ESTIMATING SOIL LOSS BY WATER EROSION

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ABSTRACT:

The study is focused on the estimation of rate of soil erosion, using the Universal Soil Loss Equation(USLE), for the embankment of Al-Garma Bridge in Basrah, Iraq. The soil erosion is estimated for the zone of average slope in the study area. The factors considered are rainfall, intensity of rainfall, type of soil, slope length, slope steepness, land use classification, and the existing of soil conservation practices. Detailed analysis of soil samples were done to asses the texture, structure, permeability and organic matter content of the soil samples of the embankment of the Al-Garma Bridge. The average annual erosivity index is obtained as (124.99(MJ. mm/(ha.h))) and the annual average soil erosion rate is estimated as (61.5 t/ha/year).

الخلاصة

هذه الدراسة ركزت على تخمين مقدار تآكل التربة ، باستخدام المعادلة الجامعة للتآكل للتعلية الترابية لجسر الكرمة الواقع في مدينة البصرة في العراق. المعاملات التي أخذت بنظر الاعتبار هي المطر ، الشدة المطرية ،نوع التربة ، طول الميل ،انحدار الميل، استخدامات الأرض، وجود استراتيجيا معينة لحفظ التربة من التآكل. تحاليل مفصلة للنماذج التي أخذت من موقع الدراسة لتحديد البناء والتركيب والنفاذية وتحديد نسبة المواد العضوية لهذه النماذج. تآكل التربة خمن للمنطقة الموجودة في الوسط أي في وسط الميل للتعلية الترابية. وجد ان المعدل السنوي لمعامل المطر هو ١٢٤,٩٩ وان معدل التآكل السنوي لموقع الدراسة هو (61.5 طن/هكتار/سنه).

Keywords: soil erosion, Universal Soil Loss Equation USLE.

1-INTRODUCTION:

Soil erosion results from the detachment, the transportation and sedimentation of the soil particles. Factors such as wind characteristics and similar climatic conditions play paramount roles in the disintegration of soil structure. Rain as an external factor plays the most important role and, of soil factors, erodibility phenomenon is importance (Giovanini et al.,2001).

It is useful to make an estimate of how fast the soil is being eroded, before implementing any conservation strategies. Thus methods of predicting the soil loss under a wide range of conditions are required. Erosion models are necessary tools to predict excessive soil loss and to help in the implementation of an erosion control strategy. As part of literature review, a wide range of soil erosion models is studied which includes the Universal Soil Loss Equation (USLE), GIS based USLE (Murimi and Prasad 1998), WEPP (Amore et al 2004), AGNPS (Harregewegn and Yohannes 2003), LISEM(De Ros and Jetten 1999) and Cs137 (Ionita and Margineanu 2000). The Universal Soil Loss Equation (USLE) was developed by Weischmeier and Smith (1978), is the most widely used erosion prediction method.

2-STUDY AREA:

To estimate soil loss field study was conducted in Al- Garmaa located in the south of Basrah. The study area was the embankment of Al-Garmaa Bridge as shown in figure (1). The climate is very hot in summer, cold and rainy in winter with an average annual precipitation of 154.4 mm and a mean annual temperature of 26.5C° (Meteorological Departments, Baghdad- Basrah). Rainfalls mostly occur in spring from March to April, autumn from October to November, and in winter from December, January, and February. The average slope of the embankment is 11%. No land cover and no land use in this embankment as shown in figures (2), (3), and(4).

