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Erosivity Index of Urban Storms: Case Study of Two Stations of Kermanshah

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Abstract: Present research examine the erosivity index of precipitation Kermanshah Province, two stations belonged to west Region Water Company named old Kermanshah and new Kermanshah were used, the duration of statistical period being 13 and 19 years. Data on stations was prepared graphically and the extraction of storms was performed visually with 15 min temporal step. After descriptive data on storm was adjusted and arranged tabularly, their kinetic energies were calculated with Wischmier and Smith formula considering maximum intensity of 30 min. Next, they were placed in continuous 1-72 h rainfall groups. Resulting conclusions indicated that about 85% of storm were in 1-6 h continuations and 6 h continuations had the highest values of kinetic energy as well as of erosion index (R), but remained in very low erosion class; and old and new Kermanshah stations were placed in very low erosion class, with annual average of erosion index less than 500 MJ mm ha^{-1} h^{-1}.

Key words: EI30, rainfall erosivity, splash erosion, storm energy, Kermanshah

INTRODUCTION

As one of the most important climatic variables, precipitation has effective role in balancing environmental system; this, of course, requires creating a situation affected by precipitation characteristics including duration, intensity, type of precipitation, shaping mechanism, etc as well as by condition prevailing in the system or water-head domain.

As water-erosion of soil is regarded as an environmental imbalance, the first step to form it is, undoubtedly, splash or rain-droplet erosion, that is caused by highly energetic and successive rain droplets striking on particles of surface soil that aqua- erosion process initially begins with dispersing and decaying of soil particles and then takes different forms (Morgan, 1986).

Knowing the rate of storm energy requires study of rainfall since there is a significant relationship between them. For this reason, extraction storm by proper temporal step is highly determining since only storm having enough energy are able to separate particles and to make them ready to be carried over at the stage of runoff production.

If studies related to water-erosion of soil, which seriously reduces soil productivity and increases the contamination level of surface water (such as increasing content of washed fertilizers), are considered as a package consisting of some components, naturally we should first determine the status of factors (precipitation) entering the system first.

To do so, it is completely essential to (1) understand the storm kinetic energies in order to initially recognize their existence in precipitation turns and (2), to reveal the time and places where highly energetic storm fall by respective techniques.

Present research has been done in Kermanshah Province by studying two stations with urban realm with the aim determining annual erosion index (R) by calculating kinetic energy of storm on the basis of 30 min intensity at most.

Old Kermanshah station is located at south of Kermanshah city and in an urban realm, this station, has continued its activity after several years of disruption from 1966 to 1990.

New station is located at northern part of Kermanshah city and its 13 years data from 1988 to 2001, was employed.

Site description: Kermanshah Province is located at west of Iran, neighboring provinces of Lorestan and Ilam on south, Kurdistan on north, Hamadan on east, and country of Iraq on west.

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Geologically including folded and face-driven limits of Zagros, province- specific topography has generated a height difference more than 3000 m, with mount Shahoo being of 3390 m high which is the highest place in the province and the lowest place being of 180 m high in Soomar area. Because the province is located in direction of rain- bearing masses sent from Mediterranean and because frontier elevations are of general northwest-southeast direction the northwest part of kermanshah province forms a highly humid region with rainfall higher than 750 mm, which is very different from other regions of province due to be orographic discharge.

The mean rainfall of kermanshah province is 485 mm and has 14 climatic sub- categories ranging from highly humid ultracold one at mount Shahoo to hot desert-arid one is Soomar region.

Precipitation is of Mediterranean type so that winters have the highest share of Precipitation summers are drywith no rainfall. Figure 1 shows are locations of stations studied relative to Kermanshah city, to Kermanshah province and to Iran.

The following is pointed several related research: (Wischmeier, 1959) analyzed data from the US research Laboratory on erosion at 35 stations and studied correlation between parameters and erosion recorded from lab plots.

In these experiments, a weak correlation was observed between soil lost during individual storm and total amount of rain with the maximum amount of rain at 5-10 and 30 min temporal-steps. But the factor showing the highest correlation was kinetic energy of rain.

At the next stage combining with temporal steps determined that kinetic energy with 30 min intensity explains erosion better than other parameters.

Attawoo and Heerasing (1997) in their research under the heading of Estimating soil erodibility and erosiveness of rain patterns in Mouritimus, exercised index R pertaining to 3 rainfall on 3 sites in order to test 2 models of predicting R.

In that research, factor R was calculated from formula of KE*I30 to detect the erosiveness of rain pattern on these 3 sites.

According to Wischmeier and Smith (1978) and Attawoo and Heerasing (1997) calculated annual R for storm with intensities more than 12.5 mm h^{-1}, along with monthly and yearly rate of rainfall were considered as the basis of calculation for computing R.

Lu *et al*. (2003) predicted for sheet and groove erosions on Australian continent, 2 topics that turned into important subjects because of reducing soil productivity and quality of water in this research spatial modeling techniques have been demonstrated with the help of revised universal soil erosion equation method (Renard *et al*., 1997) in which index is used to determine erosiveness.

By integrating erosiveness data on erosiveness with satellite images, these researchers found that erosion potential is higher in northern Australia than in South Australia and that it is significantly different between summer and winter due to the type of rainfall pattern.

Raghunath (2002) obtained the map of erosion potential for Bagmati basin, Nepal using Geographic Information System.

In this research, the base is RUSLE method (Renard *et al*., 1997) and erosion index, R, is calculated as one factor effective in calculating erosion rate with (Wischmeier and Smith, 1978) method and the highest intensity was determined to be 30 min by combing kinetic energies of individual rainfalls.

Fig. 1: General schematic view of old and new Kermanshah station

Cambazoglu and Gogus (2004) defined production rate of sediment in western basin of Black Sea in Turkey using Universal Soil Loss equation and Modified Universal Soil Loss equation methods. R is the base of USLE and MUSLE methods to derive 6 factors from the term, which is obtained in different ways.

In that research, extend Renard and Ferimond's (1994) equation of estimating factor R and calculated annual R using parameters of monthly and yearly rainfalls.

Hastings *et al*. (2003) studied intense erosion in Pinon-Juniper forest community in New Mexico. They exploited model RUSLE for this research; values of rainfall intensities were taken by HOBO data logger and calculate rainfall energy. Then the results of computing 6 factors were used to determine the rate of sediment.

By studying researches done abroad, we find that of models USLE group factor R is one of six- fold elements of equations, that is various ways in order to define the rates of sediment- producing and soil erosion.

Primarily it is necessary to study this subject, or index R to understand the degree of storm's energies in one region in terms of their ability to separate soil particles in order to predict provision for protecting from soil erosion and sediment erosions and controlling them.

In this field, numerous researches have been done in Iran some of which are referred to follows.

