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Preparing the Map of Erosion Hazard and Sedimentation in Dez Watershed by Remote Sensing and GIS

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Abstract

Regarding the importance of water sources in Iran, it is necessary to protect better water bodies such as reservoirs. The most efficient way of conserving water sources is to apply proper management to decrease erosion and sedimentation. The first step of this process is to be aware of sediment yield and identify erosion hazard areas in upper reach of reservoirs. The present study is the preparation of a map of erosion hazard and sedimentation in Dez watershed (area: 17320 km^2) which is to be applied in the rehabilitation project of Dez dam. The inaccessible location and the fact that covers a wide area have made the use of satellite images inevitable. In this study, after examining several erosion and sedimentation modeling methods, the PSIAC - with 9 effective parameters - was selected; it is an empirical model in itself. In order to prepare the first series of data, IRS satellite data, Landsat ETM+, basic maps, the Arial photos, helicopter flights and also field checks were all applied. A calibration model with the data achieved from reservoir studies, and taking account of local characteristics of the area, prepared the opportunity to identify and classify erosive zones with GIS. The results which are presented as maps and erosion statistics, not only identify hazardous erosive areas, but also open a new horizon in the field of watershed management and sediment control by having a special outlook towards executive priorities.

Keywords: Erosion, Sedimentation, Remote Sensing, GIS, Dez Dam

تهیه نقشه خطر فرسایش و تولید رسوب حوضه آبخیز سد دز با استفاده از سنجش از دور و GIS

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چکیده

با توجه به اهمیت منابع آبی در کشور ایران، نیاز است تا از بدنه‌های آب شیرین همچون سدها محافظت بیشتری گردد. یکی از مهمترین روشهای حفظ این منابع آبی، انجام مدیریت صحیح در جهت کاهش فرسایش و تولید رسوب می باشد که لازمه آن آگاهی از مقدار رسوب زایی و نواحی دارای بحران فرسایشی در حوزه های بالادست سدها است. از اینرو مطالعه حاضر، تهیه نقشه بهنگام فرسایش و رسوب در حوزه آبخیز سد دز با مساحت تقریبی ۱۷۳۲۰ کیلومتر مربع جهت علاج بخشی سد دز و درک درست از مدیریت فرسایش این نواحی را مد نظر قرار داده است. وسعت قابل توجه حوزه آبخیز موردنظر و عدم امکان انجام عملیات میدانی گسترده بدلیل ویژگیهای طبیعی و صعب العبور بودن منطقه، موجب گردید تا استفاده از تصاویر ماهواره ای و سیستم اطلاعات جغرافیایی در تلفیق با عملیات میدانی محدود مورد توجه قرار گیرد. در این مطالعه با بررسی روشهای مختلف مدلسازی فرسایش و رسوب، مدل تجربی PSIAC با ۹ پارامتر مؤثر انتخاب گردید. به منظور تأمین اطلاعات ورودی موردنیاز مدل، از داده های ماهواره ای IRS و Landsat-ETM+ ، نقشه های پایه موجود، عکسهای هوایی، بازدید هلیکوپتری و نیز عملیات زمینی بهره گرفته شد. کالیبراسیون مدل با داده های حاصل از بررسی مخزن سد و لحاظ کردن ویژگیهای بومی منطقه مورد مطالعه این امکان را فراهم آورد تا با بهره گیری از GIS و تلفیق لایه های اطلاعاتی مختلف، شناسایی و طبقه بندی مناطق فرسایشی میسر گردد. نتایج حاصله در قالب نقشه ها و آمار فرسایش، ضمن شناسایی کلاسهای فرسایشی و معرفی مناطق حاد فرسایشی، راهگشای مدیریت حوضه آبخیز و کنترل رسوب با نگرش ویژه بر اولویتهای اجرایی می باشد.

کلمات کلیدی: فرسایش، رسوب، سنجش از دور، GIS، سد دز.

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Introduction

Overuse of the natural resources causes deforestation and consequently leads to erosion, desert spread, muddy water, and limited water resources and the importance of water resources has been demonstrated in Iran since many years ago. Therefore, protecting and conserving water resources is inevitable and conducting research on erosion and sedimentation - which are two major factors in decreasing the useful capacity of reservoirs - are among the basic solutions. Such studies have been undertaken in different parts of the world for many years. Although, Iran has an old history in dam-building, the above mentioned studies have been neglected here.

In order to compensate for this problem, some rehabilitation plans have been suggested. In such plans for dams, different strategies can be applied. One is the study of erosion and sedimentation and classifying erosive regions. The goals of this study can be set out as follows.

1) Preparing sediment yield map of Dez watershed as well as an erosion hazard map, which is the primary objective.
2) Classifying erosive regions and prioritizing these regions according to the erosion intensity and sedimentation.
3) Studying general solutions to control erosion and sedimentation in hyper eroded areas and offering general suggestions to decrease erosion throughout watershed.

Use of the new science of RS and GIS to reduce the time, expense and risks of field checks is inevitable. Hence, the goals of the current study were achieved by applying the above mentioned techniques and frequent evaluations.

Literature Review

Although the history of studies about erosion and sedimentation dates back to many years ago internationally, the first comprehensive report on soil erosion and then the importance of water and soil protection was only published in Iran in 1948 by FAO experts and, in 1950, some parts of the Karaj dam watershed in Sirachal zone were studied by Iranian experts associated with FAO.

In 1961, the bureau of water and soil protection was established within the Soils Institute and five water and soil protection stations were then established in Eastern Azarbayjan (Tokmeh Dash), Western Azarbayjan (Heydar lou), Gilan (Queen), Kordestan (Karheh), Chaharmahal-O-Bakhtiari (Doto), which had as their most important goal to study humidity saving in non-irrigated lands.

Later, in 1972, the Office of Soil Protection and Watershed Management was established and gradually the executive activities were carried out in this area. By 1985 master plans had been prepared for more than eleven million hectares of watershed.

Study of erosion and sedimentation in the Dez dam watershed

Due to the importance of the Dez dam in Khuzestan and also in Iran, several studies in the upper reaches of the Dez dam have been carried out. In some of these studies, small parts of this watershed were studied locally. However in some other studies, the region was spread up to the watershed which was examined regionally. The two most important of these studies are:

- The study of erodibility and sedimentation of Dez dam watershed by the DRC in 1973.
- The study of erodibility and sedimentation of Sezar watershed in 1996 by Iranian experts.

