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To Assess the Impact of Land Use and Climate change on Streamflow of Upper Baitarani River Basin

Amit Kumar Khatai
PG Student. Dept. of Civil Engineering, CET Bhubaneswar, India

Abstract: The upper Baitarani river basin covers an area of 8619 km^2. Streamflow is important in hydrological cycle and useful for living beings. Evaluating the impacts of land use changes and climate changes on the streamflow of a watershed has been an area of interest in recent years. Hence in this current work SWAT model has been used to assess the impact of land use changes and climate changes on streamflow of Baitarani River Basin. The SWAT model is further calibrated and validated for daily and monthly streamflow at the gauging station of Anandpur barrage situated along the Baitarani River. The results show that the simulated streamflow is calibrated with values of R^2 and NSE as 0.62 and 0.59 for the time of 2000 to 2011 and validated with values of R^2 and NSE as 0.58 and 0.51 for the year 2012 to 2016 for daily basis. Similarly, streamflow is calibrated with values of R^2 and NSE as 0.84 and 0.74 for year of 2000 to 2011 and validated with values of R^2 and NSE as 0.81 and 0.7 for the time of 2012 to 2016 for monthly basis. All these analyses are done using SUFI-2 algorithm. Both is found to be satisfactory and good for different time basis. The study also indicate that the land use have changed significantly over the years resulting in an increase majorly in urban area and decrease in forest area and agriculture area leading to increase in streamflow but changes have not shown significant changes in annual average streamflow but future climate changes shown significant changes in streamflow due to variation in precipitation and temperature. Predicted streamflow also showed a significant increase on streamflow as this could be used to make required use of water and also controlling flood.
Keywords: Climate change, daily and monthly streamflow, land use change, land use prediction, precipitation and temperature, SUFI-2, SWAT model.

I. INTRODUCTION

Water and land are the vital characteristics of natural resources. So, there are many studies which are conducted to evaluate the impacts due to climate and land use changes. All studies show that these changes impact the hydrological cycle but there are not so much studied conducted in India. In India considerable loss of economy is caused due to outrageous climate events nowadays (Monirul and Mirza, 2003). This can be due to the rapid increase in population and their change in lifestyle. This commitment to such changes may initiate flood, extraordinary aridity, increased runoff, drought situation and soil erosion. Subsequently, climate plays a significant part in choosing the available quantity of water for human and environmental usage.

The hydrological cycle can be disseminated due to change in land use by altering the base flow (Wang et al., 2006) and annual discharge (Costa et al., 2003). Climate change is one of the foremost vital worldwide natural challenges, which impacts generally framework influencing on diverse things like food production, health, water supply and more. This is rising because of the increasing concentration of greenhouse gases since industrialization. The change of climate also impacts the hydrological cycle through different forms of precipitation, transpiration rates, evaporation and soil moisture. This has touched all parts of India. Around more than half of the population directly depends on climate sectors such as agriculture, forest, fisheries, etc. In this manner, India includes an essential stake in logical advancement to progress alteration and balance.

Over the span of 100 years, Odisha is standing up to a preposterous climatic condition as floods, warm waves, dry seasons, seismic tremors and winds and at the past, these have influenced 25 of 30 areas bringing about loss of lives and property (Mahapatra, 2006). Odisha is nearer to the sea and any minor change in temperature can have an effect on land mass. Unpredictable varieties in the critical parameters like temperature and precipitation impact the hydrology and accessibility of resources.

Climate change can be depicted as an alter within the climate that can be perceived by variations in the statistical distribution of climate factors for an extensive period. For this, general circulation models (GCMs) are used. These are the preeminent tool which is used for assessing the impact of change of climate on individual and nature.

Similarly, the effects of land use change of a catchment on hydrological parameters are most likely where the surface properties experience variation because of changes. Different sorts of land use straightforwardly impact the rate of penetration into the soil, runoff and therefore the total volume of runoff leaving the outlet. This cause soil erosion, organic matter depletion and nutrient leaching and many more that may help in change of flood reoccurrence, the variation of base flow, flood severity and change in discharge. So, there must be a study to assess the impacts of both changes.

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II. STUDY AREA

The river Baitarani which is at a height of 900m above the sea level originates from Guptaganga hills in Keonjhar, which is nearly 2 km from Gonasika village. Nearly 736 sq. kms. and the remaining area of Baitarani basin falls in Jharkhand and Odisha respectively with a total of 14,218 sq. kms. The area of upper Baitarani river basin is taken as my study area which has an outlet point at gauging station of Anandpur. The area considered lies between 85°10' to 86°23' and 20°53' to 22°15' and covers an area of 8,619 sq. kms. calculated using ArcGIS. The climate is Tropical with a mean yearly rainfall of 1442.53 mm. The hilly regions face lesser temperature variations compared to plain areas during the years. April and May are the hottest months and throughout December and early January are the coolest months having a minimum temperature of 12 °C whereas the maximum mean annual temperature of 37.67 °C and the mean annual minimum temperature is 20.32° C (CWC, 2014).

Fig. 1 Study Area

III. MATERIALS AND METHODS

A. Model Inputs

1) *Digital Elevation Model (DEM):* Global 1-arcsecond 30m SRTM digital elevation model of different coordinates as downloaded from the USGS (http://earthexplorer.usgs.gov/) website originally in the form of tiles and then were mosaicked to obtain a single map as shown. The study area is automatically delineated with the help of the outlet i.e. Anandpur Station.
2) *Soil:* Harmonized world soil data of 1:50,00,000 scale in vector format is downloaded from FAO (Food and Agricultural Organization) soil gateway (http://www.fao.org) as shown in the figure. The soil map is clipped by utilizing the shapefile created in the first step.
3) *Land Use:* The satellite images for the different years for land use maps were acquired from the USGS website (https://earthexplorer.usgs.gov/). Using the two tiles from path 139 and 140 and row 45, LANDSAT 5 and 8 satellite images for three different years (2003, 2010, 2017) having a spatial resolution of 30m X 30m were accomplished. Then by using ArcGIS 10.4, the tiles were mosaiced for different years and they were clipped using the shapefile of the study area. Each image is then classified into different land use categories with the help of maximum likelihood algorithm in supervised classification tool of ArcGIS 10.4. The different classes for land use divided were water body, dense forest, open forest, agriculture, barren, urban and industry.
4) *Slope:* Slope is discretised into 5 classes in this study, that are 0-5, 5-20, 20-50, 50-100 and 100-9999 which is by using DEM.
5) *Observed Data:* The daily discharge data at the outlet i.e. Anandpur is obtained from CWC, Bhubaneswar. Here, discharge data of 23 years were used, and the model is run two times for monthly and daily time series i.e. one for calibration and other for validation of streamflow with five years to skip as warmup period. The map of the year 2003 is used in calibration period and map of 2017 is used in validation period. The calibration and validation were conducted using tool SUFI2 in SWAT-CUP.

