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Application of Semi-distributed Hydrological Model in Northern Region of Bangladesh

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Abstract: *Measuring discharge in a developing and riverine country like Bangladesh is very important to predict flood and proper land utilization for sustainable development. The Teesta River is one of the most important trans-boundary rivers of northern region of Bangladesh. Bangladesh has long argued that India's construction of the Gazoldoba Barrage upstream of Dalia has significantly reduced the availability of water in the dry season. Furthermore, the release of water during the monsoon season causes flooding and bank erosion in downstream. With this issue in mind, a hydrological model for the Teesta basin has been developed using a semi distributed model Soil and Water Assessment Tool (SWAT). In this research, we are interested to investigate discharge estimation and to determine watershed parameters, land use, soil and slope modeled of Teesta watershed and the percentage area distribution, which are outlined from the data observed for Northern region of Bangladesh by using SWAT. For model calibration SWAT_CUP SUFI-2 algorithm has been used at Kaunia station, out let of Teesta watershed. The calibration and validation periods have been selected 2009 to 2013 and 2014 to 2017 respectively. Discharge for both daily and monthly time step are generated by the model. The performance of the calibration and validation has been assessed by different statistical techniques. During the calibration, in daily simulation the NSE value is 0.80 while R^2 is 0.82, which are quite reasonable and during the validation period the values of NSE and R^2 are 0.76, 0.77 respectively also quite reasonable. In monthly simulation, the NSE, R^2 values for calibration period are 0.92 and 0.93 respectively while the values of validation period are 0.84 and 0.88, respectively. Overall, the model efficiency is satisfactory. The performance of the model indicates that such an approach can indeed produce an acceptable result for both daily and monthly simulation. The results are presented graphically to compare observed and simulated result.*

Keywords: SWAT, Teesta River Basin, Watershed, Temperature, Precipitation, Calibration and Validation

1. Introduction

Bangladesh is a South Asian riverine country situated in a low-lying river delta exposed to cyclones, storm surges and potential sea-level rise. It is located between 20°34´ to 26°38´ north latitude and 88°01´ to 92°42´east longitude with an area of 1,47,610 km^2. The three largest transboundary river systems of the Indus, Ganges, and Brahmaputra (IGB) river basin, which collectively support an estimated 700 million people, are supplied by the Himalayas, known as the "water tower" of Asia or the "third pole [1]. The water resources in these basins have been widely utilized for drinking, irrigation, navigation, industry and hydropower and provide the basis for local livelihoods [2]. Eighty percent of Bangladesh is deltaic floodplain which are crisscrossed by about 230 rivers including 57 trans-boundary rivers of which 54 is shared with India and 3 with Myanmar [3]. Teesta River is one of the significant trans-boundary rivers in northern region of Bangladesh. It is a tributary of the Brahmaputra River and falls under the Brahmaputra sub-basin in the Eastern Himalayan region. One of the major Himalayan rivers, the Teesta, originates at a height of roughly 5,280 meters from the glaciers of Sikkim, flows through the Indian states of West Bengal and Sikkim through Bangladesh and meet with Brahmaputra at Chilmari, Kurigram and finally enters the Bay of Bengal [4]. Bangladesh has long argued that India's construction of the Gozaldoba Barrage in Jalpaiguri upstream of Dalia (Teesta Barrage) (Fig. 1) has significantly reduced the availability of water in the dry season and the release of water during the monsoon season causes flooding and bank erosion downstream. In order to assess the water availability and predict floods of northern part of Bangladesh, it is necessary to establish a hydrologic model over the Teesta basin. Afroz et al [3] studied the assessment of upstream water diversion from Ganges and Teesta River and found that the flow reduced in Bangladesh due to construction of Farakka Barrage and Gozoldoba Barrage at upstream of Ganges and Teesta River respectively. Flash flood risk assessment for upper Teesta River basin is studied by Mandal et al [5] by using the hydrological modeling system (HEC-HMS) software to simulate the hydraulics characteristics of the Teesta Basin for a flash flood. Khadiza et al [6] used a semi distributed model to measure river discharge for Meghna River basin in eastern region of Bangladesh. The flow characteristics of the Teesta River were analyzed by calculating monthly maximum and minimum water levels and discharges from 1985 to 2006 by Mondal et al [7] and observed discharge of the Teesta over the last 22 years has been decreasing. Pradhan et al also estimated the Rainfall Runoff using Remote Sensing and GIS in and around Singtam, East Sikkim [8], but there are not so many studies to develop a semi-distributed hydrological model like SWAT in Bangladesh river basin where SWAT model has effectively used in agricultural watersheds in numerous areas of USA and other continents [9-15]. The main purpose of this paper is to develop SWAT model by using the discharge data of the Teesta River basin along with its land use, soil types and other hydrological and meteorological data and then compare the simulated data to find out the watershed discharge parameters those can be used to measure discharge when observe dada are not available.

