ANALYSIS OF RIVER FLOW RESPONSE WITH CMIP5 CLIMATE CHANGE PROJECTION USING SWAT IN THE BINA RIVER BASIN, MADHYA PRADESH

THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING

(SOIL AND WATER CONSERVATION ENGINEERING)

Submitted By

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2022

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CERTIFICATE

Ref. No.: .... **Date: ....**

To,
The Registrar (Academic)
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Through: The Head, Department of Farm Engineering, I.Ag.Sc., BHU, Varanasi.

Dear Sir,

We have immense pleasure in forwarding the thesis entitled **“Analysis of River flow response with CMIP5 climate projection using SWAT in the Bina River Basin, Madhya Pradesh ”** submitted by **Mr. Dheeraj Sonkar, I.D. No.: 20412AEN009, Enrolment No.: 429380** in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Agricultural Engineering (Soil and Water Conservation Engineering)**, Department of Farm Engineering, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

This is to certify that the work has been conducted solely by **Dheeraj Sonkar** under my supervision and guidance and his findings and data presented herein are genuine and original to the best of my knowledge and belief and no part of the work has been submitted for any other degree or distinction.

Thanking you,

Yours faithfully

FORWARDED BY

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Scientist-D
(Co-Supervisor)

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This Thesis is Dedicated to All My Family Specially My Grandfather and supervisor Prof. R.M Singh sir

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Date
Place: ***(Dheeraj Sonkar)***

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

Sl.No	Abbreviations and Symbols	Description
1	Umax	Maximum water content in surface storage
2	Lmax	Maximum water content in root zone storage
3	CQOF	Overland flow runoff coefficient
4	CKIF	Time constant for routing interflow
5	CK1,2	Time constant for routing overland flow
6	TOF	Root zone threshold value for overland flow
7	TIF	Root zone threshold value for inflow
8	TG	Root zone threshold value for GW recharge
9	CKBF	Time constant for routing base flow
10	CN2	Curve number
11	ALPHA_BF	Base flow alfa factor
12	GW_DELAY	Groundwater delay time
13	SOL_K	Soil hydraulic conductivity
14	EPCO	Plant uptake compensation factor
15	SOL_BD	Moist bulk density
16	OV_N	Manning's "n" value for overland flow
17	SURLAG	Surface runoff lag time
18	CANMX	Maximum canopy storage
19	SOL_Z	Depth from soil surface to bottom of layer
20	CH_K2	Effective hydraulic conductivity
21	CH_N2	Manning roughness for main channel
22	SLSUBBSN	Average slope length
23	GW_REVAP	Groundwater ‘revap’ coefficient
24	SOL_AWC	Soil available water capacity
25	RCHRG_DP	Deep aquifer percolation fraction
26	ESCO	Soil evaporation compensation factor
27	GWQMN	Threshold depth of water in
28	EI	Efficiency Index
29	SCE	Shuffled Complex Evolution
30	PBIAS	Percent Bias
31	WMO	World Meteorological Organization
32	NSE	Nash-Sutcliffe
33	GIS	Geographical Information System
34	WGNLOC	Weather Generator Location
35	DEM	Digital Elevation Model
36	SCS CN	Soil Conservation Service-Curve Number
37	USDA-SCS	U.S. Department of Agriculture, Soil Conservation Service
38	SOI	Survey of India
39	ICAR	Indian Council of Agricultural Research
40	USGS	United State Geological Survey
41	PMDI	Multivariate Drought Index (MDI)
42	Avg	Average
43	DHI	Danish Hydraulic Institute

