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# Assessing the use of rainfall synthetic series to estimate rainfall erosivity in Brazil

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A B S T R A C T

Although it has been used in research or technical work, applying synthetic rainfall data series to estimate rainfall erosivity is still a tool that requires careful evaluation and validation. In this study we evaluate the potential use of synthetic data sets to estimate the rainfall erosivity index (R-factor) in order to validate the use of this tool throughout Brazil. Sub-hourly rainfall data from 141 pluviographic stations were used. Pluviographic synthetic series were generated from ClimaBR software. A computer routine was specifically developed to identify erosive rainfalls. R-factor was calculated from erosive rainfall events and from pluviographic synthetic series, as well as through regression equations proposed in the literature. It was observed that the method estimating rainfall erosivity from synthetic pluviographic series (SS) had satisfactory performance and was superior to the use of data based on empirical equations (EE). The results indicate that applying ClimaBR synthetic pluviographic series to estimate rainfall erosivity is a valid and potentially applicable alternative. Moreover, its application in Brazil showed no needs for calibration. Due to these results, we believe that R-factors can be calculated for each pluviographic station in the country by using SS, creating a useful rainfall erosivity map with wide distribution throughout Brazil.

## 1. Introduction

Storms or heavy rainfall events are the meteorological phenomenon considered as the primary cause of problems at agricultural and forest sites, causing such problems as decreasing crop productivity, increasing landslide activity, disturbing ecosystems, polluting water bodies and flooding (Haile and Fetene, 2012; Lee and Heo, 2011; Miao et al., 2012; Prokop and Poręba, 2012; Xin et al., 2011). Many of these problems have soil erosion as their major driving force, leading this process to be classified as a serious environmental issue that has attracted much attention throughout the world (Zhao et al., 2013). Rainfall causes soil erosion through the detachment of soil particles due to the impact of the raindrops and the subsequent transport of dislodged material on resulting runoff (Lim et al., 2015).

Rainfall erosivity is one of the most important factors that influences soil erosion, recognized as the best parameter for predicting the erosive potential of raindrop impact on soils (Isikwue et al., 2015). Some precipitation properties, such as rainfall intensity and kinetic energy, raindrop terminal velocity and size are the most frequently used parameters to calculate erosivity indices. Among the erosivity indexes, the rainfall erosivity factor (R-factor) of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) is the most applied index used for erosion prediction of tropical sites, such as in Brazil (Waltrick et al., 2015).

The original method to calculate the R-factor requires the direct computation of continuous long-term and high temporal resolution data of pluviographic records containing both the amount and intensity of rainfall (Isikwue et al., 2015; Wischmeier and Smith, 1978). This kind of information is difficult to obtain in Brazil due to the reduced number and unequal spatial distribution of rain gauge stations where pluviographic data are available (Cecílio et al., 2013). Moreover, the calculation of rainfall erosivity is limited due to the lack of long-term high

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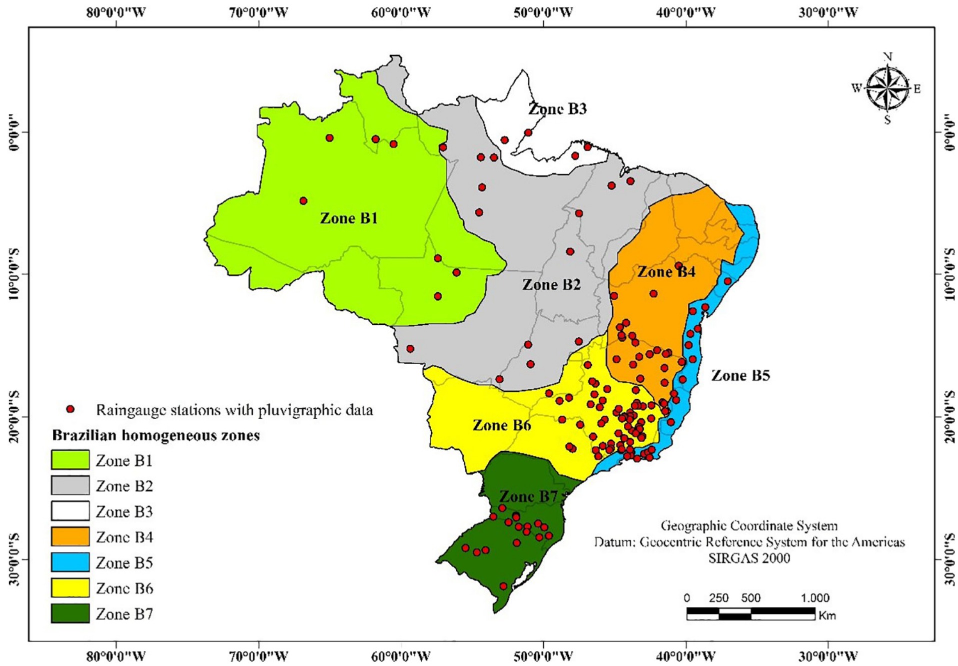