2. Study area and methods

2.1 Study Area

The Teesta River, a tributary of the Brahmaputra River, is one of the most important transboundary river of Bangladesh which falls under the Brahmaputra sub-basin in the Eastern Himalayan region [16]. It is the fourth largest trans-boundary river in Bangladesh, flowing through the five northern districts of Gaibandha, Kurigram, Lalmonirhat, Nilphamari and Rangpur, distributed 9,667 square kilometers [1] (Fig. 1). After traveling approximately 414 kilometers through India and Bangladesh, the Teesta merges with the Brahmaputra at Teestamukh Ghat (Kamarjani Bahadurabad) in Rangpur District in Bangladesh. The trans-boundary basin of the Teesta River encompasses 12,159 square kilometers, of

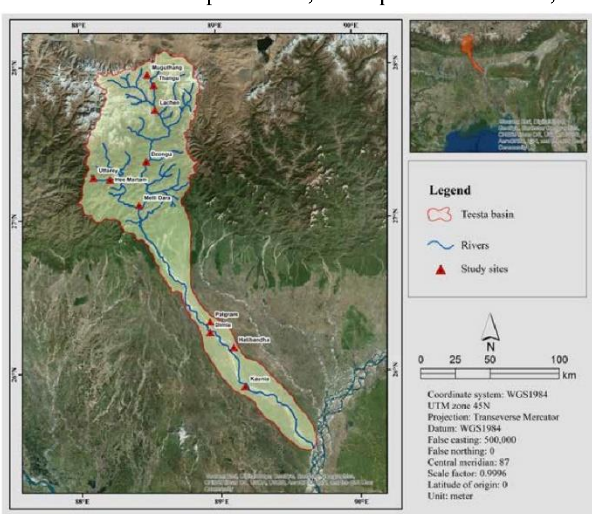

Figure 1: Teesta basin, the light green transparent shade marks basin boundary [17]

which 10,155 are in India and 2,004 are in Bangladesh. Approximately 8,051 square kilometers of the river basin lie in hilly parts of Sikkim (6,930 square kilometers) and West Bengal (1,121 square kilometers). Approximately 4,108 square kilometers of the basin lie in the plains of West Bengal (2,104 square kilometers) and Bangladesh (2,004 square kilometers) [1]. Historically, the Teesta was part of the Ganges River system, flowing south from Jalpaiguri in West Bengal in three separate channels: the Karatoya, the Purnabhaba, and the Atrai. It is speculated that the three channels led to the name "Trisrota" ("possessed of three streams") and subsequently to "Teesta". Following a flood in 1787, the Teesta changed its course southeast to join the Brahmaputra [1].

