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Abstract

Estimate of erosion and sedimentation in the basins without data is difficult such as most of the Iraqi Kurdistan watersheds. In this case using empirical data are needed in order to provide a basis for planning the actual management, also important component in hydrological studies, soil erosion, flood hazard, water supply projects and design of drainage system. Alibag catchment is one of the sub-basins of the Great Zab River, area of 237 square kilometers in the Erbil provinces, Iraqi Kurdistan. However, it has a great importance in terms of agriculture and tourism. So, it's important to estimate the amount of soil erosion. In this study the USLE (Universal Soil Loss Equation) method was used. The different layers of the USLE equation was prepared and processed in Arc GIS. Empirical equations were used for each of the parameters of USLE, by considering characteristics of similar areas. Rainfall and soil data were processed, the slope and vegetation layers were formed using aerial photos and complete with field studies. Soil loss values range between 0 and 16.6 (ton.h-1.y-1). Mean value is 6.05 and the SD (Standard Division) parameter is (0.7 ton.h-1.y-1), respectively.

Keywords

Soil erosion, USLE model, Watershed management, Alibag, Iraqi Kurdistan

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ABSTRACT

Estimate of erosion and sedimentation in the basins without data is difficult such as most of the Iraqi Kurdistan watersheds. In this case using empirical data are needed in order to provide a basis for planning the actual management, also important component in hydrological studies, soil erosion, flood hazard, water supply projects and design of drainage system.

Alibag catchment is one of the sub-basins of the Great Zab River, area of 237 square kilometers in the Erbil provinces, Iraqi Kurdistan. However, it has a great importance in terms of agriculture and tourism. So, it's important to estimate the amount of soil erosion.

In this study the USLE (Universal Soil Loss Equation) method was used. The different layers of the USLE equation was prepared and processed in Arc GIS. Empirical equations were used for each of the parameters of USLE, by considering characteristics of similar areas. Rainfall and soil data were processed, the slope and vegetation layers were formed using aerial photos and complete with field studies. Soil loss values range between 0 and 16.6 (ton.h-1.y-1). Mean value is 6.05 and the SD (Standard Division) parameter is (0.7 ton.h-1.y-1), respectively.

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INTRODUCTION

Soil erosion is a natural process and has occurred throughout geological history, this process include of detachment and transportation of soil materials by water, wind, ice, and gravity. Human activities, particularly agriculture and deforestation, however, have increased erosion rates, as they tend to remove the protective vegetation and reduce the stability of the soil. This human influenced process is termed accelerated erosion. Since 1950 accelerated erosion has resulted in the loss of 1/5 of the topsoil from the world's agricultural land and 1/5 of the topsoil from tropical forests (IFA, 1999).

Accelerated erosion impact soil by reduce the productivity and destruction of soil physicochemical properties. As well as, the accumulation of sediment create several problems for farm lands, pastures, water supply and irrigation canals and may cause pollution by heavy metals and chemical substances. It is evident today than at any other time that the soil erosion and its consequences negatively affect the ecosystem (Lal et al., 1998). Therefore, a reliable estimate of the amount and potential of soil degradation is necessary for two reasons; increase agricultural productivity by conserving and enhancing soil and, increase public awareness about the importance of soil degradation (Lal et al., 1998 & El. Swaify, 1994).

There are several methods for soil erosion estimation, mainly based on mathematical and empirical methods. Empirical models include relationships and equations which have been determined using an analysis of limited data and the regional characteristics. These models are used to estimate some special probabilistic parameters (Khosravi K. et al., 2013).

The simplest mathematical model for prediction of soil loss is the Universal Soil Loss Equation (USLE) and has been frequently used over the world since it was developed by American statistician W. H. Whichmeier in the 1960s (Fistikogli & Harmancioglu 2002, USDA/NSERL 2010). The model is empirical and was developed using over 10,000 statistical records of erosion, sampled over the American Great Plains (FAO 1996). In fact the USLE is the most widely used equation in erosion modeling (Fistikogli & Harmancioglu 2002).

The Universal Soil Loss Equation (USLE) predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning (Stone & Hilborn, 2012).

In fact the USLE is a very powerful tool when integrated with GIS, especially for the conditions in developing countries where lack of data rule out reliable applications of more advanced, physically based models (Beskow et al, 2009). The simplicity of the USLE is most likely the main reason why it is still widely used where data is insufficient. Using remote sensing techniques and geographical information system seems necessary for the analysis and estimation of erosion and deposition, erosion intensity mapping, determine the risk factors and management strategies due to erosion control (Bahrawi et al, 2016).