Sharifian (1996) studied the index of rain erossivness in Mashhad. using a rain-bearing machine, this research initially obtained relationships between similar kinetic energies and rain intensities in Mashhad, next, 25 year data was used to obtain annual R; then relationships between different parameters of rainfall, such as daily maxima 1 h rainfall, index R, etc, were defined to be used for time and places with no data.

Above-named researchers concluded that there was a minor difference between formula extracted from data of rain-bearing machine and Wischmeier and Smith (1978) equation so above mentioned equation can be exercised safely.

Based on this study, the value of rain erosiveness index was obtained at 344 MJ mm ha^{-1} h^{-1} in Mashhad.

Nabavi (1998) were investigated rain erosiveness index for Khorasan province. In this project, relationships between erosion index and annual rate of rainfall were in order to be used for area as lacking coherent data.

Among stations used, Sang-Sourakh station and Tabas stations in south Khorasaan had erosion indexes 4534.6 and 5572 J m^2 mm h^{-1}, respecting showing agreement regional climatic and environmental realties and were confirmed.

This research is performed to investigate rainfall erosiveness in Kermanshah Province and explain it's ability as annual index of erosivity.

MATERIALS AND METHODS

This research is conducted in kermanshah province and was supported by ACECR (Academic Center for Education, Cultural and research), of Razi University and performed in project No. 794-11 and is completed at the end of 2007 to implements this project in kermanshah city realm, two stations with pluviometer registers devices belonged to Energy Ministry (west water corporation), were employed, with duration of statistical period as follows:

Pluviometer register devices draw the values of rainfall on a continuous paper with a pen in such a way that sequential and rainfall values in mm are recorded on ordinate and abscissa axes.

Time intervals and respective divisions are different based on the type of equipment. In this study, the least sequential step and related rainfall values detectable optically were set at 15 min.

After taking precipitation data in the form of rainfall graphs, rainfall values were defined and separated, with sequential step 15 min.

Then extracted values were inserted in a given Table 1 with sufficient notes. These operations were carried out for 2 discussed stations with related duration of statistical period.

Separated storm had different value and times ranging from 15 min to 50 h.

At the next stage, those storm were studied and then combined that were expected to have the same origin and sequential delay during the period of raining.

Next, all tabular information of precipitations were entered in computer and prepared for subsequent calculations. Due to the long- temporal range of rainfalls storm were grouped initially. Finally about 2500 storm from 1-36 h groups were selected, adjusted and organized to do calculations.

To calculate each storm's kinetic energy at different stations, Wischmeier and Smith (1978) equation was postulated with given explanation; for each 15 min temporal step the amount of energy was calculated in J m^2 mm; after than 30 min alternations were determined the maximum of which was obtained to extract erosion index R.

This task was performed for each station and during each continuation of precipitation and finally annual

Table 1: Duration of statistical period station used

Station name	Study period	Available year
New Kermanshah	1988-2001	13
Old Kermanshah	1967-1990	19

average of said index was obtained and respective results are given in each station's explanatory table typically and separately.

$$KE = 11.87+8.73\ LOG\ (I)$$

$$R = \Sigma KE*I30$$

Where:

KE = Kinetic energy (J m^2 mm)
I = Rainfall intensity (mm h^{-1})
I30 = rainfall intensity for 30 min period
R = Erosivity index (J mm ha^{-1} h^{-1}).

RESULTS

Old Kermanshah station: Nineteen- year data was prepared graphically form this station and totally 1364 cases of rainfalls were separated into different 1-36 h continuation groups. Table 2 shows example of arrangement of data on raining events in 6 h rainfall continuation group with calculations related to their energies.

Figure 2-5 show diagrams related to some storm from 6 and 12 h rainfall groups of old Kermanshah station selected typically having different kinetic energies. In these combined figures, hyetographs indicate the rate of rainfall with 15 min intervals and linear diagrams represent respective kinetic energy.

All of the storms extracted, are classified to different groups based on it's duration and storm number availability, for example group 1 hour consist of storms that their duration is between 15 and 60 min (Table 3).

In Table 4, Storm from each continuous rainfall group were examined relative to respective erosion index (R). In order to present the results more adequately.

Table 2: Storm extracted from 6 h rainfall group of old Kermanshah station

R (J m^2 mm^{-1} h^{-1})	KE	Rainfall intensity (mm h^{-1})	I30 (mm h^{-1}) rainfall of Intensity of 30 min	Accumulation rainfall depth	Rainfall increment sequency (mm)	Increment sequency (min)	Time of of rainfall (h)	Date of rainfall
25.76	18.40	5.60		1.40	1.40	15	16.00	1972/2/7
27.99	18.66	6.00	5.80	2.90	1.50	15	16.15	1972/2/7
23.56	18.12	5.20	5.60	4.20	1.30	15	16.30	1972/2/7
25.76	18.40	5.60	5.40	5.60	1.40	15	16.45	1972/2/7
30.25	18.91	6.40	6.00	7.20	1.60	15	17.00	1972/2/7
30.25	18.91	6.40	6.40	8.80	1.60	15	17.15	1972/2/7
30.25	18.91	6.40	6.40	10.40	1.60	15	17.30	1972/2/7
17.13	17.13	4.00	5.20	11.40	1.00	15	17.45	1972/2/7
7.25	14.50	2.00	3.00	11.90	0.50	15	18.00	1972/2/7
9.11	15.19	2.40	2.20	12.50	0.60	15	18.15	1972/2/7
13.02	16.28	3.20	2.80	13.30	0.80	15	18.30	1972/2/7
2.50	11.39	0.88	2.04	13.52	0.22	15	18.45	1972/2/7
3.44	12.30	1.12	1.00	13.80	0.28	15	19.00	1972/2/7
5.46	13.65	1.60	1.36	14.20	0.40	15	19.15	1972/2/7
5.46	13.65	1.60	1.60	14.60	0.40	15	19.30	1972/2/7
5.46	13.65	1.60	1.60	15.00	0.40	15	19.45	1972/2/7
6.34	14.10	1.80	1.70	15.45	0.45	15	20.00	1972/2/7
10.07	15.49	2.60	2.20	16.10	0.65	15	20.15	1972/2/7
13.02	16.28	3.20	2.90	16.90	0.80	15	20.30	1972/2/7
9.11	15.19	2.40	2.80	17.50	0.60	15	20.45	1972/2/7
2.20	11.02	0.80	1.60	17.70	0.20	15	21.00	1972/2/7
1941.98			6.40		17.7	315		

