IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138
INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG
An International Open Access, Peer-reviewed, Refereed Journal

An Assessment of Sediment Yield for A Watershed Using SWAT Model

Anil U. Mankar[1], Rajeev Shetkar[2]
[1]Research Scholar, Professor
[1] Research Scholar, Department of Civil Engineering, Government College of Engineering, Aurangabad, Maharashtra State, India.

_**Abstract**___ The management of rainwater sustainably for development and livelihoods depends on the dams or reservoirs in modern life. The reservoir's limited capacity to store water is being threatened by silt incursion. The hydrologic evaluation of watersheds is extraction of watershed parameters using simulation models. In the current study, sediment output in the reservoir of Lower Dudhana, across river Dudhana near Brahma-Wakdi village in Selu Taluka of Parbhani district, of Maharashtra state was assessed using an open-source GIS-based SWAT (soil and water assessment tool). Further the model was calibrated with SWAT CUP. Model calibrated and validated by using sensitivity analysis. The SUFI-2 approach algorithm also takes into account the majority of sources of uncertainty. One-at-a-time and global sensitivity analyses are two different sensitivity studies that can be carried out with SUFI-2. NSE and R^2 values for the calibration period of 0.65 and 0.69, and for the validation period of 0.55 and 0.72, respectively.

Keywords: Q*GIS, QSWAT, Sediment Yield, Lower Dudhana Dam*

I. Introduction

Watershed governs a major part to address the issues of rainwater development to satisfy the waters need. To satisfy the water management issues, the expert must quantify and analyse various elements of hydrologic processes. The analysis of watershed is carried out in such way that all these processes are same for the individual micro watersheds. To have knowledge about the strategies for water and soil conservation scientifically one should understand the temporal and the spatial interaction with variation of these hydrologic components. To satisfy this strategies and goal, the use and choice of an appropriate watershed model is a must require (Sathian and Shyamala 2009). The Soil and Water Assessment Tool (SWAT) is known as one of the key hydrological models used for hydrologic and environmental issues (Arnold et al. 1998). Various articles show the use of SWAT model in the Upper Nile Basin (Van Griensven et al. 2012), (Tripathi et al.2003). Use of the model for small agricultural watershed to predict water and soil loss (Neitsch et al. 2005) is focused to present the impact of land management practices on water, sediment in large watersheds with different soils and land use. In an un-gauged area, (Prabhanjan et al.2011) checked the process of the SWAT model. A watershed from the reservoir of Lower Dudhana, across river Dudhana near Brahma-Wakdi village in Selu Taluka of Parbhani district, of Maharashtra state of India, was chosen as the study area. Despite the lack of data, the SWAT model could replicate using the default criteria.

Model calibration process goes computationally extensive and complex for the various parameters in the model. Calibration with manually and automatic calibration software both sources are available. SWAT-CUP is a computer program used in SWAT-CUP package for calibration of SWAT model. Automatic calibration only needs one set of input files where the manual calibration has features like user modelling expertise and the ability to recognise parameters (Eckhardt and Arnold. 2001). A general interface and standalone programme called SWAT CUP was created for calibrating SWAT models (Abbaspour et al., 2007).

1. Lower Dudhana Area

Present study conducted with upstream watershed and reservoir lower Dhudhana. The reservoir Lower Dudhana is across river Dudhna near Brahma-Wakdi village in Selu Taluka of Parbhani district located in Maharashtra state of India, the watershed lies between latitude 19.46 N and 20.05 N, and longitude 75.33 E and 76.42 E. Soil found in the area is mostly clayey loam. Total area of study is 4146 Km^2 out of which mostly area is covered by vegetation and by bare soil.

