The Pharma Innovation Journal 2020; 9(10): 137-147

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2020; 9(10): 137-147

www.thepharmajournal.com
Received: 19-08-2020
Accepted: 25-09-2020

# Identifying the most sensitive evapotranspiration routine parameter in an agriculture watershed by using HBV

**Abhishek Ranjan, DM Denis and H Mishra**

**Abhishek Ranjan**
Senior Research Fellow, Department of Irrigation and Drainage Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sciences, Prayagraj, Uttar Pradesh, India

**DM Denis**
Professor, Fellow, Department of Irrigation and Drainage Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture Technology, Sciences, Prayagraj, Uttar Pradesh, India

**H Mishra**
Senior Research Fellow, Department of Irrigation and Drainage Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture Technology, Sciences, Prayagraj, Uttar Pradesh, India

**Corresponding Author:**
**Abhishek Ranjan**
Senior Research Fellow, Department of Irrigation and Drainage Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sciences, Prayagraj, Uttar Pradesh, India

**Abstract**
This research prioritizes the parameters influencing evapotranspiration using a conceptual rainfall-runoff semi-distributed conceptual model, known as Hydrologiska Byråns Vattenbalansavedlning (HBV), for a small irrigated agricultural watershed in the northern semi-arid region of Uttar Pradesh, India. Lands in the watershed are mostly agricultural with wheat and paddy as the major crops. It also has pastures and orchards with a few ponds that run dry during summer. All parameters used by the model to simulate evapotranspiration are parameterized. The considered parameters are successfully modeled, calibrated, validated and their sensitivity obtained. The study prioritizes the parameters that influence evapotranspiration in descending order with the most sensitive the first and the least, last. The parameter *"athorn"* responsible for quantifying Evapotranspiration is identified as the most sensitive parameter. Objective functions as BIAS, RMSE, $R^2$, NSE, and RE are mostly minimum at a sensitivity range of -10% and +10% of *"athorn"* and its value ranges between from 0.83 to 0.083.

**Keywords:** Evapotranspiration, HBV model, sensitivity analysis, identifiability analysis, infiltration, percolation

## Introduction

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. (Vanderlinden, K., *et al*, 2004) [55] When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process. Evapotranspiration is an important process in the water cycle because it is responsible for 15% of the atmosphere's water vapor (Paul J. *et al*, 2012) [39]. If one predicts evapotranspiration rates, one will be able to estimate the water demands of the crop. This may help in the decision of whether to irrigate or not (Singh *et al*, 1995) [50]. Evapotranspiration (ET) is the second largest component of the terrestrial water budget after precipitation. In semi-arid regions, about 90% of annual precipitation is consumed in ET (Suat Irmak, 2017) and the accurate estimation of ET is required for efficient management tasks from local to regional scales, such as irrigation water management. Evapotranspiration is not easy to measure; specific devices and accurate measurements of various physical parameters or soil water balance in lysimeter are required to determine the evapotranspiration. These methods are often expensive and demanding in terms of accuracy of the measurement. A few methods are: Energy balance (Walker *et al*., 2011) [56] micro climatologically methods (Teng-Fei, *et al*. 2017) [53], Soil water balance (Jensen, 2014), ET computed from meteorological data (Teng-Fei, *et al*. 2017) [53], also evapotranspiration estimated from pan evaporation method (Jensen, 2010) [30].

The most widely used approach is the one recommended by the Food and Agriculture Organization (FAO), where ET is calculated by a reference crop evapotranspiration ($ET_o$) multiplied by a crop-specific coefficient (Allen *et al*., 1998). These methods are generally categorized as temperature, Radiation, and a combination of input data required. It is well recognized that if $ET_o$ is calculated by a different method (Ghobari. A.L, 2000). such as, Penman-Monteith, Priestley-Taylor, pan evaporation, Hargreaves, Blaney Criddle, Pan Evaporation, Christiansen Pan Evaporation etc, although the combination based Penman-Monteith equation is considered as the best methods (Allen *et al*., 1998), across a wide range of climates and is recommended by the FAO as the standard method (Tamm. T, 2002) [51]. In some parts of the world, in a semi-arid climate, Hargreaves and Samani (1985) [26] may be suitable for the prediction of $ET_o$ (Hargreaves, G.L, 1985) [26].

**Why uses this model**

The Hydrologiska Byråns Vattenbalansavedlning (HBV) model, which was developed by the Swedish Meteorological and Hydrological Institute (SMHI) in 1972, is widely used as a water balance model. Its capability in conducting hydrological analysis related to the water balance is well known and it has been used in more than 30 countries (Bergstrom, 1992) [8]. Das *et al*. (2008) [15] have shown a strong performance of the distributed HBV model. Several important strengths of the HBV model are its physically based parameters, (Teixeira, 2008) [52]. Which are useful due to the simplicity of linking them to physical attributes. The excessive number of free parameters as compared with other models the HBV model has only eight parameters, while the Sacramento model, Xinanjiang model, NedbØr-AfstrØmnings (NAM) model, and Pitman model have 21, 15, 15, and 16 parameters, respectively (Gan *et al*., 1997) [19]. Simple data demands, user-friendliness, ease of operation and high level of performance (Lindstrom *et al*., 1997) [31, 33]. Singh (1995) [50] has also shown the broad usage of the HBV model over a wide span of geographical and climatologically conditions. Although the HBV model has generally been used in relatively more humid regions than Europe, where the HBV model was developed, such as the northern part of China, (Steven. R.R., *et al*. 2015) [49] its applicability to more arid regions was also evaluated, including some successful applications in arid regions of Indonesia (Dance, 2012; Sanata, 2013) [14]. In India HBV model are more evaluated in Himalayan basins (Doherty & Johnston, 2003) [17]. Looking into its applicability worldwide an effort is made to use it for **"**Identifying the most sensitive Evapotranspiration routine parameter in an Agriculture watershed".

**Materials and Method**

**Study area**

The study area, (Figure 1) Semrakalwana watershed is a small Agriculture watershed in Allahabad district located at latitude of $25^0$ 18' 30''N and longitude of $81^0$48'30''E and comes under the UTM zone 44N. The soils in this watershed are mostly clay loam, sandy loam, and loam. The major crops grown in the village are wheat and paddy followed by pulses and potatoes (Denis. D. M., *et al* 2016; Mishra. H.,*et al* 2017; Renthlei. Z., *et al* 2017) [42]. This watershed also has a few ponds that are dry in summer and it is irrigated by canals that pass through it.

