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# Application of RS and GIS Techniques for Estimating the Rainfall Erosivity (R) of Harir River Basin in Kurdistan Region of Iraq KRI

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***Keywords:***

DEM; GIS; Rainfall; Rainfall Erosivity (R); Remote Sensing (RS); Soil Erosion; USLE

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A B S T R A C T

Geographical Information systems (GIS) has been widely utilized in engineering applications because it has been considered as a very powerful, important, strong and necessary tool especially in the study of soil erosion. In the present study the Remote Sensing and GIS have been utilized in order to determine the values and mapping the spatial distribution of the average rainfall erosivity (R) for Harir River Basin. The area of study is 350.03 km2 and it is located between (36° 20' 00" N to 36° 40' 00" N) latitude and (44° 10' 00" E to 44° 30' 00" E) longitude and the elevation of Harir River Basin is ranged from 366 m to 1823 m. The digital elevation model for Harir River Basin with 30 m resolution has been used. The (IDW) method has been utilized in order to interpolate and generate the spatial distribution of the average annual rainfall stations data. The average annual rainfall data from 2000 to 2021 for five meteorological stations (Harir, Khalifan, Shaqlawa, Rawanduz and Soran) were used. The results have been demonstrated that the average annual rainfall from 2000 to 2021 for Harir River Basin is ranged from 619.013 mm to 774. 173 mm. Additionally, three equations have been utilized in order to determine the values of rainfall erosivity of Harir River Basin. The results have been demonstrated that the average rainfall erosivity for Harir River Basin is ranged from 1528.42 (MJ.mm/ha/h/year) to 2100.00 (MJ.mm/ha/h/year). As well as the results have been demonstrated that 100% of the area of study is under class of low rainfall erosivity.

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# استخدام تقنيات الاستشعار عن بعد (RS)ونظم المعلومات الجغرافية (GIS) لحساب مؤشر التآكل المطري (R) لحوض نهر حرير في إقليم كردستان العراق

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**الخلاصة**

تم استخدام أنظمة المعلومات الجغرافية (GIS) على نطاق واسع لأنه تم اعتبارها أداة قوية جدًا ومهمة وضرورية في التطبيقات الهندسية مثل دراسة تآكل التربة. في هذه الدراسة تم استخدام الاستشعار عن بعد (RS) ونظام المعلومات الجغرافية (GIS) من أجل تحديد القيم ورسم خرائط التوزيع المكاني لمتوسط التعرية المطرية (R) لحوض نهر حرير. حيث تبلغ مساحة الدراسة 350.03 كم2 وتقع بين خط عرض (36° 20' 00" N to 36° 40' 00" N) وخط طول(44° 10' 00" E to 44° 30' 00" E) ويتراوح ارتفاع حوض نهر حرير من 366 م إلى 1823 م. تم تحميل نموذج الارتفاع الرقمي لحوض نهر حرير بدقة 30 م. تم استخدام طريقة (IDW) من أجل استيفاء وإنشاء التوزيع المكاني لبيانات متوسط هطول الأمطار السنوي للمحطات. تم استخدام بيانات متوسط هطول الأمطار السنوي من عام 2000 إلى عام 2021 من حكومة إقليم كوردستان لخمس محطات. المحطات هي حرير وخليفان وشقلاوة ورواندوز وسوران. بينت النتائج أن متوسط هطول الأمطار السنوي لحوض نهر حرير من 2000 إلى 2021 يتراوح بين 619.013 ملم إلى 774.173 ملم. بالإضافة إلى ذلك، تم استخدام ثلاث معادلات لتحديد قيم التآكل الناجم عن هطول الأمطار في حوض نهر حرير. بينت النتائج أن متوسط تآكل هطول الامطار في حوض نهر حرير يتراوح بين 1528.42 (MJ.mm/ha/h/year) إلى 2100.00 (MJ.mm/ha/h/year) وكذلك أظهرت النتائج أن 100٪ من مساحة الدراسة تقع تحت فئة التعرية المنخفضة لهطول الأمطار.

