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Research Article

An Investigation Survey on MPSIAC Model to Predict Sediment Yield in Iran

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Abstract: Lack of information to prepare erosion maps for quantitative and qualitative sediment evaluation is a major need in watershed management. MPSIAC (Modified Pacific South West International Agency Committee) Model is apparently known as an appropriate method to measure sediment yield of watersheds in Iran. In this study the results obtained from the research on Ivanaki's watershed and sixteen different research projects, which conducted by others, were selected and analyzed. The purposes of this study were to compare works done in the country and show the limitation of the model, usage of it in different conditions and possibility of calculating errors if the input data were not gathered carefully. A sensitivity analysis was conducted to find the sensitive parameters in different watersheds. A database for the model was prepared from six watersheds using Geographic Information System (GIS). By evaluation of nine main factors it was cleared that Land Use, Upland Erosion and Ground Cover were the most sensitive factors respectively and the Climate and Runoff factors were the least, while observation of Runoff and sediment yield did not show this matter. According to the results, each factor which had more input quantity had the highest sensitivity. Finally, the research indicated that the usage of MPSIAC model for watersheds with sediments more than 2.2 ton/ha/yr must not be used, since the model is so sensitive in this status and possible errors may get over 50%.

Keywords: MPSIAC Model, prediction, sediment, sensitivity analysis, watershed

INTRODUCTION

Soil erosion is one of the most prominent environment problems that should be taken under consideration. Every year million tons of sediments deposit in the rivers, lakes, reservoirs and dams that will be accumulated and human spend heavy cost for dredging them (Goldman *et al*., 1986). The frequent flooding causes of destruction of farmlands, roads and contaminates the drinking water.

MPSIAC (Modified Pacific South West International Agency Committee) Model is apparently known as an appropriate method to measure sediment yield of watersheds in Iran. Iranian consulting engineering services and researches normally use this model to predict the sediment yield on infrastructure projects and their research (Rangzan *et al*., 2008; Parsaee, 2005; Hashemi, 2002).

The model is one of the applicable experimental models which require a broad range of parameters. This model has indicated that important errors have occurred in the conducted researches and their results seemed to be invalid. For instance, utilizing the PSIAC model, but estimating the input parameters from MPSIAC formulas, resulted to a mistake causing two times bigger rate of sedimentation. Evaluation of references indicated that: firstly, there were great mistakes in their results owning to misusing of the model and they must be reviewed. Secondly, none of them applied sensitivity analysis to consider the potential of influence of the parameters. Thirdly, the calibration of this model has not been done yet and without calibration, using a model to estimate sedimentation of an area is irrational. Sensitivity analysis of a model is a technique which is implemented to evaluate and calibrate a model. This technique can be used to evaluate the effectiveness of model and real condition of the input data. If the variation of the input data has a minor effect on output data, it could be concluded that these errors affected the results slightly and thus errors derived from laboratory and field measurements of the parameter could be omitted. In contrast, if they have great effect on output data, the parameter must be measured again more preciously. In addition, there should be given a priority to more sensitive parameters while planning and investing for a watershed to reduce soil erosion. This may result in more reduction of erosion by fewer changes in parameters.

