Modeling of sediment yield and bicarbonate concentration in Kordan watershed, Iran

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Abstract
In the present study, the Soil and Water Assessment Tool (SWAT 2000) model was tested on both a monthly and yearly basis and applied to the Kordan Watershed, located in Iran. The main objective of the research was to assess the accuracy of the model in sediment-yield and surface water bicarbonate concentration estimation. The attributes of sub-watersheds, tributary channels and the main channel in each sub-watershed were generated using the Digital Elevation Model (DEM) and Geographical Information System (GIS) Arc View SWAT 2000 interface. The model was calibrated and validated for the period from 1990 until 2004. Calibration results revealed that the model predicted monthly and yearly sediment-yield, but not such good results were obtained for the bicarbonate concentration. Therefore, some efforts were made in order to find a solution for SWAT bicarbonate temporal modeling. Around 70 samples of the Kordan River water quality data were used and, upon doing statistical calculations, the best correlation between the average pH–EC of water and the bicarbonate concentration was obtained. The formula shall be tested at several watersheds, and it can also be defined to SWAT in order that the model is able to calculate bicarbonate concentration according to pH and EC of the river water, which are introduced to SWAT by the user as a stream water quality file (SWQ) .

Key Words
EC, pH, sedimentation, SWAT.

Introduction

One of the most important concerns in arid and semi-arid areas is erosion caused by water. Erosion brings about ablation, transmission and sedimentation of soil particles. Soil particle transmission from farm and orchards to other areas causes improvement of fertility in the land. But, if non-fertile soils, particularly those mixed with a high quantity of stones, are transferred to farm land and accumulate, the fertility of such lands decreases gradually. Moreover, sedimentation in water channels clogs the water ways, It may also transfer pollutants into farm lands and dams, which are used for irrigation and drinking purposes. Hence, a study of surface water potential as well as for sediment-yield seems extremely urgent, in order to plan suiTable management actions for the reduction of erosion and sedimentation. Another problem of arid and semi-arid areas is the danger of land alkalinization, which frequently causes soil to crust, swell and disperse and which greatly decreases the hydraulic conductivity. Clay particles disperse and plug soil-water flow channels. Swelling of clay particles also slows down the water flow. Decreased permeability does interfere with the drainage requirements for normal salinity control and with the normal water supply and aeration requirements for plant growth. One of the most important solutions related to the sodium hazard of irrigationwater is bicarbonate concentration. Bicarbonate toxicity generally arises from deficiencies of iron or other micronutrients caused by high pH. The optimum level of bicarbonate is 1.5-8.5 mmol/L, if the concentration of bicarbonate reaches over 8.5 mmol/L, bicarbonate hazard will be seen (FAO 1988). Precipitation of calcium carbonate lowers the concentration of dissolved calcium, increasing SAR, and the exchangeable sodium level of the soil.

$$Ca^{2+}+2HCO_3^- = CaCO_3+H_2O+CO_2 \quad (1)$$

The quantity of precipitating bicarbonate depends upon the proportion of water percolating through the soil, or the leaching fraction. (Bohn 1985).

Methods

The Study Area

Kordan Watershed is located in Karaj district, Tehran province, Iran, locating between 35˚52´54″ and 36˚06´56″N latitude and 50˚39´30″ and 51˚05´24″E longitude. Elevation of the watershed is around 4100 meters above the mean sea level. The main stream of the watershed joins Shoor River at Nazar Abad plain. Total area of the watershed is 30000 ha. The area is dominated by Andesite, Tuff, Sandstone, Shale, Alluvial

and Colluviums Structures. Topography of the watershed is undulating with the land slope varying from 5 to 67%. The general slope of the area is from North to North East. The region falls within Semi-arid climate with 4 defined seasons. Average annual rainfall in the area is 250 mm, most of which occurs during fall and winter. Daily mean temperature ranges from maximum of 25˚ C (June) to a minimum of -10˚C (January). The daily mean relative humidity varies from a minimum of 26% (July) to a maximum of 74% (January). Twenty years (1980-2000) of daily rainfall, maximum and minimum temperature, relative humidity, wind speed, and solar radiation data of the watershed were collected and analyzed to determine various statistical parameters. The monthly and annual sediment yield of the watershed for the period from 1987 to 1999, were collected from the Power ministry of Iran. For the determination of bicarbonate concentration in the Kordan River, around 70 measurement of bicarbonate concentration, were collected from the same source.