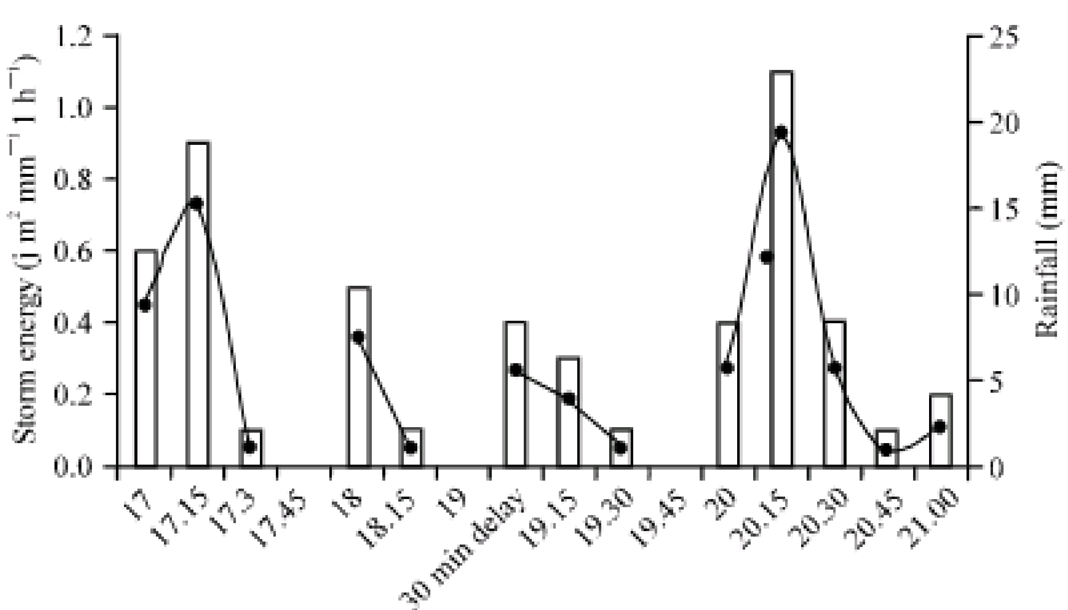

Fig. 2: Combined rainfall-energy diagram of first sample 6 h group of old kermanshah station

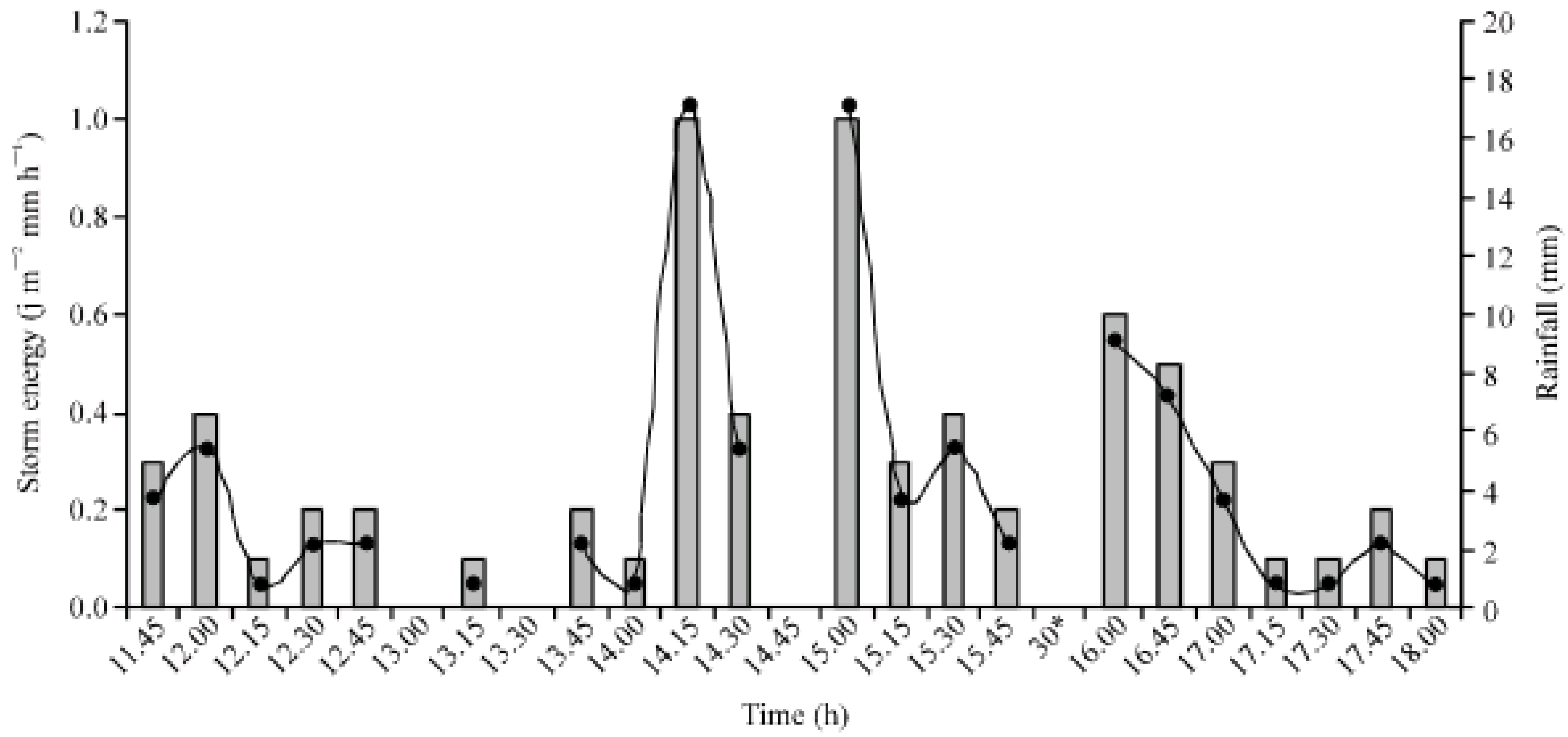

Fig. 3: Combined rainfall-energy diagram of second sample 6 h group of old Kermanshah station, *: 30 min delay