**الكلمات الدالة: نموذج الارتفاع الرقمي، نظم المعلومات الجغرافية، هطول الأمطار، التآكل المطري، الاستشعار عن بعد، تآكل التربة، معادلة فقدان التربة الشاملة.**

## 1. INTRODUCTION

The assessment of soil erosion phenomenon is very necessary since it can be utilized as a base for developing an effective plan for water and soil conservation. The phenomenon of soil erosion can be considered as one of the most dangerous phenomena that occurs in many regions around the world as a result of several factors. These factors are natural, which is means it is due to natural factors, such as rainfall and wind, or whether these factors are unnatural factors, for example that are caused by human activities [1]. The phenomenon of soil erosion has negative and dangerous effects on the region since it affects negatively on agricultural lands as well as it affects negatively on the water channels and on the water management in the region. Additionally, the phenomenon of soil erosion will also lead to increase the rate of pollution in the area which is also effect on the ecosystem and the environment of the region. Therefore, all these harms resulting from the phenomenon of soil erosion will negatively and significantly effect on the economy of the countries [2, 3]. As well as the soil erosion has been considered as a very dangerous hazard especially in the upland area [4, 5]. The water can be considered as one of the most common causes of soil erosion phenomena in many regions around the world, because it removes easily the nutrients rich in the soil. Additionally, it leads also to increase the proportion of sedimentation in the rivers and reservoirs, which in turn leads to reducing the capacity of the reservoirs and reducing the quality of the water in that regions [6]. Soil erosion has direct effect on the chemical and physical properties of the soil which can effects on any hydraulic structures and watershed management system in that region [7, 8]. In general, the perfect time for estimating the rate of soil erosion for an area that characterized with low vegetation cover is in the wet season when the rate of soil erosion is high [9]. It is very necessary to indicate the regions that may be subject to soil erosion in the future in order to provide advance information in order to know how to manage the watersheds as well as to find effective ways to conserve the soil. Therefore, limiting and decreasing rate of the soil erosion, as well as decreasing the rate of sedimentation are very important and necessary because of its direct impacts on the water quality in addition to its impact on the fertility of the agricultural lands [10]. In order to prevent and managing the soil erosion in any region, the spatial distribution and the intensity of soil erosion should be estimated. In order to estimate the soil erosion from any watershed, various methods such as the Universal Soil Loss Equation has been widely utilized for prioritization of the watersheds [11]. Where the Universal Soil Loss Equation can be considering as one of the most common, simplest empirical models that has been widely utilized around the world in order to estimate the soil erosion which can be caused by water and calculate the spatial distribution for the watershed. The USLE method has been widely utilized in order to predicts the long-term annual erosion rate in any region based on six factors, where factors include the Conservation Practice factor (P-factor), the Cropping Management factor (C-factor), the Slope Length factor (L-factor), the Slope Steepness factor (S-factor) in the region, the soil erodibility (K-factor) in the region and the rainfall erosivity (R-factor) in the region [11]. The kinetic energy of raindrops and the rate of the runoff that caused due to the rainfall are represented the rainfall erosivity [11]. Rainfall erosivity has direct effect on the rate of soil erosion, where the rainfall is the driving force of soil erosion which is effect directly on the soil and that will lead to separate the soil particles from each other and then transport them to other places by runoff [12]. Rainfall erosivity illustrates various patterns during the dry and wet seasons in terms of amount and in relationship to rainfall amount [13, 14]. The new technology has been presented an efficient, accurate, and cheaper tools such as GIS, satellite imaging and remote sensing. All These new tools have been currently integrated in order to generate an environmental information system that allows to evaluate and test the alternative management scenarios. The assessment of soil erosion by utilizing the GIS and the remote sensing techniques have been done with best accuracy and low cost in various larger areas in order to face the environmental deterioration and the land degradation in various areas [15, 16]. Geographical Information systems (GIS) has been widely utilized in engineering applications because it has been considered as a very powerful, important, strong and necessary tool especially in the study of soil erosion. The applications of USLE model