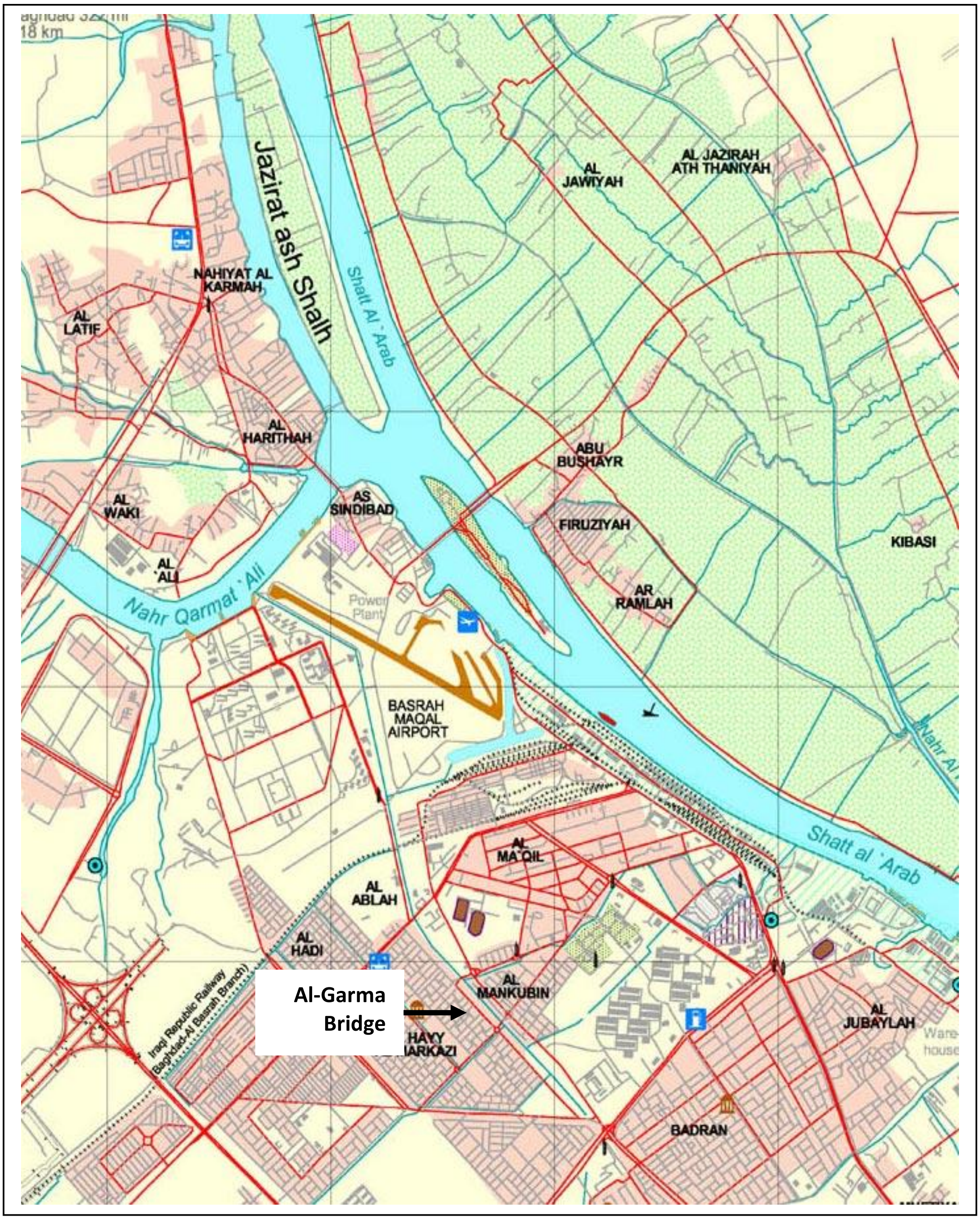

Fig.(1) Location of Al-Garma Bridge in Basrah

Fig.(2) Study embankment with remarked gully erosion

Fig.(3) Study embankment with remarked gully erosion

Fig.(4) Study embankment with remarked gully erosion

3-MODEL DESCRIPTION:

The Universal Soil Loss Equation(USLE) is a hydrological model, which uses a set of parameters to compute soil loss. The four major factors that affect erosion are climate, inherent soil properties including soil erodibility, topography and land use (Jasmin and Ravichandran 2008).

The Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978):

A = R.K.L.S.C.P ------------------------------------- (1)

Where;

A = annual average soil loss (t/ha/year),

R = rainfall and erosivity index for geographic location (MJ. mm/(ha.h)),

K = soil erodibility factor ((t/ha)/(MJ. mm)),

L = slope length factor,

S = slope steepness factor,

C = cropping factor (cover management factor),

P = conservation practice factor.

3-1- CLIMATE

The most important characteristics of rainfall are rainfall intensity and rainfall amount. The average annual erosivity factor, R, is an index of erosivity at a location. Average annual erosivity is computed as the sum of the erosivity (EI_{30}) due to rainfall at a given location , which is the product of the total energy and the maximum 30-min intensity of individual storms. The average annual erosivity is computed as (Jasmin and Ravichandran 2008):

$$\mathbf{R = \sum R_m / m} \quad \text{--} \quad \mathbf{(2)}$$

Where;

R_m = erosivity of an individual storm,

m = number of storms.