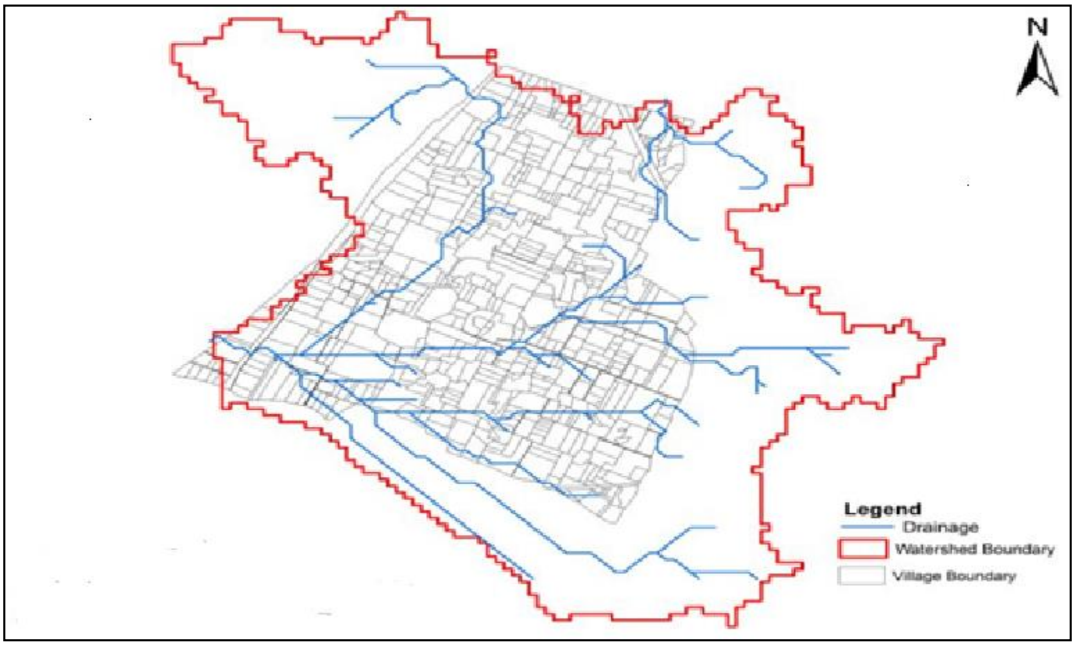


**Fig 1:** Location map of the study area

**About the HBV model**

The HBV model is a conceptual hydrological model and quantifies all parameters of the hydrologic cycle under all climate conditions especially in Scandinavian countries. It is used to assist hydropower operations by providing hydrological forecasts in Germany (Bergstrom, 1995) [7, 9]. HBV model has been applied in more than 40 countries all over the world (Lindstrom, 1997) [31, 33]. It has been applied to countries with such different climatic conditions, for example, Sweden, Zimbabwe, India, and Colombia. The model has been applied for scales ranging from lysimeter plots (Lindstrom and Rodhe, 1992) to the entire Baltic Sea drainage basin (Bergstrom and Carlson, 1994; Graham, 2000) [23]. The model has a snow routine, soil routine, and a runoff generation routine called the response routine. The soil routine groundwater recharge and actual evaporation are simulated as functions of actual water storage.

The HBV model is set up using hourly hydro-meteorological data. In (Figure 2) model input data are required as rainfall, air temperature, and potential evapotranspiration. Land cover and discharge are also needed for the validation and calibration. Further, the model is used as a semi-distributed model by dividing the catchment into subbasin (Andreassian V *et al*., 2004) [3]. Each subbasin is then divided into zones according to altitude, the lake area, and vegetation. The model is normally run on daily values of rainfall and air temperature, and daily or monthly estimates of potential evaporation (Peter E., 2007) [40]. The model is used for flood forecasting in the Nordic countries, and many other purposes, such as spillway design floods simulation (Bergstrom *et al*., 1992) [8], water resources evaluation (Brandt *et al*., 1994) [11], nutrient load estimates (Arheimer, 1998) [5], etc.

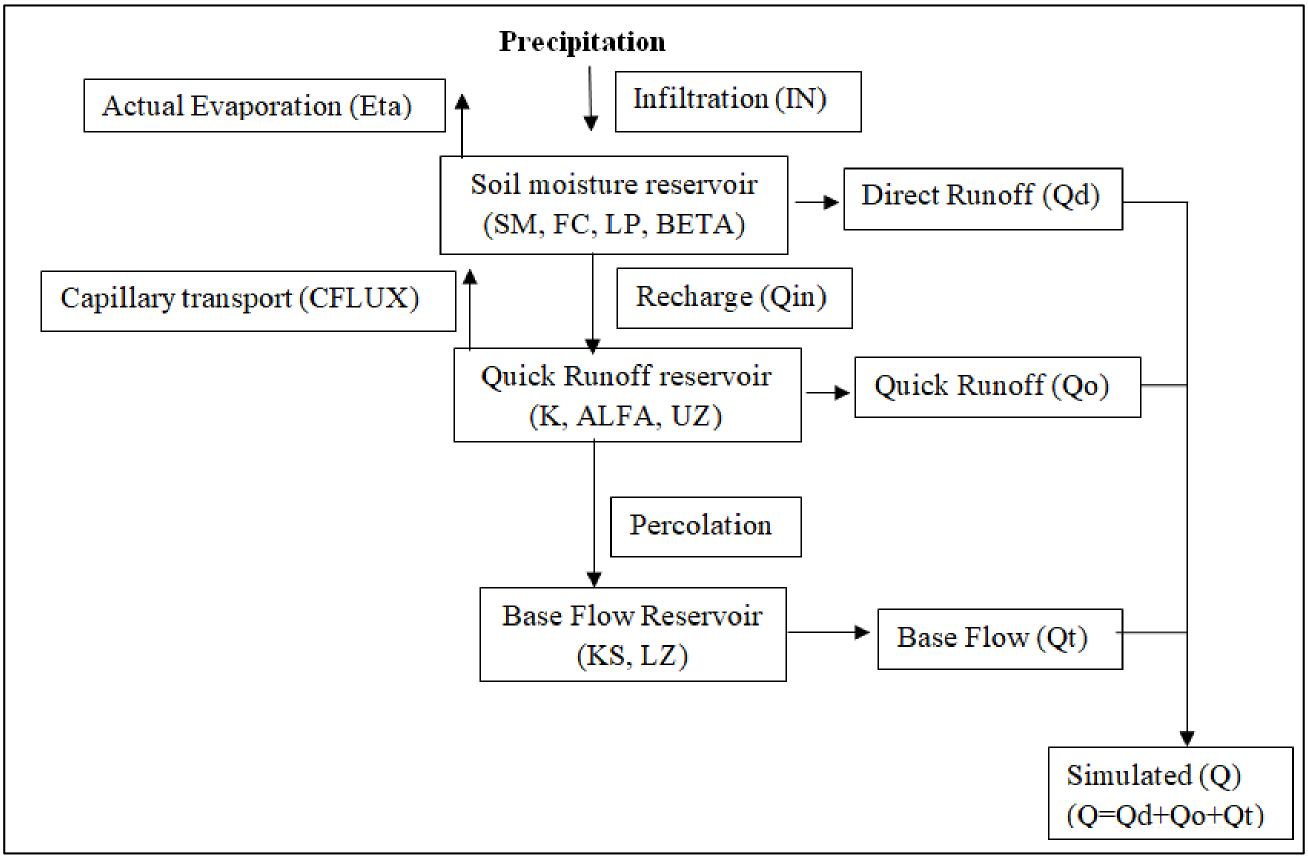


**Fig 2:** Flow diagram represents the process and structure of the HBV model.

**HBV model component**

**Soil routine**

The major parameters influencing the soil routine are the ones controlling the response function as a ratio of the effective precipitation (ΔQ) and the contribution of runoff (ΔP). They are an empirical coefficient (β) that controls the contribution to the response function and controls the drainage from the soil and is given in Equation 1.

$$\frac{\Delta Q}{\Delta P} = (SM/FC)^{\beta} \qquad \text{Equation 1}$$

Where,

SM is the computed soil moisture and FC is maximum soil moisture storage.

The limit for the potential evapotranspiration is *lp* in mm *and fc* is field capacity in mm. *lp* is always a fraction of *fc.* LP is a soil moisture value above which the evapotranspiration reaches its potential value. The standard HBV model is run with monthly data of long term mean potential evapotranspiration, usually based on the Penman formula (Penman, 1956) [39]. The model calculates the potential evapotranspiration using the Thornthwaite method if the parameter "*athorn*" is greater than 0 else the model uses Penman formula. (Penman, 1956) [39]. In equation 2 given below explains it's better.

