Statistic and probability characteristics of rain factor R in Slovak Republic

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Abstract

Because soil erosion which is caused by rain is also an important phenomenon in the Slovak Republic, higher emphasis is impute to research of water erosion caused by rain and that is why we proceeded to calculate the rain factor R. Based on data which were provided by the Slovak Hydrometeorological Insitute for 6 selected meteorological stations in Slovakia, we accomplished to the calculation of rain factor R. For the calculation we used the methodology by Wischmeier-Smith (1978) and results we comparing with the methodology of Hudson (KE> 1) and with already published values of the Research Institute of Soil Science and Conservation. We also created a line exceeded of probability from the calculated data, which gives us detailed information on the occurrence of the calculated R values 1 time per 100, 20, 10, 5, 2 and 1 year. On the basis of calculated data we created a distribution of R factor values for individual months of the growing season and found out that the highest percentage fall on the summer months June, July, August and by contrast the lowest to April and October, so it is necessary to impute emphasis to soil erosion control especially in summer months. Comparing the methodology of Hudson (KE>1) and methodology of Wischemeier-Smith, we found out that the Hudson methodology gives almost 2 times lower value of R-factor than with using the methodology of Wischmeier-Smith.

Keywords: Erosion, erosive effective rainfall, R-factor, Wischmeier-Smith, probability.

Article Info

Introduction

The simplest definition of soil fertility is the ability of soil to supply plant nutrients. This ability can be significantly disrupted by many factors. One of these factors is soil erosion which is caused by water concretely by rain.

Soil creates the environment for plants, animals and definitely for man and also represents irreplaceable resource for man. World population increased from 2 to 10.000,000 from the beginning of agricultural production 10 to 12.000 years ago, to 6.5 billion in 2006 and may stabilize to 10-12 billion in 2100. This constantly growing numbers lead us to think about the importance of soil protection, which has incalculable value to mankind.

Soil erosion by water is one of the most widespread forms of soil degradation in Europe affecting an estimated 105 million ha, or 16% of Europe´s total land area (excluding the Russian federation; EEA, 2003) (The State of Soil in Europe, 2012). In condition of Slovak Republic predominates manifestations of water erosion and potentially is endangered 39,65% (957 173 ha) of agricultural soil (Soil as the Component of Environment in Slovak Republic 2010, 2011). These alarming numbers invoke detailed need of research of

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soil water erosion. One of the factors which influenced the rainfall erosion is rainfall erosivity factor R. There are lots of different ways how to calculate rainfall erosivity factor and one of the well know is methodology designed by Wischmeier-Smith (1978).

Material and Methods

Slovak Hydrometeorological Institute in Bratislava provided data about one minute precipitation for chosen meteorological stations situated in area of southwestern Slovakia. Totally were processed data from 5 meteorological stations for different time period. We used the methodology of Wischmeier-Smith (1978) which considers the erosive effective rainfall, those rainfalls, which are higher than 12.5mm and with intensity higher than 24.00 mm.h^{-1} in one rain division. The main different in this work is that each minute of rain was consider for individual rain division. The following equations were used for calculation of rain factor:

$$R = E * I_{30} \quad \text{[MJ.ha}^{-1}\text{.cm.h}^{-1}\text{]}$$ (1)

Where:
R – rain factor [MJ.ha^{-1}.cm.h^{-1}],
E – rain kinetic energy [J.m^{-2}.mm^{-1}],
I_{30} – maximal 30-minutes rain intensity [cm .h^{-1}].

$$KE = (11,87 + 8,73 * \log_{10} I) * H_z \quad \text{[J.m}^{-2}\text{.mm}^{-1}\text{]}$$ (2)

Where:
KE – kinetic energy of rain [J.m^{-2}.mm^{-1}],
H_z – pecipitation height [mm].

The main difference in this work is that, for the data preparation was design new methodology which is modified Wischmeier-Smith methodology i.e. the chosen effective erosive rainfalls were not divided into rain divisions but each minute of selected rains were considered for individual rain division. This designed methodology eliminates the individual mistakes for choosing of rain divisions.

