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Discussions

Interactive comment on "How rainfall event characteristics affect the applicability of I_{30} as an index of intense or erosive rainfall: a brief review with proposed new rainfall index" *by* David L. Dunkerley et al.

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In this study, the author discusses a set of limitations of the 30-min maximum rainfall intensity index (I30) for the analysis of rainfall erosivity, and suggests an alternative index (EDf5, Event duration fraction 5%) that does not rely on a fixed clock period (such as the I30) for the study of rainfall characteristics that drive runoff generation and soil erosion processes. He applies tipping-bucket raingauge records of two climatologically contrasted sites in Australia (262 and 430 rainfall events recorded in two sites under arid and wet tropical conditions, respectively) to illustrate the better performance of the proposed EDf5 index for discriminating the rainfall characteristics of these two stations.

Mean I30 of all rainfall records is similar for the two analyzed stations (about 8 mm h-1). However, taking EDf5 as an alternative index to characterize the rainfall characteristics, the rainfall of the arid-zone site shows a higher intensity than in the tropical site (mean EDf5 for all the rainfall events is 7.4 and 3.8 mm h-1 for the arid and tropical site, respectively).

Although initially tested on the basis of empirical data collected in USA, I30 has been applied worldwide as an important rainfall variable for the study of surface processes (e.g., runoff generation, soil erosion, runoff/sediment redistribution), showing in many cases a valuable capacity for predicting sediment yield and Hortonian runoff production. Furthermore, I30 plays a central role in the USLE family of soil erosion models, where combined with the (total) kinetic energy of precipitation (Wischmeier's EI30 index) it characterizes the erosivity of the rainfall events. The use of I30 as a rainfall variable or as a soil erosion model parameter has, however, been subjected to important criticizes since the 1960's, when pioneering works by Norman Hudson and Rattan Lal in Africa, and Roy Morgan in Europe detailed some of the critical limitations of I30 for the study of soil erosion. In the current paper, the author brings back in this paper a renewed discussion about the limitations of I30 for the study of surface processes. I really appreciate the effort. However, I have important concerns regarding the lack of integration of results by previous studies on similar topics with the content of the paper, some of the limitations described in this study for the application of I30, the simplicity of the present analysis and associated speculative discussion of the results, and the adequacy of the proposed new index (EDf5) to characterize rainfall erosivity.

(1) The initial short review on the use and limitations of the I30 parameter/index for the analysis of surface processes lacks historical context of discussions by previous works. The use of I30 draws attention to short (30 min) peak periods of intense rainfall discharge. As originally applied by Wischmier and Smith, the inclusion of the I30 parameter in the rainfall erosivity index was an attempt to correct for overestimation of light intensity, non-erosive rain. Soon, however, different researchers identified some

important limitations of I30 for its use as an erosive parameter or stand-alone index; mainly I30 does not correlate well with the ratio of intense to non-erosive rain, and there is not clear physical reason to select a fixed 30-min period (against other periods) to describe peak rainfall discharge (a good reasoning for these points can be found in Morgan's renowned book on soil erosion and conservation). On the basis of these criticism, a wide variety of alternative rainfall erosivity indexes were developed, including KE>25 and KE>10 that threshold rainfall intensity values at 25 and 10 mm h-1 levels, or AImax, that applies a fixed clock period of 7.5 mins for the calculation of max rainfall intensity. Further investigations in dryland areas (see for example the results by Uson & Ramos 2001 in areas of the Mediterranean basin) have demonstrated that high intensity rainfall bursts within short to long rainfall events of 1-48 h event duration tend to concentrate water discharge in time periods that are typically shorter than 30 mins, so in order to assess the impact of rainfall characteristics on surface processes for these highly erosive areas it is necessary to evaluate also shorter max rainfall intensity periods (e.g. I15, I10, I5). Many other studies have also discussed the limitations of I30 and other alternative indexes of intensity/erosivity, overall suggesting that no single index provides a perfect characterization of the impact of rainfall characteristics on surface processes and, therefore, a range of indexes should be used. Although to date the bibliography on the use and pitfalls of I30 is very rich, there is very limited integration of these studies in the paper, particularly in the introduction, where the main limitations for the use of I30 are described, and in the discussion.