Period taken for calibration = 12 years (2000-2011)
Period taken for validation = 5 years (2012-2016)

B. SWAT

Soil & Water Assessment Tool is created by Jeff Arnold for the Agricultural Research Service (ARS) of the US Department of Agriculture and Agricultural Experiment Station in Texas. This model with ArcView GIS interface is used to predict the impact of land on water and sediment loads and many more in any type of watershed with varying soil and land use over an extensive period. (Arnold et al., Srinivasan et al., 1998; Arnold and Fohrer, 2005; Gassman et al., 2007). This is a continuous time, long-term simulation, deterministic model which needs data about terrain, soil, climate and land practices in the watershed. The model incorporates the hydrological processes related to sediment movement and water movement, crop growth, nutrient cycling, etc. on a spatial and temporal frame, using a daily time to a yearly time scale (monthly also). SWAT can also be used for modelling watersheds that are ungauged. The relative impact of alternative input data on quality of water or other variables can also be quantified using SWAT model. Simulation of any size of basins or a variety of management strategies can be performed without too much investment of time or money. SWAT model utilises temporal and spatial data as input. These includes DEM, land use, and soil data map. Other data includes daily observed streamflow and climate data. This model divides the area into number of basins-based DEM which is subsequently followed by division into several Hydrological Response Units (HRUs) based on one sort of land use, soil and slope combinations. Sub-basin is suitable when considering spatiality for watershed commanded by one sort of soil and land use. Input for each sub-basin is prepared as Climate, HRUs, groundwater, main channel water storage structures and tributary channels. These are the components of the hydrological process. Generally, precipitation is the major source of water in SWAT system. The SWAT 2012 model is integrated with ArcGIS 10.4 software to perform the simulation of streamflow of the study area.

The simulation of the hydrologic cycle contains land phase and water phase. In land phase, water balance equation is used but for water phase, Muskingum method is utilised for simulation by calculating for each HRUs. In this study, the water balance equation (land phase) is applied in SWAT to simulate the hydrological cycle. That is:

$$SW_t = SW_o + \sum_{i=1}^{t} (R_i - Q_i - E_i - w_i - Q_i)$$

Where, $SW_t =$ moisture of soil at time t, SW_o = initial moisture of soil, R_i = precipitation of ith day, Q_i = surface runoff ith day, E_i = evapotranspiration ith day, w_i = water infiltration to the bottom of soil profile ith day, and Q_i = amount of water returning to the groundwater ith day.

C. Sensitivity Analysis

Soil Water Assessment Tool Calibration and Uncertainty Program established by Eawag Swiss Federal Institute, is a program which gives result for the calibration, validation and sensitivity analysis of models. It has various techniques for the analysis of the model for analysis. This accesses the SWAT input files and runs the SWAT simulations by adjusting the given parameters. The impact of different parameters on simulation result is assessed through the sensitivity analysis. This analysis recognizes and ranks the parameters which have significant impact on model outputs. Changing the sensitive parameters can have most effect in outputs. To find the sensitive parameters, at first 16 parameters were used which can directly show impacts on streamflow thus, could have an impact on outputs. After an iteration, the parameters were identified which are sensitive and later these were changed for further iteration to get a good objective function and variance can be minimized.

1) *Calibration and Validation:* These were done to maximize the efficiency of the model by utilizing the parameter values with range. Calibration includes altering the input (range of parameters from minimum to maximum) and comparing output with the recorded data obtained from agencies till a satisfactory objective function is attained. Sensitivity analysis, calibration and validation were done through the SWAT-CUP using SUFI2 algorithm since this is broadly used calibration tool and had achieved good results. 200 iterations were done by changing the sensitive parameters for daily and monthly streamflow until the objective functions are satisfied. Then the model is then validated for 2012-2016 keeping the calibrated parameters same and is run for the same number of iterations to test the ability of SWAT model for its prediction.
2) *Objective Function:* SWAT-CUP compares between simulated and observed values and gives values in a set of several objective functions.

Coefficient of determination (R^2)

$$R^2 = \frac{[\sum_{i=1}^{n}(Q_{si}-Q_{sm})(Q_{oi}-Q_{om})]^2}{\sum_{i=1}^{n}(Q_{si}-Q_{sm})^2 \sum_{i=1}^{n}(Q_{oi}-Q_{om})^2}$$

Nash Sutcliffe efficiency (NSE)

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Q_{oi} - Q_{si})^2}{\sum_{i=1}^{n}(Q_{oi}-Q_{om})^2}$$

Where, Q_{si} is the simulated data, Q_{sm} is the observed data, Q_{oi} is the mean observed, Q_{om} is the mean simulated data.