The location of Dez watershed

The geographical position of Dez watershed is 48^0 10' - 50^0 21' eastern longitude and 32^0 36' - 34^0 07' northern latitude. The total area of the watershed is about 17320 Km^2. The watershed is spread over the six provinces of Khuzestan, Isfahan, Chaharmahal-O-Bakhtiari, Markazi, Hamedan and Lorestan (Figure1). Table1 presents the part of above mentioned provinces involved in watershed.

Table 1- The area of different provinces that compose Dez dam watershed

province	area in watershed	area in comparison with whole watershed
Khuzestan	2305	13.30%
Isfahan	1864	10.76%
Markazi	1259	7.27%
Hamedan	14	0.08%
Chaharmahal-o-Bakhtiari	735	4.24%
Lorestan	11143	64.35%
Whole watershed	17320	100%

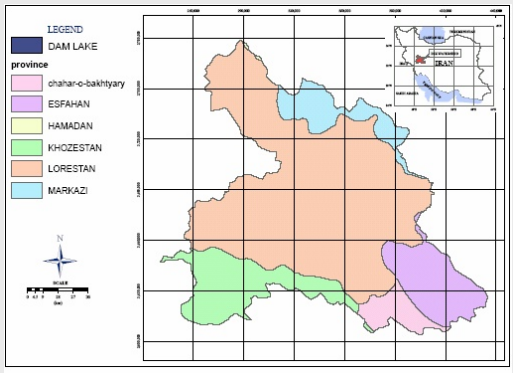

Figure1- The location of different provinces which compose Dez dam watershed

Methodology

The use of GIS and RS was necessary to decrease time, expense and also risk. Figures 2 and 3 present the steps of the study and each of them is explained more fully in the following sections.

Finding Current Methods to Evaluate Erosion

(a) Universal Soil Loss Equation (USLE)

In North America, sediment yield estimates are frequently derived from the Universal Soil Loss Equation (USLE) which provides erosion volumes and these are then transformed to sediment yields by applying a Sediment Delivery Ratio (SDR). However, this approach is only valid on gently sloping cropped areas such as the mid-western plains of the United States and it is not applicable to mountainous regions such as the Zagros Mountain range.

The MUSLE and RUSLE models are basic improvements on USLE. They provide the value of soil erosion, needs to be corrected by applying the Sediment Delivery Ratio (SDR). Therefore models based on USLE may not be appropriate for Dez watershed.