Soil erosion studies in Iraqi Kurdistan watersheds mainly should be depended on the empirical models because there are no hydrological stations and sufficient data. Although in recent decades the region is facing drought, but no plans have been prepared for watershed management. Alibag basin is important in terms of agriculture and tourism. In addition, Alibag Waterfall is one of the most beautiful waterfalls in Kurdistan region. This study used the USLE method with GIS to estimate of erosion - sedimentation rate and prove its efficiency on an important branch of *Great Zab* basin in Erbil province. The results of this study can be used for similar basins.

METHODOLOGY

Study Area

Alibag catchment is located around 130 km to the north of Erbil, capital of Iraqi Kurdistan and situated between latitudes of northern 36° 24′ 22 to 36° 39′ 15 and longitudes of eastern 44° 21′ 03 to 44° 40′ 00 (Fig. 1). Area of the studied region is 237 km^2 and the highest point is 2490 m and the lowest point has about 525 m height from sea level.

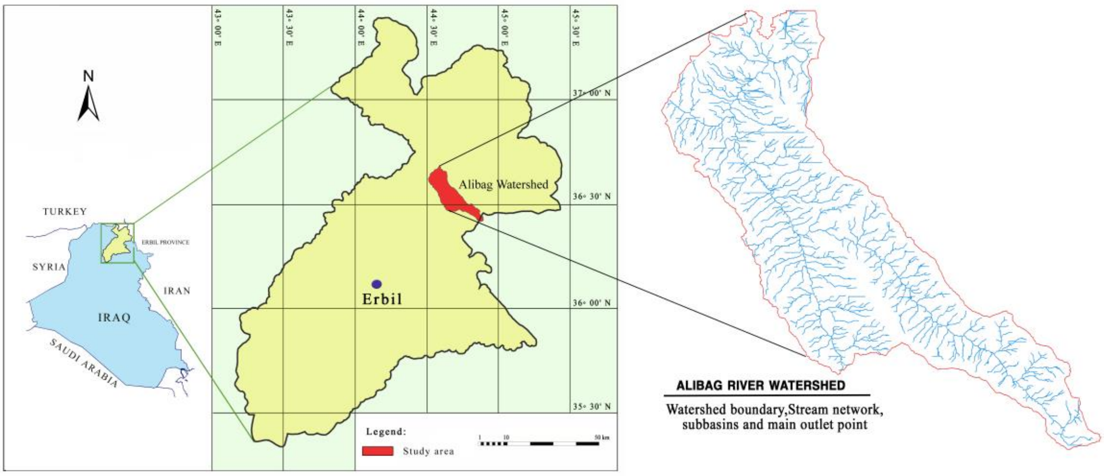

Fig.1. Location and hydrological map for the study area

Over the whole area, the *Zagros Mountain* can be distinguished as a physiographic region. In general the climate of the Erbil province is of Mediterranean type, viz., with rainy cold winters and dry hot summers. There is no rain during July and August (Aziz et al., 2001). Moreover, during March and April rainfall tends to be associated with thunderstorms. The study area fell under semi-wet according to the classification scheme proposed by Lang (Aziz et al., 2001). August is the hottest month; January is the coldest month. The annual rainfall for some stations around the study area is shown in table 1. Also, the iso-rainfall map prepared based on these statistics (Fig. 2).

Table1. Mean annual rainfall at some stations surrounding the study catchment during the period 2003-2015

Station	Geographic parameters			Mean annual rainfall. mm
	Latitude	Longitude	Altitude (amsl)	
Harir	36.5333N	44.3500E	741	538.0
Khalifan	36.6000N	44.4000E	720	661.7
Ranya	36.2500N	44.8833E	882	743.8
Rawanduz	36.6167N	44.5000E	667	666.2
Shaqlawa	36.4000N	44.3167E	975	736.1
Soran	36.6500N	44.5333E	680	610.5

* *Reference: Meteorological services, Ministry of Agriculture and water resources – KRG*

Description of USLE

USLE was present in 1959 by Wischmeier and Smith. Six major factors are used to calculate the soil loss [eq.1]. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location:

$$A=RKLSCP \qquad [1]$$

Where A is annual soil loss (ton/ha/year), R is rainfall and runoff erosivity index (MJ.mm/ha/h/year), K is soil-erodibility factor (ton.ha/MJ/mm), L is length of slope factor, S is degree of slope factor, C is cropping-management factor and, P is conservation practice factor.

