SOIL EROSION ASSESSMENT WITHIN THE ERBIL WATERSHED USING GEO-INFORMATICS TECHNOLOGY

[1] HASAN MOHAMMED HAMEED

[1] Civil Engineering Department, Soran University, Erbil City, Kurdistan Region, Iraq
Corresponding author›s e-mail: hasan.hamid@soran.edu.iq

Abstract

The spatial pattern distribution of average soil loss per year has been computed relying on the five criteria inputted in the Revised Universal Soil Loss (RUSLE), as well as with the application of Remote Sensing and Geographical Information Systems (GIS) techniques. The aim of this study is to calculate soil erosion by runoff in the Erbil watershed for different types of land cover and land-use. The soil erosion rate per year was recorded by incorporating environmental data and topographic factors in a grid (30 m resolution) by GIS and remote sensing package. The GIS database layers consist of rainfall erosivity (R), slope length and gradient (LS), soil erodability (K), land cover management (C) and conservation practice (P) criteria were estimated to identify their effects on average annual soil loss in the study area. Potential average annual soil loss of the Erbil watershed has been divided into three classes; low, moderate and high levels. The analysis indicates that 22.8% of the Erbil watershed is at a low-risk level of the soil loss, 9.5% medium-risk, whilst 67.8% it located under a high-risk level of soil erosion. The results indicated that soil loss rate per year estimated for the entire watershed is 14.35 ton. ha-1. yr-1, the study also refers to that most of the soil erosion occurs areas of agricultural activity.

Keywords: Soil Erosion, RUSLE, Erbil Watershed, GIS, Remote Sensing

گۆڤاری زانكۆی هەڵەبجە:گۆڤارێكی زانستی ئەكادیمیە زانكۆی هەڵەبجە دەری دەكات	
بەرگ	٦ ژمارە ١ ساڵی(٢٠٢١)
ڕێككەوتەكان	ڕێكەوتی وەرگرتن: ٢٠٢٠/١٢/٣ | ڕێككەوتی پەسەندكردن: ٢٠٢١/١/٣١ | ڕێككەوتی بڵاوكردنەوە: ٢٠٢١/٣/٣٠
ئیمەیلی توێژەر	farhad.rashid@univsul.edu.iq
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پوختە

هەلسەنگاندنی دارمانی خاک لە حەوزی هەولێر بە بەکارهینانی زانستی زانیاری شوێنی هەلسەنگاندنی دابەشبونی شوینی بۆ تیکرای لەدەستدانی خاك بۆ هەرسالێك پە یوە ستە بە ٥ فاکتەری سەرەکی لە یاسی تیکرای لە دە ستدانی خاکی گشتی (RUSLE) سە رە رای بە کارهینانی زانستی زانیاری شوینی و چاودیری دوور. ئامانجی لیکولینە وە کە دە رخستنی داخورانی خاکە لە ریگای شیکردنە وە ی شیوازە جیاوازە کانی رووپوشی زە وی یاخود بە کارهینانە جیاوا زە کانی رووی زە وی. داخو رانی سالا نە ی خاك ئە ژ مار کراوە لە ریگە ی لێکدانی داتای ژینگەو توپۆگرافی لە ووردی (٣٠) مەتر، لەگەل هەژمارکردن و شیکردنە وە ی داخورانی خاك بە بە کارهینانی چە ند چینیك کە هە ریە کە لە داخورانی داباربنو داخورانی لیژی و جوراوجوری خاکی بەکارهیناوە بۆ دەستکەوتنی نەخشەیەکی پۆلێنکراوی شوێنی بۆ (٣) جۆر وەکو ناوچەی لەدەستدانی لەسەرخو، ناوچەی لەدەستدانی مامناوەند هەروەها ناوچەی لەدەستدانی بەرز. لە دەرئە نجامدا دەرکەوت کە ٢٢,٨٪ ناوچەی لێکۆلینەوە لەدەستدانی لەسەرخۆ و، ٩,٥٪ ناوچەی لەدەستدانی ناوەند، و هەروەها ٦٧,٨٪ ناوچەی لێکۆلینەوە لەدەستدانی بەرز لەخۆ دەگرێت. هەروەها ئەم لێکۆلینەوەی روونی کردەوە رێژەی لە دەستدانی خاك لە سالیکدا مەزندە دەکرێت بە١٤,٣٥ تەن بۆ هەر هێکتار دەبیت کە زورینە ی زەویە کشتوکالیەکانی ناوچەکە دە گریتە وە.

تخمين تعرية التربة في حوض أربيل باستخدام تقنيات علم المعلومات المكانية

ان تخمين التوزيـع المكاني لمعدل فواقد التربة لكل سنة تعتمد على خمس عوامل في قانون معدل فقدان التربة الشامل (RUSLE) وبالاضافة الى استخدام تقنيات نظم المعلومات المكانية والاستشعارعن بعد. هدف البحث هو حساب تاكل التربة بواسطة السيح السطحي في منطقة الدراسة لمختلف انواع الغطاء الارضي او استخدامات الارض المختلقة. تم احتساب معدل تعرية التربة السنوية من خلال دمج بيانات بيئية وطبوغرافية على مستوى ٣٠ متر لكل خلية. تتالف الطبقات المستخدمة في تحليل تعرية التربة على كل من التعرية المطري، تعرية الانحدار، تعرية نوعية التربة، ادارة الغطاء النباتي و عمل حماية التربة. تم استخدام هذه العوامل في تخمين معدل فواقد التربة السنوية واستخراج خارطة مكانية لتصنيف منطقة الدراسة الى ثلاث اصناف؛ منطقة واطئة التعرية بلغت مساحتها ٢٢,٨٪ ومنطقة متوسطة التعرية وبلغت مساحتها ٩,٥٪ ومنطقة عالية التعرية بلغت مساحتها ٦٧,٨٪ و ذلك من اجمالي مساحة منطقة الدراسة. واظهرت الدراسة ان معدل فواقد التربة لكل سنة هو ١٤,٣٥ طن لكل هكتار في السنة وهذه الفواقد تشمل اغلب المناطق الزراعية في منطقة الدراسة.

