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Effect of LULC changes on surface runoff in Brahmani river basin using Soil and Water Assessment Tool (SWAT)

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Abstract--- Understanding the rainfall-runoff process is critical for estimating water availability. The study's major goal is to use a hydrological model (Arc SWAT) to calculate an estimate and surface runoff the influence of LULCC (Land Use Land Cover Changes) in the Brahmani River Basin from 1983 to 2019. Two distinct loss models were used to simulate runoff: the Green-Ampt model (GA) and the Soil Conservation Services Curve Number (SCS-CN) model. As input data to the model, different maps such as the elevation map, drainage map, slope map, land cover map/land use, and soil map of the watersheds are created using GIS technologies and remote sensing. At five observing stations in Keonjhar, Swampatana, Rengali, Akhuapada, and Indupur, the runoff was simulated. Due to a decrease in infiltration rate, runoff increased by 6.06 percent during this period. In the SCS-CN and GA approaches, the coefficient of determination (R^2) is 0.89 and 0.87 and the Nash-Sutcliffe efficiency (NSE) is 0.86 and 0.85, respectively, when comparing observed and calculated data. In the Brahmani River Basin, the SCS model performed better than the GA model. The model was calibrated and validated using the water and soil assessment tool calibrated uncertainty programs (SWAT-CUPs) methodology and the sequential uncertainty fitting (SUFI-2) technique.

Keywords--- *Sensitivity analysis, Green-Ampt model and SCS-CN model, RS-GIS, Runoff, Arc SWAT.*

Introduction

Definition of Hydrology and Related Sciences

The word hydrology etymologically comes from the Greek roots "hydro" which means water and study logos. Therefore, we can simply say that hydrology is the science that studies water. However, there is a definition, the most complete known to date. The moment says: 'Hydrology is a natural science that investigates the circulation, occurrence, and distribution of water, its physical, chemical and environmental aspects, including living creatures.' Hydrology, in order to guide its analysis, raises the need for other disciplines such as meteorology and climatology, ecology, mathematics and statistics, soil science, forestry, geology, hydrochemistry, geography, physics, and others. So it is also aided by photo interpretation, cartography, computing, etc.. Meteorology and Climatology: allow data analysis and processing of meteorological conditions and especially those that affect the hydrological balance such as are the rainfall and evapotranspiration of a given region. Edaphology and Geology: allows the study of infiltration processes, percolation, soil susceptibility to erosion, surface runoff, etc. Other sciences such as Botany, Physiology, Plant ecology, Forestry, for the study of the Repopulation and Management of the forest and the territory, since the presence of vegetation and its activity, is one of the elements that most affect the water cycle.

Deforestation and Hydrological Consequences

Deforestation is one of the activities that has significantly affected the balance of the waters, both on the surface and in the subsoil when decreasing its infiltration capacity. Deforestation problems have a hydrological significance preponderant since it should be mentioned that the decrease in assets forest can be synthesized in the loss of billions of hectares of forests, which implies an increase in unprotected land areas that increase both wind and water erosion and therefore the loss natural soil fertility, leading to desertification and loss of biological heritage. We can mention some direct negative effects of water because of the bad land-use planning, such as:

- Modifications in the total hydrological regime that causes droughts or floods, microclimate and microclimate changes (climatic changes), land saturation, and health hazards.
- Deterioration of water resources in quality and quantity, due to poor use of slope forests and lack of conservation soil and its contamination.
- Increased erosion, Stalinisation and acidification, due to increased insufficient management of hydro forestry resources.
- The decrease in access to water resources for domestic and agricultural consumption and industrial.

In conclusion, the forest hydrological issue is very critical, and the level of environmental deterioration has led to increasing amounts of severe floods that have had a severe economic impact, especially those resulting in the loss of many human lives and other ecological harm not accounted for in their true magnitude, and that's why the field of actions of forest hydrology must be addressed quickly,

particularly regarding restoration work in the mountainous forests, which are being cut down and cause environmental damage when their runoff becomes uncontrolled downstream.

Hydrological Cycle

Water is one of the most important elements for life and the development of organisms. Also, all geomorphologic processes and edaphological, which are the physical relationships that occur in the earth's crust and that give rise to the formation of the soil from the rock, depending on this element, atmospheric cycles, and the dynamics of "atmospheric weather" are manifest through the water. Water comes in three physical states: solid (in the form of ice), liquid and gaseous (in the form of vapor). Water molecules can go from one being to another absorbing or releasing heat. They can go from gaseous to liquid by condensation; if the temperatures are lower than 0°C go directly to the solid-state by sublimation, producing ice crystals. In the evaporation process, the molecules leave the surface of the liquid water and become gaseous molecules. The direct change from solid to gaseous state is called also sublimation. Water can change from solid to liquid by fusion and from liquid to solid by freezing.