in the grid environment when it is integrated with the GIS will be very helpful in analyzing and determination the rate of soil erosion in any area [17]. The GIS allows more accurate and effective application of the USLE model for the small watershed, where the most applications of the GIS model were subject to limitations of data [18]. Therefore, the GIS has been widely utilized as a basic approach for measuring the soil erosion at all scales and watersheds [18-23]. Many studies have been demonstrated and approved that the rainfall erosivity factor is the most common factor that has a direct and major effect on the rate of soil erosion at many regions around the world [11, 24-26]. Where around 80.0% of soil loss caused due to the rainfall erosivity [27]. Estimation of rainfall erosivity factor has been considered as a very complex procedure as well as it is involves collecting the data for long-term. Because the pluviograph data for many areas around the world are not readily available, therefore the average monthly rainfall amount [28] and the average annual rainfall amount [27, 29, 30] have been utilized in order to determine the values of soil erosion for various watersheds. In the North East of India [17] have been utilized the equation that has developed by [11] integrated with GIS in order to determine the values of rainfall erosivity in Dikrong River Basin. The results have been demonstrated that the average rainfall erosivity was 1894.60 (MJ.mm/ha/h/year). In China [31] have been utilized [32] equation integrated with GIS in order to determine the values of rainfall erosivity in Liao Watershed. The results have been demonstrated that the annual rainfall erosivity is ranged from 8420.0 (MJ.mm/ha/h/year) to 10275.0 (MJ.mm/ha/h/year). In Central Chile [33] have been conducted a study in order to determine the values of rainfall erosivity in Central Chile. Where the precipitation ranged from 140.0 mm/year to 2200.0 mm/year. The results have been demonstrated that the rainfall erosivity was ranged from 90.0 (MJ.mm/ha/h/year) in the north up to 7375.0 (MJ.mm/ha/h/year) in the southern area. In Switzerland [14] have been conducted a study in order to calculate the rainfall erosivity in Switzerland. The results have been demonstrated that the average magnitude of long-term rainfall erosivity was 1330.0 (MJ.mm/ha/h/year). Where in Ticino station maximum rainfall erosivity that has been estimated was 5611.0 (MJ.mm/ha/h/year). As well as the minimum rainfall erosivity that has been estimated was 124.0 (MJ.mm/ha/h/year). In Africa based on time series of three hours precipitation data [34] have been conducted a study in order to estimate rainfall erosivity. In Chhattisgarh [6] have been conduct a study in order to determine the values of soil erosion and the factors that effects on the soil erosion rate of Kulhan Watershed based on USLE integrated with GIS. The results have been demonstrated that the rainfall erosivity is ranged from 90.540 (MJ.mm/ha/h/year) to 180.1120 (MJ.mm/ha/h/year) and the average rainfall erosivity was 135.3260 (MJ.mm/ha/h/year). In Europe [35] have been conduct a study in order to determine the values of rainfall erosivity in Europe. The results have been demonstrated that the average rainfall erosivity for Switzerland and European was 722.0 (MJ.mm/ha/h/year). Where in Alpine and Mediterranean areas the rainfall erosivity was maximum and it was more than 1000.0 (MJ.mm/ha/h/year). In other hand in Nordic countries the rainfall erosivity was minimum and it was less than 500.0 (MJ.mm/ha/h/year). In India [10] have been utilized the equation that has developed by [11] integrated with GIS in order to determine the values of rainfall erosivity in Kapgari Watershed. The results have been demonstrated that the annual rainfall erosivity is ranged from 4998.88 (MJ.mm/ha/h/year) to 7248.410 (MJ.mm/ha/h/year) and the average rainfall erosivity was 6177.820 (MJ.mm/ha/h/year). In Morocco [36] have been utilized the equation that has adapted by [37] integrated with GIS in order to determine the values of rainfall erosivity in Ikkour Watershed. The results have been demonstrated that the annual rainfall erosivity is ranged from 29.030 (MJ.mm/ha/h/year) in the north to 35.660 (MJ.mm/ha/h/year) in the south. In Central Vietnam [38] have been utilized the equation that has suggested by [39] integrated with GIS in order to determine the values of rainfall erosivity in SAP Basin. The results have been demonstrated that the rainfall erosivity is ranged from 1634.00 (MJ.mm/ha/h/year) to 1732.00 (MJ.mm/ha/h/year). In South West of Ethiopia [40] have been utilized the equation that has adapted by [41] integrated with GIS in order to determine the values of rainfall erosivity in Somodo Watershed. The results have been demonstrated that the rainfall erosivity is ranged from 990.9820 (MJ.mm/ha/h/year) to 1082.10 (MJ.mm/ha/h/year).In the present study the Remote Sensing and GIS techniques have been utilized in order to estimate the rainfall erosivity (R) in Harir River Basin in the north of Erbil, Iraq.

