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Research Paper

Understanding Sensitivity of the Soil Moisture Routine Parameters using Integrated Hydrological Modelling System (HBV) in a Small Semi-Arid Agricultural Watershed

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ABSTRACT

Hydrologic processes and their principles are universal. However, the magnitude and impact of hydrological parameters influencing these processes vary along with space and time. Researchers since several decades are in the process of understanding and simulating them. One of such simulation is through the Hydrologiska Byrans Vattenbalansavedlning (HBV) model developed at the Swedish Meteorological and Hydrological Institute (SMHI) Stuttgart, Germany. This work explains how this model will perform in semi-arid conditions to understand the most sensitive parameter influencing soil moisture, among all and calibrate their optimum values. The watershed chosen is small agricultural watershed in a semi-arid region with fertile soil and limiting water. The study revealed that the "LP" a soil moisture value above which the evapotranspiration reaches its peak is the most sensitive. Thereafter parameters "fc", "athron", "$_{\beta}$" "cflux", "pcalt", "perc", and "khq" follow suit. These parameters are sensitive within -10% and +10% of their optimum values. Other parameters as prec", "cevpl", "alfa", "hq", "recstep", "soilstep", "stf, "uzlo" have new values that are not similar to the original values as recommended. All values have been tested for their one at a time sensitivity using the objective functions values of the root mean square error , BIAS, Relative error, R^2 and Nash Sutcliffe efficiency coefficient. This indicates that the model does perform well in semi-arid conditions to simulate the Soil Moisture Routine of an agricultural watershed. It is recommended that the HVB can be used in semi-arid conditions for successfully simulating the Soil Moisture processes.

Keywords: HBV; Semi –arid; Sensitivity analysis; Objective function.

INTRODUCTION

Soil moisture is the water that is held in the spaces between soil particles and is a very important factor in managing irrigated farms (Grayson et al., 1998). Soil moisture includes two main components that are surface soil moisture and the root zone soil moisture (Arheimer, 1998). The component of soil moisture in the hydrologic cycle is significant. It controls the exchange of water and energy fluxes between the land, atmosphere and vegetation (Dickinson et al., 2004). It is the major component in the soil in relation to plant growth. Soil water dissolves salts and nutrients that makes up the soil solution, which is an important medium for supply of nutrients to growing plants. The absorption of water by plants is optimum at optimum soil moisture .However not all the water, in the soil is available to plants. Much of water remains in the soil as a thin film (Royce, 2004). It also regulates the soil temperature (Rogers et al., 2014).

In this research, the Hydrologiska Byrans Vattenbalansavedlning (HBV) model developed at the Swedish Meteorological and Hydrological Institute (SMHI) Stuttgart, Germany in 1972, is used to identify the most sensitive soil routine parameters in a small agricultural watershed. It tries to understand some actual catchment behaviour through the manual calibration process. Previous studies conducted upon this watershed have indicated that the overall irrigation performance is not satisfactory. The supply and demand of irrigation water is not met and with a recommendation of water user association. The objective of this study is to model the most sensitive parameters influencing soil moisture in an agricultural watershed using HBV and to find the optimum values of parameters influencing them. Looking into the above considerations a study of parameters influencing soil moisture in the watershed was undertaken to find the most sensitive parameter influencing soil moisture.

MATERIALS AND METHOD

The study area, a watershed named Samrakalwana with an area of 9.9 km^2, is in Prayagraj 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 annual water balance components averaged over a time period of sixteen years of the watershed were found to be as rainfall (1066 mm), evapotranspiration (764.5 mm), surface runoff (184.74 mm) and groundwater as 88.53mm (Mishra et al., 2017). In this catchment, the soil is mostly clay loam, sandy loam and loam. The major crops grown in this watershed are wheat and paddy followed by pulses and vegetables. However, only 66% of area is having sufficient irrigation or moisture. Rest of the areas are having deficit soil moisture (Renthlei, 2017).

HBV is a conceptual hydrological model and quantifies runoff under climate conditions especially in Scandinavian countries. It was initially developed at the Swedish Meteorological and Hydrological Institute (SMHI) Stuttgart, Germany in the early 70's to assist hydropower operation by providing hydrological forecasts (Bergstrom, 1995). HBV model has been applied in more than 40 countries all over the world (Lindstrom, 1997). This model has been used in different climatic conditions across the globe. This model has been applied for scales ranging from lysimeter plots to the entire Baltic Sea drainage basin (Graham, 2000). The model includes processes for ground water recharge, snow routine, soil routine, actual evaporation and runoff generation routine called the response routine.