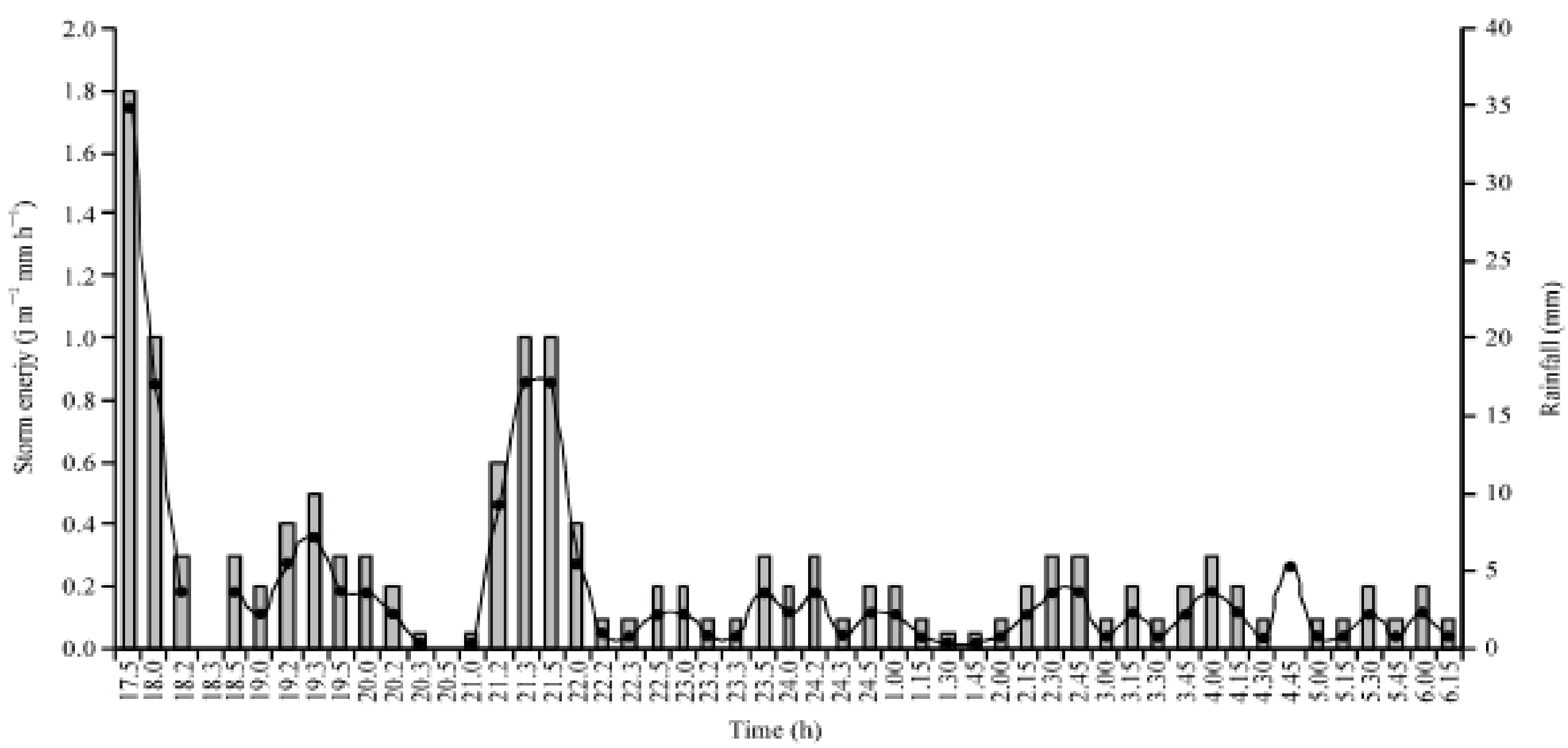

Fig. 4: Combined rainfall-energy diagram of first sample 12 h group of old Kermanshah station

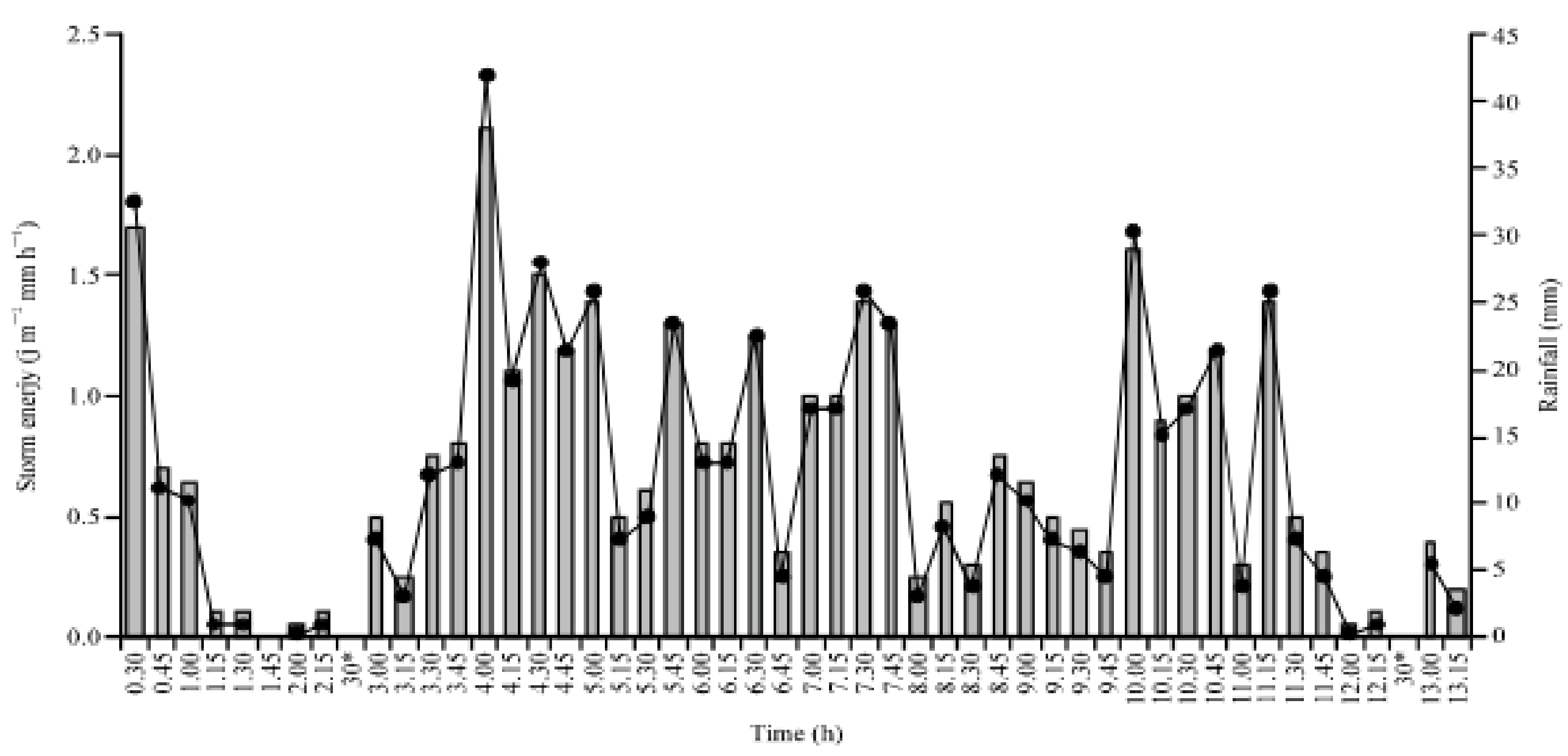

Fig. 5: Combined rainfall-energy diagram of second sample 12 h group of old Kermanshah station, *: 30 min delay