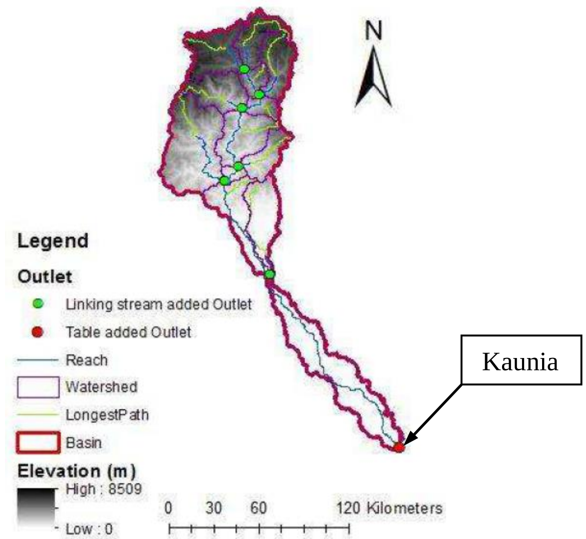

Figure 2: Study area, Teesta basin with distinct boundary

2.2 Methods

Soil and Water Assessment Tool (SWAT) is a river basin scale semi-distributed hydrological model developed by United States Department of Agriculture (USDA) [18-20]. SWAT is a physical process based continuous time model to simulate runoff, sediment and nutrients from catchment. The major components of SWAT include hydrology, weather, soil erosion, soil temperature, stream routing, crop growth, nutrients, pesticides and agricultural management conditions over long period of time. SWAT divides a watershed into sub-watersheds, each sub-watershed is connected through a stream channel and further divided into Hydrologic Response Units (HRUs). The hydrologic cycle as simulated by SWAT is based on the water balance equation

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - W_{sep} - Q_{gw})$$

where t is the time in days, SW_t and SW_0 are the final and initial soil water content on day i (mm H_2O) respectively, Qsurf is the amount of surface runoff on the day i (mm H_2O), E_a is the amount of evapotranspiration on day i (mm H_2O), W_{sep} is the amount of water entering the vadose zone from the soil profile on day i (mm H_2O), and Q_{gw} is the

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amount of return flow on day i (mm H_2O). Surface runoff can be estimated by the model using Soil Conversation Service (SCS) curve number method [21]. This method is widely used for the predicting the approximate amount of runoff from a given rainfall event. Soil properties, land use and hydrologic condition are the main factors to evaluate runoff from this method. The SCS curve number equation is

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)}$$

where R_{day} is the rainfall depth for the day (mm) and S is the retention parameter (mm). The retention parameter and perdition of lateral flow by SWAT model are computed as bellow

$$S = 25.4 \left(\frac{100}{CN} - 10\right)$$

where CN is the curve number. Lateral flow is computed as

$$q_{lat} = 0.024 \frac{2SSCsin\alpha}{\theta_d L}$$

where q_{lat} is later flow (mm/day), S is drainable volume of soil water per unit of saturated thickness (mm/day), SC is saturated hydraulic conductivity (mm/h), α is slope of the land, θ_d is drainable porosity, L is flow length (m).

A large number of specialized and time series datasets are required to simulate the water balance of a watershed using the SWAT model to establish the water balance [22]. For developing hydrological model different types of data are used such as:

- DEM (Digital Elevation Model)
- Land-use Data
- Soil data
- Climate data (Precipitation, Temperature, Humidity, Wind speed, Solar radiation)
- Hydrological data (River discharge, Water level, Water temperature, Water pressure)

These data are required for developing SWAT model which are collected from different sources such as Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), United States of Geological Survey (USGS), Food and Agriculture Organization (FAO) etc. Data used for SWAT model development and corresponding data sources are given in the following table.

Table 1: Data used for SWAT model development and the data sources

Variable Name	Data Source
Digital Elevation Model	STRM
Land use Map	GLOBCOVER
Soil Map	FAO-UNESCO
Climate	BMD
Discharge Data	BWDB
Stream Network Data	USGS Hydro-SHEDS

2.2.1 Digital Elevation Model

For this study the STRM (Shuttle Radar Topography Mission) 90m resolution Digital Elevation Model was used shown in Figure 2. It is downloaded from open source http://srtm.csi.cgiar.org. Topography was defined by a DEM (Digital Elevation Model) that describes the elevation of any point in a given area at a specific spatial resolution. DEM was processed according to study area for input and then by using DEM and river shape extracted the flow direction, flow accumulation, stream network generation and delineation of the watershed and sub-basins. There are 13 sub-basins were produced and DEM ranges from 0 m to 8509 m above the mean sea level (Fig. 2).

2.2.2 Stream Network

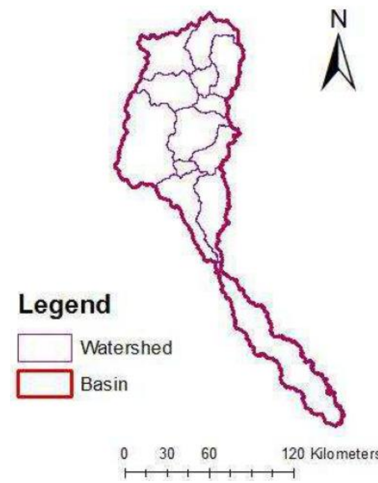

Figure 3: River Network, sub-basin and outlet of Teesta River Basin required.

