# ASSESSMENT OF RESERVOIR INFLOW PREDICTION THROUGH CONSTRAINING SWAT PARAMETERS TO REMOTELY SENSED ET DATA IN DATA SCARCE REGION OF CHENNAI, INDIA

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**ABSTRACT**

Prediction of reservoir inflow is an important aspect of water supply management in an urbanized region. In this regard, this study aims to improve the reservoir inflow prediction using the calibration of the MODIS (Moderate resolution Imaging Spectroradiometer) evapotranspiration (ET) data in addition to the streamflow in the SWAT (Soil and Water Assessment Tool) model. The results of this study show that constraining SWAT parameters to the ET combined with streamflow helps to improve the simulation of ET. Thereby, it enhances the representation of vertical fluxes in regional hydrology. The reservoir inflow was calibrated with streamflow alone with Nash-Sutcliffe Efficiency (NSE) of 0.63, whereas the inclusion of ET provides an NSE of 0.59. However, the simulation of ET has improved by 10%. The results of this study demonstrate that the inclusion of ET data helps to improve the simulation of hydrologic processes in the region.

***Index terms***- reservoir inflow, SWAT modelling, remotely sensed ET, data-scarce catchment

## 1. INTRODUCTION

Improving the accuracy of reservoir inflow predictions is critical for water supply management and disaster management [1,2]. Reservoir inflow can be predicted accurately with advancements in hydrological modelling tools. However, these modelling techniques need many parameters to be calibrated with field observed data for producing reliable prediction outcomes [3]. Recent studies suggest that the application of remotely sensed ET data into the calibration procedures of hydrological modelling help to improve the prediction performances [1]. The ET data became important in this aspect since it represents the major water loss from both plants and soils [4]. Also, the inclusion of ET data helps us to solve the parameter equifinality while using a large set of parameters to simulate the hydrologic process [5]. The MODIS ET data is commonly used in recent studies due to its data accuracy and availability of data [5]. The advancement in the remotely sensed ET data provides important inputs for the calibration of models in the data scare regions [6]. Hence, the main objective of this study is to utilize the remotely sensed ET data along with the measured streamflow data for improving the predictions of reservoir inflow in a rapidly urbanizing, data-scarce Chembarambakkam catchment of Chennai metropolitan city of India. The SWAT model was used for the simulation of reservoir inflow and MODIS global ET data along with streamflow measurement were used for the calibration of the model.

## 2. MATERIALS AND METHODS

### 2.1. Study area

The Chembarambakkam catchment is part of the Chennai basin, in Tamil Nadu, India. It is located between 12°50’00” and 13°10’0” N and 79°50’00” to 80°10’00” E, with an average elevation of 38.43m and a total area of 324.91 $Km^2$. The annual average rainfall in this region is 1398.33 mm and most of the rainfall is received from short spells of monsoon seasons from October to November (2). The Chembarambakkam reservoir is one of the major water supply sources to Chennai city with a storage capacity of 103.21 $Mm^3$. The climate is semi-arid with an average temperature of 30℃. In recent years, this region has witnessed several flood events during 2005, 2008, and 2015, along with multiple meteorological droughts during 2002-2004, 2009, and 2012-2013. This interannual variability in the occurrence of rainfall and availability of water sources provides challenging situations for the water resources managers that required special attention.

### 2.2. SWAT modelling for reservoir inflow

The SWAT model has been chosen for the simulation of reservoir inflow, due to its advantages of representation of the hydrology of the system and its wide application in watershed studies [7]. The SWAT model uses as inputs the Digital Elevation Model, Soil information, Land use and Land cover information, and hydro-climatic information of the region of the study. The main outputs of this model are streamflow, ET, sediment load, and nutrient loads [8]. The sensitivity and uncertainty analysis and calibration of the streamflow and ET were carried out using the Sequential Fitting Algorithm (SUFI-2) in SWAT-CUP (Calibration and Uncertainty Program) [7].

### 2.3. Model input preparation

A DEM data of 30 m resolution was acquired from NASA's Shuttle Radar Topography (SRTM). Soil data of the study area were collected from the National Bureau of Soil Sciences, Pune, LULC of the study area was prepared at the Institute of Remote Sensing, Anna University, Chennai for the year 2006 from LISS III. The rainfall and hydro-climatic data are collected from India Meteorological Department, Chennai, India, and Public Works Department, Tamil Nadu, India. The reservoir inflow data for the simulation period was collected from Chennai Metro Water Supply and Sewerage Board, Chennai. The Evapotranspiration data from MODIS global ET data was acquired from the Google earth engine for the period from 2005 to 2019 as an additional calibration parameter to reduce the uncertainty in the SWAT simulation.