Erosivity of an individual storm is calculated as

$$\mathbf{R_m = EI_{30}} \quad \text{--} \quad \mathbf{(3)}$$

Where;

E = total storm energy (MJ /ha),

I_{30} = maximum 30-min intensity of individual storm (mm/h).

The total energy of a storm is computed by

$$\mathbf{E = e\,\Delta v} \quad \text{--} \quad \mathbf{(4)}$$

Where;

e = unit energy (MJ/(ha. mm)),

Δv = rainfall amount (mm).

The unit energy is computed from

$$\mathbf{e = 0.29\,[1- 0.72\,\exp\,(- 0.082i)]} \quad \text{----------------} \quad \mathbf{(5)}$$

where;

i = rainfall intensity (mm/h)

3-2- SOIL:

Erodibility defines the resistance of the soil to both detachment and transport and erodibility varies with soil texture, aggregate stability, shear strength, and organic amount. It was shown that large particles are resistant to transport because of the greater force required entraining them and that fine particles are resistant to detachment because of their cohesiveness.

Soil varies in their susceptibility to erosion. Some soils are naturally more erodible than other soils. Knowledge of basic soil properties such as texture provides an indication of erodibility, which is an important variable.

The equation for soil erodibility factor is: (Jasmin and Ravichandran 2008)

$$K=(k_t k_o + k_s + k_p) / 100 \text{ -------------------------- } (6)$$

Where;

K =soil erodibility factor ((t/ha)/(MJ.mm)),

k_t = soil texture subfactor,

k_o = soil organic matter subfactor,

k_s = soil structure subfactor,

k_p = soil profile permeability subfactor.

The soil texture sub factor equation is given by

$$K_{tb} = 2.1[(p_{si} + p_{vfs})(100 – p_{cl})]^{1.14} / 10000 \text{ --- } (7)$$

$$K_{t68} = 2.1[68(100 – p_{cl})]^{1.14} / 1000 \text{ -------------- } (8)$$

$$K_t = k_{tb} \text{ for } p_{si} + p_{vfs} \leq 68\% \text{ ---------------------- } (9)$$

$$K_t = k_{tb} – [0.67(k_{tb} – k_{t68}) 0.82] \text{ for } p_{si} +p_{vfs} >68\% \text{ ------- } (10)$$

Where;

p_{si} = percentage of silt,

p_{vfs} = percentage of very fine sand,

p_{cl} = percentage of clay,

k_{tb} = base soil texture subfactor,

k_{t68} = soil texture subfactor corresponding to 68%.

The soil organic matter subfactor is given by

$$K_o = (12 – O_m) \text{ -------------------------------------- } (11)$$

Where;

Om = percentage of inherent soil organic matter

The soil structure subfactor is given by

$$Ks = 3.25 (S_s - 2) \text{ -------------------------------------- } (12)$$

Where;

S_s = soil structure class

The soil structure class

1- very fine granular, 2- fine granular, 3- medium or coarse granular, and 4- blocky, play or massive.

The soil profile permeability subfactor is given by

Kp = 2.5 (Pr - 3) ----------------------------------- (13)

Where;

Pr = the soil profile permeability rating

The soil profile permeability rating

1- rapid, 2- moderate rapid, 3- moderate, 4- slow to moderate, 5- slow, and 6- very slow.

3-3- TOPOGRAPHY:

The slope length component and slope steepness component constitute the topography part of the model.

The LS factor can be obtained from the equation (Morgan1979)

$$LS = \sqrt{L/100}\left(0.136 + 0.097 S + 0.0139 S^{2}\right) \text{ ------ (14)}$$

Where;

L =slope length (m),

S = slope %.

3- 4- LAND USE:

Erosion occurs when the soil is left bare and exposed to rain drop impact. Among the four factors, land use is the most important because it has the greatest effect and it is the only factor that can most easily be changed to control soil loss and sediment yield. This factor includes the effect of cover, crop sequence, productivity level, length of growing season, tillage practices, residue management, and expected time distribution of erosive events.

The cropping system factor (C) is the ratio of soil loss from land cropped under specific conditions to the corresponding loss from clean- tilled, continuous fallow land. This factor measures the combined effect of all the interrelated cover and management variables. The (C) factor was computed for each crop, crop stage, and supporting practice information in each land use, using agricultural studies (NRCE 1992) and Wischmeier and Smith (1978).

The supporting practices factor (P) is the ratio of soil loss with a specific support practice to the corresponding loss with up- and down- slope culture. The (P) factor was computed for each supporting practice information in each land use, using agricultural studies (NRCE 1992) and Wischmeier and Smith (1978).