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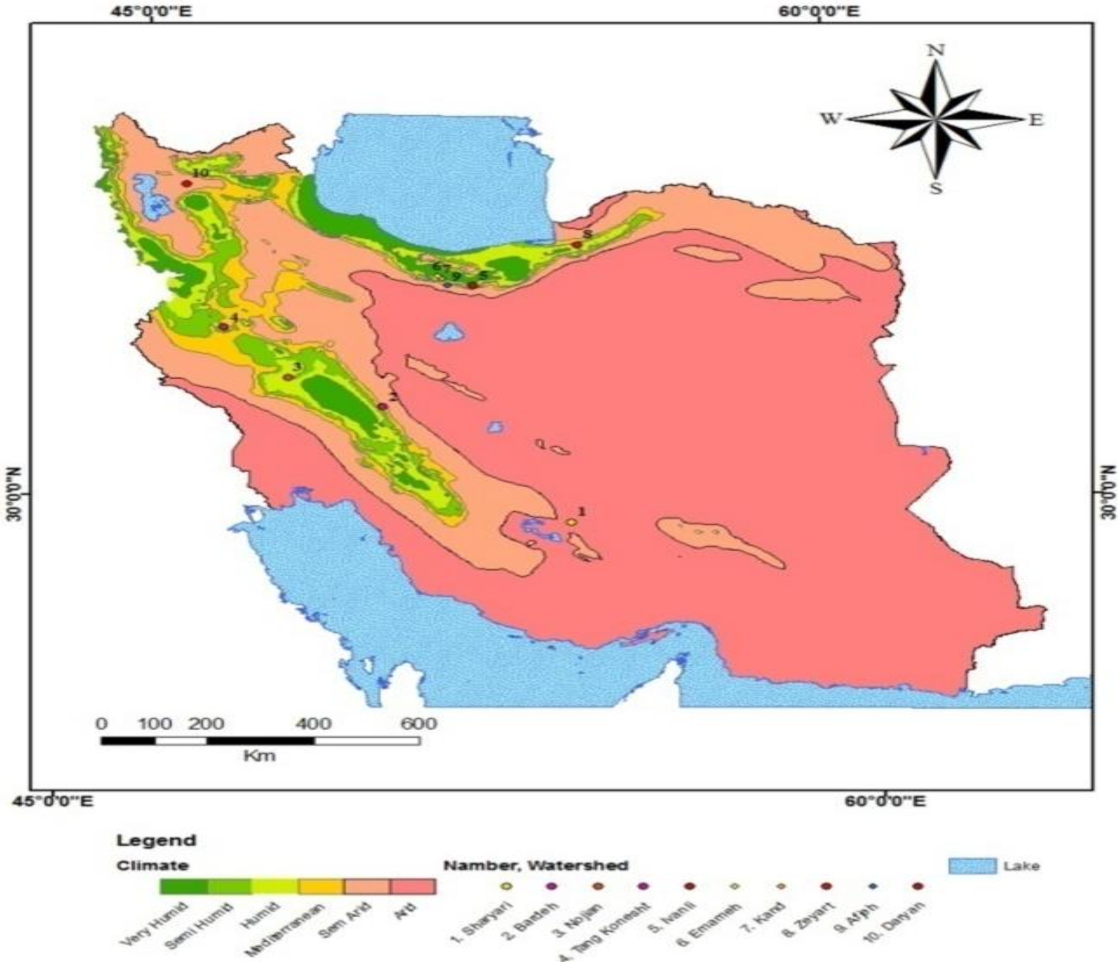

Fig. 1: Location of watersheds studied

MATERIALS AND METHODS

In this research, the model was briefly evaluated on fifteen previous researches which were conducted under humid, Mediterranean arid and semi-arid conditions on ten watersheds (Fig. 1).

Then the Ivanaki's watershed was selected and sediment yield were estimated using MPSIAC model, comparing with Transport-Curve Method for Suspended Sediment Load based on hydrometric station data.

The catchment of Ivanaki River is part of Iran's Central Desert, where located on the East of Tehran. The length of Ivanaki's River is about 50 km which flows from North to South. Its catchment is located on longitude of 520 1' to 520 21' and latitude of 350 20' to 350 43' with an area of 835 km^2 and perimeter of 146 km. The elevation of catchments outlet is 1081 and the highest elevation is 3804 meters above the sea level. The catchment was divided into four sub basins (Table 1 and Fig. 2):

The old and hard Geological formations are located on the north part of the catchment and erodible formations are located on the south of the catchment. The amount of annual rainfall is 124.4 mm and the temperature changes from 6°C during the winter to 30.7°C during summer time.

Table 1: Ivanaki's watershed sub basins area and parameters

Sub basin	Erimeter (km)	Area (km^2)	Percentage (%)
A	58.84	108	12.87
B	87.88	319	38.23
C	83.85	241	28.90
D	48.01	36	4.28
E	64.50	131	15.69

MPSIAC model: Comparative analysis was a common technique in Environmental Impact Statement (EIS) preparation, because it showed the effects of alternative actions in relation to present conditions or some recognized standard. Generally, there was a lack of on-site field data and because the large expense required for information collection, appropriate methods and data had to often be extrapolated to area under consideration. This study showed an application of the Pacific Southwest Inter-Agency Committee (PSIAC) (1968) sediment yield prediction procedure (PSIAC) compared with measured yields from sagebrush