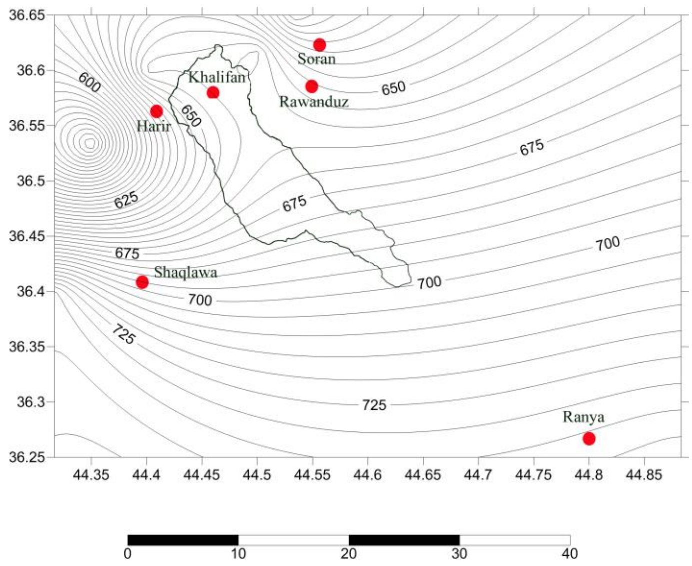

Fig.2 Isohyetal map for the study area

Rainfall erosivity index (R-Factor)

Rainfall erosivity is defined as the aggressiveness of the rain to cause erosion (Lal, 1990). The most common rainfall erosivity index is the R factor of USLE (Wischmeier & Smith, 1965, 1978). The R factor has been shown to be the index most highly correlated to soil loss at many sites throughout the world (Wischmeier, 1959; Stocking & Elwell, 1976; Wischmeier & Smith, 1978; Lo et al, 1985; Renard & Freimund, 1994).

Since pluviograph data are not readily available in many parts of the world, mean annual (Banasik & Gôrski, 1994; Renard & Freimund, 1994; Yu & Rosewell, 1996c) and monthly rainfall amount (Ferro et al., 1991) have often been used to estimate the R factor for the USLE.

In this study (Cooper, 2011), (Renard & Freidmund, 1994) and (Ferrari et al, 2005) method were used to estimate rainfall erosivity indices based on climatological similarity. These researchers have suggested equation [2] for California (Mediterranean climate), [3] for southeastern Australia (Temperate climate) and [4] for Italy (Mediterranean climate), respectively.

$$R = (0.82P^{1.09}) / 0.5876 \qquad [2]$$
$$R = 0.0483\, P^{1.61} \qquad [3]$$
$$R = 4.0412\, P - 965.53 \qquad [4]$$

Where, R is rainfall erosivity index and P is annual rainfall.

Mean annual rainfall for study area applied by above equations and results are shown in table 2. These results correspond with (Van der Poel, 1980) (Table 1, Appendix). In addition, the Iso-erodent map was prepared for the study area (Fig. 3).

Table 2: R-factor calculation by three methods for mentioned stations

Station	Method			Average,
	Cooper	Renard & Freidmund	Ferrari et al - linear	MJ mm ha^{-1} h^{-1} yr^{-1}
Harir	1322.2	1203.7	1208.6	1244.8
Khalifan	1656.7	1679.6	1708.5	1681.6
Ranya	1882.0	2027.6	2040.3	1983.3
Rawanduz	1669.0	1698.1	1726.7	1697.9
Shaqlawa	1860.8	1994.0	2009.2	1954.7
Soran	1517.5	1475.4	1501.6	1498.2