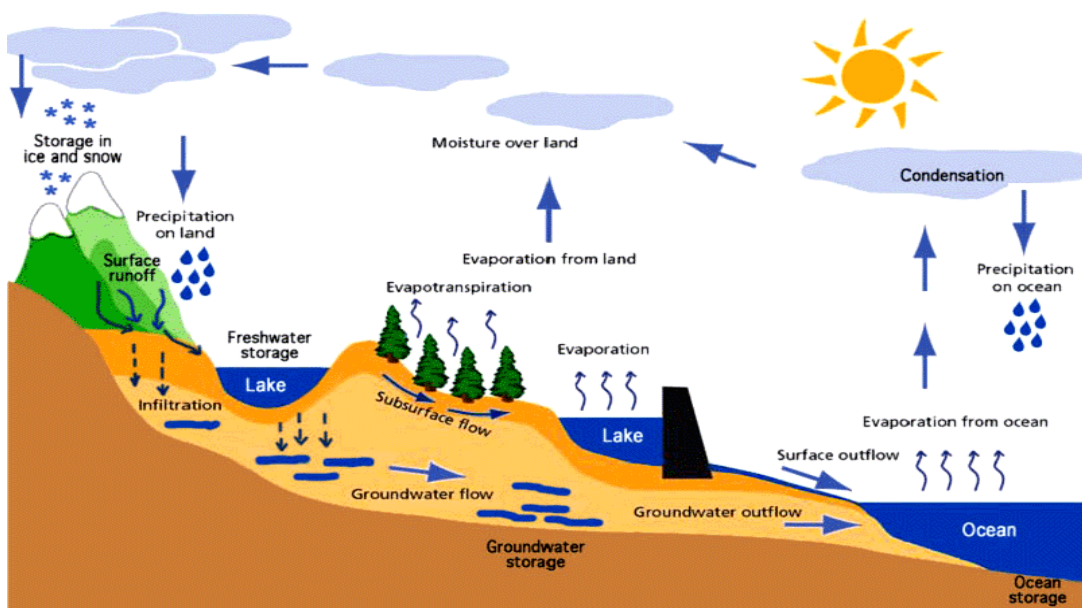


Figure 1.1: Water cycle

Remote Sensing and GIS are Essential Components in Hydrological Modelling

Remote sensing is a significant technique for hydrological modeling nowadays. The technology can forecast or calculate the amount of precipitation, soil moisture, snow cover, and evapotranspiration, as well as water quality, across large geographic areas. Additionally, satellite photos can supply detailed information regarding watershed features (e.g. stream network properties, topography). Remote sensing enables precipitation to be detected where the measurements of the rain gauge are limited. The precipitation on various scales

can be estimated by remote sensed technologies [5]. The GIS uses a range of remote sensing techniques together with geographical locale information, to allow for many forms of data analysis at the same geographic location. The information is provided via the GIS (Geographic Information System). Data required to carry out GIS studies can be provided by Remote Sensing [14].

New hydrological models have made it simpler to utilize geographic information systems (GIS) for data processing. The Arc SWAT is a GIS-based SWAT interface that allows the user to address hydrological issues. In addition, geographic data like the digital elevation model (DEM), land use, and soil may be entered into the GIS using the interface model.

Study Area

Brahmani Basin

One of Orissa's main rivers is the Baitarani River. The basin is in the State of Orissa with the exception of 736 km² in the Singhbhum district of Jharkhand. Orissa district of Keonjhar comprises the majority of Baitarani's basin region. The Baitarani river springs at a height of 900 meters in the Guptaganga hills of district Keonjhar in Orissa, roughly 2 km away from the village of Gonasika. After running 80 km north, the river alters its route suddenly to the right. From the confluence of the Kangira River to the confluence of the Mahanadi River the river is a border.

Brahmani Basin Description

Geographical Information

The Brahmani Basin (Figure 3.2), which covers three Indian States: Chhattisgarh, Jharkhand, and Odisha, is located in North-East India. The Basin is surrounded by Chota Nagpur Plateau in the north and by the ridge to the west and south that divides it from the Mahanadi Basin (NRSC and CWC 2011; Asian Development Bank 2013). The four areas of the Basin are the northern plateau, eastern ghats, coastal lowlands, and central tablelands. The main soil types of the Basin are red and yellow, red sandy and loamy soils, mixed red and black soils, and coastal alluvium (Asian Development Bank 2013). Brahmani River is the junction of the South Koel and Sankh Rivers. The Baitarni Basin is the next basin (more information on this Basin is in CWC, 2016). Brahmani Basin spans 34,614 km², and the river Brahmani, with its tributaries, is 799 km long.

Climate

The Brahmani Bay has a tropical monsoon climate, where the southwest monsoon months of June to October account for the 80percent of yearly precipitation. The highest temperature range is between 47°C and 4°C (NRSC and CWC 2011; Asian Development Bank 2013). The coastline region has a moderate temperature and humidity.

Basin land use

Brahmani Basin's land use is a combination of forest and agriculture (Figure 3.4). Agricultural land accounts for around 52% of the basin. In the rest of the basin, forests are the major land use. The forest area is decaying quickly (AsianDevelopmentBank2013).

Basin Agriculture and Infrastructure

Agriculture is vital for the economy, livelihoods, and food and social development of the Brahman basin. Agricultural areas may be found in and across the Basin. These districts have irrigated farmland and rain-fed agriculture. A full review of agricultural results is provided in an accompanying technical report (Mainuddinetal2016). The following findings give a high-level summary.

20.2 percent (8.65 million hectares (Mha)) of India's total agricultural area is the land of the three basin states. Collectively, the States provide 14.7% (14.1 million tonnes) of the total rice output in India. The cultivation of irrigated rice accounts for only 6% of the entire state rice production. While the basin states have some of India's largest global rice crops, they produce some of the lowest (Mainuddin et al 2016).

Kharif, Rabi, and Zaid are the crop seasons in the basin, Kharif and Rabi being the most important (NRSC and CWC 2011). Rice dominates Kharif, Rabi is dominated by safflower, and Zaid is dominated by peanuts. In the simulation conducted in this work, we integrate another form of irrigated rice crop called a double/triple crop. This sentence refers to the practice of farming irrigated rice numerous times in one year and refers to the use of irrigation water to lengthen the Kharif crop season.

Mainuddin et al. (2016) researched the intensity of agricultural activities in Basin Districts (defined as the number of times a crop is planted per year in a given area). This study found that the crop intensity in the north of the basin is lower than in the south (Figure 3.4). The data also suggest that the intensity of agriculture in the south has grown over time. The major factor for lower crop intensity and yields in the northern upper section of the basin was a lack of additional irrigation that uses excess water from irrigation to extend crop time. Low yield crop types, a fertilizer deficiency, and farming practices all lead to decreased crop intensity.

Irrigated lands in the basin are mainly located in command sections within agricultural districts but a few small amounts of irrigated crops are directly watered by the rivers. In Command Areas, water storage infrastructure, such as weir or dams, is widespread. In the Brahman Basin, we have modeled 20 water storage facilities (19 medium and 1 large), covering around 500,000 hectares of irrigated land, of which 427,000 are located in Odisha.