4- DATA COLLECTION AND METHODOLOGY:

The estimation of rate of soil erosion has been conducted in the embankment of the AL-Garmaa Bridge using the Universal Soil Loss Equation (USLE). Soil erosion depends upon rainfall intensity, type of soil, slope length, slope steepness, land use / land cover and soil conservation practices. Rainfall data were collected from the office of (Al-anwaa Al-Jawiya) in Basrah for the period (1988 to 2007)except 2003 and 2004. Rainfall records during these years were missing due to the war circumstances. These gagging read rainfall for each 12 hours only and not data for the intensities of this rainfall reading. The relationship between intensity and duration may be expressed by the equation (Holfelder 1980).

$$\mathbf{i = a / (t + b)} \quad \text{-----------------------------------} \quad \mathbf{(15)}$$

Where;

i = rainfall intensity (mm/h),

t = duration of rainfall (min),

a,b = constants.

Rainfall intensity curves have been derived from 24- hour records for frequencies of rains up to once in 10 years as shown in figure (5). From figure (6) “probability of daily rainfall” shows the number of rain events over the period of one year is very small indeed; 19 days with a 24- hour- rain of 1 mm and 15 days with a 24- hour- period of 2 mm.

For European countries ceiling intensities from 25mm/h to 38 mm/h are generally adopted. For Basrah the consultant proposes to use a ceiling intensity of 17.5 (mm/h) which corresponds approximately to duration of 15 min for a “one to two year storm” i.e. I_{30} equal to 12.7 (mm/h)for a duration of 30 min. (Holfelder 1980).

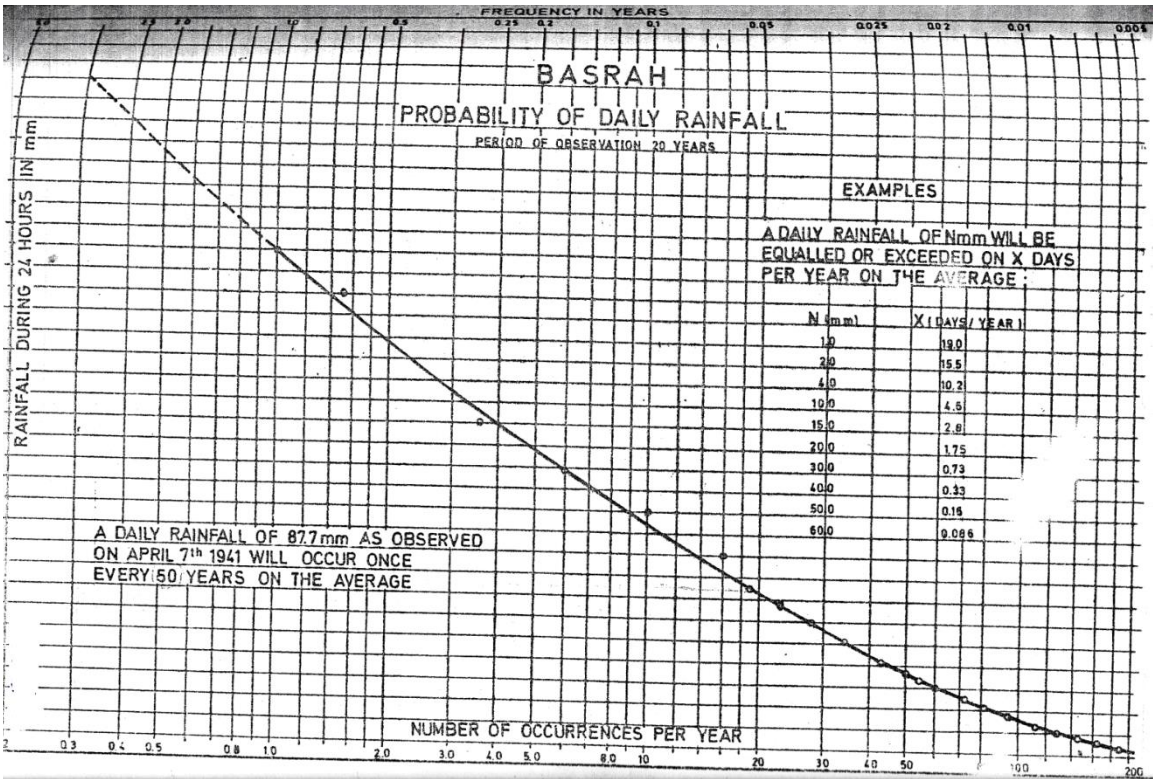

Fig.(5)Basrah probability of daily rainfall (period of observation 20 years). Holfelder(1980).

