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Using monthly rainfall data to estimate rainfall erosivity factor of Iraq

Key words: erosivity factor, soil, rainfall, modified Fournier index, linear regression, Kriging

Introduction

The big effect on soil erosion in Iraq comes from climate factors. The main factor which has major effect to case the soil erosion is rainfall. In addition, human activity could be other source to increase of soil erosion which impact on agriculture field, construction building and water resource and so far. Therefore, the estimation of soil erosion become very important for the researchers and decision makers. Universal soil loss equation (USLE) is a method that was improved by Wischmeier and Smith (1978). Renard, Foster, Weesies, McCool and Yoder (1997) modified it and proposed for the first time the name RUSLE for the updated framework. The equation is:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \qquad (1)$$

where:
A – annual soil loss [t·ha^{-1}·year^{-1}];
R – rainfall erosivity factor [MJ·mm·ha^{-1}·h^{-1}·year^{-1}];
K – soil erodibility factor [t·h·MJ^{-1}·mm^{-1}];
LS – topographical factor (L – slope length; S – slope steepness) [-];
C – crop management factor [-];
P – conservation practice factor [-].

Rainfall erosivity explains the erosion soil by the potential of rainfall as a numeric and is one of the key input parameters for (R)USLE modelling. Recently, rainfall erosivity has grown in importance because it has been used as an input parameter not only for modelling soil erosion but also for sediment yield, water quality modelling and other purposes thus, the accurate valuation of rainfall erosivity could be effective to better modelling results (Wischmeier, 1959; Renard et al., 1997). The interval 15 or 30 min are very difficult obtaining that used to calculate erosivity factor also, the few weather stations were continually recorded of weather parameters in the past (Pérez-Sánchez & Senent-Aparicio, 2016).

Therefore, the various equations were suggested by authors to give estimation of the *R* factor which depends on available information of stations that have recording of precipitation over a period of 24 h. Thus, Fournier index (Fournier, 1960) was used widely because it required few data. The average annual precipitation and monthly precipitation are the main parameters to calculate Fournier index. However, it was modified by Arnoldus (1977) who suggested the modified Fournier index (*MFI*). Also, others expressions was found by Renard and Freimund (1994) to find *R* which depend on *MFI* such as exponential ($R = 0.07397 \cdot MFI \cdot 1.847$) and quadratic ($R = 95.77 - 6.081 \cdot MFI + 0.477 \cdot \cdot MFI \cdot 2$). The exponential structure was used in recent research but with very difference of coefficients (Apaydin, Erpul, Bayramin & Gabriels, 2006). Also, there are many structures could be complex and depend on functions which are sinusoidal or some variables such as latitude and longitude of the study area for example expressions were supposed by Davison et al. (2005). De Luis, Gonzalez-Hidalgo and Longares (2010) find trends of annual total precipitation (P_t), modified Fournier index (*MFI*) and precipitation concentration index (*PCI*) and analyse the relationship between them which show the effect of rainfall during 1951–2000 in environments and its erosion risk. In this paper we attempted to estimate *MFI* by monthly rainfall data to find the erosivity factor of Iraq and using Kriging method to represent the *MFI*.

Material and methods

Study area and data acquisition

The monthly rainfall data of 29 weather stations of Iraq are obtained from the Iraqi Meteorological Origination and Seismology (IMOS) of period 1980–2010. To describe the stations according to their places and the annual precipitation, the stations were divided to three kinds. Table 1 and Figure 1 show the information stations. The annual mean is estimated at 216 mm, but in the north-east, the ranges of rainfall graded from 1,200 mm to less than 100 mm which covers 60% of south of Iraq. The annual winter precipitation is over 400 mm of the northern zone stations with a Mediterranean climate. The middle stations is located between Desert and Mediterranean zones have annual precipitation in range of 200–400 mm in winter season. The southern stations which have places in Desert zone was distinguished by precipitation amount at 200 mm in winter season or less annually.

