Sediment Yield Modelling of Mohgaon Watershed of Narmada River Basin using SWAT Model

A.K. Thawait, M.S. Chauhan

***Abstract*— This study was undertaken to examine the applicability of soil and water assessment tool model for Mohgaon watershed in Burhner river basin of upper sub basin of Narmada river, Madhya Pradesh, India for simulating sediment yield. The Semi Automated Sequential Uncertainty Fitting (SUFI2) calibration process built in Swat Calibration and Uncertainty Program (SWAT-CUP) were used to calibrate the model parameter using sediment load data for 5 years and validated with observed data for 4 years. This study showed that the swat model is capable of predicting sediment yield and hence can be used as a tool for water resource planning and management of watersheds.**

***Index Terms*— SWAT; SUFI-2; sediment yield; soil erosion; land degradation; watershed modeling; Mohgaon; hydrology.**

I. INTRODUCTION

Soil and water are critical resources in the watershed that should be managed properly for continued supply of ecosystem services, such as good water quality and quantity, to support a wide and diverse range of utilization. However, many of the watersheds in developing countries are in a state of degradation as a result of overexploitation and mismanagement of land resources. Excessive soil erosion is one of the manifestations of land degradation. Many issues, such as sedimentation, ecological degradation, and pollution, are also associated with soil erosion, and may affect aquatic and coastal ecosystems as well.

Soil erosion do also degrades the on – site soil quality in an irreversible way and is quantified by the average amount of soil removed from a defined area over a given time-period. Sediment yield is the amount of soil transported to rivers and lakes in a given period over a defined area. Heavy metals, pesticides and non point nutrient pollutants are transported with soil particles. So, higher sediment yields will lead to water eutrophication and disturbance to the fragile ecosystems.

One of the possible solutions to the problem of land degradation due to soil erosion is therefore, to understand the processes causing erosion at the micro watershed level and to implement watershed management measures. In recent decades, several simulation models have been developed for estimating soil erosion and understanding the spatial and temporal complexities of the watershed catchment response. Various soil conservation practices have been proposed to minimize sediment yield in various watersheds but the control of erosion is site-specific and practices that are effective at one watershed may not perform well at others. Simulating the impact of alternative soil conservation practices is complicated because it involves the detachment and movement of soil upland, after which soil particles are transported by streams and runoff into a watershed outlet. The main advantages of modelling soil erosion are that the models can simulate long-term values of sediment yields without the need for time-consuming and costly experiments. Moreover, models can be used to answer the "if-then" questions that are sometimes impossible to perform in the real world.

Erosion models have increasingly been attributed to the fast growth of both geographic Information Systems (GISs) and computer technology. A number of models have been applied to investigate erosion problems in various regions around the world. The objectives of this study were to test the performance of SWAT model to predict sediment yield by sensitive analysis of sediment parameters in Mohgaon watershed and to develop calibrated runoff and sediment parameters so that the model can be used in ungauged watersheds having similar topography and meteorological characteristics, for sediment yield prediction.