Jharkhand and Odisha have each 10 storage facilities, the largest of which is Odisha. The overall water storage potential (assuming complete storage) is roughly 4850 MCM, with Odisha contributing for roughly 4000 MCM.

Climatic and Stream Flow Data

Gridded rainfall data was collected from the Indian Meteorological Department (IMD) for the purposes of model creation and transformed into source-compatible time series. We utilize gridded Princeton data for evapotranspiration, as only point evapotranspiration data was available from IMD. The data have been translated into the same time series that are Source compatible. From 1988 through 2012,

the Basin shows a year-to-year and season-to-season variance in precipitation and evapotranspiration.

The bulk of streamflow gauges monitored by CWC are in use. One gauge was used by the State of Chhattisgarh (Lawa Bomtel). Once fresh data from the state of Jharkhand had been obtained, it was concluded that the data was not appropriate for use. The data were only accessible in the monsoon season and the early analysis suggested that there were probable quality concerns. The model was created using streamflow gauges. There were a total of 43 years of streamflow data measurement, however, some measurements captured data for only a subset of the 43-year period. Some double mass parts were employed to do minor quality inspections for streamflow gauges (e Water 2014) and discovered that flows on surrounding gauges were consistent with predicted values.

Irrigation demands

Mapped Command Areas are used to specify irrigation requirements and to identify irrigated crops. In addition to irrigated double and triple rice fields, mostly in the command regions, numerous rice fields are also considered irrigated every year (identified as double/triple). Some of these are located outside the control regions. The approach was used in previous research (NRSC and CWC 2011). Table 2 shows the storage, command, and irrigated areas related to it.

Kharif (rice), Rabi (safflower), and Zaid are the crop reflected in the baseline model of the scenario (groundnut). This is in line with the results of the previous NRSC and CWC studies (2011). The Source software2 irrigator demand model was used to show irrigation requirements of the major types of basin crops for each irrigation Command area (rice, safflower, and groundnut). This also enables the simulation of scenarios that take account of the impact on water needs of changes in an agricultural area and crop type, as well as the ability of the existing infrastructure to meet these demands.

As mentioned before, the model incorporates both Jharkhand and Odisha storage nodes for the present medium and major irrigation warehouses. There were no storage facilities of this scale in Chhattisgarh. Rengali Dam is the largest storage facility in Odisha. This dam comprises power and environmental needs, as indicated in Chapter 5 of this study.

Nodes and connections define the reaches. The main aspects of the river system are covered in the node-link network. The nodes constitute the addition or deletion of streams as well as temporary storage of water. • Inflows into dams or tributary streams are prominent examples of nodes.

Water storage in dams or weirs, followed by release through valves or through spillways

Water extraction for irrigation

water extraction for urban water supply

water losses to groundwater systems due to evaporation or seepage

discharges to effluent streams or downstream rivers

The following are the key feature categories utilized to characterize the system in the model:

Links - links nodes and transfers the system water. When the routing is incorporated, the lag and flow attenuation may be added into the model, affecting its look.

- Gage stations – locations to measure streamflow, which provide locations for model calibration.
- Inflow nodes – illustrate upstream or downstream inflows (referred to as residual catchments). Inflows are required for each sub-catchment of the system. 39 sub-catchments are determined using the Brahmani model based on the placement of the gauges and medium and large irrigation systems.
- Confluences - these are the sites where affluents and return flow join a river. The confluences in the Brahmani model were defined using information from the river network.
- Storages - used for holding and controlling water in the model of the river system at a given position. The models have been stored using Google Earth and local information.
- Users of water and supply points – these are the places where requests are made for water supply to consumers. Requests were calculated using CWC and state information.
- Loss nodes – loss nodes show a combination of physical processes and corrections for non-counted modeling mistakes that indicate the amount of water lost in the system.

Method

ArcGIS

Two steps were done prior to ArcGIS image processing: 1) data preparation, and 2) classifications.

3.1 Classification Diagram

- Collection of Data: -
 - a. Satellite Image
- Processing of Image: -
 - a. Geo-referencing
 - b. Shape-file generation
 - c. Raster map
 - d. Mosaicking
- Analysis of Image:
- Classification of Image:

3.1.1 Collection of Data

The Landsat picture of the BR basin is available at the United States Geological Survey website at <http://earthexplorer.usgs.gov>. The four images available for download from the years 1999, 2002, 2006, 2010, and 2014 have been downloaded. In this research, the Landsat 8 and Landsat 5 satellite pictures were employed. In order to have shots that fall in the same annual vegetation period, all of the dates for photos were selected to be in sync.

3.1.2 Pre-processing of images.

The picture pre-processing was completed in the examination of images. A piece of picture pre-processing involves restoring and rectifying an image. Pre-study picture mosaicking methodology is employed in pre-study. Satellite photographs are joined with this to make a composite image. The usage of the GIS clip tool after merging the photos lets you specify the geographic area you want to investigate. Picture enhancement and extraction are used to locate the ground characteristics of an image.

3.1.3 Analysis of Images

With the Image Analysis tool in ArcMap, you may analyze layers of image and raster information to tackle the task of performing complicated handling and investigation procedures. Single tick apparatuses enable the single click application of processes, such as cutting, segmentation, NDVI generation, mosaicking, and bartering. a false-color composite image that appears to use 3D elements. It is a mix of three bands (visible, non-visible, and intermediate) used to display the visualization in a particular hue that was originally captured in the region of the electromagnetic band that people can see or can't see. Multispectral photographs have hidden information in the nonvisible spectrum as well as on the surface. To use this knowledge, the visible spectrum, which can be seen by the necked eye, should be reassigned to the outer range. Reflection of vegetation shows an abundance of near-infrared light, therefore the mixing of band affects that vegetation reflects in colors of red. The higher the intensity of the red, the greater the effect on plants.