The selection of which mothed to estimate rainfall erosivity is more relevant from others is depends on intensity of torrential rainfall. The daily precipitation data was required for long period and various time intervals (15 and 30 min), the intensity and core position are required also therefore, because, these specific data are not obtained in Iraq, we used *MFI* which based on Fournier index to estimate the regional erosivity of rainfall. The formula of modified Fournier index was:

TABLE 1. The information stations of Iraq

Station	Longitude [°]	Latitude [°]	Elevation [m]
Northern zone			
Emadiyah	43.30	37.05	1 236
Salahaddin	44.20	36.38	1 075
Sulayma-niyah	45.45	35.53	843
Sinjar	41.83	36.32	583
Duhook	43.00	36.87	554
Teleafer	42.48	36.37	373
Kirkuk	44.35	35.47	331
Dukan	44.95	35.95	276
Mosul	43.15	36.31	223
Tuz	44.65	34.88	220
Khanqin	45.38	34.35	202
Makhmoor	43.60	35.75	22
Middle zone			
Biji	43.53	34.9	116
Hadithah	42.35	34.13	108
Samaraa	43.88	34.18	75
Heet	42.75	33.63	58
Rutba	40.28	33.03	222
Ramadi	43.32	33.45	48
Khahlis	44.53	33.83	44
Baghdad	44.40	33.3	32
Hai	46.03	32.13	17
Southern zone			
Hella	44.45	32.45	27
Kerbela	44.05	32.57	29
Najaf	44.32	31.95	53
Diwaniya	44.95	31.95	20
Samawa	45.27	31.27	11
Nasiriya	46.23	31.02	5
Amara	47.17	31.83	9
Basrah	47.78	30.52	2

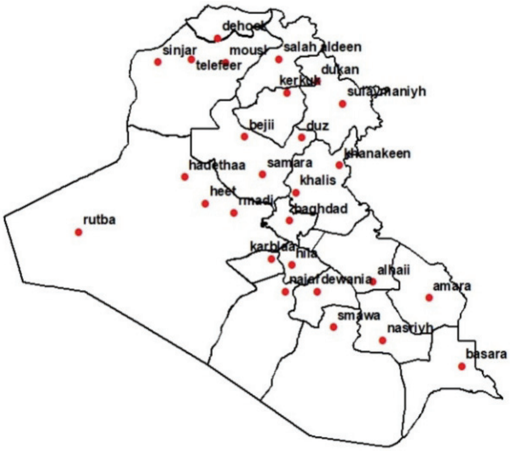

FIGURE 1. Localization of the study stations of Iraq

$$MFI = \sum_{i=1}^{iz} \frac{P_i^z}{P_t} \tag{2}$$

where:
MFI – modified Fournier index [-];
P_i – monthly total precipitation [mm];
P_t – annual total precipitation [Mm].

The classes of erosivity rainfall were determined by means of the modified Fournier index are shown in Table 2.

TABLE 2. The classes of erosivity by modified Fournier index

Erosivity class	*MFI*
Very low	0–60
Low	60–90
Moderate	90–120
High	120–160
Very high	> 160

Results and discussion

The behavior of *MFI* of all stations in Iraq is represented in the Figures 2, 3 and 4. The modified Fournier index is

