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Hydrological Model for Estimating Volume of Inflow into the Peppara Dam Reservoir Using GIS and SWAT

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Abstract - *This article presents an application of SWAT model to simulate and predict the volume of inflow into Peppara dam reservoir. The model was calibrated and validated using SWAT CUP (SWAT-Calibration Uncertainty Programs). The calibration was done from 2004 to 2013 and validation was performed from 2014 to 2018. The coefficient of determination (R^2) and Nash Sutcliffe Efficiency (NSE) obtained were 0.77 and 0.69 respectively during calibration stage and 0.79 and 0.74 respectively during validation stage. Model showed good performance during calibration and validation stage. This rainfall runoff can be used for predicting the volume of inflow into the reservoir for various rainfall events and it can help in planning the water distribution to TVM corporation.*

***Key Words*: Watershed model; GIS; SWAT: Peppara dam reservoir**

1.INTRODUCTION

Hydrological model is a simplification of real-world system, that helps in understanding, predicting and managing water resources. Soil and Water Assessment Tool (SWAT) is one type of tool used for developing a hydrological model. Hydrological processes occur in watershed. The analysis of watershed is a fundamental step. Hydrological models are used to determine the stream flow over a long period**.** This model which produces historical current or natural stream flow records and is used to generate the future yields. Objective of this research is to develop a model for predicting volume of inflow into the Peppara dam reservoir. This model will help in planning the water distribution as well as for electricity generation planning in TVM corporation. The SWAT-CUP tool is a program that interfaces with Arc SWAT to perform calibration, validation and sensitivity analysis.

2. STUDY AREA

The catchment area of Peppara dam reservoir is the study area. Peppara dam is located at Peppara around 55 km from Trivandrum City. Peppara dam is constructed across Karamana river. It is the main drinking water supply to Thiruvananthapuram district and sub urban areas. Peppara wild life sanctuary is one of the most beautiful wildlife sanctuary of kerala. Peppara dam reservoir located in latitude of 8.6228° N and longitude of 77.1379°E. Area of the reservoir is 5.82 sq.km