In the past was also used methodology designed by Wischmeier-Smith, but this methodology used data about precipitation in graphical form. But in the present time are data not only about precipitation recorded in digital form i.e. the data are more detailed and therefore it is better to do calculation with using of these data. The Figure 1 shows the preparation of data for consequent calculation of rain factor.

Figure 1. Provided data in digital form in one – minute step in program MS Excel

For the data preparation was design new methodology i.e. the chosen effective erosive rainfalls were not divided into rain divisions but each minute of selected rains were considered for individual rain division. This designed methodology eliminates the individual mistakes for choosing of rain divisions.

The values of exceedance were obtained from exceedance probabilty curves. These curves were constructed according to the method of moments which is preferably used in hydrology. These curves were created with using methods of moments, which is clasical methods of parameters calculation from theoretical equations derivated from theory of random sampling. From lot of asymetrical distributions of probability i sused Pearson distribution of III. type. Parameters of Pearson curve were determined by methods of moment and shape and course of curve are expressly determined by arithmetic average, variation coefficient and coefficient of asymmetry (Antal, 1990).

According Hudson (1971) is calculation of EI_{30} and KE>1 the same, but advantage of KE>1 index is that it can be used also for less detailed records about rains. For both these methodologies it is necessary to know rain depth, which fall down and also appropriate intensities. Simple calculation is introduced in table 1.

Procedure of calculation according this methodology is following:

1. For chosen rain depth is calculated the rain intensity
2. Then is the rain arrange according intensities shown in the Table 1
3. For each intensities groups is calculated kinetic energy according following equation:

$$\hspace{12cm} (3)$$

$$[J.m^{-2}.mm^{-1}]$$

Where:
KE – kinetic energy [$J.m^{-2}.mm^{-1}$],
I – rain intensity [$mm.h^{-1}$]

4. At the end, the sums of each intensity are sum up and the total kinetic energy of rain is calculated

Table 1. Example of calculation according Hudson methodology

Intensity [$mm.h^{-1}$]	Precipitation amount [mm]	Rain kinetic energy [$J.m^2.mm$]	Sums Column 2 x Column 3
0-25	30	-	-
25-50	20	26	520
50-75	10	28	280
>75	5	29	145
Total	65	-	945 $J.m^{-2}$

After calculation of kinetic energy of each rain we proceeded according Wischmeier- Smith methodology i.e. maximal 30-minutes intensity was chosen and the values were inducted to the equation for calculation of rain factor.

Results and Discussion

As example we present the line of exceedance of probability for locality Hurbanovo (Figure 1). From this line it is possible to establish the values of rain factor wich can be reached once per 100, 50, 20, 10, 5, 2 and one year. The concrete values can be seen in table 2.

Table 2. Values of rain factor deducted in dependion of repetition time, Hurbanovo (1970-2008)

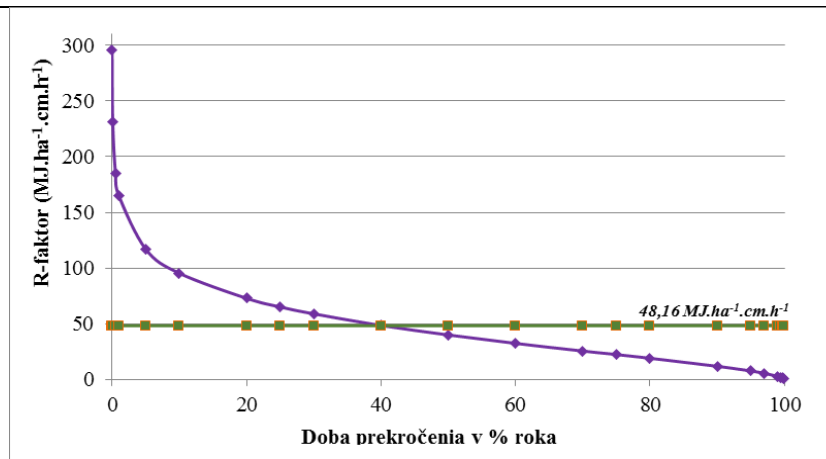| Probability of repetition %	1	5	10	20	50	100
Occurence of rain 1x per N years			N			
	100	50	20	10	5	1
Value of R-factor [$MJ.ha^{-1}.cm.h^{-1}$]	0,68	72,68	95,37	117,02	136,27	165,14