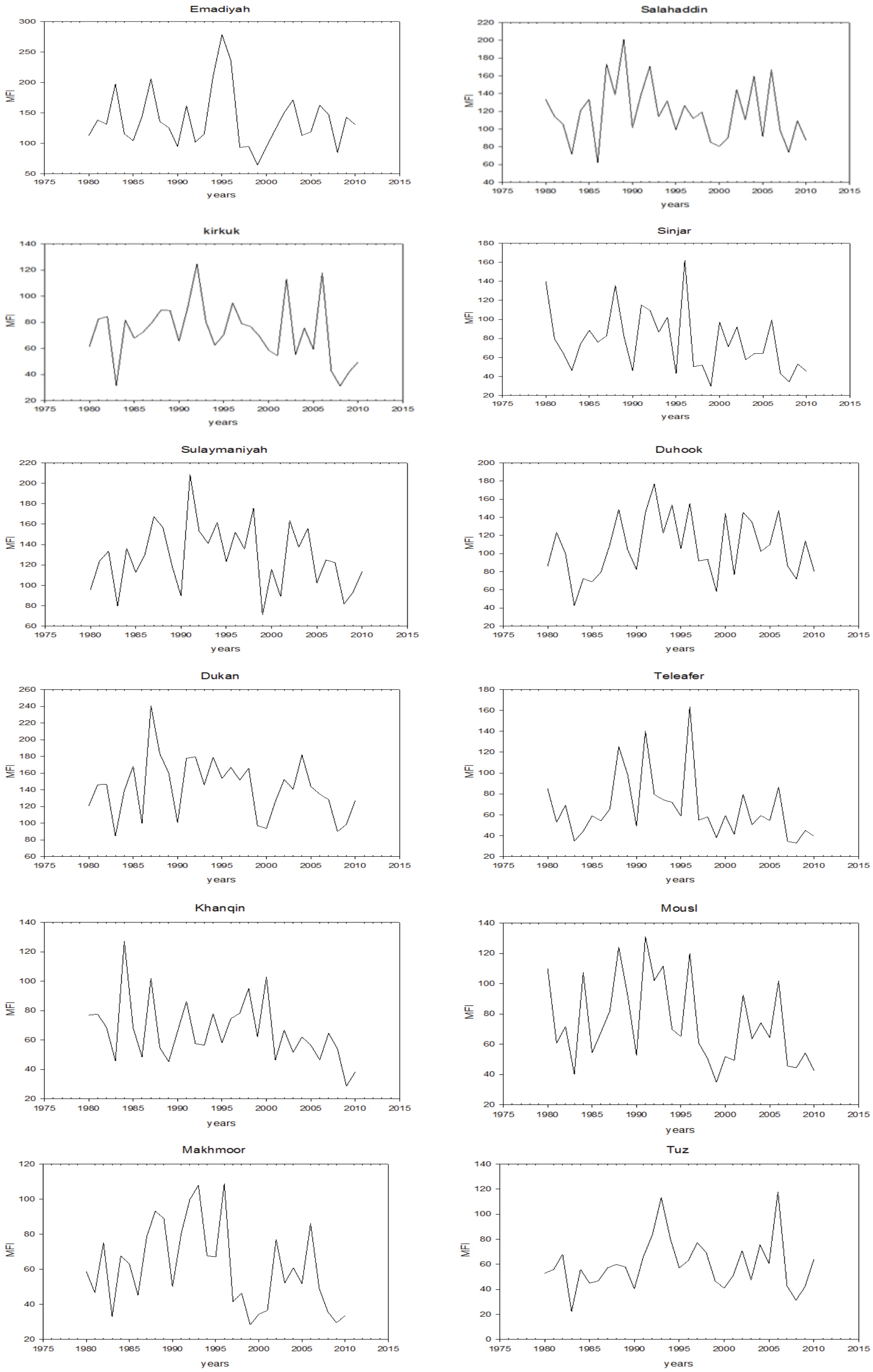

FIGURE 2. The fluctuation of modified Fournier index throughout study period in north stations