1.Introduction

Soil erosion by surface water, wind, ice, or gravity is a widespread problem throughout the world. Soil erosion is a parameter identifying the ecological sustainability of any re-use land scheme(Fernández & Vega, 2018; Chalise et al., 2019). Wind and water are the essential agents of soil erosion where the process includes detachment, transportation, and deposition(Fu et al., 2006; Hussein et al., 2007). It is one of the foremost problems in natural resources management. During the 20th century soil erosion increased and now a pproximately 85% of the world's land loss is associated with soil erosion, most of which has occurred since the end of the Second World War so causing crop production to decrease by 17% (Angima et al., 2003).

The processes of erosion, transport, and sedimentation impacts on the construction of dams, urbanization, road networks and other human activities. The main sector which effected by soil erosion is agriculture. The Agricultural sector without soil management activities may have major impacts on the land such as soil degradation and lower fertility leading to increased flow to lake, rivers and groundwater. (Karamage et al., 2017). Much of the soil could be depleted by surface water or wind, such as wind speeds could impact on loose soil from hilly or flat land, and precipitation also effects directly on soil erosion as water flows over the surface (Pal & Chakrabortty, 2019). Some soil erosion Problems include the lack of nutrients in the soil, with reduced crop yields. The soil needs to be protected from erosion in order to maintain human existence (Kouli & Soupios, 2009). Accelerated land degradation is a big concern worldwide, its scale, nature, intensity and complex processes are having important economic and environmental impacts. Numerous human-induced practices, such as mining, building, and farming, damage the surfaces of the soil, contributing to erosion (Panagos et al., 2014). Soil loss from agriculture activities are, therefore higher than that from uncultivated areas (Wagner & Frevert, 1955).

Erosion of soil in northern Iraq by water flow is a major problem. Application of Revised Universal Soil Loss Equation (RUSLE) of water erosion prediction is used to estimate the soil erodibility factor for major soil groups in the region. The RUSLE model provides data analysis that can be checked, validated and replicated by users in the context of producing a soil loss assessment(Pijl et al., 2020). RUSLE computes the average annual erosion expected as; $A = K \times C \times LS \times R \times P$, where A is estimated spatial soil loss, expressed in ton per acre-1 yr-1. R is the rainfall-runoff factor. K is the soil erodibility. L is Slope length. C is the land cover or land use. P is the conservation support practice (Renard et al., 1997). RUSLE is a soil erosion model that calculates the long-term average annual soil loss resulting from the drainage from different field slopes in defined yield and management systems as well as from rangeland (Fagbohun et al., 2016). There are several studies were applied Geographic Information Systems and Remote sensing with RUSLE model to estimate soil losses such as (Al Rammahi & Khassaf, 2018; Alexakis et al., 2013; Angima, Stott, O'Neill, et al., 2003; Ezekiel et al., 2020; Fagbohun et al., 2016; Ghalib & Al-qurnawi, 2016; Hussein et al., 2007; Kouli et al., 2009; Lee & Lee, 2006;

Miheretu & Yimer, 2018; Ostovari et al., 2017; Prasannakumar et al., 2012; Publishing et al., 1997; Rahman et al., 2009; Saha et al., 2018; Yuksel et al., 2008).

Moreover, RUSLE has achieved to be an effective method for expecting spatial distribution of soil erosion by a combination of GIS and RUSLE model (Kouli et al., 2009). In recent decades, major advances have been made in the application of GIS to solve soil conservation problems (Alkharabsheh et al., 2013; Shi et al., 2004; Singh & Panda, 2017). GIS shows a the role in preparing different types of thematic layers and of the soil loss rate estimation(Rahman et al., 2009; Saha et al., 2018). The objective of the study is to use the RUSLE model to estimate soil loss and the pattern associated with water erosion in the Erbil plain basin and using a suitable technique such as GIS and remote sensing to assess factors that impact on the soil erosion.

1.1Study area

The study area is located in the center of the western part of the Erbil province as shown in fig. 1. |The area of the Erbil basin is around 1586.6 Km2. Erbil city is located in the middle south of the study area. Erbil province is located in the northern part of Iraq and Erbil city is the capital of the Iraqi Kurdistan Region. The Erbil watershed is located at latitudes between 36° 15’ 48.44” and 35° 51’ 31.1” and longitudes between 43° 30’ 25.76” and 44° 16’ 38.95”. The climate of the study area is semi-arid conditions in the Erbil Plain zone (Warm Steppe region of climate), and with hot dry summers and cold rainy winter, where the thermal and rainy system belonged to the Mediterranean precipitation system. The yearly average rainfall which starts from October to the end of May, is estimated at about 400 mm(Hameed, 2013).