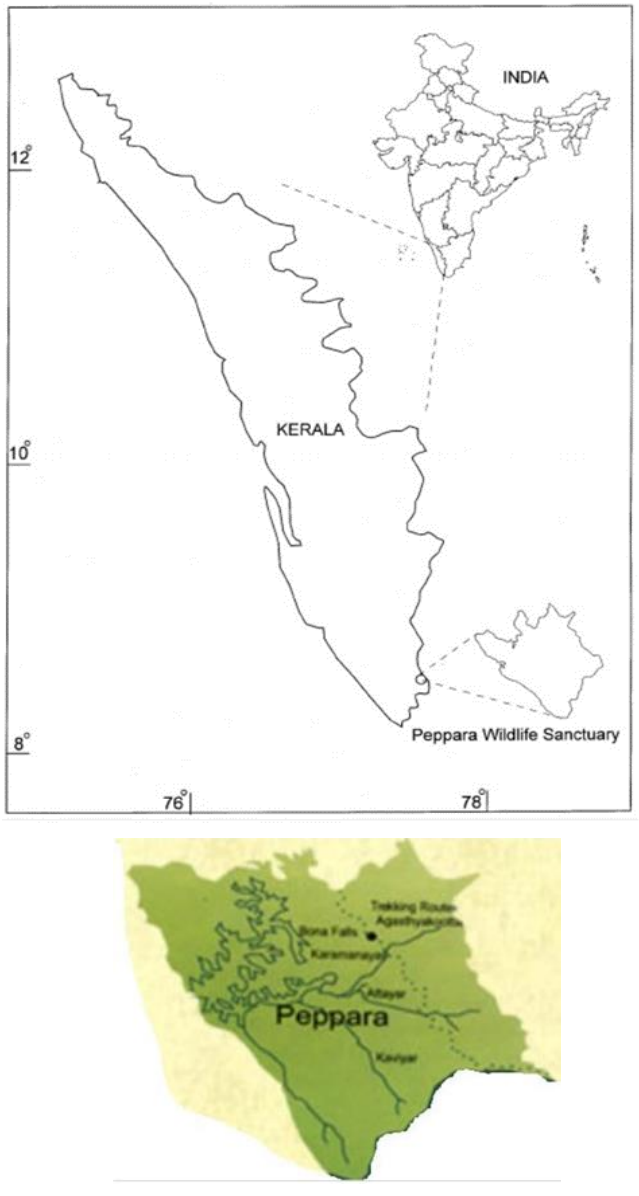

Fig -1: Location map of Peppara

3. METHODOLOGY

SWAT model was simulated by using Arc SWAT with help of DEM, Land use land cover map, soil map and meterological data from Nedumangadu station. SWAT simulation was done from 2004 to 2018. The reservoir waterlevel was collected from KWA (Kerala Water Authority)

4.MODEL EFFICIENCY

The performance of the model was determined by statistical co- efficients. The calibration and the validation were carried out using the Coefficient of Determination (R^2), Nash–Sutcliffe Efficiency index (NSE)

$$R^2 = \frac{[\Sigma_i (Y_i^{obs} - Y_i^{obs,mean})(Y_i^{sim} - Y_i^{sim,mean})^2]}{\Sigma_i (Y_i^{obs} - Y_i^{obs,mean})^2 \Sigma_i (Y_i^{sim} - Y_i^{sim,mean})^2} \quad (1)$$

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n} (Y_i^{obs} - Y_i^{sim})^2}{\sum_{i=1}^{n} (Y_i^{obs} - Y_i^{mean})^2}\right] \quad (2)$$

where, Y_i^{obs} = i^{th} observation

Y_i^{sim} = i^{th} simulated value

Table-1 General performance rating

	Very good	Good	Satisfactory	Un Satisfactory
R^2	>0.7	0.60< R^2≤ 0.70	0.50<R^2≤ 0.60	≤0.50
NSE	0.75 <NSE <1.00	0.65 <NSE ≤0.75	0.5<NSE≤ 0.65	≤0.50

5. CALIBRATION AND VALIDATION

The SWAT-CUP tool is a program that interfaces with Arc SWAT to perform calibration, validation and sensitivity analysis. The method SUFI-2 (Sequential Uncertainity Fitting Version 2) was selected. SUFI 2 provides good accuracy and has the ability to capture the observed data with small uncertainties. Calibration was done for 10 years (2004-2013) along with sensitivity analysis that is same data set and parameters are used for both. The sensitivity analysis is so used to identify and rank the most responsive hydrological parameters that have significant impact on specific model output. Calibration and sensitivity analysis were carried out for 3 iterations each having 500 simulations. 18 parameters were used. In each of the simulations the values of parameters get updated in such a way that more data are bracketed in the 95 PPU. It calculated at the 2.5% and 97.5% level of the output variables disallowing 5 % of the bad simulation. To evaluate the significance of the relative sensitivity t-stat and p- value were utilised. t- stat provides a measure of sensitivity. p-value determines the significance of sensitivity. The larger absolute t-stat signifies greater sensitivity. Closer to zero the p-value, the higher significance. Validation is the process of comparing the model and its behaviour to the real system and its behaviour. The purpose of validation is to check the accuracy and performance of the model basis on the past data for which we already have actuals. Validation was done from 2014 to 2018. Observed data is the Peppara dam reservoir inflow. The surface area of the reservoir was multiplied with reservoir water level difference to obtain volume of inflow into Peppara dam reservoir.