Figure 1. Line of exceedance of probability, Hurbanovo (1970-2008)

The next created chart shows the comparison of frequency of precipitation in each years of examined period on the locality Sereď. The both methodology have different criteria for choosing of erosive effective rainfalls.
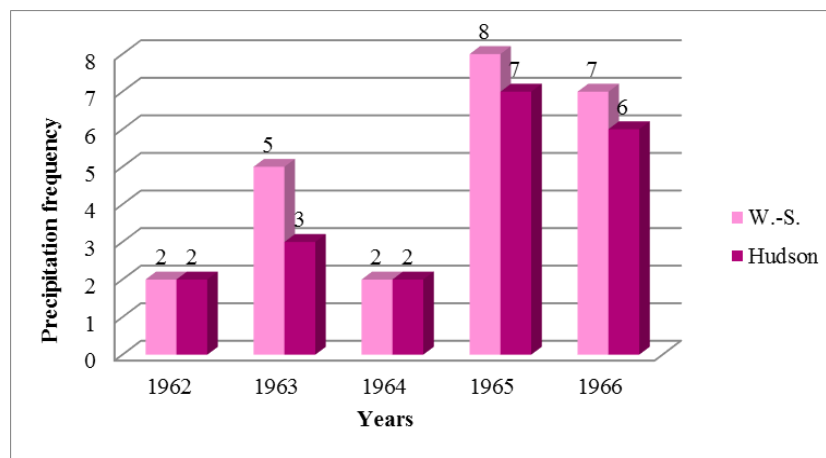

Figure 2. Comparison of precipitation frequency according Wischmeier-Smith and Hudson, Sereď (1962-1966)

As we can see from created figure 2, in the years 1963, 1965 and 1966 there occurred the differences in precipitation frequency. In others examined years were number of erosive effective rainfall same for both methodology. According Hudson methodology is number of erosive effective rainfall lower than number of erosive effective rainfalls according Wischmeier-Smith methodology. The table 3 shows comparison of R-factor values, which was calculated with using both mentioned methodology i.e. Hudson and Wischmeier-Smith methodology for each year of examined period on Sereď locality.

Table 3. Comparison of annual and average

	$R_{annual\ W.-S.}$	$R_{annual\ KE>1}$
1962	28,7243	18,3626
1963	32,3413	18,6151
1964	25,3072	18,3626
1965	83,3082	40,3854
1966	65,8864	59,4856
Average	47,1135	31,0423

On the base of calculation method was created following figure 3, which illustrates comparison of average values of rain factor.

As we can see from listed figure 3, the value, which was calculated according Wischmeier-Smith methodology for meteorological station Sereď for period 1962-1966 is more than 2-times higher than value calculated according Hudson methodology.
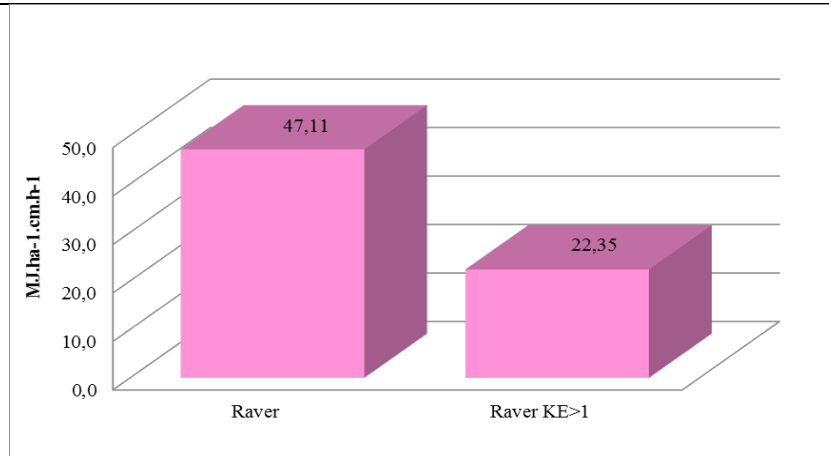
Figure 3. Comparison of average rain factor values (Wischmeier-Smith and Hudson), Sereď (1962-1966)

