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Spatial and Temporal Variations in the Rainfall Erosivity Factor in Iran

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ABSTRACT

Accelerated soil erosion is an undesirable process that adversely affects water and soil resources. Rainfall erosivity is an important factor in water erosion models. Accordingly, the present study was conducted to estimate the rainfall erosivity throughout Iran based on the latest available detailed rainfall data while considering its temporal and spatial variations. To accomplish this, the data from 18 synoptic stations of the Iranian Meteorological Organization, known to have reliable data and hyetographs with a 23 year common period, were accordingly analyzed. The kinetic energy of rain for each storm event was calculated based on Wischmeier and Smith's original model, i.e. the USLE, and many of its modifications. Later, the rainfall erosivity factor was calculated on a monthly, seasonal, and annual basis using the calculated kinetic energy. The results revealed that the greatest risk of erosivity occurred in March, December, and November, as indicated by *R* factors of 0.228, 0.201, and 0.147 MJ mm ha^{-1} h^{-1}, respectively, while June and August had the lowest erosivity factors, as indicated by *R* factors of 0.017 and 0.027 MJ mm ha^{-1} h^{-1}, respectively. Furthermore, analysis of the spatial variations in *R* verified that the Anzali and Babolsar Stations, located in northern Iran, had the maximum erosivity values, with *R* factors of 11.518 and 4.260 MJ mm ha^{-1} h^{-1}, respectively. Conversely, the Bam and Semnan Stations, located in the central and eastern Iran, had the minimum erosivity values, as indicated by *R* values of 0.201 and 0.212 MJ mm ha^{-1} h^{-1}, respectively. The long term mean annual rainfall erosivity factor of Iran was ultimately found to be 1.226 MJ mm ha^{-1} h^{-1}.

Keywords: Iran, Rainfall Erosivity, Smith Method, Soil Erosion, USLE, Wischmeier.

INTRODUCTION

Annually, approximately 2% of the gross world product is spent on protection against natural disasters (Blagovechshenskiy *et al.,* 2004). According to the Forest, Rangeland and Watershed Management Organization of Iran, some $150 M are annually spent on the watershed management projects implemented to prevent or to alleviate part of soil erosion related problems in the country. However, the spatial and temporal variability in the factors responsible for soil erosion may be very large, which can result in a high variation in the prediction of soil loss (Sadeghi and Behzadfar, 2004; Sadeghi, 2005). Such errors may ultimately lead to improper decision-making (Wang *et al*., 2002). Indeed, calculation mistakes of soil erosion can have widespread impacts on the environmental management because soil erosion results in degradation of ecosystem function (Ludwig and Tgway, 2000; Ludwig *et al.*, 2006), decreased productivity and sustainability of agriculture (Diamond, 2005), and displacement of human populations (Opie, 2000). Diamond (2005) found five examples of societal collapse in the past that were related to soil erosion in different ways.

Water, wind, glaciers, and gravity are the primary factors of soil erosion. The annual

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potential yield of sediment loss due to water erosion from 72.5 million km^2 of the global land area has been estimated at approximately 130 billion metric tones (Reich *et al.,* 2004). The extent of water erosion is greater, and its results are much more complicated, than the other types of erosion in Iran. Water erosion is basically initiated by detachment, which is mainly controlled by shear forces of the falling raindrops, and represented by rainfall erosivity factor (Petkovesk and Mikos, 2004; Asadi *et al.,* 2008). This factor is used to quantify the ability of rainfall to cause soil loss under different conditions and it is one of the six factors in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1958a) and the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.*, 1997), which are both employed to predict soil erosion. A study conducted on runoff and soil-loss data generated in an individual storm at 37 sites in the eastern United States revealed that the product of the total storm kinetic energy (E) and the maximum 30-min rainfall intensity of the storm (I_{30}) provided the best correlation between soil loss and 19 other measured rainfall characteristics (Wischmeier and Smith, 1958a and b; Hussein, 1998; Van der Knijff *et al.*, 1999 and 2000; Sadeghi and Behzadfar, 2004; Nyssen et al., 2005; Yin *et al.*, 2007). As a result, Wischmeier and Smith (1978) further defined R as the average of the annual summations of storm (EI_{30}) values, excluding storms in which the total rainfall depth was less than 12.7 mm (Yin *et al.*, 2007). Unfortunately, detailed information on both rainfall quantity and intensity needed for a direct estimation of the R-factor is usually unavailable for standard meteorological stations. Moreover, the workload involved would be rather heavy for any national or continental assessment (Van der Knijff *et al.*, 1999 and 2000). In identifying rainfall-based erosion by using GIS in integration with the USLE model in a small region of the Gediz River basin, Turkey, Fistikoglu and Harmancioglu (2002) presented the difficulties in applying the methodology when the required data are deficient in both quantity and quality, as the case is with most developing countries. Cohen *et al.* (2005) developed normalized risk maps for the five USLE factors, including *R* factor, in a watershed located in western Kenya. They suggested a critical need for efficient ground-based sampling schemes to be used in conjunction with flexible statistical models based on the USLE factors for future investments in erosion risk assessment in the tropics.