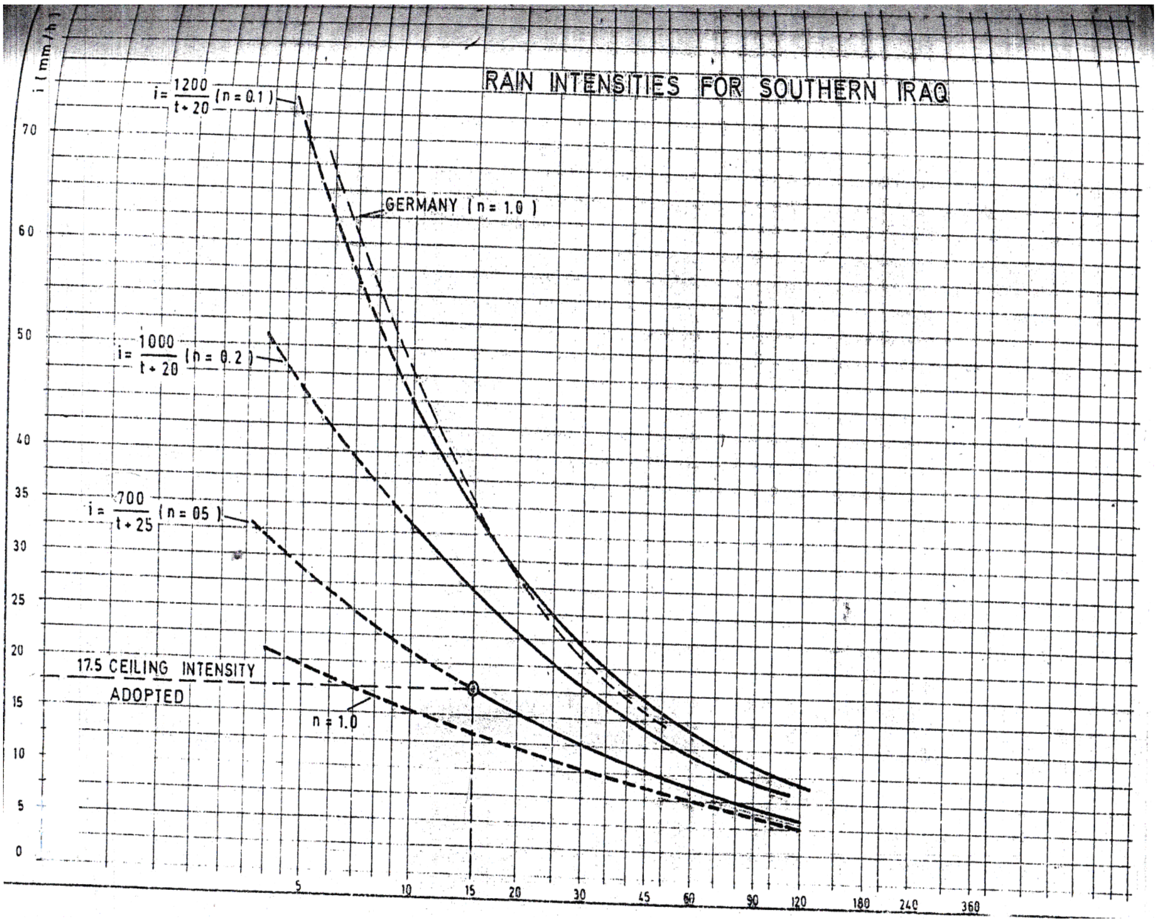

Fig.(6) Rain intensities for southern Iraq. Holfelder (1980).

From these data the annual erosivity index (R) for each year is calculated and the average annual erosivity index is estimated. The average slope of the embankment is 11%. From the average slope zone three soil samples has been taken and the physical soil analysis was done through sieve analysis and hydrometer analysis was done for finding out the percentage of sand, silt, and clay in each sample. The percentage of organic carbon content of soil samples and the permeability for each sample were determined.

Values for cover factor (C) and practice factor (P) were taken as (1). This was done according to the physical condition of the site.