Table- 2: Calibration Parameters

Parameter code	Parameter's name
R_CN2.mgt	Initial SCS CNII value
V_ALPHA_BF	Base flow alpha factor
V_GW_DELAY.gw	Ground water delay time (days)
V_GWQMN.gw	Threshold water depth in Shallow aquifer for flow
R_ESCO.hru	Soil evaporation compensation factor
R_EPCO.hru	Plant uptake compensation factor
R_CH_N2.rte	Manning's "n" value for the main channel
R_CH_K2.rte	Effective hydraulic conductivity in main channel (mm/hr)
R_OV_N.hru	Manning's "n'' value for the Overland flow
R_REVAPMN.gw	Threshold depth of water in Shallow aquifer for 'revap'
R_GW_REVAP.gw	Ground "revap'' co efficient
R_SURLAG.bsn	Surface runoff lag time
R_SOL_K.sol	Saturated hydraulic conductivity
R_SOL_BD	Moist bulk density (Mg/m3)
R_SOL_AWC.sol	Available water capacity of the Soil layer
R_ALPHA_BNK.rte	Baseflow alpha factor for bank storage
R_RCHRG_DP.gw	Deep aquifer percolation factor
R_SLSUBBSN.hru	Average slope length

6. RESULT AND DISCUSSION

Table-3: Parameter value obtained from calibration

Parameter name	Fitted value
R_CN2.mgt	0.700500
V_ALPHA_BF.gw	0.459190
V_GW_DELAY.gw	93.449997
R_OV_N. hru	0.121
R_SOL_K.sol	93.699974
R_SOL_AWC.sol	0.76
R_SOL_BD.sol	1.580314
R_GW_REVAP.gw	0.021320
R_SLSUBBSN.hru	67.540001
R_SURLAG.bsn	1.302350
R_ESCO.hru	0.564086
R_REVAPMN.gw	55.000004
R_CH_K2.rte	95.275002
R_RCHRG_DP.gw	0.745000
R_EPCO.hru	0.975500
V_GWQMN.gw	0.767737
R_ALPHA_BNK.rte	0.558250
R_CH_N2.rte	0.297800

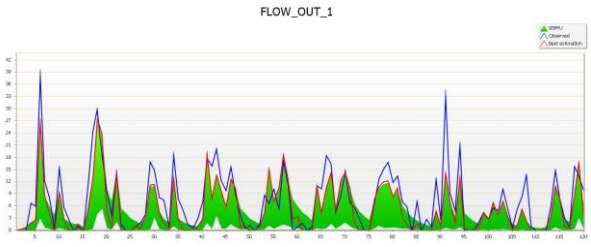

Fig -2: Monthly observed and simulated flow in calibration

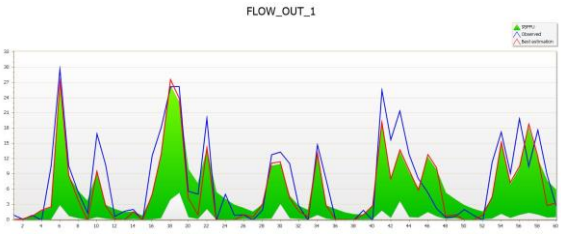

Fig -3: Monthly observed and simulated flow in validation

Table- 4: Summary of the calibration and validation result

	Calibration (2004 -2013)	Validation (2014-2018)
R2	0.77 (Very good)	0.79 (Very good)
NSE	0.69 (Good)	0.74 (good)

7. CONCLUSIONS

The Arc-SWAT model was developed to estimate reservoir volume of inflow performed effectively for Peppara reservoir catchment. During calibration of model the value of R^2 and NSE obtained were 0.77and 0.69 which were within the good limits and the values for the same obtained during validation were 0.79 and 0.74 which shows good performance of the model. 18 Parameters were used in this study. Curve number, Base flow alpha factor, Ground water delay time, Manning's "n" value for the overland flow, Saturated hydraulic conductivity, Available water capacity of the soil layer and moist bulk density are the most sensitive parameters in the Peppara dam reservoir catchment. This rainfall runoff model can be used for predicting the volume of inflow into the reservoir for various rainfall events and it can help in planning the water distribution to TVM corporation.

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