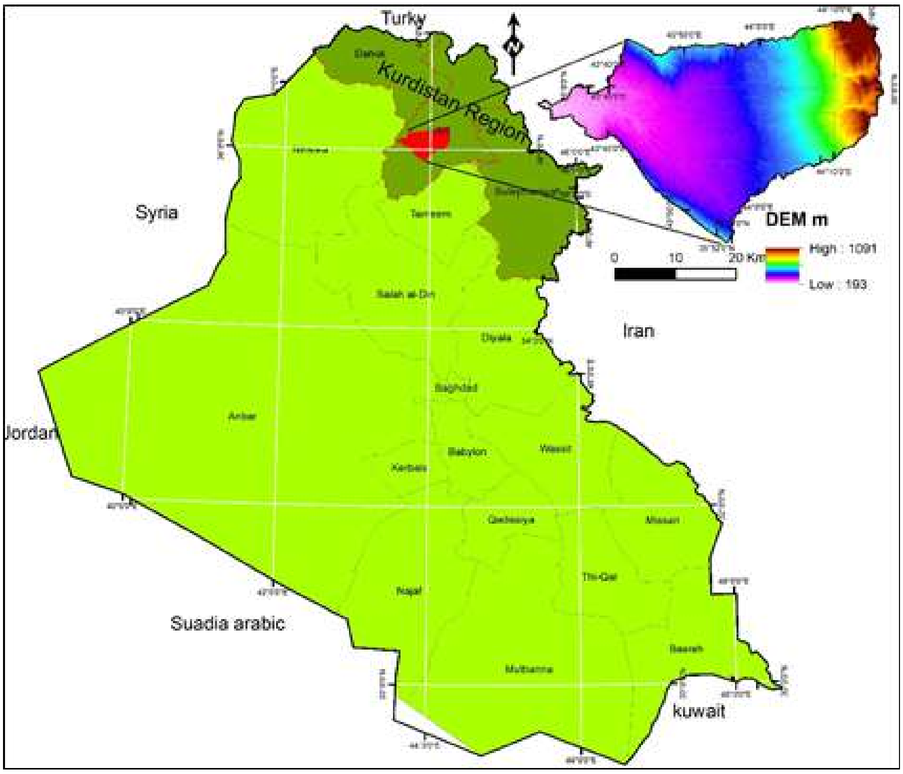

Fig. 1 shows location of the study area

The average annual temperature is around 21 Co. The principal types of soil in the study area are classified into three classes shown in Fig. 2 (a): lithosolic soils in sand stone and gypsum, brown soil medium and shallow phase over Bakhtiari gravel (sand, silt and partly clay) and brown soil deep phase (sand, clay and silt), where area of each class is 83.9, 37.9, 118.8 and 1350.2 Km2 respectively (Hameed, 2017). The principal forms of vegetation comprise dense vegetation, medium vegetation, and low vegetation dependent on the season of rainfall of the study area. (Hameed et al., 2015). The land cover can be extracted from satellite images using remote sensing and GIS techniques to define different categories of land use as shown in figure 2 (b)(Kheir et al., 2008).

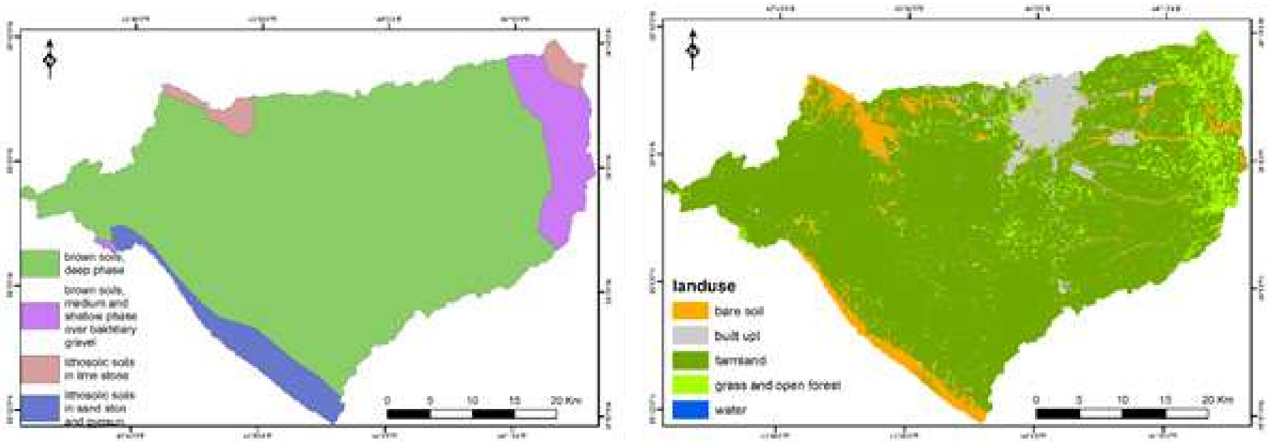

Figure 2 illustrates soil types (a) on the left, and land cover/land use (b) of the study area

The watershed of Erbil was divided into five groups of land use. Throughout the season the distribution of vegetation varies as it contains grasslands, pastures, and shrubs that are primarily based on the volume of precipitation. The built-up area comprises buildings, driveways, pavements, etc. In addition, the majority of the Erbil watershed is covered with agricultural areas. Therefore, Spatial distribution of vegetation changes from season to season in the study area. The agricultural activities in the study area depend on fed-rainfall which leads to an increase the amount of vegetation in the spring season while the quantity of vegetation decline during summer and fall season.

2.Data and Methodology

The overall approach included the RUSLE model used in a Geographic Information System (GIS) environment, with criteria extracted from soil maps, meteorological stations, Digital Elevation Model (DEM) and satellite images. Individual GIS files were compiled in the RUSLE model for each factor and combined with cell-grid procedures in a GIS package. RUSLE model helps to compute an average annual soil loss for a site of interest including management strategies(Millward & Mersey, 1999), and cropping systems. Integrating the RUSLE model to the Geographic Information System and remote sensing environment helps to estimate soil

(HUJ) P-ISSN: 2412-9607, e-ISSN: 2617-3360

loss rate and produce the spatial distribution maps. The grid system is cell-based illustrations of layers that offer analytical capabilities for continuous data processing and permits fast map layer overlay operations (Kouli et al., 2009). Rainfall pattern, soil type, topography, land use/land cover are used as input data in RUSLE model to an estimate the expected average annual erosion by using the following equation(Kayet et al., 2018; Napoli et al., 2016):

$$A = R \times K \times LS \times C \times P \qquad (1)$$

Where, A is the calculated spatial average soil loss per unit area (t ha-1 yr-1).