(2) The author identifies as a critical limitation for the application of I30 that this parameter/index of rainfall intensity cannot be determined for rainfall events of less than 30-min duration and, therefore, these short events have to be excluded from analysis. I do not agree that I30 cannot be calculated for these very short events. Provided that the minimum inter-event time (MIT) is set at time periods longer than 30 mins (in this study MIT is 6h, as commonly applied in RUSLE-based studies) there is no limitation to calculate the maximum rainfall intensity during a period of 30 consecutive minutes for each event, even for single and 2-tip events: I30 for an event of 2 mm and 5-min

duration is 4 mm h-1, and I30 for and event of 7 mm and 23-min duration is 14 mm h-1. Of course, we can criticize that I30 loses utterly for these very short events the capacity to describe the peak rainfall intensity, as the mean rainfall intensity of these events is higher than the calculated I30 values. In fact, while for events with a duration sensibly longer than 30 mins, I30 provides a relatively good characterization of peak rainfall discharge, for ∼30-min events, I30 equals the mean rainfall intensity of the event (Im), and for events shorter than 30 mins, I30 values drop below the Im levels. In any case, there is no practical reason to exclude <30-min duration rainfall events from the calculation of I30 and further data analysis.

(3) The paper dis-proportionally highlights the relevance of very short (<30-min duration) rainfall events for characterizing rainfall erosivity. Runoff production and sediment yield in drylands are characterized by a high time compression: the majority of erosion and runoff production is caused by a few significant events. Rather than isolated rainfall burst of very short duration that typically accumulate very small total rainfall depths, these significant erosive events have generally longer duration, from 2-4 hours (in many cases taking place in the form of convective thunderstorms) to much longer periods, totaling significant volumes of rainfall. Of course, these highly erosive events typically contain short-lived periods of extreme or very intense precipitation discharge, but their effects on surface processes are not only directed by the extreme intensity of these within-storm short burst, but also by the accumulation of significant rainfall depths that can hardly be generated by an isolated storm of very short duration. Rather than any practical difficulties in the characterization of maximum rainfall intensity (such as I30) for very short precipitation events, the general lack of analysis of these small events in hydrological and soil erosion studies is caused by the absence of any active hydrological response in terms of runoff and/or sediment production. In fact, it is not by chance that by convention, for the USLE family of erosion models (and also for other alternative models), small events accumulating less than 12.5 mm rainfall depth (if <6.25 mm fall in 15 mins) are excluded from EI30 calculation and soil erosion modelling. Simply, these events have a non-erosive behavior and, collectively, they have little (if any) effect on

the distribution of annual soil erosion. In this study, the author indicates that the mean intensity and duration of the <30-min events that were excluded for the computation of I30 are 14.9 mm h-1 and 16.1 min (4 mm total rainfall depth) for FG, and 10.7 mm h-1 and 11.6 min (2 mm total rainfall depth) for MM. These very small rainfall volumes (2-4 mm) can hardly produce any active hydrological response. The author also indicates that some of these short events have depths in the range of 10-15 mm, which he speculates are sufficient to trigger overland flow in the studied areas. Although I reckon that a rainfall volume of 10-15 mm in nearly or less than 30 mins may induce runoff under some particular conditions, I think that more information should be required to highlight the relevance of these very short events. First, a rainfall-depth distribution plot showing the amount of very short precipitation events that surpass the invoked 10-15 mm rainfall-depth threshold (or alternatively, the USLE-family based 12.5 mm rainfall threshold) would help to rationalize the relevance of these events. Second, if no runoff/soil erosion data is available in the study sites, at least some references would be necessary to associate these small rainfall volumes with the speculated active runoff/sediment yield responses.

(4) Very likely, the most important limitation of this study is the lack of surface hydrology data for testing the exposed I30 limitations and speculated EDf5 advantages for the study of the relationship between rainfall intensity and surface processes. This reduces the present analysis to a simple climatological characterization of rainfall series and keeps the discussion on rainfall erosivity in a very speculative stage. Although the author speculates in several sections whether I30 or EDf5 provides a better approach to characterize the erosivity of rainfall events, no evidence on the basis of empirical data is provided. As a technical note, I support the use of rainfall series of just two sites for part of the analysis. However, I also believe that any attempt to criticize the use of I30 in soil erosion studies or to provide alternative indexes of rainfall erosivity must be accompanied by further empirical evidence, including the analysis of, at least, a few runoff and sediment yield data.