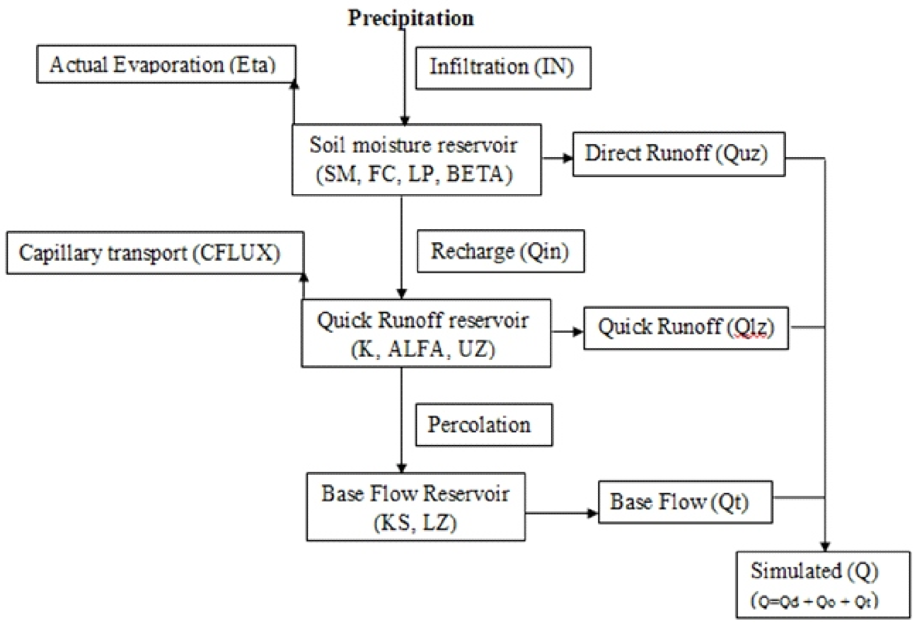

Fig. 1 Flow diagram represents the process and structure of the HBV model.

These are simulated as the functions of actual water storage. The HBV model is set up using hourly hydro-meteorological data. In this model, input data used is rainfall, air temperature, potential evapotranspiration and land cover and discharge are also needed for the validation and calibration (Fig.1). Further, the model is used as a semi-distributed model by dividing the catchment into sub-basin (Andreassian et al., 2004). Each sub-basin is then divided into zones according to altitude, lake area and vegetation. Model is used for flood forecasting in the Nordic countries and many other purposes, such as spillway design floods simulation (Bergstrom et al., 1992), water resources evaluation (Brandt et al., 1994), nutrient load estimates (Arheimer, 1998) etc.

Model Calibration and Validation

The input data was for a period of 16 years, January 2000 to March, 2016. Data from 2000 to 2003 was used for warming the model, while from 2004 to 2010 was used for calibration and the rest for validation. Observed and measured parameters, given in Table 1 and representing the processes influencing the hydrologic cycle, are used for calibration. For a few parameters that were not the best parametric values through a values was used according to Habtom (2009). Initially, simulated data values were visually compared with the corresponding observations (Brath et al., 2006). If the simulation is not satisfactory, the parameter value is changed and the model is run again. The simulation was repeated until a satisfactory solution was obtained. An important part of the hydrological modelling process was to establish that the results that were simulated by the model with te physical system of the watershed to be represents and the main parameter are used in this model are discussed below in Table 1.

Sensitivity Analysis Methodology

Sensitivity analysis is done to understand the influence of the extent of negative or positive change in the optimum value of a parameter on the output. Sometimes a slight change in a parameter triggers a large change in the output values and vice versa. Thus it is said that, that this parameter is highly sensitive to the output or otherwise. These changes in values of a parameter influence the output within a certain range. The highest positive range value is called the highest limit and the lesser one is considered as the lowest limit. The values of the parameters are advised to be simulated within this range. Going beyond these limits for simulation is not recommended. In the process of estimation of soil moisture, all concerned parameters do influence each other and hence require to be recommended with the range of their values, they least influence the output. This is understood better through Objective Functions. Each Objective Function explains the acceptance level or limits of the range of the particular parameter upon the desired or actual output. The Objective Functions used here are explained below. Final the lower and upper limits of the parameter is considered beyond which it does not influence the results. Hence it is called that the parameter with least influence the results within these limits and as we move beyond them, the results are open to errors and the results will be subjected to uncertainties.

Objective Function

The objective functions used in this research BIAS, RMSE, R^2, NSE, RE.

BIAS

In statistics, the BIAS is an estimator and the difference between this estimator's expected value and true value of the parameter value is represent the true value of the parameter being estimated. An estimator value of zero is called UNBIASED.

$$BIAS = abs\left(\frac{1}{n}\left(\sum_{i=1}^{n}\left[Q_{obs,i} - Q_{prd,i}\right]\right)\right) \quad (1)$$

Where, $Q_{obs,i}$ 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.