## 2. OBJECTIVE OF THE STUDY

The objectives of the study are listed below:

- To estimate and mapping the spatial distribution of average annual rainfall and average rainfall erosivity (R-factor) of Harir River Basin based on Remote Sensing (RS) and GIS techniques and to classify the area of study according to the average rainfall erosivity (R-factor) classes.
- To validate and investigate and illustrate the capability of Remote Sensing (RS) and GIS techniques in estimating and mapping the average annual rainfall and the average rainfall erosivity (R-factor) of Harir River Basin.

## 3. AREA OF STUDY

Harir River Basin is located in the north of Erbil governorate, the capital city of Kurdistan region of Iraq. Harir River Basin is 350.03 km² and it is located between (36° 20' 00" N to 36° 40' 00" N) latitude and (44° 10' 00" E to 44° 30' 00" E) longitude as it has been demonstrated in Fig 1.

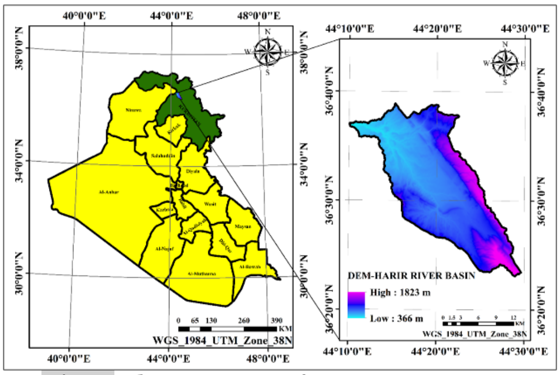


**Fig.1.** The Location of Harir River Basin

## 4. MATERIALS AND METHODS

### *4.1 Digital elevation model (DEM)*

In the present study, the digital elevation model of Harir River Basin with 30 m resolution has been downloaded from the website of United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/) as it has been demonstrated in Fig 2. As well as the coordinate system for the DEM of the study area has been defined according to UTM-WGS-1984-ZONE-38 NORTH. Additionally, the elevation of Harir River Basin according to the digital elevation model of the basin is ranged from 366 m to 1823 m as it has been demonstrated in Fig 2.

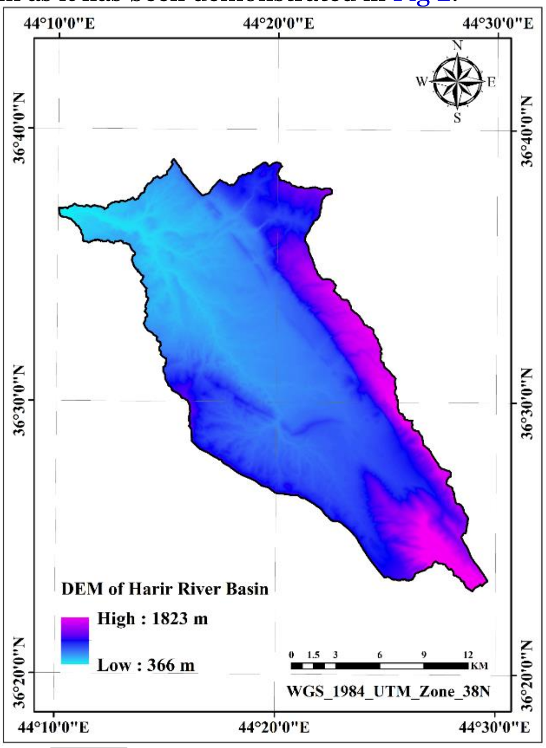


**Fig.2.** The DEM of Harir River Basin.

### *4.2 Rainfall*

The spatial distribution of rainfall for the study area is very essential, since the rainfall has large effect on the soil erosion rate. For the current study the average annual rainfall from (2000 to 2021) have been gathered from Meteorological Department of the Ministry of Agriculture and

Water Resources, Kurdistan Region Government (KRG), Iraq in 2022 [42] for five meteorological stations. Where the stations are Harir (that is located in the area of study), Khalifan, Shaqlawa, Rawanduz and Soran (that located outside the area of study). As well as the spatial distribution data of average annual rainfall have been determined as a continuous surface raster layer by utilizing the interpolation method. The Invers Distance Weighted method (IDW) interpolation has been utilized in order to interpolate and generate the spatial distribution of the average annual rainfall stations data.