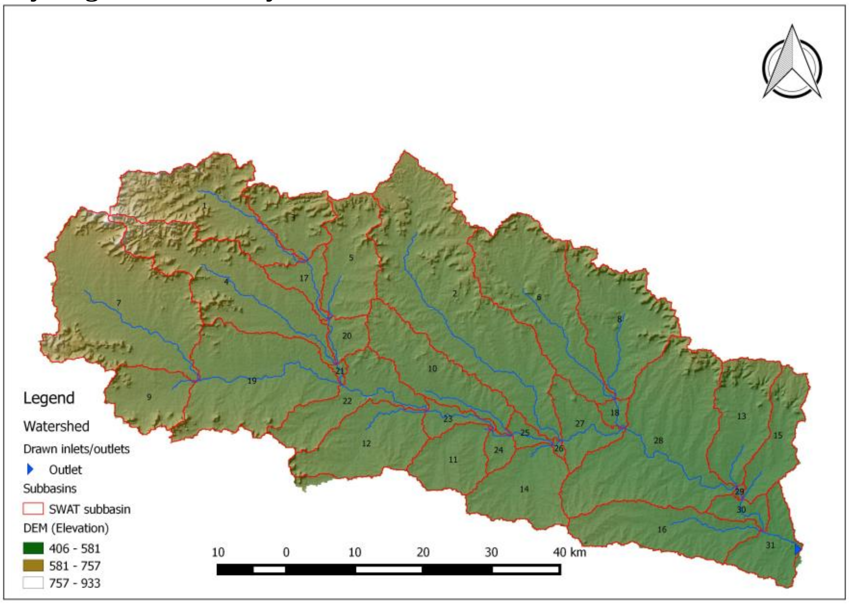

Figure 1: Study Area location

2. Data Required

To simulate a SWAT model correctly the crucial data sets like topography information, soil data, terrain cover data, and daily climatic data (rainfall, wind velocity, relative humidity, temperature, and solar data) needed. Daily meteorological data was used for the current investigation.

3. Methodology

4.1 Data preparation-

Digital Elevation Model (DEM):

The watershed boundary was delineated from the National Aeronautics and Space Administration's SRTM. The elevation data of the Lower Dudhana watershed collected from website of BHUVAN and USGS with 30 m resolution. The resolution of 30m by 30m was derived for the relevant Lower Dudhana area.

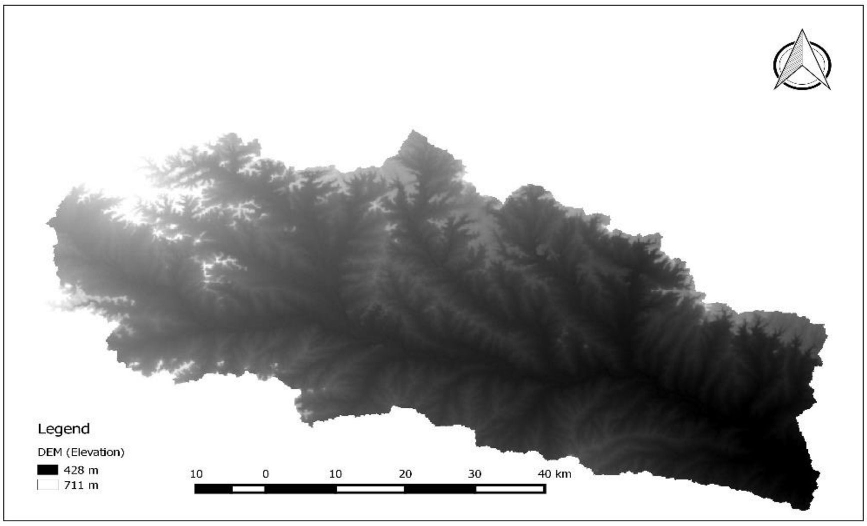

Figure 2: Digital Elevation model of Lower Dudhana

Land use map: it covers categories of open forest, dense forest, exposed rock, agricultural land, waste land, open scrub, settlement, stone quarry etc. Land use land cover map was acquired from LANDSET-LISS II Earth data using Landsat 1 photos was used which consisted of 16 categories as shown in figure below:

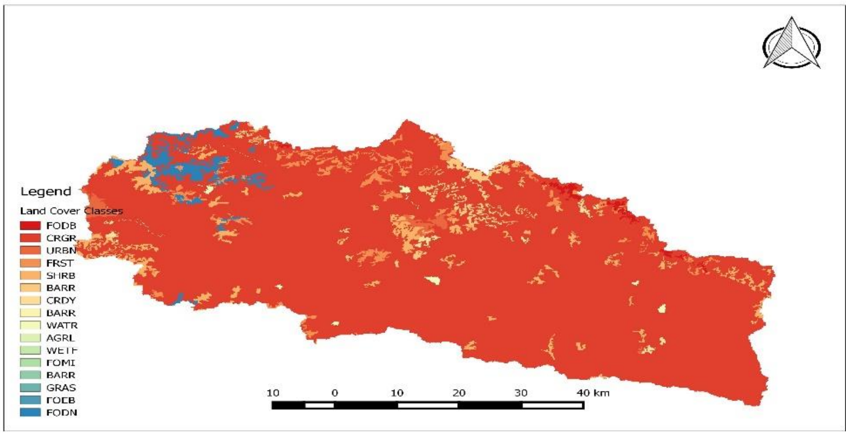

Figure 3: Land Cover Map of study area

Soil Data: The ISRIC-World soil information website (International Soil Reference and Information Centre) was used to obtain information on soil classification and its physical characteristics. Then which was clipped for the relevant study location. The clayey loam soil that makes up the watershed for the Lower Dudhana Dam is further divided into two categories based on its physical characteristics.