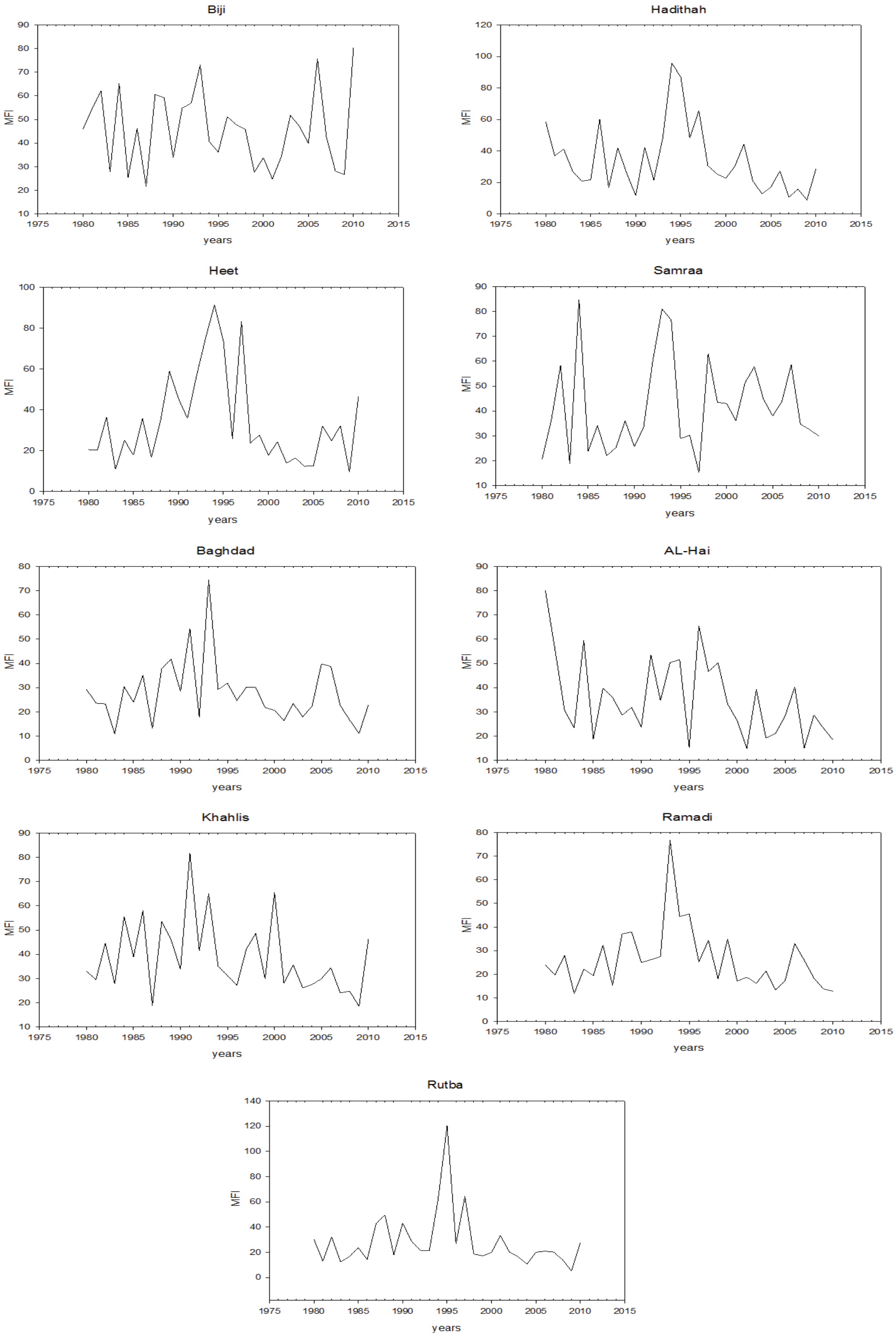

FIGURE 3. The fluctuation of modified Fournier index throughout study period in middle zone