Table 3: Total No. of storm of continuous rainfall groups

	Rainfall groups (h)											
Station name	1	2	3	6	9	12	18	24	36	48	72	Total
Old Kermanshah	482	295	224	211	88	38	21	4	1	0	0	1364
New Kermanshah	318	188	165	138	53	25	16	5	1	0	0	909

Table 4: Erosion indexes of continuous rainfall groups of old Kermanshah station

	Groups								
Rainfall	1	2	3	6	9	12	18	24	36
Average	3361.58	5133.82	6063.98	13101.00	7933.03	4575.20	4358.49	7159.76	3640.11
Max single storm	5661.85	10972.52	10102.57	10535.08	11463.15	7737.46	7716.31	19871.23	3640.11
Min single storm	0.06	0.50	0.62	8.70	63.97	58.44	377.99	1378.52	364.11

Table 5: Typical annual erosivity index range classification

Classification	MJ mm ha^{-1} h^{-1}
Very low	<500
Low	500-1000
Medium	1000-3000
High	3000-6000
Very high	>6000

Table 6: Storm extracted of 6 hr rainfall group of New Kermanshah station

R (J m^2 mm h^{-1})	KE	Rainfall intensity (mm h^{-1})	I30 (mm h^{-1}) Rainfall Intensity of 30 min period	Accumulation rainfall depth	Rainfall increment temporal (mm)	Increment temporal (min)	Start temporal of rainfall	Start date of rainfall
2.20	11.02	0.80		0.2	0.2	15	16.00	1989/3/26
3.77	12.56	1.20	1.00	0.5	0.3	15	16.15	1989/3/26
11.04	15.77	2.80	2.00	1.2	0.7	15	16.30	1989/3/26
9.11	15.19	2.40	2.60	1.8	0.6	15	16.45	1989/3/26
3.77	12.56	1.20	1.80	2.1	0.3	15	17.00	1989/3/26
13.02	16.28	3.20	2.20	2.9	0.8	15	17.15	1989/3/26
17.13	17.13	4.00	3.60	3.9	1.0	15	17.30	1989/3/26
13.02	16.28	3.20	3.60	4.7	0.8	15	17.45	1989/3/26
9.11	15.19	2.40	2.80	5.3	0.6	15	18.00	1989/3/26
5.46	13.65	1.60	2.00	5.7	0.4	15	18.15	1989/3/26
3.77	12.56	1.20	1.40	6.0	0.3	15	18.30	1989/3/26
2.20	11.02	0.80	1.00	6.2	0.2	15	18.45	1989/3/26
2.20	11.02	0.80	0.80	6.4	0.2	15	19.00	1989/3/26
0.00	0.00	0.00	0.40	6.4	0.0	15	19.15	1989/3/26
3.77	12.56	1.20	0.60	6.7	0.3	15	19.30	1989/3/26
17.13	17.13	4.00	2.60	7.7	1.0	15	19.45	1989/3/26
15.05	16.73	3.60	3.80	8.6	0.9	15	20.00	1989/3/26
11.04	15.77	2.80	3.20	9.3	0.7	15	20.15	1989/3/26
9.11	15.19	2.40	2.60	9.9	0.6	15	20.30	1989/3/26
0.84	8.40	0.40	1.40	10.0	0.1	15	20.45	1989/3/26
0.84	8.40	0.40	0.40	10.1	0.1	15	21.00	1989/3/26
3.77	12.56	1.20	0.80	10.4	0.3	15	21.15	1989/3/26
598.02			3.80		10.4	330		

As shown in Table 4, mean erosion index of each continuous rainfall group, obtained based on the year of having that group, shows that storm of 6 h group have the ability to separate more soil particles, or are more erosive, than the other groups and that following this group the groups of 9 and 24 h had gained higher values in this sense.

But on the whole and based on average of mean storm energy of old Kermanshah station with 387.67 MJ mm ha^{-1} h^{-1} fall in very low erosion class based on respective classification and this matter includes continuous rainfall groups.

Figure 6 and 7 depict the value of erosion index for storm from 6 and 12 h continuous rainfall groups. From these diagrams and contents of Table 5 it is clear well that accumulation of the value of erosion index of any storm in each group lies at a lower level while there are maximum points having considerable energies.

New Kermanshah station: This station is located at northern part of Kermanshah city and its 13 years data from 1988-2001, was employed.

Total number of this station's raining events is 906 cases in various continuous rainfall group raining from 1 to 36 h, as shown in Table 6.

Some part of information on different continuous groups and respective energies. Rainfall rates and related

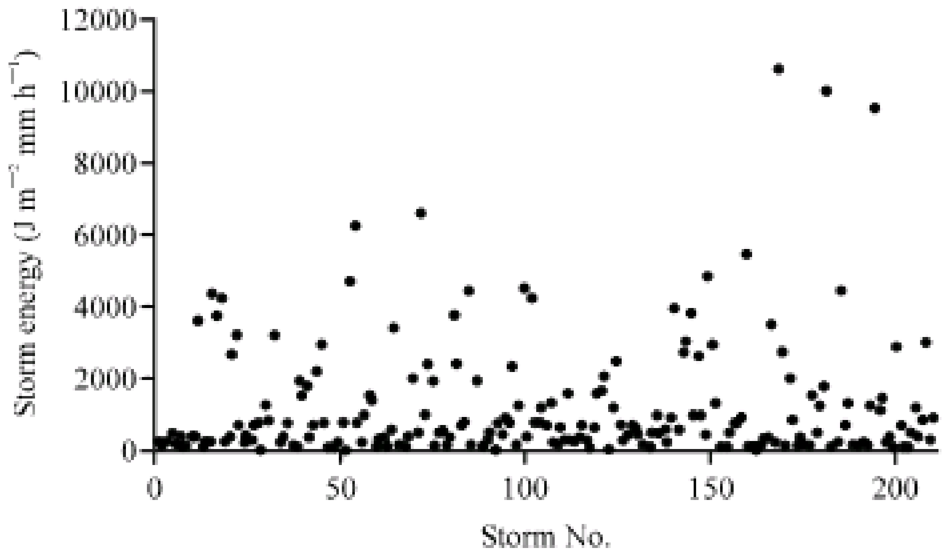

Fig. 6: Value of erosion index for storm from 6 h group of old Kermanshah station