R is the rainfall-runoff erosivity factor [MJ mm/(ha h year-1)].

K is the soil erodibility factor [t ha h/(ha MJ mm)].

L is the slope length factor.

C is the cover management factor.

P is the conservation support practice factor.

2.1. Data processing and RUSLE criteria extraction

The RUSLE model has been applied to estimate the mean annual depletion of soil loss in a study area(Lin et al., 2020). The RUSLE model does not need very expensive or limited data(Fernández & Vega, 2018). The RUSLE model could be supported by data usually available or could be obtained for free for example, limited rainfall data and satellite imageries with medium or low spatial resolution(Teng et al., 2018; Thomas et al., 2017). The approach of GIS and the RUSLE equation used in this work in a raster layer context in order to extract different parameters and the annual soil erosion of the region being investigated(Phinzi & Silas, 2019). Geo-environmental and topographic parameters that are applied in the RUSLE formula were extracted from the Digital Elevation model and rainfall data collected from the metrological station within and around the study area at the Ministry of Agriculture and Water Resources in Erbil. Satellite image (Landsat 8) in 2019 was downloaded from the United State Geological Survey (USGS). The resolution of the bands as raster layers is 30 m. These data are utilized to explain the land use of the study area and the geo-reference of the satellite imagery band is WGS84 Datum project 38N. The soil map of the Erbil watershed is obtained from the Ministry of Agriculture and Water resources of the Kurdistan Region Government, Iraq. The soil map was created by the FAO coordinate the office in Erbil city in 2001. The Digital Elevation Model (DEM) was downloaded from the United States Geological Survey (USGS) website. The Digital Elevation Model has 30 m resolution, and the coordinate system of data is WGS-84. To create a compatible spatial analytic environment in the GIS and remote sensing package, the pixel size of all generated layers was held in 30m by 30m resolution.

2.2. Rainfall Erosivity (R)

The precipitation is a measure to show the impact of surface water (runoff) movement on the erosion force. This is described as a function of the volume, precipitation duration and intensity that can be calculated from a single storm or several storms to include cumulative erosivity over any period of time(Jazouli et al., 2018). The estimated annual rainfall data from seven rain gauge stations in and around of the study area is used to estimate the rainfall distribution layer of the entire watershed. The average annual rainfall in the study area varied between 208 mm to 400 mm. the Inverse Distance Weighted (IDW) method in IDRISI Selva was applied to estimate the spatial distribution layer of the mean annual rainfall (P) factor in the study area. Fig. 3 shows rainfall station distribution (a) and rainfall erosivity factor (R) as illustrates in Fig.3 (b).. Seven years of rainfall data (2012-2018) were used to generate the Rainfall erosion (R) factor by applying the following relationship developed (Saha et al., 2018)

$$R = 0.363 P + 79 \qquad (2)$$

Where, R is the mean rainfall erosivity factor per year (MJ mm ha-1 h-1).

P is the average annual rainfall (mm).

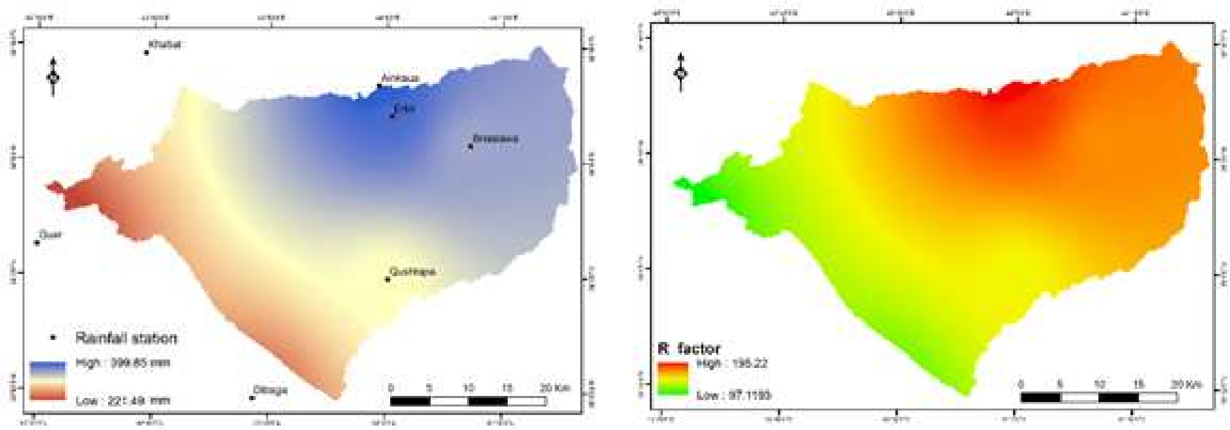

Fig. 3 Mean annual rainfall distribution (mm) station (a) on the left, and R-factor (b)

2.3. Soil erodibility factor (K)

Soil erodibility factor (K) reflects the vulnerability to erosion of the soil or surface material. It describes the average long-term response of the soil and the soil profile to the erosive force of rainfall and runoff(Ostovari et al., 2017). The K factor refers to the combined impact of rainfall, runoff and infiltration on soil depletion,

accounting for the effect of soil resources on soil loss during storm action on upland areas(Prasannakumar et al., 2012).

In this analysis, the soil erodibility factor (K) from the Harmonized World Soil Database (HWSD) was created. The HWSD includes a grid system and shapefile data which related to attribute databases. Each grid pixel in the database of soil layer of the HWSD is connected to soil parameters commonly used such as pH, soil depth, soil cation exchange capacity, water storage capacity, organic carbon, and clay fraction. The HWSD and its geographical layer can be imported directly in GIS and Remote Sensing software as shape-file layer and fig. 4 shows the spatial distribution of soil erodibility factor (K) in the study area.