5-RESULTS AND DISCUSSION:

The annual values of rainfall for each year are shown in figure (7) and table (1). It was shown that the maximum rainfall occurred at 1991as (247.1) and the minimum rainfall occurred at 1990 as (48.3). The annual values of erosivity index for each year are obtained as shown in table (1) and figure (8).

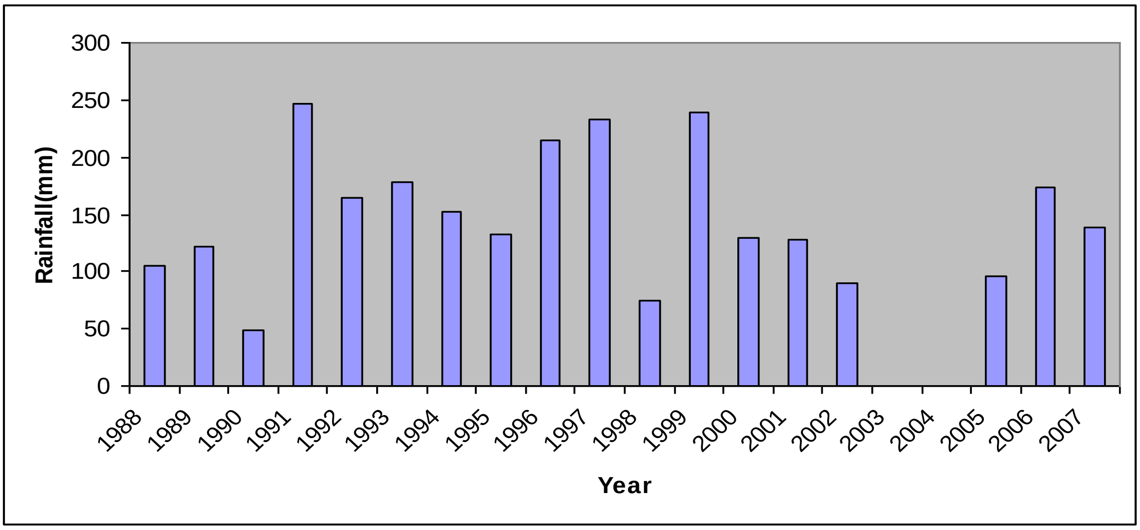

Fig.(7) Annual values of rainfall

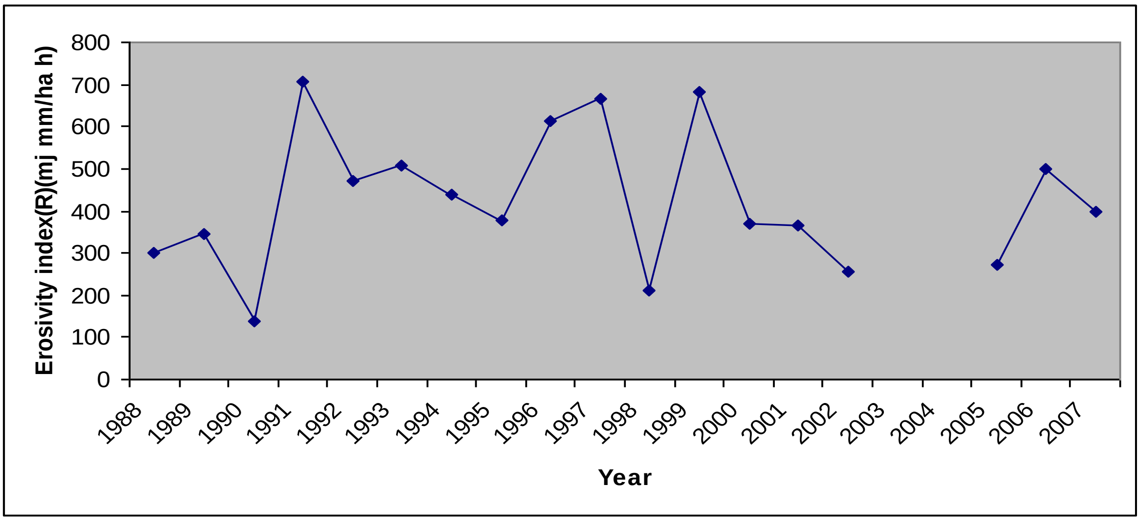

Fig.(8) Annual values for erosivity index (R)