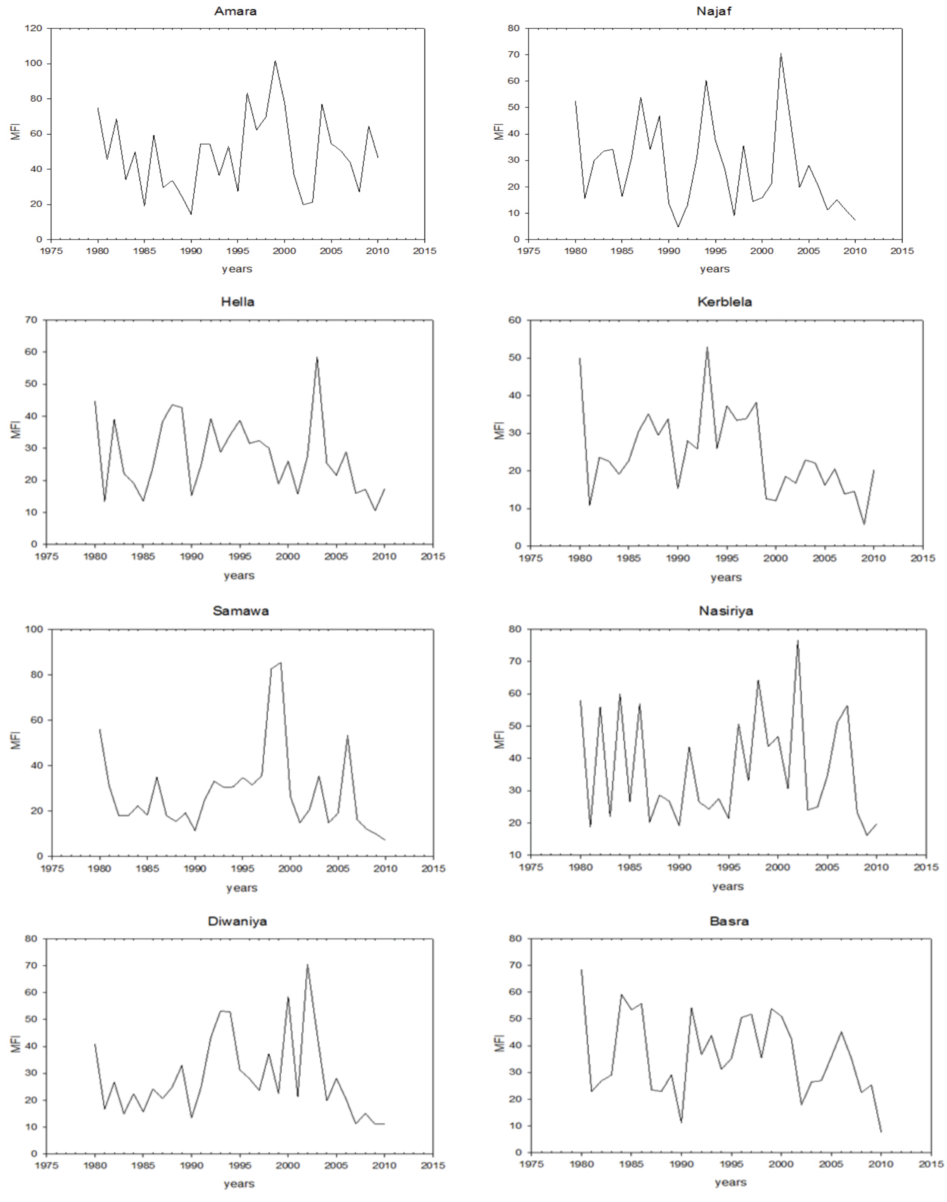

FIGURE 4. The fluctuation of modified Fournier index throughout study period in south zone

very fluctuation throughout the study period. In the northern stations, although, the most of years have *MFI* range above 160, the maximum range was recorded in Emadiyah, Salahaddin, Sulaymaniyah and Dukan stations which exceeded 200. The minimum value of *MFI* was happened in Tuz station, which was less than 20, whereas other stations are recorded minimum around 20–40.

TABLE 3. Linear regression model and coefficient of determination

Station	Linear regression model	R^2
Emadiyah	*MFI* = 0.1644(*P*) + 23.4740	0.4132
Salahaddin	*MFI* = 0.1543(*P*) + 25.2910	0.5518
Sulaymaniyah	*MFI* = 0.1391(*P*) + 30.6180	0.6452
Sinjar	*MFI* = 0.2170(*P*) – 2.5158	0.7404
Duhook	*MFI* = 0.1695(*P*) + 14.7660	0.7666
Teleafer	*MFI* = 0.0385(*P*) – 0.7418	0.1024
Kirkuk	*MFI* = 0.1370(*P*) + 24.9340	0.6236
Dukan	*MFI* = 0.1472(*P*) + 34.2560	0.5022
Mosul	*MFI* = 0.1931(*P*) + 4.6365	0.7426
Tuz	*MFI* = 0.1740(*P*) + 11.4980	0.7282
Khanqin	*MFI* = 0.1693(*P*) + 16.7360	0.4316
Makhmoor	*MFI* = 0.1873(*P*) + 6.0488	0.7326
Biji	*MFI* = 0.1773(*P*) + 9.1576	0.7075
Hadithah	*MFI* = 0.331(*P*) – 7.1527	0.6928
Samaraa	*MFI* = 0.2294(*P*) + 1.8792	0.7202
Heet	*MFI* = 0.3212(*P*) – 5.0046	0.7335
Rutba	*MFI* = 0.2976(*P*) – 4.6537	0.5737
Ramadi	*MFI* = 0.2453(*P*) – 1.7073	0.7112
Khahlis	*MFI* = 0.199(*P*) + 4.3539	0.5259
Baghdad	*MFI* = 0.2618(*P*) – 1.4769	0.6563
Hai	*MFI* = 0.2795(*P*) + 0.4538	0.6410
Najaf	*MFI* = 0.265(*P*) + 2.1089	0.6372
Kerbela	*MFI* = 0.2547(*P*) + 1.5952	0.5346
Hella	*MFI* = 0.2308(*P*) + 4.7188	0.5608
Diwaniya	*MFI* = 0.2994(*P*) – 2.1333	0.7486
Samawa	*MFI* = 0.3326(*P*) – 3.2167	0.7011
Amara	*MFI* = 0.2441(*P*) + 7.6148	0.6857
Nasiriya	*MFI* = 0.2104(*P*) + 10.5750	0.4590
Basrah	*MFI* = 0.1943(*P*) + 9.6087	0.6329