### *4.3 Rainfall erosivity (R-factor)*

The rainfall erosivity is represent the result of multiplying the maximum rainfall intensity for thirty minutes by the total kinetic energy [11]. Additionally, the rainfall erosivity is represent the interaction that caused between soil surface and the kinetic energy of raindrops [11, 43]. There are various methods that can be utilized in order to determine the values of the rainfall erosivity factor. In the present study, three different methods (equations) [27, 44, 45] have been utilized in order to calculate the rainfall erosivity based on the climatological similarity. Where [45] has been suggested equation (1) for Italy, [27] has been suggested equation (2) for Continental United States U.S. and [44] has been suggested equation (3) for California.

$$R = 4.0412P - 965.53 \quad (1)$$

$$R = 0.0483P^{1.61} \quad (2)$$

$$R = 0.82P^{1.09} / 0.5876 \quad (3)$$

Where, P represents the average annual rainfall in (mm) and R represents the rainfall erosivity in (MJ.mm/ha/h/year). Additionally, the ArcGIS10.8.1 has been utilized to generate the spatial distribution of the average rainfall erosivity (R) of Harir River Basin by utilizing (IDW) method. The rainfall erosivity classes have been classified according to Table 1 [46].

**Table1**

The rainfall erosivity classification

| No. | Rainfall Erosivity Classes | Rainfall Erosivity (MJ.mm/ha/h/year) |
|---|---|---|
| 1 | Low Rainfall Erosivity | R ≤ 2452 |
| 2 | Medium Rainfall Erosivity | 2452 < R ≤ 4095 |
| 3 | Medium-Strong Rainfall Erosivity | 4095 < R ≤ 7357 |
| 4 | Strong Rainfall Erosivity | 7357 < R ≤ 9810 |
| 5 | Very Strong Rainfall Erosivity | R > 9810 |

## 5. RESULTS AND DISCUSSION

### *5.1 Rainfall*

In the present study, the average annual rainfall data has been interpolated from the five metrological stations in order to create the spatial distribution of the average annual rainfall for Harir River Basin in raster format layer based on (IDW) method. Additionally, the results have been demonstrated that average annual rainfall for Harir River Basin from 2000 to 2021 is ranged from 619.013 mm to 774. 173 mm. The (IDW) method in ArcGIS 10.8.1 was very useful as it has been utilized to generate the average annual rainfall spatial distribution according to the average annual rainfall for Harir River Basin from 2000 to 2021. Fig 3 demonstrate the location of the meteorological stations and the spatial distribution of the average annual rainfall for Harir River Basin from 2000 to 2021.

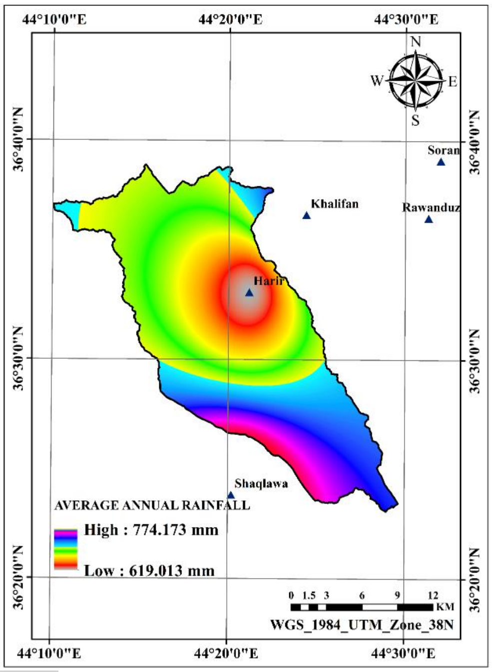


**Fig.3.** The spatial distribution of the average annual rainfall of Harir River Basin from (2000 to 2021) and the location of the meteorological stations

The average annual rainfall in (mm) for each station from 2000 to 2021 has been demonstrated in Table 2. Additionally, Fig 4 illustrates the average annual rainfall for each station from (2000 to 2021).

