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Application of Soil and Water Assessment Tool for Runoff Modeling of Karam River Basin in Madhya Pradesh

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Abstract : ***The SWAT 2010 model was applied to the Karam river basin tributary of Narmada for runoff modeling. The capability of the model was tested for a period 38 year (1976-2012). Karam river which meets the Narmada river basin at Dhar district in Madhya Pradesh. Two rain gauge stations are influencing the project catchment area namely, Nalacha and Mhow. Yearly rain fall and runoff data for 38 year were collected for the study. Using Arc GIS sub watershed boundaries, drainage network, slope, land use map and soil map, are generated. SWAT was linked with calibration uncertainty program (SWAT-CUP) used for the calibration process The model stimulated annual rainfall for 10 year and model was compared with actual observed result. SWAT cup was used for the calibration of the period 2000-2010. The result of this study shows SWAT model can generate the annual average rainfall and produce the runoff very close to the observed value.***

Key words: Karam watershed, Soil and water assessment tool, SWAT-CUP, Calibration, Runoff model.

I .Introduction

Water resources are the most valuable resources that are the basis for existences and development of society. Proper utilization of this resource is important that include both quality and quantity. The surface water in the form of river and lakes discharge is predominantly obtained from rainfall after being generated by rainfall runoff process.

There are numbers of hydrological model applied for water resources management system. Large numbers of parameters are involved in hydrological model that are used for surface runoff, ground water, subsurface runoff, evapotranspiration and lateral flow. This kind of model development required adequate observation. This model can offer a good scientific frame work for watershed analysis. The water shed models generally used as HSPE (hydrological stimulation program), HMS (hydrological modeling system), CREAMS (chemical runoff erosion from agricultural management system) EPIC (erosion productivity impact calculator), AGNPS (agricultural non productive Sources), have been developed for water shed analysis.

A relative recent model developed by US Development of Agriculture (USDA) called SWAT (Soil and water assessment tool Arnold 1998) has proven very successive application in water assessment of hydrology and water quality. SWAT model is worldwide used model. This model is physical based and offers continuous time stimulation. Soil and water assessment tool released in 2009 and named as SWAT 2009. Development of this model has been taken place since 1990s. SWRRB, SWAT94.2, SWAT 96.2, SWAT 98.1, and SWAT 99.2 version of this model are widely distributed.

The SWAT model was developed to predict impact of land management practices on water, sediment yield, and agricultural chemical yield such as nitrogen, phosphorus and biological oxygen demand, chemical oxygen demand, runoff modeling, water balances modeling of large basin. For the calibration analysis sequential uncertainty fitting (SUFI-2) program linked with Arc SWAT CUP is used. The Soil and water assessment tool is also used for critical source area for phosphorus, estimated pollutant losses. The main purpose of this study is runoff modeling of Karam river basin, Madhya Pradesh in India.

II. Material and Methods

For running the SWAT model there are four major input data are used such as Digital Elevation Model (DEM), land use map, soil map, climatic data and stream gage data collected.

Study area: Narmada river is the third longest river that flows entirely within India, after the Godavari and the Krishna. It is also known as "Life Line of Madhya Pradesh" for its huge contribution to the state of Madhya Pradesh in many ways. The study area is Karam river basin tributary of Narmada, Madhya Pradesh central portion of India. Karam river which meet Narmada river near village Jalkoti and Lasangone of Dhar-Maheshwar of district Madhya Pradesh at Lat 22° 21’ 23.147’’ N and Long 75° 28’ 45.886’’ E With approximate catchment area 800.5 hectares and lies within 10 sub basin.

The two rain gauges are located at the catchment area namely Nalacha and Mhow. The yearly rainfall and runoff data were collected for this study. The average weighted annual rainfall is 896.01mm, maximum weighted annual rainfall is 1584.09 mm and minimum weighted annual rainfall is 496.62mm. The Figure 1 shows the location of the study area named Karam watershed.

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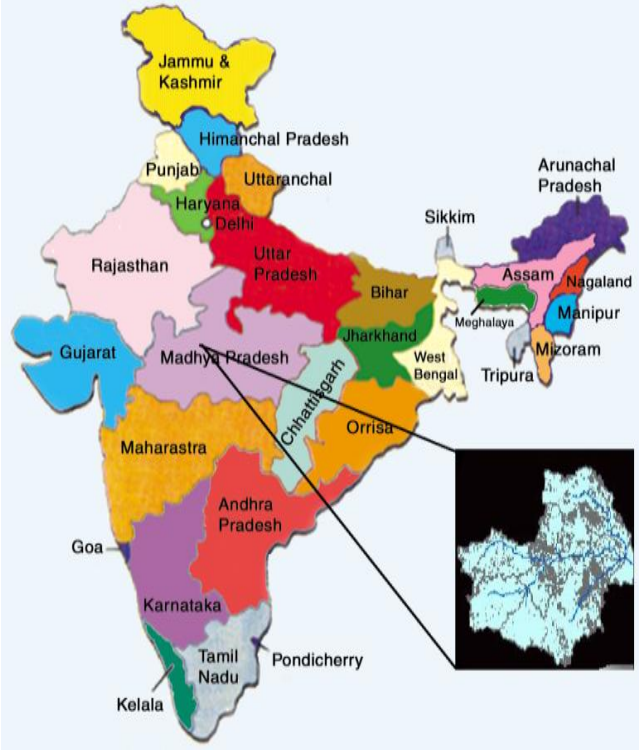