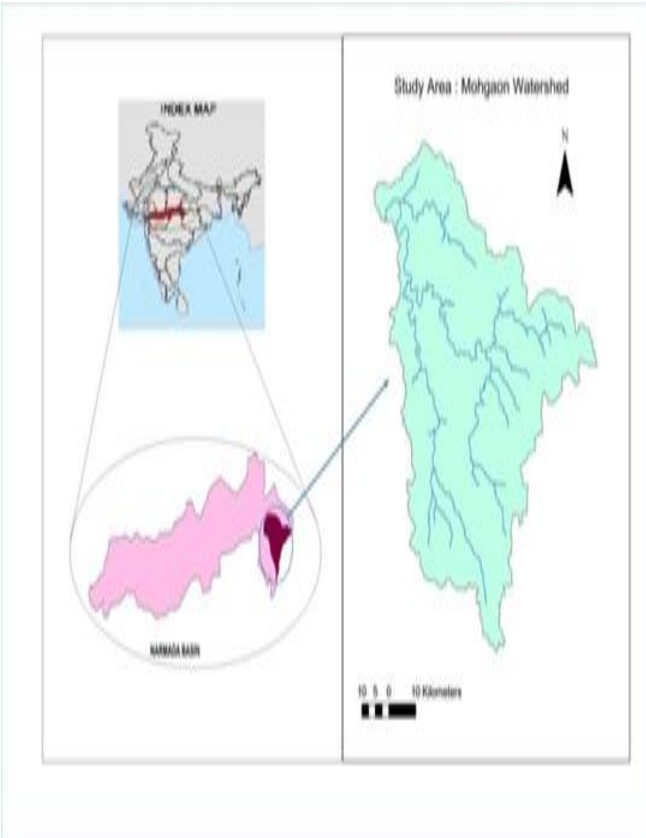

Fig.1: Location of Study Area

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II. MATERIALS AND METHODS

Study Area

The Study area is the part of the Burhner River sub-basin of Narmada River basin of Madhya Pradesh in India. This study area lies between longitude 80° 47′ - 81° 30′ E and latitude 22° 15′ 22° 85′-N covering the catchment area around 3974 km^2 up to Mohgaon gauge station which is at the outlet of the catchment (Figure 1). The Burhner river rises in the Maikala range, south-east of Gwara village in district Mandla of Madhya Pradesh at an elevation of about 900 m at the north latitude 22° 32′ to east longitude 81° 22′. The Burhner River has 4 main tributaries Hallon, Kukra and Kanai. It flows in westerly direction upto a length of 177 km to join the Narmada River near Monot. Climate of the basin can be classified as sub-tropical and sub-humid with average annual rainfall of 1,547 mm. The evapotranspiration varies from 4 mm day in winter to 10 mm/day in summer. The catchment area comprises both flat and undulating lands covered with forest and cultivated lands. Soils are mainly red and yellow silty loam and silty clay loam. Forest and agricultural lands share nearly 58 and 42% of the catchment area, respectively. The major soils of the watershed are therefore Chromic Vertisols (62.5%), Cambilsols (32.05%), and Luvisols (3.34%) in their respective area coverage with small pockets of Vertisols on the hill tops and river and streams valleys and Chromic Luvisols as small pockets in different parts. The soils seem to have derived from basalts and tuffs.

Model Input

Input for SWAT is defined at several levels of detail: watershed, sub basins, or HRU. The input data include topography, weather, land use, soil and management adopted.

Meteorological Data

Meteorological data is needed by the SWAT model to simulate the hydrological conditions of the basin. The meteorological data required for this study was collected from IMD, Bhopal and also http://globalweather.swat.tamu.edu. This website collaborate with The National Centres for Environmental Prediction (NCEP), Climate Forest system Reanalysis (CFSR), which designs and executes as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of state of these coupled domains over this period. Data from four stations, which are within and around the study area, were obtained from station records between 2000 and 2010.

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Topography

Topography is defined by Digital Elevation Model (DEM) that describes the elevation of any point in a given area at a specific spatial resolution as a digital file. It is one of essential spatial input for SWAT to delineate the watershed in to number of sub watersheds or sub basins based on elevation and analyze the drainage pattern of the land surface terrain. Terrain parameters like slope gradient and slope length, and stream network characteristics, length and width were derived from the DEM received from the NASA 60-meter Shutter Topography Radar Mission (STRM) dataset. A SRTM with 60x60 m resolution was obtained from ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer). The DEM data was processed from STRM dataset (Figure 2).