44	NAM	Nedbor-Afstromings
45	SWAT-CUP	SWAT Calibration Uncertainty Procedures
46	95PPU	95 % prediction of uncertainty
47	GLUE	Generalized Likelihood Uncertainty Estimation
48	SUFI-2	Sequential uncertainty fitting
49	PSO	Parameter Solution
50	USDA-ARS	United States Department of Agriculture-Agricultural Research Service
51	IPCC	Intergovernmental Panel on Climate Change
52	MK	Mann-Kendal
53	ISDR	International Strategy for Disaster Reduction
54	WWDR	World Water Development Report
55	PDSI	Palmer Drought Severity Index
56	SPI	Standardized Precipitation Index
57	SWAT	Soil and Water Assessment Tool
58	UTM	Universal Transverse Mercator
59	HRU	Hydrological Response Unit
60	LULC	Land use Land cover
61	MCMC and PSO	Markov chain Monte Carlo and Parameter Solution
62	WBL	Water Balance Error
63	PET	Potential Evapotranspiration
64	CS-MWD-D	Clay soil-Moderately Well Drained-Deep
65	CS-WD-D	Clay Soil- Well Drained-Drained
66	CS-WD-MD	Clay Soil-Well Drained-Moderately Deep
67	LS-ED-S	Loam Soil-Extremely Drained-Shallow
68	LS-ED-VS	Loam Soil-Extremely Drained- Very Shallow
69	LS-WD-D	Loam Soil-Well Drained-Deep
70	LS-WD-S	Loam Soil-Well Drained-Shallow
71	LS-WD-SD	Loam Soil-Well Drained-Shallow Deep
72	SND	Sandy Area
73	FRSE	Forest-Evergreen
74	E137	Current fallow in District Sagar
75	FRSD	Forest-Deciduous
76	WATR	Water
77	SETL	Urban
78	BARN	Barren
79	AGRL	Agricultural Land-Generic
80	FCC	False Color Composition
81	Sl.No	Serial Number
82	N	North Direction
83	E	East Direction
84	R^2	Coefficient of Determination
85	*et al*	and others
86	Fig.	Figure
87	hrs	Hours
88	m	Meter
89	mm	Millimeter
90	Km^2	Square Kilometer

91	m^3/s	meter cube per second
92	mm/year	Millimeter per year
93	^{o}C	Degree Centigrade
94	%	Percentage
95	o	Degree
96	'	Minute
97	viz.	Namely
98	i.e.,	That is
99	>	Greater than
100	<	Less than
101	=	Equal to
102	&	and
103	s	Standard Deviation
104	α	Significance Level

CHAPTER 1

INTRODUCTION

1.1 General

River basins are vital for hydrological and environmental enhancements due to the fact whilst managed nicely they produce non-stop streamflow from baseflow and runoff. Runoff is the drift of water that occurs when soil turns into saturated and extra water from rain, snowmelt, or various sources is going over the ground surface and it is a crucial factor of the hydrologic cycle. The relationship between precipitation and runoff like other aspects of the water cycle, changes with time and site. Runoff is important in the hydrological cycle because it manages the amount of water that flows into streams by releasing excess precipitation to the oceans. The water balance equation models the hydrological cycle by way of accounting for the waft of water into and out of a gadget through time. The primary goal of hydrological Modeling is to quantify a watershed hydrologic response to climatic parameters, soils, land use and management conditions. This flip plays a significant function in water aid making plans, flood forecasting, pollutants control and an expansion of different applications.

Streamflow is influenced by natural factors such as precipitation, temperature, and geomorphological characteristics, as well as man-made activities such as irrigation and dam construction. There was a lot of literature in the 1990s and 2000s on how natural forces, such as climate change and global warming, had an impact. The research on regional streamflow is extensive (Tran and O’Neill, 2013).

The evaluation of changes in river flow is the most common method for analysing the impact on regional water resource availability and is used in water resource management decision-making procedures (Papadaki, 2020).

The study of land use and land cover change and their consequences on hydrology is one of the most frequently investigated scientific topics. Land-use practices and water resource management are unbreakably linked (Lahmer et al, 2001). Since LULC change impacts not only hydrology but also biodiversity, soil erosion, ecosystem services, socio-cultural practices, groundwater recharge, and other factors. To investigate the impact of LULC change on hydrology researchers used a variety of strategies including the paired catchment approach, statistical approaches and hydrological Modeling approaches (Anil et al, 2017).

One of the most exciting topics in a hydrological study is the assessment of the impact of climate change on streamflow. Changes in air temperature and precipitation have a significant impact on the hydrologic cycle both directly and indirectly as well as on water resources. Climate alternate impacts hydrological regimes via way of means of changing the volume, intensity, form and timing of precipitation in addition to the charge of evapotranspiration. Continuous land-use and land-cover changes complicate understanding of the processes implicated in hydrological cycles across the world with many ecological responses varying on the kind of biome and its characteristics. These changes can have a variety of effects on biodiversity varying on the kind of biome and its location (Tsegaye et al, 2019).

1.2 Role of Remotes Sensing and GIS in Hydrological Streamflow Modeling

Remote sensing has been identified as a technology for producing information in a geographical and temporal domain in digital form with high resolution rather than point measurement.