Table 1 : List of parameters representing the processes and their units

Parameter	Parameter descriptions	Unit
*"ALFA"**	This parameter explains the non-linearity and it is typically in the order of 1. Generally it is not calibrated. It is modelled to fit higher peaks in a hydrograph. The higher the value, the higher the peak is and faster the recession. The quicker the recession the faster the release of water from the system. Thus reducing the soil moisture. Generally the higher limits are 1.5.	mm/day
ATHORN*	This parameter is used in the model to calculate the Potential Evapotranspiration. The condition is that it has to be more than zero and begins with a minimum value of 0.2	mm/ day^{0}C
β*	It is an empirical coefficient influencing the ratio of discharge to rainfall exponentially. It controls the soil moisture storage from each millimetre of rainfall.	No unit
CEVPL*	It is the general evaporation correction factor used for the correction of the specific input potential evaporation values for lake zones or water bodies.	mm/day
CFLUX*	Represents the maximum capillary flow from upper soil layers to the lower soil moisture zone.	mm/day
CRITSTEP*	It is the number of time steps for which, the results are accumulated before calculation	No unit
ETF*	It is the temperature factor for evaporation	No unit
FC*	The field capacity and denotes the maximum soil moisture storage in the watershed.	mm
HQ*	It is a high flow level at which the recession rate is assumed.	mm/day
KHQ*	It is the recession rate followed by the high flow level assumed by the HQ.	per/day
K0*	Top recession coefficient for upper soil strata.	per/day
K4*	Recession coefficient for lower soil strata	per/day
LP*	It is a soil moisture value above which evapotranspiration reaches its potential value.	No unit
PCALT*	It is the lapse rate for precipitation and is applied to adjust to the concerned altitude. This value can be different for high altitudes and glaciers.	1/100 m
PCALTL*	It is the highest altitude for which the parameter PCALT is used.	m
PREC*	The weighted mean of percolation of several stations in the watershed of the single precipitation value of a small watershed.	mm
RECSTEP*	It is the number of internal computation steps in the routine during a day.	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*	It describes the seasonal variation. It acts like a switch used to turn on a set of seasonal factors by which the parameter *athorn* will be multiplied.	No unit
UZL0*	Lower limit for the recession coefficient of the top layer.	mm
* IHMS Integrated Hydrological Modelling System Manual Version 6.3 (2013).		

Root-Mean-Square Error (RMSE)

It is a measure to differentiate between values simulated and observed.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left[Q_{obs,i} - Q_{prd,i}\right]^2}{n}} \tag{2}$$

Where $Q_{obs,i}$ 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.

Coefficient of Determination (R^2)

It is also known as the coefficient of determinate, or the coefficient of multiple determinates for multiple regressions (Nash and Sutcliffe, 1970). In statistics, the coefficient of determination R^2 is a number that indicates the proportion of the variance in dependent variables that is predictable from the independent variable.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left[Q_{obs,i} - Q_{prd,i}\right]^2}{\sum_{i=1}^{n}\left[Q_{obs,i} - \bar{Q}_{obs,i}\right]^2} \tag{3}$$

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.

Nash-Sutcliffe Model Efficiency Coefficient (NSE)

It is used to quantitavely describe the accuracy of model outputs for other things than discharge (such as nutrient loadings, temperature, contractions etc.)

$$NSE = 1 - \left(\frac{\sum_{i=1}^{T}(Q_{si} - Q_{oi})^2}{\sum_{i=1}^{T}(Q_{oi} - \bar{Q}_{oi})^2}\right) \tag{4}$$

Where Qs is the simulated flow and Qo is the observed flow.

Nash-Sutcliffe efficiencies can range from -∞ to 1. An efficiency of 1 is considered 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, where as an efficiency less than zero ($-\infty < E < 0$) occurs when the observed mean is a better predictor than the model. Essentially, the model efficiency is closer to 1, then more accurate of the model.

Relative Error (RE)

Relative error gives an indication of how good a measurement is relative to the size of thing being measured. The relative approximation error which is usually defined as ratio of the absolute error and actual value.

$$RE = \frac{\sum_{i=1}^{n}(Q_{oi} - Q_{si})}{\sum_{i=1}^{n} Q_{oi}} \tag{5}$$

Where Qsi and Qoi are, the simulated flow and observed flow. It is expected that the value of NSE and R^2 be close to 1.0 while inversely the values of RE and RMSE should be as close to Zero.

RESULTS AND DISCUSSION

The process involving simulation of soil moisture using HBV model and is represented in two zones. First in the soil zone and the sink/ reservoir. The upper zone is responsible for the fast runoff for a rain event and the lower is active post rainfall. The moisture and water exchange is given in the Fig. 1. Initial simulations do not exhibit the extent of inter dependency of the parameters listed in Table 1. They also do not contain themselves within the range of values as per the recommendation by the SHMI. This is due to fact that this model was developed according to the Swedish conditions. The climatic conditions in this agricultural watershed is very different as it falls in semi-arid zone with maximum summers temperatures around 47°C and in winters around 2 °C. The calibrated values are sans their sensitivity analysis and are given in Table 2. The values given in Table 2 are non-automatic calibrated values and represent the best fit as compared with the concerned Objective Functions.

Table 2: The optimum Soil Moisture Routine parameters and their response to Objective Functions.