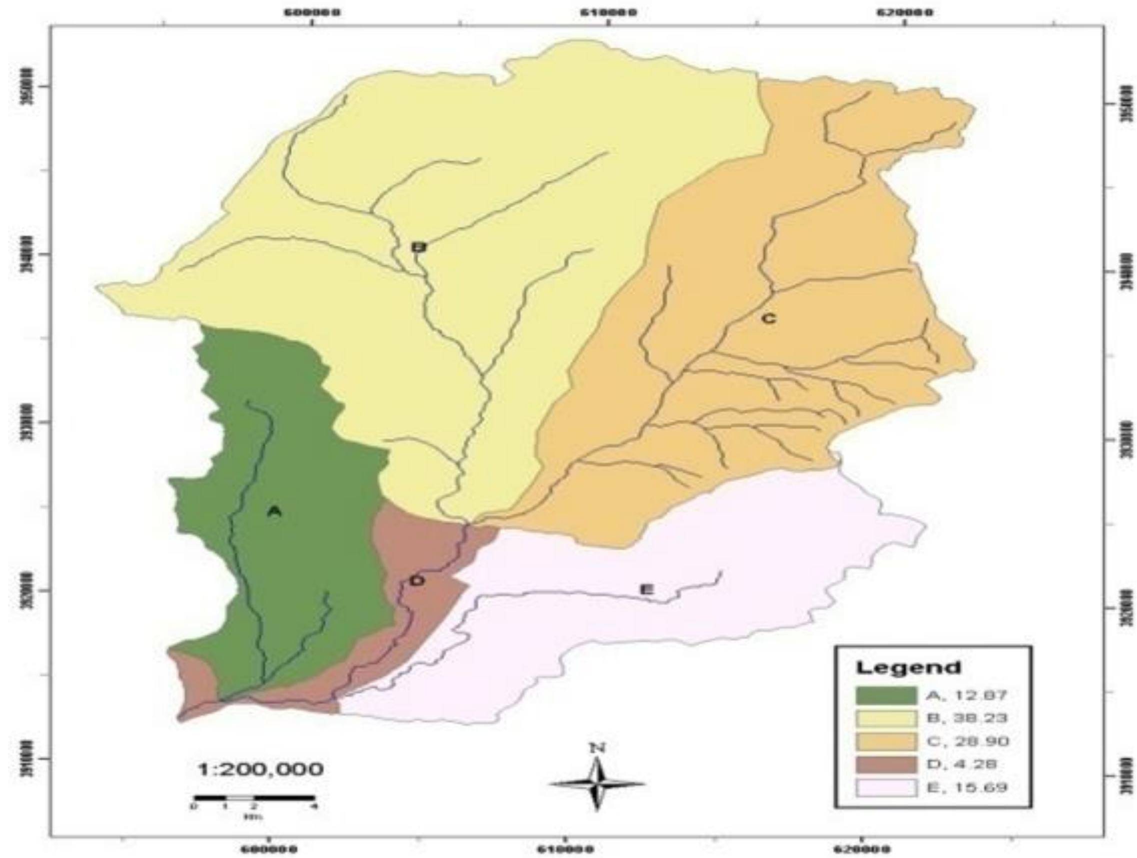

Fig. 2: Sub basins of Ivanaki's watershed

Table 2: Nine MPSIAC factors and their valuations (Johnson and Gebhardt, 1982)

MPSIAC Factors	Equation and Description
Surface geology	$Y_1 = X_1$, where X_1 is a geologic erosion index based on rock type, hardness, fracturing and weathering from geologic reports (hard massive rock has an index of one and marine shale, mudstone or siltstone has an index of 10)
Soils	$Y_2 = 16.67X_2$,whereX_2istheUniversalSoilLossEquation(ELSE),soilerodibilityfactorvaluedeterminedbyproceduresofWischmeierandSmith (1978).
Climate	$Y_3 = 0.2X_3$, where X_3 is 2-year, 6-hour precipitation amount in mm determined from weather records.
Runoff	$Y_4 = 0.2X_4$, where X_4, is the sum of yearly runoff volume in mm times 0.03 and of yearly peak stream flow in $m^3/sec/km^2$ times 50.
Topography	$Y_5 = 0.33X_5$, where $X_5$is slope steepness in percent.
Ground Cover	$Y_6 = 0.2X_6$, where X_6 is bare ground in percent.
Land use	$Y_7 = 20 - 0.2X_7$, where X_7 is canopy cover in percent.
Upland erosion	$Y_8 = 0.25X_8$, where X_8 is the Soil Surface Factor (SSF),determinedby proceduresdescribed inBureau ofLand Management (BLM), Manual 7317.
Channel erosion	$Y_9 = 1.67X_9$, where X_9 is the SSF gully rating associated with X_8.