Because of its high sensitivity and multispectral gathering remotely sensed data from spaceborne platforms gives geographical information about the many processes of the land phase of the hydrological cycle. This geographical information may be used as input data for hydrological models and is especially useful for predicting the number of critical variables particularly when dispersed hydrological models are employed. Remote sensing becomes hired withinside the cutting-edge images to create enter information for thematic maps together with land use, land cover, and geomorphology for a bodily primarily based totally absolutely allotted hydrological model.

The use of remote sensing technology necessitates the administration of a huge quantity of spatial data, which requires the use of an efficient system to manage such data. As a result, Geographic Information Systems permit for the storage, analysis, and retrieval of facts for massive and complex situations. A Geographical Information System (GIS) is a computer primarily totally based system created device used to integrate, gather, store, retrieve, manipulate, and show spatial facts to remedy complex making plans and control issues. This device makes a speciality of the suitable user device integration for offering geographical records to help operations, control, analysis, and decision-making. Two approaches are viable for this objective. A version or institution of fashions is described withinside the version-pushed method, as is the wished spatial (GIS) enter for the era of enter facts and output maps. The facts-pushed method is the second one option. It restricts the enter spatial facts to traits gathered from usually available maps, including topographic maps, soil maps, and so on. The cap potential of a GIS to hastily integrate facts from diverse reasserts has led to vast boom in its use in hydrological applications. It also gives you the option of combining data from various sources and types. One common use is the extraction of hydrologic catchment parameters such as elevation matrix, flow direction matrix, ranking elevation matrix, and flow accumulation matrix using a digital terrain model (DTM). It also allows you to analyse both geographical and non-spatial data at the same time.

1.3 Hydrological stream flow Modeling

Hydrological Modeling has been used to calculate streamflow amounts in areas subject to land-use change for basin managing, flood alleviation, hydraulic base projects, water quality, and quantity, and sediment production (Sarkar and Kumar et al, 2012).

Hydrological models, on the other hand differ in terms of geographical distribution, temporal and spatial scale, and shape (Chakraborty and Biswas 2021). Among the most popular models are the HEC-HMS, MIKE-SHE, SMS-2D, and SWAT (Junior et al, 2015).

All models are not simplified in the same way some are more simplified than others, but at the heart of each model is a mathematical description that simplifies the components being evaluated and allows models to make quantitative predictions Soil properties. for example, fluctuate over short distances in the runoff process. A mathematical model cannot account for every variance in space. As a result, average values are calculated for groups of variables that have unities. Metric fashions are empirical fashions that generate each the version shape and the associated parameter values from on hand time series, in accordance with (Wagener and Gupta et al, 2004). Modeling of gauged catchments (e.g. Modeling of river behaviour, real-time flood forecasting, adjusting and comparing water useful resource management) runoff estimation of ungauged catchments; consequences of river activity (erosion, sedimentation) prediction of catchment reaction to modified conditions (e.g. land use change, weather change) and water exceptional investigations are standard duties for hydrological simulation fashions (e.g. nutrients, migration of microbes, salinity, and alkalinity of soils, acid precipitation, nonpoint supply pollution). Rainfall-runoff models are fundamental tools in engineering and environmental research that are frequently used for hydrological investigations. In addition, the problem of watershed management is receiving more attention. Some of the models are also used in military missions (Singh et al, 2006).

1.3.1 Soil and Water Assessment Tool Model

The climate and physical aspects of the basin (such as terrain, soil, and vegetation), as well as human activities, are crucial factors influencing hydrological processes in basins. Physically primarily based totally dispensed fashions are well-installed fashions for assessing the impact of land control practices on water, sediment, and agricultural chemical yields in sizeable and complicated watersheds. Many hydrological models have been developed and applied across the world. One such model is the SWAT found to be an excellent research tool for hydrological studies.

The soil and water assessment tool are a watershed scale version evolved through USDA-ARS to are expecting the effect of land control practices on water, sediment, and agricultural chemical yields over lengthy durations in massive, complicated watersheds with various soils, land use, and control conditions (Arnold et al, 1998). This technique has several advantages including the fact that it is publicly available. Data handling efficiency an easy to use interface and a large database (Hurkmans et al, 2009). SWAT are a comprehensive, semi-disbursed river basin version that calls for an excessive range of enter parameters which complicates version parameterization and calibration. The SWAT version has a daily, time step and is meant to evaluate the effect of land use and control on water, sediment, and agricultural chemical yields in unmeasured watersheds. The SWAT version implementation has verified dependability and consistency.