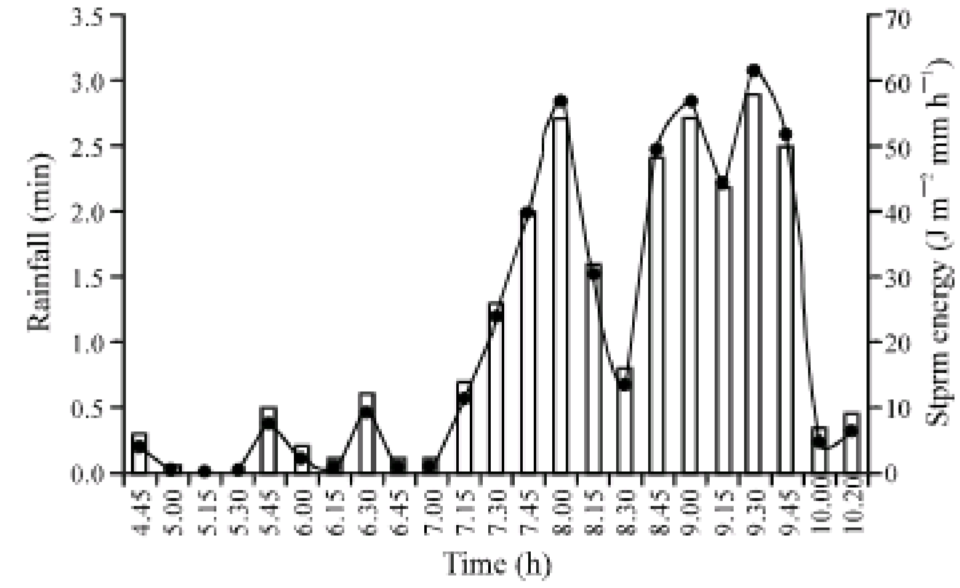

Fig. 8: Combined rainfall-energy diagram of first sample 6 h group of new Kermanshah station

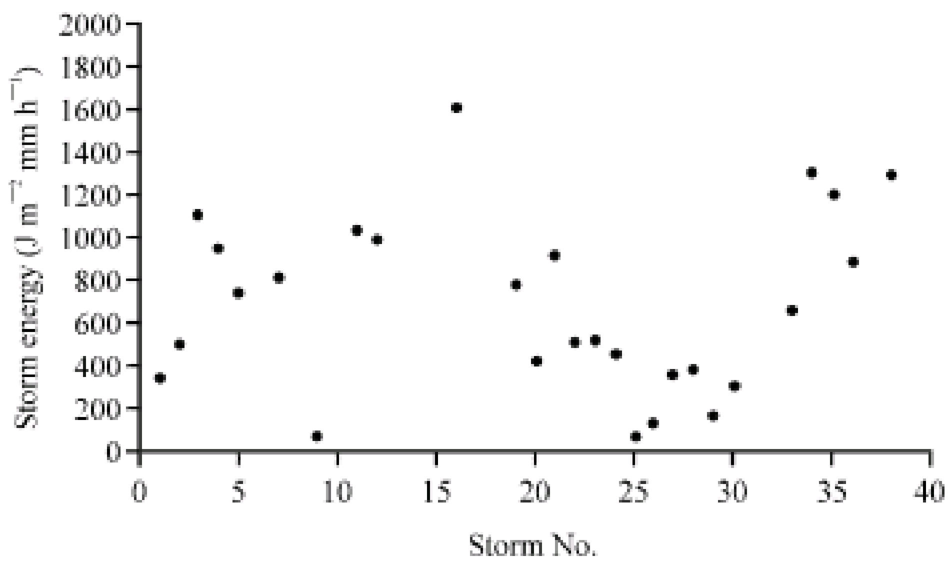

Fig. 7: Value of erosion index for storm from 12 h group of old Kermanshah station

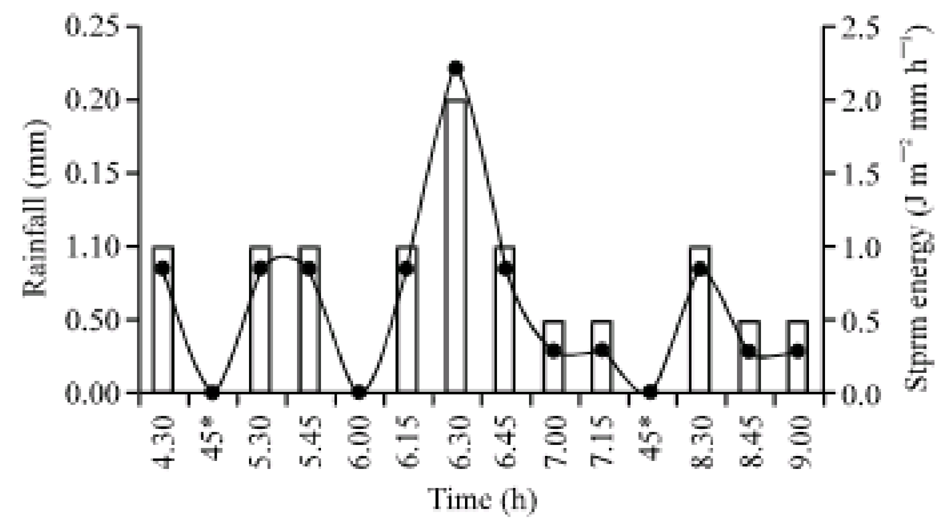

Fig. 9: Combined rainfall-energy diagram of second sample 6 h group of new Kermanshah station, *: 45 min delay