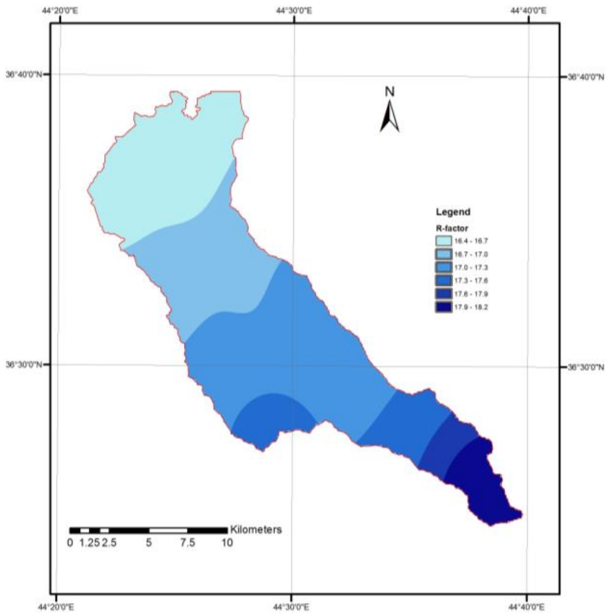

Fig.3: Spatial distribution of R-factor (Iso-erodent) in Alibag watershed

Soil-erodibility factor (K-Factor)

The soil erodibility factor is the average soil loss in tones/hectare/year for a particular soil in cultivated, continuous tilled up and down the slope with an arbitrarily selected slope length of 22.13 m (72.6 ft) and slope steepness of 9%. K is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute (Stone & Hilborn, 2012). These researchers prepare table for this purpose (Table 2, Appendix), and K-factor for Alibag watershed is obtained a map layer that shown in Fig. 4.

The study area is mountainous and mostly consists of cliffs and steep and rocky terrain. The soil in the mountains has been formed from the original rocks and it has a low potential for agriculture, but it is rich in the natural rangeland (Kahraman, 2004). However, the pedons of the mountain region with higher annual rain fall more than 650 mm and lower mean annual temperature 20 C^{o} show a greater degree of soil development in comparison to the pedons of other regions. In this study, field visit and lab analysis showed that soils is shallow to moderate deep, silty to clay with variable gravel and stone content and rock outcrops (Table 3, Appendix).

Slope Length and Slope Steepness (LS)

LS is the slope length-gradient factor. The LS factor represents a ratio of soil loss under given conditions to that at a site with the “standard” slope steepness of 9% and slope length of 22.13 m. The steeper and longer the slope, increase the risk of erosion (Stone & Hilborn, 2012). The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by (Wischmeier and Smith 1978):

$$LS = (L/22.1)^{m}\,(0.065 + 0.045\times S + 0.0065\times S^{2}) \qquad [5]$$

Where L=slope length (m) and S=slope gradient (%) and m, defined previously, is equivalent to 0.5 for s> 5%, 0.4 for 3% < s ≤ 5%, 0.3 for 1% < s ≤ 3%, y 0.2 for s ≤ 1%. Fig. 5 shows the map layer of LS- factor for Alibag watershed.