It has been used globally due to its significance in several elements of water aid initiatives. Many fashions are being developed, however bodily primarily based totally semi-disbursed trends consisting of SWAT are well-hooked up strategies for investigating the effect of land control techniques on water, sediment, and agricultural chemical yields in massive complicated watersheds. For example, withinside the case of a watershed control software for conservation and development, runoff is one of the maximum important hydrological cycle occurrences. In India the SWAT calculate has been used to estimate surface runoff. It has also been used to simulate a hydrological water balance (Akpoti and colleagues, 2021).

The SWAT model provides a great deal of flexibility in basin breakdown. The basin can be split into hydrological response units (HRUs), grid cells, or sub-basins. Different areas of the basin can be separated in many ways. The SWAT model's new routing structure guides and adds flows down via the basin reaches and reservoirs. In addition modifications were made to model lateral flow, groundwater flow, reach route transmission losses and sediment and chemical movement via ponds, reservoirs, streams, and valleys. The SWAT model can simulate hundreds of subbasins over timescales of one hundred years or more. Hydrology, weather, sedimentation, soil temperature, crop development, nutrients, pesticides, groundwater, lateral flow and agricultural management are all key components of the model.

SWAT-CUP (SWAT Calibration Uncertainty Procedures) is a computer application that is used to calibrate SWAT models. SWAT-CUP is a free to use public domain application. SWAT-CUP includes a variety of programs. Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (Parasol), and Sequential Uncertainty Fitting are among these applications (SUFI-2). It allows for SWAT model sensitivity analysis, calibration, validation, and uncertainty analysis. The application connects SWAT processes such as GLUE, parasol, SUFI-2, MCMC, and PSO.

SUFI-2 The SUFI-2 algorithm was used to estimate several SWAT parameters for discharge estimates (Abbaspour et al, 2007). In SUFI-2 uncertainty is defined as a difference between observed and simulated variables and it is measured by fluctuation between them. SUFI-2 merges calibration and uncertainty assessment to identify parameter uncertainties while computing the narrowest forecast uncertainty band achievable. As a result the uncertainty in these parameters reflects all sources of uncertainty namely the conceptual model, forcing inputs (e.g., temperature) and the parameters themselves. In SUFI-2 input parameter uncertainty is represented as a uniform distribution and model output uncertainty is measured at 95 percent prediction of uncertainty (95PPU). The latest version of SWAT-CUP includes a more strong SWAT editing application that manages all SWAT parameters including multiple soil layers, management rotation operation, precipitation data, and so on. Users are also permitted to provide twenty parameters after their application that are linked to SWAT. SWAT-CUP offers corresponding processing, Bing Map display of outlet position, multi-purpose purpose construction, origin, and calculation of 95 PPU for all variable quantity into output. rich, output.hru, and output.sub files without quantities and one at a time sensitivity analysis.

1.4 Statement of the Problem

In the Bina basin different water resources management practices have been applied however the study area is still under some hydrological problems such as drought and erosion which facilitates soil fertility losses and sedimentation of reservoirs. These problems are happening in the basin because of a lack of proper water resources management practices.

Therefore, assessment of land use a land cover on streamflow modeling of the hydrology of the watersheds is necessary for an effective water resource management strategy.

1.5 Objective of the study

The current research work's aims are as follows:

- ✓ Analysis of river flow response.
- ✓ Effect of climate parameters on water balance components.
- ✓ Compare climate parameter with historical data.

* * *

CHAPTER 2

LITERATURE REVIEW

Reviews of the literature revealed that numerous studied have been conducted using SWAT model in different parts of the world. Reviews of past studies have been presented here under following heads:

1. Streamflow Response
2. Studies in Climate change
3. SWAT CUP–SUFI 2

2.1 Streamflow Response

The hydrological version of the take a look at vicinity become simulated with inside the Soil and Water Assessment Tool (SWAT) on a day by day, time step from 1979 to 2013 the usage of LULC information from 1995 and 213, in addition to slope and soil information with a five year warm-up period. Using discovered streamflow information from the Anandapur hydrological gauge station. Streamflow finished from the version the usage of 1995 LULC is calibrated from 1986 to 1992 and verified from 1993 to 1995. Likewise, the version simulated the usage of 2013 LULC is calibrated from 2004 to 2010 and verified from 2011 to 2013 The goal features in SWAT-CUP in phrases of R^2, NSE, and PBIAS display that the SWAT version laboured satisfactorily.