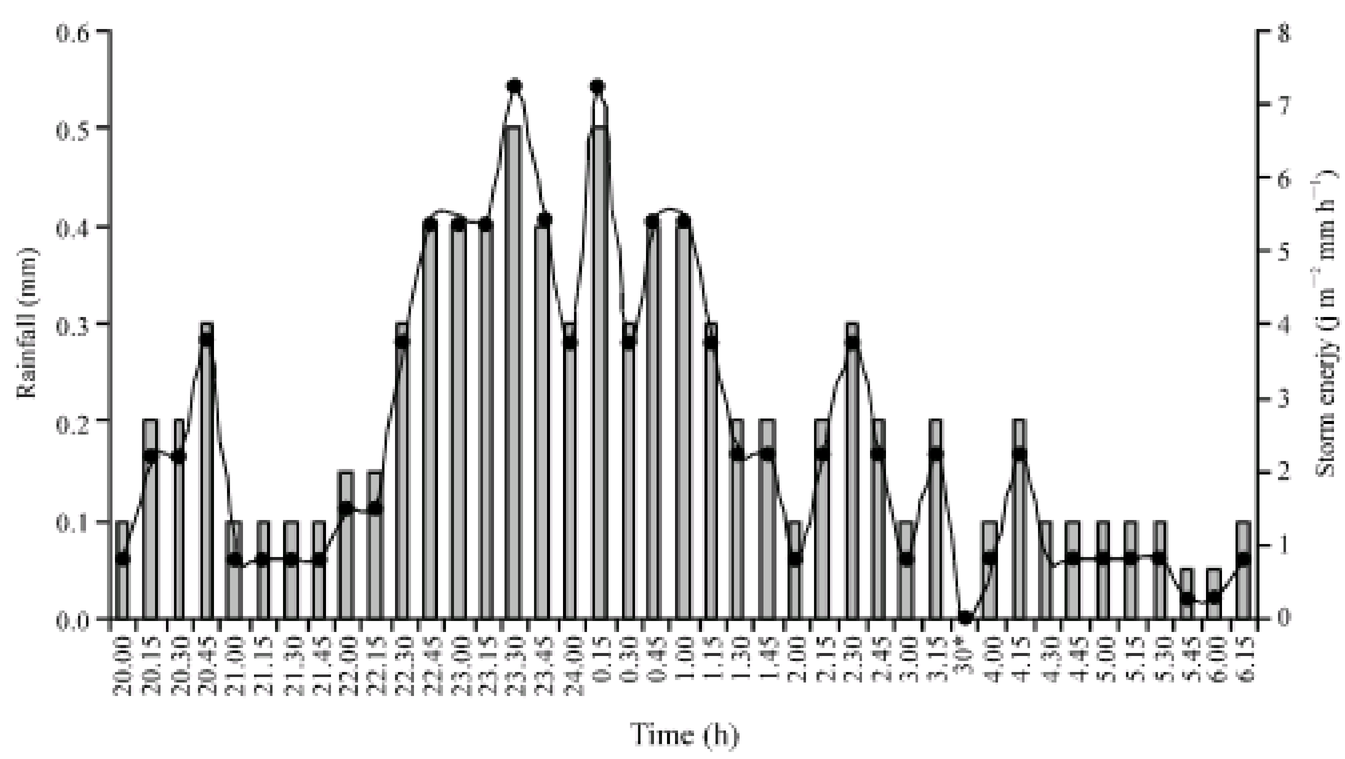

Fig. 10: Combined rainfall-energy diagram of first sample 12 h group of new Kermanshah station. * 30 min delay

kinetic energies of some selected storm are set In Fig. 8-11 in the form of combined (bar and line) diagrams.

Minimum, maximum and mean values of erosion index of each continuous rainfall group are inserted in Table 7 according to which 24 h group has the maximum R value followed by 6 h continuous group.

But in addition, annual average of erosion index of storm of this station equal to 399.2 MJ mm ha^{-1} h^{-1} and fall within very low class.

Figure 12 and 13 showing the values of erosion index of storm from any continuous rainfall group indicate that most values of this index for each continuation

Table 7: Erosion indexes of continuous rainfall groups of new Kermanshah station ($J\ m^2\ mm\ h^{-1}$)

	Group								
Rainfall groups	1	2	3	6	9	12	18	24	36
Max single storm	4562.7	5149.56	9890.42	9275.32	8409.79	12727.75	12758.73	34900.29	462.39
Min single storm	0.06	0.34	0.35	1.08	4.72	30.06	92.56	536.45	462.39
Average	1877.6	4056.39	5225.78	11601.8	6781.9	3964.87	5096.06	13686.84	231.20

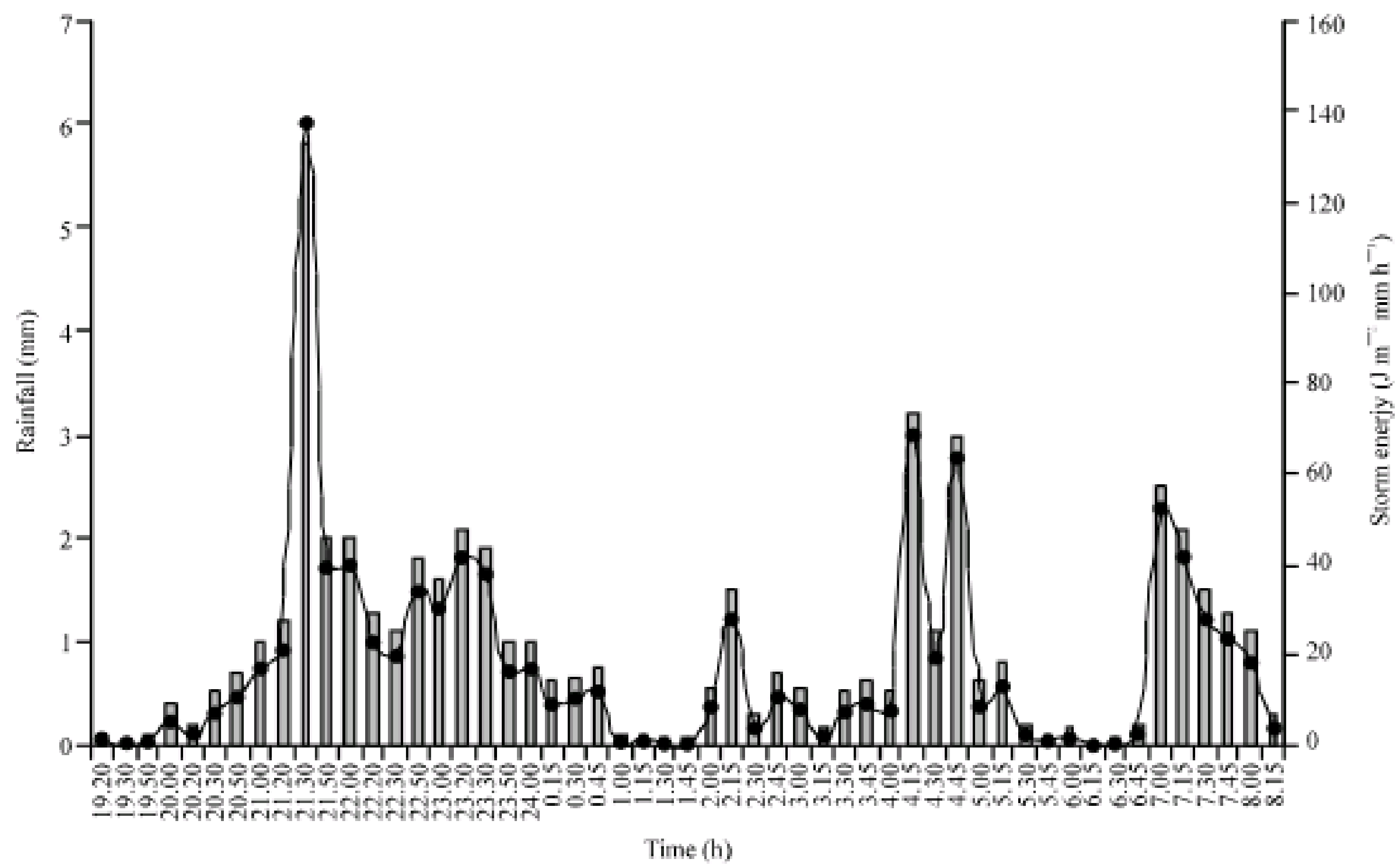

Fig. 11: Combined rainfall-energy diagram of second sample 12 h group of new Kermanshah station