**Table2**

The average annual rainfall in (mm) for each station from (2000 to 2021)

| No. | Station | Latitude | Longitude | City | Average Annual Rainfall in (mm) (From 2000 to 2021) |
|---|---|---|---|---|---|
| 1 | Harir | 36.5514 | 44.3528 | Erbil | 619 |
| 2 | Khalifan | 36.6104 | 44.4064 | Erbil | 763 |
| 3 | Soran | 36.6518 | 44.5332 | Erbil | 697 |
| 4 | Rawanduz | 36.6081 | 44.5219 | Erbil | 732 |
| 5 | Shaqlawa | 36.3972 | 44.3366 | Erbil | 804 |

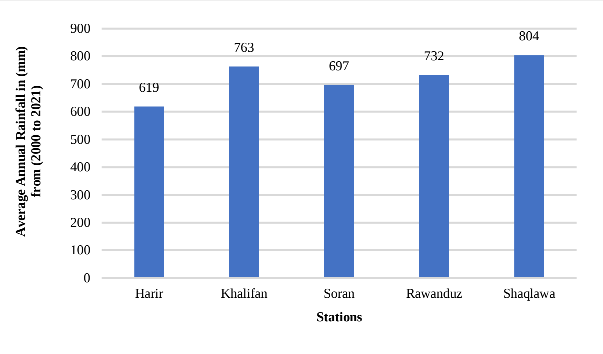


**Fig.4.** The average annual rainfall for each station from (2000 to 2021)

### *5.2 Rainfall erosivity (R-factor)*

For the current study the rainfall erosivity has been calculated according to equation (1,2 and 3). The results have been demonstrated that the average rainfall erosivity for Harir River Basin is ranged from 1528.42 (MJ.mm/ha/h/year) to 2100 (MJ.mm/ha/h/year). The (IDW) method in ArcGIS 10.8.1 was very useful as it has been utilized in order to create the spatial distribution of the average rainfall erosivity for Harir River Basin from the five stations as it has been demonstrated in Fig 5.

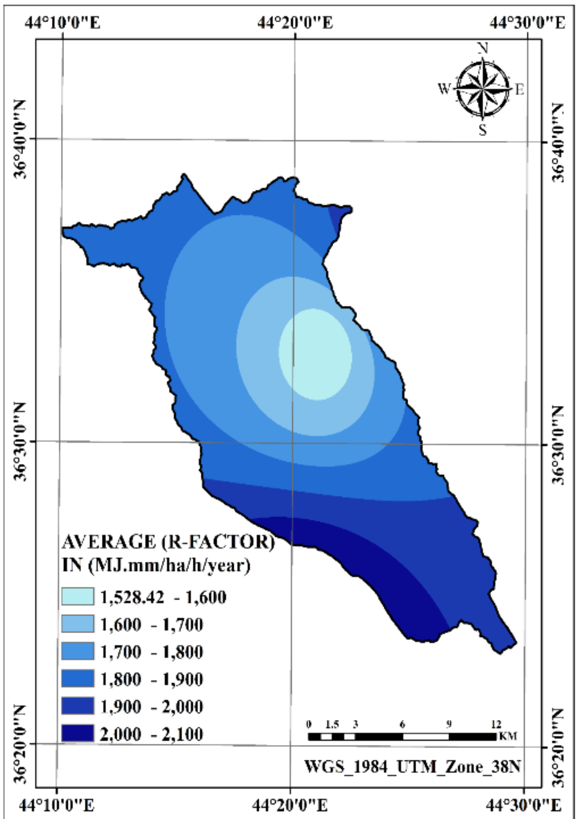


**Fig.5.** The spatial distribution of the average rainfall erosivity (R-Factor) in (MJ.mm/ha/h/year) of Harir River Basin from 2000 to 2021

The average rainfall erosivity in (MJ.mm/ha/h/year) for each station has been calculated as it has been demonstrated in Table 3.