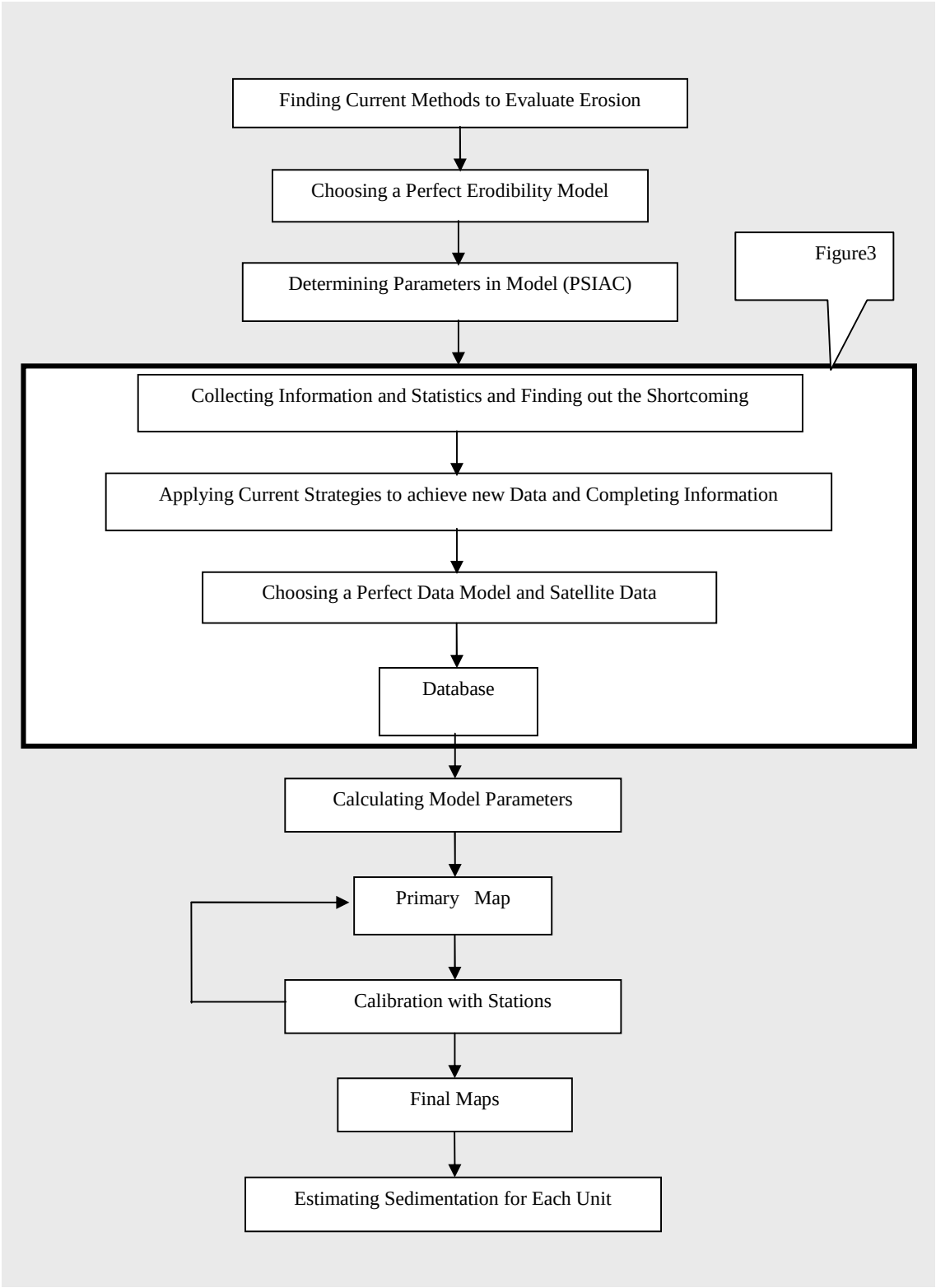

Figure 2- Flowchart for doing project

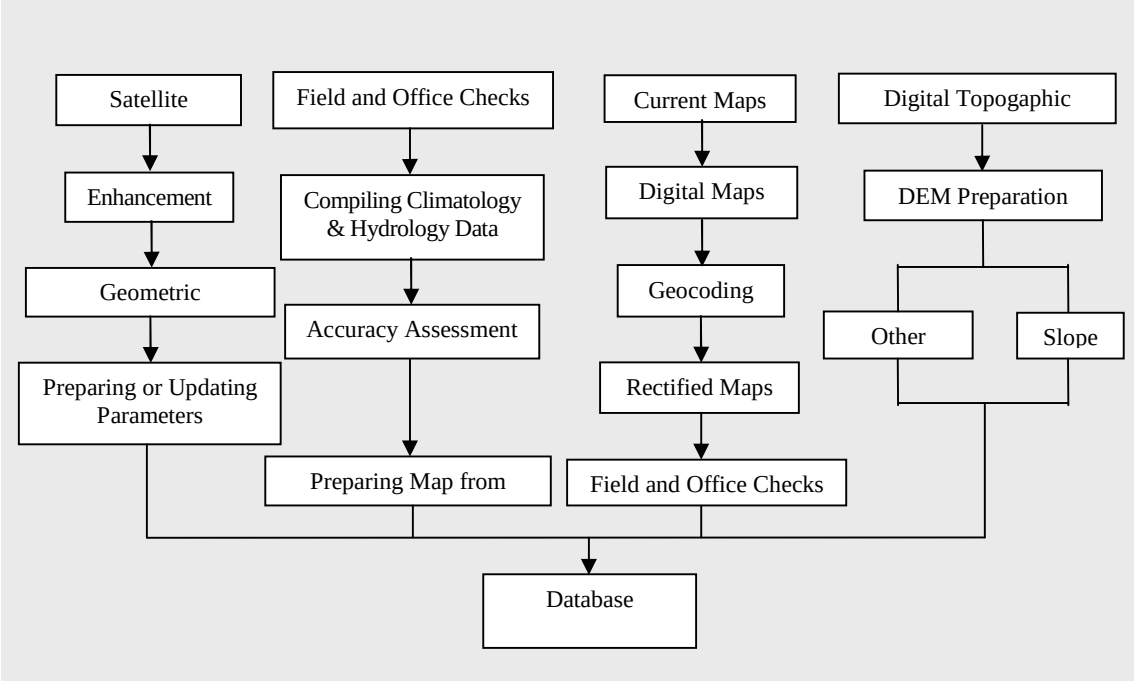

Figure 3- Flowchart for establishing database

(b) Numerical Modeling of Erosion Processes

The U.S. Army Corps of Engineers in Document # 36 (1995) reviewed the following current numerical models:

A) SP: Simplified Process Model; Hartley (1987)
B) AGNPS: Agricultural Non- Point- Source Model; Young *et al.* (1987)
C) Runoff: Runoff Simulation Model; Borah (1989)
D) WEPP: Water Erosion Prediction Project; ScS (1995)
E) KINEROS: Kinematic Runoff and Erosion Model; Woolhiser, *et al.* (1989)
F) KYERMO: Kentucky Erosion Model; Herschi (1988)

One of the conclusions achieved by the US Army corps was that applying physically based models on large watersheds is not a common practice. Basically, the models were developed for watersheds smaller than 50km^2 and some of the sub-watersheds. The Dez watershed would be larger than this value. Also there are inadequate data to utilize the above models. Hence, numerical modeling techniques are not recommended.

(c) PSIAC Model

The PSIAC Model (Pacific Southwest Inter-Agency Committee, 1968) was developed to allow the estimation of sediment yield for a large variety of factors within a watershed. For the first time, it was applied on a watershed named Walnut Gulch located in south east of Arizona. Later, in 1982, Johnson and Gembhart converted the descriptive concepts of first model into numerical amount, in 1991 each of the parameters were presented mathematically.

In the PSIAC Model nine factors were recommended for erodibility and annual sediment as follows: (1) geology; (2) soils; (3) climate; (4) runoff; (5) topography; (6) ground cover; (7) land use; (8) upland erosion; and (9) channel erosion

Each of these factors is to be ranked based on a visual appraisal of the watershed. In the old PSIAC Model, the range of total ranking values was set down as -20 to +130 but in the revised PSIAC it's 0 to 150 and the ranking produced the following five classes of sediment yield. (Table 2)

Table 2- Erosion description value and sediment in PSIAC technique

class	Sediment yield description	Ranking value	Middle Range sediment yield $M^3/ km^2/ Yr$
5	Very high	100-150	3000
4	High	75-100	800
3	Moderately high	50-75	300
2	Moderate	25-50	150
1	Low	0-25	80

Choosing a Perfect Erodibility Model for the Dez Watershed

The PSIAC Model for determining watershed sediment yield was developed in 1968 and was subsequently upgraded in 1991. This method was selected for the study due to the following reasons:

- PSIAC was applied by Development and Resources Corporation (DRC) in 1973 to estimate erosion of Dez watershed and to design treatments for rehabilitation.
- PSIAC is one of the most highly recommended models in the US.
- This Model has a reliable accuracy and it has been applied in some watersheds such as: Khaharan, Kahibar, Zayandeh Rud, Maroon, Halil Rud, Dez, Saravan, Zir Dan and Ozan Darreh.
- The PSIAC is currently applied in order to estimate soil erosion and sediment yield in master plans.
- In comparison to other experimental models, the PSIAC uses the most effective factor of soil erosion in computing specific erosion and sediment yield.

Determining Parameters under the PSIAC Model

As mentioned before, 9 parameters are included according to PSIAC in erodibility estimates. Then, by applying a special ratio, erosion is estimated which provides a basis for sediment estimating. Therefore, it is worthwhile to discuss the significance and the division of the parameters. The first division should include watershed parameters related to geographic features, namely: X_1= geology; X2=soils; X_5= topography; X9= land use; X6= ground cover.