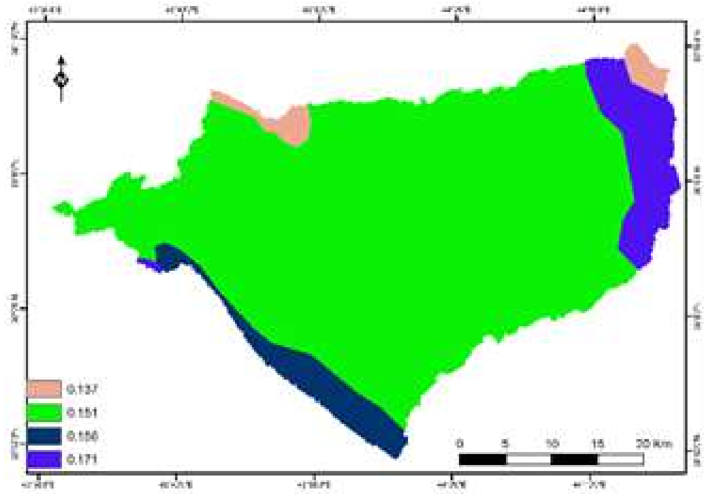

Fig. 4 Spatial distribution of k factor

The compute of soil erodibility factor is made as follows according to William's equation (1995):

$$K_{soil} = f_{csand} \cdot f_{cl\text{-}si} \cdot f_{orgc} \cdot f_{hisand} \qquad (3)$$

$$f_{csand} = (0.2 + 0.3 \cdot exp^{-0.256 \cdot ms(1\text{-}msilt/100)}) \qquad (4)$$

$$f_{cl\text{-}si} = (\,msilt / (mc + msilt))^{0.3} \qquad (5)$$

$$f_{orgc} = (\,1 - 0.25 \cdot orgc + exp^{3.72 - 2.95 \cdot orgc}) \qquad (6)$$

$$f_{hisand} = (1 - \frac{0.7 \cdot \frac{1-ms}{100}}{\frac{1-ms}{100}} + exp^{-5.51+22.9 \cdot (1-\frac{ms}{100})}) \qquad (7)$$

where Ksoil is the erodibility factor, ms is percentage of sand, Msilt is percentage of silt, mc is the percentage of clay and orgc is the percentage of organic matter(chadli, 2016).

2.4. The slope length (LS) factor

The Digital Elevation Model was used to create a topographic factor that includes the slope length factor (L) and the slope steepness factor (S)(Pijl et al., 2020). The topographic factor mainly represents the impact of the surface topography on water erosion. Slope and length are incorporated into the RUSLE component(Oliveira et al., 2013). Slope length (L) and slope steepness (S) have been derived by using DEM with 30m resolution, obtained from the Global Digital Elevation Model of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)(Gulinck et al., 2005). The LS parameter represents the soil loss ratio at a site with normal slope steepness of 9 percent and a length of 22.13m under a defined condition. The higher risk level of soil erosion is located on that area which has a steeper and longer length of slope. To estimate the slope of the study area and generate the slope length factor (LS), the filling of the digital elevation model was initially done in ArcMap software to remove slight sinks in the data. The follow direction was generated from fill DEM using 8D direction, where the flow starts from each pixel to its neighbor lower cell value. The determination of the flow path of the streams system, and then a raster layer of cumulative flow to each cell was calculated helping to find the length slope as shown in equation 8. The second factor used in the equation 8 is the slope in degrees for each cell from Digital Elevation Model (DEM)(chadli, 2016; Hameed et al., 2015). Therefore, the topographic factor is calculated using Equation (8):

$$LS=(\sin slope/0.0896)^{1.3} \times (\text{flow accumulation } \times \frac{\text{Cell size}}{22.13})^{0.4} \quad (8)$$

The cumulative upslope for a given cell was calculated from flow accumulation. LS are the combined slope length and slope steepness factor, cell size is the size of grid cell. sin slope is slope in degree value. Fig. 5 (b) shows LS of the study area(Prasannakumar et al., 2012).

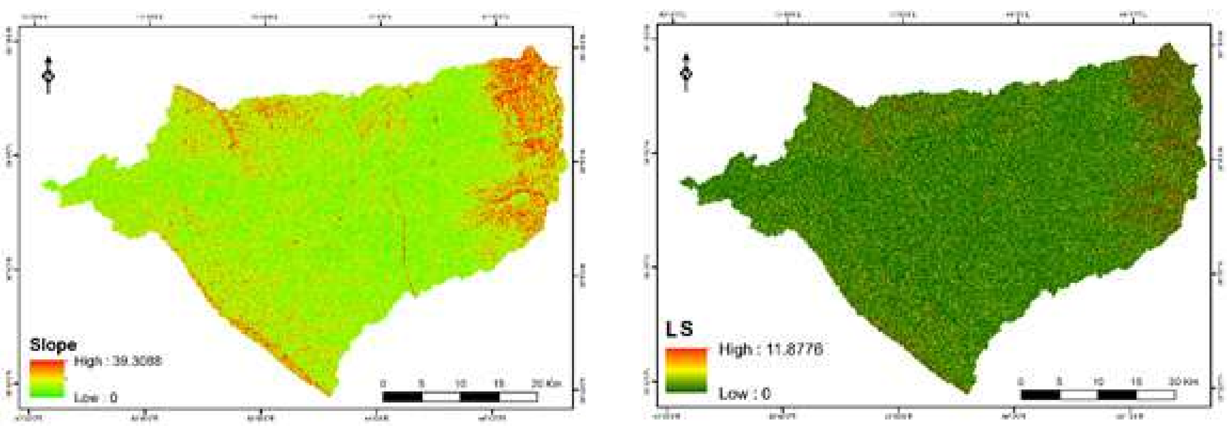

Fig. 5 illustrates the slope (a) on the left, and LS factor of the study area(b)

