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Modeling Rainfall Erosivity Factor for Single Showers: A Case Study in Khuzestan Province, Iran

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This study tries to investigate relationship between rainfall parameters and USLE R factor. To gain R-factor, at first, shower kinetic energy was calculated and then its erosivity computed by using maximum 30 minutes rainfall intensity. Therefore 3 meteorological stations in Khuzestan province and one station per Kohgiloyeh & BoyerAhmad and Boushehr provinces were selected and their recorded hyetographs of 13 years were analyzed. For any hyetographs, rainfall erosivity was computed in any one month, season, or year and corresponding rainfall parameters were extracted too. Temporal and spatial variation of rainfall erosivity was studied and relationships between R factor and rainfall characteristics were investigated by using regression analysis. It was resulted that February to March and winter season has the most erosivity risk. Spatial analysis of rainfall erosivity in selected area showed that Dezful and Ramhormuz have the maximum erosivity factor. Mean annual erosivity factor of Khuzestan province was computed 28.07 ton.m/ha.h. Regression analysis showed strong relationships between rainfall amount (mm) and maximum 30 minutes rainfall intensity (cm/h) with R factor. A model that computes R-factor by means of rainfall amount was suggested.

Key words: Rainfall Parameters, Erosivity, Regression, Khuzestan Province, Iran.

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Introduction

Knowledge of spatial and temporal variation of rainfall erosivity is necessary for crop management in agriculture. Times with high erosivity risk and any vegetation cover on soil have high sediment production potential. Rainfall erosivity is the ability to erode soil grains. Rainfall and rain drops characteristics affect on erosivity. Duration, amount, maximum 30 minutes intensity, drops diameter, elevation etc are the characters that affect on erosivity. Wichmeier & Smith [10] described a method to calculate the R-factor. And thus, to estimate R-factor by this method, at first, rainfall energy must be computed by given equation 1 [10]:

$$E_i = 210.3 + 89 Log I_i \qquad (1)$$

Where:

E_i : Kinetic energy of rainfall (j/m^2/cm)

I_i : Rainfall intensity (cm/h) per unit time of storm

Wichmeier & smith suggested that R-factor has strong relation with I_{30} (maximum 30 minutes intensity). Equation 2 describes this relation:

$$R = \frac{\sum_{i=1}^{n} E_i I_{30}}{100} \qquad (2)$$

Where:

$\sum_{i=1}^{n} E_i$: Sum of kinetic energy of rainfall (i=1 to i=n)

I_{30} : Maximum 30 minutes rainfall intensity (cm/h)

In the regions with strong oceanic influence or at high elevation, overall rainfall energy appears to be considerably lower than predicted by general or USLE equations [8]. Estimating R-factor by above equations is time-consuming and need to hyetographs that recorded by tipping-bucket rain gauges. These data usually are not accessible comfortably. Many researchers have been working on rainfall erosivity and its relationship with some characteristics of rainfall and its spatial and temporal variability. Replacing R-factor by some characteristics of rainfall can help users to compute R-factor easily.

Atre *et al* [1] introduced an equation that can be helpful to compute daily values of R-factor from daily values of rainfall amount (mm). Bagarello & Asaro [2] established the relationship between the single storm erosion index (EI) and corresponding rainfall amount. They suggested that in many cases, daily rainfall amounts can not be assumed a representative of individual events.

Mikhailova *et al* [7] showed a positive linear relationship between R-factor and average annual precipitation and negative linear relationship with elevation.

Patil *et al* [8] reported relationship between annual rainfall and erosivity in power type($Y=ae^{bx}$).

Loureiro Nuno *et al* [6] introduced a regression equation for their study area. That equation showed relationship among monthly R-factor with monthly rainfall for days with >= 10.0 mm and monthly number of days with rainfall >= 10.0 mm.

Poch *et al* (9) computed R-factor for Finland. Seasonal and monthly variation of R-factor in their study area was considerable but spatial variation is not.

The objective of this paper is to report a model fitting to compute R-factor for single storms and to investigate spatial-temporal variations.