rangeland areas in southwest Idaho (Johnson and Gebhardt, 1982).

Application of the PSIAC procedure was similar to studies reported by Shown (1970), Lifeste (1978), Clark (1980) and Renard (1980) with some changes, to utilize available sagebrush rangeland watershed data. Although the procedure was developed for the Pacific Southwest, it included factors important in estimating sediment yield with a wide variety of conditions, in response to changes in grazing and vegetative cover, to compare measured and predicted sediment yields and to show how the method could be used in predicting the effects of rangeland management practices on sediment yield.

Sediment yields were computed by a modified PSIAC procedure using Eq. (1):

$$Q_s = 0.253e^{0.036R} \qquad (1)$$

This method assigns a score to each factor depending on its intensity. Afterwards, the sedimentation of the watershed is calculated using the sum of main factors in an exponential as presented in equation 1. Affecting factors in MPSIAC and their valuation are shown in Table 2 (Johnson and Gebhardt, 1982).

Where, Q_s is sediment discharge, in terms of tons/ha/yr and R is Erosion Index which is the summation of nine main factors (Table 2).

Sensitivity analysis: Sensitivity Analysis is a technique for Evaluating and Calibrating models. This Technique helps to understand the influence of every input data, directly on the output results. Lane and Ferria method was applied to evaluate sensitivity analysis. Input data were increased or decreased by 20% with the aim of calculating R and the variation of erosion. Sensitivity of twenty input data and nine main factors were calculated using Eq. (2) as below:

$$SI = \frac{(Qs - Qsa)/Qsa}{(P - Pa)/Pa} \tag{2}$$

where,

P_a = An input initial parameter
P = Related to the increased or decreased input data
Q_{sa} = The calculated sediment using P_a
Q_s = The calculated sediment obtained from P
SI = Sensitivity index

Finally, sensitivity index for different values of input data and R was evaluated. A computer program in Visual Basic using Excel was prepared to do the calculation.

Transport-curve method for suspended sediment load: Suspended Sediment Discharge records were derived from analytical results of sediment samples and water discharge obtained from Ivanaki hydrometer Station. They were computed as daily time series records.

The fundamental methods, the U.S. Geological Survey (USGS) for collecting and computing daily suspended sediment discharge records, were implemented. The method was based on the derivation of a temporal relation by interpolating between measured suspended sediment concentration values and using measured and estimated concentration values with time-weighted water discharge values to calculate suspended sediment discharges (Porterfield, 1972). A temporal plot of suspended sediment concentration values representative of the mean cross sectional value at the time of collection was developed. A linear curve interpolation based on these values and other hydrologic information, was developed. Concentration values were merged with discharge values representing a selected time interval (daily) and summed to derive daily suspended sediment discharges using Eq. (3):

$$Q_s = Q_w C_s K \tag{3}$$

where,

Q_s = Attributed to suspended sediment discharge, in tons per day
Q_w = The water discharge, in cubic meters per second
C_s = The mean concentration of suspended sediment in the cross section in milligrams per liters

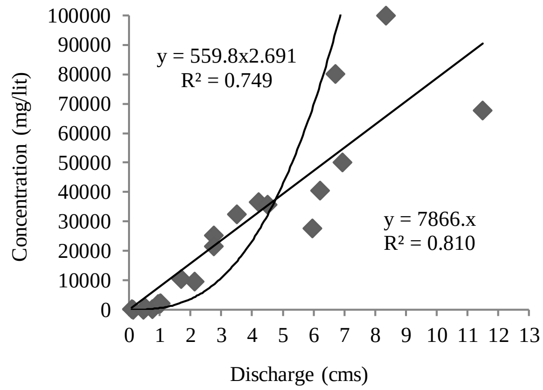

Fig. 3: Water-discharge versus suspended sediment concentration at Ivanaki's station