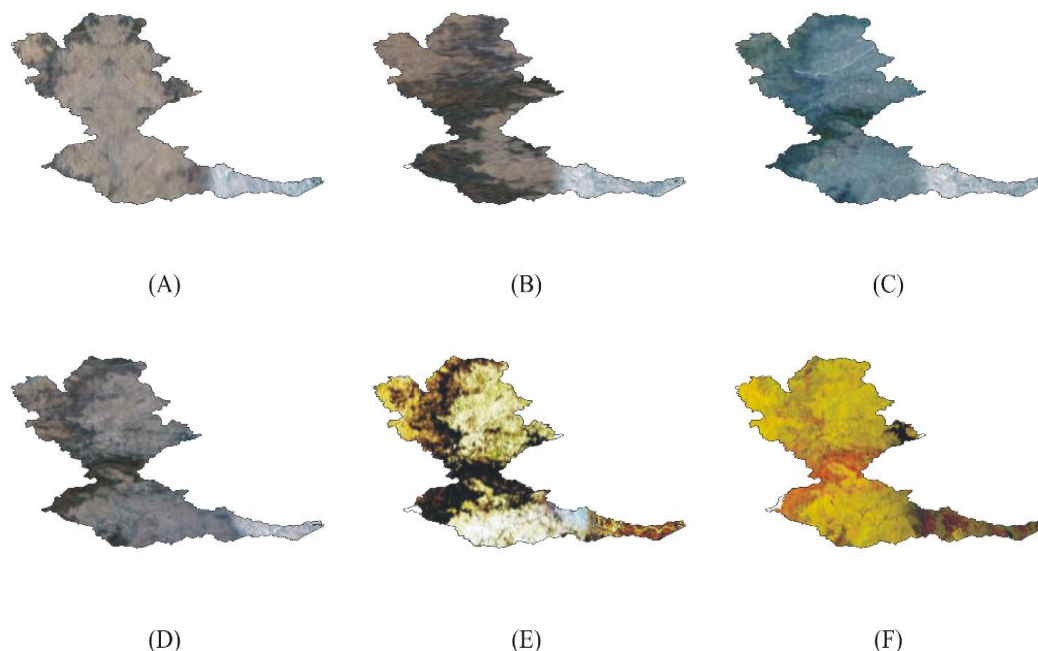


Figure 3.1: False Color Composite of Brahmani River Basin for different years

3.2 Summary of the Model

Using the SWAT model was used to simulate runoff, validate and calibrate the runoff utilizing SWAT-CUP allows for a better understanding of the SWAT model's usefulness with regard to runoff. Land use alters the runoff. Please review the specifics of the steps below.

3.2.1 SWAT: Tool for Soil and Water Evaluation

Soil SWAT is the Water and Soil Evaluation Tool's official short name. In 1980, Dr. Jeff Arnold created a USDA SWAT model, a semi-distributed model for process-based watershed or river basin size (ARS). This model was extensively used in estimating watershed hydrology and was also used for anticipating the impact of land-use initiatives on water, impact on water, crop yields, and sediments over a longer period in micro-watersheds as well as in larger sub-basins. The watershed is initially subdivided into sub-basins or sub-catchments within this system (SWAT) on the premise of distinct land use soils and slope combinations, which are then separated by a series of (HRUs) hydrological response units. Arc GIS contains the model SWAT-2012 used for SRB streamflow simulation. In order to compute expected surface runoffs [26] and [27], daily rainfall data and SCS curve values are employed. The Green-Ampt (18) equation calculates the volume of runoff for each precipitation event. The Buckingham methodology is used to go through the tributary and major rivers and to assess possible evapotranspiration using the Priestly-Taylor methodology.

3.3 Model Configuration

With the use of ArcGIS methodology, the Arc-SWAT platform assisted in the completion of the model setup. The structure of this layout is similar to how you'd think: First, a data set (for example, the DEM) is utilized to delineate the watershed. After that, land use property data and slope and soil information are used to identify the watershed's boundary. Lastly, a model is utilized for analysis.

3.3.1 Details of Model Inputs:

3.3.1.1 Data from the non-spatial

Valuable for analysis of watershed metrological materials is the investigation. The daily hydrological inputs which were entered into the Arc SWAT model over a time period spanning 1999 to 2014, including precipitation, minimum-maximum wind speed, temperature, solar radiation, and humidity, were all collected via the climate generator tool inside the model.

3.3.1.2 Spatial information (GIS data)

A: Digital Elevation Model

DEM is the cells in the form of electronic data that specify the mean elevation of each grid cell over a geographic region, in which each grid cell describes mean elevation at a particular position with a certain spatial resolution. In this case, delineation of the watershed is attached to several sub-basins or watersheds inside the SWAT model in terms of elevation. The DEM map was created using SRTM data and used a 1:50,000 scale as well as a 30m x 30m resolution. To assemble a single map, these tiles were mosaicked. An ArcGIS shapefile was developed for the river basin which was used as a reference in conjunction with ArcGIS software to complete the assignment, which was then overlaid with the mosaic DEM in order to generate the DEM of a Brahmani river basin.

Soil Information

Information about soil was provided by the Food and Agriculture Organization of the United Nations, which then went into the model as a kind of input. To get the global soil map, the base map of a river basin was used to trim the global soil map.

LULC: Data on Land Use And Cover

The land usage map of a Brahmani River basin in Odisha, Jharkhand, and West Bengal was produced using Arc Map 10.2, utilizing satellite imagery to produce a single map, and then cut off to obtain the map of the area. A map showing the locations of LULC maps has been added to the SWAT model, which was developed previously and using classification tasks and divided into five categories.

Slope Information

A significant impact on overall runoff volume is seen in the terrain's slope. In order for water to go overland, it must have some speed. In cases when the slope is gentle, there will be a longer period of time when water may infiltrate, which slows the quantity that makes it to the stream. The slope of a channel determines the peak amplitude and runoff duration. the slope was rising/falling more quickly in the flow's direction. The tilt of the drainage area was given a classification system ranging from 0 to 3 meters, 3 meters to 8 meters, 8 meters to 15 meters, 15 meters to 25 meters, and 25 meters to 9,999 meters.