Sl. No	Parameters	Optimum Range	Objective Function				
			R^2	RMSE	BIAS	NSE	RE
1	ALFA	1	1	0	0.003023	1	0.000064
2	FC (mm)	180- 200	0.97	0.02	0.96	0.99	0.10
3	ATHORN	0.1494 – 0.1826	0.972906- – 0.970662	0.018773- 0.018897	0.852797- 1.044104	0.991386- 0.987087	0.092738- -- -----0.11362
4	β	1.026-1.474	1	0	0.01769- 0.024018	0.999996- 0.999993	-0.00192- 0.002614
5	CEVPL	1.15	1	0	0	1	0
6	CFLUX (mm/day)	1.35- 1.65	1	0	0.00443- 0.006485	1	-0.00048- 0.000706
7	CRITSTEP	1	1	0	0	1	0
8	ETF	-1	1	0	0	1	0
9	HQ (mm/day)	2	1	0	0	1	0
10	K0 (per day)	1	1	0	0	1	0
11	K4 (per day)	0.0054	1	0	0	1	0
12	KHQ	0.1116- 0.1364	1	0	0.001276- 0.000162	1	0.000139- -1.00008
13	LP	0.9- 1.1	1- 0.966644	0- 0.20851	0- 0.937902	1- 0.98958	0- 0.10205
14	PCALT	0.09- 0.11	1	0	0.380678- 0.376696	0.998286- 0.998316	0.041392- -0.04103
15	PCALTL	450-550	1	0	0.590304- 0.574487	0.995946- 0.996007	0.063662- -0.06318
16	PERC	2.1	1	0	0	1	0
17	RECSTEP	1	1	0	0	1	0
18	SOILSTEP	3	1	0	0	1	0
19	STF	4	1	0	0	1	0
20	UZL0	1	1	0	0	1	0

Sensitivity Analysis

The accepted range of the individual parameter used in the HBV model to compute the soil moisture is given in Table 2. These parameters are tested for sensitivity using Objective Function. It is interesting to know how these parameters behave in an agricultural watershed and not in Scandevidian conditions.

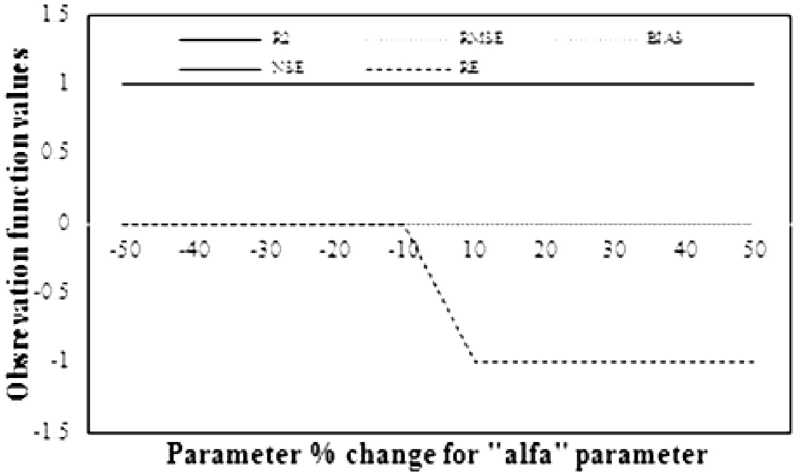

Fig. 2a. Sensitivity analysis for parameter 'alfa'

As per the recommendation by the modellers the parameter “alfa” with a unit mm/day, has a value of 1 and needs no calibration. The same was tested within a minimum and maximum range of 1 and 3, with initial value as 1. It is observed that any increase or decrease in this parameter does not influence the output hence it is concluded that this value is least sensitive and can be kept as “1”. Any increase or decrease of this value does not influence the moisture content in the lower and upper layers of the watershed. Since this an agricultural watershed, moisture from the upper layer moves into the lower while retaining moisture in its layers within its field capacity. The sensitivity results are seen in Fig. 2a. It is insensitive to all Objective Functions except BIAS and RE where it almost tends to zero, referring to its insensitivity.

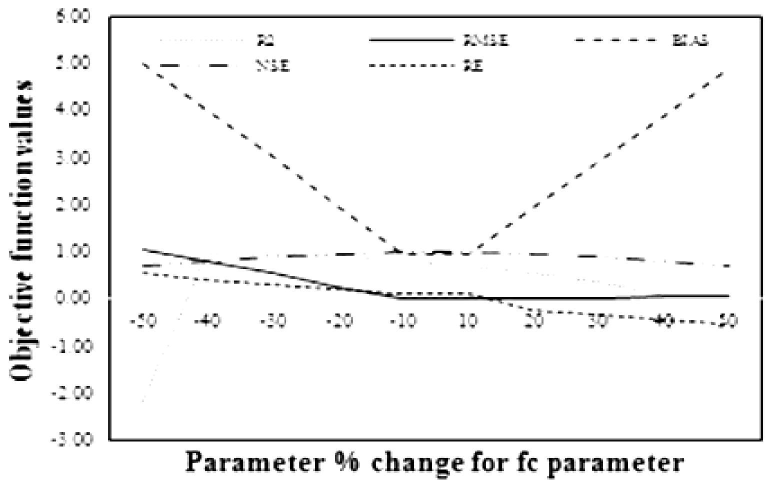

Fig. 2b. Sensitivity analysis for parameter 'fc'

The parameter "FC" is the soil moisture routine. Thus the processes in the soil system is the process to be processes in the model. It represents the first layer or strata of soil on which the rainfall falls. Soil moisture refers to field capacity and denotes the maximum soil moisture storage in the watershed. A low FC depicts that less water is available in the watershed for the use of crops and hence results in moisture stress. It varies from soil to soil and land use and land cover. In this study the sensitivity of this parameter was tested with an initial value of 200. Further the lower limit was considered as 20 and the upper limit as 600. The results show that this parameter can be calibrated in this agricultural watershed only between 180 and 200. This shows that this watershed has high moisture potential and can store moisture. The moisture stress in the watershed is minimum and moisture is available of evapotranspiration. Any value beyond these indicate their influence upon the soil moisture. The sensitivity of this parameter is seen in Figure 2b. This can be seen in the Table 2. Its sensitivity can be understood through R^2 and BIAS.