For watershed delineation the digital stream network was The digital stream network data is available from United States Geological Survey (USGS) Hydro-SHEDS at http://hydrosheds.cr.usgs.gov/index.php. Hydro-SHEDS deliver data in various regional extents, types, and resolutions. For this study the used data resolution was 15s. The watershed is delineated using watershed delineation tool in SWAT with using DEM and stream network.

Teesta River is divided into 13 sub-basins and 13 sub-basins into 257 hydrological response unit (HRU) based on soil type, land use and slope classes that allow a high level of spatial detail simulation (Fig. 3). We have taken the basin outlet at Kaunia station to measure simulated discharge which is used for measuring river flow (Fig. 2). The Figure 2 reveals the watershed and outlet of Teesta River basin. The green dots are indicated the linking stream added outlets and red dots are indicated the manually added outlet at Kaunia.

2.2.3 Land Use

Land-use changes has a great impact on flooding and water cycle. Land cover data was taken from ESA (European Space Agency) Glob-Cover project with resolution of 300 m. The data is available at http://due.esrin.esa.int/page_globcover.php. Land use has a great impact for infiltration, surface flow, river flow and climate change also. More precipitation occurs in forest land area instead of barren land. Forested area has less runoff because rainfall speed is restricted by leaves and trees before it reaches to ground. Some water is absorbed by plant root and some water is gone back to atmosphere by transpiration. If the forested and other area are used by houses, farms, roads, street then it has great effect on surface runoff. The land use patterns of this study area are shown in Figure 4.

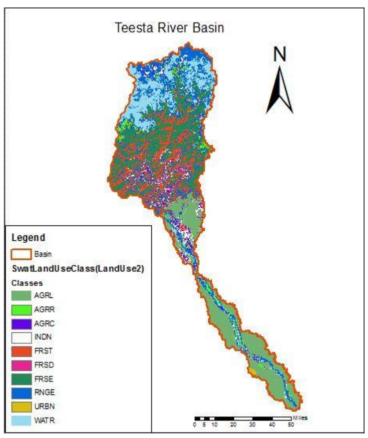

Figure 4: Major Land-Use in Teesta River Basin

Table 2 represents the value and label of the of the land use classification in study area. The data input as raster file and define as lookup table. In Teesta River basin there are ten types of different land use (Table 2). Most of the land (23.80%) is covered by Agricultural Land Generic followed by Range-Grasses (21.92%), Forest Evergreen (21.15%) and so on. The lowest portion of land is used for Residential purpose (0.18%).

Table 2: Land use of Teesta River Basin

Code	Land Use Type	Percentage of Area (%)
AGRL	Agricultural Land-Generic	23.8
AGRR	Agricultural Land-Row Crops	0.75
AGRC	Agricultural Land-Close-grown	1.72
INDN	Indian grass	2.23
FRST	Forest-Mixed	15.18
FRSD	Forest-Deciduous	0.09
FRSE	Forest-Evergreen	21.19
RNGE	Range-Grasses	21.92
URBN	Residential	0.18
WATR	Water bodies	12.73

2.2.4 Soil Data

Soil data is significant for the SWAT model. SWAT model requires physicochemical properties and soil textures of different types. Soil data input as a shape file and collected from FAO-UNESCO Soil Map of the world at http://www.fao.org/soilsportal/. The scale of digitized soil map is 1:5.000.000 scale range. After input soil shape file then by lookup table use SNUM- a sequential code number that ranges from 1 to 6,997, unique for each soil mapping. Soils are divided into four groups based on their grain sized, clay, silt sand and rock. There are 9 types of soil are found in Teesta River basin area which is shown in Figure 5.