3.4 Simulation of Models

In all, the process of the simulation consists of five distinct parts, each with its own procedure: 1) establishing a SWAT project, 2) designating a watershed, 3) running the HRU analysis, 4) producing the input tables, and 5) running the simulation.

3.4.1 Delineation of Watersheds

The concept of delineation illustrates the development of a border that shows where a certain outlet or hazard analysis critical control is found. This delineation of the watershed involves identifying all the land or channel segments in order to understand how the watershed operates. By using DEM, a user of Arc SWAT is supplied with the watershed delineator, which is needed to accurately delineate the watershed and sub-basins.

3.4.2 SWAT-CUP Abbreviations:

In SUFI-2, simulation model uncertainty is shown as homogenous circulation whereas uncertainty of the input parameter is shown as scattered in a range between 90% and 95%. (i.e., 95PPU). This figure is determined for both the 97.5% and 2.5% output variable levels, and 5% of the simulations are prohibited which have the worst results.

- Function Objective: efficiency of Nash-Sutcliffe (NSE) and determine coefficient (R^2)
- Also known as the P-factor, the PPU reflects the proportion of underlying which is subject to the 95% PPU. By using this method, we can accurately represent the amount of uncertainty recorded.

- Represents calibration accuracy. For a simulation with a p-factor equal to one and r-factor equal to zero, the results are perfectly identical to the measurements.
- T-Stat: Serves as a measurement of sensitivity, which is defined as the ability to detect change. A bigger absolute number has a higher sensitivity.
- This p-value, determined using the sensitivity measure, shows that the results of the experiment are significant. If a value is near to zero, it's of increasing importance.

3.4.3 Calibrated Model and Technique of Validation

Data from the Indian Water Resources Data System for daily discharge for the examined catchment were gathered for the period of January 1983 till Dec 2019. This data collection has been used to compare and to further calibrate and validate simulated information collected by the SWAT model. In this study, 16 decades of history were taken into account. A number of years you have to leave (NYSKIP) (1983-1986). Many studies have highlighted a warm-up phase of around 3 years for successful results. Period of calibration: Seventeen years (1987-2004) and Fourteen years (2005-2014). The Arc SWAT model, the calibration and validation of the model was carried out utilizing a (Sequential Uncertainty Fitting Version 2) SUFI2 approach as outlined by the SWAT CUP program. The initial phase in the investigation is to create very sensitive parameters for both the watershed in calibration in SWAT.

Results

4.1 Calibrated and Validated Results

4.1.1 Monthly Time Step

The model was simulated and calibrated for 1983 to 2019, including the three year warm-up period, i.e. 1983 to 1986. Additional validation of the calibrated model was made for 2005-2019, from 1987 to 2004. The results were compared to the daily time stage as follows and were compared for the monthly period.-

(A) Simulated Period

For the initial simulated data for surface rinse it was determined that the Nash-Sutcliffe Efficiency (NSE) was 0.87 and for the first run of the form monthly correlation coefficient(R^2), as shown in figures.

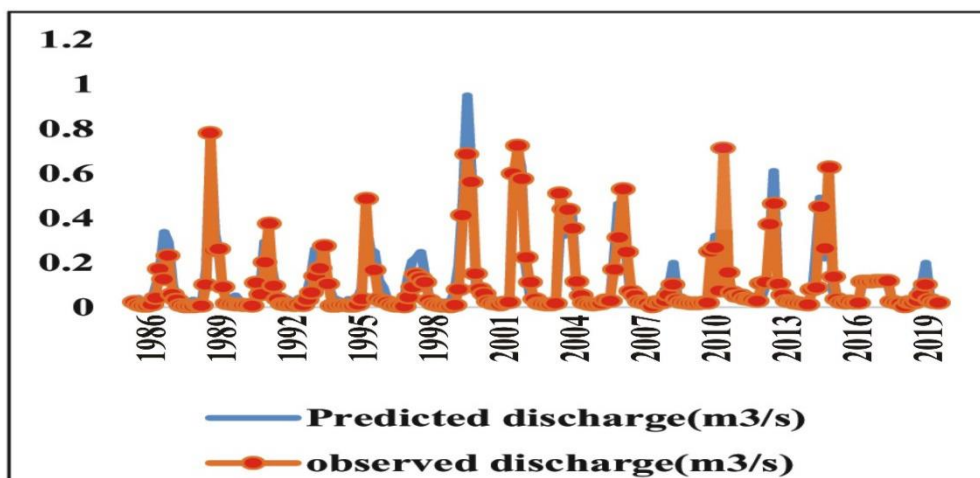


Figure 4.1: Simulated vs Observed data for monthly time step of BRB

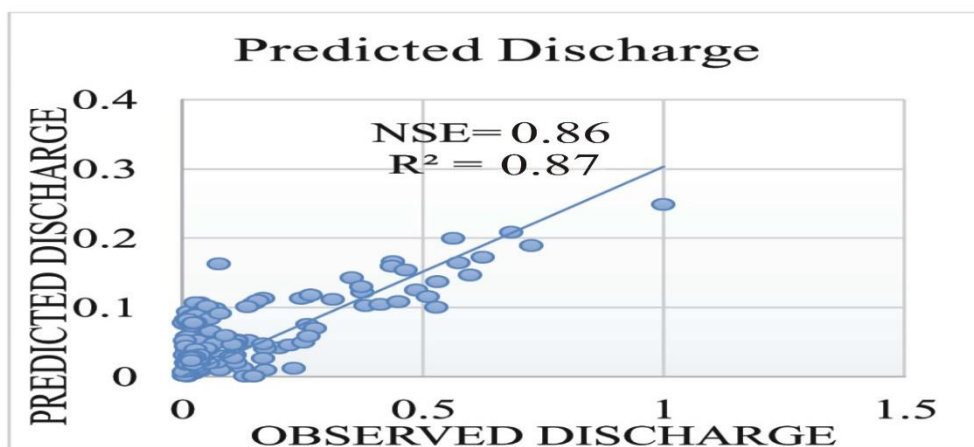


Figure 4.2: Correlation between observed and simulated data of BRB

(B) Calibrated Period □

The efficiency of Nash-Sutcliffe is 0.86, and the correlation coefficient for the calibrated data for a surface flush is 0.88 for the first duration of the monthly time stage as shown in Figure. These numbers can be judged well in accordance with the performance assessment standards.