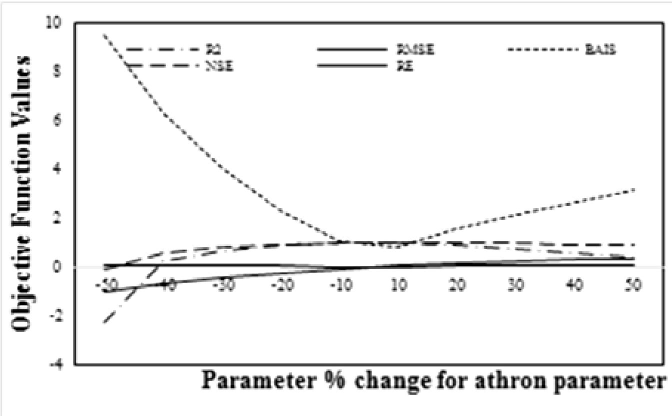

Fig. 2c. Sensitivity analysis for parameter 'athron'

The parameter ATHRON with unit mmm/day°C is used when the model is to calculate the Potential Evapotranspiration using Thornwait method. According to the Swedish conditions its minimum value is 0.15 and maximum 0.3. It is an important parameter that influences the monthly seasonal variation upon the potential evapotranspiration as influenced by the climate. However in this part of the globe it is to take care of the variations due to the semi-arid conditions. The initial values for understanding it upper and higher limits were taken as 0.166. The lower limits were at 0.016 with upper limits as 0.498. The sensitivity of ATHRON can be seen in the Objective Function in BIAS, where it was highly sensitive beyond a range of 0.1494 and 0.1826. The sensitivity results are seen in Fig. 2c.

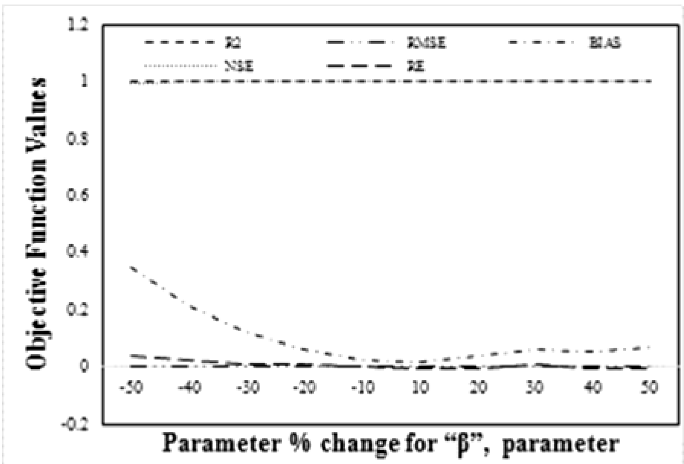

Fig. 2d. Sensitivity analysis for parameter '"β", '

"β", influences the contribution to the response function or the soil moisture variation in storage from each unit depth (mm) of the rainfall. An increase in "β", leads to more infiltration in the soil and less contribution to runoff. Hence "β", drains moisture exponentially from the soil. In this watershed the sensitivity of this parameter is tested within the range of 0.13 and 4.02 with initial value of 1.34. The sensitivity analysis profile is given in Figure 2d. This sensitivity of this parameter can be observed in BIAS as per quantification in Table 2.

For frozen water bodies "cevpl" is considered as 1. However in semi-arid areas like this agricultural watershed, the temperature does not go to sub-zero, such as to freeze the water. Since the watershed has a high "fc" value along with a low "β", the ponds are filled with water. In the watershed out of fourteen ponds only three are dried due to the using the water for Zaid crops. Also 60% of the watershed is irrigated by the canal (Mishra et al., 2017; Sharma et at., 2019; Denis et al., 2017). Due to this water remains in the soil layers throughout the year. The initial value of the parameter is 1.15 and the lower and upper limits are 0.155 and 3.45. The sensitivity analysis results show that any increase or decrease in these values do not influence the output. Hence this can be considered as a non-sensitive parameter.