Potential evaporation = *athorn* · T (= 0 if T < 0) Equation 2

Where,

T is the actual air temperature. Thereafter a parameter *stf* is used. *Stf* describes the seasonal variation and is multiplied with *athorn.* It has three values 0, 1or 2. If 0 *stf* means no factor is used, 1 means 0 that the following factors are used (one for each month) [0.7 0.7 0.8 1.0 1.3 1.2 1.1 1.0 0.9 0.8 0.7]. If *stf* = 2 is used *athorn* is multiplied by [0.6 1.9 2.4 1.8 1.4 1.3 1.0 0.9 0.6 0.4 0.2 0.3]. These values were developed for Scandinavian conditions and cannot be assumed to be valid in general for this region of the planet.

**Methodology**

This research involves identifying the most sensitive Evapotranspiration routine parameter in an agricultural watershed using the HBV model. This research was carried out in three main stages which are: Calibration, Validation and Sensitivity analysis.

**Calibration**

Calibration is a process to search for the best parameter values that can be carried by following a trial and error procedure, which was the most used approach in the past (Habtom. B.K. 2009) [24]. Accordingly, one makes an initial guess of the parameter value and runs the model, therefore, obtaining simulated data values that are visually compared with the corresponding observations (Brath, A *et al*, 2006). If the simulation is not satisfactory the parameter value is changed and the model is run again. The simulation is repeated until a satisfactory solution is obtained. (Abebe *et al*, 2010) [1]. An important part of the hydrological modeling process is to establish that the results are simulated by the model with the physical system to be representing (Seibert. J *et al*., 2012) [48]. The hydrological model is calibrated to get a good fit between the observed and simulated variables. The calibration method for the HBV model developed by (Harlin 1991) [25] used as different criteria for different parameters and optimization is made for one parameter at a time while keeping the others are constant (Press *et al*, 2010).

An important part of the hydrological modeling process is to establish that the results are simulated by the model with the physical system it represents (Abebe *et al*., 2010) [1]. The hydrological model is calibrated to get a good fit between the observed and simulated variables with the main parameter are used in this model are discussed below in Table 1.

**Table 1**: The parameters calibrated, validated and checked for sensitivity analysis are

| parameter | Parameter descriptions | Unit |
|---|---|---|
| ALFA | Recession coefficient for the upper soil strata when water discharge equals to hq | mm/day |
| ATHORN | For the quantification of Potential Evaporation | mm/day$^0$C |
| BETA | Exponent formula for drainage from soil | No unit |
| CEVPL | Evaporation from lakes/ water bodies | mm/day |
| CFLUX | Maximum capillary flow from upper strata to soil moisture zone | mm/day |
| CRITSTEP | Number of time steps for which, the results are accumulated before calculation | No unit |
| ETF | Temperature factor for evaporation | No unit |
| FC | Field capacity | mm |
| HQ | Recession coefficient for the upper soil strata when water discharge is equals to hq | mm/day |
| K0 | Top recession coefficient for upper soil strata. | per/day |
| K4 | Recession coefficient for lower soil strata | per/day |
| KHQ | Recession coefficient for the upper soil strata when water discharge equals to hq | per/day |
| LP | Limit for potential evaporation | No unit |
| PCALT | Elevation correction factor for precipitation | 1/100 m |
| PCALTL | Elevation of the station | m |
| PREC | Precipitation | mm |
| RECSTEP | Depending on the outflow from the soil strata | No unit |
| SOILSTEP | Soil zones will be considered as one zone and only one soil computation will be performed at each time step to save computation time | No unit |
| STF | Used to turn on a set of seasonal factors by which the parameter *athorn* will be multiplied | mm/day$^0$C |
| UZL0 | Lower limit for *k0* recession | mm |

**Validation**

Validation is a process of signifying that a site-specific model is accomplished in making precise predictions periods exterior a calibration period (Refsgaard J. C and Knudsen 1996) [45]. A validation process involves two distinct steps: (a) Validation Check and (b) Post-Check action. The check step uses one or more computational rules to determine if the data is valid. The Post-validation action sends feedback to help enforce validation (Royce. F.L. 2004) [43]. The data series are going to into three sets. The first set of two years for warming the model and the second set of three years for calibration and remaining set for the validation (Fenicia. F *et al*. 2007) [18]. The objective functions are available in the HBV for testing the validity of modeling at the Semrakalwana Catchment with the HBV model. The objective functions used to measure the reliability of the model between calculated and the observed and correlation coefficient $R^2$ (Gitte. B *et al*. 2009) [20].

**Sensitivity Analysis**

'Sensitivity analysis' aims to describe how much model output values are affected by changes in model input values. It explores how changes in the model output can be qualitatively and quantitatively attributed to different change sources (Refsgaard *et al*., 1995) [44], of sensitivity analysis indicate the sensitivity of simulation to uncertainties in the values of input data in the model. Sensitivity analysis attempts to establish how the model depends on the attributed values, structure and assumptions (Fenicia. F *et al*, 1995). It is an important method for testing the quality of a given model, and it is also used for checking the reliability of the analysis (Bardossy. 2008) [6]. It helps in analyzing how sensitive the output is the changes in one input while keeping the other inputs constant. An objective function is used to establish the sensitivity of the parameters.

The objective functions used in this research are BIAS, Root-mean-square error (RMSE), coefficient of determination ($R^2$), Nash-Sutcliffe efficiency (NSE) and Relative error (RE).

In statistics, the BIAS of an estimator is the difference between this estimator's expected value and the true value of the parameter value and true value of the parameter being estimated. An estimator (or) decision rule with zero BIAS is called UNBIASED (Merz. R., *et al*. 2004) [35].

$$\mathrm{BIAS} = \mathrm{abs}\left(\frac{1}{n}\left(\sum_{i=1}^{n}\left[Q_{abs,i} - Q_{prd,i}\right]\right)\right) \qquad \text{Equation 3}$$

Where $Q_{abs,i}$ and $Q_{pred,i}$ are the observed and predicted flow for each time step and

'n' is the number of steps in the simulation period considered.

Root-mean-square deviation (RMSD) or Root-mean-square error (RMSE) is a frequently used measure of the difference between values (sample and population values) predicted by a model (or) an estimator and the values observed (Almorox *et al*., 2004) [2].

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}\left[Q_{abs,i} - Q_{prd,i}\right]^2}{n}} \qquad \text{Equation 4}$$

Where $Q_{abs,i}$ and $Q_{pred,i}$ are the observed and predicted flow for each time step and n is the number of steps in the simulation period considered.

$R^2$ is a statistical measure of how close the data are to the fitted regression line. It is also known as the coefficient of determinate, or the coefficient of multiple determinates for multiple regressions (Nash and Sutcliffe, 1970) [37]. In statistics, the coefficient of determination$R^2$ is a number that indicates the proportion of the variance independent variables that is predictable from the independent variable.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left[Q_{obs,i} - Q_{prd,i}\right]^2}{\sum_{i=1}^{n}\left[Q_{obs,i} - \bar{Q}_{obs,i}\right]^2} \qquad \text{Equation 5}$$

Where, $Q_{abs,i}$ and $Q_{pred,i}$ are the observed and predicted flow for each time step and n is the number of steps in the simulation period considered (Healy, M.J.R. 1984) [27].

The Nash-Sutcliffe model efficiency coefficient (E) is commonly used to assess the predictive power of hydrological discharge models. However, it can also be used to quantitatively describe the accuracy of model outputs for other things than discharge (such as nutrient loadings, temperature, contractions etc.) (Petersen, C.T *et al.*, 1995) [41]

$$\mathrm{NSE} = 1 - \left(\frac{\sum_{i=1}^{n}(Q_{si}-Q_{oi})^2}{\sum_{i=1}^{n}(Q_{oi}-\bar{Q}_{oi})^2}\right) \qquad \text{Equation 6}$$

Where, Qs, Qo, and Qo are, respectively, the simulated flow, observed flow, and average observed flow. Nash-Sutcliffe efficiencies can range from -∞ to 1. An efficiency of 1 (E=1) corresponds to a perfect match between model and observations. An efficiency of 0 indicates that model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero (-∞ < E < 0) occurs when the observed mean is a better predictor than the model.