(5) The present data analysis is very simplistic, even from the climatological point of view. The author claims a higher capacity of EDf5 than I30 to discriminate between arid and tropical conditions in terms of rainfall intensity characterization. He bases his conclusions on the analysis of mean I30 and EDfx values of two long-term rainfall series. For normally distributed data, the mean value provides a valuable descriptive statistic of central tendency. However, for data samples that do not follow a Gaussian distribution, the arithmetic mean losses its descriptive capacity. Rainfall intensity data such as I30 and EDfx deviate strongly from normality: there is a lot of low rainfall intensity values and just a few high and extreme intensity values in the rainfall series. Other descriptive statistic may be much more meaningful for the analysis of I30 and EDfx data, such as the median, interquartile range and extreme, outlier values.

(6) I have serious concerns on the applicability of EDf5 as a feasible index for characterizing rainfall erosivity. Even without empirical runoff/sediment yield data, I can perceive a strongly unbalanced behavior of EDf5 for describing rainfall erosivity. Namely, EDf5 will tend to strongly overestimate the erosivity of small rainfall events and to largely underestimate the erosivity of large events. We can illustrate this issue with an example of two hypothesized events of contrasted nature: a very short event of 5 mins with a high peak of rainfall discharge for a few (10-20) seconds and a total depth of 3 mm (Event 1), and a 10-h duration storm of $\sim$30 mm rainfall depth and a peak discharge of rainfall of similar magnitude in intensity during 20-30-min duration (Event 2). The very small rainfall depth of Event 1 would make this precipitation irrelevant in terms of runoff production and/or sediment yield. However, for Event 1, EDf5 may take values of the same magnitude or even higher than for Event 2, largely failing to characterize the erosivity of the two different events. In the hypothesized situation of these two contrasted events, the comparison of the rainfall intensity properties of a 15-second rainfall period (Event 1) against a 30-min rainfall period (Event 2) is probably not very useful for evaluating rainfall erosivity. In addition to the unbalanced nature of EDf5 in the context of rainfall erosivity characterization, it is not clear to me the reasoning followed by the author for selecting EDf5 against other alternative EDfx indexes of shorter (e.g., 1%,

3%) or larger (e.g., 10%, 20%, etc.) time fractions.

(7) Last, the paper, as presently organized, presents a new rainfall intensity/erosivity index (EDf5) against a series of drawbacks for the use of I30 without considering the possible drawbacks that may affect the new index and providing no empirical evidence of its relevance and advantages for the study of the relationships between rainfall characteristics and surface processes. As previously indicated, the present broad knowledge on the use of simple rainfall indexes for the study of runoff and sediment yield dynamics suggests that no unique index of rainfall intensity/erosivity provides a perfect approach for revealing the complex relationships between surface processes and rainfall characteristics. Differently, a set of supplementary rainfall indexes and variables should be applied. In fact, the new EDf5 index is affected by some of the limitations that are already described in the paper for the use of I30 as a stand-alone rainfall erosivity index (e.g., the EDf5 index does not incorporate any information on antecedent rainfall conditions, which is claimed in the paper as a significant limitation of I30) and may be also affected by other important issues (e.g., the above-mentioned issues on the overestimation/underestimation of rainfall erosivity for small/large rainfall events) that are not evaluated against empirical runoff/erosion information in this paper.

In brief, I appreciate the effort made by the author in this paper that brings back the historical discussion on the use of I30 as a parameter/index of intense and/or erosive rainfall on hydrological and soil erosion studies. However, I think that the development and presentation of an alternative or supplementary index of the proposed characteristics should require (i) a more integrated vision of previous historical studies on this issue, (ii) reconsideration of the validity some of the described drawbacks for the use of other commonly applied (fixed clock period) peak rainfall intensity indexes, (iii) a more detailed climatological analysis of the rainfall series that are presented in the paper, and (iv) the inclusion of, at least, a few empirical runoff/sediment yield data for evaluating the relevance of the new index for the study of the relationships between rainfall characteristics and surface processes.

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