3) *Model Performance:* NSE and R^2 are used as to evaluate the performance of models. Performance ratings of recommended statistics for simulation of streamflow

D. Land use Prediction using Markov Chain

1) *Markov Chain Model Analysis:* This is presented by Andrei A. Markov who is a Russian mathematician in the year 1970. Markov chain is used mainly for simulating land use change. The simulation process of this model mainly generates a probability transfer matrix to forecast future changes. It is a stochastic model that describes the probability between initial and final state to find the transition between different land use using transition matrix. This analysis is a random process that is discrete in time and state both. Markov Chain model is first used by Burnham (Mishra and Rai, 2016; Parsa et al., 2016). This can be represented by (Subedi et al., 2013):

$$Lu_{(t+1)} = P_{ij} * Lu_t$$

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & P_{1m} \\ \vdots & \vdots & \vdots \\ P_{m1} & P_{m2} & P_{mm} \end{bmatrix}$$

where Lu_t and $Lu_{(t+1)}$ are land use at time t and t + 1 respectively. P_{ij} is the transition probability matrix whose value ranges from 0 to 1 and m is the land use type number. A transition matrix contains information about the probability of transition between the different land use. For the matrix to be valid, the sum of all terms must be 1. This study uses 2003 and 2017 land use map to generate the transition matrix change.

Cellular Automata is a dynamic model with a spatial-temporal calculation. This is a simulation model where space, state and time are discrete variables and interactions assigned are local variables. It is created by Stanislaw Ulam and John Neumann at Los Alamos National University in 1940 for application in land use changes theoretically.

Afterwards, CA is used by Tobler in geographical modeling (Arsanjani et al., 2013), and is widely used in the spatial model for forecasting future land use. The basic principle is that the land use changes for any location can be explained by the current state and changes in neighboring cells (Koomen and Borsboom-van Beurden, 2011).

CA-Markov Chain model is the combination of both models and are advantageous for land use change modelling (Mishra and Rai, 2016; Parsa et al., 2016).

This combination is done because Markov chain model comes short at spatial referred output and there is no spatial distribution of individual land use, but transition probabilities can be correct on classification basis (Arsanjani et al., 2013). The Cellular automata included to this model lead to feasible spatial transitions in a zone for an extensive period (Subedi et al., 2013). The CA-Markov uses transition area file for improving other land use characteristics. This is done to predict 2030 and 2060 land use map.

2) *Validating LULC Prediction Model:* The validation of the predicted model of land use change is done by comparing the simulated result of land use from CA-Markov model with the reference map that is classified for the same year.Comparing the predicted land use map with the reference is done by Kappa Index, which is extensively preferred in validation of predicted land use change (Mishra and Rai, 2016; Parsa et al., 2016; Subedi et al., 2013). This is accessible in IDRISI Selva.

E. LARS-WG

The Long Ashton Research Station Weather Generator is a stochastic weather generator tool which can be used to generate climate data at a place under present and future conditions (Racsko et al., 1991; Semenov et al., 1998; Semenov and Brooks, 1999). First model is introduced in Budapest (1990) as a part of Assessment of Agricultural Risk in Hungary and which is then revised by Semenov in 1998.

All the input data are in daily time format which includes precipitation, min and max temperature and solar radiation. This tool uses historical data for a site to calculate parameters for fitting the probability distributions of weather variables as well as correlations between generated and observed time series.

These parameters generated are then used to generate synthetic weather time series of discretionary length by arbitrarily choosing values from the appropriate distributions.

By consoling the parameters of distributions for a site with the predicted changes of climate got from the climate models (global or regional), a daily climate scenario for this site is produced.

This is used in different climates and performs well in producing weather including extreme weather events (Semenov et al., 1998, Semenov, 2008).

This uses a semi-empirical distribution (SED) which is defined as the cumulative probability distribution function (PDF) to approximately simulate dry and wet series, daily precipitation, temperatures and solar radiation and this distribution. The number of intervals (n) utilised in SED in new version of the model is 23 as compared to 10 in the previous one which henceforth, gives an increasingly precise representation of the observed distribution.

This can moreover be used for generation of long-term climate information for hydrological studies, simulate data to unobserved locations and serves as a cheap tool to produce weather data. Model Calibration is done by “SITE ANALYSIS”, which analyses daily observed weather data to determine site parameters and stores the information in two parameter files i.e. wgx-file and stx-file (Chen et al,2013).

1) *Model validation:* The two parameters which were gotten from historical climate information during calibration are utilised to create climate condition with the same statistical characteristics. Validation is done to analyse and compare the statistical characteristics of the historical climate information and synthetic climate information to see how well the model can simulate the precipitation and temperatures at the chosen sites that to be used in the study (Chen et al, 2013). For validation Q Test is utilised. The test includes the Kolmogorov-Simirnov (K-S) test to compare likelihood conveyance.
2) *Synthetic data generation (GENERATOR):* The parameter files which were gotten from observed climate information during calibration process are utilised to create daily time series climate information comparing the initial observed climate information. These information comparative to a specific climate scenario can be produced by using General Circulation Models (GCMs) (Chen et al, 2013). LARS-WG 5 includes climate based on 15 numbers of General Circulation Models (GCMs), which are all gotten from the fourth IPCC report, are included (Chen et al, 2013). In this study, predictions of future climate data were done by utilizing the HadCM3 GCM model under SRA2 scenario for the time span of 2011-2030 and 2046-2065. The Hadley Centre Couple Model 3 version is utilised in Fourth Assessment report including third and fifth. This model is one the most renowned GCMs of the climate and is positioned high (fourth out of 22 CMIP3 models). This is created in the year 1999 at UKMHC7 Research Center in England with a spatial resolution of 2.5° X 3.75° (Khadka et al, 2014). This has the ability of capturing the time-dependent of historical climate data in response to natural forcing and this has made an important tool in studies concerning the identification of past climate changes.

F. Impact of Climate change on Streamflow

Three simulations were done to evaluate the effect of climate change on streamflow by SWAT. For this analysis, the one factor at a time approach is considered.

I: Land use map of 2017 and Climate of 2012-2016
II: Land use map of 2017 and Climate of 2026-2030 and
III: Land use map of 2017 and Climate of 2056-2060

G. Impact of Land use change on Streamflow

Same approach is followed to see the effect of land use change on stream flow.