Essentially, the closer the model efficiency is to 1, the more accurate of the model.

The relative error indicates how good measurement is relative to the size of the thing being measured. The relative approximation error is usually defined as the ratio of the absolute error and actual value (Beven, 2003) [10].

$$\mathrm{RE} = \frac{\sum_{i=1}^{n}(Q_{oi}-Q_{si})}{\sum_{i=1}^{n}Q_{oi}} \qquad \text{Equation 7}$$

Where Qs, Qo, and Qo are, respectively, the simulated flow, observed flow, and average observed flow.

## Results and Discussion

This chapter deals with the results and discussion obtained by adopting the methodology given above. It "Identifying the most sensitive Evapotranspiration routine parameter in an Agriculture watershed by using HBV" the parameter influencing ETp, which using a conceptual model HBV. The model is calibrated, parameter parameterized and range of the parameter is identified to repersent in Table 2. The Objective function is used to find the acceptable range of each parameter influencing the ETp.

**Table 2:** Show parameter used in Initialization the model

| S. No. | Parameters | Initial Values | Lower limit | Upper limit | Sensitivity Minimum | Range |
|---|---|---|---|---|---|---|
| 1 | ALFA | 1 | 0.1 | 3 | NO CHANGE | 1 |
| 2 | ATHORN(mm/dayºC) | 0.166 | 0.0166 | 0.498 | 0.083 to 0.83 | 0.1494 – 0.1826 |
| 3 | BETA | 1.34 | 0.134 | 4.02 | NO CHANGE | 1.026 & 1.474 |
| 4 | CEVPL | 1.15 | 0.155 | 3.45 | NO CHANGE | 1.15 |
| 5 | CFLUX (mm/day) | 1.5 | 0.15 | 4.5 | NO CHANGE | 1.35 & 1.65 |
| 6 | CRITSTEP | 1 | 0.1 | 3 | NO CHANGE | 1 |
| 7 | ETF | -1 | 0.1 | -3 | NO CHANGE | -1 |
| 8 | FC (mm) | 200 | 20 | 1500 | NO CHANGE | 100 & 200 |
| 9 | HQ (mm/day) | 2 | 0.2 | 6 | NO CHANGE | 2 |
| 10 | K0 (per/day) | 1 | 0.1 | 3 | NO CHANGE | 1 |
| 11 | K4 (per/day) | 0.0054 | 0.00054 | 0.0162 | NO CHANGE | 0.0054 |
| 12 | KHQ (per/day) | 0.124 | 0.0124 | 0.372 | NO CHANGE | 0.1364 & 0.1116 |
| 13 | LP | 3 | 0.1 | 1 | NO CHANGE | 0.9 & 1.1 |
| 14 | PCALT | 0.6 | 0.01 | 0.3 | NO CHANGE | 0.09 & 0.11 |
| 15 | PCALTL (m) | 500 | 50 | 1500 | NO CHANGE | 450 & 550 |
| 16 | PREC (mm/day) | 3 | 0.3 | 9 | NO CHANGE | 2.1 |
| 17 | RECSTEP | 1 | 0.1 | 3 | NO CHANGE | 1 |
| 18 | SOILSTEP | 3 | .3 | 9 | NO CHANGE | 3 |
| 19 | STF | 1 | 0.4 | 12 | NO CHANGE | 1 |
| 20 | UZL0 | 1 | 0.1 | 3 | NO CHANGE | 1 |

### Sensitivity analysis for 'athron'

When, *stf* is 1 athron is a correction factor and the acceptable range of the athron has been found be between -10 to +10 of 0.083. Between this range the $R^2$ is found to be maximum, BIAS minimum, RMSE is minimum, NSE maximum and RE minimum.

The below graph shows the difference between objective functions for *'athorn'* parameter. The Figure 3 shows the graph in between Parameter percentage change and Objective function values. There are changes happened in ETp (Evapotranspiration) while using this parameter in the model. In this graph, we also show the $R^{2,}$ RMSE, BIAS, NSE & RE. The objective function value will be minimum at -10% to 10%.

All model parameters could be compared on a standard scale and sensitivity result based on an RMSE measure. In the HBV model formulation, *'athron'* plays a key role in partitioning the effect of ETp.

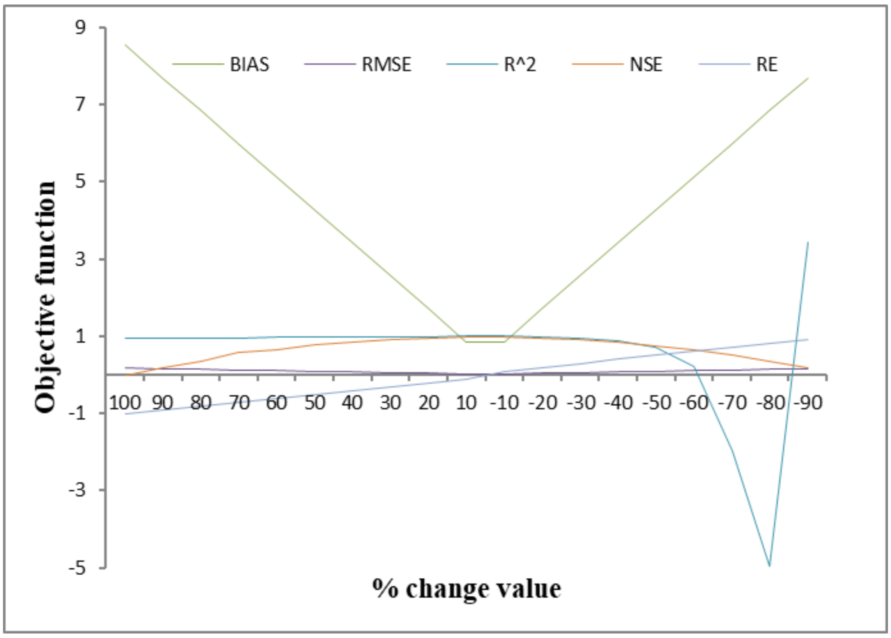


**Fig 3:** Sensitivity analysis for *'athron'*

**Analysis for 'BIAS'**
In statistics, the BIAS of an estimator is the difference between this estimator's expected value and the true value of the parameter value and true value of the parameter being estimated. An estimator (or) decision rule with zero BIAS is called UNBIASED.

**Analysis for 'RMSE'**
Root-mean-square error (RMSE) is a frequently used measure of the differences between values predicted by a model. The RMSD represents the sample standard deviation of the differences between predicted values and observed values. These individual differences are called residuals when the calculations are performed over the data sample that was used for estimation and is called prediction errors.

**Analysis for '$R^2$'**
In statistics, the coefficient of determination denoted $R^2$ or $r^2$ and pronounced "R squared", is a number that indicates the proportion of the variance in the dependent variable that is predictable from the independent variable. $R^2$ Is a statistical measure of how close the data are to the fitted regression line. It is also known as the coefficient of determinate, or the coefficient of multiple determinations for multiple regressions. In statistics, the coefficient of determination $R^2$ is a number that indicates the proportion of the variance independent variables that is predictable from the independent variable.

**Analysis for 'NSE'**
Nash–Sutcliffe efficiency can be used to quantitatively describe the accuracy of model outputs other than discharge. This method can be used to describe the predictive accuracy of other models. Nash–Sutcliffe efficiency can range from −∞ to 0. The Nash-Sutcliffe model efficiency coefficient (E) is commonly used to assess the predictive power of hydrological discharge models (Graham, 2000) [23]. However, it can also be used to quantitatively describe the accuracy of model outputs for other things than discharge. An efficiency of 1 (E=1) corresponds to a perfect match between model and observations. An efficiency of 0 indicates that model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero ($-\infty < E < 0$) occurs when the observed mean is a better predictor than the model.