**Fig. 1.** Brazilian homogeneous zones according to rainfall characteristics (Baena et al., 2005) and the spatial distribution of Brazilian rain gauge stations used in this paper.

resolution time series rainfall data (Panagos et al., 2015). These facts lead to a low availability of consistent R-factor values for Brazil and many other countries (Isikwue et al., 2015).

On the other hand, some empirical equations can also be used to estimate rainfall erosivity. These equations use geographical coordinates and/or pluviometric records such as annual, monthly or daily rainfall amounts to calculate rainfall erosivity (Aquino et al., 2008; Capolongo et al., 2008; Davison et al., 2005; Hoyos, 2005; da Silva, 2004; Yu et al., 2001; Zhang et al., 2008). However, empirical equations should be used with caution in different applications, as the relationships are location dependent and cannot be applied to larger areas in most cases (de Oliveira et al., 2012). Moreover, empirical equations frequently cannot capture the high rainfall intensities which have a significant influence on average rainfall erosivity (Panagos et al., 2015). Regarding limitations of the empirical equations, they are still the most used method to predict R-factor throughout Brazil (Almagro et al., 2017; de Almeida et al., 2017; de Oliveira et al., 2012; Rosa et al., 2016), mainly the eight equations presented in the da Silva (2004) review paper.

On the other hand, some papers (Lobo et al., 2015; Yu, 2002) have proposed the use of a weather generator to generate daily rainfall synthetic series and then calculate R-factor. These synthetic series statistically preserve the mean and variance found in historical observations and are commonly used in modelling applications such as crop productivity (Zhang and Liu, 2005), streamflow simulation (Li et al., 2015; Šípek and Daňhelka, 2015) and soil loss prediction (Routschek et al., 2014) under land use changes and/or climate changes. However, some papers (Yu, 2003; Zhang et al., 2010) show that R-factors calculated with synthetic series often need to be calibrated due to systematic discrepancies of real R-factor values. Thus, we believe that there is still a gap in the use of weather generators which justifies more studies on its application to erosivity estimations.

Some researchers (Cecílio et al., 2013; Moreira et al., 2009, 2016) have used a Brazilian Weather Generator named ClimaBR (Baena et al., 2005; de Oliveira et al., 2005a, 2005b; Zanetti et al., 2005) in order to calculate the R-factor of some Brazilian regions. However, none of these papers have even proven the efficiency of ClimaBR to predict the R-factor in Brazil. Although ClimaBR synthetic series to estimate R-factor has been used in research or technical work, its application is still a tool that requires careful evaluation and validation. Therefore, in this study we have evaluated the potential use of synthetic rainfall series generated by ClimaBR to estimate R-factors for Brazil, contrasting it to the R-factor calculated with the empirical equations presented in the Silva (2004) paper, which are still the most frequently used equations around Brazil.

## 2. Material and methods

We have divided this paper into the following steps:

a) Calculation of R-factors using observed sub-daily high resolution pluviographs from 141 pluviographic stations (R-$factor_{observed}$);

b) Generation of daily rainfall synthetic series to the 141 pluviographic stations;

c) Calculation of R-factor for the 141 stations using the synthetic series (R-$factor_{ss}$);

d) Calculation of R-factor for the 141 stations using rainfall amount data (monthly and annual rainfall depths) and empirical equations (R-$factor_{eq}$) presented in da Silva (2004), which are still the most commonly used around Brazil; and.

e) Statistical analysis of the results.

### 2.1. Data description

We used sub-daily rainfall pluviographs from 141 Brazilian Institute of Meteorology (INMET) pluviographic stations in order to compute R-$factor_{observed}$ (Fig. 1). The time period of these series ranged from 3 to 31 years (average: 13 years) and are individually presented in the supplementary information Table SI1. Baena et al. (2005) previously validated all the rainfall series data.

The rainfall data used to generate synthetic series and compute R-$factor_{ss}$ of the same 141 rainfall stations consisted of validated series of measured daily rainfall amounts. The time period of these series ranged from 10 to 71 years (average: 30), and are also individually presented in the supplementary information Table SI1. These data were also used to compute R-$factor_{eq}$.