Fig.1 Index map of study area

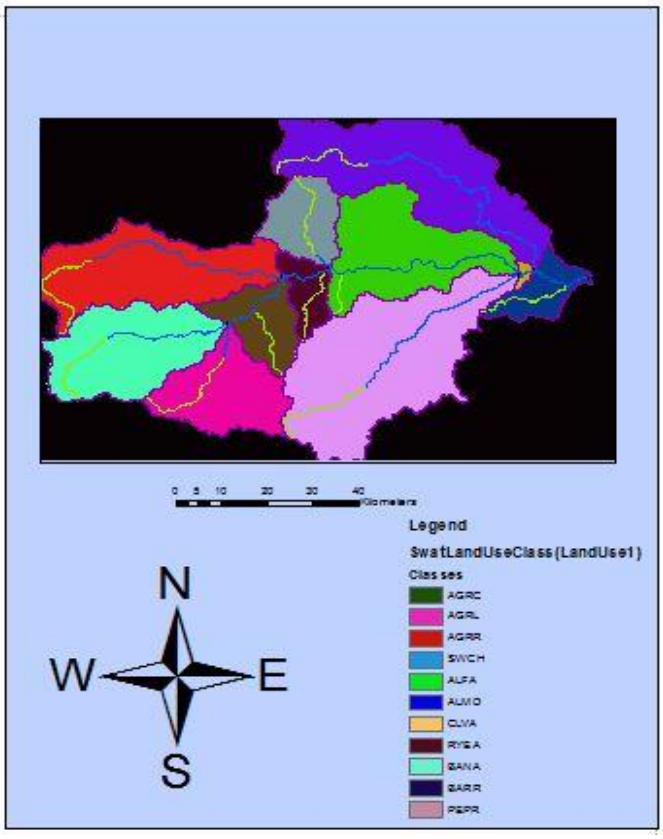

Fig.2 Land use map of study area

Description of SWAT: US Department of Agriculture (USDA) (Arnold *et al* 1998) developed Soil and water assessment tool (SWAT). It has proven very successful hydrology model in various application. SWAT is physically based hydrological model that offers continuous time stimulation. The various input data needed to run the swat model are weather data, soil properties, topography, vegetation and land management factor of that catchment area. Arnold compared the results of SWAT to historical stream flow and groundwater flow in three Illinois watersheds in earlier development of SWAT.

SWAT has been very useful tool for testing and forecasting of water circulation in soil, sediments of soil and crop rotation and sediments pesticides and herbicides in the large basin. One of the main drawbacks of SWAT modeling is it could not be used in testing of deep aquifer. Several data include land use data, soil data climatic data in order to run the model. The various models are adopted by USDA agricultural department for monsoon climate. Among this model SWAT is the most useful hydrological tool for the design of the large river basin. It has recently developed model for long term simulation. It has no area limitation this model. SWAT can tested any large river basin in the world. In order to choose the hydrological model for river basin the following factor should be considered the level of application, the required accuracy space time and mainly the data availability of the river basin. In the lake of available data SWAT modeling is too difficult to the user. The land use, slope and soil map of catchment area are shown in figures.