Jain *et al.* (2021) Using the SWAT model, a portion of the Sutlej River from Suni to Kasol in the Western Himalayas was simulated for flow and sediment load output. Based on measured runoff and sediment load yields the model was calibrated and validated. They evaluated the results as logically sufficient for calculating flow and sediment load from a remote watershed with limited data.

Parajuli *et al.* (2021) The temporal and spatial variability of LULC changes in the Big Sunflower River Watershed was investigated. We used the Soil and Water Assessment Tool (SWAT) model to illustrate the effects of these LULC changes on stream discharge. The model performed satisfactorily to well ($R^2 = 0.46–0.88$, NSE = 0.34–0.64). The stream discharge remained constant.

Das *et al.* (2020) The studies specialize in the consequences of LULC alternate at the hydrologic tactics of the top Baitarani River system.

Sahoo *et al.* (2020) The impact of LULC versions on floor runoff in a tropical, urbanised, and data-scarce watershed is verified on this examine. The Soil and Water Assessment Tool (SWAT) version changed into used to assess the effect of LULC modifications on hydrological procedures among 1995 and 2015. During the examine period the watershed noticed a upward thrust in agreement and dryland agriculture whilst the forest, rice fields and sugarcane plantations decreased. The effects of the Soil Water Assessment Tool version for the calibration (2003 to 2008) and validation (2009 to 2013) durations equalled the located data [$R^2 > 0.91$ and Nash-Sutcliffe Efficiency > 0.91]. Long-time period modifications in LULC expected modifications in runoff (+8%), water yield (+0.28%), groundwater (-1.8%), and evapotranspiration (-1.15 %).

Choto *et al.* (2019) SWAT version have been used on this have a look at to analyse the results of LULC at the hydrological strategies of the Gojeb Watershed with inside the Omo Gibe basin. The version's overall performance become assessed the use of sensitivity, uncertainty analysis, calibration, and validation. The LULC alternate analyses have been finished over 3 time periods (1989, 2000 and 2013) the use of ERDAS Imagine 2014 and a most probability classifier. The effects of the time collection LULC modifications have been used to estimate circulate waft. The effects display that maximum of the wooded area land become transformed into cultivated land throughout the have a look at period, with a boom in cultivated land of 14.97% over the have a look at periods, growing circulate waft and sediment yield of 8.6 m^3/s and 41.07

ton/km^2 respectively. The version overall performance become assessed the use of the Nash Sutcliffe efficiency (NSE), Coefficient of determination (R^2), and Percent bias (PBIAS). The version effects agreed properly with the discovered values, with NSE > 0.75, $R^2 > 0.78$ and PBIAS 0.5 value.

Tulu *et al.* (2018) Understanding a watershed hydrological reaction to adjustments in (LULC) is important for water useful resource control planning. The aim of this has a look at became to observe the hydrological consequences of land use land cowl alternate withinside the Andassa drainage basin from 1985 to 2015 and to forecast the effect of LULC adjustments on hydrological fame in 2045. In the analyses the hybrid land use category technique (1985, 2000 and 2015) Cellular-Automata Markov (CA-Markov) for predicting the 2030 and 2045 LULC states and the Soil and Water Assessment Tool for hydrological Modeling had been used. To isolate the consequences of LULC adjustments the LULC maps had been used autonomously at the same time as the alternative SWAT inputs remained constant. The Partial Least Squares Regression (PLSR) version became used to observe the contribution of every of the LULC classes. During the 1985–2015 period there has been a non-stop boom of cultivated land and built-up area in addition to a withdrawal of forest, shrubland, and grassland, that is expected to stay withinside the 2030 and 2045 periods. The LULC adjustments that happened among 1985 and 2015 improved annual flow (2.2%), moist seasonal flow (4.6%), floor runoff (9.3%), and water yield (2.4%).

Yan *et al.* (2013) The SWAT model was used to evaluate the impact of land-use change on drainage basin stream flow and sediment yield in China's Upper Du watershed. The results showed that changes in grassland had no significant impact on stream flow.