Results

Calibration of the model

The annual and monthly values of sediment yields from 1987 till 1990, recorded at the outlet of the watershed were used for calibration of the model. The calibrated parameters are presented in Table 1. After calibration, the model was validated by the whole available hydrologic data. The annual and monthly values of sediment yields from 1987 till 1999, recorded at the outlet of the watershed were used for validation of the model. Statistical analysis of the observed and simulated data is presented in the Table 2.

Table1. Parameters used for the model calibration.

Serial number	calibrated value	values selected	prescribed range
1	Manning's n for overland flow	0.065	0.01-0.12
2	Maning's n for the main channel	0.135	0.01-030
3	Maning's n for the tributary channel	0.11	0.01-30
4	Effective hydrolic conductivity, mm/h	10	0.01-150
5	Alpha facroe for ground water	0.80	0.00-1.00
6	Base flow alpha factor	0.08	0.00-1.00

Table2. Statistical analysis of monthly and yearly sediment yield for both observed and simulated data.

Statistical parameters	annual sediment yield (tone)		monthly sediment yield (tone)	
	Observed	simulated	Observed	simulated
Mean	2785	2547	225	237
Standard Deviation	2399.5	1405.3	644.88	647.5
Count	14	14	48	48
t-calculated	0.2088ns		-0.45ns	

ns: non significant

The annual values of both observed and simulated sediment-yields are compared graphically in Figure 1. A high value of r^2 indicated a close relation between the observed and simulated sediment yield, although for the use of the model in estimation of the actual sediment yield, the formula which is obtained and shown in the Figure 2, must be used. Abbaspour *et al.* (2002) and Pandey *et al.* (2005) observed the regression coefficient of 86 and 80 %, respectively, for the annual sediment yield. The monthly sediment yield predictions of the model from year 1987 to 2000 were compared as well. Figure 3 shows a close relation between the observed and simulated values. The r^2 is 90%, which is close to the results of the earlier researches of Nasr *et al.* (2000) and Pandey *et al.* (2005) in which the regression coefficient were 87, 90 and 85 percent, respectively.

Bicarbonate Concentration

The bicarbonate concentration of each soil layer was entered into the nitrate database of the model in order to be used as nitrate data input to simulate the concentration of the bicarbonate as it does for nitrate. The r^2 of 23 %, and the t-test indicated that the regression coefficient is not significant at the level of 95% confidence. This means that SWAT is not able to simulate bicarbonate changes in the water. There fore, according to the importance of bicarbonate simulation in water, it was tried to find a relation between some water quality parameters of the model water quality file, by which the model could simulate the bicarbonate concentration. Since some water quality parameters such as pH and EC are easily available at database of hydrometric stations, and these both parameters are effective on the bicarbonate concentration, we elaborate on these parameters in relation to bicarbonate concentration. A very good relation between average of pH-EC and Bicarbonate concentration was found, as shown in the Figure 4.

As the Regression test indicates, there is good relationship between the average pH-EC and bicarbonate concentration. Hence, the following relation (formula 2) can be a good estimation for measuring the bicarbonate using pH and EC values.

$$[HCO_3^-]=0.016(\frac{pH+EC}{2})-0.0504 \quad (2)$$

Where: $[HCO_3^-]$ is the bicarbonate concentration in milligrams per liter; EC is the electrical conductivity in µmhos/cm.