Materials and Methods

Study area is khozestan, southwestern province of Iran, a region which has 266mm annual mean precipitation with an arid climate. To model rainfall erosivity factor of single storms in this area, five synoptic meteorological stations were selected. Figure1 and 2 shows location and station of the study area in Iran and main characteristics of them were shown in Table 1. Two stations were selected in neighboring provinces of Gachsaran and Boushehr because of the lack of stations in eastern part of the study area.

Figure 1 Location of the study area in Iran and distribution of the stations

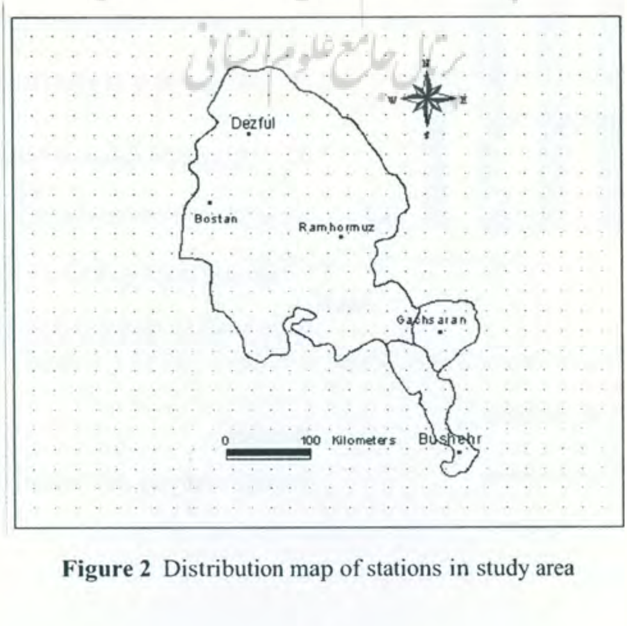

Figure 2 Distribution map of stations in study area

Table 1 Some main characteristics of the stations

No.	Station	Long.(E)	Lat.(N)	Elevation(m)
1	Bostan	41° 0′	31° 43′	7/8
2	Dezful	48° 23′	32° 24′	143
3	Ramhormuz	49° 37′	31° 16′	150
4	Gachsaran	50° 46′	30° 26′	699/5
5	Boushehr	50° 50′	31° 59′	19/6

Recorded hyetographs were collected and then analyzed. For every single storm, some characteristics like, duration (min), rainfall amount (mm) and maximum 30 minutes intensity (I_{30}) (cm/h) were extracted from hyetographs. Further, R-factor of a single storm and corresponding characteristics of the storms were listed. To fit a curve to data, skew ness of the array data must be checked, which must be near to 0.5. To receive good skew ness, different types (10 types) of curves were fitted after transforming the data, using SPSS.

Then, for every types of models, some indexes that used for evaluation of the model were computed. They are relative error (RE), RMSE and coefficient of efficiency (QE). Equations number 3 to 5 were used to estimate these indexes.

$$RE = \left|\frac{y_o - y_e}{yo}\right| \times 100 \qquad (3)$$

Where:

RE: relative error in percent

y_o : Observed value of dependent variable

y_e : Estimated value of dependent variable

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_o - y_e)^2}{n}} \qquad (4)$$

Where:

$RMSE$: Relative mean square error

y_o : Observed value of dependent variable

y_e : Estimated value of dependent variable

n : Observation numbers

$$QE = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(R_o - R_{\bar{o}}\right)^2 - \frac{1}{n}\sum_{i=1}^{n}(R_o - R_e)^2}{\frac{1}{n}\sum_{i=1}^{n}\left(R_o - R_{\bar{o}}\right)^2} \qquad (5)$$

Where:

R_o : Observed value of rainfall erosivity

$R_{\bar{o}}$: Mean value of rainfall erosivity

R_e : Estimated value of rainfall erosivity

n : Observation numbers

Model that has RE<40 % [3] and RMSE near to 0 [5] and QE near to 1 [5] is the best one.

Results

Spatial analysis of rainfall erosivity in study area showed that Dezful and Ramhormuz have high annual erosivity factor. This has been further showed by Figure 3, created by Surfer 3.2.