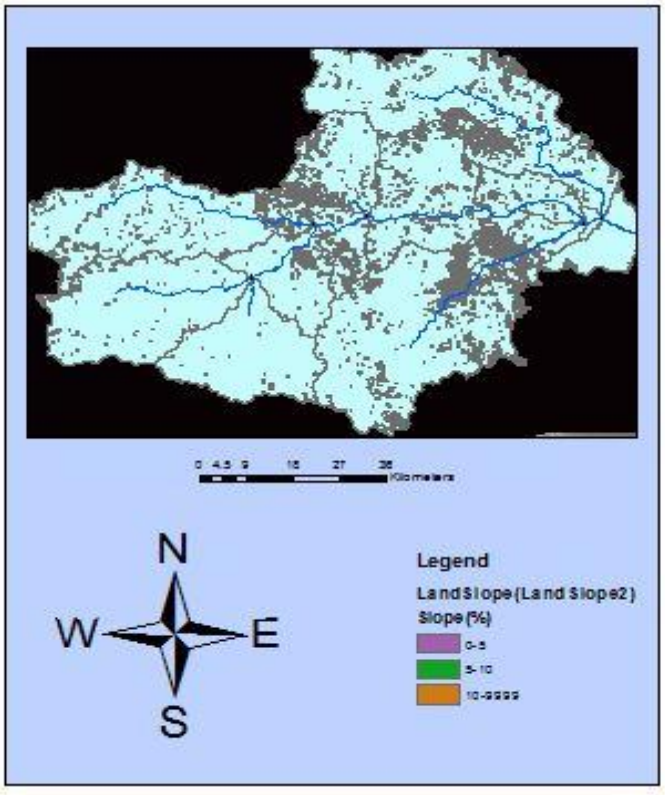

Fig 3 Slope map of study area

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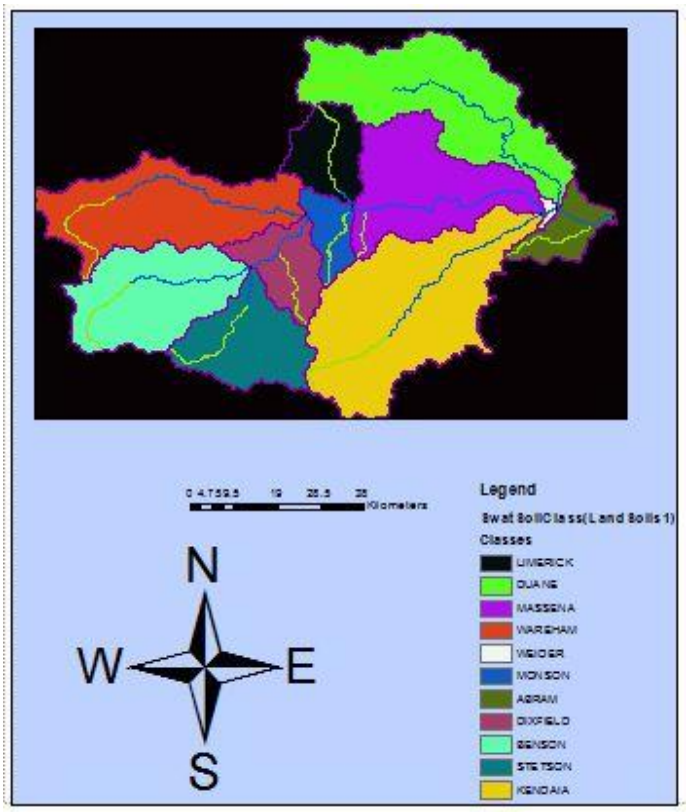

Fig. 4 Soil map of study area

Description of SWAT-CUP

SWAT-CUP (SWAT Calibration Uncertainty Procedures) is a computer program for calibration of SWAT models. SWAT-CUP is a public domain program, and it can use freely. The program links GLUE, parasol, SUFI-2, MCMC and PSO procedures to SWAT. It enables sensitivity analysis, calibration, validation and uncertainty analysis of SWAT model.

In the new version of SWAT-CUP a more powerful SWAT edit program is provided where all SWAT parameter are handled, including different soil layers and management rotation-operation, precipitation data etc. The users are also allowed 20 parameter placed at the end of their own program which linked in to SWAT. SWAT-CUP includes parallel processing, visualization of outlet location using Bing Map, creation of multi objective function, extraction and calculation of 95 PPU for all variables in to output.ric, output.hru, output.sub files without measurements and one-at-a-time sensitivity analysis.

SWAT model contain large number of parameter. So it is too difficult to calibrate the model. Because of this reason we have to take good care of calibration and uncertainty performance. To perform calibration and uncertainty analysis, in recent years many procedures have become available. As only one technique cannot be applied to all situations different projects can benefit from different procedures. Table 1 shows the various parameters are used for the calibration

Table 1 Description of stream flow calibration parameter

Parameters	Description
r__CN2.mgt	Cure number
v_ALPHA_BF.gw	Base flow alpha factor
v_GW_DELAY.gw	Ground water delay time
v_GWQMN.gw	Threshold depth of water

SWAT-CUP contains different types of program. These program include Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (Parasol), and Sequential Uncertainty Fitting (SUFI-2). In this paper we are calibrated result using SUFI-2. The sensitivity analysis showed that from 28 parameters, only 4 revealed meaningful effects on the flow simulation. The curve number (CN2), the base flow alfa factor (V_ALPHA_BF.gw), ground water delay time, threshold depth of water (V_GWQMN.gw) are the most sensitive of all controlling the surface flow. For the base flow, threshold water depth in the shallow aquifer for flow (GWQMN), saturated hydraulic conductivity (sol_k), deep aquifer percolation fraction (rchrg_dp), and groundwater revap coefficient (GW_REVAP) have the highest influence.