The modified Fournier index of middle zone have range of 0–120 and most values are recorded in range of 20–60, however, there are extreme values of *MFI* that could be clear in Hadithah and Rutba station which recorded a maximum *MFI* value. In the other hand, the minimum values of *MFI* are noticed in range of 0–20 of most stations in this zone. Figure 2 explains the change of *MFI* with study period.

In the south zone, the fluctuation of *MFI* is obvious and its values of most years of all stations are noticed in range of 0–60. Also, Amara station which are noticed more than 100 of *MFI* in south zone and minimum value happened in Najaf station that could be clear in Figure 4.

The relationship between *MFI* and annual rainfall of each station was explained in Table 3. The linear regression equation to predict *MFI* and coefficient of determination were calculated. The minimum values of R^2 were noticed in Emadiyah, Teleafer, Khanqin and Nasiriyah stations that have value less than 0.5, however the maximum was noticed in Duhook station.

Figures 5, 6 and 7 show the change of *MFI* based on three decades. It could be clear that the 1980–1990 and 1990–2000 periods have same *MFI*'s range but the spatial distribution of *MFI* is different between decades. Where, the maximum range could be similar in the north of Iraq but other ranges are very different obviously if we compare 44–64 range of period 1980–1990 with 45–65 range of period 1990–2000 which extend over wild area toward east and west of country.

On the other hand, the *MFI*'s spatial distribution of 2000–2010 period has different range from other periods where maximum range is 116–136 and minimum range is 16–36. The minimum *MFI*' range of all periods cover most of our country that actually because the shortage of rainfall however there is variety of *MFI* in north of Iraq.

Conclusions

The modified Fournier index is much fluctuated and its range is different from zone to others where *MFI* was very high in the northern stations of country because most of years have *MFI* above 160