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2.5. Land cover management factor (C)

The land cover or land use management factor (C), is a significant factor for soil loss decrease and relies on the pattern of the land cover or use in an area. The soil loss decreases when vegetation covers increases. Together with slope steepness and length factors, the land cover or land use factor are most sensitive to soil loss(Kouli et al., 2009). The seasonal changes of C-factor variation relies on numerous parameters, for instance rainfall, agricultural activities, type of land cover/land use, etc. The land cover/land use (C) parameter changes from approximately zero for a well-protected land cover or dense vegetation to around 1 for barren areas. The effect of land cover or land use (C) parameter on soil loss is not as important when the land-cover formation of an area comprises the highest percentage of forest and crops (Ganasri & Ramesh, 2016).

The land cover or land use management factor layer was created with the help of Landsat images which is the primary determinant for assessment of C parameter as shown in fig. 6(b). The difference Vegetation Index was applied to determine the C factor using IDRISI Selva. The atmosphere correction method was applied to correct atmospheric disturbances from satellite imageries and remove an aerosol content from imaged. For calculating the NDVI below equation used;

$$NDVI = (NIR - RED) / (NIR + RED) \qquad (9)$$

After extracting NDVI layer from satellite imagery following equation (Eq. 10) has been applied to create land cove or land use (C) factor layer (Saha et al., 2018);

$$C = 1.20\text{-}1.21 \times NDVI \qquad (10)$$

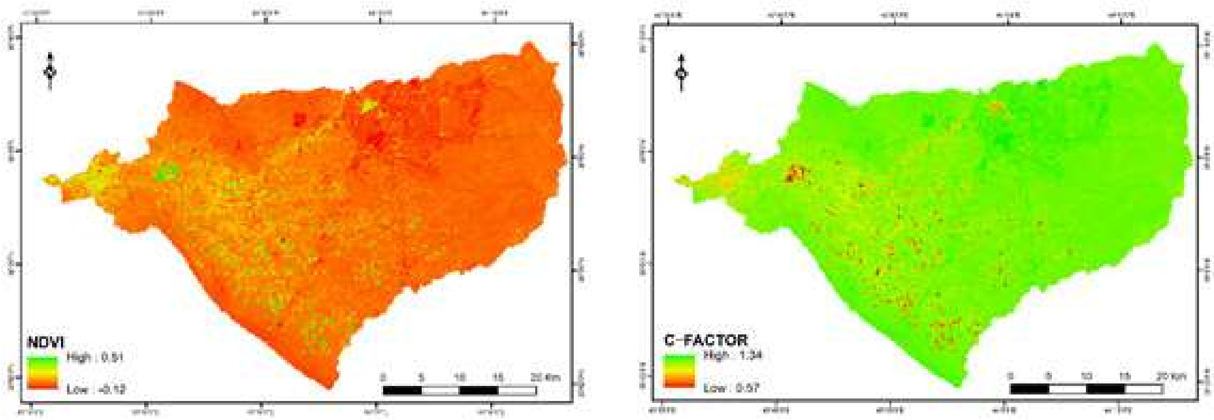

Fig. 6 NDVI of the study area (a) on the left, and C-factor (b)

2.6. Support Practice Factor (P)

The Support Practice Factor shows the rate of soil loss according to the different cultivated land on the earth(Jazouli et al., 2018). Table 1 illustrates the value of support practice factor according to the cultivating methods and slope. P values range from 0 to 1. The value 0 represents a very good man-made erosion resistance facility, while the value 1 no man-mad resistance erosion facility(Alexakis et al., 2013)

Table 1: Support practice factor P (Publishing et al., 1997)

Slope %	Contouring	Strip Cropping	Terracing
0.0 - 7.0	0.55	0.27	0.1
7.0 - 11.3	0.6	0.3	0.12
11.3 – 17.6	0.8	0.4	0.16
17.6 – 26.8	0.9	0.45	0.18
26.8 >	1	0.5	0.20

3. Result and Discussion

3.1. Rainfall erosivity factor

The result of several studies showed that the soil loss rate in the watershed is more responsive to those areas which have more precipitation(Ezekiel et al., 2020). The monthly and annual average rainfall was used as an indicator of variation in the rate of soil erosion. Availability of annual rainfall data has a significant benefit in estimating average annual rainfall and shows the spatial distribution of rainfall depth of the whole study area (Ganasri & Ramesh, 2016). The spatial rainfall depth layer was used for R factor computation and the estimated rainfall erosivity (R) factor which has values ranges started from 97.11 to 195.22 MJ/ mm ha-1 yr-1. The mean of rainfall erosivity of the study area is 156 MJ/ mm ha-1 yr-1 and the standard deviation is 17.4 MJ/ mm ha-1 yr-1. The result of the R parameter indicates that the north and northeast have more values of rainfall while the south and southwest have less rainfall as show in fig. 3 (b). the rainfall erosivity is a significant criterion for estimating soil losses risk under land use and climate change.