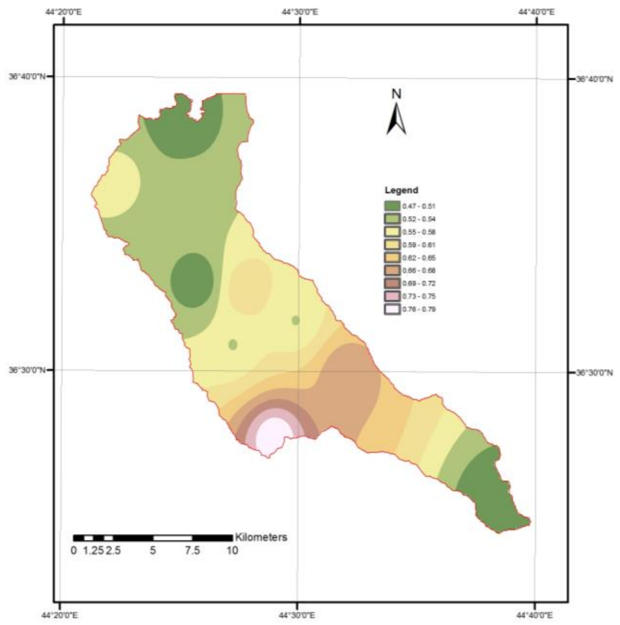

Fig. 4: Spatial distribution of K-factor in Alibag watershed

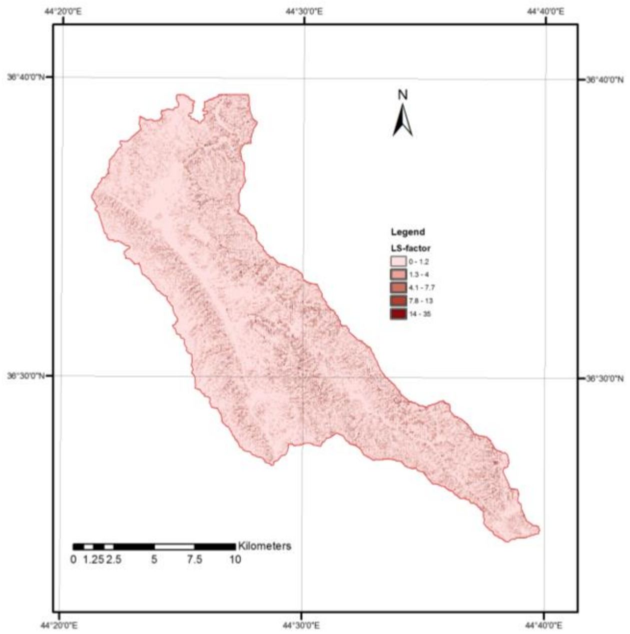

Fig. 5: Spatial distribution of LS-factor in Alibag watershed

Cropping-Management (C-Factor)

The C-factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith, 1978). The dominant vegetation in the Alibag watershed includes oak forest, bare land, farmland and shrubbery. Mountain areas take the very steep slopes and cliffs (Table 4, appendix). Farmland covered by cereals (spring & winter), seasonal horticultural crops, artificial forest and fruit trees. Assessment of the C-factor was made separately for each land unit and the corresponding land cover was obtained from (John & Leonard, 1986), (Hurni, 1983) and (Stone & Hilborn, 2012); the values is variable from 0.03 to 0.30 (Fig. 6).

According to land use classification, the most common land use type and land cover are forest 36%, bare land 22%, farmland 17%, rocky mountain 13%, shrubbery 8% and residential area 1% (Fig. 7 and Table 4 appendix).

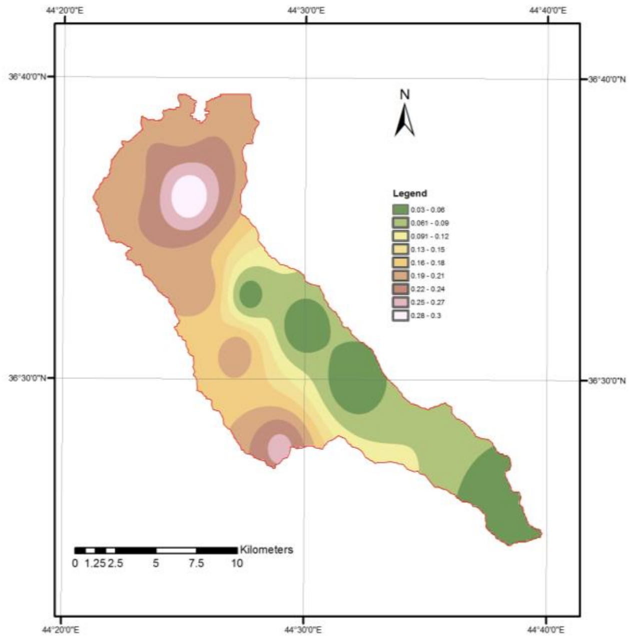

Fig.6: Spatial distribution of C-factor in Alibag watershed

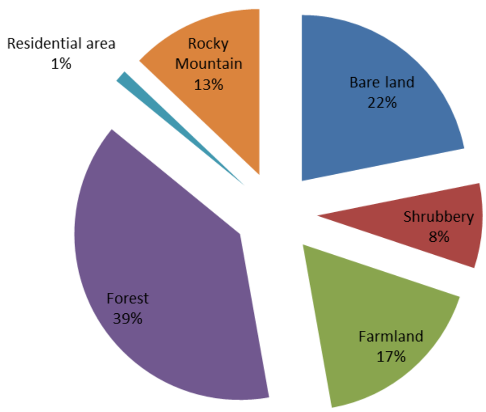

Fig. 7: Land use/land cover of the study area

Conservation Practice (P-Factor)

The P-factor is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope tillage. It reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The most commonly used supporting cropland practices are cross-slope cultivation, contour farming and strip cropping (Malleswara and Singh, 2014).

According to the observations, there are no protective practices in the forest and bare land. On the other hand, the majority of farmlands are located in low slope area, and in the steep areas not be seen any farm management practices. P-factor value for farmland was considered equal to 0.75(depends on slope of cropped lands) and for other units equal to 0.6-1(Fig. 8).