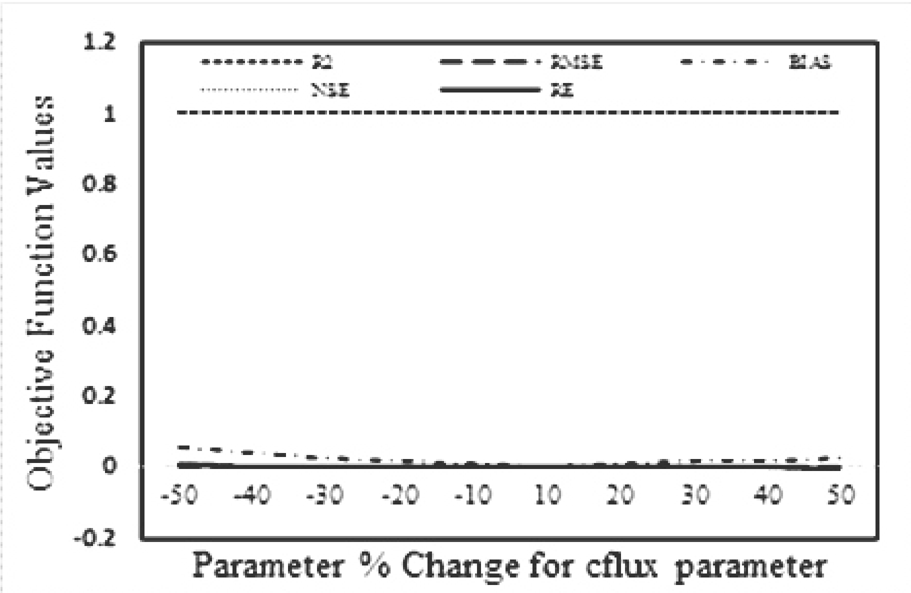

Fig. 2e. Sensitivity analysis for parameter 'cflux'

This parameter "CFLUX" with unit as mm/day is generally not calibrated, but due to change in climatic conditions in this region, the initial value was kept at 1.5 with the lower and upper limits as 0.15 and 4.15. This parameter was sensitive beyond the range of 1.35 and 1.65. The results can be seen in Fig. 2e. This parameter is sensitive to BIAS and RE. The "hq" parameter is the product of the squared root of observed discharge over the whole period and the mean of the annual peaks multiplied by the area of the watershed. Hence it is not calibrated. Since it is not calibrated its sensitivity rages is not analysed. It must be selected in the upper part of the observed discharge data range. At this high flow level, the parameter khq is assumed as it corresponds to the outflow from the response box and is calculated for each watershed. For this watershed it has a value of 2. This is also a non-sensitive parameter.

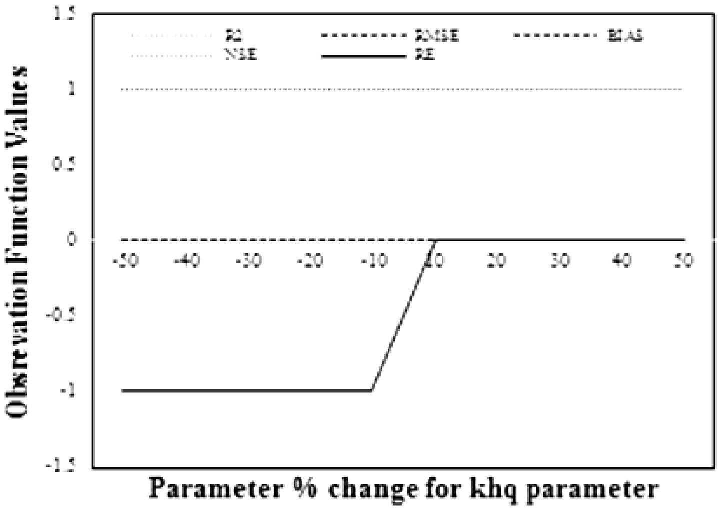

Fig. 2f. Sensitivity analysis for parameter 'khq'

A reduced "khq" will correspond to a shift of the hydrograph to its right as it delays the runoff. If it is more than 0 then k0, k1, k2 and k3 are not used. The initial value of khq is 0.124. Its sensitivity was analysed between 0.0124 and 0.372. The identified rage is from 0.1364 to 0.1116. The analysis is showed in Fig. 2f.

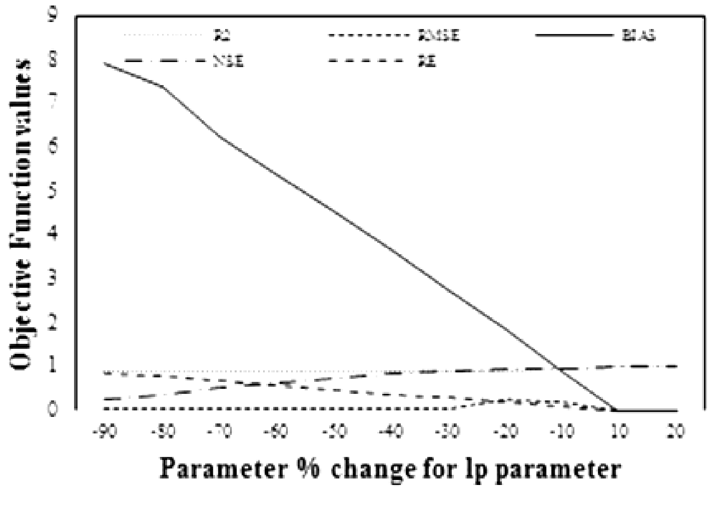

Fig. 2g. Sensitivity analysis for parameter 'lp'

The base flow increases with "LP" and quick runoff decreases. It allows more infiltration and quick runoff. It is a fraction of the field capacity. It reflects to that soil moisture above which the evapotranspiration reaches its potential value. It is the evapotranspiration limitation. It controls the shape of the reduction curve for potential evapotranspiration and determines the actual evapotranspiration in reference to the available soil moisture. It also has a moderate effect on the volume balance. The initial value was kept at 1, while it was found to be sensitive beyond 0.9 and 1.0. The sensitivity is shown in Fig. 2g. Its sensitivity is seen for Objective Functions except R^2 and highly sensitive to BIAS. This is one of the most sensitive parameter in the entire watershed.