**Table3**
The rainfall erosivity (R-Factor) of Harir River Basin in (MJ.mm/ha/h/year) according to (Ferrari, et al.) method, (Renard & Freidmund) method, (Cooper) method and the average rainfall erosivity in (MJ.mm/ha/h/year)

| NO. | Station | Rainfall Erosivity According to Ferrari et al Method | Rainfall Erosivity According to Renard & Freidmund Method | Rainfall Erosivity According to Cooper Method | Average Rainfall Erosivity in (MJ.mm/ha/h/year) |
|---|---|---|---|---|---|
| 1 | Harir | 1535.97 | 1508.58 | 1540.55 | 1528.37 |
| 2 | Khalifan | 2117.91 | 2112.57 | 1935.01 | 2055.16 |
| 3 | Soran | 1851.19 | 1826.21 | 1753.30 | 1810.23 |
| 4 | Rawanduz | 1992.63 | 1976.10 | 1849.48 | 1939.40 |
| 5 | Shaqlawa | 2283.59 | 2298.31 | 2048.62 | 2210.18 |

According to the results of the average rainfall erosivity, the area of study has been classified into six classes: 5.8518% of the study area is under average rainfall erosivity ranged from 1528.42 to 1600 (MJ.mm/ha/h/year), 13.0369% of the study area is under average rainfall erosivity ranged from 1600 to 1700 (MJ.mm/ha/h/year), 28.1366% of the study area is under average rainfall erosivity ranged from 1700 to 1800 (MJ.mm/ha/h/year), 26.8191% of the study area is under average rainfall erosivity ranged from 1800 to 1900 (MJ.mm/ha/h/year), 18.046% of the study area is under average rainfall erosivity ranged from 1900 to 2000 (MJ.mm/ha/h/year) and 8.1096% of the study area is under average rainfall erosivity ranged from 2000 to 2100 (MJ.mm/ha/h/year) as it has been demonstrated in Fig 6 and summarized in Table 4. As well as based on the results and according to Table 1 it has been demonstrated that 100% of the area of study is under class of low rainfall erosivity as it has been demonstrated in Table 4.

**Table4**
The rainfall erosivity class, the percentage of area, the area in Km² and the average rainfall erosivity (R-Factor) of each class of Harir River Basin

| No. | Average rainfall erosivity in (MJ.mm/ha/h/year) | Rainfall Erosivity Class | Area% | Area in Km² |
|---|---|---|---|---|
| 1 | 1528.42 to 1600 | Low Rainfall Erosivity | 5.8518% | 20.483 |
| 2 | 1600 to 1700 | Low Rainfall Erosivity | 13.0369% | 45.633 |
| 3 | 1700 to 1800 | Low Rainfall Erosivity | 28.1366% | 98.487 |
| 4 | 1800 to 1900 | Low Rainfall Erosivity | 26.8191% | 93.875 |
| 5 | 1900 to 2000 | Low Rainfall Erosivity | 18.046% | 63.167 |
| 6 | 2000 to 2100 | Low Rainfall Erosivity | 8.1096% | 28.386 |

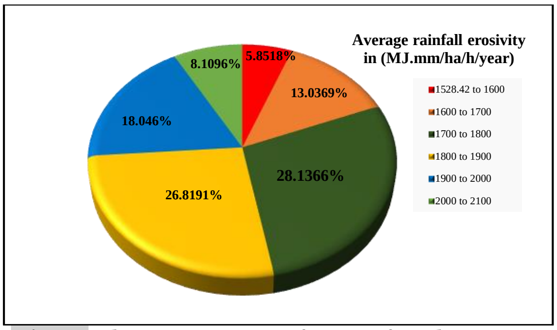


**Fig.6.** The percentage of area of each average rainfall erosivity class in Harir River Basin

Fig 7 illustrates the average rainfall erosivity for each station. Additionally, the results have been demonstrated that when the average annual rainfall increase that will lead to increase the average rainfall erosivity as it has been demonstrated in Fig 8.