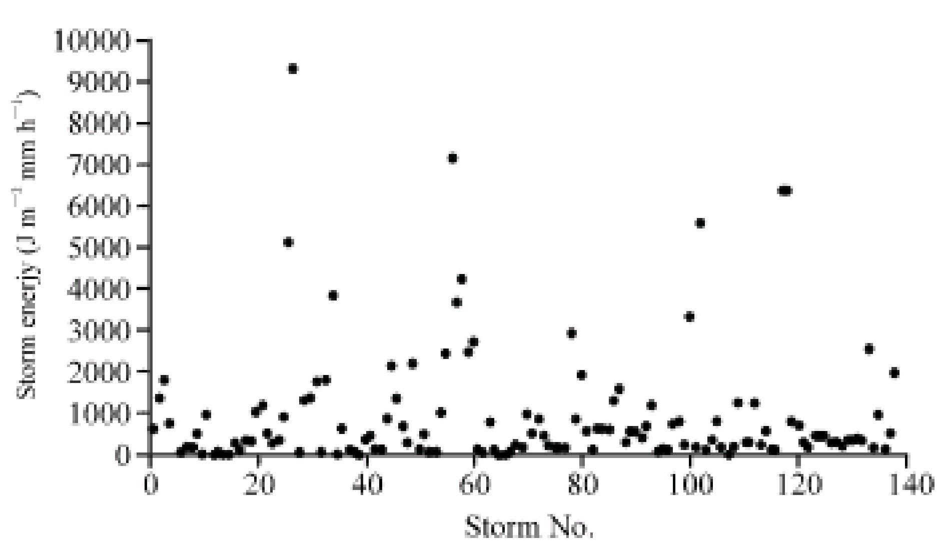

Fig. 12: Erosion index for 6 h rainfall group energy of new Kermanshah station

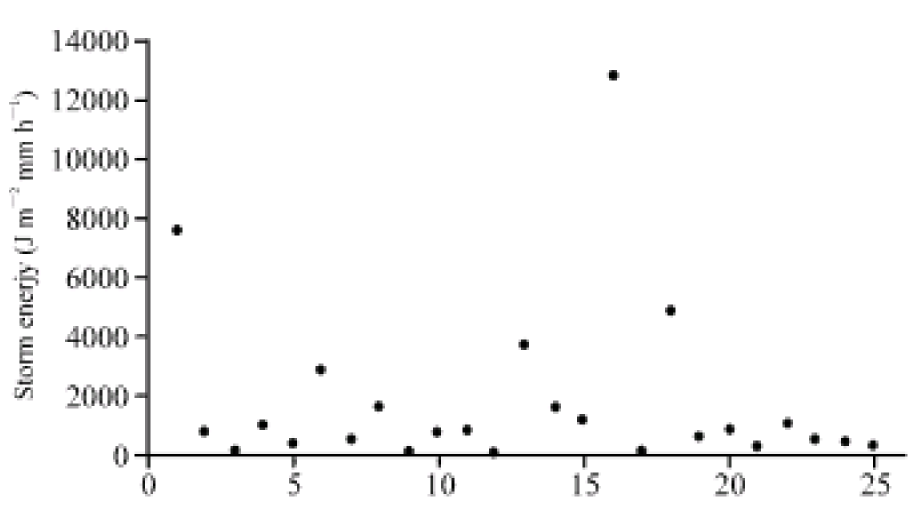

Fig. 13: Erosion index of 12 h rainfall group energy of new Kermanshah station

group lie at a low level of energy although highly energetic storm manifest themselves in the mean temporal.

DISCUSSION

This research has studied kinetic energy and erosion index of storm occurred in the realm of Kermanshah City during respective statistical period provided that rainfall graphs be existing.

To calculate index R and kinetic energy, EI 30 and Wischmeier and Smith (1978) equation were employed. Calculations were performed, separated for each station, so that obtained are station-specific, include the domain covered by the station.

Two old/new Kermanshah stations in realm of Kermanshah city. If we consider both stations together with each other, there will be, for example, a virtual station in niner-city of Kermanshah. Separate calculations of these stations showed that, for discussion of continuous rainfall groups, 6 h group from old and 24 h group from new Kermanshah stations had the highest values of R.

If ignore 5 cases of 24 h rainfall of new kermanshah, 6 h groups from both stations will have the highest values of R while the annual average of R fall in very low erosion class for both stations, indicating that, in this sense, there is no specific difference in precipitation features between southern and northern parts of Kermanshah city although this subject needs further research on individual high-energy storm.

REFERENCES

Attawoo, M.A. and J.M. Heerasing, 1997. Estimation of soil erodibility and erosivity of rainfall patterns in Mauritius. Proceedings of the 2nd Annual Meeting of Agriculture Scientists, Aug. 12-13, Food and Agricultural Research Council, Réduit, Mauritius, pp: 219-239.

Cambazoglu, M.K. and M. Gogus, 2004. Sediment yields of basins in the western black sea region of Turkey. Turk. J. Eng. Environ. Sci., 28: 355-367.

Hastings, B.K., M.S. Freeman and B.F. Jacobs, 2003. Rapidly eroding Pinon-Juniper woodlands in New Mexico: Response to splash treatment. J. Environ. Qual., 32: 1290-1298.

Lu, H., I.P. Prosser and C.J. Moran, 2003. Predicting sheetwash and rill erosion over the Australian continent. Aust. J. Soil Res., 41: 1037-1062.

Morgan, R.P.C., 1986. Soil Erosion and Conservation, Longman Scientific and Technical. John Wiley and Sons, New York.

Nabavi, N.Q., 1998. Determination of rainfall erosivity index in Khorasan Province. M.Sc. Thesis, University of Tarbiat Modares.

Raghunath, J., 2002. Potential erosion map for bagmati basin using GRASS-GIS. Proceedings of the Open Source GIS-GRASS Users Conference, Sep. 11-13, Trena, Italy, pp: 1-9.

Renard, K.C., G.R. Foster, G.A. Weesies, D.K. McCool and D.C. Yoder, 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), 3rd Edn., USDA-ARS, U.S. Government Printing Office, Washington, DC.

Renard, K.G. and J.R. Freimund, 1994. Using monthly precipitation data to estimate the R-factor in the revised USLE. J. Hydrol., 157: 287-306.

Sharifian, H., 1996. Study of rainfall erosiveness ability in Mashhad. M.Sc. Thesis, University of Tarbiat Modars, Agriculture Faculty, Tehran, Iran.

Wischmeier, W.H. and D.D. Smith, 1978. Predicting Rainfall Erosion Losses-A Guide to Conservation Planning. 3rd Edn., USDA Agriculture Handbook, US Government Printing Office, Washington DC. USA., 2 pp: 1-58.

Wischmeier, W.H. and D.D. Smith, 1959. A rainfall erosion index for a universal soil loss equation. Soil Sci. Soc. Am. Proc., 23: 246-249.