**Analysis for 'RE'**
The relative error indicates how good measurement is relative to the size of the thing being measured. The relative approximation error is usually defined as the ratio of the absolute error and actual value.

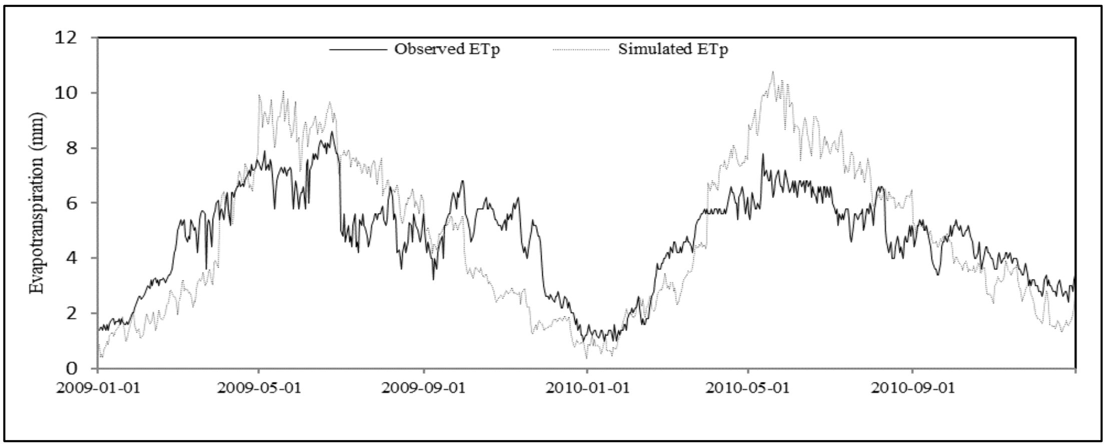


**Fig 4:** Simulation of ETp for model Warming Period 2009-2010.

**Simulation results of the Calibration Period**

The optimum values of the evapotranspiration routine parameters (ALFA, ATHORN, and STF) were determined by considering the coefficient of determining ($R^2$) as high as possible. The selection of the best parameter set was made based on quantitative interpretation. For warming of model (Figure 4) to simulate the evapotranspiration in 2009-2010.

**Table 3:** Acceptable range of the parameters and objective function values range

| S. No | Parameters | Acceptable Range | Objective Function | | | | |
|---|---|---|---|---|---|---|---|
| | | | $R^2$ | RMSE | BIAS | NSE | RE |
| 1 | Athorn | 0.1494 – 0.1826 | 0.998615 to 0.997892 | 0.013996 to 0.013996 | 0.845899 to 0.845898 | 0.989982 to 0.989982 | -0.1 to 0.1 |

Low field capacity (50 mm) suggests a system, which is filled quickly. In this way, water is available for direct runoff. Moreover, a high value of ALFA is needed to capture the quick response of the system. All the parameters represent the characteristics of the catchment. During the calibration, it is seen that *athron* was the most sensitive parameter for evapotranspiration and other parameters have not been changed during model calibration.

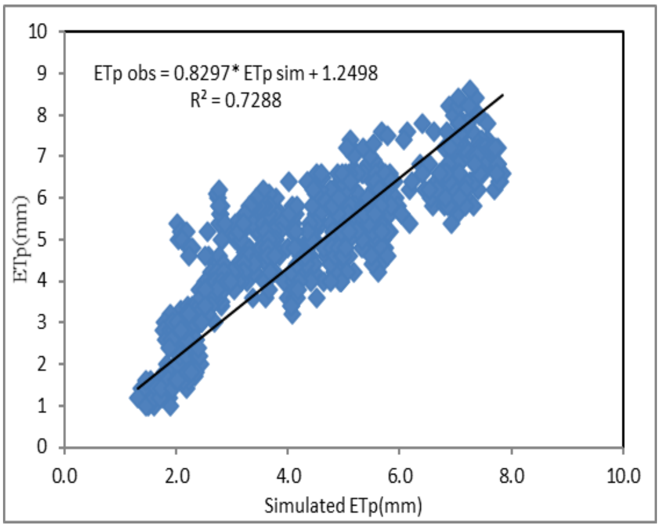


**Fig 5:** Relationship between observed and simulated $ET_p$ by calibrated parameters for 2009-10.

The parameters calibrated are given in Table 3. These parameters were calibrated for the years2009, 2010, 2011, 2014 and 2015. Results of ETp obtained are shown in the figures 5-15. Parameters shown in Table 4. are responsible for the Potential Evapotranspiration.