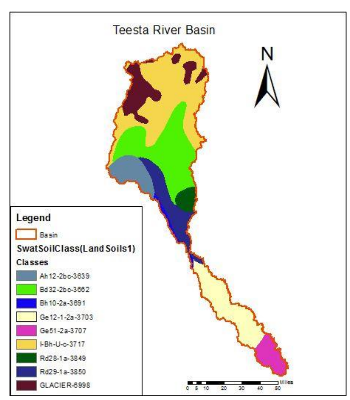

Figure 5: FAO soil types in the Teesta River Basin

Depending on hydraulic conductivity soil are also divided into four hydrologic groups. They are Hydrologic group A having highly infiltration rates, Hydrologic group B having moderate infiltration rates, Hydrologic group C having slow infiltration rates and Hydrologic group D having very slow infiltration rates even when thoroughly wetted. Surface flow depends on soil initial condition and soil texture. In a barren land surface soil is easily eroded and soil erosion is less in forest land. Soil profile of Teesta flood plain in the upstream it is found that most of the plain land is sandy soil or sandy loam. The soil is mainly formed by sedimentation and currents of Teesta River.

Soil has great impact to store precipitation; different soil has different capacities to absorb rainfall. Sandy soil holds less water than clay soil and loamy soil. Clay soil holds more water than sandy soil. Sand absorbs less water than clay. Table 3 reveals the FAO soil types of Teesta River Basin with hydrologic code, texture, percentage of total watershed area and the quantity of Clay, Silt, Sand and Rock.

Table 3: FAO soil description

SNAM (Sequential Code)	Hydrologic Group	Area (%)	CLAY (%)	SILT (%)	SAND (%)	ROCK (%)
Ah12-2bc-3639	C	7.05	23	33	44	0
Bd32-2bc-3662	C	22.32	21	37	42	0
Bh10-2a-3691	C	0.9	24	44	32	0
Ge12-1-2a-3703	C	13.99	20	20	54	0
Ge51-2a-3707	C	5.34	24	36	40	0
I-Bh-U-c-3717	C	29.38	36	33	41	0
Rd28-1a-3849	C	2.9	12	17	72	0
Rd29-1a-3850	C	8.12	17	26	57	0
GLACIER-6998	D	10	5	25	70	98

2.2.5 Meteorological Data

SWAT model require a large amount of meteorological data for model run. The meteorological data were collected from Bangladesh Meteorological Department (BMD) [23]. For SWAT model precipitation, temperature (max and min), solar radiation, wind speed, and humidity data are required to run the model where the records of precipitation and temperature are the minimum mandatory inputs and the other parameters are optional [24]. Meteorological data were used from 1995 to 2017 for the study. SWAT use Meteorological data for simulation performed for the watershed in a short listed below:

- Input data time Series: Daily data
- Simulation period: (2009-2017)
- Precipitation: Daily (mm)
- Temperature (maximum and minimum)
- Relative Humidity (%)
- Wind Speed (m/s)

2.2.6 Hydrological Data

For SWAT model it is very important to input the hydrological data. Hydrological data were collected from Bangladesh Water Development Board [25]. Hydrological data that used in the study mainly water level, discharge data for calibration and validation is from 2009 to 2017. Daily discharge data were used for calibration at the Kaunia station (SW 294) in Rangpur district for the calibration and validation.

3. Observed Results

In SWAT model the weather data definition dialog is divided in six tabs: Weather Generator data, Rainfall data, Temperature data, Solar Radiation data, Wind speed data and Relative Humidity data. In SWAT model we have used precipitation, temperature, wind speed, relative humidity data from 1995-2017. But some limitation of observed discharge data, we have simulated the model from 2009 to 2017. The model can read this input directly from the file or generate the value using daily averaged data analyzed for several years. It includes the WGEN weather generator model to generate climate data or fill in gaps in measured records [26]. The weather generator first independently generates precipitation for the day, followed by generation of maximum and minimum temperature, wind speed and relative humidity.

3.1 Precipitation

From hydrological view point any form of water reaching the earth's surface is called the precipitation. The usual forms are rain, snow, hail, dew etc. In a tropical country like Bangladesh major portion of precipitation occurs in the form of rain only. The maximum rainfall occurs in June to September where December to March remains dry period. The precipitation of Teesta River basin is shown in Fig. 6.