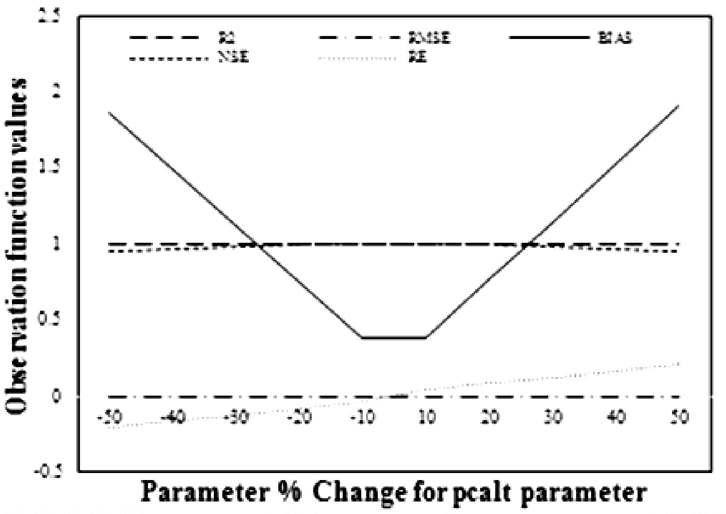

Fig. 2h. Sensitivity analysis for parameter 'pcalt'

The “PCALT” factor for precipitation changing with altitude. Since this watershed is an agricultural watershed and almost a flat one PCALT initiates from 0.1 and sensitivity is analysed between 0.1 and 0.3 0. This parameter is sensitive beyond the minimum and maximum limits of 09 and 0.11. The analysis can be seen in Fig. 2h. It is sensitive to all Objective Functions except R^2 and RMSE.

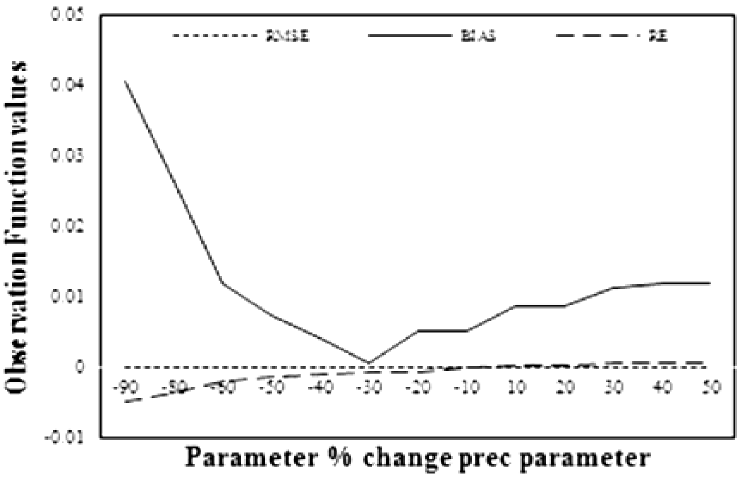

Fig. 2i. Sensitivity analysis for parameter 'prec'

It is the term referred to percolation. A higher value results in release of large amount of water from the upper layer to lower layer. This results in more storage of water in the lower layer. It's initial value of 2.1 is not show sensitivity in any Objective Function. This is shown in Fig. 2i. The recession coefficient “k4”is for the lower soil strata. It influences the initial conditions and if its value is high much runoff is created. This results in reduction of soil moisture in the watershed. It has a value of 0.0054. At this value the watershed holds a lot of water and hence allows to hold the moisture. This is a non-sensitive parameter.

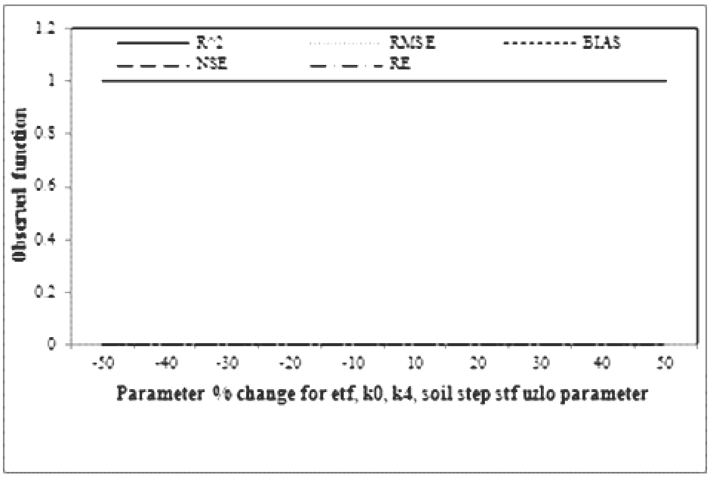

Fig. 2j. Sensitivity analysis for '"K0", "RECSTEP", "SOILSTEP", "STF", "UZL0" parameter showing no response.