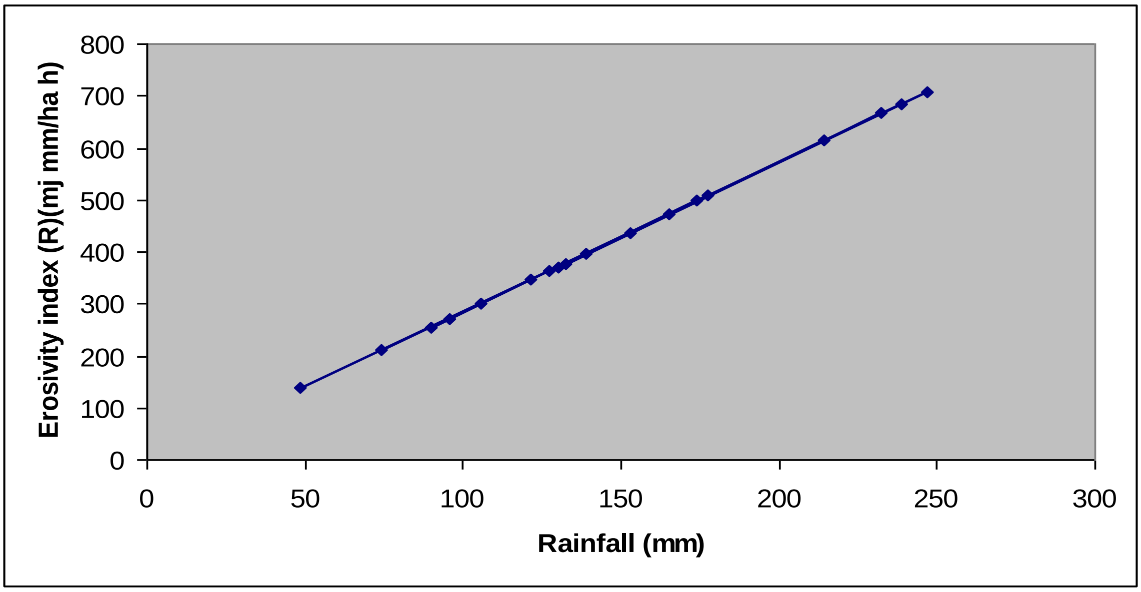

Fig.(9) The relationship between rainfall and the erosivity index

Table (1) : Annual distribution of the erosivity index values (R).

Year	Rainfall (mm)	Kinetic energy(E)	Erosivity index (R)
1988	105.7	8.615	109.4
1989	121.4	9.91	125.9
1990	48.3	3.93	49.9
1991	247.1	20.24	257
1992	165.2	13.5	171.5
1993	177.6	14.51	184.3
1994	153	12.49	158.6

1995	132.3	10.796	137.1
1996	214.2	17.54	222.8
1997	232.5	19.04	241.8
1998	74.2	6.04	76.7
1999	238.6	19.54	248.2
2000	130	10.61	134.7
2001	127.3	10.39	131.9
2002	89.7	7.31	92.8
2005	95.5	7.78	98.8
2226	174.1	14.224	180.6
2007	139.2	11.36	144.3

From table (1),figure(7), and figure (8) it was shown that the minimum erosivity index (R)is 49.9 at 1990 where the rainfall is also minimum and the maximum value of the erosivity index (R) is 257 at 1991 where the rainfall is also maximum and the average annual erosivity index is obtained from equation (2) as 124.99 (MJ mm/ha h). Figure (9) showed that the erosivity index is increased when rainfall increased too.

On the basis of investigations conducted with the presented methodology, the percentage values of silt, clay, sand, very fine sand, and organic amount have been obtained as shown in table (2).

Table (2): Soil parameters for estimation of soil erodibility factor (K).

Sample	O_m%	P_{sl}%	P_{sd}%	P_{vfs}%	P_{cl}%	S_s	P_r
1	4.36	30.64	49.54	12.32	7.5	3	2
2	3.55	1.55	74.98	21.7	1.77	3	2
3	4.12	17.06	61.5	15.94	5.5	3	2
Average	4.01	16.4	62	16.65	4.92	3	2

By using the above values of these indicators and applying them in equation (6) the erodibility factor (K) have been obtained for each sample as shown in table (3).

Table (3): Values of the erodibility factor (K).

Sample	K
1	0.211
2	0.127
3	0.167
Average	0.168

The least resistant particles are silts and fine sands. Thus soils with high silt content are erodible (Richter and Negendank 1977). The erodibility factor is 0.127 for samble(2) and 0.211 for sample (1) and this because the percentage of silt in sample (2) is very small comparatively with sample (1) which is 30.64.