The aforementioned parameters are natural parameters related to the geographical features. These parameters respond to other parameters, such as X_3= climate (rainfall), which causes erosion and the development of gullies and rivers. The response of the geographic parameters to the rainfall is represented by the following parameters: X_4= run off; X8= up land gulling; X_9= sediment transport in the stream channel.

The outcome of rainfall and climate parameters is river runoff and suspended load measured at gauging stations. These output data are then transformed to produce specific sediment yield maps. In PSIAC, X_8 and X_9 are the most effective parameters which totally carry about 1.2 to 1.3 of total ranking.

In PSIAC, the most important parameters are X_8 and X_9 which together can form one third to one-half of the total parameter areas together.

It should be noted that the response parameters X_8, X_9 and X4 should be applied on the sub-watershed boundaries. That means each sub-watershed should have a value for each of the three parameters.

Results

PSIAC parameters in Dez watershed

(a) Surface Geology (X_1)

Knowing the surface geology features of a watershed is important for estimating erosion and sediment yield. Soft stones are eroded easily and play an important role in sedimentation. Erosion in stone surfaces is influenced by two basic elements:

- dynamic elements such as climate, geographical conditions and topographic situation
- static elements which are dependent on the lithology of the region

Both physical and physiographical factors interfere in environmental governing systems (Figure4). Therefore these parameters must be considered as important - rock destruction, transportation of rock fragments, and sedimentation.

In addition to topographic situation and geographical elements, the effects of atmospheric processes are also important. For example, changes in temperature cause a high degree of erosion in stones. In this model, dependency of stone resistance toward erosion, different degrees are used. In the revised PSIAC the following formula is applied: $Y_{1=} X_1$ where Y_1 is surface geology and X_1 is the surface geology erosion indicator which is determined on the basis of stone type hardness and fracture.

The results of studying geology features on 31 sub-basins and a classified geology map were prepared according to PSIAC. (Figure 5)

Figure 4- The effects of geological factors on the shapes of river flows

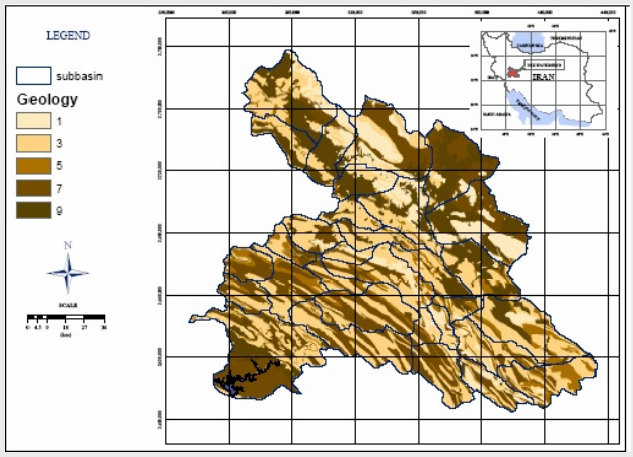

Figure 5-Classified geology map

(b) Soils (X_2)

During a certain amount of rainfall, some soils are eroded more than others due to their different origins. Therefore, the aforementioned phenomenon, also known as soil erosion, depends on soil features.

In PSIAC, a range of 0 to 10 is selected for soil factors. This range is based on soil texture, the resistance of particles, lime stone, clay disperse and primary humidity of soil; normally, this range is determined by soil texture. Many researchers, like Mayer, depict that all particles of soil don't react similarly against detachability. Actually this phenomenon depends on clay proportion, silt and sand. The studies of Quansah shows that soil detachability increases when fine sand increases.

Generally speaking; in fine texture soil, more volume of rainfall flows as runoff rather than in medium texture soil. This also increases erosion and sedimentation. Hence, the range will be near to 10. The formula is: X_2= 16.67k; where X_2 is the soil factor and K is soil erodibility.

In the universal erosion equation, K is determined by find sand plus silt, sand percentage, organic material percentage, soil structure and soil permeability.

The following is a soil study procedure in the study area. Its inaccessible location made it almost impossible to carry out an appropriate field check. For this reason, the soil map is not to a desirable scale. It was done by calculating 3 factors as primary and 5 factors as complementary. Since there wasn't an appropriate soil map, sampling was needed in order to calculate K.

Every academic land study needs benchmarks and so soil sampling in Dez watershed also needed an appropriate standard. One of them was the Mahler standard which is expected to complete information on the Dez watershed. Meanwhile during the studies, sampling could not be carried out according to above standard. Regarding the Mahler standard and scale of the studies, the number of samplings required would be very many and so it was impossible to apply this standard due to time and expense.

Because of the problems mentioned above, a soil map was prepared as follows. First, the area was divided into homogeneous parts according to elevation, slope, slope trend, vegetation cover percentage, its reflection in satellite images and also pervious studies. Next, the dispersion of sampling points was determined in order to estimate K. After field checks and laboratory experiments, the results were entered on a graph in order to determine soil erodibility and K. Then, according to the satellite image and the experiences of experts, the data gathered at one point was extended to the area. Eventually, a soil erodibility map with the X_2 parameter was prepared (Figure 6).

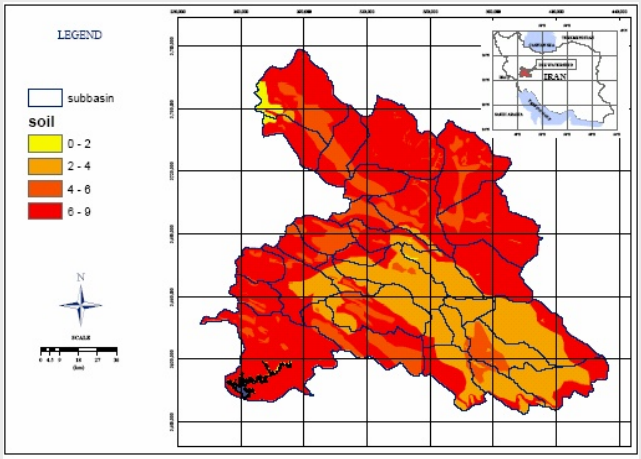

Figure 6- Soil erodibility map

(c) Climate (X_3)

Erosion and sedimentation are, to a great extent, are dependent on climate since climate not only effects soil but also vegetation cover. Among other effective elements on erosion intensity, are precipitation and temperature. Precipitation and especially intensive rainfall are even more effective; rainfall has an effective on both runoff and erosion. Snowfall has a minor role unless it melts, in which case it leads to runoff. Temperature is important when the difference between night and day is great.