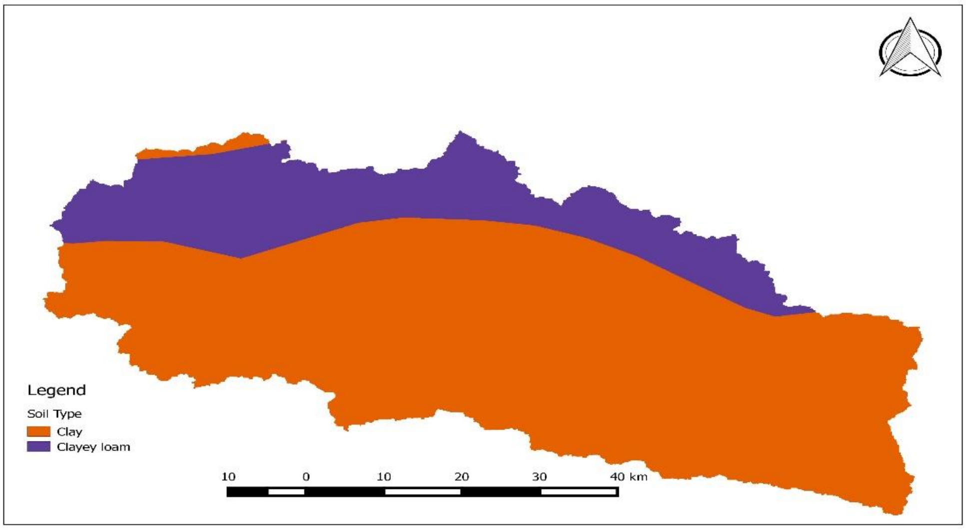

Figure 4: Soil Map of Study Area

Weather Data: The daily data of precipitation, Relative humidity, temperature, Solar Radiation is available from the Global weather data portal with the use of the weather data generator tool, SWAT calculated Statistical parameters, which further are used to deal with missing data.

4.2 Details of SWAT set:

The hydrology process is carried out by water balance equation. The hydrology used in SWAT model is followed by two important steps, first is land phase and other is routing phase. In this phase the pesticides loading and sediment are calculated from each subbasins. For the diversity of the entire watershed, watershed divided into smaller sections or sub-basins which contribute the stream flow. The sub-basins are further divided into even smaller hydrological response units (HRUs). HRUs are regions having the same type of soil and land cover. QSWAT v1.7 was used as a plugin in QGIS 2.6.1 for this analysis of the watershed Lower Dudhana.

MODEL SETUP: SWAT follows mainly three steps for setting up the model and performing a run which are described below.

STEP 1: Delineate Watershed

Watershed is delineated to identify the boundaries and margins of the sub-basins. Drainage networks can be determined from the delineated watershed and sub basins. DEM Map gives digital representation of topographic surface. SWAT was able to produce streams with source nodes in the watershed based on the DEM and threshold value provided, and sub-basins based on the position of outlet point. Figure 1 below illustrates how the Lower Dudhana Dam's watershed was divided into a total of 31 contributing sub-basins.

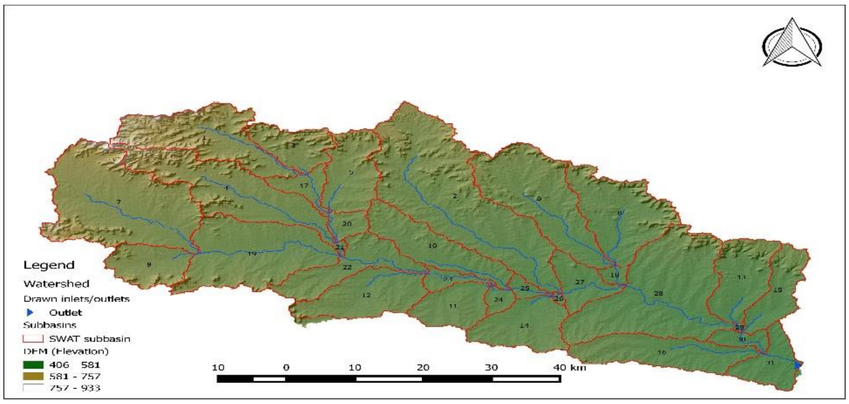

Figure 5: Step 1-Delineated Watershed

Step 2: Create HRUs

Hydrological Response Unit (HRU) is a single unit representation for all the surface characteristics like land use, soil and slope. All characteristics are evenly distributed to improve the model performance. The final output map of HRU analysis will the input map for the simulation. The SWAT database and the pixel data in the raster files of the land cover and soil map are now linked to these lookup tables. Each pixel value in the 2 distinct maps was given a specific code (same to that which is provided in the SWAT database), which identified the type of land cover or soil type present in the area. In the study region, there were 2 different types of soil and 16 different classes of land cover, which served as the basis for the creation of 140 HRUs.