The 'E' portion of this value represents the rainfall energy, while the 'I_{30}' term represents the maximum 30-min rainfall intensity during the storm. Rainfall and runoff normally provoke soil erosion under specific conditions that may lead to soil loss. Therefore, holding the other input factors constant results in identification of soil losses that are directly proportional to the rainfall erosivity factor, R. This index has been widely tested, adopted and used in several countries and regions in which rainfall is characterized by a moderate to high intensity (Kinnell, 1973; Sharpley and Williams, 1990; Wang and Jiao, 1996; Yu and Rosewell, 1996; Oduro-Afriyie, K., 1996; Mikhailova *et al*., 1997; Yu, 1998; Hu *et al*., 2000; Loureiro and Coutinho, 2001; Yu *et al*., 2001). In addition, many studies conducted in various areas in China (Jia *et al*., 1987; Wang, 1987; Huang *et al*., 1992; Zhang *et al*., 1992; Wu, 1994; Zhou *et al*., 1995; Wang and Jiao, 1996; Yang, 1999; Yin *et al*., 2007) have demonstrated that EI_{30} is a reliable index for the prediction of erosivity. This clearly emphasizes the importance of EI_{30} in triggering soil erosion process. Besides, the duration, intensity, rain drop diameter, elevation, and spatial and temporal variability of rainfall also influence the rain erosivity (Nyssen *et al*., 2005). Wischmeier and Smith (1958a) studied 183 storms in the Zanzoil region of the United States and found that soil loss was strongly related to rainfall intensity (I_{30}), which itself varies with time. However, long-term precipitation data with high temporal resolution, which are typically not widely available, are required to calculate the reliable *R* factor (Petkovesk and Mikos, 2004). For example, Atre (1997) estimated the rainfall erosivity in Rahuri, India, during the pre-monsoon, monsoon, and post-monsoon

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periods and highlighted the differences among the studied periods. Van der Knijff *et al.* (1999 and 2000) stated that the long-term average *R*-values are often correlated with more readily available rainfall figures like annual rainfall or the modified Fournier's index. Accordingly, they developed erosivity maps on monthly, seasonal, and annual bases for the entire Europe by using the same simplified approach. Spatial variation of the *R* factor in the Republic of Korea was also evaluated by Qihu *et al*. (2000), who found that the *R* values were greater in eastern Korea and declined as they approached the coastal zones. Additionally, Posch and Seppo (2003) computed the rainfall erosivity for Finland and observed monthly and seasonal differences in erosivity. Furthermore, they found that the seasonal and monthly variation in the *R* factor in their study area was considerable, but the spatial variation was not. Also, Petkovesk and Mikos (2004) approximated the *R* factor for sub-Mediterranean southwest Slovenia by applying more commonly available daily precipitation data. They then provided a set of equations for calculating monthly and annual R factor values based on the results of their study. The spatial and temporal variation in the erosivity factor (R) in Brazil was reported by Silva (2004), who utilized the data collected for 1,600 rain gauge stations and GIS to determine *R*. Moreover, the variation in the erosivity factor that occurred temporally and spatially was studied by Aslan *et al.* (2005) in Turkey, who verified that the R factor varied between central and northeastern Turkey. The rainfall erosivity and its variability in connection with slope gradient, slope aspect, rain depth, drop size and distribution, threshold velocity, and wind effects in the northern Ethiopian highlands was also studied by Nyssen *et al.* (2005). Finally, Yin *et al.* (2007) studied the spatial variation in the *R* factor of eastern China by evaluating the data sets collected for 5 soil conservation stations and analyzing 456 storm events recorded in 5 to 60 minute fixed intervals. They verified spatial variation of erosivity factor through developing an isoerodent map.

Despite the abundance of comprehensive studies conducted in different regions worldwide, no studies have been conducted to evaluate temporal and spatial variations in the erosivity factor for Iran to date. In addition, the reliability of an erosivity map of Iran, which has been developed using the modified Fournier erosivity index (Iranian Forests, Rangeland and Watershed Management Organization, 2007), has not yet been ascertained. Therefore, the present study aimed a) to calculate Wischmeier and Smith's *R* factor directly from maximum available rainfall data b) to study the temporal variation in the rainfall erosivity (R) in different time scales and c) to develop an isoerodent map for the entire country. The results of the study should guide the development of proper management of soil and water resources in Iran.

MATERIALS AND METHODS

Study Area

The Islamic Republic of Iran has a total land area of 1,648,195 km^2 and lies between 25º 00´ and 39º 47´ N-latitude and 44º 02´ and 63º 20´ E-longitude. The altitude varies from -40 to 5,670 m, which has a pronounced influence on the diversity of the climate. The mean annual rainfall in Iran is approximately 246 mm. However, Iran has a broad spectrum of climatic conditions across regions with significant rainfall variability and temperature variability. Iran as a whole is a semiarid country. The southern half of the country is located in the subtropical zone and the northern half is located in the temperate zone, while the central plateau of the country (around 30º N) is a desert zone. Furthermore, the northeastern portion of the country is located on the desert and steppe of Turkmenistan, while the southwest border of the country is located on the hot and arid Saudi Arabian peninsula. Currently, Iran faces many sediment-related problems. Since 1960's, serious problems in connection with soil erosion and sediment yield have been reported

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and many attempts have been made to draw a realistic picture of soil erosion and sediment yield rate in the country. These attempts have led to many figures that are mostly unreliable and range from 0.8 to 8 billion tones per annum i.e. some 7 to 70 t ha^{-1} Y^{-1}. Based on these data, many short term infrastructure designs and mid- and long-term planning have been made (Sadeghi, 2009). Figure 1 shows the general location of Iran as well as the location of the individual synoptic stations evaluated in this study. More than 58 existing climatological stations were initially considered for this study; however, 18 synoptic stations with reliable and long data collection period were finally selected for the study. The common data collection period of 1970 to 1992 was then selected based on the maximal usage of the available data and the minimal and completion of the missing and unrecorded data for further analysis. A list of the selected stations and their specifications is provided in Table 1.