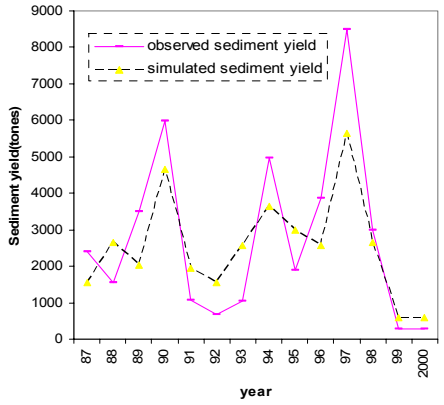

Figure 1. Observed and simulated annual sediment yield for model calibration (1987-2000).

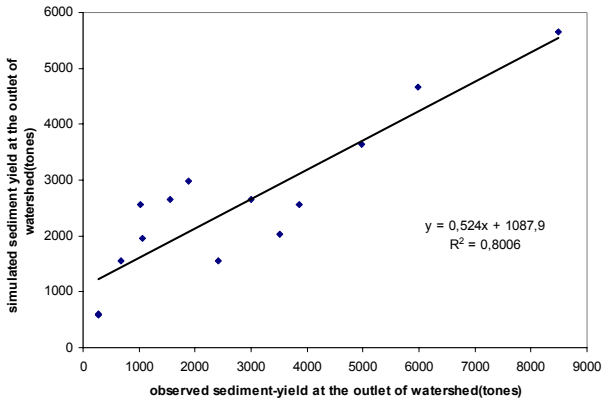

Figure 2. Regression comparison between observed and simulated annual sediment yield for model calibration (1987-2000).

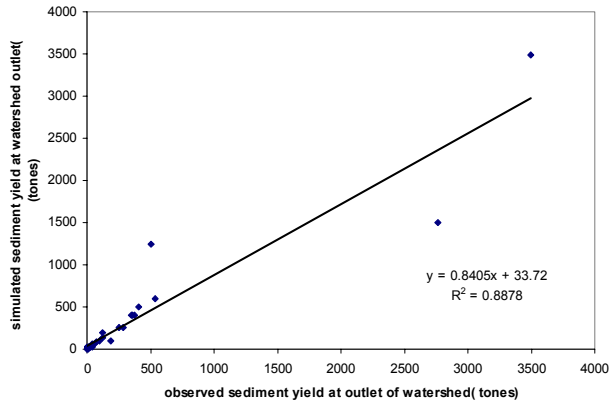

Figure 3. Regression comparison between observed and simulated monthly sediment yield for model calibration (1987-2000).

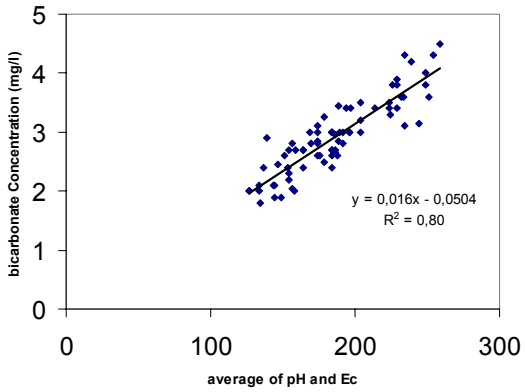

Figure 4. Relation between average pH-EC and bicarbonate concentration (mg/L) of the river water.

Conclusion

Based on the analysis of the results obtained from hydrologic modeling studies of the Kordan watershed, it was concluded that the SWAT model is able to simulate both yearly and monthly sediment yield of the watershed. But the monthly simulation was much more accurate (with higher r^2) than the yearly one. This conclusion should be tested for other watersheds and for all daily, monthly and yearly values.
According to the results, the model is quite efficient and can be used in watersheds where are not gauged and there is no hydrometric station. It is also proposed to use the model for simulating all the missing data of this matter. The model program is defined for the quality factors of nitrate, phosphate, pesticides, BOD, excluding bicarbonates. This disadvantage of the model limits its utility in arid areas. The proposed formula (formula 2), should be tested for several watersheds so that the relation be smoothed and more accurate. If such a relation could be written into the source code of SWAT, then user may define pH and EC of water into the stream water quality file of SWAT. In such a way, SWAT simulates average concentration of bicarbonate which will be used in making decision for irrigation and leaching management.

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