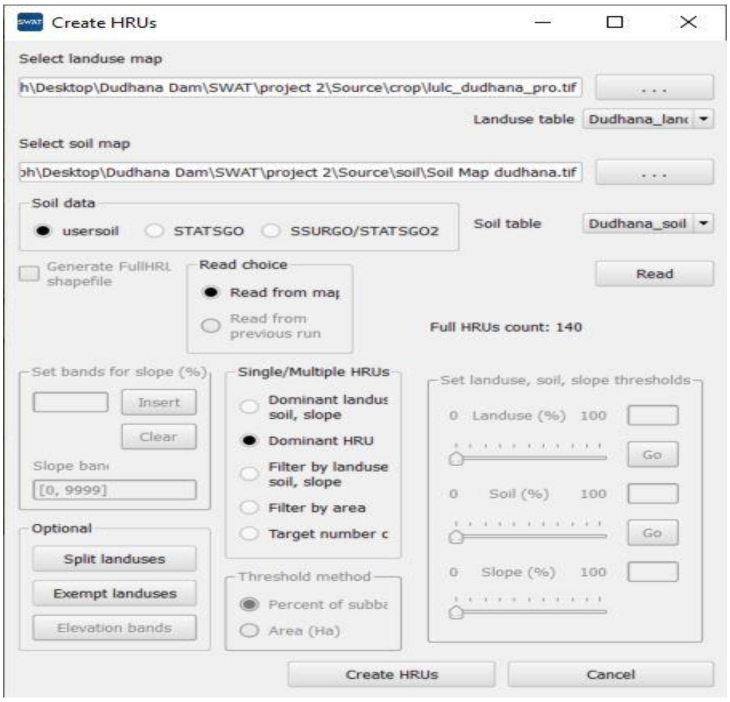

Figure 6: Step 2- Create HRUs

STEP 3: Edit inputs and run SWAT

In this step the provision of all the maps, weather information is now given. After pressing the step 3 button, the SWAT editor window appears, requiring the editor to first connect to the database. A "weather data definition window pops up when the "write input tables" tab at the top is clicked, and in this window, temperature, precipitation, relative humidity, wind speed, sunlight data and weather generator data are provided. SWAT editor calculated the missing data based on weather generator tool.

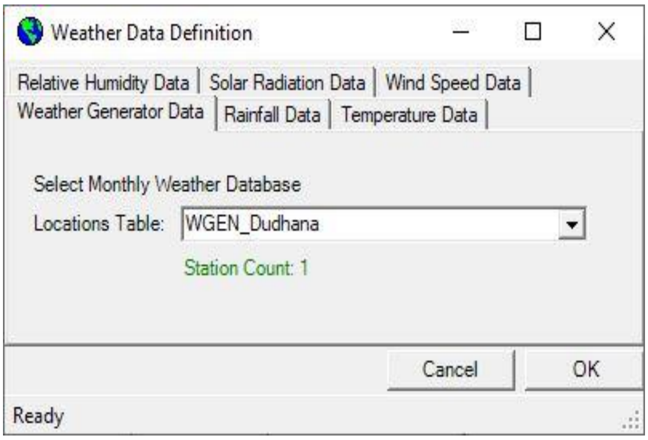

Figure 7: Weather Data Definition Window

The model could now be constructed and run. The initial warm-up period was set to 2 years, and the model was simulation for monthly and yearly output data using daily input data after giving the weather data using the option "write SWAT input tables" under "write input tables."

4.3 SWAT CUP Calibration:

Import a swat TxtInOut directory into a new project that has already been created. Choose the calibration technique that will be applied to the project. A project directory is created after saving, and the TxtInOut files are copied from the specified location into the SWATCUP directory. Edit the files such as Par_inf.txt, SUFI2_swEdit.def, observation. Rch, extraction and objective function files under calibration inputs. There are approximately 500 simulations in every iteration of SUFI2, and only 4 times are necessary to arrive at a satisfactory solution (SWAT-CUP documentation). Edit the data in this section, including the number of observed variables, the variable's name, the subbasin number, the number of observed data points, and the number of observed variables, to incorporate the objective function. Two files, Var file rch.txt and SUFI2 extract rch.def, under Extraction, must be modified. The SWAT swEdit.def file requires the beginning and finishing simulation numbers to be given. Edit the data in this section to include the objective function, including the number of observed variables, the variable's name, the number of subbasins, the number of recorded data points, and the number of observed variables. Under Extraction, two files—Var file rch.txt and SUFI2 extract rch.def need to be changed.