Research Methodology

Soft and hard copies of rainfall hyetographs with sub-hourly resolution were collected from the Iranian Meteorological Organization for 23 years (1970 to 1992), and were utilized to evaluate the rainfall erosivity on a storm, monthly, seasonal, and annual basis. The rainfall kinetic energy for each storm event in the aforementioned period was subsequently calculated using the following equation (Wischmeier and Smith, 1958a and b; Foster *et al.*, 1981; Kinnell, 1981; Renard *et al.*, 1997; Hussein, 1998; Lee, 2004):

$$E_i = 0.29[1-0.72\exp(-0.05I_i)] \qquad (1$$

Where, E_i is kinetic energy of rainfall in MJ ha^{-1} mm^{-1}(= 0.001 t m ha^{-1} cm^{-1}) and I_i (≤ 76 mm. h^{-1}) is the rainfall intensity in mm h^{-1} for any time step. Also E_i is 0.285 for I_i above 76 mm h^{-1}.

The rainfall erosivity factor (R) was then computed utilizing the following equation (Wischmeier and Smith, 1958b; Foster *et al.*, 1981):

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

Where, R is rainfall erosivity factor in MJ mm ha^{-1} h^{-1} (= 10×t m cm ha^{-1} h^{-1}), E is the storm energy from step i= 1 to n, and I_{30} is the maximum rainfall intensity during 30 minutes of an individual storm in cm h^{-1}.

The R factor was calculated as the sum of the erosion index values for all rainfall storms in one year (Wang *et al.*, 2002). After computing the rainfall erosivity for each storm, the monthly and seasonal values were calculated using the R values of the corresponding storm events that occurred in the study time scale. As per Iranian calendar, January to March, April to June, July to September and October to December were denoted as winter, spring, summer and autumn, respectively. In addition, the Thiessen method (Sadeghi and Behzadfar, 2004) was used to obtain an average R value for the study area based on the geographical distribution of the climatic stations. The

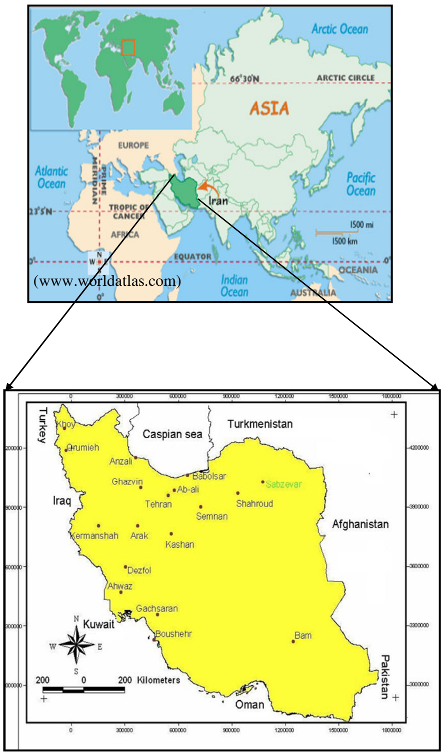

Figure 1. General map of Iran and location of the synoptic stations used in the study.

Table 1. Some characteristics of the stations used for calculation of erosivity factor, *R*, in Iran.

No.	Station	Long (E)	Lat (N)	Annual average precipitation (mm)	Elevation (m, ams)	Data availability
1	Ab-Ali	35° 45'	51° 53'	525.70	2465.20	1968-1999
2	Ahwaz	31° 20'	48° 40'	212.70	22.50	1970-1997
3	Anzali	37° 28'	49° 28'	1855.80	-26.20	1970-1998
4	Oromeieh	37° 32'	45° 04'	345.10	1315.90	1970-1984
5	Arak	34° 06'	49° 46'	341.50	1708.00	1967-1999
6	Babolsar	36° 43'	52° 39'	891.30	-21.00	1966-1998
7	Bam	29° 06'	58° 21'	61.60	1066.90	1970-1998
8	Boshehr	28° 59'	50° 50'	276.70	196.00	1980-1997
9	Tehran	35° 41'	51° 19'	230.50	1190.80	1962-1984
10	Khoy	38° 33'	44° 58'	292.40	1103.00	1962-1973
11	Dezfol	32° 24'	48° 23'	404.60	143.00	1970-1993
12	Sabzevar	36° 12'	57° 43'	187.80	977.60	1967-1998
13	Semnan	35° 35'	53° 33'	139.30	1130.80	1974-1998
14	Shahroud	36° 25'	54° 57'	154.40	1345.30	1970-1998
15	Ghazvin	36° 15'	50° 50'	316.80	1279.20	1974-1998
16	Kashan	33° 59'	51° 51'	138.80	982.30	1973-1998
17	Kermanshah	34° 21'	47° 47'	447.20	1318.60	1971-1984
18	Ghachsaran	30° 26'	50° 50'	465.10	699.50	1984-1998

temporal variation in rainfall erosivity was then scrutinized throughout Iran by analyzing the variation in rainfall properties including depth, frequency and intensity, as well as general climate conditions in the vicinity of the study stations. Finally, a graphical presentation of spatial variations in erosivity in different time scales was created using Excel 2003 and Arcview 3.2. The entire maps were developed based on interpolation method and inverse distance weight approach in geographical information system and Arcview 3.2 environment.