Table 4.1: Calibration (1987-2004)

Gaugingstation	NSE	R^2
Keonjhar	0.85	0.88
Swampatana	0.82	0.86
Rengali	0.84	0.87
Akhuapada	0.87	0.90
Indupur	0.83	0.85

Table 4.2: Validation (2005-2019)

Gaugingstation	NSE	R ²
Keonjhar	0.88	0.90
Swampatana	0.86	0.88
Rengali	0.87	0.91
Akhuapada	0.89	0.92
Indupur	0.86	0.90

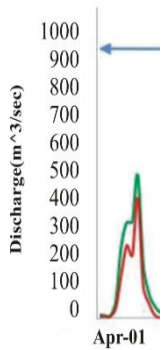


Figure 4.3: Calibrated vs Observed data for monthly time step (1987-2004) and validated vs Observed data for monthly time step (2005-2019) of BRB

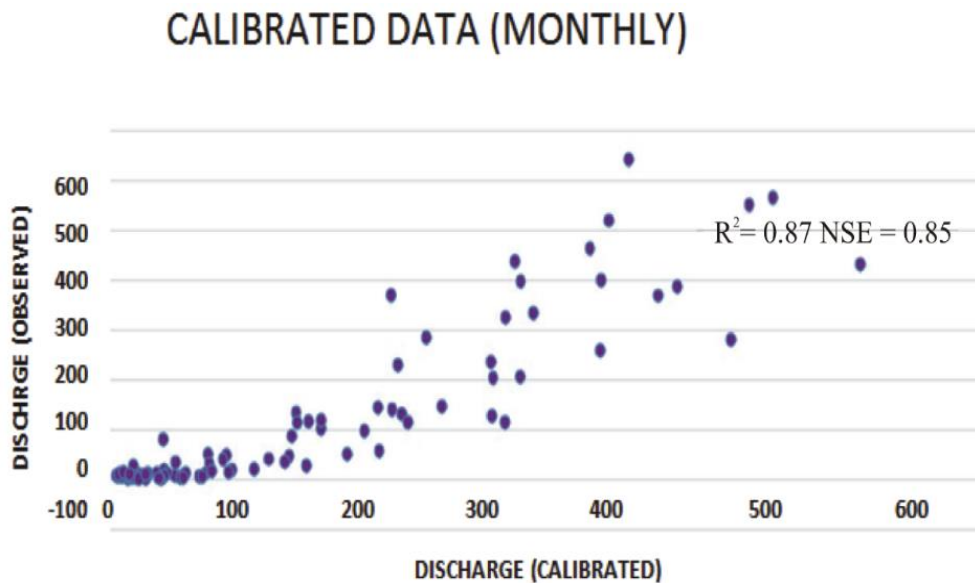


Figure 4.4: Correlation between observed and calibrated data of BRB

(C) Validation Period

The calibrated model efficiency has also been confirmed for each month. The efficiency of Nash-Sutcliffe, NSE is found to be 0.89, and R² for surface runoff verified data is found to be 0.92 as shown in the figure for daily start-up time which is satisfactory according to the performance requirements. The next page

has shown all the findings of good fitness of simulated, calibrated, and verified data in tabular form below in Table 16.

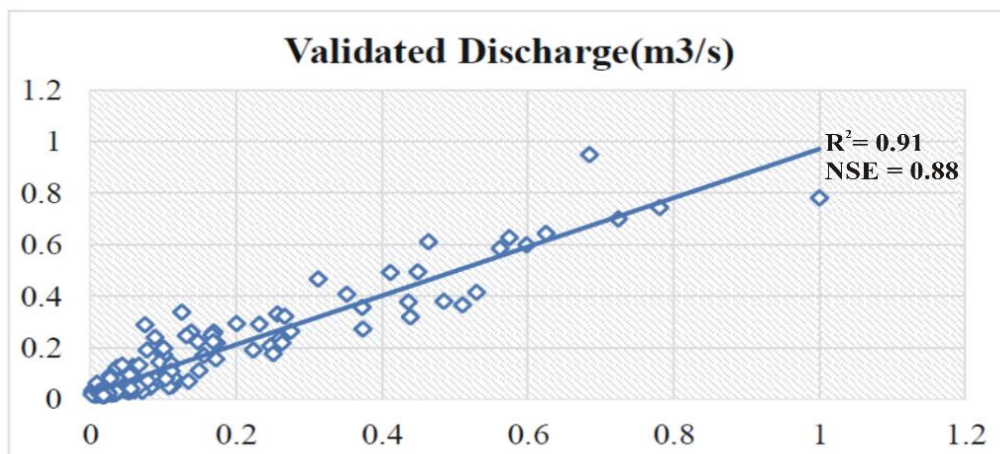


Figure 4.5: Correlation between observed and simulated data of BRB

Table 4.3: Performance evaluation for monthly time step

DATASETS		R ²	NS E
Simulated	data(1983-2019)	0.87	0.85
Calibrated	data(1986-2004)	0.86	0.84
Validated data(2005-2019)		0.90	0.87

4.2 Impact of Land Use changes on Runoff

The influence of changes in land use on observed and simulated runoff has been examined in the last ten years, namely 1983, 1993, 2002, 2007, 2013, and 2019. Supervised classification is the classification approach in which these classes are established by spectral pixel features inside an image matching to field training regions selected to reflect known qualities. The five main categories of land, agriculture, forestry cover, water bodies, and stormy soil were constructed. The LULC map has nonetheless been drawn out for the years 1983, 1993, 2002, 2007, 2013, and 2019.