Harun *et al.* (2012) The SWAT model was used to simulate runoff in the Roodan watershed of Iran, which had low storage soils, using a unified approach of curve number bookkeeping procedure and plant evapotranspiration method.

Singh *et al.* (2012) A watershed scale model was used to forecast monthly stream flow in the Nagwa watershed in eastern India. Based on measured stream flow the model was calibrated and validated and the ambiguity in Soil Water Analysis Tool (SWAT) model output was quantified using a sequential uncertainty fitting algorithm (SUFI-2).

Calijuri *et al.* (2010) The SWAT model was applied to the Sao Partolimeu watershed in south eastern Brazil to identify the sites most influenced by erosion for that soil type and land use.

2.2 Climate Change

Singh *et al.* (1999) Variations in the normal display of any local climatic features can be observed as manifestations of global scale climate variations. Rainfall is regarded as an important feature the understanding of which trends and changes will aid in the resolution of uncertainties (Singh, 1998) and it provides the knowledge base for decision making on a wide range of local issues related to cultivation, irrigation, hydro electricity generation industry and other human activities.

Rao *et al.* (2014) reported that global climate change can affect long term rainfall patterns, affecting water availability, as well as the increasing frequency of floods and droughts. According to one study the frequency of more intense rainfall has increased in many parts of Asia while the number of rainy days and total annual precipitation has decreased. The effects of climate change and variability on water resources have an impact on stream hydrology. Because of projected future climate change, stream flows may increase dramatically during the monsoon season but decrease during the non-monsoon season.

Labat *et al.* (2004) The study of groundwater resources and climate variation is based on a long-term, continuous, dependable, and dense database of hydro-meteorological data and soil moisture. These data must be combined with a large amount of quantitative information that is spatially distributed such as hydraulic conductivity and porosity. Remote sensing is a convenient and appropriate method for assessing temporal and spatial variations in water fluxes in various water cycle components. Any variation in precipitation regime and quantity as well as temperature and evapotranspiration affect groundwater recharge.

Knez *et al.* (2013) stated that climate change is a difficult present day issue. Almost every day we receive reports about heat waves, floods, and storms and their effects on society and the environment. These are threats to our current way of life, requiring responsibility, environmental behaviour, and environmentally sustainable progress. There is an increasing appreciation that climate change is not only an economic and ecological problem but also a physiological and social one, implying that drastic policies are required to prevent a serious negative impact on natural resources by encouraging sustainable behaviour.

Intergovernmental Panel on Climate Change (2013) has reported that a compromise is that the mean worldwide temperature will rise by about 4.6 degrees Celsius under high emission situations by the end of the twenty-first century with the CO_2 concentration in the atmosphere doubling.

Intergovernmental Panel on Climate Change (2007) Climate change over is regarded as one of the most serious global challenges of the twenty first century. Climate change is now widely acknowledged to have occurred and that further change is unavoidable. The average global temperature increased by 0.74 degrees Celsius over the last century between 1906 and 2005. This happened in two stages, from the 1910s to the 1940s and then more severely from the 1970’s to the present.

Intergovernmental Panel on Climate Change (2001) Changes in the climate regime can have an impact on the natural processes of a watershed ecosystem and have long term consequences for ecological processes. Climate change according to the IPCC, can affect key spatial patterns and fluxes of water in a landscape particularly in areas where evapotranspiration and snowmelt are the primary components of the water budget and can affect the hydrologic cycle and different methods of a watershed. Changes in the runoff, nutrient enrichment, sediment loading, and evapotranspiration rates in a watershed system are all possible consequences.

Huntington *et al.* (2006) Climate extrade has been proven to influence the spatial and temporal distribution of water resources in addition to the depth and frequency of severe organic events. The international common floor air temperature improved during the 20th century and even as the significance of destiny will increase is uncertain maximum checks suggest that destiny warming is incredibly likely. Increases in precipitation over land had been connected to will increase in runoff in river basins throughout the conterminous United States. In contrast in maximum areas of Canada growing temperatures mixed with nearly no extrade in precipitation led to no extrade in annual streamflow from 1947 to 1996.

Hailemariam *et al.* (2005) Climate change can also have an impact on freshwater availability for both human and ecosystem uses. River flow declines also have an impact on the sustainability of water supplies and reduce the hydroelectric power potential. Climate change can have a significant impact on sediment transport and erosion processes, with the maximum rates of soil loss taking place in areas with high flexibility in precipitation and runoff. Changes in temperature and precipitation components cause changes in the hydrological cycle which can have a direct impact on the spatial and temporal availability of water resources as well as a significant impact on water balance.