RESULTS

Through analyzing more than 5422 storm events, the rainfall erosivity values were calculated on monthly, seasonal, and annual basis for the selected stations and are summarized in Table 2. The rainfall erosivity values for the different stations and months, as well as its variation on seasonal bases, comparison between seasonal rainfall erosivity in different stations, and the annual erosivity map of Iran are shown in Figures 2–5. The spatial variations in the erosivity factor for different points and time scales are also depicted in Figures 6–8.

The average annual rainfall erosivity in the study area was found to be 1.226 MJ mm ha^{-1} h^{-1}, while the maximum and the minimum values of 0.228 and 0.017 MJ mm ha^{-1} h^{-1} were observed in March and July, respectively. Additionally, the seasonal values of R were ordered as winter, autumn, spring and summer with respective values of 0.467, 0.460, 0.207 and 0.092 MJ mm ha^{-1} h^{-1}. The Anzali and

Table 2. Amounts of rainfall erosivity (MJ mm ha^{-1} h^{-1}) indifferent stations and time scales in Iran.

No	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
1	Ab-Ali	0.23	0.29	1.00	0.37	0.37	0.06	0.12	0.13	0.01	0.31	0.58	0.55	1.52	0.80	0.26	1.44	4.02
2	Ahwaz	0.40	0.17	0.48	0.04	0.00	0.00	0.00	0.00	0.00	0.09	0.32	0.36	1.05	0.04	0.00	0.77	1.86
3	Anzali	0.98	0.44	0.41	0.18	0.12	0.36	0.28	0.85	1.53	2.32	2.84	1.21	1.83	0.66	2.66	6.37	11.52
4	Oromeieh	0.08	0.02	0.07	0.10	0.32	0.11	0.05	0.00	0.00	0.06	0.10	0.09	0.17	0.53	0.05	0.25	1.00
5	Arak	0.12	0.45	0.16	0.15	0.13	0.00	0	0.00	0.00	0.06	0.12	0.17	0.73	0.28	0.00	0.35	1.36
6	Babolsar	0.36	0.17	0.17	0.02	0.03	0.08	0.24	0.36	0.61	0.91	0.87	0.42	0.70	0.13	1.21	2.20	4.26
7	Bam	0.05	0.01	0.05	0.03	0.02	0.00	0.01	0.02	0.00	0.00	0.01	0.01	0.11	0.05	0.03	0.02	0.20
8	Boshehr	0.41	0.11	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.18	0.46	0.86	0.00	0.00	0.69	1.55
9	Tehran	0.18	0.11	0.25	0.11	0.04	0.02	0.01	0.00	0.00	0.11	0.04	0.10	0.54	0.17	0.01	0.25	0.97
10	Khoy	0.01	0.00	0.12	0.29	0.25	0.46	0.04	0.00	0.30	0.13	0.10	0.13	0.13	1.00	0.34	0.36	1.83
11	Dezfol	1.00	0.72	0.62	0.16	0.01	0.00	0.00	0.00	0.00	0.15	0.34	1.08	2.34	0.17	0.00	1.57	4.08
12	Sabzevar	0.19	0.28	0.17	0.16	0.09	0.00	0.01	0.00	0.00	0.02	0.02	0.12	0.64	0.25	0.01	0.16	1.06
13	Semnan	0.03	0.02	0.05	0.03	0.02	0.00	0.00	0.02	0.00	0.00	0.01	0.03	0.10	0.05	0.02	0.04	0.21
14	Shahroud	0.09	0.07	0.15	0.26	0.20	0.00	0.00	0.00	0.01	0.02	0.07	0.18	0.31	0.46	0.01	0.27	1.05
15	Ghazvin	0.09	0.16	0.20	0.10	0.13	0.01	0.02	0.00	0.00	0.11	0.02	0.13	0.45	0.24	0.02	0.26	0.97
16	Kashan	0.06	0.07	0.06	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.19	0.04	0.00	0.04	0.27
17	Kermanshah	0.20	0.24	1.17	0.13	0.16	0.00	0.00	0.00	0.00	0.34	0.21	0.78	1.43	0.29	0.00	1.33	3.05
18	Ghachsaran	0.26	0.16	0.24	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.47	0.66	0.30	0.00	0.68	1.64
	Entire country	0.11	0.11	0.23	0.10	0.08	0.02	0.02	0.03	0.05	0.11	0.15	0.20	0.45	0.21	0.10	0.46	1.23