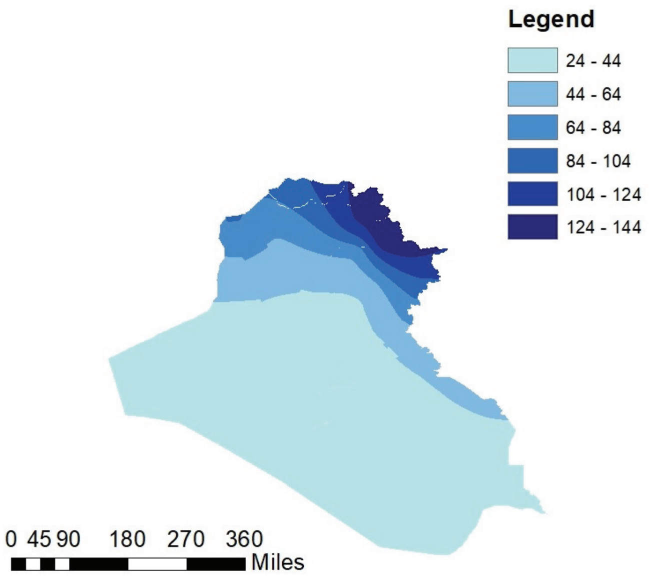

FIGURE 5. Modified Fournier index's spatial distribution of period 1980–1990

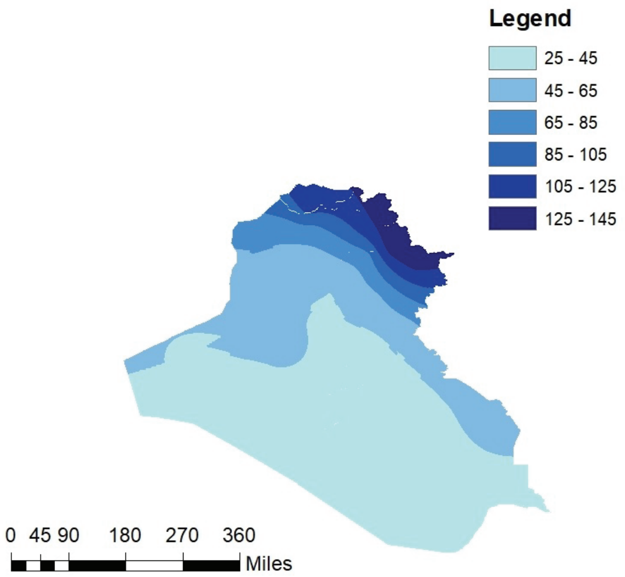

FIGURE 6. Modified Fournier index's spatial distribution of period 1990–2000

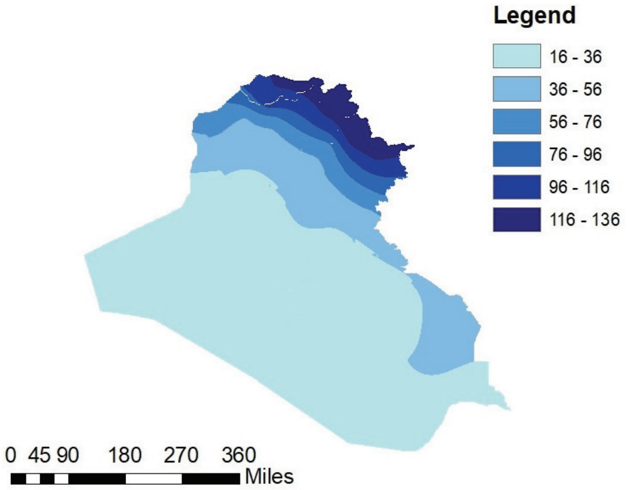

FIGURE 7. Modified Fournier index's spatial distribution of period 2000–2010

or 120–160 that means the effective erosion on soil very high especially Emadiyah, Dukan, Sulaymaniyah and Salahaddin have maximum values of northern stations. Whereas, in the middle zone the stations have moderate erosion effect on soil but most of years of study period have *MFI* like to the southern zone which the station have less than 60. The linear regression model is useful to predict *MFI* of most stations. Coefficient of determination has minimum values in

Emadiyah, Teleafer, Khanqin and Nasiriyah stations that have value less than 0.5 however the maximum was noticed in Duhook station. The erosion on soil by rainfall obviously have a big effect and varity in the north of Iraq that due to receive varity and more amount of rainfall than other territories. On the other hand, the middle and south receive the smallest amount of rainfall, that means the erosivity effect smaller than north of Iraq. The period 2000–2010 has very small *MFI* because the shortage of rainfall therefore the erosivity effect in 1980–1990 and 1990–2000 decades was bigger than 2000–2010 decade.

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Summary

Using monthly rainfall data to estimate rainfall erosivity factor of Iraq. The erosivity factor have a major effect on soil therefor a lot off researchers are interested about it. Actually, the erosivity depend on rainfall that could be a main source to water which effect on soil. To understand the erosivity factor in Iraq, we attempt to explain erosivity factor throughout 30 years (1980––2010). Because of daily data of interval 15 and 30 min are not provided in this area, we used the Fournier modified index (*MFI*) that based on monthly date of rainfall. Also, we applied linear regression equation between annual rainfall and the *MFI* to predict the variables and coefficient of determination was calculated. The study period divided to three decades and spatial distribution by Kriging method was used to interpolate the *MFI* of study area which calculate by ArcGIS 10.4.1. The results show that in the northern

zone of Iraq *MFI* maximum values were recorded and in the range of *MFI* above 160. Moreover, in Emadiyah station the *MFI* excessed 250, which means the erosivity factor has a big effect on soil in this zone. Whereas, in middle zone, the *MFI* has range 0–120 but most of years of study period recorded 0–90 of the *MFI*. In southern zone, the *MFI* was 0–60 therefore the erosivity factor was moderated or law. The linear regression models were found for each station of study area and only Emadiyah, Teleafer, Khanqin and Nasiriya have weak coefficient determination.

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