For determining the climate factor in revised PSIAC, the following formula is used: $X_3 = 0.2\ P_2$, where X_3 is the climate factor and P_2 is 6 hours rainfall intensity with a returning period of 2 years in mm. This task was done as follows. First the maximum 24 hours rainfall was calculated and compared with 6 hours rainfall; then, the maximum rainfall over 24 hours at Brujerd fixed gauging station (the nearest rain gauging station to the East of the area) was applied to the maximum 24 hours rainfall of three other rain gauging stations (all of them had a 2 years returning period). The maximum rainfall intensity for Kamandan, Cham Zaman and KazemAbad was calculated. Eventually, in order to determine the covering area, the Theissen Method was employed. After calculating 6 hours' rainfall, Theissen polygons were applied in PSIAC. The result is presented in Figure 7.

(d) Runoff (X_4)

The runoff of a watershed presents the efficiency of an irrigation system which is the result of irrigation system operation on the erosion on areas with good precipitation (in PSIAC, the runoff range varies between "0 to 10": zero is for watersheds with high permeability and very low runoff and 10 is for a watershed that converts most part of precipitation in to runoff). In revised PSIAC the following formula is used to determine runoff:

$$X_4 = 0.2(0.03R + 50QP) = 0.006R + 10QP$$

Where X_4 is runoff in PSIAC, R is annual runoff elevation (mm) and QP is specific peak discharge measured as cubic meters per square kilometer.

It is worthwhile mentioning that the specific discharge of each hydrologic unit is calculated by dividing the flood peak discharge by its area. As mentioned before, in order to determine the effect of runoff in erosion, the hydrologic features of area, such as runoff and flood specific discharge with frequent returning period must be studied. The hydrologic studies of the area were carried out completely and the results are presented.

In order to estimate the maximum level of discharge and runoff in each sub-basin, the information and statistics were studied. In this comparison, the following items were included: maximum monthly discharge, maximum daily

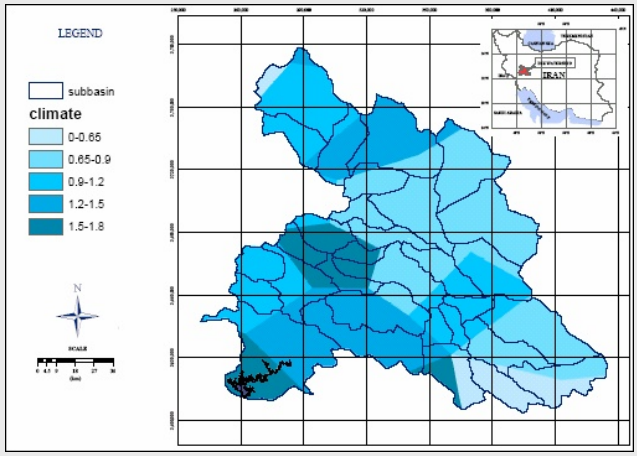

Figure 7-Climate map

discharge, maximum moment discharge and flood hydrograph. Figure 8 shows the results of data revised PSIAC and evaluating X_4 in Dez watershed.

(e) Topography (X_5)

One of the important factors in erosion is topography which is normally estimated by slope. This occurs because of acceleration in rain drops.

The importance of slope and topography in erosion has a range of 0 to 20 in the PSIAC model. Zero is for low slope areas, alluvial lands, mountainous slopes (parts with slope of 3%) and so is for mountainous area with a steep slope (more than 30%).

In the revised PSIAC the following formula is used to determine topography: X_5= 0.33 S where X_5 is sedimentation degree and S is the percentage of average slope. In this study, in order to extract the slope, topographic maps were first digitized and were then put in database; after that, the lines were converted into Digital Elevation Maps (DEM) by interpolation in GIS Environment. The next step was to extract an average slope map in a software environment with slope order. Eventually, X_5 was achieved. Figure 5 shows the results of applying data to the revised PSIAC and evaluating X_4 in Dez watershed.

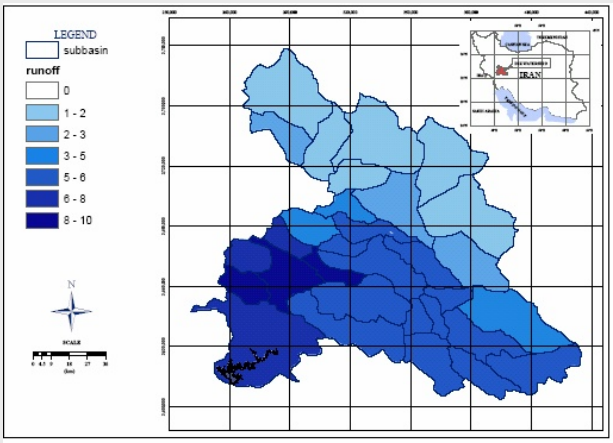

Figure 8- Runoff map

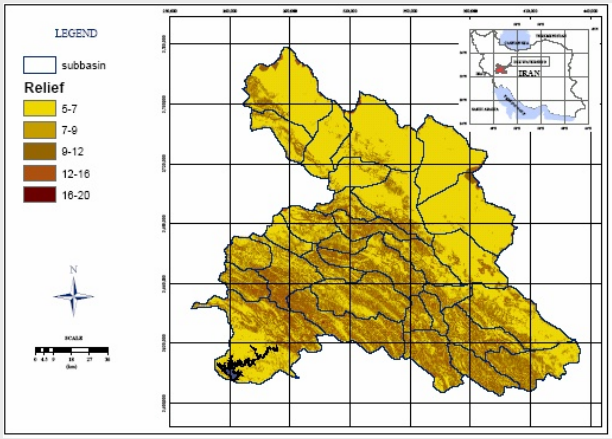

Figure 9- Relief map

(f) Ground Cover (X_6)

Ground cover means every type of land cover that protects soil against erosion factors, such as rain drop hits, runoff and wind. Some effective land covers are vegetation, litter and rocky outcrops. Any of the above mentioned effective land covers could have a positive effect. In the revised PSIAC, a range of 0 to 20 was devoted to this factor and the following formula in used to determine ground cover: X_6= 0.2 pd where X_6 is ground cover factor and P_b is percentage of bare land.

