MODELLING RAINFALL-RUNOFF PROCESS FOR SUB CATCHMENT OF NARMADA RIVER BASIN AT HOSHANGABAD USING SEMI DISTRIBUTED MODEL HBV

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DATA avability statement

The data that support the findings of this study are available on request from the corresponding author, [abhishek]. The data are not publicly available due to restrictions e.g. their containing information that could compromise the privacy of research participants.

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ABSTRACT

In this study, the light version of Hydrologiska Byrans Vattenbalansavdelning hydrological model (HBV), has been used to synthesize river discharge and daily flow series for twelve years in the sub catchments of the Narmada river basin at Hoshangabad. The plain area of Narmada river basin at Hoshangabad is used for this study,with a drainage area of 10594 km^2 and co-ordinates lies between 22°46'Nand 77°43'E.The model was run using twelve years data. Parametrization of parameters were obtained after warming, calibration and validating the results. There after the sensitivity analysis was done and acceptable range for each parametrized parameter was obtained. The Coefficient of Determination of observed and simulated discharge at the Hoshangabad was found to be 0.84. In Narmada River Basin at Hoshangabad hydrologicalmodeling using the HBV model, MAXBAS is the most sensitive parameter. The sensitive parameters from high to low along with their slopes values are Maxbas: 0.23, Alpha: 0.018, Fc: 0.012, K1:0.010, Beta: 0.008, K2: 0.005, Perc: 0.001 and Lp 0.001. The study shows that light version of the HBV model can be used to model the runoff of the sub catchment of the Narmada river basin at Hoshangabad.

Keywords: HBV light model, Sensitive parameter, Parametrization, Narmada River, M.P.

INTRODUCTION

Hydrology is that the main governing backbone of every kind of water movement.Hydrological models square measure vital tools for water resource coming up with and management and in assessing the consequences of climate and land use modification on the hydrological cycles and runoff regimes (Pechlivanidis et al., 2011; Zhang et al., 2012). abstract hydrological models square measure wide accustomed simulate the land section of hydrological cycles since they will capture the

dominant structure dynamics while remaining ungenerous andcomputationally economical while requiring computer file that square measure typically without delay out there and comparatively easy and straightforward to use (Thyer et al., 2009; Kavetski and Clark, 2010). an effort has been created to use HBV model to get the discharge from the narmada geographical region set at Hoshangabad in m.p.,having catchment area of 10594 sq. kilometers. The model consists of many parameters out of that the foremost sensitive 9 parameters are tag and valid. The following square measure the parameters and clarification however they're employed in the model.

1. FC (Field capacity): This represents the utmost soil wet storage (mm.) and features a vary from a hundred millimetre-1100 mm. It influences the overall volume of runoff. At low soil wet level, most of the precipitation is unbroken at intervals the unsaturated zone. If FC is simply too high the soil water level will increase throughout the spring flood.

2. LP: this is often the limit for potential evaporation. And its values vary from one.0 or but zero.9. it's a soil wet price on top of that evapotranspiration reaches its potential price, the disk parameter is often not tag however is adjusted if needed.

3. Beta: it's the exponent within the equation for the discharge from the soil water zone. the worth of Beta ranges from zero.25-3. Beta as FC conjointly influences the overall price and is tag by perceptive the time of year discharge.

4. Perc: this is often the Percolation capability of the higher response box . The water from higher reservoir percolates down in step with the parameter Perc. The unit is in millimetre per day. The vary of Perc is from 1-12 millimetre per day. This parameter influences the form of the hydrograph however not the amount. the bottom flow is additionally adjusted with Perc. an occasional Perc price can end in low base flow.

5. Alfa:It could be a live of the non-linearity, usually within the order of one. The vary of Alfa is from zero.1 to 1.1.when the discharge peaks square measure simulated Alfa is adjusted. Alfa is mostly not tag and is employed to suit the upper peaks into the hydrograph. the upper Alfa, the upper the peaks and faster recession.