4. Results and discussion:

For a single time-step, SWAT provides the output data for each sub-basin. For example, since there were 31 sub-basins in this study and the model was simulated for annual output, there were 31 output values of sediment yield for each distinct sub-basin for a single year. As a result, the sediment output from every sub-basin was added in order to calculate the gross sediment yield for each year of the study's period.

It was noticed after the simulation that sub-basins numbered 1, 3, 4, 7 and 9 were major source of sediments in their respective reach, and sub-basins numbered 5, 6, 8 and 13 were moderate while the remaining basins' contribution was very low. This is depicted in figure 10 below. But when the streams were observed, streams from sub-basins numbered 7, 4 and 1 were majorly responsible for taking the sediments up to the dam reservoir while sediments from sub-basins numbered 5, 12, 27, 28, 29 and 30 were moderately contributing and streams from rest of the sub-basins were carrying very low sediments. This is depicted in figure 08 below.

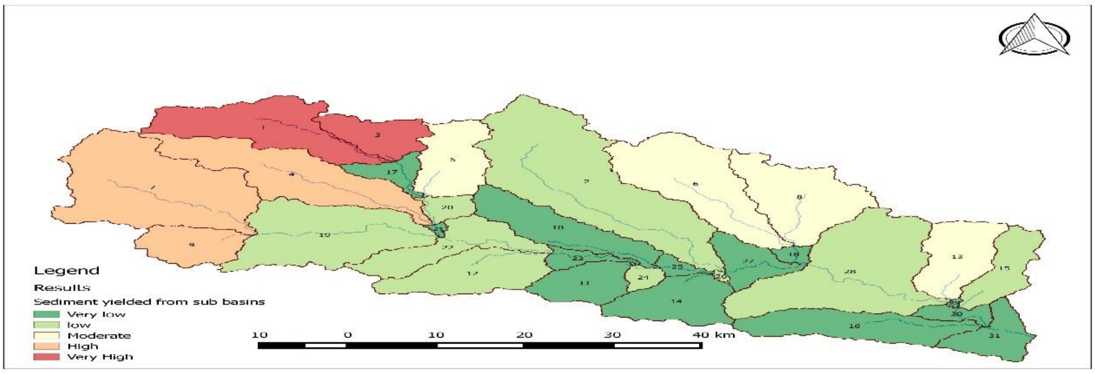

Figure 08: Sediment Yield from Sub-Basins

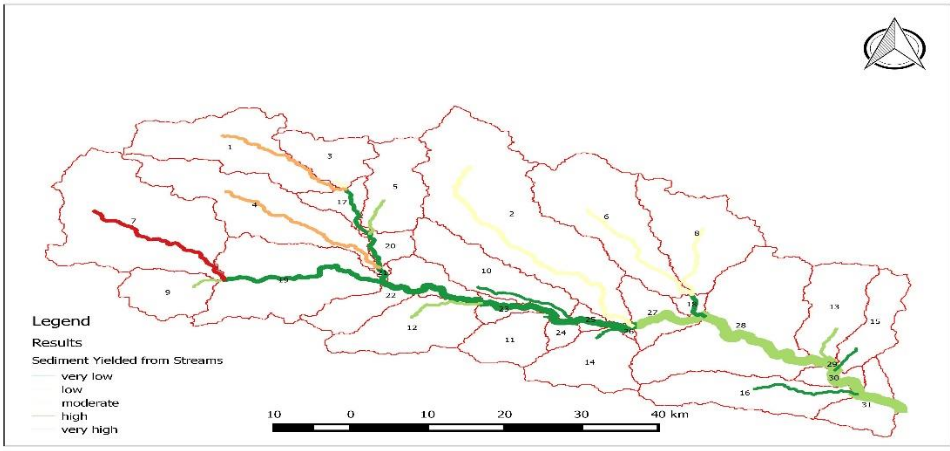

Figure 09: Sediment Yield from Reaches

Sensitivity Analysis

Table 2 displays the findings of the sensitivity analysis performed on the 4 sensitive parameters. GW_DELAY is the most vulnerable factor, followed by ALPHA_BF, GWQMN and CN2. Numerous additional research for the area have also produced results that are similar to or equivalent. Base flow is the main determinant of river flow in the subbasin; hence it makes sense that GW_DELAY would rank as the most sensitive metric. The fourth sensitive element, CN2, which is also the most significant surface runoff affecting factor, follows the same rationale.

Table 1 **Sensitive parameters**

Parameter	Default Range	Range after calibration
GW_DELAY	30 to 450	223.871 to 617.329
ALPHA_BF.gw	0 to 1	-0.398 to 0.538
GWQMN	0 to 2	0.724 to 2.196
CN2	-0.2 to 0.2	-0.375 to 0.015

Dotted Plots

By plotting parameter values or relative changes against an objective function gives parameter sensitivity. Figure 13 displays dot plots for the four sensitive parameters. The most sensitive parameter, according to the dot plots, is ALPHA BF.