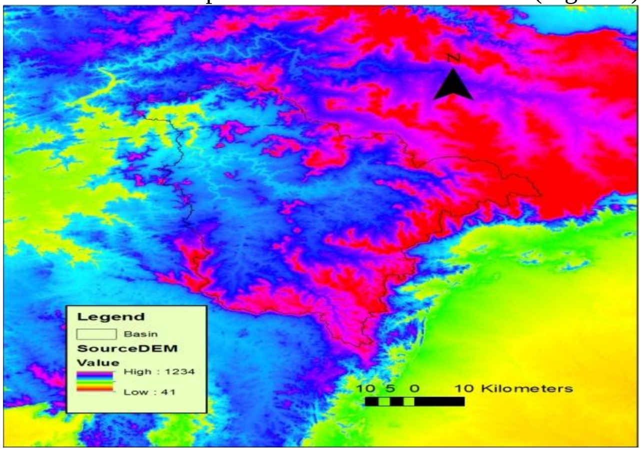

Fig. 2: DEM of Study Area with Watershed Boundary

Soil

The SWAT model requires different soil textural and physical-chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of soil. In this particular study, The FAO–UNESCO global available soil data (1:50, 00,000 scales) in vector format had been downloaded from the FAO Geo Network portal. It is converted into a grid format for SWAT model input parameters. The main soil categories which fall in the Mohgaon watershed are Chromic Cambisols, Chromic Luvisols and Chromic Vertisols of soil class shown in Soil map (Figure 3).

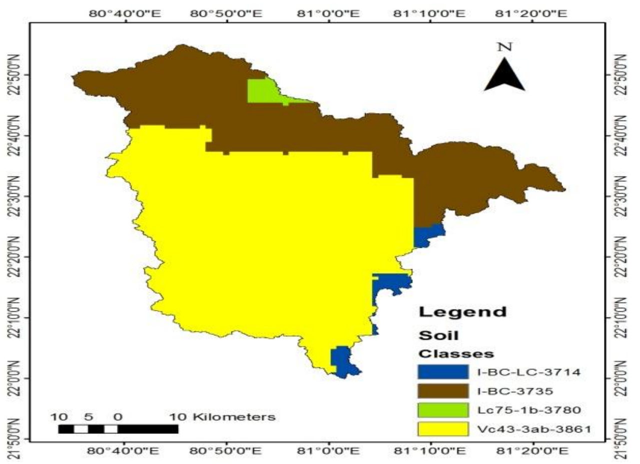

Fig. 3: Soil Classes Map of Mohgaon Watershed

Land Use/Land Cover

The land use is one of the most important factors that affect runoff, evapotranspiration and surface erosion in a watershed. The land use map of the study area of year 2000 (1 meter resolution) was obtained from Landsat USGS from the study of Burhner river basin. The reclassification of the land use map was done to represent the land use according to the specific land cover types and the respective crop parameter was selected from SWAT database. SWAT calculated the area covered by each land use. The different land use/cover map with identified categories is given (Figure 4).

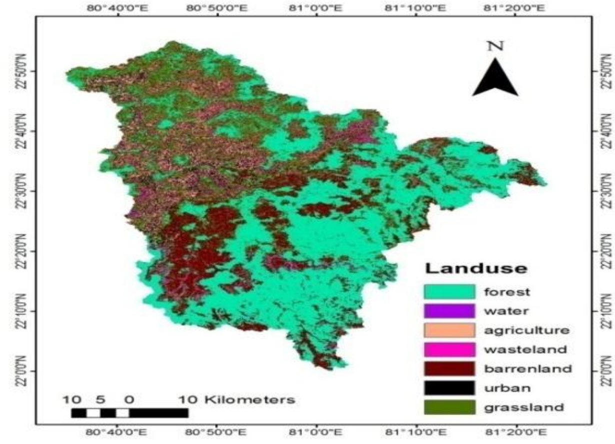

Fig. 4: Land Use Map of Mohgaon Watershed

Slope

Watershed slope reflects the rate of change of elevation with respect to distance along the principal flow path. Principal flow paths being delineated, the watershed slope was computed as the difference in elevation between the end points of principal flow path divided by the hydrologic length of flow path. In this study, the slope of the watershed was discritized into 3 as recommended in SWAT manual which corresponds to the landscape. Most part of lowland of the watershed lied between 0-10 %, the middle lies between 10-20 % and the upper land is above 20 % as shown in the map (Figure 5). The slope of the watershed was necessary spatial data required by SWAT model integrated with Hydrologic Response Unit (HRUs).