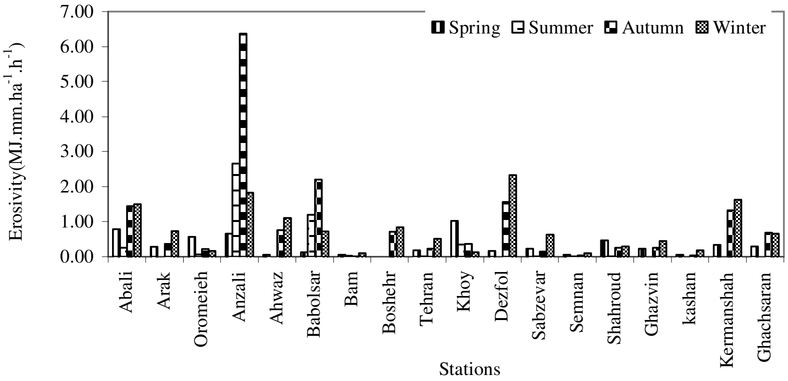

Figure 2. Comparison between seasonal rainfall erosivity (y axis in MJ mm ha^{-1} h^{-1}) in different stations (x axis) in Iran.

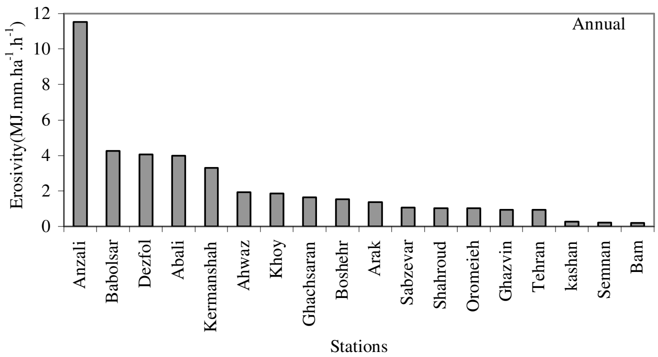

Figure 3. Spatial variation of rainfall erosivity factor (y axis in MJ mm ha^{-1} h^{-1}) in different stations (x axis) in Iran.

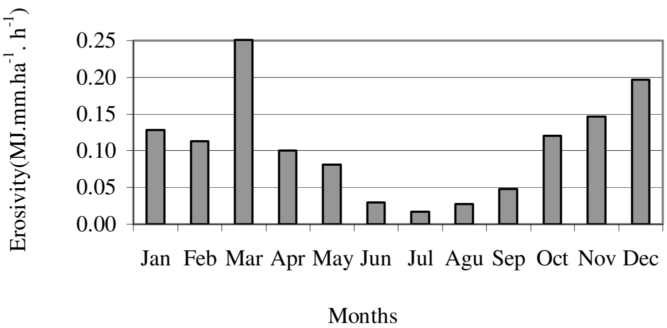

Figure 4. Average monthly rainfall erosivity factor (y axis in MJ.mm.ha^{-1}.h$^{-1)}$ in Iran.

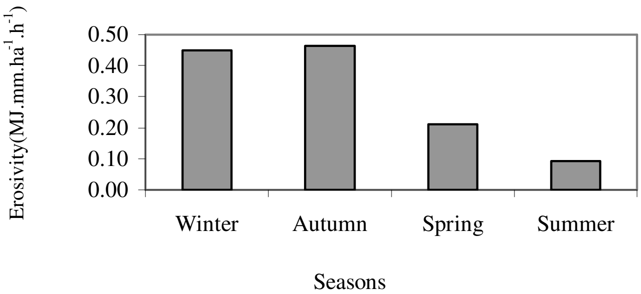

Figure 5. Average seasonal rainfall erosivity factor (y axis in MJ.mm.ha^{-1}.h$^{-1)}$ in Iran.