6. K2:-It could be a recession constant for the lower response box. As Mount Godwin Austen enlarged an excessive amount of runoff was created.
7. K1:-It is that the recession constant for the higher response box
8. Maxbas:-It could be a transformation operate. The generated runoff of 1 time step is distributed on the subsequent days exploitation one free parameter, Maxbas, that determines then base in associate equal triangular coefficient operate.

9. Cet:-It could be a potential evaporation correction issue. it's associate ex gratia parameter needs extra information to use i.e. Mean temperature (T_Mean).

Materials and methods

Study area:- The Narmada basin, hemmed between Vindhya and Satpura ranges, extends over an area of 98,796 km^2 (38,145.3 sq mi) and lies between east longitudes 72 degrees 32' to 81 degrees 45' and north latitudes 21 degrees 20' to 23 degrees 45' lying on the northern extremity of the Deccan plateau.The Upper plain area of Narmada river basin at Hoshangabad sub catchment is used for this study, which is having drainage area of 10594 square kilometer and co-ordinates lies between 22°46'N and 77°43'E. The length of the stream beneath this structure is eighty two km.

About HBV model

The HBV model could be a abstract, semi-distributed, rainfall-runoff model that is developed by Bergström at the Swedish meteorologic and Hydrological Institute (SMHI) (Bergström & Forsman, 1973). Seibert (2005) developed a brand new version known as HBV light, that is a straight forward to use Windows version for analysis and education. Seibert (2005) and Hohenrainer (2008) describe the model as follows: daily discharge is simulated by HBV exploitation daily rain, temperature and potential evaporation as input. It is not necessary to line initial conditions; the model incorporates a 'warming-up' amount within which Associate in Nursing initial state is reached.

HBV model parts

Routines

The standard version of the HBV *light* model consists of many (sub)routines : a snow routine simulating snow accumulation, melting and freezing; a soil moisture routine simulating storage, evapotranspiration and recharge; a response function consisting of 2 groundwater boxes (an higher box with 2 outflows with completely different recession coefficients, and a lower box with one outflow that receives water from the higher box by percolation); and a stream routing routine distributing the calculated discharge for some unspecified time in future onto successive days. The snow routine and also the soil routine are spatially distributed,the response function is lumped over the entire sub-basin..

Snow routine Precipitation accumulates as snow if the temperature (T) is below a perticular threshold temperature (TT), snow soften starts if T > TT. All precipitation that falls as snow is increased with a snowfall correction factor(SFCF). Snow soften is calculated with a degree-day methodology and soften water and rain are preserved within the snowpack till they exceed a perticular portion (CWH, the water holding capability of the snowpack). Soften water refreezes if T < TT, but at a lower potency. All water that cannot be preserved within the snowpack is passed on to the soil moisture routine. Computation is completed for every elevation-vegetation zone severally.

Soil moisture routine Rainfall (P) and snowsoften are divided into an area aming to the soil (moisture) storage and an area to the groundwater (recharge to the response function). So recharge is merly generated in case of rainfall or snowsoftning. The fraction of water aiming to the response function is looking on the relation between water content of the soil moisture routine (SM) and also the most soil moisture storage (FC).

$$\frac{recharge}{P(t)} = \left(\frac{SM(t)}{fc}\right)^{beta}$$

FC may be a model parameter and is not essentially ediquate to the equal to actual field capacity. Water is taken out from the soil storage solely by evapotranspiration. The actual evapotranspiration (ET_{act}) depends on potential evapotranspiration (ET_{pot}) and also the actual soil moisture content (by employing a threshold value for soil moisture(LP) above which ET_{act} reaches ET_{pot}).ET_{act} is computed as a fraction of ET_{pot}. Evapotranspiration are often simulated when ther's a snow cowl.

Computation is done for every elevation-vegetation zone severally. There is no surface runoff; the quick element is modeled through the response routine.