Goswami *et al.* (2010) Climate extrade has been extensively mentioned in current years and it can be one of the maximum severe worldwide demanding situations of the twenty-first century. It has been found that the Earth's weather has been converting pretty and hastily over the past century and that those adjustments are predicted to continue. Changes are seen withinside the environment with growing worldwide and nearby temperatures and discernible adjustments in hydrologic cycles in lots of elements of the globe which include India.

Dragoni *et al.* (2008) To conquer contemporary and destiny water and environmental problems, it's far essential to behaviour targeted studies primarily based totally on an excellent set of meteorological and hydrological data which can be presently a long way from satisfactory. It is important to defend and repair ecosystems that offer important water resources including people who defend recharge areas, wetlands, and mountain forests. Water deliver and call for ought to be decreased via greater green irrigation systems, farmer training, wastewater recycling, water conservation via public awareness, and groundwater rules for higher groundwater management (Jung et al, 2010) Individual catchment traits have an impact on adjustments in waft traits because of weather change. Basin geology and elevation are first order controls at the timing and importance of basin runoff in reaction to weather change. If a drainage basin is positioned at a low elevation and is ruled with the aid of using rainfall adjustments in precipitation manipulate runoff greater than temperature adjustments while basins positioned at excessive elevations with snow melt-ruled regimes are extraordinarily touchy to temperature adjustments.

Dragoni *et al.* (1998) Climate change inexorably affect the water cycle with global warming cited as the primary cause. Along with trends in mean values in all aspects of weather (precipitation, temperature, evaporation, etc.), variations in the frequency of exceptional events as well as the hydrological regime can be expected. There could be significant economic and social consequences. This has frequently occurred in the past and it would be unusual if it did not occur again in the future. Aside from natural climate variability there are compelling reasons to believe that man's activities over the last two centuries have resulted in a significant rise in air temperature the wellknown anthropogenic greenhouse effect.

Differences in worldwide climate appeared to have a significant effect on the Northern Hemisphere's mid and high latitudes where temperatures have been noticeably rising since the 1970’s.

Dibike *et al.* (2005) Changes in international weather could have a good sized effect on neighbourhood and local hydrological regimes which will in turn have an effect on ecological, social, and financial systems. Nevertheless, huge variations are discovered in local modifications in weather in comparison to the worldwide suggest change.

Cubasch *et al.* (2001) Another study found that since the beginning of the industrial revolution, human activity has begun to have an impact on a global scale. Because of the increasing concentration of greenhouse gases in the atmosphere the changing climate of the earth and the difference in the quantity and allocation of rainfall. The environment has become mankind's most pressing concern. As a result of rising global temperatures, sea-level rise, changes in precipitation patterns up to 20%, and changes in other local climate conditions are expected.

Chyba *et al.* (1997) Climate change is defined as a shift in the statistical distribution of weather patterns that lasts from decades to millions of years. It is caused by biotic processes, variations in solar radiation received by Earth, plate tectonics and volcanic eruptions, among other things. Certain human activities have also been identified as significant contributors to recent climate change also known as "global warming".

Burgueno *et al.* (2004) He is dating among weather extrade and water resources, with a focal point on groundwater, become reported. It additionally ambitions to lessen the effect of weather extrade and defend groundwater resources. The weather has modified withinside the past is converting now and could hold to extrade withinside the future. The contemporary climatic trend (i.e. a warming trend) which isn't a speculation however a worldwide observation can be associated with a herbal warming segment that started out withinside the 19th century the warming is being increased and elevated due to anthropogenic sports including greenhouse increasing emissions from fossil fuels during the last centuries.

2.3 SWAT Model

Gomes *et al.* (2022) Soil and water assessment tool (SWAT) is a distributed, process based computational hydrologic model designed to aid in the evaluation of watershed response to agricultural operations and management practices. The model has been applied worldwide to solve all kinds of water quantity and quality related problems. SWAT theoretical documentation provides a detailed description of the hydrologic processes simulated within the model.

2.3.1 SWAT Model Calibration and Validation

Ridwansyah *et al.* (2014) the SWAT model was evaluated for its applicability in Modeling mountainous catchments in West Java Province, Indonesia. The SWAT model simulation was done from 2005 to 2010 with Land use information used in 2009. The calibration R^2 and NSE values remained 0.71 and 0.72 respectively. While the validation R^2 and NSE values were 0.71 and 0.70, respectively. The study found that the SWAT model could be a useful monitoring tool particularly for tropical watersheds.