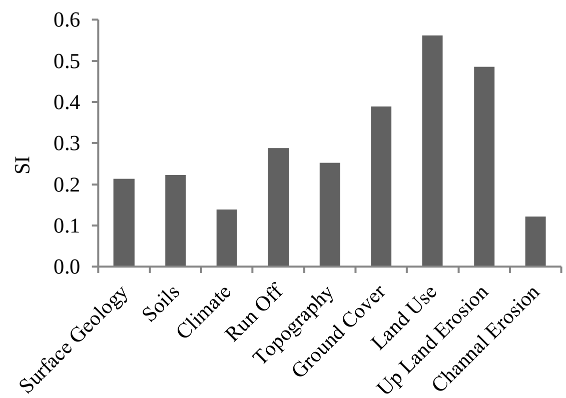

Fig. 4: Sensitivity analysis of nine main factors in MPSIAC model in ivanaki watershed

K = A coefficient value equal to 0.0864, based on the unit of measurement of water discharge that assumes a specific weight of 2.65 for sediment in SI units

The results were expressed graphically as a single average relation (Fig. 3). Such relations, referred to collectively as sediment transport curves, are widely used to estimate sediment concentrations or sediment discharges for periods when water discharge data are available but sediment data are not (Colby, 1956). Sediment transport curves were classified according to the amount of daily discharge rate. The curve represented suspended sediment load (Glysson, 1987) based on water flow rate.

Transport-curve relations normally are defined as a power function (Glysson, 1987) but in this case a liner function had a better regression coefficient. Bed Load was estimated by increasing 10% to suspended load (SPOVP, 2011).

RESULTS AND DISCUSION

As it is shown in Table 3, there are great differences between the results obtained from different

Table 3: Information of sedimentation rate and sensitive factors in MPSIAC model in different researches

Name of watershed	Area (ha)	Amount of Qs ton/ha/yr	Sensitive factor	Reference
Nojian	34087	24.6	Channel erosion	Shah (1995)
	34007	14.39	Channel erosion	Davari (2005)
Emameh	37200	2	Up land erosion	Pakparvar (2004)
	37200	14.73	Land use	Heidarian (1994)
	37200	18.75	Up land erosion	Razmjo (1999)
Kand	5900	3.6	Up land erosion	Pakparvar (2004)
	5900	16.85	Land use	Heidarian (1994)
Afjeh	34000	12.9	Vegetation	Heidarian (1994)
	34000	15.37	Up land erosion	Razmjo (1999)
Daryanchai	4600	4.46	Land use	Saeedi (1999)
	14348	11.63	Topography	Nikjoo (1994)
Ivanaki	83500	3.34	Land use	Authors
	83500	3.21	Land use	Mohamadiha (2011)
Zeyart	9873	2.232	Topography	Tajgardan and Adobe (2008)
Tang konesht	14348	2.093	Land use	Rastgo *et al*. (2006)
Sharyari	15714	2.14	Land use	Bayat (2011)
Bardeh	3200	0.46	Climate	Parehkar (2011)

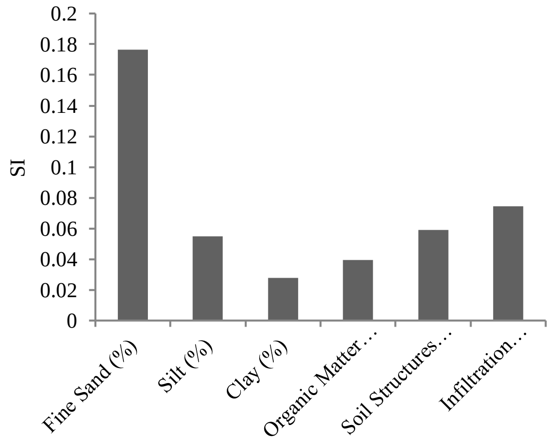

Fig. 5: Sensitivity analysis of soil factors in MPSIAC model in Ivanaki's watershed