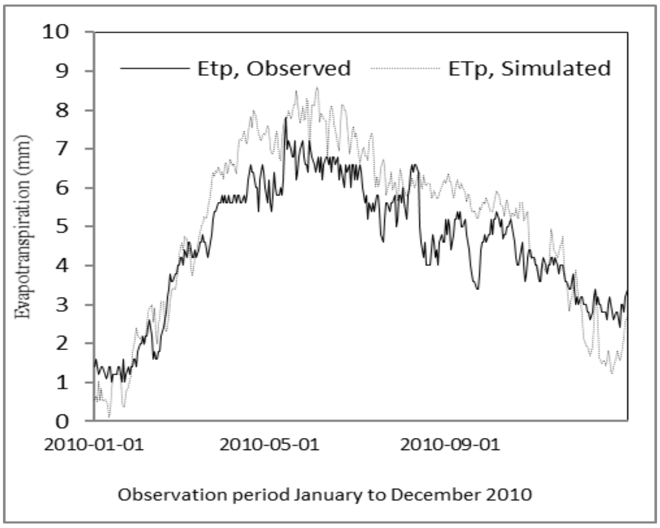


**Fig 6:** Observed and Calibrated ETp for 2010

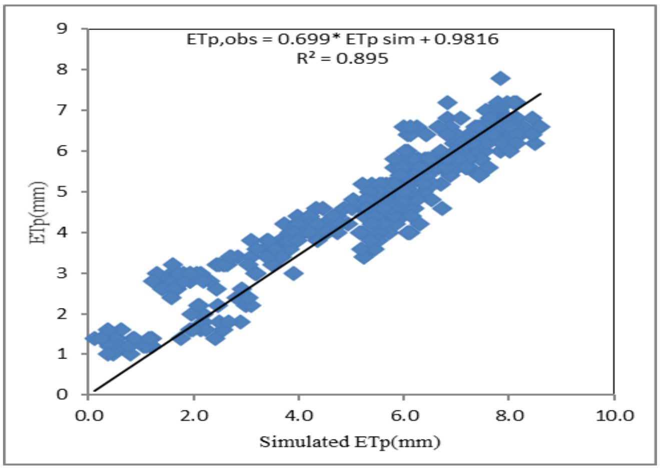


**Fig 7:** Relationship between observed and simulated $ET_p$ by calibrated parameters for 2010

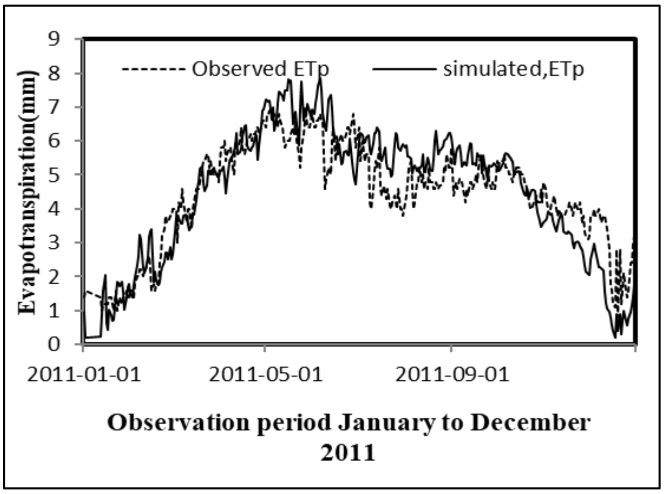


**Fig 8:** Observations and Calibration ETp for 2011

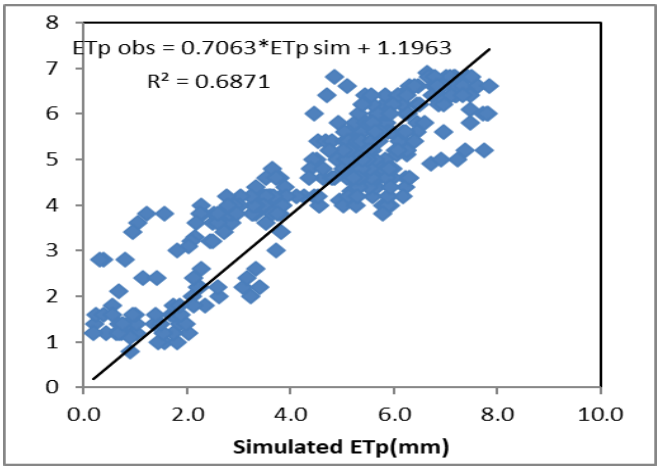


**Fig 9:** Relationship between observed and simulated $ET_p$ by calibrated parameters for 2011.

Simulated values are very high in magnitude compared to the Observed values, so an adjustment has to be done in the simulated values for 2014 & 2015 is to be done in Table 4 and Table 5.

**Table 4:** Contents to be reduced from the simulated ETp values to adjust the rise in magnitude for the simulated ETp for the months of the year.

| Months | ETp values |
|---|---|
| January – March | 2.8 |
| April | 5.8 |
| May | 6.8 |
| June | 7.8 |
| July | 6.8 |
| August - October | 5.8 |

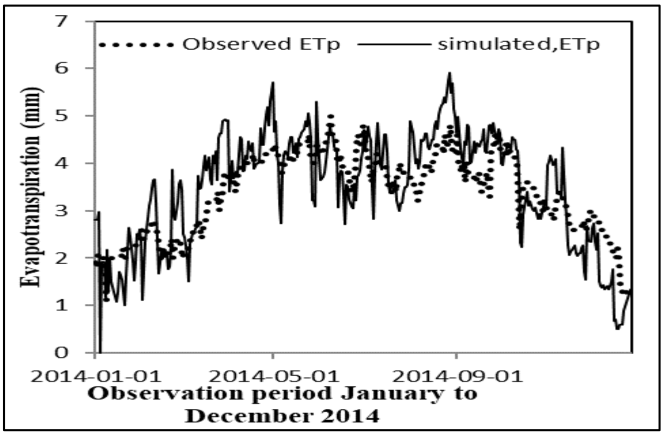


**Fig 10:** Observed and Calibrated ETp for 2014.

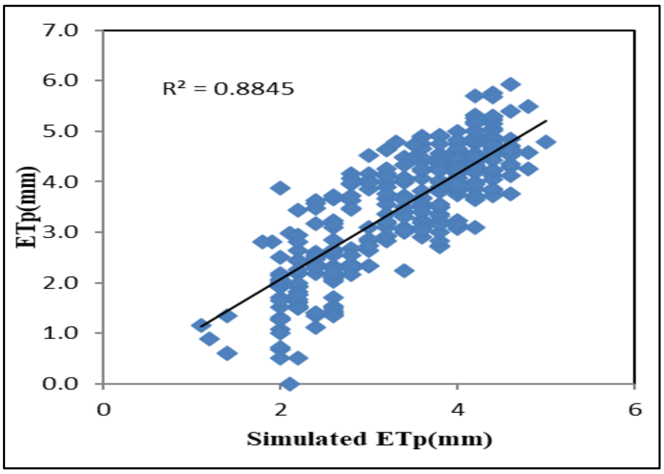


**Fig 11:** Relationship between observed and simulated $ET_P$ by calibrated parameters for 2014

**Table 5:** Contents to be reduced from the simulated ETp values to adjust the rise in magnitude for the simulated ETp for the month of the year.

| Months | ETp Values |
|---|---|
| January – February | 5.5 |
| March | 6.0 |
| April | 6.1 |
| May | 7.3 |
| June | 6.3 |
| July | 7.0 |
| August | 7.9 |
| September – October | 7.3 |
| November | 6.0 |
| December | 5.2 |

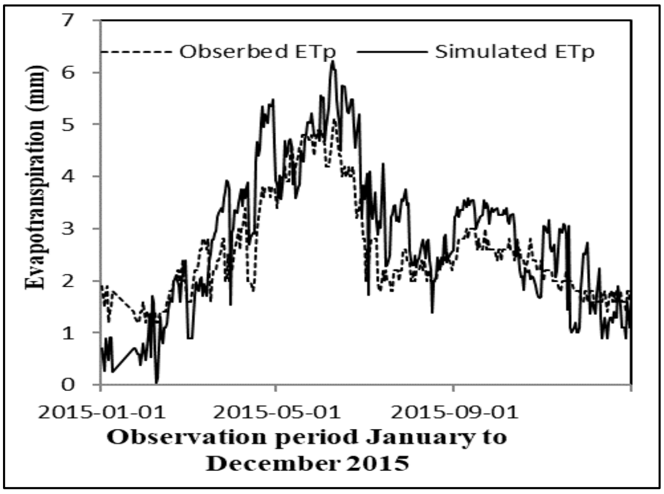


**Fig 12:** Observed and Calibrated ETp for 2015

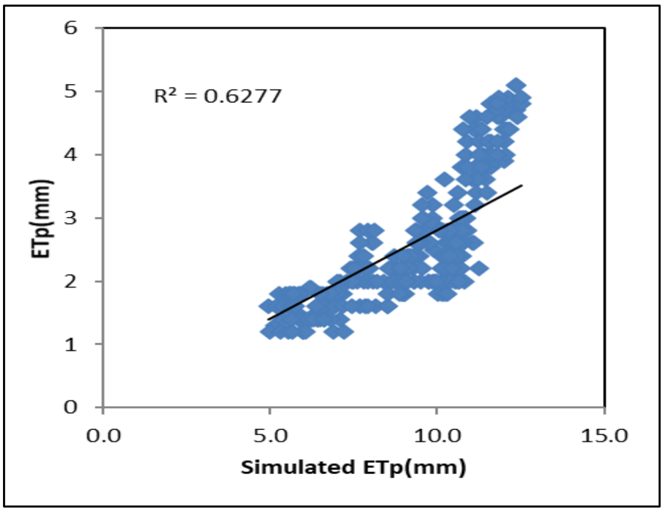


**Fig 13:** Relationship between observed and simulated $ET_P$ by calibrated parameters for 2015.

### Simulation results of the Validation period

The HBV model is developing for Swedish conditions (Jan 1996). However, it does work when data input is provided. The process of the model is used to understand at the village level. All input parameters influencing the total evaporation at the village is carefully parameterized. The model calibrates and validates it on a yearly timescale.