From equation (14) the (LS) factor is obtained as 2.93 for the zone of the average slope.

The cropping management factor (C) and the erosion control practice factor (P) are eliminated which relate specifically to agricultural lands and is applied as a single unit.

Equation (1) is used to estimate the soil erosion for the embankment for the period from 1988 to 2007 as shown in table (4).

Table (4): Values of parameters for estimating soil erosion.

Total(R) (MJmm/ha h)	K ((t/ha)/MJ mm)	LS	C	P	Soil erosion (A)(t/(ha/))
2249.5	0.168	2.93	1	1	1107.29

From the average annual erosivity index (124.99) the average annual soil erosion is obtained as (61.5(t/(ha/year))).

CONCLUTONS:

1-The Universil Soil Loss Equation (USLE) prove to be a very sensitive tool to evaluate soil erosion indexes for:

a- different soil types

b- different rainfall intensities

2- A linear relationship was detected between rainfall and erosivity index.

3- Soil erodibility factor (K) increases with percentage of silt in the studied samples.

4- Annual soil erosion rates according to USLE is in the order of 61.5(t/ha/year).

RECOMMONDATIONS

1- Study the effect of probability maximum precipitation (PMP) on soil erosion.

2- Incorporate the delivery factor in estimating soil erosion.

3-

NOTATIONS:

USLE - universal soil loss equation

A - annual average soil loss

R - erosivity index

K - soil erodibility factor

L - slope length factor

S -slope steepness factor

C -cropping factor

P - conservation practice factor

R_m -erosivity for an individual storm=EI_{30}

m -number of storms

EI -total energy of a storm

I_{30} -maximum 30 minute- intensity of individual storm

e -unit energy

Δv -rainfall amount

i - rainfall intensity

Kt -soil texture sub factor

Ko -soil organic matter sub factor

Ks -soil structure sub factor

Kp -soil profile permeability sub factor

Psi -percentage of silt%

Pvfs -percentage of very fine sand%

Pcl -percentage of clay%

Ktb -base soil texture sub factor%

Kt68 -soil texture sub factor corresponding to 68%

Psd -percentage of sand%

Om -percentage of inherent soil organic matter%

Ss -soil structure class

Pr -soil profile permeability rating

a&b -constants

t -duration of rainfall

REFERENCES:

Amore E., Carlo M., Nearing, MA Santoro, VC(2004).Scale effect of USLE and WEPP application for soil erosion computation from three Sicilian basins. J Hydrol 293:100-114.

De Roo APJ, Jetten VG(1999). Calibrating and validating the LISEM model for two data sets from Netherland and south Africa. Catena37.477-493.

Giovannini, G., Valijo, R., Lucchesi, S., Bautista, S., and Liovet, J. (2001). Effect of land use and eventual fire on soil tradability in dry Mediterranean conditions. Forest Ecol. Manage., 147;15-23.

Haregewegn N., Yohannes F.,(2003).Testing and evaluation of agricultural non- point source pollution model (AGNPS) on Augucho catchment, Western Hararghe, Ethiopio. Agric. Ecosyst Environ99-201-212.

Holfelder G.,(1980). Basrah sewerage and drainage scheme, preliminary phase report, Ministry of housing and construction, Baghdad , Iraq.

Ionita I., Margineanu RM(2000).Application of Cs137 for measuring soil erosion and deposition rate in Romania Acta Geologia Hispania 35-311-319.

Jasmin I., Ravichandran, S., (2008). (RUSLE2) Model application for soil erosion assessment using remote sensing and GIS., Center for water resources, College of Engineering Guindy, Anna University, Chennai, India.

Meteorological Departments, Baghdad- Basrah.

Morgan R., (1979). Soil Erosion., National College of Agricultural Engineering, Silsoe, Bedfordshire, by Longman Inc., New York.

Murimi S. K.,Prassad H.(1998). Modelling potential soil erosion in lake Nakuru Drainage Basin. Ecohydrology. Subramanian V and Ramanathan AL., pp403-414.

Natural Resources Consulîation Engineers (NRCE), (1992). *Watershed Management Studies of Damavand. Ministry of Construction*, Tehran, Iran.

Richter. G. and Negendank, J. F. W.(1977). Soil erosion processes and their measurement in the German area of the Moselle river. Earth surface processes, 2,261-78.

Wischmeier W.H., and *D.D. Smith, (1978). Predicting rainfull erosion tosses-a guide to conservation planning.* USDA, AJncuItural Handbook, NO. 537,58pp.