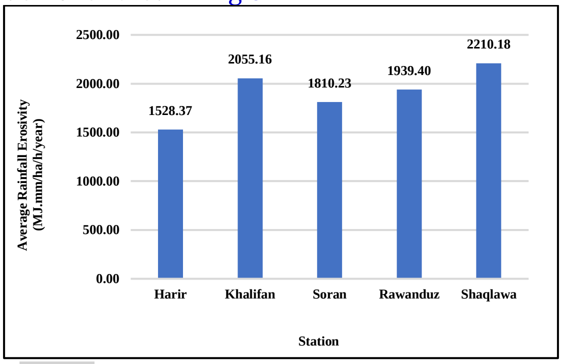


**Fig.7.** The average rainfall erosivity for each station in (MJ.mm/ha/h/year)

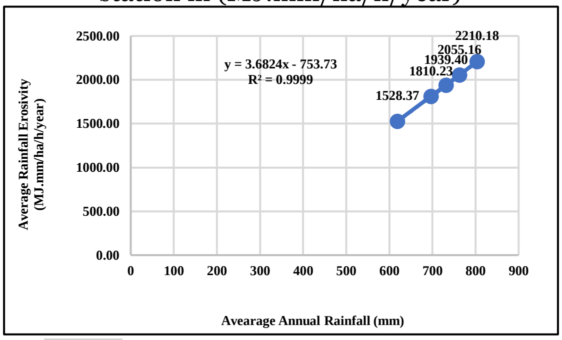


**Fig.8.** The relation between the average annual rainfall (mm) and the average rainfall erosivity (MJ.mm/ha/h/year)

## 6. CONCLUSIONS

- For the current study the average annual rainfall has been interpolated from the five metrological stations in order to extracting and generated the average annual rainfall for Harir River Basin in raster format layer based on (IDW) method.
- The average annual rainfall from 2000 to 2021 has been utilized in order to generate and mapping the average annual rainfall spatial distribution of Harir River Basin.
- The results have been demonstrated that the average annual rainfall for Harir River Basin from 2000 to 2021 is ranged from 619.013 mm to 774. 173 mm.
- The (IDW) method in ArcGIS 10.8.1 was very useful as it has been utilized in order to generate the average annual rainfall spatial distribution for Harir River Basin from 2000 to 2021 and the (IDW) method has been utilized in order to generate the spatial distribution of the average rainfall erosivity for Harir River Basin.
- The results of the average rainfall erosivity (R-factor) have been demonstrated that the average rainfall erosivity is ranged from 1528.42 (MJ.mm/ha/h/year) to 2100 (MJ.mm/ha/h/year). The results have been demonstrated that 100% of the area of study is under class of low rainfall erosivity.
- 5.8518% of Harir River Basin is under average rainfall erosivity ranged from 1528.42 to 1600 (MJ.mm/ha/h/year), 13.0369% of Harir River Basin is under average rainfall erosivity ranged from 1600 to 1700 (MJ.mm/ha/h/year), 28.1366% of Harir River Basin is under average rainfall erosivity ranged from 1700 to 1800 (MJ.mm/ha/h/year), 26.8191% of Harir River Basin is under average rainfall erosivity ranged from 1800 to 1900 (MJ.mm/ha/h/year), 18.046% of Harir River Basin is under average rainfall erosivity ranged from 1900 to 2000 (MJ.mm/ha/h/year) and 8.1096% of Harir River Basin is under average rainfall erosivity ranged from 2000 to 2100 (MJ.mm/ha/h/year).
- The assessment of mapping and estimating the spatial distribution of the average rainfall erosivity (R-factor) of Harir River Basin by utilizing the GIS and the Remote Sensing (RS) techniques have been done with best accuracy, efficiency and low cost.

## 7. RECOMMENDATIONS

- It is strongly recommended that the study of rainfall erosivity (R-factor) mapping should cover the entire watersheds in Kurdistan Region of Iraq and increase the duration of the study by enhancing gauge measurement of data.
- It is strongly recommended to use other methods (equations) to estimate the rainfall erosivity (R-factor) for other watersheds in Kurdistan Region of Iraq.

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