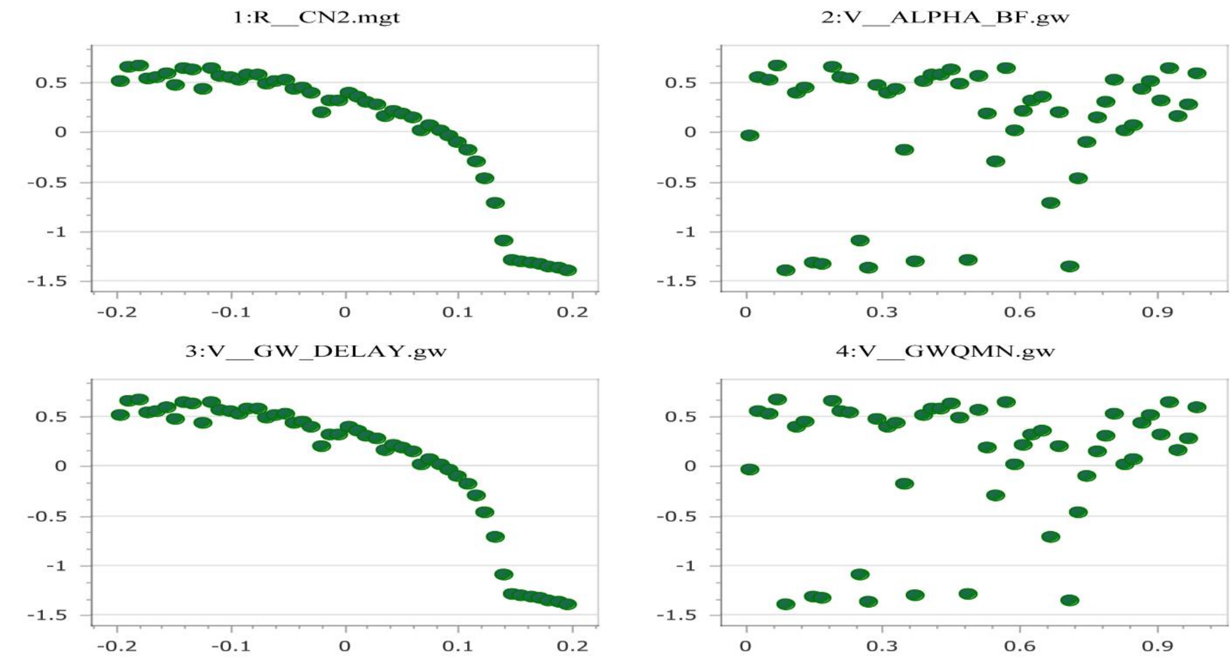

Figure 10 Dot Plots of Sensitive Parameters

Sediment load Calibration

The actual and simulated flow is used to compare the metric. The coefficient of determination and NSE were used for the performance. NSE and R^2values were 0.65 and 0.69 prior to calibration, demonstrating the model's predictive power even in the absence of calibration.