Response function The groundwater is simulated by linear reservoirs. The standard version of HBV *light* consists of 2 groundwater boxes placed in non parallel. The output from the soil routine is that the input for the upmost groundwater box. Water will leave the higher groundwater box by percolation to the lower box or by generating discharge. Water will leave the lower box by generating runoff (Q2: base flow) or by evaporation from a lake. The lower groundwater box has the tiniest recession constant.Total discharge is computed because the add of Q1 and Q2. Computation is completed lumped for the entire catchment.

Routing routine The whole discharge of the response routine for one occasion step is distributed over the successive day's using the parameter MAXBAS. This parameter is that the base of a equal triangular weighting coefficient.

Methodology

This study involves charecteristics most sensitive Response routine parameter in associate agricultural watershed using HBV model. The analysis can be carried out in 5 main stages that are:

1. **Warming of the model** this can be the primery stage, during this stage the model are going to be run with the assumed parameters and information.
2. **Standardization of the modeling** this stage model standardization is that the method of adjustment of the model parameters and forcing inside the margins of the uncertainties.
3. **Parameterization** is that the method of deciding and process the parameters necessary for a entire or relevant specification of a model or geometric object.
4. **Sensitivity analysis** may be a technique accustomed confirm however completely different values of a variable quantity can impact a specific variable quantity beneath a given set of assumptions.
5. **Validation** to check's the accuracy of the model's illustration of the real system. Model validation is outlined to mean "substantiation that a processed model insides its domain of relevance possesses a satisfactory vary of accuracy in line with the supposed application of model".

HBV model calibration

When the model was run with the initial input information then it absolutely was determined that the graph was simulated were not matching data ought to be determined thanks to the hydrological model is that the simplified illustration in an exceedingly advanced hydrological system and will not replicate the real world with accuracy. A hydrological model to want the fine standardisation of the model parameter to enhance the dependability of the model. a crucial a part of the hydrological modelling method is to ascertain that the results square measure simulated by the model with the physical system to be represents. Hydrological model square measure tag so as to induce a decent match between the determined and simulated variables.

HBV model validation

Validation may be a method of demonstrating that a given site-specific model is capable of creating correct predictions for amounts outside a standardisation period. easy model structures, tag over a particular amount, square measure influenced by the rainfall-runoff sequence specific to it amount (Lee, McIntyre et al. 2005) so in order to prove validity of a model, the model ought to be tested against a second, freelance set of stress conditions.

The information series square measure going to be divided into 2 sets. the primary set of 1 years for warming the model and also the second set of 10 year for standardisation and validation. the target functions offered in HBV model square measure going to be used for testing the validity of modeling the narmada geographical area at hoshangabad with the HBV model. The target functions accustomed live the dependability of the model between calculated and also the determined discharge and coefficient of correlationR^2.

Sensitivity Analysis

Sensitivity analysis' aims to explain what quantity model output values square measure stricken by changes in model input values. it's the investigation of the importance of impreciseness or uncertainty in model inputs during a decision-making or modeling method. the precise character of a sensitivity analysis depends upon the actual context and also the queries of concern. Sensitivity studies will give a general assessment of model exactness once accustomed assess system performance for different eventualities.

Objective function

R^2

. It 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.

In statistics, the coefficient of determinationR^2 is a number which indicates the proportion of the variance in dependent variables that is predictable from the independent variable.

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

Where $Q_{|,|i}$ 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.

RESULT AND DISCUSSION

The study space was NARMADA geographic area. The Hoshangabad sub structure was hand-picked because the principal and presentation basin. the beginning time for computation was set to 01 Gregorian calendar month 2006.

Warming the Model

The model heat up was done by running the model for a amount of 3 years of amount from 2006 to 2008 then discharge was computed for the full amount of 01 Gregorian calendar month 2009 to thirty one Gregorian calendar month 2017.