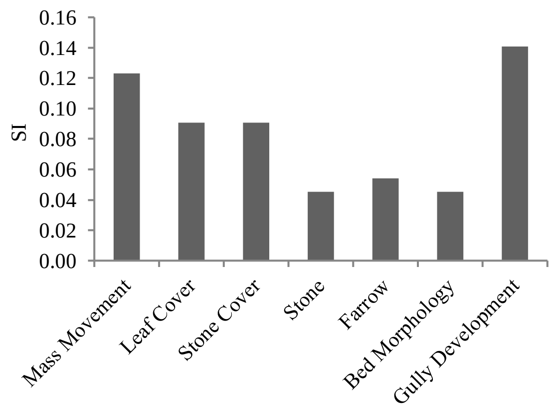

Fig. 7: Sensitivity analysis of SSF factors in MPSIAC model in Ivanaki watershed

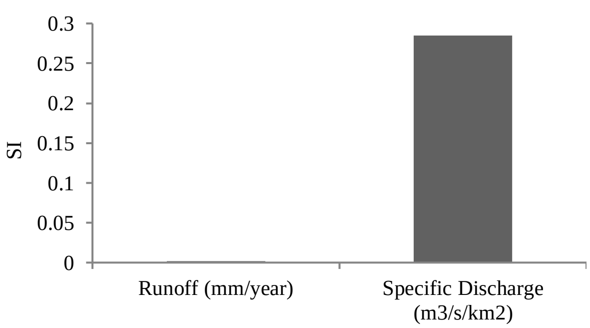

Fig. 6: Sensitivity analysis of Runoff in MPSIAC model in Ivanaki's watershed

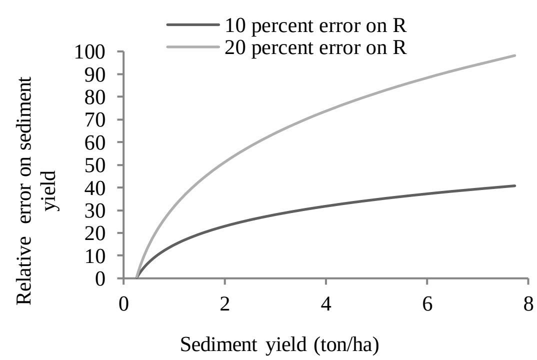

Fig. 8: Relative error occurs in sediment yield if 10 and 20% errors occur on estimating of R

researchers. For instance, a great difference of 12.73 to 16.75 ton/ha/yr in sediment yield is seen in Emameh's watershed. This shows the dependence of the Model on expert ideas. As it was mentioned before, ignoring human errors in calculating input data, sensitivity analysis of nine watersheds but different researchers were conducted to find this paradox.

Since modeling of Ivanaki Watershed was done by authors, the graphs obtained from this analysis were selected and shown as a sample (Fig. 4 to 7).

As shown in Fig. 8, *R* was a high sensitive factor. Valuing the MPSIAC factors on a large watershed would make 10 percent error on estimating *R* and then about 30 percent error could appear to sediment yield of

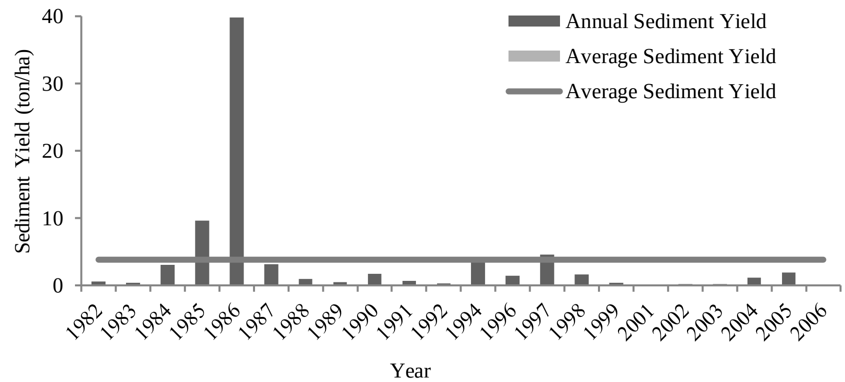

Fig. 9: Annual sediment according to hydrometric station data

a watershed with 5.3 ton/ha/yr sedimentation. Using MPSIAC where initial R being more than 60 is not recommended. When R is greater than 60, 20% error in R causes 54% error on estimated sediment rate and sensitivity of the model could be 2.7. This evaluation indicated that MPSIAC model for evaluation of watersheds with more than 2.2 ton/ha/yr should not be implemented.