I: Land use map of 2003 and Climate data of 2012-2016
II: Land use map of 2017 and Climate data of 2012-2016
III: Climate data of 2012-2016 and land use map of 2030
IV: Land use map of 2060 and Climate data of 2012-2016

H. Prediction of Stream Flow for the year 2030 and 2060

By using the calibrated parameter values, streamflow for both the predicted years were determined on daily basis varying only the meteorological parameters and land use maps keeping the soil and slope the same.

IV.RESULTS

This part consists of maps used as input, parameters used for analysis, calibrated and validated streamflow results using SWAT-CUP, prediction of land use maps, prediction of precipitation and temperature, impact of land use change and climate changes on streamflow along with simulation of future streamflow.

A. Maps used as input

The DEM map with outlet point at Anandpur, land use classified map (supervised classification) and soil map with their classification (FAO) and classified slope map with different legends are

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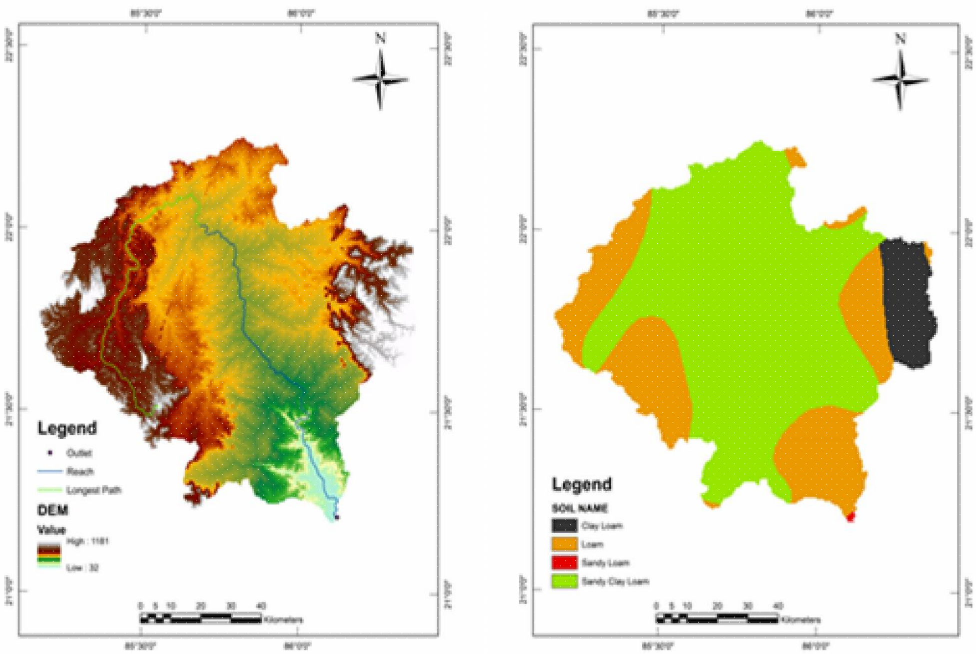

Fig. 2 DEM and Soil

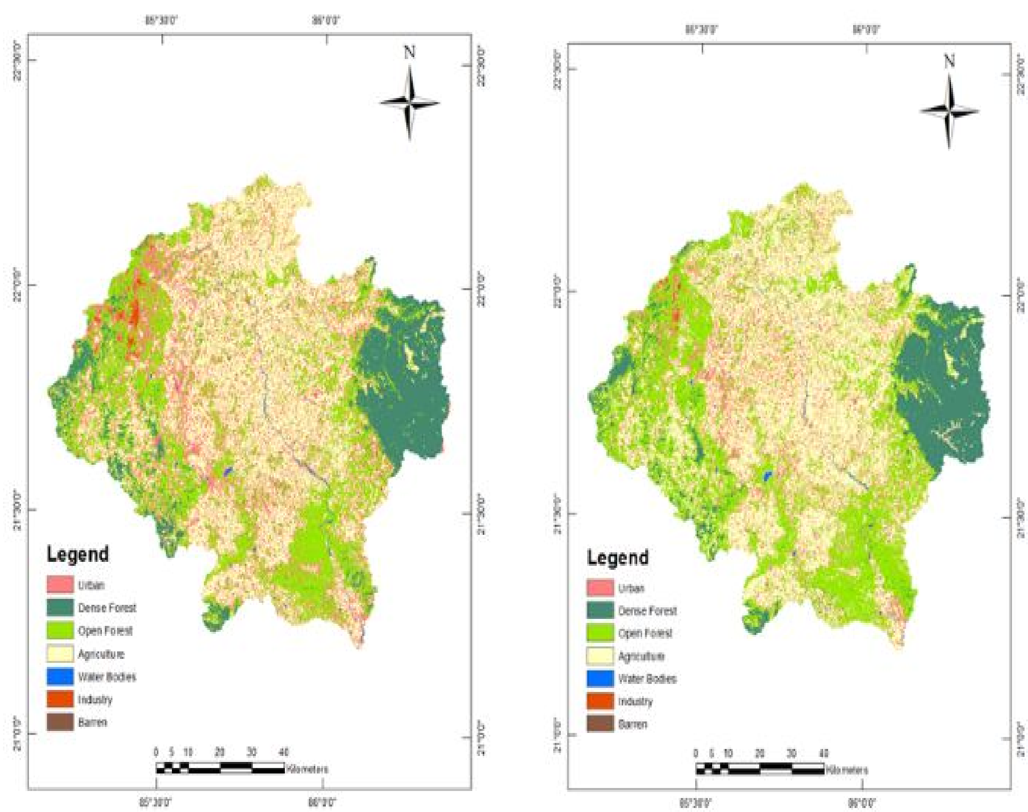

Fig. 3 Land Use 2003, 2017

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B. Sensitivity Analysis

The maximum and minimum values of these sixteen flow parameters were used referring to journals. The description of parameters with the minimum, maximum values and their fitted values at last iteration are represented in the table.