In this study, P_b was estimated accordingly. Since collecting information about ground cover with common ways is too difficult and costly, this task has been carried out with satellite images. To this purpose, two image lands blend and produce a new combined index called the "vegetation index". The purpose of this index is to evaluate certain vegetation features, such as canopy cover, biomass, and vegetation percentage.

According to references, more than 90% of multi spectrum information is presented just with two spectral bands. Normally, vegetation reflex in spectrum area visible light (43- 66 micrometer) is low and in the area of near infrared can help to separate vegetation cover, soil surface and water. To this purpose, the NDVI index is a common index for studying density and canopy cover. This index is calculated in following formula:

$$\text{NDVI} = \frac{NIR - R}{NIR + R}$$

NDVI varies between -1 and +1; first the positive amount of water and bare soil is determined then, by increasing vegetation cover density, its trend tends to be positive.

In this report, the NDVI vegetation index was extracted by using ETM+ images of Land sat 7 and LISSIII image of IRS-1D. By using this index bare land percentage and canopy cover were determined through the following formula: V= 93.07466 (NDVI) +8.79875

In this ratio, V is canopy cover percentage. Since, canopy cover percentage and bare land percentage have an opposite relationship, (1 – V) presents bare land percentage in every area regarding to vegetation cover, its density, ground cover and natural features. Some percentage must be deducted as litter, leaves, branches canopy cover, and rocky outcrops.

After several studies with field checks and photos, eventually the following formula was achieved: P_b = 1- [(93.07466 (NDVI) + 8.79815) + 5]

P_b - bare land percentage - was applied in the revised PSIAC and its result is presented in Figure 10. It is worth mentioning that, in the present study, the ground cover range is 9 - 19.

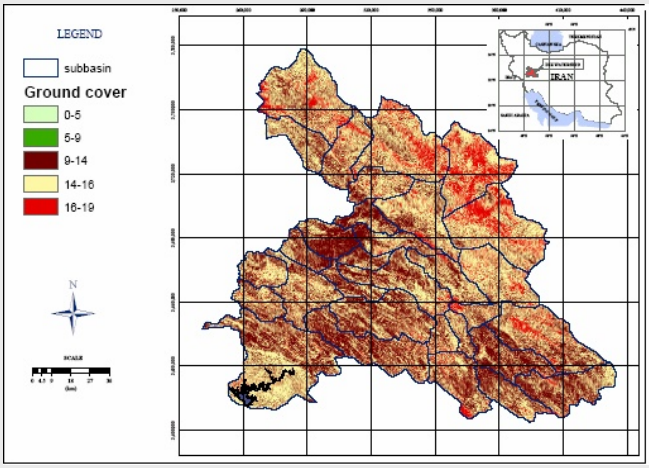

Figure 10-Ground cover map

(g) Land Use (X_7)

Human activities or land use is also a factor is increasing erosion, whereby inappropriate land use causes erosion. Among common activities that erode land are: tillage, over-grazing by animals, and other inappropriate land uses. Over-grazing can be considered as the most destructive factor. In this study, regarding to the importance of canopy cover in the revised PSIAC, the quantity of which was estimated in the previous part by satellite images and field checks, V presents PC. Figure 11 clearly shows land use score in Dez watershed.

(h) Upland Erosion (X_8)

In order to study the role of upland erosion in sedimentation, several other kinds of erosion are to be studied such as rainfall erosion, sheet erosion, rill erosion and gully erosion (except erosion of channels). The following formula is used in the revised PSIAC to determine upland erosion:

X_8= 0.25 SSF

X_8= the value of current erosion position

SSF = Soil Surface Factor (which is determined by the BLM method).

The following steps were followed to determine X8.

a) Achieving primary knowledge by satellite images and studying and identifying homogeneous units.

b) Preparing forms for field checks according to BLM

c) Conducting field checks during several steps through several helicopter flights and field controls.

d) Presenting the results of sampling as points and calculating the parameters of BLM table for points and calibrating primary value for the areas.

e) Expanding the point sampling in order to cover the whole area for calculating the parameters.

Figure 12 shows the recommended areas for field control and helicopter flight in order to determine the first and last amounts of SSF and SSFG in Dez watershed. These points were identified after field checks using satellite images (Figure 13) and other helping layers in GIS environment. Then, the weight average of points was applied in order to calibrate the first group of areas. By digital comparison (cross tab operation) the two maps were analyzed and, in this way, the amount for each equal and even unit in the BLM table was extracted.