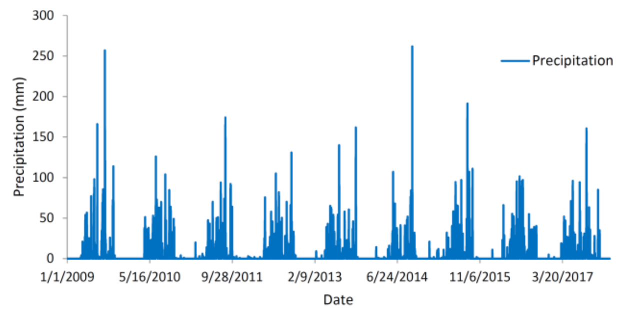

Figure 6: Daily average precipitation

3.2 Temperature

The Temperature data has been calculated as daily based and considered as averaged Maximum-Minimum temperature. The maximum temperature occurs in the month of April to August sometimes in September where the minimum temperature occurs in the month of November to January. The daily averaged maximum-minimum temperature has been shown in the following Figure 7.

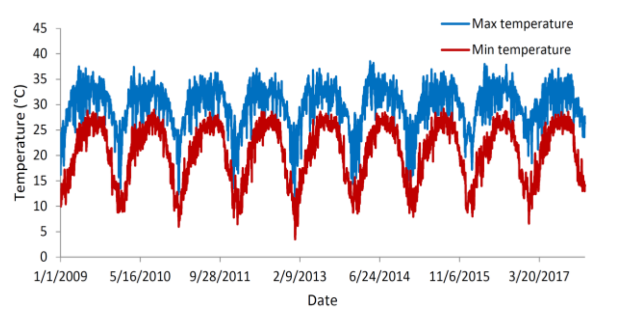

Figure 7: Daily average Maximum and Minimum Temperature

3.3 Observed discharge with Precipitation

Precipitation is one of the main factors for discharge. Normally if precipitation is increased then discharge is increased also that is that there are some similarities between observed discharge and precipitation. Generally, peak discharge is occurred at the time of high precipitation. The discharge along with precipitation in the period of 2009 to 2017 of Teesta basin is shown in the following Figure 8

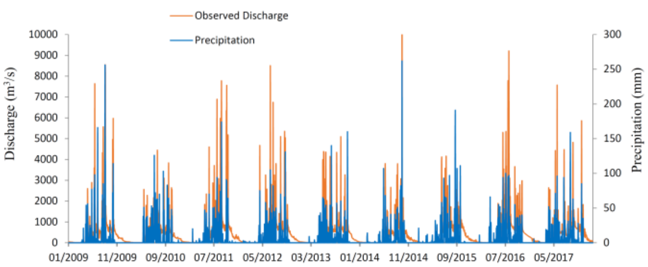

Figure 8: Comparison between observed discharge and precipitation of Teesta basin

From Figure 8 we can see that if precipitation increases then discharge increases and if precipitation decreases then discharge decreases.

4. SWAT-CUP for Calibration and Validation

After getting the simulated result from SWAT model we need to compare our simulated result with observed result. Usually, simulated result will not coincide with observed result because there are many physiographic parameters use in SWAT which influence discharge cannot measure directly. So, we need to calibrate our model by changing the model input parameters values to produce simulated result that are within in a certain range of observed result. Calibration can be done manually or auto calibration by SWAT-cup [27]. SWAT-CUP is a computer program for calibration of SWAT model that include Sequential Uncertainty Fitting (SUFI2) algorithm, GLUE, Parasol, procedures to SWAT. SWAT-CUP is an additional software that is used to manually and automated calibrate the parameters and analysis the sensitivity and uncertainty of parameters. A semi-automated approach (SUFI2) is incorporated in SWAT-CUP where we can manually adjust parameters and ranges iteratively between auto calibration and incorporating sensitivity and uncertainty analysis [28]. Completing calibration, we need validation our model by using the calibrated parameters values from calibration. In this study, calibration and validation in SWAT model were done by SUFI2. The calibration and validation periods have been selected for 2009 to 2013 and 2014 to 2017 respectively.

5. Model performance evaluation

The acceptance of SWAT simulation results is determined by examining the coefficient of determination (R^2), the Nash and Sutcliffe efficiency (NSE). The R^2 value is an indicator of the strength of the linear relationship between the observed and simulated values. The NSE simulation indicates how well the plot of observed values versus simulated values fits the 1:1 line. If the R^2 and NSE values are less than or very close to zero, the model prediction is unacceptable or poor. When the values are one, the model's prediction is accurate [29]. Model simulation is generally considered to be satisfactory if R^2 >0.75 [30] and NSE > 0.50 for stream flow [31]. R^2 and NSE are statistically defined as follows