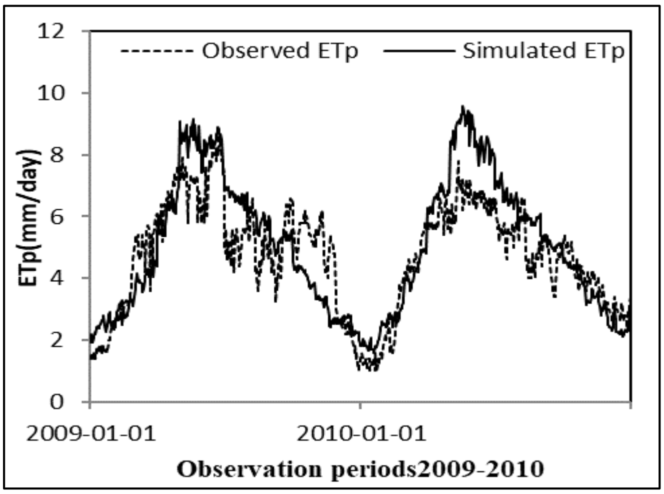


**Fig 14:** Simulation of ETp for model validation Period 2009-2010(athorn=0.083).

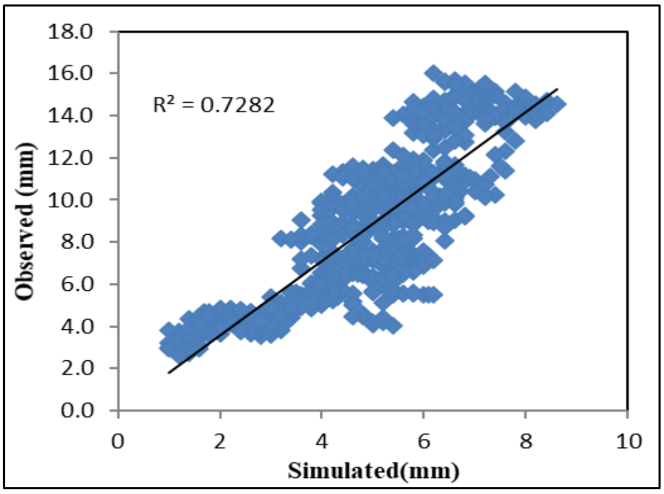


**Fig 15:** Relationship between observed and simulated $ET_P$ by calibrated parameters for 2009-10 (athorn=0.083).

## Discussion

The HBV model was used successfully to model ETp for the study area. Both calibration and validation results show a strong relationship between the simulated and observed $ET_p$ from the study area. The results from the model calibration and validation are shown in Fig. Best results (with best $R^2$=0.895) were attained during the calibration period than the validation period for the basin. These $R^2$ values are shown in Figure 5-15.

A high correlation between observed and simulated $ET_p$ of ($R^2$ =0.895) during the calibration period and ($R^2$ = 0.7288) during the validation period. Figures 14 and 15 show the regression between observed and simulated ETp during calibration and validation periods.

## Conclusion

The use of the HBV model with generalized model parameters has grown unexpectedly fast. In this process a database of model parameters developed from regional model calibration has been very important. Equally important is the access to a consistent database of meteorological data used as input to the model. These two factors have opened new possibilities for nationwide hydrological mapping and many other aspects of large scale hydrological modelling and climate impact studies.

This study evaluated the effects of various parameter scale selections in the HBV model simulation. A comparison of hydrological simulation using average parameter values from short temporal calibration and using manual optimization was also conducted. We can obtain the following conclusions:

1. In Semrakalwana catchment hydrological modelling using the HBV model, athorn are the most sensitive parameters for ETp (Evapotranspiration) in this catchment.
2. Powerful validation is essential for further development of a model for two reasons: identification of weak parts and evaluation of improvements.
3. In some parameters, the RMSE and $R^2$ values will not change i.e., constant 1 and 0 respectively. The BIAS value will be changing, when the parameter % value decreases and increases.
4. BIAS, RMSE, $R^2$, NSE, and RE the objective function values are mostly minimum at -10% and 10% of parameter percentage change range from 0.83 to 0.0083.

This study presents the potential the HBV model to quantify the water balance components in semi arid region. This study presents a calibrated and validated value of potential evapotranspiration on a daily basis and a better way of selecting parameters for parameterization in different watersheds. The calibrated values represent the hydrology of the small agricultural watershed. The study revels that being an agricultural watershed the athron is the most sensitive parameter indicating that the land in the watershed is covered with vegetation. The value of athron for Samrakalwana watershed can vary between 10% +,- 0.083 only. The R2 remains maximum while all the other objective functions BIAS minimum, RMSE is minimum, NSE maximum and RE remain minimum.

## Acknowledgement

This study was conducted through the memorandum of Understanding between the Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Allahabad, India and the Swedish Meteorological and Hydrological Institute (SHMI). The authors duly acknowledge the grant received by Uttar Pradesh Council of Agricultural Research, Luc-know, Uttar Pradesh for funding this research under the project ‘‘Farming System Based Water Budgeting for Semrakalwana Village at Allahabad’’. The cooperation received by the farmers of Semrakalwana Village in collection of data is also acknowledged.

## Data Availability Statement

Some or all data, models, or code generated or used during the study are available in a repository online in accordance with funder data retention policies (provide full citations that include URLS or DOIs)

All the data in this publication is available on Digital Object Identifier (DOIs): 10.6084/m9.figshare.8796113

## References

1. Abebe NA, Ogden LF, Pradhan RN. “Sensitivity and uncertainty analysis of the conceptual HBV rainfall–runoff model: Implications for parameter estimation”. Journal of Hydrology. 2010; 389:301-310.
2. Almorox J, Benito M, Hontoria C. “Estimation of monthly Angstrom-Prescott equation coefficients from measured daily data in Toledo, Spain”. Renewable Energy. 2004; 30:931-936.
3. Andreassian V, Perrin C, Michel C. “Impact of imperfect potential evapotranspiration knowledge on the efficiency and parameters of watershed models”. Journal of Hydrology. 2004; 286(1-4):19-35.
4. Andreassian V, Michel C. “Crash tests for a standardized evaluation of hydrological models”. Hydrol. Earth Syst. Sci. 2009; 13:1757-1764.
5. Arheimer B. “Riverine Nitrogen - Analysis and Modeling under Nordic Conditions. Doctoral Thesis, Department of Water and Environmental Studies”. Linkoping University, Linkoping, 1998, 66.
6. Bardossy A, Singh SK. “Robust estimation of hydrological model parameters”. Hydrol. Earth Syst. Sci., 2008; 12:1273-1283.
7. Bergstrom S. “The HBV model, computer models of watershed hydrology”. Water Resources Publications, 1995.
8. Bergstrom S. “The HBV Model: Its Structure and Applications, Swedish Meteorological and Hydrological