Table 4.4: Land Use Land Cover data

Year	Forest (km ²)	Water (km ²)	Built-up (km ²)	Agriculture (km ²)	Barren (km ²)
2019	6419(26.15%)	1147(4.67%)	4076(16.60%)	5926(24.14%)	6983(28.44%)
2013	6473(26.37%)	1131(4.61%)	3989(16.25%)	5774(23.52%)	7184(29.26%)

2007	7357(29.97%)	1158(4.72%)	3625(14.77%)	5127(20.88%)	7284(26.67%)
2002	7725(31.47%)	1075(4.38%)	3496(14.24%)	4934(20.10%)	7321(29.82%)
1993	8095(32.97%)	1009(4.11%)	3117(12.70%)	4671(19.03%)	7659(31.20%)
1983	8145(33.18%)	974(3.97%)	2875(11.71%)	4796(19.53%)	7761(31.61%)

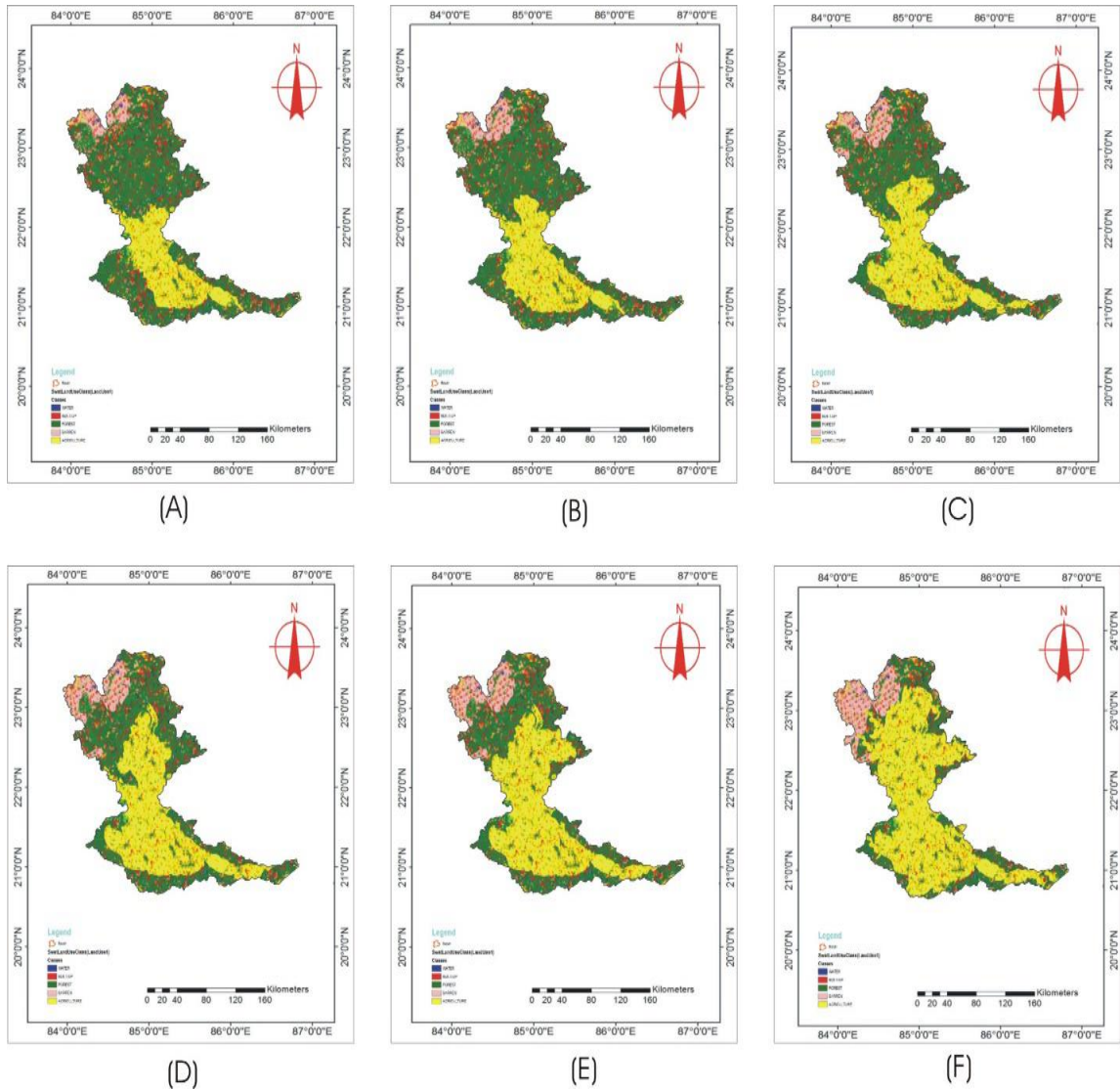


Figure 4.6: LULCC of BRB over 1983 - 2019

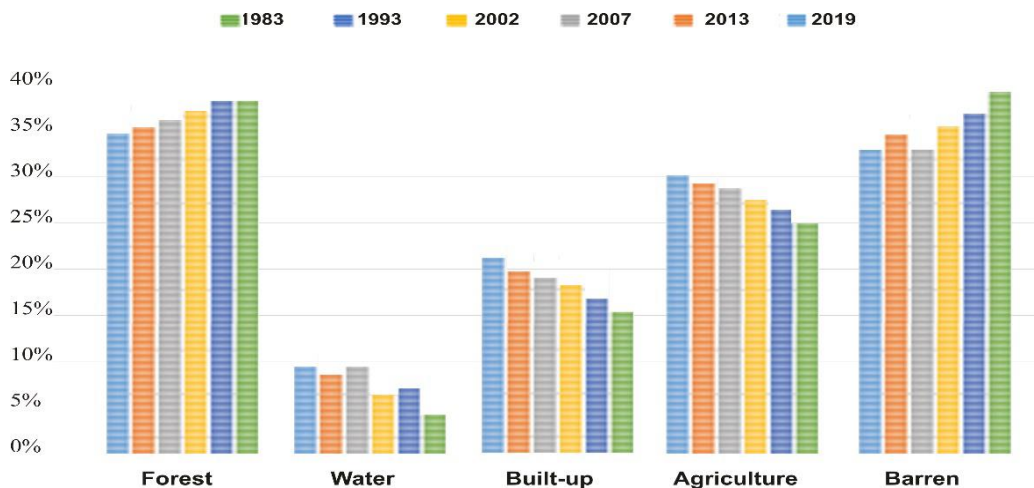


Figure 4.7: Histogram representation of LULC classification of BRB (1983-2019)

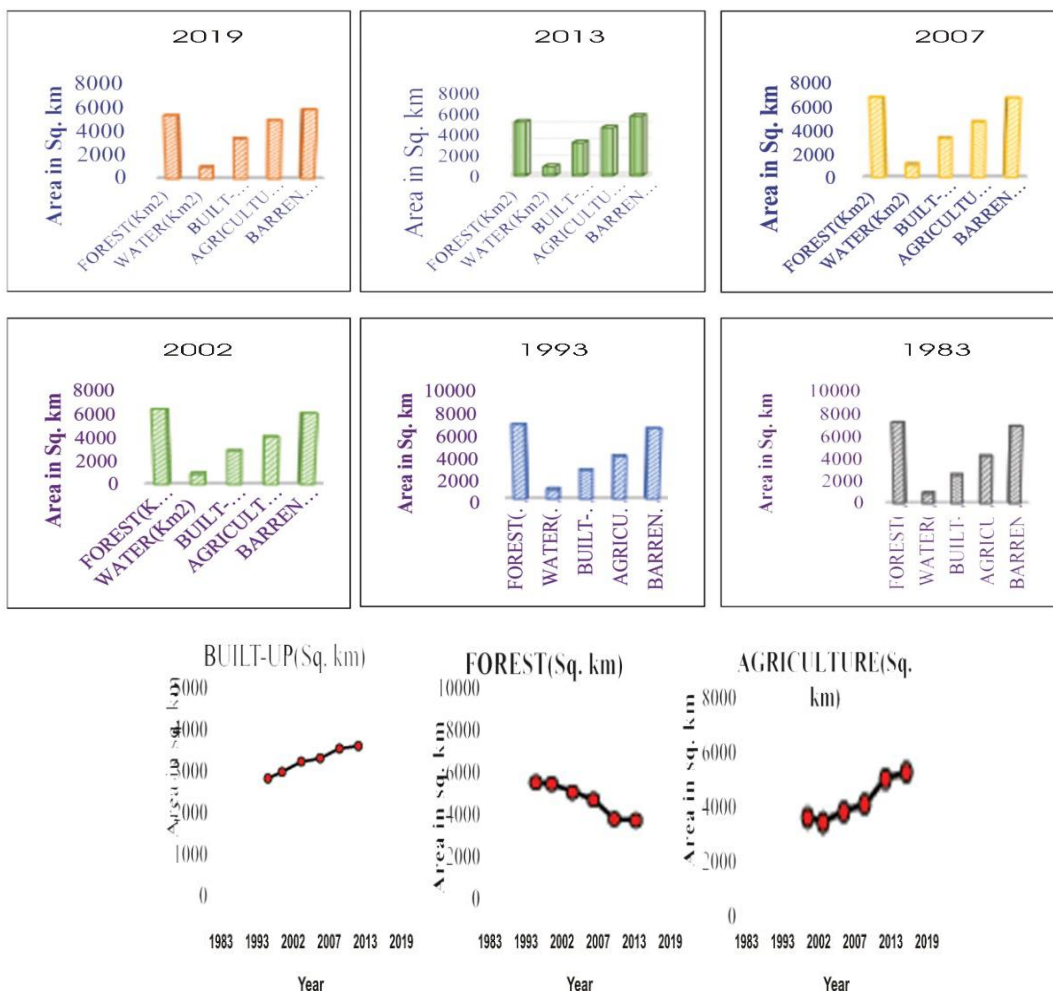


Figure 4.8: Graphical representation LULCC of BRB over 1983-2019

Deforestation, agricultural growth, and urbanization are the primary developments in the basin The (Graphical representation LULCC of BRB over 1983-2019). Urban/Upper Country: In 1999, the city/constructed land was 11.71% and in 2018 it rose to 16.60%, which means that 41.76% change over 36 years.

Conclusion

The coefficient and coefficient of determination of Nash-Sutcliffe is around the one, which indicates that the model performance is excellent, 0.89 and 0.87 respectively (simulating outcomes). From a comparative examination, it has been found that the error indices in the SCS-CN approach are estimated somewhat lower than in the Green-Ampt approach. The accumulated area and agricultural percentage have changed by 41.76% and 23.60% and forest and storm terrain correspondingly decreased by 21.19% and 10.03% from 1983 to 2019. In 1999, the monthly rainfall and area rinses were maximum 1207.78mm and 10 40.68mm, whereas in 2014 they were correspondingly 1353mm and 1103.76mm. While rainfall stayed about the same (shown in the figure). The NSE and R² values are 0.86 and 0.88 respectively when the observed and calibrated data are compared. The NSE and R² are at 0.89 and 0.92 for the monthly period, for comparison between the observed and the verified findings. In the predictions of runoff during extreme rainfall events, this study is also valuable. Analysis of various occurrences provides results that can contribute greatly to the planning and management of water resources in the Middle Brahmani Basin. On the basis of early results of the model, a model is a helpful tool for analyzing the possible influence on river watersheds of the region of land use and climatic change.

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