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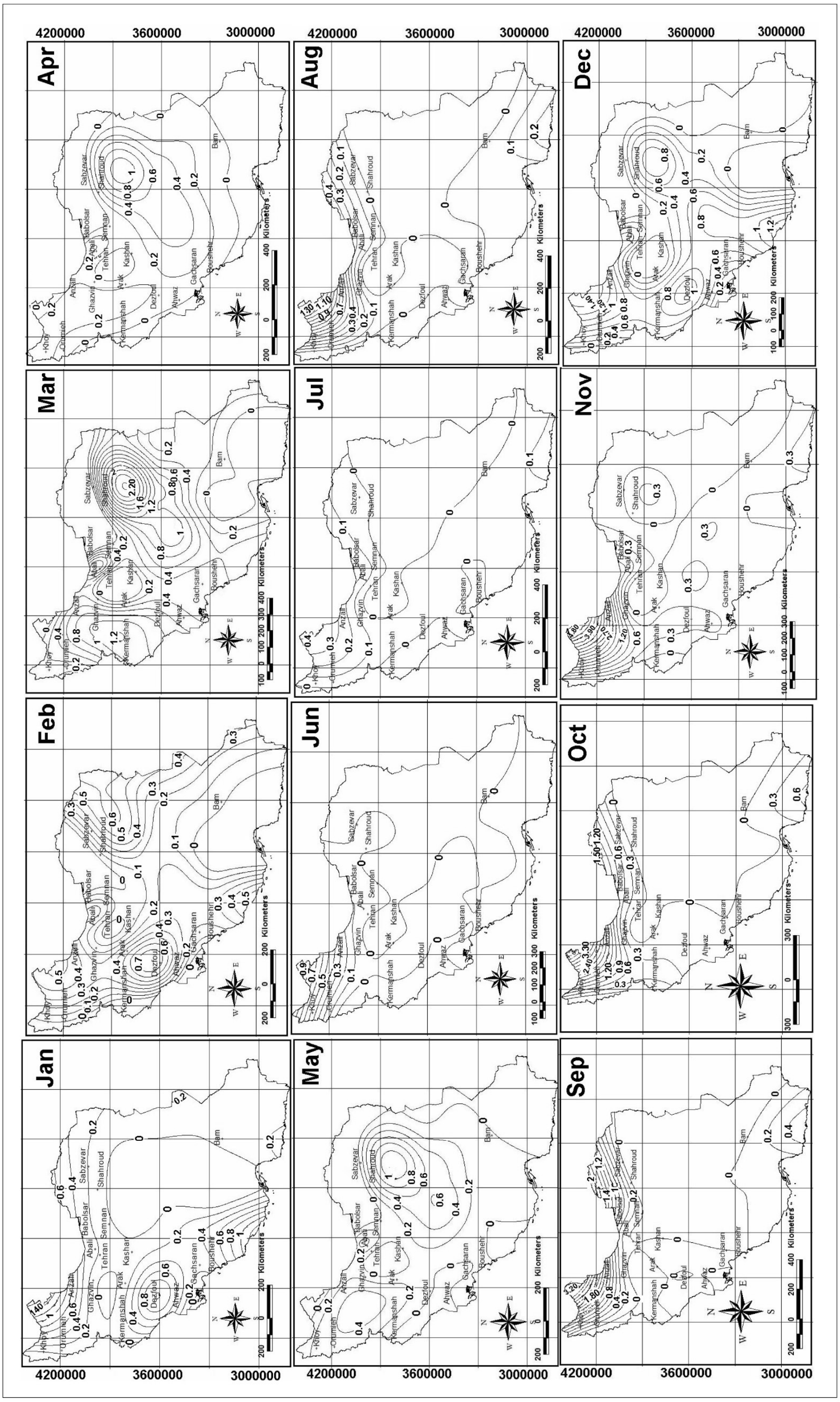

Figure 6. Spatial variation of erosivity factor R (MJ mm ha^{-1} h^{-1}) in different months throughout Iran.

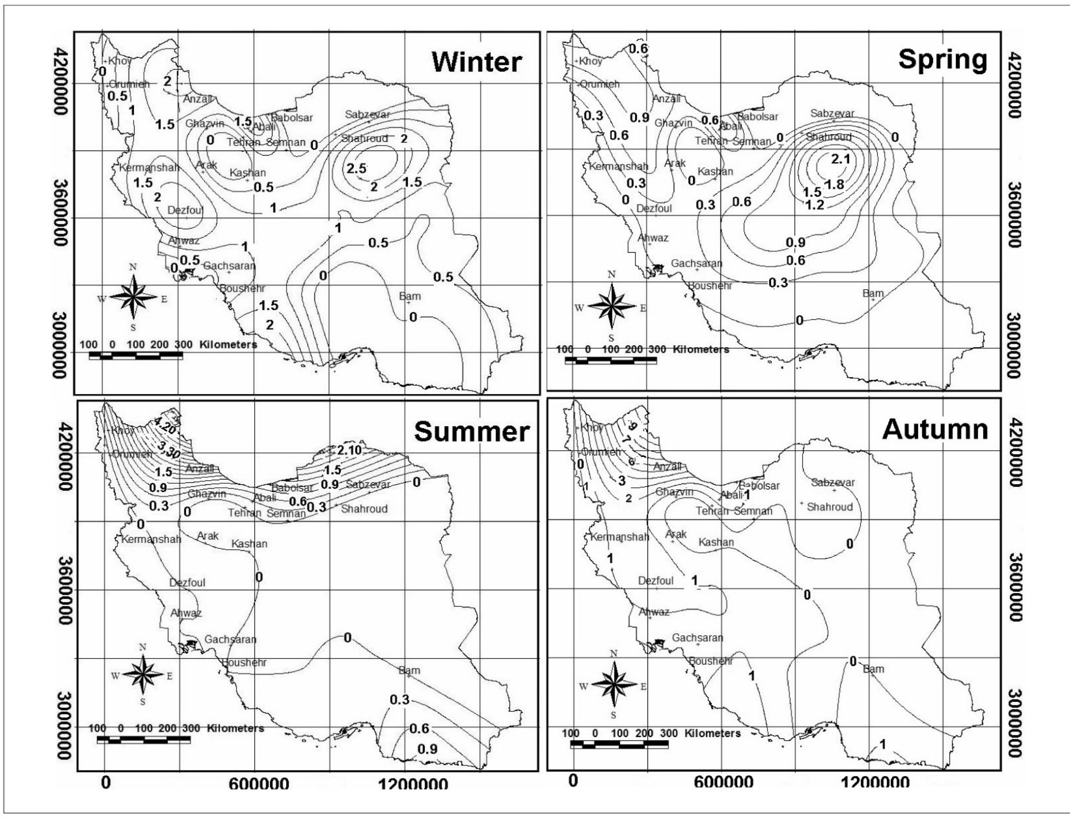

Figure 7. Spatial variation of rainfall erosivity factor (MJ mm ha^{-1} h^{-1}) in different seasons in Iran.