Institute (SMHI), Hydrology", Norrkoping, 1992, 35.
9. Bergstrom S. "Computer Models of Watershed Hydrology". Water Resources Publications, Highlands Ranch, Colorado, USA, 1995; 443-476.
10. Beven KJ. "Rainfall-runoff modelling", The Primer, Jhon Wiley and Sons, Chichester, UK, 2003.
11. Brandt T, Dieterich M, Danek A. "Vestibular cortex lesions affect the perception of verticality". Ann Neurol. 1994; 35(4):403-12.
12. Boyd B. "A Procedure for Estimating Total Evapotranspiration using Satellite-Based Vegetation Indices with Separate Estimates from Bare Soil, 2007.
13. Brigitte M. "Evapotranspiration and terrestrial water storage in the global climate system in this Terrestrial water storage (TWS) and evapotranspiration (ET), 1979.
14. Dance N. "Kajian Perubahan Karakteristik Hdirologi Daerah Aliran Sungai Cikapundung Hulu Menggunakan Model HBV96. B. S. Dissertation". Parahyangan Catholic University, Bandung (in Indonesian), 2012.
15. Das T, Ardossy B, Zehe AE. "Comparison of conceptual model performance using different representations of spatial variability". J. Hydrol. 2008; 356(1e2):106e118. http://dx.doi.org/10.1016/j.jhydrol.2008.04.008.
16. Denis DM, Kumar M, Srivastava S, Suryavanshi S, Denis AF, Singh R. "A high resolution assessment of water footprint of wheat to understand yield and water use heterogeneity". Water resources management. 2016; 30(8):2641-2649.
17. Doherty J, Johnston JM. "Methodologies for Calibration and Predictive Analysis of a Watershed Model". Journal of the American Water Resources Association (JAWRA). 2003; 39(2):251-265.
18. Fenicia F, Solomatine DP. "Soft combination of local models in a multi-objective framework". Nat. Hazards Earth Syst. Sci. 2007; 10:1238-1246.
19. Gan TY, Dlamini EM, Biftu GF. "Effects of model complexity and structure, data quality and objective functions on hydrologic modelling". J. Hydrol. 1997; 192(1e4), 81e103. http://dx.doi.org/10.1016/S0022-1694(96)03114-9.
20. Gitte B, Jonas G, Hanna G. "The German Federal institute of hydrology calibrated HBV rainfall-runoff model for the river Rhine". Hydrol. Earth Syst. Sci., 2009; 12:1156-1162.
21. Graham LP. Modeling runoff to the Baltic Sea". Ambio. 1999; 28:328-334.
22. Grillakis MG, Tsanis IK. "Application of the HBV hydrological model in a flash flood case in Slovenia. Nat". Hazards Earth Syst. Sci., 2010; 10:2713-2725.
23. Graham LP. "Large-scale hydrological modeling in the Baltic basin "Division of Hydraulic Engineering, Dept of Civil and Environmental Engineering, Royal Institute of Technology, Report TRITA-AMI Ph D 1033, Stockholm, 2000.
24. Habtom BK. "Evaluation of Climate Change Impact on Upper Blue Nile Basin Reservoirs". Journal of Hydrology. 2009; 165:356-363.
25. Harlin J. Development of process oriented calibration scheme for the HBV hydrological model". Nordic Hydrol. 1991; 22:15-36.
26. Hargreaves GL, Samani ZA. Reference crop evapotranspiration from temperature". Appl. Engg. Agric. Trans., ASAE. 1985; 1(2):96-99.
27. Healy MJR. "The Use of $R^2$ as a Measure of Goodness of Fit". J.R. Statist. Soc. 1984; A147:608-609.
28. Hundecha Y, Bardossy A. "Modelling of the effect of land use changes on the runoff generation of a river basin through parameter regionalization of a watershed model". Journal of Hydrology. 2004; 292:281-295.
29. Jan S. "Estimation of parameter uncertainty in HBV model". *Nordic Hydrology*, 1996; 28(4, 5):247-262.
30. Jensen ME. "Estimating evaporation from water surfaces". In Proceedings of the CSU/ARS Evapotranspiration Workshop, Fort Collins, CO, USA, 2010.
31. Lindstrom G. "A simple automatic calibration routine for the HBV model". Nordic Hydrology. 1997; **28**(3):1997, 153-168.
32. Lal MP, Martijnetal BJ. "Calibration of a semi-distributed hydrological model using discharge and remote sensing data". IAHS Publ. 2009, 333.
33. Lindstrom L, Johansson B, Persson M, Gardelin M, Bergstrom S. "Development and test of the distributed HBV-96 hydrological model". J. Hydrol. 1997; 201(1e4), 272e288. http://dx.doi.org/10.1016/S0022-1694(97)00041-3.
34. Mishra H, Denis DM, Suryavanshi S, Kumar M. "Hydrological simulation of a small ungauged agricultural watershed Semrakalwana of Nortern India". Applied Water Science, 2015. DOI 10.1007/s13201-017-0531-7.
35. Merz R, Bloschl G. "Regionalization of catchment model parameters". J Hydrol. 2004; 287(1):95e123. http://dx.doi.org/10.1016/j.jhydrol.2003.09.028.
36. Miha P, Mira K. "The implementation of the HBV model on the save river basin, 2006.
37. Nash JEJ, Sutcliffe V. "River flow forecasting through conceptual models". Part I. A discussion of principles, J Hydrol. 1970; 10:282-290.
38. Paul JD, Susan EW, Richard JM. Ocean Salinities Reveal Strong Global Water Cycle Intensification during 1950 to 2000". Journal of Science. 2012; **336**(6080):455-58.
39. Penman HL. "Evaporation: an introductory survey, Netherlands". Journal of Agricultural Science. 1956; 4:9-29.
40. Peter E. "Revisiting the Thornthwaite and Mather water balance, 2007.
41. Petersen CT, Jorgensen U, Svendsen H, Hansen S, Jensen HE, Nielsen NE. "Parameter assessment for simulation of biomass production and nitrogen uptake in winter rape". Eur. J Agron. 1995; 4(1):77-89.
42. Renthlei Z, Denis DM, Kumar R, Kumar M, Srivastava S, Denis A *et al*. "Irrigation performance Assessment of a canal irrigated area: A case study of Samrakalwana village in Allahabad." J Indian Water Resour. Soc. 2017; 37 (N4):17-24.
43. Royce FL. An evaluation of reference evapotranspiration models in Louisian, 2004.
44. Refsgaard J, Storm B. "Computer Models in Watershed Hydrology". Water Resources Publication, 1995, 809-846.
45. Refsgaard JC. "Distributed Physically-Based Modeling of the Entire Land Phase of the Hydrological Cycle". Distributed Hydrological Modeling. Water Science and Technology Library. Kluwer Academic Publishers, Dordrecht, 1996. 55-67.
46. Sanata W. "Analisis Neraca Air Harian DAS Cikapundung Hulu Menggunakan Model HBV96".

*Parahyangan* Catholic University, Bandung (in Indonesian), 2013.
47. Singh VP, Woolhiser DA. "Mathematical Modeling of Watershed Hydrology". J Hydrol. Eng. ASCE **7**(4), 2002, 269-343.
48. Seibert J, Vis MJP. "Teaching hydrological modeling with a user-friendly catchment-runoff-model software package". Nat. Hazards Earth Syst. Sci. 2012; 10:2713-2725.
49. Steven RR, Doddi Y. "Effects of temporal variability on HBV model calibration". Journal of Hydrology. 2015; 295:153-160.
50. Singh VP. "Computer Models of Watershed Hydrology". Water Resource. Publication, Colorado, USA, 1995.
51. Tamm T. "Effects of meteorological conditions and water management on hydrological processes in agricultural fields: parameterization and modelling of Estonian case studies". PhD Dissertation for the Department of Civil and Environmental Engineering, Helsinki University of Technology, 2002.
52. Teixeira AHD. "Measurement and modeling of evapotranspiration to assess agricultural water productivity in basins with changing land use patterns, 2008.
53. Teng-Fei, Jian-Hua Si, Feng Qi, Hai-Yang Xi. **"**Simulation of Pan Evaporation and Application Estimate the Evaporation of Juyan Lake, Northwest China under a Hyper-Arid Climate". Journal of Water science. 2017; 9:952.
54. Uhlenbrook S, Mmohamed Y. "Analyzing catchment behavior through catchment modeling in the Gilgel Abay, Upper Blue Nile River Basin, Ethiopia". Hydrol. Earth Syst. Sci. 2010; 14:2153-2165.
55. Vanderlinden K, Giraldez JV, Van M. "Assessing reference evapotranspiration by the Hargreaves method in Southern Spain". J Irrig. Drain. Eng. ASCE. 2004; 129(1):53-63.
56. Walker JP. "Evaluation of energy balance, combination, and complementary schemes for estimation of evaporation" (IAHS Publ. 2011). 2011, 344.
57. Yang A. "Three evapotranspiration (ET) estimation methods included in the Daisy model, 2010.