3.2. Soil erodibility factor (K)

To generate a map of soil erodibility, K factor values were assigned to the respective soil types in the soil layer. K-factor values are computed to range between 0.138 to 0.171 Mg.h.MJ−1. mm−1. The lower values of K-factor point to the capability of soil such as permeability, soil type, low antecedent moisture content, etc. The soil erodibility factor layer as shown in Fig. 4 was generated from HWSD soil map which relies on different soil textures. Eq. 3 was applied to calculate the Soil erodibility factor (K) depend on properties of data. Fig. 4 shows that 85% of K-factor in the study is 0.151 Mg h MJ−1 mm−1. The average of soil erodibility is 0.153 Mg h MJ−1 mm−1 and the standard deviation is 0.552 Mg h MJ−1 mm−1. The range of K factor shows moderate soil erodibility, therefore moderate or high runoff was produced as a result of a high capability to detachment of the soil particles.

(HUJ) P-ISSN: 2412-9607, e-ISSN: 2617-3360

Topographic factor (LS)

The slope gradient and slope length of the topographic factors have a significant influence on soil erosion(Jazouli et al., 2018). ASTER DEM was used to prepare a slope and flow accumulation grid, a LS-factor map that is shown in Fig. 5 (b) was created. The LS factor values range from 0 to 11.87 but most of the area is within 0 to 1.5 with some high values in hilly areas. The LS-factor values based on the existing C and P-factors, but generally, the steeper slopes have the higher the LS-layer values (Angima, Stott, O'Neill, et al., 2003).

3.3. Land cover C-factor

The cover-management factor C refers to the effect of ground cover and soil disturbance activities on erosion. The C factor is related to both erosivity and erodibility. Plant canopy, for example, decreases the erosivity of soil because of raindrops and surface runoff. The presence of roots and incorporated residue in the soil decreases soil erosion(van der Knijff et al., 2000). Using the satellite images to derive NDVI from Landsat data of Erbil watershed was used as shown in fig. 6 (a). C factor layer was created as shown in Fig. 6 (b). The values of land cover (C) layer varied between 0.57 to 1.37.

3.4. Spatial Distribution of Soil Erosion

RUSLE Eq. ArcGIS package was applied to estimate the annual mean of soil loss using data on rainfall spatial distribution, soil texture, topography parameters, and land cover. In this study, the annual soil loss mean map was extracted for Erbil watershed. Several data sources have been used as input in in RUSLE model which stored as raster layers (30-meter resolution) in the ArcGIS. Average annual soil loss is calculated from the impact of factor Land cover (C), Topographic (LS), Soil erodibility (K), Support Practice (P) and Rainfall erosivity (R) which reflects the geo-environmental scenario of Erbil watershed. The soil loss rate computed for the study area ranges from 0 to 43.43 t h-1 y-1. The result of the study was compared with other studies that applied in areas having similar condition (Angima et al., 2003; Lee et al., 2006). The estimated yearly mean soil loss of the Erbil basin was classified into four categories dependent on the values of soil loss rate per year which are shown the spatial distribution of each class in fig. 7.

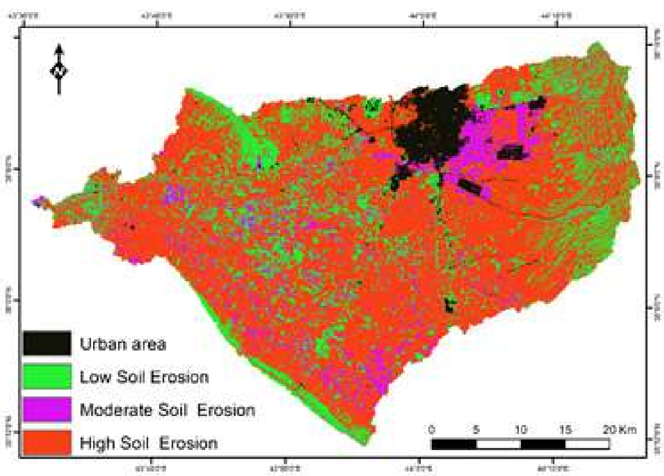

Fig. 7. Shows the estimated average soil loss per year

Table 2 illustrates the soil loss rate classes zone

Soil erosion classes	Rate of soil loss (t h^{-1} y^{-1})	Area ha	Area (%)
No data	0	84.5	5.3
Low	0-1.5	341.4	21.6
Moderate	1.5-5	142.1	9
High	> 5	1016	64.1

Table 2 illustrates the results of soil erosion per year. About 21.6% of the Erbil watershed is shown as low potential soil loss risk which is less than 1.5 t h-1 y-1, while 9% of the study area is moderate soil erosion which represents about 142.1 km2 of the whole area. The rest of the study area classified as a high risk level of soil loss occupies about 64.1% of the whole area of the Erbil watershed. Soil erosion risk levels of moderate (1.5 - 5 t h-1 y-1) and high (5 – 43.56 t h-1 y-1) cover 1158.1 Km2 of the study area and accounted around 1,667,664 tons per year of the total soil loss. The spatial pattern of classified soil erosion risk zones refer to that the area with high erosion risk are distribution in all study area.

The soil erosion risk in the Erbil watershed was overlaid with the soil erosion risk regions in order to evaluate the role of land use on the soil erosion as shown in the table 3.

Table 3. shows land cover or land use types and soil loss

Land cover Low risk km2 Moderate risk km2 High risk km2 High risk %

Land cover	Low risk km^2	Moderate risk km^2	High risk km^2	High risk %
Bare soil	50.9	7.8	43.6	4.3
Farmland	259.2	127.7	921.0	90.7
Grassland	31.3	6.5	51.4	5.1