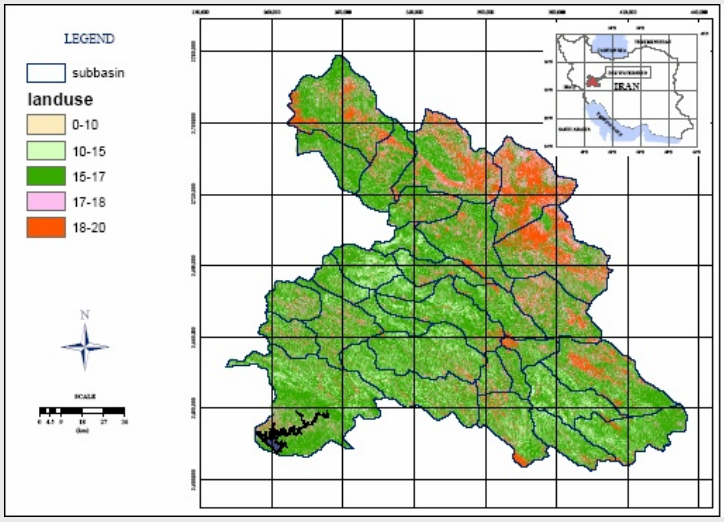

Figure 11- Land use map

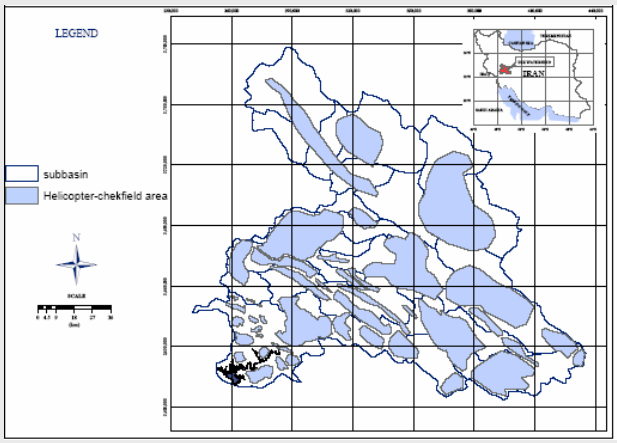

Figure 12- Helicopter routes and areas were checked

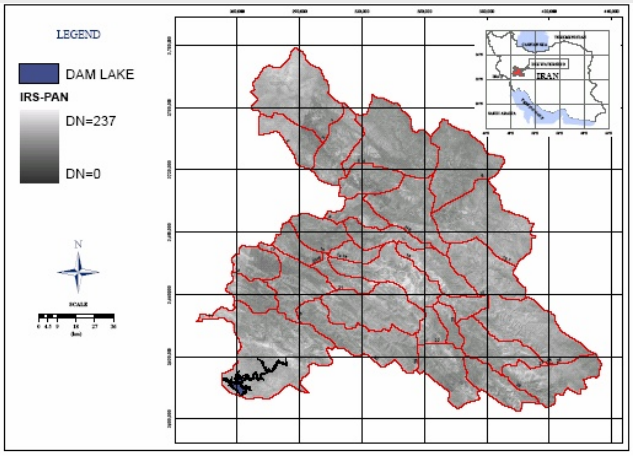

Figure 13 - IRS-PAN image

It is also worth mentioning that the areas presented in Figure 14 are designed in such a way to cover all 31 sub-basins or major parts of them.

After calculating the parameters, values of the BLM table, SSF and SSFG were determined and applied in new equations of PSIAC.

(i) Channel (River) Erosion and Sediment Transport (X_9)

The last effective factor in soil erosion and sedimentation is channel erosion and sedimentation. In this factor, both river-bank erosion and sediment transport by flood are important. This erosion is caused by the abrasion of channel walls and mostly occurs in times of flood and full-water seasons.

This happens due to an increase in destructive force and deposition (**Figures 15, 16**). It is worthwhile to note that, in determining SSF, X_8 is considered as a parameter of the BLM table. In the revised PSIAC, the following formula is used: $X_9 = 1.67$ SS.F.G, where X_9 is the river erosion parameter and SS.F.G is Gully erosion value according to BLM.

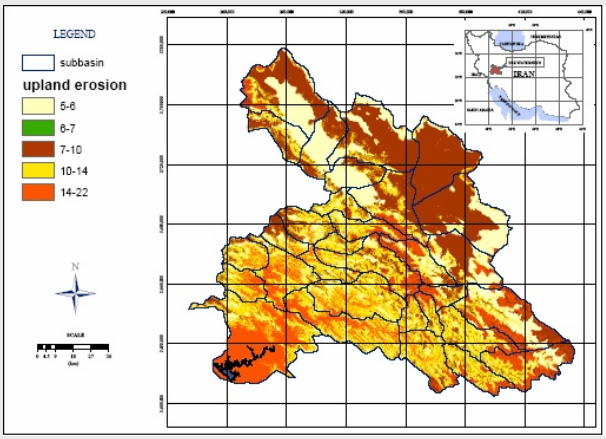

Figure 14 - Upland erosion map

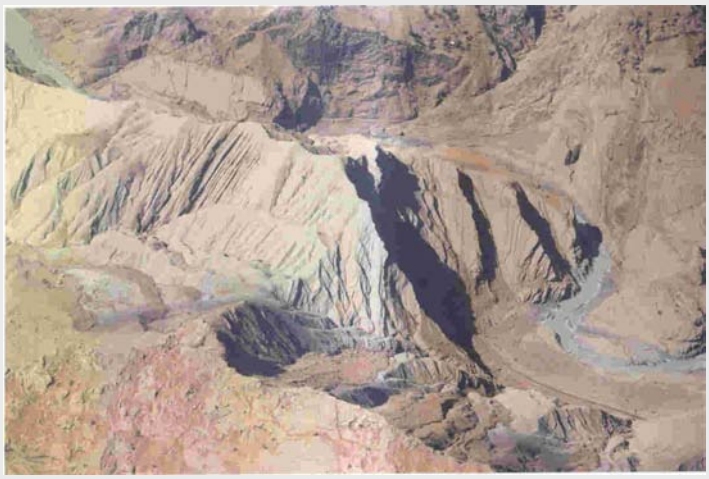

Figure 15- Sample of channel erosion on the entrance of Dez reservoir

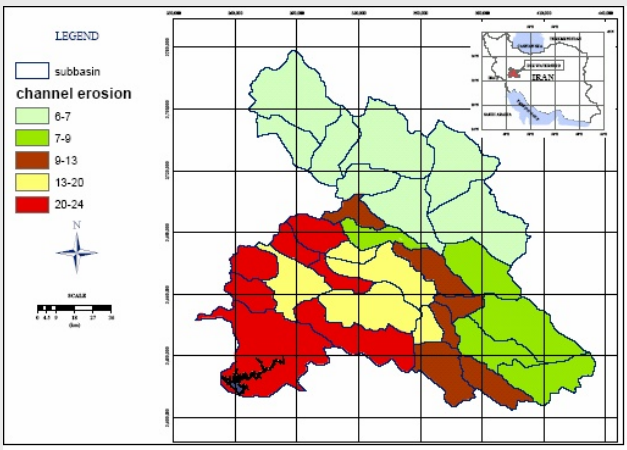

Figure 16- Channel erosion map

Estimating sediment load by PSIAC method

In order to estimate sediment load according to PSIAC, the following formula is used: $QS= 38.77\ e^{0.0353R}$.

In above ratio, R is the total score gained by a summation of all nine parameters and QS is the annual sedimentation in cubic meters per square kilometer.

In Figure 17, the total score gained by summation all nine parameters in Dez watershed. R_{max} was about 123 m^3 in a 24*24 m^2 cell. As the legend of the map shows, yellow and red parts have a degree of higher erosion than the other parts.

According to this fact, about 35% of Dez watershed is grouped among high degree eroded and sedimentation areas at about 17267245 cubic meters per year. This estimate has been calibrated as follows.