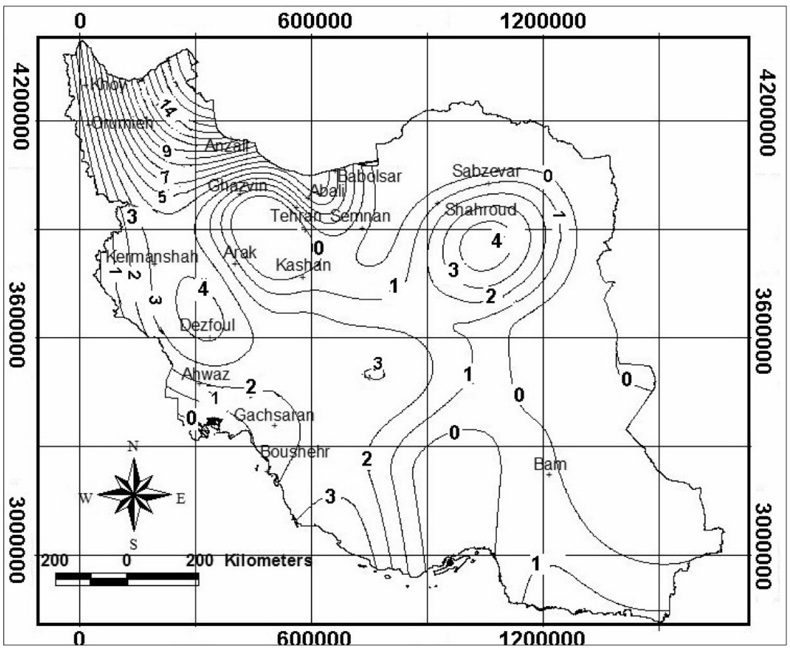

Figure 8. Annual erosivity factor (MJ mm ha^{-1} h^{-1}) map of Iran.

Babolsar Stations had also the maximum erosivity, as indicated by respective R values of 11.518 and 4.260, while the Semnan and Bam stations had the minimum erosivity values of 0.212 and 0.199 MJ mm ha^{-1} h^{-1}, respectively.

DISCUSSION

As shown in Figures 2–5, the rainfall erosivity in Iran varied greatly with time, which indicates that temporal variations should be considered when estimating erosivity. Indeed, when different months were prioritized based on rainfall erosivity (Figure 6), March and July were found to have the maximum and minimum erosivity, respectively, with relative contribution of 18.62 and 1.41% in annual erosivity. December, November, January, February, October, April, May, September, June and August were situated in between, with respective relative contribution of 16.36, 11.98, 10.60, 9.30, 9.20, 7.83, 6.60, 3.90, 2.42 and 2.21%; however, their ranking changed in the different stations. Accordingly, the seasonal contribution of winter, autumn, spring, and summer to the annual erosivity varied and was, respectively, 38.09, 37.54, 16.85, and 7.52%. Thus, more than two thirds of the erosive rains occurred in autumn and winter, i.e. from October to March, when the least protective vegetation cover exists on the ground. These findings are in contrast to the results of a study conducted by Silva (2004), who reported that December and January had the maximum erosivity, while June and September had the minimum erosivity in Brazil. However, the results of the present study agree with the findings of Aslan *et al.* (2005), who evaluated the temporal variation in R factors for different parts of Turkey. Overall, these findings verify big differences in geo-climatic conditions in different parts of the world. The high temporal and spatial variation in *R* values throughout Iran can also be attributed to a broad spectrum of climatic conditions across the country with significant variability in rainfall characteristics (Abbaspour *et al.*, 2009) that exerts considerable differences in inter and intra variations in rainfall patterns, leading to different rain intensity and temporal distribution, based on which erosivity factor is calculated for sundry time scales. However, the large size of Iran and its different climatological zones may also control the spatial variation in *R* that was observed in the present study. Scrutinizing the results also shows that despite the changing contribution of different stations to the annual erosivity in different time scales, the largest annual, spring, and summer time *R* values belong to Anzali and Babolsar Stations that have the highest annual precipitations among the studied stations (Table 1). This is different than the results of a study conducted by Posch and Seppo (2003), who reported that R did not vary spatially in Finland; but, it agrees with Yin *et al.* (2007) who proved spatial variation in *R* in China. Comparison of the results from the present study with other countries verifies temporal and spatial variability of R factor in different parts of the world and the impossibility of simple generalization and extension of findings on erosivity from one area to another. This variation may be attributed to the large area of Iran and its wide range of climatological conditions.

The annual erosivity map of Iran developed in the present study has reasonable agreement in terms of severity with that developed by Iranian Forests, Rangeland and Watershed Management Organization using the modified Fournier erosivity index (2007). The agreement shows up mainly in the western and northern parts of the country (Sadeghi and Moatamednia, 2009). The other maps with different time scales were developed for the first time during the present study. The reasonable applicability of the modified Fournier erosivity index also is in agreement with Van der Knijff *et al.* (1999 and 2000), who verified the applicability of simplified approaches to estimate R for the entire Europe. Interestingly, the north western part of the annual erosivity map prepared in the present

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study is in relative conformity with the north eastern part of the erosivity map developed for the western neighboring country of Iraq by Hussein (1998).