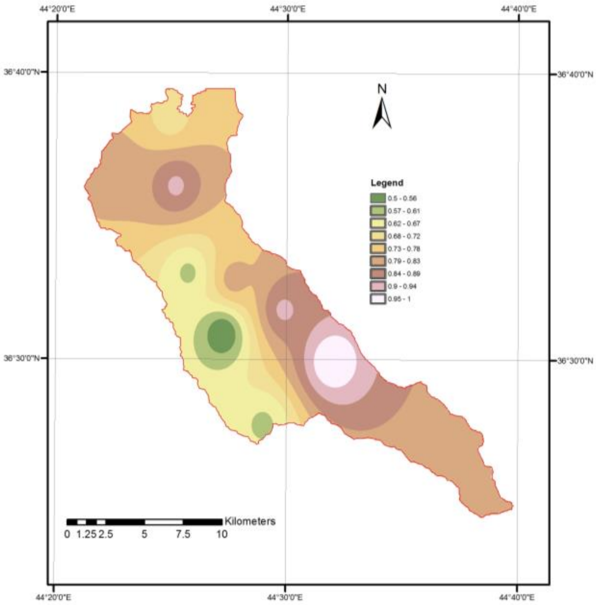

Fig.8: Spatial distribution of P-factor in Alibag watershed

RESULTS AND DISCUSSION

Annual potential of soil loss was estimated by multiplying R, K, LS, C and P factors with use of ArcGIS software environment. The resulting map for the study area is presented in Fig. 9. Soil loss values range between 0 and 16.6 ton.h^{-1}.y^{-1}. Mean value is 6.05 and the SD parameter is 0.7 ton.h^{-1}.y^{-1}, respectively (Fig. 9). The estimated soil loss rate is classified into five categories and is given in Table 3. The map of classified soil-loss shows that 39.6% of the total area falls under the *slight* with tolerable rate of 0-5 ton.h^{-1}.y^{-1}, followed by 42.7% of the total area, comes under *moderate* soil loss with rate of soil erosion 5-10 ton.h-1.y-1. The *high* soil loss occupies 17.7 % of the total area, as it is losing more than 10 ton.h^{-1}.y^{-1}. Other soil loss categories, like *severe* and very s*evere*, were not observed (According to Singh et al, 1992).

Table 3: The estimated soil loss rate classes for Alibag watershed

Potential Soil Loss , ton.h^{-1}.y^{-1}	Percentage of the total area
0-0.4	2
0.5-1	8
1.1-3	20
3.1-7	40
7.1-16.6	30

As seen from the Table 7, most areas of the watershed fall within the minimal and low erosion category which is mostly seen in the middle parts of the watershed. About 17.7% of the watershed is categorized as Moderate erosion risks which are mostly found in south, southeast, east and northeast parts of the region (Fig. 9). The reason for this rate of soil loss is related to its close relationship with the slope length and slope steepness (Fig. 10). In this area, slope change between 40 and 71.94%.

RECOMMENDATIONS

USLE is a field scale model, thus it cannot be directly used to estimate the amount of sediment reaching downstream areas because some portion of the eroded soil may be deposited while traveling to the watershed outlet, or the downstream point of interest. However, The total soil loss for a given area is not the same as the sediment yield measured at a point of interest, such as a watershed outlet (Narasayya K., 2016). It is recommended that some hydrological stations be established on major rivers in Kurdistan region to compare the estimated data with actual data and prepare a plan to deal with the risks of soil erosion.