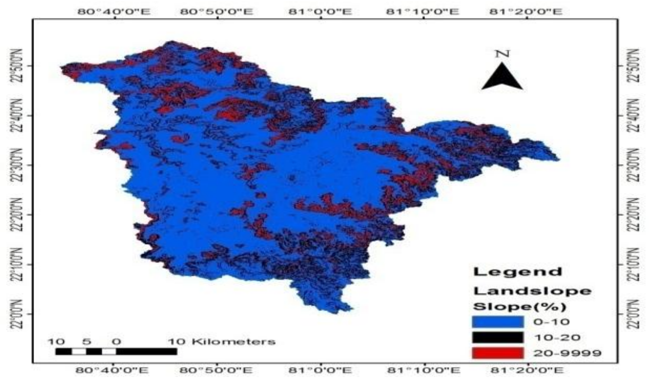

Fig. 5: Slope Map of Mohgaon Watershed

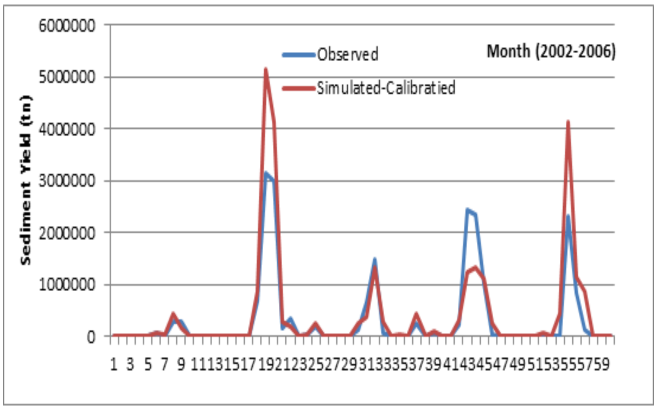

Fig.6: Monthly sediment calibration plot

III. RESULTS AND DISCUSSIONS

SWAT Model Calibration and Validation of Sediment

The outlet of study area watershed i.e. Mohgaon gauging station has been used for sediment calibration. The monthly observed sediment yield was calibrated for the 5 year period (2002-2006). For calibration procedure with SUFI2, 8 parameters were found for sediment yield calibration. The outlet of study area watershed i.e. Mohgaon gauging station has been used for sediment calibration. The best parameters calibrated value after calibration were analysed and all the ranking of most sensitive calibration parameters comparison with *t*-stat and *p*-value in which minimum value of USLE C factor for land cover / plant (USLE_C), Channel erodibility factor coefficient (CH_COV2), Linear parameter for calculating the maximum amount of sediment that can be re-entrained during channel sediment routing coefficient (SPEXP), Manning's n value for the main channel coefficient (CH_N2) are the most sensitive parameters.

Calibrated observed and simulated sediment yield values in graphical plot are shown in the Figure 6. The comparison of observed and simulated sediment yield during calibration is shown in Figure 7 and the performance of objective functions i.e. R^2 and E_{NS} are given in (table 1).

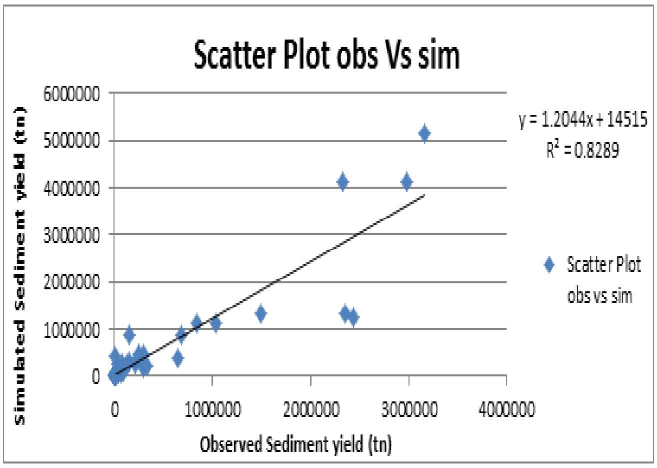

Fig.7: Scatter plot of observed and simulated monthly Sediment yield during calibration