Table 1 parameter used in model and their Initialization and calibration value

s. no.	Parameters	Initialization	Calibrated value

		Values	
01	Fc	100	608
02	Lp	0.1	0.334
03	Beta	0.25	1.584
04	Alpha	0.1	0.593
05	Perc	1	7.27
06	K1	0.01	0.0387
07	K2	0.02	0.099
08	MAXBASE	1	3.164
09	Cet	0.1	0.341
10	Pcalt	10	10
11	Tcalt	0.6	0.6
12	TT	0	0
13	CF MAX	0.5	0.5
14	SP	1	1
15	SFCF	0.5	0.5
16	CFR	0.05	0.05
17	CWR	0.1	0.1

Table 2 Parameter and their Allowable range

S.no.	parameters	Initialization value	Allowable range
01	Fc	100	500-700
02	Lp	0.1	0.2-0.4
03	Beta	0.25	1.25-1.75
04	Alpha	0.1	0.57-0.65
05	Perc	1	6-9
06	K1	0.01	0.02-0.05
07	K2	0.02	0.08-0.12
08	MAXBASE	1	1-5
09	Cet	0.1	0.2-0.8

Sensitivity analysis

Sensitivity analysis for Coefficient of determination (R^2)

The sensitivity analysis for all the nine sensitive parameters was done and is shown in figure 4.13 to figure 4.21. From these figures we can see the range in which these parameters are sensitive. Since the model parameters did not have a uniform increase or decrease for the sensitivity analysis, they are shown here as individual graphs. The trend lines in these graphs show the range in which these parameters are sensitive and have their influence upon the model. The slope of the graphs explains the most sensitive parameter and sensitive parameters from high to low along with their slopes values are shown in below figure:

4.3 Discussion

The HBV model was used with success to model discharge for the study space. each standardisation and validation results show a sturdy relationship between the simulated and discovered discharge from the study space. The results from the model standardisation and validation square measure shown in on top of Fig. Best results (with best R2=0.83) were earned throughout the validation amount than the standardisation amount for basin.These R2values square measure shown in Fig four.5. to 4.12. High correlation between discovered and simulated discharge (R2=0.78) throughout the standardisation amount and (R2 = zero.83) throughout the validation amount. Figure 4.13 to 4.21 shows the sensitivity analysis of the 9 parameters the parameter. MAXBAS is usually influences the narmada geographic area at hoshangabad.

There were four sorts of routine parameter utilized in HBV lightweight model. they're following:-

1. Snow parameter
2. Soil parameter
3. Response parameter
4. Routing parameter

The structure failed to have snow thus, snow parameters had not needed during this study. In soil parameters among Fc, LP and Beta FC was most sensitive with slope price zero.012 followed by Beta with slope price zero.008 and LP with slope zero.001. In Response parameters among K1, K2, Alpha and Perc ALPHAwas most sensitive with slope price zero.018 followed by K1 with slope price zero.1, Dapsang with slope price zero.005, and Perc with slope price zero.001. Maxbashad the foremost sensitivity with slope price zero.23. Parameter Cet had least sensitivity towards the discharge.

SUMMARY AND CONCLUSIONS

This study evaluated the consequences of varied parameter scale alternatives within the HBV model simulation. Comparison of hydrological simulation mistreatment average parameter values from short temporal standardisation and mistreatment manual improvement was conjointly conducted. we are able to acquire the subsequent conclusions:

1. The structure failed to have snow thus, snow parameters had not needed during this study

2. In soil parameters among Fc, LP and Beta FC was most sensitive with slope price zero.012 followed by Beta with slope price zero.008 and LP with slope zero.001
3. In Response parameters among K1, K2, Alpha and Perc ALPHA was most sensitive with slope price zero.018 followed by K1 with slope price zero.1, Dapsang with slope price zero.005, and Perc with slope price zero.001.
4. Maxbas had the foremost sensitivity with slope price zero.23
5. Parameter Cet had least sensitivity.

Simulation solely replicate the model sensitivity to alter in land and prediction will solely be as correct because the model structure and also the knowledge quality but a crucial consistency within the model results. The HBV model is originally a conceptually lumped model. tho' an excellent deal of effort has been invested with in accounting for abstraction variability of precipitation and temperature within the ''distributed'' HBV model, it still falls short in its ability to account for full abstraction variability because of its abstract and lumped in nature. HBV simulations square measure additional sensitive to changes.

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