Table2 Stream flow calibration parameter uncertainties

Parameter	SUFI-2 Minimum value	Maximum value
r__CN2.mgt	-.02	0.2
v_ALPHA_BF.gw	0	1
v_GW_DELAY.gw	30	450
v_GWQMN.gw	0	2

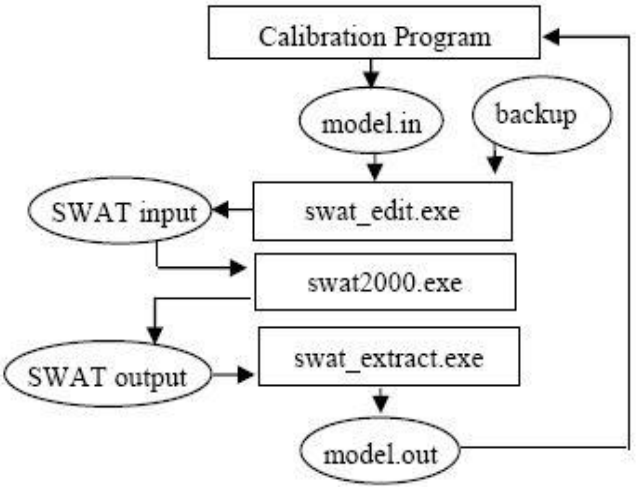

Fig 5 Interaction between a calibration program and SWAT in SWAT-cup

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III. Model Result and Discussion

Some parameter are more sensitivity to the results like base flow alpha factors, ground water delay time, cure number and threshold depth of water. Table 3 shows results of sensitivity analysis at Karam basin. In calibration three variables such as P_factor, R_factor, and R^2 are computed for all types of objective function. Nash- Sutcliffe is the best fitness among the others. The value corresponding to this variable are 0.71, 1.35.0.36, 0.74 are respectively. Figure 5 shows the means annually flow calibration.

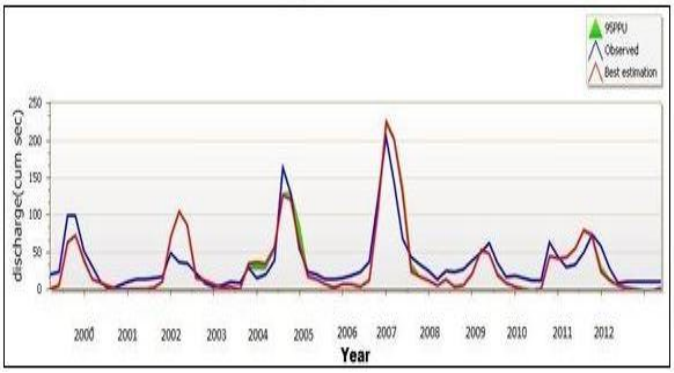

Fig 6.The means annually flow calibration

Table 3 Objective functions at calibration period

Objective function	P factor	R factor	R^2
Mult	0.73	1.37	0.78
Sum	0.71	1.34	0.76
Chi^2	0.71	1.35	0.74
NS	0.71	1.31	0.75
BR^2	0.71	1.36	0.81

This model is relatively good fit in the catchment area. The R^2 and NS coefficient are two important statically analysis for the result. According to Norusis (1999) when the R^2 value is equal to 1, the model is considered to be good. When the R^2 value is less than one the model would considered are not suitable. The study shows that the R^2 value is 0.76 during calibration period. Figure 6 shows simulation result of mean annual water pathway in (2000-2012).

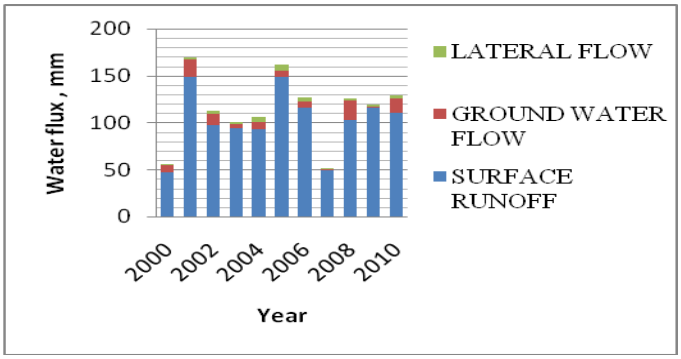

Fig.7 The mean annual different water pathway

IV. Conclusion

In this study SUFI-2 was used for model calibration. By using SUFI-2 we could perform the uncertainly analysis and calibrate the model for more number of parameter. Most of the river originates from the intense storms during the rainy period. This statically analysis indicate that SWAT and SUFI-2 are a fair model for simulation and calibration for discharge by in Karam river basin. The model gives relatively good result in Karam basin.

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