Table I
Fitted And Ranges Of Flow Parameters

Rank	Parameter	Qualifier	Fitted Value	Minimum Value	Maximum Value
1	CN2	r_	-0.5925	-1.5	1.5
2	SOL_K	v_	0.6725	0	1
3	GW_DELAY	v_	60.4925	1	450
4	GWQMN	v_	2437.5	0	5000
5	HRU_SLP	r_	0.13725	0	0.3
6	SOL_BD	r_	0.235225	0.01	1
7	CH_N2	r_	0.288075	0.01	0.5
8	ESCO	r_	18.4125	5	150
9	ALPHA_BNK	r_	0.2825	0	1
10	REVAPMN	r_	-0.772	-0.8	0.8
11	GW_REVAP	r_	0.1615	-0.2	0.4
12	CH_K2	r_	99.7525	1	400
13	SLSUBBSN	r_	0.5075	0	1
14	SOL_AWC	r_	13.75	0	500
15	ALPHA_BF	r_	0.215	-1	1
16	OV_N	r_	0.755	-1	1

Table II
Sensitivity Analysis Of Flow Parameters

Rank	t-Stat	P-Value
1	-12.5897598	0
2	-4.54592803	0.00000992
3	-4.16624381	0.000047682
4	-2.48575764	0.013824406
5	-1.52083841	0.130026347
6	-0.76172837	0.447202696
7	-0.61987519	0.53611103
8	-0.39899918	0.69035902
9	0.098389148	0.921730977
10	0.369883882	0.711896714
11	0.603395534	0.546992737
12	0.996451914	0.320346367
13	1.012036516	0.312856813
14	1.364207889	0.174177537
15	1.828559549	0.069093568
16	5.111956682	0.000000799

C. Results for Simulation, Calibration and Validation

1) *Daily Time:* Simulation and calibration were done for the time period of 1995 to 2011 by including five years of warmup period. The model is validated for the period of 2012 to 2016 using 2007 land use map.

a) *Simulated:* The results show that the SWAT model overpredicts the peak flows and base flows when compared to observed data. The Coefficient of Determination R^2 is found as 0.48 for the simulated data for the streamflow. These simulation data were not satisfactory; hence calibration is done.

b) *Calibration:* For improving the simulation data, calibration is conducted. By changing the parameters, the peak flow and base flows were reduced. The Coefficient of Determination R^2 is found as 0.62 and NSE is found as 0.59 for the calibrated streamflow. These data were good according to performance ratings.

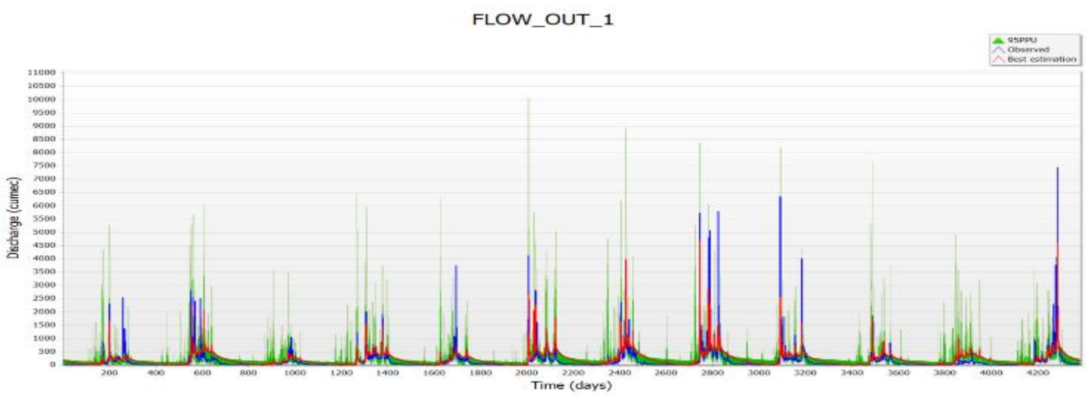

Fig. 4 Calibrated vs observed streamflow

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c) *Validation:* The model is validated for the period 2012 to 2016 with the same parameters without changing the values from the calibration. The Coefficient of Determination R^2 is found as 0.58 and NSE is found as 0.51 for the calibrated streamflow. These simulation results were satisfactory according to performance ratings.

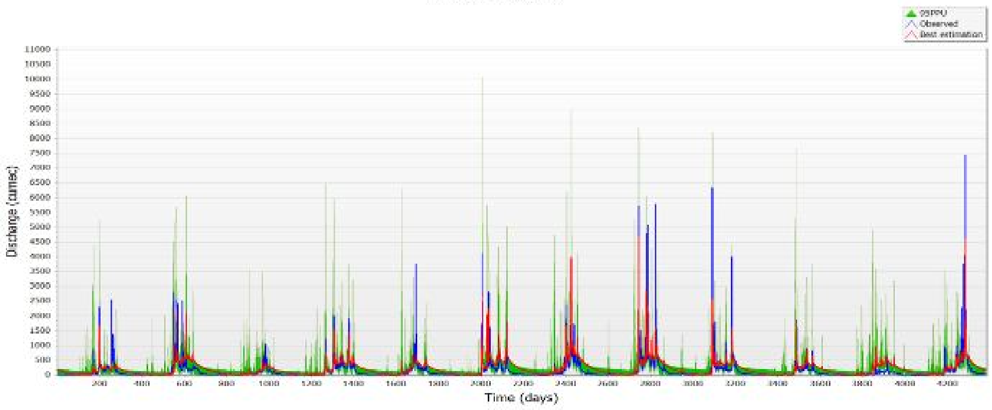

Fig.5 Validated vs observed streamflow

Table III
For Daily Basis

Data Set	R^2	NSE
Simulated Data (2000-2011)	0.48	___
Calibrated Data (2000-2011)	0.62	0.59
Validated Data (2012-2016)	0.58	0.51

2) *Monthly Time:* In the same way, the simulation, calibration and validation were done for the monthly time step. The curve smoothens out as compared to daily time analysis due to averaged value.

a) *Simulated:* The Coefficient of Determination R^2 value is found as 0.811 for the simulated data (SWAT model) when compared with observed streamflow which is very good.

b) *Calibrated:* After calibrating the Coefficient of Determination R^2 value is found as 0.84 and NSE value is found as 0.74 for the calibrated streamflow. These simulation data were very good according to performance ratings and gave even good results compared to simulated streamflow.