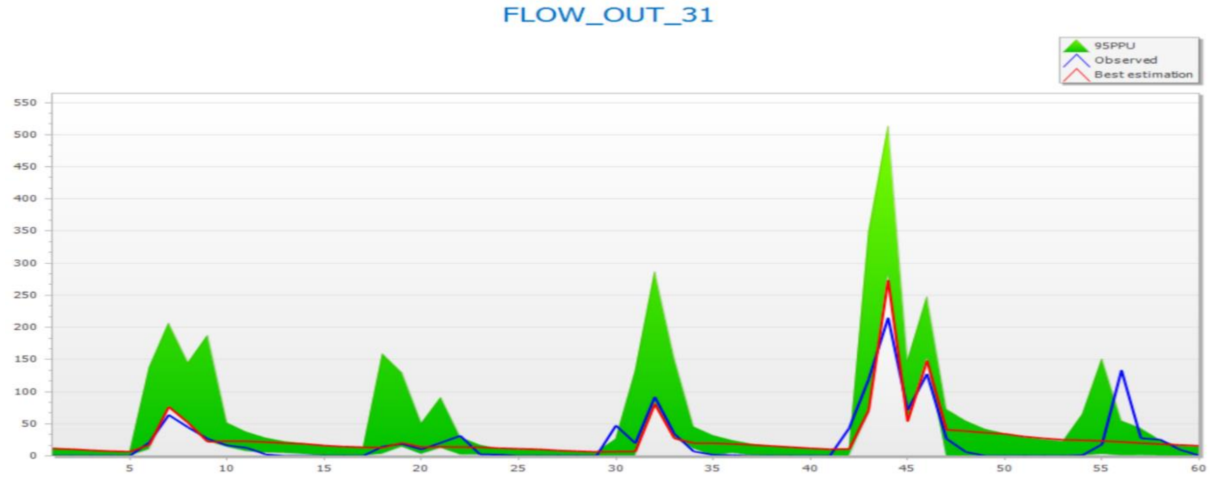

Figure 11 Shows simulated discharge for 95PPU

Validation of model

The validation of model gives relationship between observed and predicted data for calibration results. When calibrated it found an effective for prediction of Nash-Sutcliffe simulation efficiency and coefficient of determination (NSE and R^2) during the period having 0.55 and 0.72, respectively. The model in the current study was calibrated using SUFI-2, which was found to be very user-friendly.

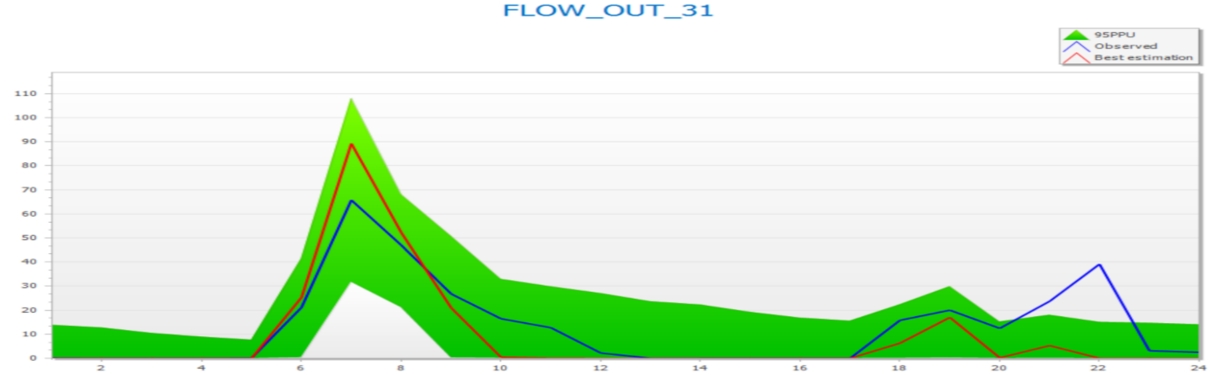

Figure 12 simulated discharge of 95PPU using validation period

5. Conclusions

In the present study the Average rate of sediment yield was found for each sub-basin. It is observed that more than 2% of the gross storage of dam was reduced due to problem of sediment yield. The results confirmed that SWAT model successfully applied in data scarce watersheds of Lower Dudhana watershed for modelling of sediment yield. The swat model successfully applied for finding the sedimentation rate. The study confirmed that streams in sub-basins numbered 1, 3, 4, 7 and 9 were major contributors in yielding the sediments in reservoir. So various control measures like crop rotation, contour bunding, contour ploughing can be adopted to reduce the erosion from these areas.

REFERENCES

Amir Hamzeh Haghiabi, Ehsan Zaredehdasht, "Evaluation of HEC-RAS ability in erosion and sediment transport forecasting" *World Applied Sciences Journal 17 (11): 1490-1497,2012*

Arnold, J. G., Srinivasan, R., Muttiah, R.S., and Williams, J. R. 1998. "Large area hydrologic modelling and assessment part I: model development" JAWRA J. Am. Water Resour. Assoc. 34(1): 73-89

Central Water Commission, February 2019, "Handbook for Assessing and Managing Reservoir Sedimentation", Doc. No. CDSO_GUD_DS_04_v1.0

Dutta, S and Sen, D. (2016). Sediment distribution and its impacts on Hirakud Reservoir (India) storage capacity, *Wiley Online Library, 21(3), pp. 245-263.*

G. D. Betrie, Y. A. Mohamed, A. van Griensvenand R. Srinivasan," Sediment management modelling in the Blue Nile Basin using SWAT model", Hydrology and Earth system sc (2011), Volume 15, issue 3.

J. R. Williams (1975), "SEDIMENT ROUTING FOR AGRICULTURAL WATERSHEDS", Water resource bulletin, American water resource association, Vol. 11, No. 5.

Lambert, V., Bainbridge, Z. T., Collier, C., Lewis, S. E., Adams, M. P., Carter, A., Saunders, M. I., Brodie, J., Turner, R. D., Rasheed, M. A and O'Brien, K. R. (2021). Connecting targets for catchment sediment loads to ecological outcomes for seagrass using multiple lines of evidence, Marine Pollution Bulletin, 169.