$$R^2 = \left(\frac{\sum_{i=0}^{n} (Q_{obs} - \bar{Q}_{obs})(Q_{sim} - \bar{Q}_{sim})}{\sqrt{\sum_{i=0}^{n} (Q_{obs} - \bar{Q}_{obs})^2} \sqrt{\sum_{i=0}^{n} (Q_{sim} - \bar{Q}_{sim})^2}} \right)^2$$

and

$$NSE = 1 - \frac{\sum_{i=0} (Q_{obs} - \bar{Q}_{sim})^2}{\sum_{i=0} (Q_{sim} - \bar{Q}_{obs})^2}$$

where Q_{obs} is the observed data on day i, Q_{sim} is the simulated output on day i, $\bar{Q}_{obs}$ is the mean observed data during study period, $\bar{Q}_{sim}$ is the mean simulated data during study period and n is the total observed data.

6. Results and Discussion

The main aim of calibration is to provide the best possible fit values amongst the observed and simulated stream flow for a particular calibration period. Here we calibrated our model by manual and automated changing the parameter values within their range. The hydrological model generated for both daily and monthly discharge simulation at Kaunia point in Teesta River. The fitted values of calibrated sensitive parameters for both simulations are given in Table 4. Using the same calibrated values of parameters, we have done the validation. In this study, a five years data series that is in the period 2009-2013 has been used for calibration. After finalizing the parameters, the model was simulated for the entire time frame and the last four years of simulation from 2014 to 2017 was chosen as the validation period for the model in both daily and monthly simulation.

6.1 Calibration and Validation result in daily simulation

In the calibration period, the values of statistical tools NSE and R^2 are $0.80(0 \leq NSE \leq 1)$ and $0.82(0 \leq R^2 \leq 1)$ whereas in the validation period these are 0.76, and 0.77 respectively. The calibration and validation graph along

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with simulated discharge and observed discharge is shown in Figure 9 and Figure 10 respectively.

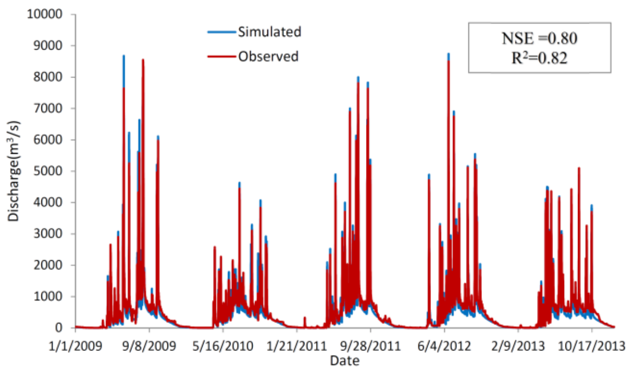

Figure 9: Daily flow calibration period (2009-2013)

NSE value is 0.80 for calibration period which is acceptable and for validation NSE value 0.76 is also adequate. The R^2 values are 0.82 and 0.77 for calibration and validation respectively. It indicates that model results produced for the flow were acceptable and good for both periods.

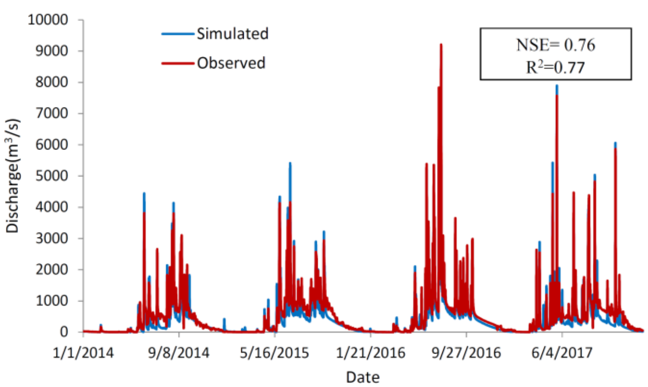

Figure 10: Daily flow validation period (2014-2017)

The PBIAS of annual stream flow for the calibration period and validation period are 10.0% and 28.6% respectively. The positive value indicated that the model had underestimated bias during the calibration and validation period.