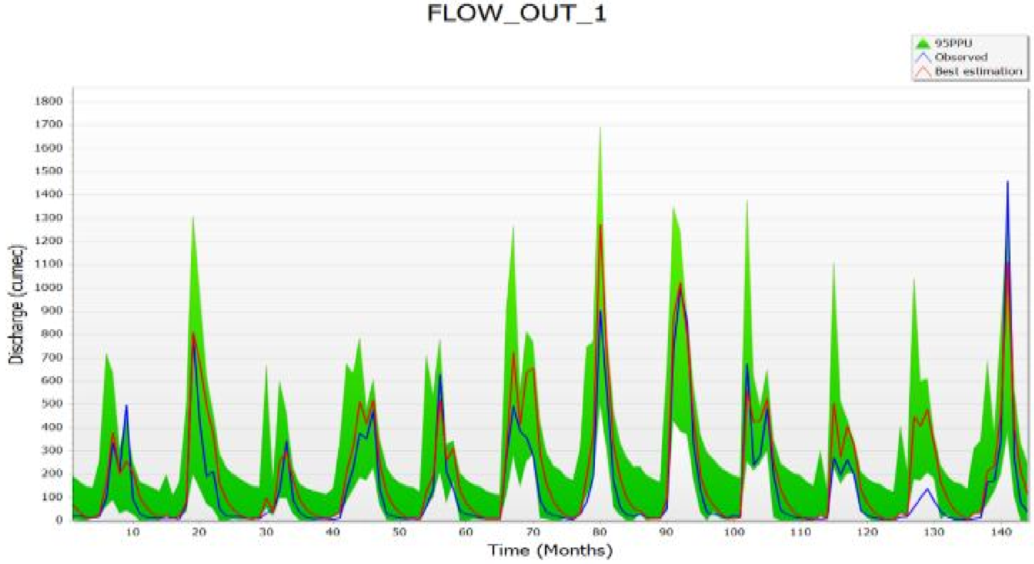

Fig. 6 Calibrated vs observed streamflow

c) Validation: The Coefficient of Determination R^2 value for the validated streamflow is found as 0.81 and NSE value is found as 0.70 which also represent good values according to performance rating.

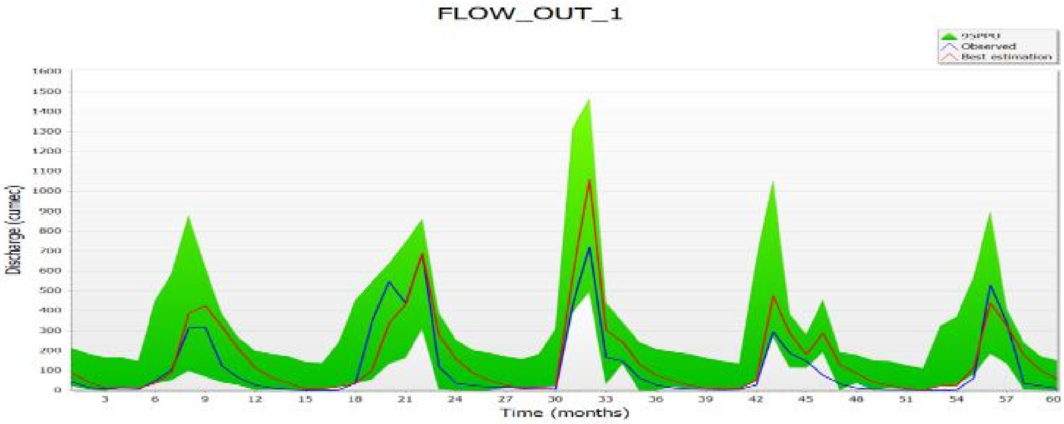

Fig. 7 Validation vs observed data

Table IV
For Monthly Basis

Data Set	R^2	NSE
Simulated Data (2000-2011)	0.81	___
Calibrated Data (2000-2011)	0.84	0.74
Validated Data (2012-2016)	0.81	0.7

D. Validation of the CA-Markov Model

For validation, the simulated map is used to compare with the land use map which is classified in supervised classification. The land use for 2017 is predicted through the model by using the maps of the year 2003 and 2010 to present simulated map and then the comparison is done with the actual land use map of 2017.

The Kappa coefficient is used by CA-Markov model for validation results. The validation process is done using the validate tool. The validation results showed Kno = 0.8107, Klocation = 0.8304, KlocationStrata = 0.8304 and Kstandard = 0.773. The values exceeding 0.8 for each kappa index are taken to be accurate (Viera and Garrett, 2005). Therefore, this modeling is suitable for predicting future LULC maps thus, used in this study.

The predicted map for 2030 and 2060 using CA-Markov modeling at 10 number of iterations are shown in fig.

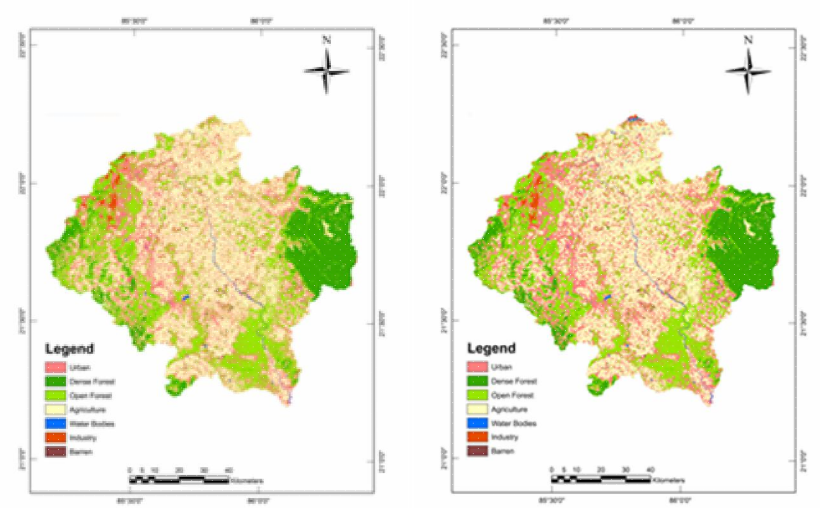

Fig. 8 Simulated 2030 and 2060 Land use

E. Calibration and Validation LARS-WG

Calibration and validation of the precipitation and temperature were done using "Site Analysis" and "Q test" present in LARS-WG. Performance of this tool is checked using Kolmogorov-Simonov test. Performance in simulating precipitation and temperature for Anandpur is in the table. All shows a p-value of K-S test greater than 0.05 during validation. This shows that SED is able to generate observed probability distributions correctly. The correlation between the mean observed and mean generated precipitation, maximum and minimum temperature were found to be very good.

