), 30-min resolution (38%) and 60-min resolution (38%). They decided to adjust all data to be compatible with data at 30-min resolution. Applying their correction factor to adjust 60-min resolution data decreases the bias between the estimated EImax30 compared to the true EImax30 (Fig. 1d) but a mismatch of 22% still remains. Consequently, the calculated R factor, which is the mean annual sum of all EImax30, considerably underestimates erosivity and subsequently any predicted soil loss in Europe. A simple correction by adding 22% to the calculated values may not be appropriate. The bias will likely vary within Europe given the variation in climate, the country-wise varying resolution of rain data as used by Panagos et al. (2015) and two additional sources of bias that were introduced by Panagos et al. (2015) and which differ regionally (see below).

4. The bias in the calculations by Panagos et al. (2015) leads us to expect that their R factor should be lower than the values reported in previous studies, which were derived from temporally resolved data. This is the case for instance for Germany. The R factor range reported by Panagos et al. (2015) originating from 148 stations is clearly lower than that reported by Sauerborn (1994), who evaluated 139 stations. It is likely that most stations used in the two studies are identical because data for both studies were provided by the German Weather Authority (Deutscher Wetterdienst). The high-resolution data used by Sauerborn (1994) also provide proof that better data are available, but were not used by Panagos et al. (2015).

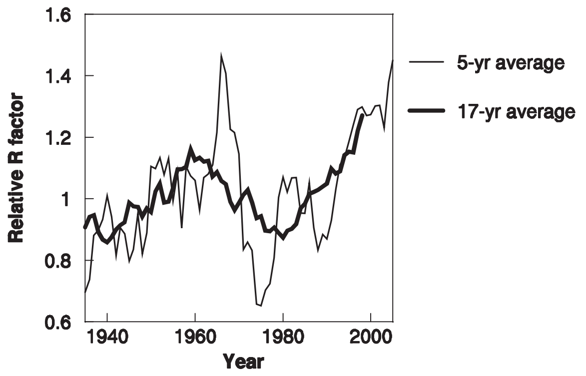

**Fig. 2.** Variation of the R factor relative to its site-specific long-term average depending on the analyzed period. The relative R factor was calculated as a regional mean of 11 stations using the data of Fiener et al. (2013) from Germany and the data of Verstraeten et al. (2006) from Belgium for record periods of 5 years (the shortest period in Panagos et al., 2015) and 17 years (Panagos' mean record period). The x axis denotes the central year of the respective periods.

Surprisingly, the expected underestimation is not met by the results for Austria although again several stations are identical. While the minimum reported by Panagos et al. (2015) is, as expected, lower than the minimum reported by Strauss et al. (1995) (35 vs. 47 kJ mm $m^{-2}$ $h^{-1}$ $year^{-1}$), the mean and the maximum reported by Panagos et al. (2015) are far above the respective values reported by Strauss et al. (1995). Strauss et al. (1995) found a maximum of 138 kJ mm $m^{-2}$ $h^{-1}$ $year^{-1}$, while the maximum given by Panagos et al. (2015) is 435 kJ mm $m^{-2}$ $h^{-1}$ $year^{-1}$. Such a high R factor is very unlikely in Austria. The equation provided by Strauss et al. (1995) (31 stations, $r^2 = 0.88$) predicts that an R factor of 435 kJ mm $m^{-2}$ $h^{-1}$ $year^{-1}$ would only occur in areas where long-term average summer rainfall (May to October), the best predictor, is 3250 mm $yr^{-1}$. In reality, summer rainfall exceeds 1000 mm $yr^{-1}$ in Austria only in 5% of all 160 stations reported by the Austrian Zentralanstalt für Meteorologie und Geodynamik (http://www.zamg.ac.at/; last access: 25 Feb 2015). The maximum of these 160 stations has a summer rainfall of 1357 mm $yr^{-1}$, which leads to a predicted annual R factor of only 184 kJ mm $m^{-2}$ $h^{-1}$ $year^{-1}$. Mean normal period summer rainfall of all 160 stations is 644 mm $yr^{-1}$ and somewhat above the mean rainfall of the stations evaluated by Strauss et al. (1995) (517 mm $yr^{-1}$) because Strauss et al. (1995) as Panagos et al. (2015) mainly considered stations in the eastern part of Austria where rainfall is lower. The most likely reason for this discrepancy thus is that Panagos et al. (2015) did not use rain data but total precipitation data, including snowfall. Clearly, the erosivity of snow (melt) cannot be calculated using the equations provided by Wischmeier (1959) for rainfall. However, we can only speculate on this because Panagos et al. (2015) wrongly use precipitation and rain as synonyms and because they do not provide the Erosion index that would allow judging what fraction of the total annual erosivity is expected to occur during the winter period with snow. The high R factors shown for the Alps in the maps of Panagos et al. (2015) are therefore likely to be wrong. Similar errors can be expected for other high-altitude or high-latitude areas in Europe receiving significant amounts of snow.

5. Panagos et al. (2015) used data from different periods (e.g. Bulgaria 1951–1976; Latvia 2007–2013) and of different durations (presumably 7 to 56 years as in their Table 1, or 5 to 40 years as in their Abstract). They claimed time discrepancies to be of minor importance in evaluating spatial trends of rainfall erosivity (page 803) without further analysis or discussion of the associated uncertainty introduced into the spatial trends. The rare European long-term R data sets based on high resolution rainfall data (e.g. one station from Brussels with 105 years of data, Verstraeten et al., 2006; ten stations from Germany with 71 years of data, Fiener et al., 2013) indicate that annual R factors are highly variable in time and additionally they show cycles and/or trends. The random variation could be ignored if a data set is long enough. In the case of Verstraeten et al. (2006), Fiener et al. (2013) and Strauss et al. (1997) about 30 years were needed, which is met by 13% of the stations used by Panagos et al. (2015). More important is the presence of cycles and trends, which calls for a detrending of data. The data of Verstraeten et al. (2006) and Fiener et al. (2013) show that the regional R factor may vary by more than 100% between different 5-year periods (the shortest period in Panagos et al., 2015) and the variation is still more than 40% for their mean recording period of 17 years (Fig. 2). Combining data from different periods will thus translate the temporal variation into a spatial pattern that in fact does not exist and which is superimposed on the true pattern.

Remark: We use the unit kJ mm $m^{-2}$ $h^{-1}$ $year^{-1}$, which is the most often used unit of the R factor in Europe, while Panagos et al. (2015) report their R factors in MJ mm $ha^{-1}$ $h^{-1}$ $year^{-1}$. Both units can be easily converted by dividing the values in MJ mm $ha^{-1}$ $h^{-1}$ $year^{-1}$ by a factor of 10.

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