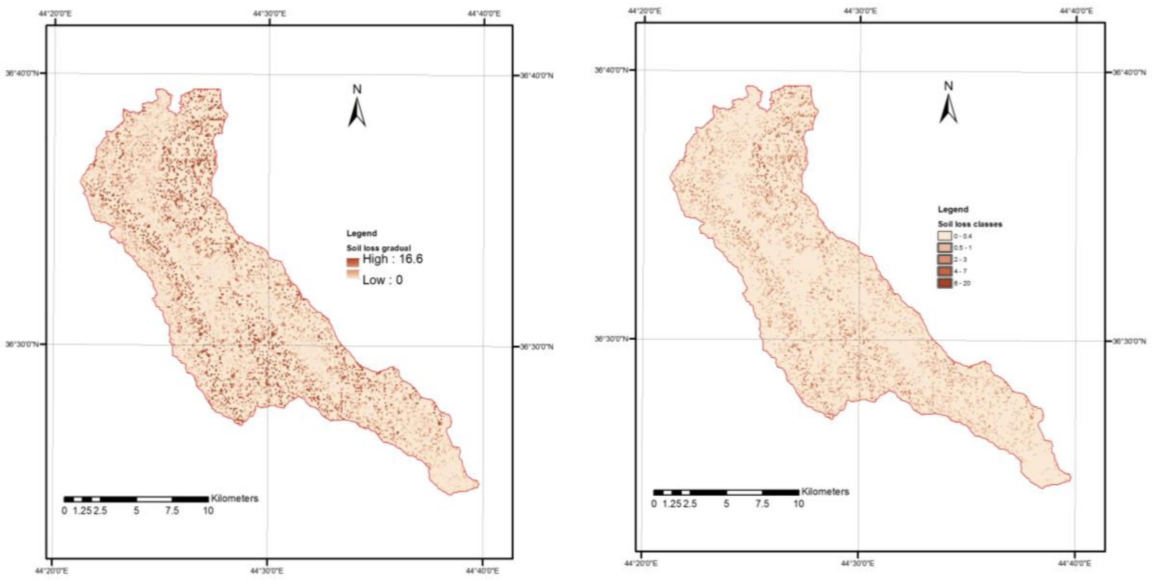

Fig.9: Spatial distribution of soil loss (Left: gradual, Right: classes) for Alibag watershed

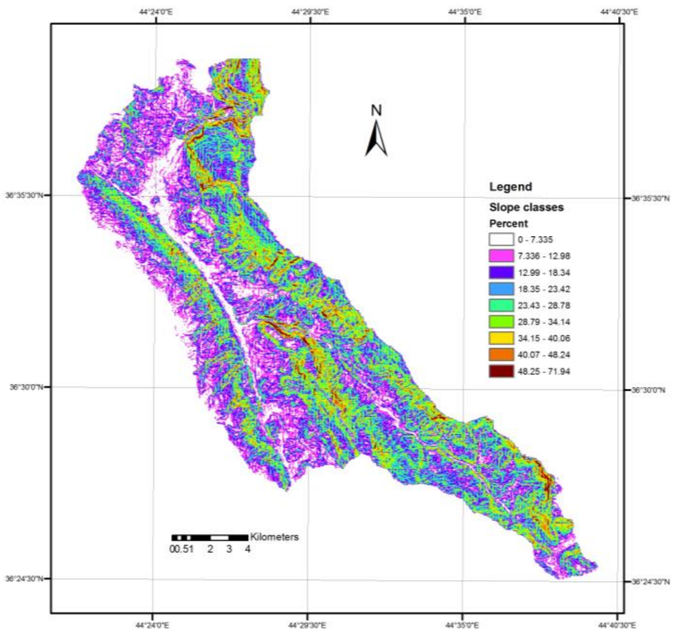

Fig. 10: Spatial distribution of slope classes

GIS and remote sensing techniques can assist in developing management scenarios and provide options to policy makers for handling soil erosion problem in the most efficient manner for prioritization of watershed areas for treatment. So, it is recommended that prepared a comprehensive plan to estimation soil loss amounts for all zones in Iraqi Kurdistan region. Such a plan can be used as a basis for ecological, agricultural, engineering and touristic projects. However, estimated soil loss and sediments must be confirmed by practical tests.

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APPENDIX

Table1. Relation between annual rainfall and mean annual R-valves (Van der Poel, 1980)

Mean annual rainfall, mm	R-factor, MJ.mm/ha/year
300-400	-
400-500	1630
500-600	2000
600-700	2400
700-800	2800

Table 2: Soil Erodibility Factor (after Stewart et al. 1975) [(a)]

Textural Class	OM (%)		
	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fines and	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay	-	0.13-0.2	-

(a) The values shown are estimated averages of broad ranges of specific soil values. When a texture is near the border line of two texture classes, use the average of the two K_{fact} values.