Calibrating as QS and the Final Map

In order to calibrate the number obtained, the following procedure was carried out. The number was divided by 15.3 cubic million meters, the deposition number achieved by the reservoir studies. By estimating the balance coefficient which was about (15.3/17.267245) 0.88607 cubic meter, the total sedimentation of Dez watershed was calculated to be 15776904 cubic meters per year. The balance coefficient was applied on primary raster map in a GIS environment, and its result was the final sediment map provided by PSIAC. Then this map was classified (according to Table3). Figure 17 shows the combination of 9 parameters of PSIAC models (R) in Dez watershed.

The analysis stage of this project was based on 24*24 square meter cells and the sediment map is designed on the basis of it. So, understanding the total sedimentation of sub-basins and their specific sedimentation is difficult for users. To solve this problem, the sub-basins were selected as the basis of the present tables. It should also be mentioned that, in order to understand the results easily, the area according to sedimentation has been classified based on Table3 which also has been presented in Figure 18.

The area of each sub-basin plays an important role in sedimentation so that sometimes it causes mistakes in understanding sedimentation in different parts of the watershed. As an example if the amount of sedimentation in one area is certain, the sedimentation of greater area is more than the smaller areas. But specific sedimentation which can be a basis for comparing sedimentation in sub-basins is greater in smaller areas.

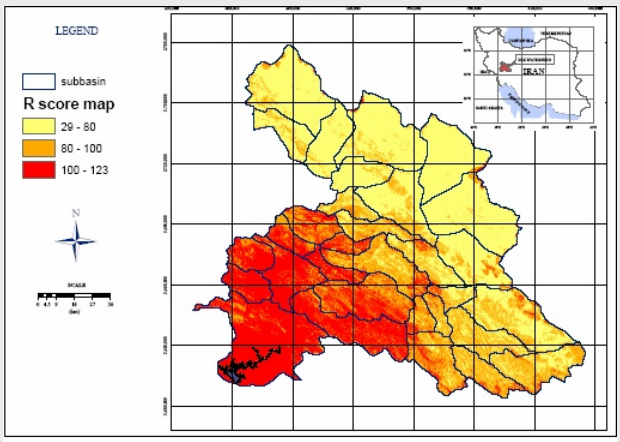

Figure 17- R score map

Table 3- Sediment Class (Refahi, 1996)

Sediment Class	Intensity of sedimentation	Sedimentation		Score of intensity sedimentation
		M^3/km^2	$Acer/mil^2$	
V	Very high	> 1429	> 3	> 100
IV	High	476-1429	1-3	75-100
III	Average	238-476	0.5-1	50-75
II	Low	95-238	0.2-0.5	25-50
I	Very low or little	< 95	< 0.2	0-25

With regard to previous explanations, in this study the specific sediment map of Dez watershed has been prepared based on the sub-basins, as shown in Figure 19.

Hence, based on the texts explained above and in order to avoid making mistakes, the specific sediment map (scale 1:250,000) was delivered to the user as an updated erosion and sedimentation map (Figure 19).

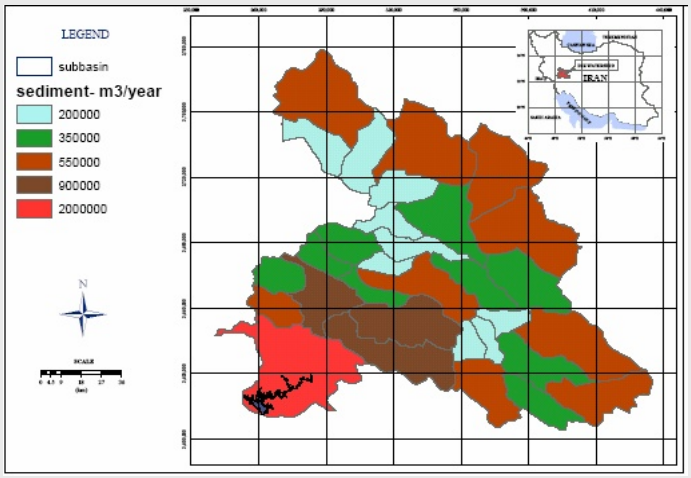

Figure 18- Sediment map

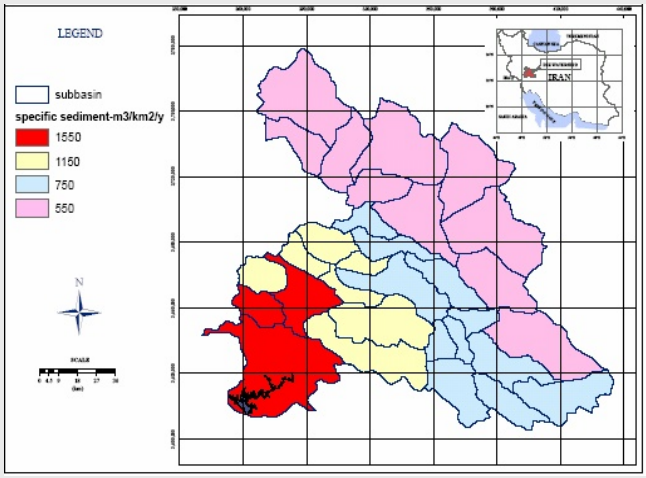

Figure 19- Specific sediment map

Conclusion

1. According to the study and Table 3, the study area can be categorized in three erosive zones - low to mild, high, and very high.

2. The Southwest of the watershed (near the dam) is extremely eroded because of its geology and soil erodibility; the northern parts are weakly eroded and the interior parts are mildly eroded.

3. Applying PSIAC, X8 (erosion) and X9 (channel erosion) according to their score in the PSIAC model are the most important factors which totally cover $^1/_2$ to $^1/_3$of all scores.

4. By using satellite images of and carrying out helicopter flights over the study area, it was discovered that just 20% of the study area is suitable for a rehabilitation project.

5. The common approach to limiting erosion is 'grazing' control.

6. According to studies, it can be concluded that terracing is the most effective factor and check dams don't play any major role in decreasing the sedimentation due to the steep slope of rivers.

7. Satellite images play an effective and important role in preparing information; such as a land use map, studying the types of the erosion in the area, bare and uncovered lands.

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