Liu, C., He, Y., Li, Z., Chen, J and Li, Z. (2021). Key drivers of changes in the sediment loads of Chinese rivers discharging to the oceans, International Journal of Sediment Research, 36(6), pp.747-755.

Mathew W. George, Rollin H. Hotchkiss, Ray Huffaker, "Reservoir Sustainability and Sediment Management" *Journal of Water Resources and Planning , Management, 2017, 143(3):04016077*

Mohammad, M. E., Al-Ansari, N and Knutsson, S. (2016). Annual Runoff and Sediment in Duhok Reservoir Watershed Using SWAT and WEPP Models, *Engineering, 8, pp. 410-422, http://dx.doi.org/10.4236/eng.2016.87038*

Mohanta, N. R., Biswal, P., Kumari, S. S., Samantaray, S and Sahoo, A. (2021). Estimation of Sediment Load Using Adaptive Neuro-Fuzzy Inference System at Indus River Basin, India, In: Satapathy S., Zhang YD., Bhateja V., Majhi R. (eds) *Intelligent Data Engineering and Analytics, Advances in Intelligent Systems and Computing, Springer, https://doi.org/10.1007/978-981-15-5679-1_40*

Neitsch, J. R., Arnold, J. G. Kiniry, J.R. (2005) Input/Output file documentation Version 2005. User Manual Grassland, Soil and Water Research laboratory, Agricultural Research Service, Blackland Research Center, Texas Agricultural Experiment Station, Temple Texas.

Obialor, C. A., Okeke, O. C., Onunkwo, A. A., Fagorite, V. I and Ehujuo, N. N. (2019). Reservoir Sedimentation: Causes, Effects and Mitigation, International Journal of Advanced Academic Research, 5(10), pp. 92-108.

Prabhanjan; E. P. Rao; and T. I. Eldho," Application of SWAT Model and GeospatialTechniques for Sediment-Yield Modeling in Ungauged Watersheds", ASCE(2015)

Puwadon Phomcha, Prakob Wirojanagud, Thaveesak Vangpaisal and Thanapon Thaveevouthti, "Suitability of SWAT Model for Simulating of Monthly Streamflow in Lam Sonthi Watershed", the journal of industrial technology (2011), Vol. 7, No. 2.

Sanjay K. Jain, Jaivir Tyagi, Vishal Singh, "Simulation of runoff and sediment yield for a Himalayan watershed using SWAT model" *J. Water Resource and Protection, 2010,2,267-281*

Sanjeet Kumar; Ashok Mishra; and Narendra Singh Raghuwanshi, " Identification of Critical Erosion Watersheds for Control Management in Data Scarce Condition Using the SWAT Model", ASCE (2015), Volume 20 Issue 6.

Sathian, K.K. and Shyamala P. (2009) "Application of GIS Integrated SWAT Model for Basin Level Water Balance". Indian Journal of Soil Conservation, 37, 100-105

Scott C. James, Craig A. Jonfs, Matthew D. Grace, Jesse D. Roberts, "Advances in sediment transport modeling" *Journal of Hydraulic Research Vol.48, No.6(2010), pp. 754-763*

Sean J.Zeiger, Jason A.Hubbart, "A SWAT model validation of nested-scale contemporaneous stream flow, suspended sediment and nutrients from a multiple-land-use watershed of the central USA", Elsevier(2016), Volume 572, Pages 232-243.

Tiao J.chang, Travis D. Bayes, "Development of erosion hotspots for a watershed" *Journal of Irrigation and Drainage Engineering December 2013/ 1011*

Trieu Anh Ngoc, "Assessing the effects of upstream dam developments on sediment distribution in the lower Mekong Delta, Vietnam" *Journal of water resource and protection, 2017,9,822-840*

Tripathi, C.N. and Goasin, A.K. (2003) "Micro Watershed Modeling in India Using GIS Technologies and Agricultural Policy Environmental Extender (APEX) Model – A Case Study". International Journal of Engineering Research and Application, 3, 1640-1648

Vahid Nourani, Aida Yahyavi Rahimi, Farzad Hassan Nejad, "Conjunction of ANN and threshold-based wavelet de-noising approach for forecasting suspended sediment load" *International Journal of Management and Information Technology, Volume 3, No. 1, Jan 2013*

Van Griensven, A., Ndomba, P., Yalew, S. and Kilonzo, F. 2012. A critical review of SWAT applicationin the upper Nile basin countries. Hydrol. Earth Syst. Sci., 16(9):3371-3381

Xiao Yun Chen, Kwok Wing Chau, "A hybrid double feedforward neural network for suspended sediment load estimation" *Water Resources management (2016) 30:2179-2194*