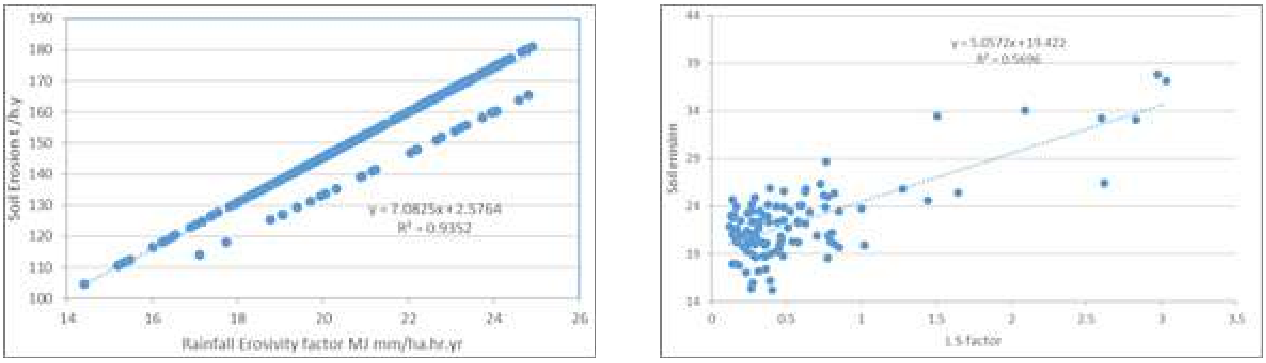

Figure 8. illustrates the regression of soil loss with rainfall erosivity (a) on the left, and Slope length (b).

Soil erosion has a close relationship with land cover or land use. The farmland zones refer to the high level of soil loss risk in the Erbil watershed as shown in the table 3. Approximately 90.7% of high level of soil erosion risk is located on the farmland exclusive of built-up and water areas. The agricultural activities such as tillage, land preparation and ploughing leads to an increase in soil loss as illustrated in table 3. In the fall season, farmers begin to prepare agricultural lands for wheat and barley cultivation which are considered the main crops in the study area; precipitation also starts in October to May, therefore rainfall affects directly on increasing of soil erosion.

Spatial distribution of rainfall erosivity generated from eq. 2 depending on the average annual rainfall of the study shows that the R-factor affects directly the quantity of soil loss. Fig. 8 (a) illustrates the relationship between soil erosion and the R-factor. The R-factor has a coefficient of determination (R2) of 0.93, while the regression between soil erosion and slope factor as shown on the figure 8 (b) explains that the R2 is 0.56. The correlation in this situation turns to topography of the study area, where 57.8% (916.7 Km2) of the slope in the study area is flat to undulating area. The relationship between soil erosion and slope length is 56.9%. The topographic factor of the study area is reflected in the slope steepness and length. Seven slope classes namely; flat (less than 2 degree), undulating (2-5 degree), moderately sloping (5-8 degree), hilly (8-17 degree), moderately steep (17-24 degree), steep (24-33 degree) and very steep (more than 33 degree)(Pamela et al., 2018) as shown in table 4.

Table 4 shows slope steepness classes and average soil erosion

Steepness Categories degree	Topographic Classification	Area Km^2	Area ha	Area %	Average erosion t. ha^{-1} .$year^{-1}$
<2	flat	245.8	24589.4	15.5%	14.1
2 - 5	undulating	670.9	67091.6	42.3%	14.2
5 - 8	Moderately sloping	392.8	39282.3	24.8%	14.2
8 - 17	hilly	251.7	25177.3	15.8%	15.2
17 - 24	moderately steep	19.7	1974.0	1.25%	17.5
24 - 33	steep	2.8	286.2	0.18%	18.1
33 >	very steep	0.08	8.0	0.01%	19.8

Table 4 illustrates the area covered by each class of slope classification. Slope class of undulating (2o -5o) covert major parts of the study area which means that about 42.4% has a slope less than 5o. Moderately sloping area (5o-80) covered approximately 24.8% while flat part (less than 20) and hilly part (8o-17o) occupied about 15.5% and 15.8% respectively of the relief classification of the study area. Moderately steep (17o – 24o), steep (24o – 33o) and very steep (more than 33o) areas are mostly located in the eastern part of the study area (1.4 %). The undulating slope class has the highest soil erosion rate of 962764.4 t year−1 while the moderate sloping are prone to an soil erosion rate of 563701 t year−1. The varying parts of the slope are characterized by different mean of soil loss. The average soil erosion of the flat, undulating and moderately sloping areas is approximately 14 t. ha−1 .year−1, while the average soil erosion of the steep and very steep are 18.1 and 19.8 t. ha−1 .year−1 respectively. This shows that soil erosion average risk areas in the high slope is more than soil erosion average in the gentle and moderate slope zones as shown in figure 8.

4.Conclusion

An estimation of soil loss rate per year for the Erbil watershed is achieved with GIS and remote sensing technology depending on the RUSLE model considering topographic data, rainfall, soil, and land cover. The aim of this study is to quantify and map potential soil erosion in the Erbil watershed. The generation of databases in the traditional ways can waste-time, and is difficult to solve as dealing with large amount of data. Management techniques to decrease soil degradation help to produce different types of layers from various sources and also manage a large amount of data. Therefore, several thematic layers demonstrating different criteria of RUSLE model were created and overlaid in GIS packages to estimate the spatially distributed mean annual soil loss map. The results of the study showed that the area covered low, moderate and high soil erosion. The average annual soil loss estimated for the entire watershed is 14.35 ton ha-1 yr-1. A major part of the study area is under moderate to high soil loss zone. Only 22.8% of the watershed is under low soil loss, while 67.8% of the study area is located at a high level. The study also indicated that agricultural activities with an increase in rainfall lead to more soil loss. Annual soil loss rate has estimated to identify priority zones for the application of soil maintenance and the effective checking of soil erosion.

Recommendation

The majority of the study area have affected by soil erosion as the study has shown, and it is mostly impact by land use change. It is mostly affected by agricultural activities which need to be protected. it is important to put strategic planning in land rehabilitation and expect the potential of erosion risk triggered by land use and apply also more studies in Erbil watershed to classify the soil type and estimate all factors that effect on the soil erosion.

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