The "CRITSTEP" value is 1 as it is not a parameter to be influenced by the climate. This is a non-sensitive parameter. The "ETF" is the temperature factor for evaporation and is not influenced by any increase or decrease of its value. This is a non-sensitive parameter. While "K0", "RECSTEP", "SOILSTEP", "STF", "UZL0" are non-sensitive parameters this can be seen in Fig. 2j. Sensitivity analysis of these parameters determines how different values of an independent variable affect a particular dependent variable under a given set of conditions. In this study the sensitivity analysis involved has the concepts of one at a time (OAT) analysis. This study helps to understand how this model created for Swedish conditions behaves in a semi-arid part of the country India. Each parameter is parametrized and its sensitivity checked and ranged defined as shown in the Table 3.

Table 3 : Optimum values of initial, lower and upper limits of the parameters along with their sensitivity ranges.

Sl. No.	Parameters	Initial Values	Lower limit	Upper limit	Sensitivity Minimum	Range
1	"ALFA"	1	0.1	3	NO CHANGE	1
2	FC (mm)	200	20	600	180 & 200	180 & 200
3	ATHORN	0.166	0.0166	0.498	0.1494 & 0.1826	0.1494 & 0.1826
4	β	1.34	0.134	4.02	1.026 & 1.474	1.026 & 1.474
5	CEVPL	1.15	0.155	3.45	NO CHANGE	1.15
6	CFLUX (mm/day)	1.5	0.15	4.5	1.35 & 1.65	1.35 & 1.65
7	CRITSTEP	1	0.1	3	NO CHANGE	1
8	ETF	-1	0.1	-3	NO CHANGE	-1
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	0.124	0.0124	0.372	0.1364 & 0.1116	0.1364 & 0.1116
13	LP	1	0.1	1	0.9 & 1.1	0.9 & 1.1
14	PCALT	0.1	0.01	0.3	0.09 & 0.11	0.09 & 0.11
15	PCALTL	500	50	1500	450 & 550	450 & 550
16	PREC	3	0.3	9	2.1	2.1
17	RECSTEP	1	0.1	3	NO CHANGE	1
18	SOILSTEP	3	.3	9	NO CHANGE	3
19	STF	4	0.4	12	NO CHANGE	4
20	UZL0	1	0.1	3	NO CHANGE	1

SUMMARY AND CONCLUSIONS

This study, intends to analyses the interaction between the various parameters of the Soil Moisture Routine a hydrologic process in the HBV model. It analyses the influence of each parameter upon other related parameters that have the capability of influencing the soil moisture in the watershed. Since this model is designed as per the Swedish conditions, its performance in the semi-arid part of the state of Uttar Pradesh, India is being understood. This study tries to understand the performance of each parameter in the Soil Moisture Routine and their functional range. This is done by finding the extent of sensitivity using one at a time analysis. This helps the modeller to understand the most sensitive parameter in the routine. This study will also help planners and hydrologists to use the HBV model for forecasting the water balance or soil moisture status of the watershed. In this case it is an agricultural watershed hence this study becomes very critical to understand the moisture stress periods in the watershed.

The parameters are analysed and whose optimum values were obtained can be catogarized into two groups. Firstly those parameters (“lp”, “fc”, “athron”, “β” “cflux”, “pcalt” , “perc” , “khq”) that are influencing the soil moisture and are inter related to each other and secondly (“prec”,“cevpl”,“alfa”, “hq”, “recstep”, “soilstep”, “stf, “uzlo”)those that are not representing any process but are values or numeric fractions. The most sensitive parameter in the watershed is the “lp” parameter. Its calibrated value is “1” and is sensitive beyond the range of 0.9 and 1.10. Even slight upper and lower values will drain the watershed resulting in “very quick runoff”. The parameter “fc” governing the field capacity, “β”, influencing the ratio of discharge to runoff, all are contained with the -10 % and +10% variation of their calibrated ranges. Although in Swedish conditions “athron”, that influences the potential evapotranspiration, needs no calibration, in semi-arid conditions the range is quantified between 0.1494 and 0.1826. This is due to large variation in the temperature in semi-arid regions. “cflux” representing the flow from upper region to lower region under Swedish conditions need not be calibrated but under semi-arid conditions the new range is defined as minimum and maximum 1.35 to 1.65 from 0.15 to 4.15. This is due to the fact that for a large number of days the moisture in the soil is frozen and capillary phenomena is continues throughout the year.

Since “pcalt” influences the processes involved in change in precipitation due to altitude, here it is least sensitive as the entire region of the watershed is a levelled area with mild slope. Although “perc” is an important parameter and variation will drain the water from the upper layer to lower layer. Values of “khq” are more than “0”, and between the ranges of 0.1364 to 0.1116, hence, “k0”, “k1” and “k3” are not considered as they represent the lower levels. For rest of the parameters such as “prec”, “cevpl”, “alfa”, “hq”, “recstep”, “soilstep”, “stf, “uzlo” sensitivity analysis did not yield any results and the calibrated optimum values are acceptable as obtained. Similar results have also been reported by Nibret et.al (2010) for PERC also. From the above research it can be concluded that HBV model can be used in Agricultural watersheds even in semi-arid conditions. Parameters representing processes can be calibrated even in conditions with high temperatures around calibrated optimums within their sensitivity ranges of only +10% to -10%. However parameters that are not sensitive can be adopted from the original recommended values.

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