To elucidate the reasons for the results presented above, the characteristics of the individual storms included in this study were evaluated (Figure 9). Although the maximum number of storms occurred in January and March, the erosivity of these storms was quite different. Indeed, as shown in Figures 6 and 9, the number of storms cannot be used to estimate the potential rainfall erosivity. This may be because the maximum 30 minute intensity of storms that occurred in March was 5.60 mm h^{-1}, which was much higher than the maximum intensity of 3.30 mm h^{-1} that occurred in January. In addition, the maximum mean rainfall per storm observed in March was 17.32 mm, while it was 8.94 mm in January, which may also account for the greater erosivity that was observed in March. It can then be understood from the results of reconnaissance study of the relationship between storm frequency, rain intensity and depth, and rain erosivity that an individual rainfall specification cannot control the temporal and spatial variations of erosivity in Iran. This is in the line with the findings of Nyssen *et al.* (2005)

CONCLUSION

The results of the present study verified that there is significant variation in the rainfall erosivity during individual months and seasons in Iran. The average annual rainfall erosivity in Iran was found to be 1.226 MJ mm ha^{-1} h^{-1}. The seasonal values of *R* were also ordered as winter, autumn, spring and summer with the maximum and the minimum monthly values in March and July, respectively. Analysis of the spatial variations of R values also revealed that the Anzali and Babolsar Stations had the maximum erosivity, while the Semnan and Bam Stations had the minimum erosivity values. Based on these findings, some other factors affecting soil erosion can be accordingly managed to mitigate the potential effects of rain erosivity on soil erosion. However, further quantitative studies are needed to evaluate the primary factors influencing temporal and spatial variations in *R* factor in Iran and to provide additional detailed and high resolution studies in different regions of the country.

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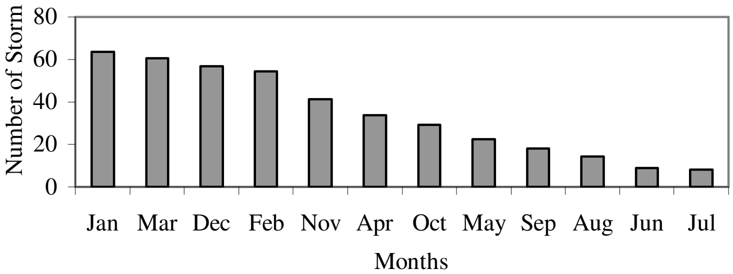

Figure 9. Frequency (y axis in No.) of monthly storm occurrence in Iran.

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تغییرات مکانی و زمانی عامل فرسایندگی در ایران

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چکیده

فرسایش تشدیدی خاک یکی از فرآیندهای نامطلوب است که تاثیرا ت ناخوشایندگی بر منابع آب و خاک می‌گذارد. فرسایندگی باران یکی از عوامل مهّم در مدل‌های فرسایش آبی است. بر همین اساس، مطالعه حاضر به‌منظور بررسی تغییرات مکانی و زمانی عامل فرسایندگی در ایران و مبتنی بر آخرین داده‌های تفضیلی بارندگی موجود صورت گرفت. در همین راستا، داده‌های مربوط به ۱۸ ایستگاه سینوپتیک با داده‌های قابل اعتماد و کاغذهای باران‌نگار و طول دوره آماری مشترک ۲۳ سال انتخاب شد. سپس مقدار انرژی جنبشی کلیّه رگبارهای ثبت شده برای آن‌ها بر اساس رابطه ویشمایر و اسمیت و مورد استفاده در رابطه جهانی فرسایش خاک و بسیاری از نسخ آن محاسبه گردید. در مرحله بعد مقادیر عامل فرسایندگی در مقیاس‌های مختلف ماهانه، فصلی و سالانه و بر مبنای مقادیر انرژی جنبشی محاسبه شد. نتایج نشان داد که بیشینه فرسایندگی در ماه‌های مارس، دسامبر و نوامبر به‌ترتیب با مقادیر ۰/۲۲۸، ۰/۲۰۱ و ۰/۱۴۷ مگاژول میلی‌متر بر هکتار ساعت رخ داده حال آن‌که کمینه آن طی ماه‌های جولای و اوت به‌ترتیب با مقادیر ۰/۰۱۷ و ۰/۰۲۷ مگاژول میلی‌متر بر هکتار ساعت اتفّاق افتاده است. به‌علاوه بررسی تغییرات مکانی عامل فرسایندگی نیز تائید نمود که انزلی و بابلسر واقع در شمال کشور با مقادیر به‌ترتیب ۱۱/۵۱۸ و ۴/۲۶۰ مگاژول میلی‌متر بر هکتار ساعت دارای بیش‌ترین و بم و سمنان با مقادیر به‌ترتیب ۰/۲۰۱ و ۰/۲۱۲ مگاژول میلی‌متر بر هکتار ساعت دارای کم‌ترین مقدار فرسایندگی بوده‌اند. سرانجام مقدار سالانه فرسایندگی باران در ایران ۱/۲۲۶ مگاژول میلی‌متر بر هکتار ساعت برآورد شد.