Table 3: Particle size distribution and soil organic matter content for some selected sites within the study catchment

No	Geographic coordinate		Soil particle distribution			Soil Texture class	%OM
	Longitude	Latitude	%Sand	%Clay	%Silt		
1	36.46222222	44.48361111	14.1	37.2	48.7	Silty Clay Loam	1.9
2	36.51500000	44.45416667	26.7	47.9	25.4	Clay	1.7
3	36.55027778	44.42916667	33.0	43.7	23.3	Clay	2.1
4	36.54638889	44.46166667	5.3	45.9	48.8	Silty Clay	1.9
5	36.52888889	44.49805556	25.0	50.0	25.0	Clay	1.4
6	36.42444444	44.64000000	28.8	41.6	29.7	Clay	1.0
7	36.64027778	44.41527778	19.9	47.5	32.6	Clay	1.3
8	36.60088100	44.41976000	15.3	32.5	52.2	Silty Clay Loam	0.9
9	36.60859000	44.37540300	7.1	44.0	48.9	Silty Clay	1.5
10	36.49881400	44.53274800	9.2	45.2	45.6	Clay loam	1.3

Table 4: Location of field studies to land use identification in Alibag watershed

No	Location	Geographic coordinate		Dominant land use
		Longitude	Latitude	
1	Khalifan	44.400495	36.603108	Farmland, artificial forest
2	Alana	44.431419	36.550104	Farmland, fruit trees
3	Tutmarah	44.400495	36.603108	Bare land, farmland
4	Binawi	44.479883	36.488551	Bare land, farmland
5	Kani Watman	44.374127	36.610722	Bare land, shrubbery
6	Sereshma	44.408249	36.644285	Farmland, shrubbery
7	Alibag waterfall	44.446072	36.631564	Steep slopes, cliffs
8	Malakan	44.591497	36.459667	Partly farmland, cliffs

Table 5: Soil erosion rate classes (*Singh et al, 1992*)

Soil Erosion Class	**Potential Soil Loss tones/hectare/year**
Slight	0-5
Moderate	5 – 10
High	10 – 20
Very High	20 – 40
Severe	40 – 80
Very Severe	> 80

پوختە

خەملاندن بۆ بڕی ڕامالینی خاك و نیشوو لەو ئاوزێلانەی كە زانیارییان لەبەردەستدا نیە، كارێكی ئەستەمە وەك ئەوەی لە زۆربەی ئاوزیلەكانی هەرێمی كوردستاندا دەبینرێت. لەم دۆخەدا پەنا دەبرێتە بەر بەكارهێنانی ڕێبازی ئەزموونی بە مەبەستی ئامادەكردنی بناغەیەك بۆ پلاندان و بەرێوەبردن. ئەم خەملاندنە گرنگە و بەكاردێت لە بوارەكانی توێژینەوەی هایدرۆلۆجی، ڕامالینی خاك، پێشبینی مەترسی لافاو، پرۆژەی دابینكردنی ئاو و دارشتنی سیستەمی ئاوەرۆ و ڕەواندن.

ئاوزێلی عەلیبەگ یەكێكە لە ژێرحەوزەكانی ڕووباری زێی گەورە، ڕووبەری 237 كیلۆمەتری چوارگۆشەیە و دەكەوێتە پارێزگای هەولێر لە هەرێمی كوردستان. ئەم ناوچەیە بایەخدارە لە ڕووی كشتوكاڵ و گەشتوگوزار. بەم هۆیە گرنگە ئاستی ڕامالینی خاك بخەملێنرێت.

لەم توێژینەوەیەدا مودیلی USLE (هاوكێشەی جیهانی ڕامالینی خاك) بەكارهات. چینە جیاجیاكانی هاوكێشەكە ئامادە و پرۆسێس كران لە پرۆگرامی Arc GISدا. چەندین هاوكێشەی ئەزموونی بەكارهات بۆ هەر كام لە پارامەترەكانی USLE بە ڕەچاوگرتنی تایبەتمەندی ناوچەی هاوشێوە: زانیاری لەسەر باران و خاك پرۆسێس كران. بە هەمان شێوە، چینەكانی لاری زەوی و ڕووپۆشی ڕووەك بە پێی وێنەی ئاسمانی ئامادەكران و بە سەردانی مەیدانی تەواوكاریان بۆ ئەنجام درا. لە ئەنجامدا دەركەوت كە بڕی ڕامالینی خاك لە نێوان 0 بۆ 16.6 تەن/هێكتار/ساڵ دایە. نرخی تێكرا 6.05 و لادانی ستاندەرد (Standard Division) یەكسان بە 0.7 تەن/هێكتار/ساڵ.