Consequently were created charts from obtained values about redistribution of rain factor for each months of vegetation period. This step was necessary because we want to know how different methods of rain factor calculation influenced its redistribution during the vegetation period.
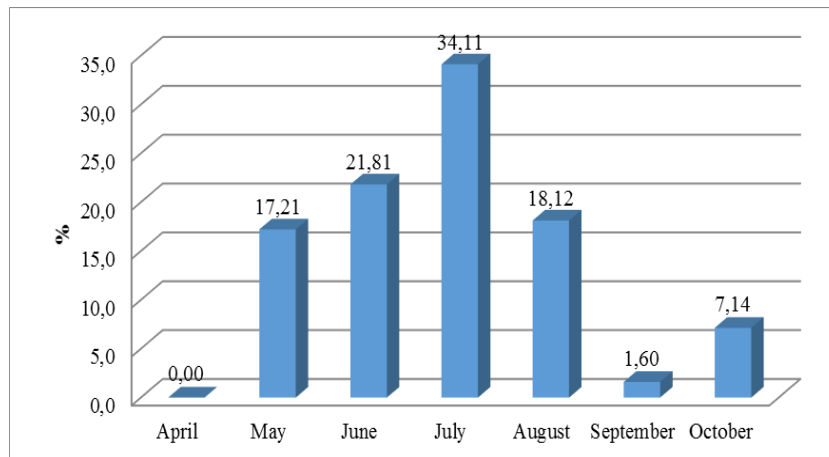

Figure 4. Redistribution of rain factor according Wischmeier-Smith on the particular months of vegetation period, Sereď (1962-1966)

Despite the fact, that values of redistribution of rain factor are different, the highest percentage fall on the same months of vegetation period i.e. on months June, July and August and the lowest on April (when no erosive effective rainfall was observed according both methodologies) and then on September and October.
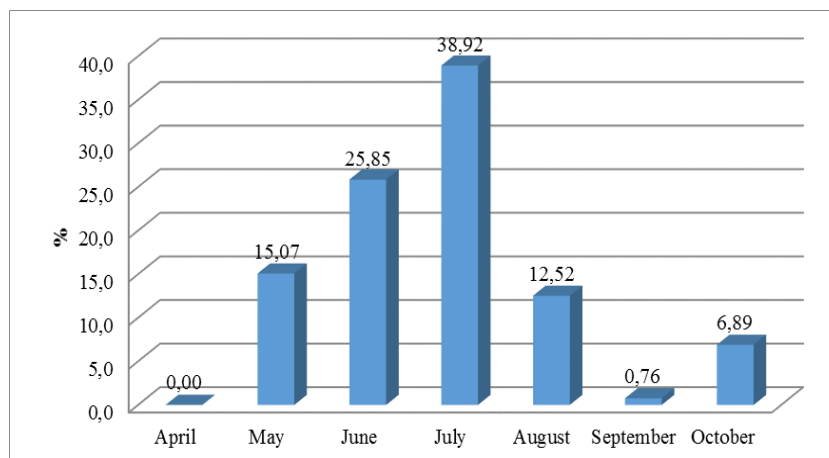

Figure 5. Redistribution of rain factor according Hudson on the particular months of vegetation period, Sereď (1962-1966)

Conclusion

Created lines of exceedance of probability for 6 localities in Slovak republic provides usefull information about values of rain factor, which was calculated according new methodology. According obtained values can be concluded that that antierosion measurements are not suffcient, because they were done with using older methodology which can be wrong because of individual mistakes of researcher.

Comparing the methodology of Hudson (KE>1) and methodology of Wischemeier-Smith, it was found out that the Hudson methodology used for the calculation and the calculated values of R-factor are almost 2-times lower than with using the methodology of Wischmeier-Smith. Also it was found out that aside from used methodology the redistribution of rain factor for individual months of vegetation period is the same. The mentioned fact has very important influence on prevention measures against erosion caused by rain, because especially in this period is soil endangered by erosion, so it is very important to design right anti-erosion measures. This fact point at re-evaluation of used methodology for calculation of rain factor in our conditions.

Acknowledgements

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