F. Impact of Land use change on Stream Flow

TABLE V. Different Land Use In Upper Portion Baitarani Basin

ID	LULC Specification	2003	2017	2030	2060
		in %			
1	Urban	13.29	22.1	25.14	26.76
2	Forest	43.37	39.13	37.32	35.75
3	Agriculture	42	37.46	36.05	35.61
4	Water	0.45	0.51	0.51	0.71
5	Industry	0.13	0.43	0.59	0.79
6	Barren	0.76	0.37	0.39	0.38

Comparing the mean annual discharge due to 2003, 2017, 2030 and 2060 land use map, only due to change in land use, the streamflow has increased every year but not significantly. There is a massive conversion of agricultural and open forest area into urban areas. The increase in streamflow is due to decrease in vegetation areas leads to an increase in water storage in soil. This increase is not significant may be because area of water bodies did not change drastically compared to previous maps.

Table VI. Streamflow Response to Land Use Change

Scenario	Mean annual Streamflow (m^3/sec)
I	195.36
II	195.76
III	195.98
IV	196.24

G. Impact of Climate Change

The results for the observed, 2011-2030 and 2046-2065 for scenario A2 according to the downscaled HadCM3 (precipitation & temperature) are shown. This indicate an increase in both precipitation and temperature compared to historical period. When only considering climate change, an overall increase in mean monthly streamflow is predicted for future scenario.

Table VII. Observed and Predicted Changes

Parameter	Observed	A2 Scenario	
	1995-2011	2011-2030	2046-2065
Temperature (°C)	26.04	26.24/ (+0.768%)	27.24/ (+4.6%)
Precipitation (mm)	3.926	4.051/ (+3.18%)	4.042/ (+2.954%)

Climate change showed a significant impact on stream flow. Comparing the average monthly discharge due to climate data of 2012-16, 2026-30 and 2056-60, streamflow has increased in the second scenario (245.6433 m^3/sec) and decreased in the third scenario (221.6933 m^3/sec), but both the years have an increased flow compared to the first scenario (194.1678 m^3/sec). This change is due to increase in precipitation and in temperature also.

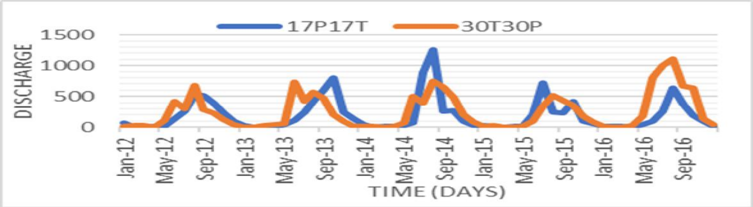

Fig. 9 Comparison of streamflow of 2017 and 2030 with only climate change

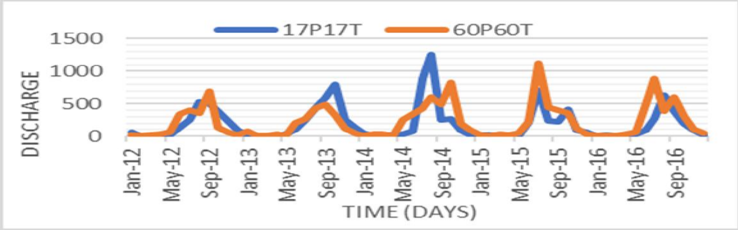

Fig. 10 Comparison of streamflow of 2017 and 2060 with only climate change

Table VIII. Streamflow Response To Climate Change

Scenario	Mean Monthly Streamflow	% change from Scenario I
I	194.168	-
II	245.643	26.51%
III	221.693	14.17%

H. Prediction of streamflow for the year 2030 and 2060

The calibrated parameters derived from sensitivity analysis were used to simulate the streamflow using the input data of their respective years. The both changes contribute to changes in water balance components and their effect has more significant impact on streamflow.

Table IX. Calibrated Values

Parameter Name	Calibrated Values
CN2	35
SOL_K	7.85, 4.63
GW_DELAY	60.492
GWQMN	2437.5
HRU_SLP	0.16884
SOL_BD	1.76
CH_N2	0.018033
ESCO	0.95
ALPHA_BNK	0
REVAPMN	500
GW_REVAP	0.022745
CH_K2	0
SLSUBBSN	150
SOL_AWC	0.14
ALPHA_BF	0.6725
OV_N	0.1215

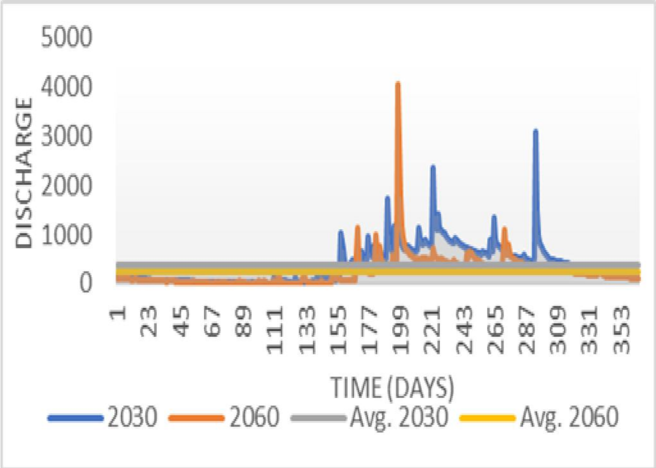

Fig.11 Simulated daily streamflow for 2030 and 2060

By comparing the three scenarios on an average the streamflow of the year 2030 is way more compared to 2060. This effect majorly due to climate change i.e. decrease in precipitation and an increase in temperature. The simulation showed a maximum streamflow of 3067 m^3/sec for 2030 and 4034 m^3/sec for the year 2060. This showed that there is a decrease of 36.12% in mean streamflow for the year 2060 compared to 2030.