Variable	p-factor	r-factor	R^2	E_{NS}
Sed_out_3	0.65	0.41	0.83	0.79

Table 1: Sediment yield calibration results on monthly basis (SUFI2) during 2002–2006

Sediment Yield Validation

The Sediment validation was done after fixing 8 calibrated sediment parameters and then simulating four years of periods (2007-2010) of observed sediment by using SUFI2 on monthly time scale. The time series plots of model validation for monthly sediment yield are shown in Figure 8. Scatter plot of observed and simulated values of monthly sediment yield during validation is shown in Figure 9 and model performance evaluation is shown in Table 2.

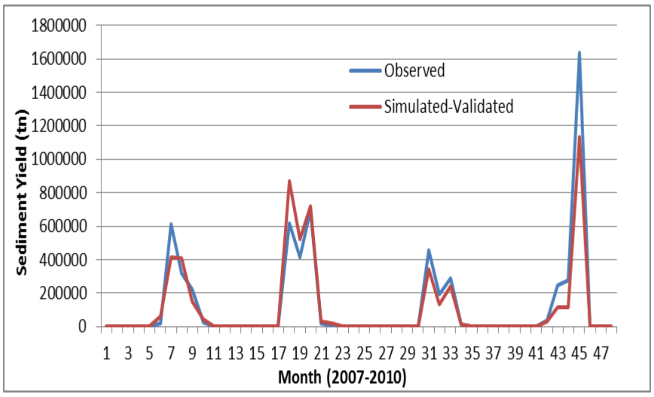

Fig.8: Monthly Sediment Validation Plot

IV. CONCLUSION

Flow and sediment data of ten years data were used to calibrate and validate the SWAT model. Sensitivity analysis of sediment yield was performed and various input parameters were analysed. The study showed that sediment yield prediction were sensitive to land cover, channel slope, channel erodibility factor, overland slope, slope length. The result showed reliable estimates of average monthly sediments yield with a high coefficient of determination (R^2)

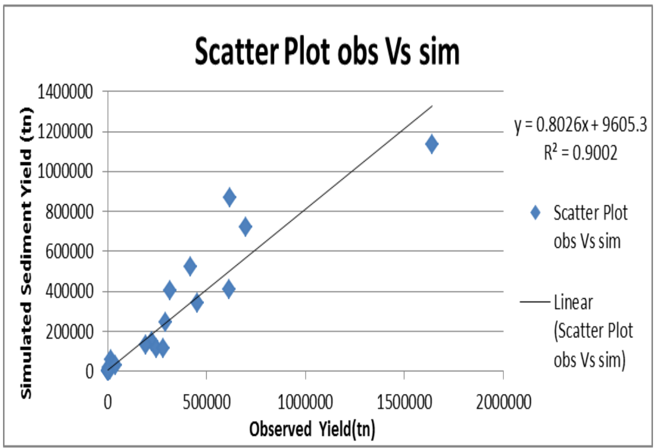

Fig.9: Scatter plot of observed and simulated monthly sediment yield during validation

Variable	p-factor	r-factor	R^2	E_{NS}
Sed_out_3	0.31	0.39	0.90	0.87

Table 2: Sediment flow validation results on monthly basis during 2007–2010

watershed and Nash-Sutcliffe model efficiencies (E_{NS}) during both the calibration and validation period. The respective R^2 values for the monthly sediment yields were 0.83 and 0.90. In general, SWAT model performed well in predicting the sediment yields from the study.

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