6.2 Calibration and Validation result in monthly simulation

In monthly simulation, the NSE values for calibration and validation period are 0.92 and 0.84 respectively. The coefficient of determination (R^2) are found to be 0.93 and 0.88 for calibration and validation period. It also indicates that the model result produces acceptable flow that is very good. PBIAS are determined as 8.8 for calibration and 16.1 for validation respectively. It indicates that at calibration stage the parameter is very good and validation stage these are also satisfactory. It also indicates underestimation of simulated flow because of positive PBIAS. The model generated mean monthly discharge and observed mean monthly discharge at Kaunia point is shown in Figure 11.

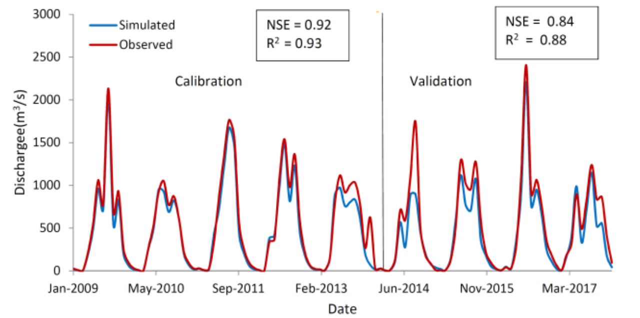

Figure 11: Monthly observed and simulated flow at Kaunia point for calibration and validation period

Overall, the model performance test values indicate that the model results are very good in both in daily and monthly simulation that we can use this calibrated model to predict or measure the discharge by using meteorological data (precipitation, temperature, solar radiation, humidity, wind speed).

Table 4: Fitted value of calibrated parameters in daily and monthly simulation

Parameter	Name	Range	Fitted value (monthly simulation)	Fitted value (daily simulation)
r__CN2.mgt	Initial SCS runoff curve number for moisture condition II	[-0.15, 0.25]	0.08	0.033
r__SOL_AWC().sol	Available water capacity of the first soil layer (mm/mm)	[-0.15, 0.15]	0.14	0.09
r__SOL_K().sol	Saturated hydraulic conductivity of first soil (mm/hr)	[0, 0.2]	0.035	0.01
v__GW_DELAY.gw	Groundwater delay (days)	[30, 450]	87.5	45.83
v__GWQMN.gw	Threshold depth of water in the shallow aquifer for return flow to occur (mm H_2O)	[0, 5000]	125	208.33
v__REVAPMN.gw	Threshold depth of water in the shallow aquifer for revap to occur (mm H_2O)	[0, 500]	262.5	454.17
V__GW_REVAP.gw	Groundwater revap coefficient	[0.02, 0.2]	0.178	0.03
v__ALPHA_BF.gw	Baseflow alpha factor(days)	[0, 1]	0.73	0.98
v__RCHRG_DP.gw	Deep aquifer percolation fraction	[0, 0.3]	0.58	0.54
v__CH_N2.rte	Manning's n value for the main channel	[0.0, 0.3]	0.03	0.03
v__CH_K2.rte	Effective hydraulic conductivity in main channel alluvium (mm/hr)	[0.0, 500]	437.5	170.83
v__CANMX.hru	Maximum Canopy Storage (mm H_2O)	[0,10]	1.75	9.58
v__ESCO.hru	Soil evaporation compensation factor	[0.6, 0.85]	0.98	0.93
V__EPCO.hru	Plant uptake compensation factor	[0, 1]	0.88	0.18
V__SURLAG.bsn	Surface runoff lag coefficient	[1, 24]	6.64	5.04

7. Conclusions

Teesta River basin is most important basin for the northern part of Bangladesh. This research exercises the use of hydrological data with Arc-SWAT in combination of SWATCUP software to indicate model performance which can produce acceptable results. In this study, different satellite-based data and organization open-source data were used. Besides, there are many different parameters of the governing equation were used for adjusting value. The model was generated for both monthly and daily simulation. In this research, overall monthly simulation shows good efficiency of the model than daily simulation though daily simulation is more effective for a SWAT application. There were few under-estimations of the model from observed period. Most of the time the model agrees with observed value but at some case, the model underestimates the simulated value with the observed value because of the data limitation and most of the basin area was in Indian portion. The statistical fitting values were well matched every time but sometimes it deviated from the best fit value. It is also observed that SWAT model performed well for this watershed with different source of data with parameterization methods. The knowledge is enhanced by building hydrological model for the studied catchment. We can use this hydrological model for other river catchments.

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