### 2.4. Calibration configuration

For the assessment of the inclusion of ET, we have conceptualized two models for the calibration. *Model 1* (baseline) corresponds to the case where only streamflow input was used for calibration purposes. In *Model 2*, a two-step procedure was used, starting initially with streamflow, followed by a combination of streamflow and ET. This two-step approach was motivated by the desire to follow reduce the uncertainties in the remotely sensed data. In *Model 2 (19 parameters)*, five parameters are increased compared to *Model 1 (14 parameters)*, to represent the process of ET (5).

## 3. RESULTS AND DISCUSSION

### 3.1. Sensitivity and uncertainty analysis

The simulation was carried out from the year 1998 to 2019 with 6 years warm-up period in which 2004 to 2013 was used for model calibration purposes and the remaining period was taken for validation of the model. The analysis of the selected parameters in both conceptual models reveals that the initial curve number, the threshold factor for return flow, groundwater delay, soil evaporation compensation factor, and baseflow alpha factor for bank storage are more sensitive toward the reservoir inflow predictions in this catchment. Figure 1 shows the rank of the sensitive parameters toward the reservoir inflow. While including the ET into the calibration scheme. The parameters related to groundwater recharge are showing higher sensitivity toward the flow.

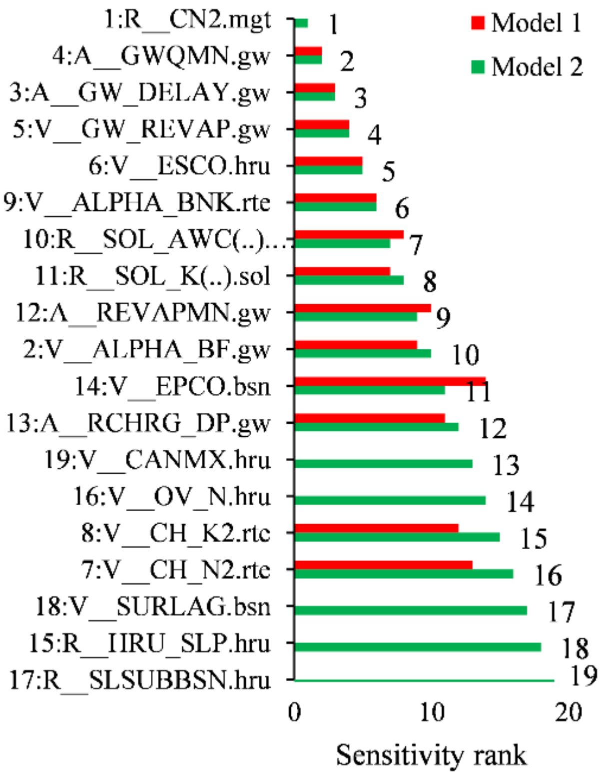


Figure. 1. Sensitivity analysis of parameters from two models

### 3.2. Reservoir inflow predictions and application of ET data

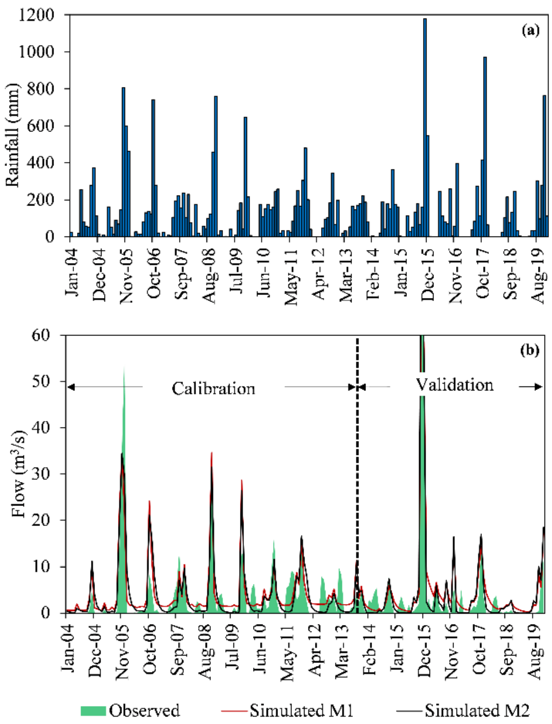


Figure. 2. (a) Rainfall (b) Calibration and validation of the reservoir inflow

The NSE for calibration of reservoir inflow in Model 1 (0.63) and Model 2 (0.59) is similar, nevertheless, the representation of the higher flows is slightly better in model 2 (Figure 2). This is mainly due to the representation of the ET in the calibration process where the parameters increased for the same reason.