Since nine main factors add to gather and results the amount of$R$, all of them have the same sensitivity. Therefore, it could be concluded for a specific watershed, the greater a factor gets to be, the more sensitivity is attributed to it.

Between nine main factors of MPSIAC model, Land Use in seven works (Emameh and Kand: Heidarian; Ivanaki: Behnam and Mohammadiha; Tang Konesht: Rastgo; Sharyari: Bayat; and Daryanchai: Saeedi), Up Land Erosion in four works (Afjeh: Razmjo; Kand: Pakparvar; Emameh: Razmjo and Pakparvar), Channel Erosion (Nojian: Shah Karami and Davari) as well as Topography Factor in two jobs (Daryanchai: Nikjo; Zeyart: tajgardan) and for Climate (Bardeh: Parehkar) and finally Vegetation (Afjeh: Heidarian) in one watershed showed the highest sensitivity. It could be concluded that among them, Land Use had the highest sensitivity which shows that it should be estimated more preciously.

As it can be seen in Table 2, nine main factors were calculated from secondary parameters. It could be concluded that among them, Gully Development had the highest sensitivity, since it affected on Channel and Up Land Erosions at the same time. Farrow erosion in ten cases and mass movement in two cases showed the least sensitivity. Some parameters like infiltration classes at borderline values were sensitive, since its classes changed by small variation. For example, infiltration of 0.5-0.125 cm/hour is placed in class of five while less than 0.125 is placed into another class. Therefore if infiltration is estimated 0.124 cm/hour while it was 0.126 mm/hour, the class of infiltration could be estimated wrongly.

One issue should be considered is the duration of Modeling. MPASIC shows an average of sediment yield for a long term period. As it can be seen in Fig. 9, sediment yield was about 39 ton/ha in 1986. During years 1984 to 1988, because of wet period, runoff was high and consequently erosion was high, whereas MPSIAC showed an amount of sedimentation about 3.34 ton/ha/yr on Ivanaki's watershed.

As it can be seen in Fig. 9, sedimentation was high in year 1986, which runoff was the highest amount in this period. It shows that sedimentation was sensitive to runoff, while MPSIAC did not show this matter on all watersheds worked by different researchers. Factors like Soil factor were needed experimental works at labs. Estimation of these factors is expensive and time consuming. Eventually, the obtained data is related to a local point of the watershed. Expanding these local points on a large area is difficult and causes spatial errors. Some data like rainfalls could cause spatial and temporal errors as well. Utilizing satellite image processing and GIS could help to reduce these errors.

CONCLUSION

MPSIAC model was developed on watersheds under sagebrush crop. The amount of measured sediment yield was between 1.50 to 1.9 ton/ha/yr and the amount of predicted sediment yield was between 1.03 to 2.67 ton/ha/yr. When an experimental model is developed by interpolating a range of data, extrapolating this model could make an enormous error. The sensitivity analysis showed the same results. The model for evaluation watersheds with the amount of sediment more than 2.2 ton/ha/yr must be used with more caution, because the model is so sensitive in this status and possible error may get over 50 percent. Therefore MPSIAC cannot be implemented on the area with the sediment yield more than 2.2 ton/ha/yr.

By evaluation of nine main factors it was cleared that Land Use, Up Land Erosion were the most sensitive factors respectively. Land Use was the most sensitive factor (in seven researches out of 17). Therefore, it could be concluded the most investment should be done on this issue to prevent the soil erosion and sediment yield which are concerns to landowners and managers responsible for maintaining rangeland productivity and conservation of land resources.

Climate and Runoff factors were not sensitive in MPSIAC model. While the hydrometric data showed that runoff could affect highly on the sediment yield. The annual specific sediment yield differed in a range of 0.007 to 28.6 with an average of 3.82 ton/ha/yr, while MPSIAC model resulted to 3.34 ton/ha/yr in Ivanaki's watershed. It showed that estimating of MPSIAC parameters should be done using each year data and afterward the average of predicted sediment yield is used for developing projects.

Remote sensing and satellite image processing could reduce the error due to special and temporal varieties.

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