V. CONCLUSIONS

The study is conducted on the Upper portion of Baitarani river basin. HRU analysis showed that there were eighty-two HRUs with one sub basin for the area considered. The simulated streamflow is calibrated with values of R^2 and NSE as 0.62 and 0.59 for the time of 2000 to 2011 and validated with values of R^2 and NSE as 0.58 and 0.51 for the year 2012 to 2016 for daily basis. Similarly, streamflow is calibrated with values of R^2 and NSE as 0.84 and 0.74 for year of 2000 to 2011 and validated with values of R^2 and NSE as 0.81 and 0.7 for the time of 2012 to 2016 for monthly basis. Both time step is found to be satisfactory based on performance rating. The impact of climate change is done using LARS-WG. This is used to generate the future time data for precipitation, maximum and minimum temperature using HadCM3 and showed good validation results. The analysis showed that there is a decreasing trend for precipitation and increasing trend for temperature. The results showed that there is an increase in precipitation as compared to historical data but for the period ;2046-65 the precipitation got decreased compared to 2011-30 but the temperature showed increase for each period. This resulted in increase in streamflow for near future and far future and had the maximum effect. The land use is predicted using CA-Markov model for 2030 and 2060 and the validation values were found to be good. The land use change did not have any significant effect on streamflow for this watershed. But the climate change had significant effect which is nearly increase in 26.51% and 14.17% on streamflow for the years 2030 and 2060 respectively compared to 2017. The future streamflow showed a peak streamflow of 3067 and 4034 m^3/sec to be experienced in their respective years and mean streamflow would decrease by 36.12% for 2060 compared to 2030.

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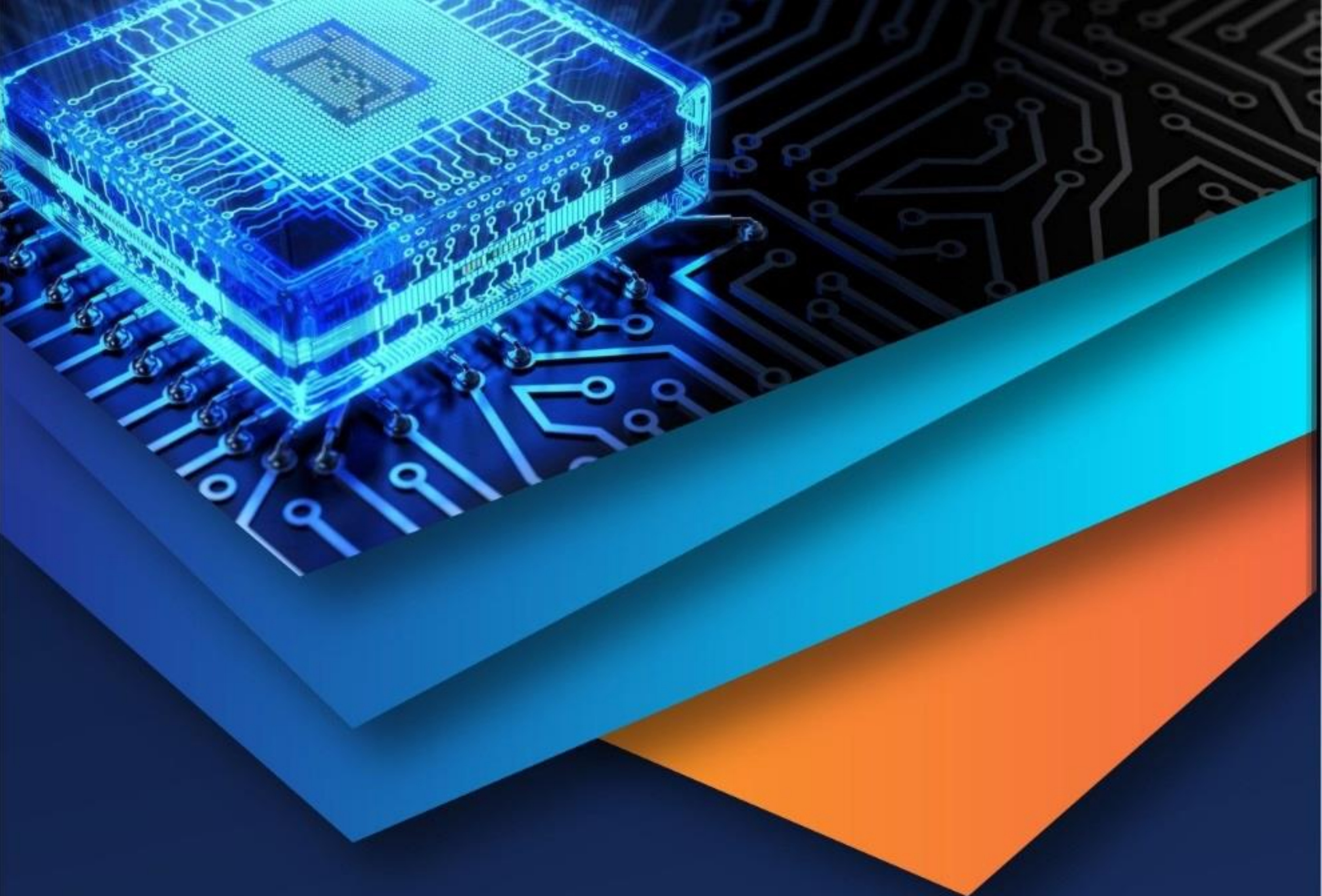

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