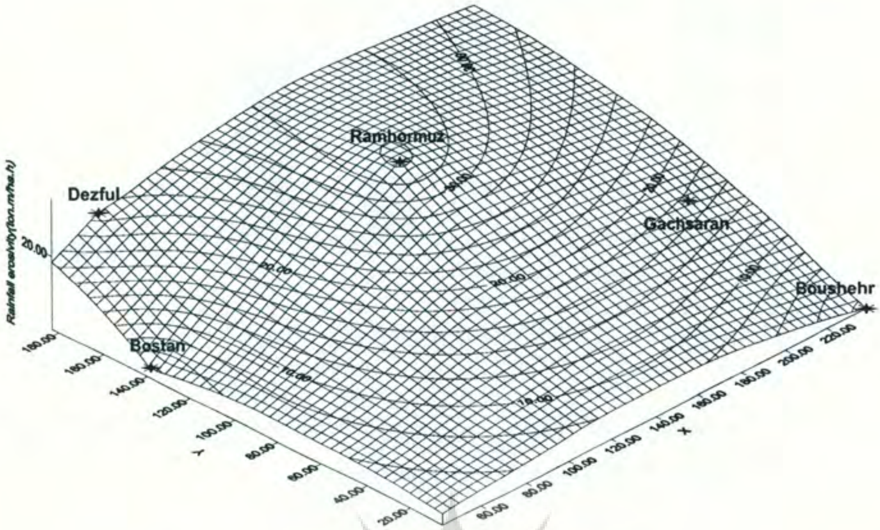

Figure 3 Spatial variation of R-factor in study area

Temporal analysis of rainfall erosivity showed that months between December to March and winter season have high erosivity factor, which are shown in Figures 4 and 5.

Figure 4 Monthly variation of rainfall erosivity in study area

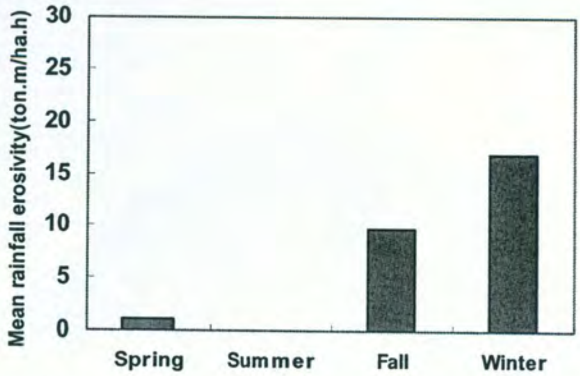

Figure 5 Seasonal variation of rainfall erosivity

Iso-erodent map that shows points with equal erosivity risk was created by Arcview 3.2 (Figure 6). This map can help soil conservationist to measure prioritization.

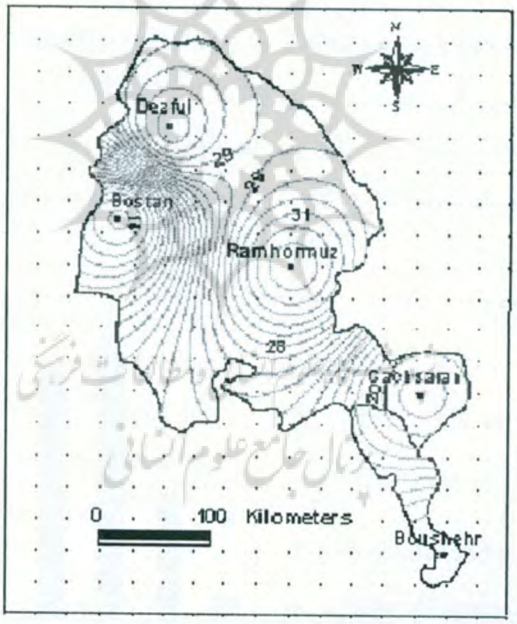

Figure 6 Iso-erodent map of study area

After collecting hyetographs and computing R-factor, rainfall characteristics were extracted. Regression analysis were used and result is shown in Table 2. In every relationship, transformed variable has been used because the real shape of variable had skew ness.