Figure 3 shows the comparison of annually aggregated MODIS ET data along with the SWAT simulated ET data from Model 1 and Model 2. It clearly shows the improvement over the hydrologic representation.

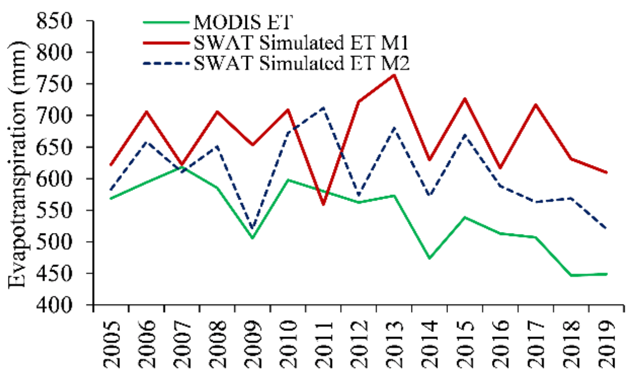


Figure. 3. ET simulations in SWAT compared with remotely sensed MODIS ET data

## 4. CONCLUSIONS

This work aims to assess the influence of remotely sensed ET data on the calibration procedure of reservoir inflow calibration. The results of this study revealed that accounting remotely for sensed ET measurements increases the performance of SWAT ET to a significant extent. Also, the representation of medium to higher flows is better simulated in this approach. However, the differences in ET simulation from MODIS ET outcomes may be attributed to uncertainties involved in the MODIS ET data, and the rainfall distribution accounted for in this study. Nevertheless, accounting remotely for sensed ET data helps us to improve the representation of hydrologic processes.

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## 5. REFERENCES


[1] Zhang Q. Development and application of an integrated hydrological model for lake watersheds. Procedia Environmental Sciences [Internet]. 2011;10(PART B):1630–6. Available from: http://dx.doi.org/10.1016/j.proenv.2011.09.257

[2] Anandharuban P, Elango L. Spatio-temporal analysis of rainfall, meteorological drought and response from a water supply reservoir in the megacity of Chennai, India. Journal of Earth System Science. 2021;130(1).

[3] Shafii M, Tolson B, Matott LS. Uncertainty-based multi-criteria calibration of rainfall-runoff models: A comparative study. Stochastic Environmental Research and Risk Assessment. 2014;28(6):1493–510.

[4] Herman MR, Nejadhashemi AP, Abouali M, Hernandez-Suarez JS, Daneshvar F, Zhang Z, et al. Evaluating the role of evapotranspiration remote sensing data in improving hydrological modeling predictability. Journal of Hydrology [Internet]. 2018;556(November):39–49. Available from: https://doi.org/10.1016/j.jhydrol.2017.11.009

[5] Rajib A, Evenson GR, Golden HE, Lane CR. Hydrologic model predictability improves with spatially explicit calibration using remotely sensed evapotranspiration and biophysical parameters. Journal of Hydrology [Internet]. 2018;567(October):668–83. Available from: https://doi.org/10.1016/j.jhydrol.2018.10.024

[6] Daneshvar F, Frankenberger JR, Bowling LC, Cherkauer KA, Moraes AG de L. Development of Strategy for SWAT Hydrologic Modeling in Data-Scarce Regions of Peru. Journal of Hydrologic Engineering. 2021;26(7):1–13.

[7] Hui J, Wu Y, Zhao F, Lei X, Sun P, Singh SK, et al. Parameter optimization for uncertainty reduction and simulation improvement of hydrological modeling. Remote Sensing. 2020;12(24):1–23.

[8] Neitsch SL, Arnold JG, Kiniry JR, Williams JR. Soil & Water Assessment Tool Theoretical Documentation Version 2009. Texas Water Resources Institute. 2011;1–647.