Table 2 Results of regression analysis to computing R-factor for single storms

Equations	**R^2**	**RE**	**RMSE**	**QE**	**N.Equations**
$\left(\frac{1}{R}\right)^{0.29} = 0.48 + 121.7\left(\frac{1}{T}\right)^{0.91} - 387.5\left[\left(\frac{1}{T}\right)^{0.91}\right]^2 - 1684.2\left[\left(\frac{1}{T}\right)^{0.91}\right]^3$	0.58	48.99	1.15	0.58	6
$\left(\frac{1}{R}\right)^{0.29} = 0.16 + 1.38\left(\frac{1}{P}\right)^{0.43} + 2.87\left[\left(\frac{1}{P}\right)^{0.43}\right]^2 - 0.94\left[\left(\frac{1}{P}\right)^{0.43}\right]^3$	0.95	12.42	0.39	0.95	7
$\left(\frac{1}{R}\right)^{0.29} = 0.93\left[\left(\frac{1}{I_{10}}\right)^{0.6}\right]^{1.07}$	0.90	17.18	0.58	0.89	8
$\left(\frac{1}{R}\right)^{0.29} = 0.72\left[\left(\frac{1}{I_{30}}\right)^{0.97}\right]^{0.73}$	0.95	12.92	0.47	0.93	9
$\left(\frac{1}{R}\right)^{0.29} = 4.57e^{-1.81(I_{60})^{0.43}}$	0.74	29.73	1.09	0.62	10
$\left(\frac{1}{R}\right)^{0.29} = 3.18e^{-1.07(I_{120})^{0.09}}$	0.40	52.38	1.48	0.30	11
$\left(\frac{1}{R}\right)^{0.29} = 0.34 + 0.18\left(\frac{1}{I_{mean}}\right)^{1.35} - 0.0039\left[\left(\frac{1}{I_{mean}}\right)^{1.35}\right]^2 + 5\times10^{-5}\left[\left(\frac{1}{I_{mean}}\right)^{1.35}\right]^3$	0.88	21.05	0.69	0.85	12
$\left(\frac{1}{R}\right)^{0.29} = 0.49e^{0.06\left(\frac{1}{Q_1}\right)^{0.75}}$	0.56	41.18	1.38	0.39	13
$\left(\frac{1}{R}\right)^{0.29} = 0.01e^{2.92\left(\frac{1}{Q_2}\right)^{0.16}}$	0.74	30.74	0.95	0.71	14
$\left(\frac{1}{R}\right)^{0.29} = 0.5 + 0.03\left(\frac{1}{Q_3}\right)^{0.86} + 0.0034\left[\left(\frac{1}{Q_3}\right)^{0.86}\right]^2 - 5\times10^{-5}\left[\left(\frac{1}{Q_3}\right)^{0.86}\right]^3$	0.83	24.75	0.91	0.74	15
$\left(\frac{1}{R}\right)^{0.29} = 0.29\left[\left(\frac{1}{Q_4}\right)^{0.6}\right]^{1.07}$	0.90	17.32	0.59	0.89	16

Discussion

Comparison of the single storms shows that storms that occurred in February had more precipitation than rest of the month. Equally, storms with more precipitation had more erosivity. Winter season has more erosivity risk and storms had maximum 30 minutes intensity. This characteristic was very useful to describe spatial variation of rainfall erosivity in study area.

Evaluation of prepared models by means of indexes suggests a single model for computing R-factor for single storms. This model is:

$$R' = 0.16 + 1.38P' + 2.87P'^2 - 0.93P'^3$$

Where:

R': is transformed shape of R-factor ($R' = \left(\frac{1}{R}\right)^{0.29}$)

P': is transformed shape of rainfall amount per storm ($P' = \left(\frac{1}{P}\right)^{0.43}$)

This model shows that R-factor had significant relationship with rainfall amount. Indexes that introduced for this model had the value of:

R^2=0.95, RE=12.42, RMSE=0.39, QE=0.95

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