Shawul *et al.* (2013) SWAT model performance and applicability in analysing the influence of hydrologic parameters on stream flow variability and measurement of monthly and seasonal water yield at the outlet of Shaya mountainous drainage basin were evaluated. Statistical model performance measures, R^2 of 0.71, NSE of 0.71, and per cent difference (D) of 3.69 for calibration and 0.76, 0.75, and 3.30 for validation, indicated that the model simulation performed well on the monthly time step. As a result, the SWAT model can be applied to replicate the hydrology of un-gauged watersheds in mountainous areas that behave hydro-meteorologically similarly to the Shaya watershed.

Xie *et al.* (2012) SWAT codes were calibrated and evaluated for Sub-Saharan African basins using 7-year (July 2002–April 2009) 10-day Gravity Recovery and Climate Experiment (GRACE) data and multi-site river discharge data. The study found that in arid and equatorial humid regions simulated total water storage variations have less agreement with GRACE data and model-based partitioning of total water storage variations into different water storage compartments may be highly uncertain. As a result additional work will be required in the future to improve model fit in these areas with the poor model fit and to reduce uncertainty in the component wise assessment of groundwater storage variations.

Jajarmizadeh *et al.* (2012) The SWAT model have been used for the average monthly flow in the Roodan watershed in Iran to detect responsive factors and calculate the monthly flow in a barren region with minimal precipitation using the Sequential Uncertainty Fitting (SUFI-2) algorithm. The model produced acceptable NashSutcliffe and coefficient of determination (R^2). Values of R^2 and NS were 0.93 and 0.92 respectively for calibration. For validation both values were described at 0.83.

Arnold *et al.* (2012) gave a brief description of the key SWAT components. A general overview of a logical calibration and validation pattern more detailed calibration options and parameters and discussed weaknesses and future research needs regarding SWAT calibration and validation approaches.

Shrestha ***et al.*** **(2010)** SWAT model calibrated and validated for Kliene Nete Drainage basin (Belgium) covering 581km^2. For the period 1994-1998, 7 SWAT parameters of the model were calibrated using a heuristic approach. These calibrated parameters are validated in another self governing period (1999-2002). The most sensitive parameter is found to be CH k2 (Channel Effective Hydraulic Conductivity). The calibration and validation periods' Nash Sutcliff Efficiency (NSE) values are 74 and 67%, respectively. These 'goodness-of-fit' statistics, backed up by graphical representations, demonstrate that the SWAT model can accurately analyse such watersheds.

Chaubey ***et al.*** **(2010)** The opportunity of growing regionalized version parameter units to be used in ungauged watersheds become investigated. Using information from precedence watersheds in Arkansas the look at evaluated regionalization methods worldwide averaging and regression-primarily totally based parameters at the SWAT version. On 3 gauged watersheds the ensuing parameters had been evaluated, and version overall performance become determined. The Nash-Sutcliffe efficiencies (NS) for flow go with the drift acquired the use of regression-primarily totally based parameters (0.53–0.83) in comparison favourably to the corresponding values acquired thru version calibration (0.45–0.90). Model overall performance the use of globally averaged parameter values become additionally typically satisfactory (0.4 - 0.75). The findings of the look at display that regionalized parameter units for the SWAT version may be won and used to expect hydrologic reaction in ungauged watersheds.

2.3.2 Applications of the SWAT model

The model was calibrated between 2002 and 2004 and validated between 2005 and 2007. For calibration NSE coefficient of 0.76 was obtained while a coefficient of 0.50 was obtained for validation. The results show that the stream cannot supply the essential water for agricultural areas during drought periods.

Setegn *et al.* (2010) The execution and pertinency of the SWAT version in forecasting monthly sediment yield have been evaluated in addition to the consequences of subbasin delineation and slope discretization on sediment yield prediction withinside the Anjeni watershed, Ethiopia. For the calibration and validation periods, the once a year common measured sediment yield turned into 24.6 tonnes ha, and the common annual simulated sediment yield turned into 27.8 and 29.5 tonnes ha respectively. The found values have been located to be in correct settlement with the simulated sediment yield with Nash-Sutcliffe efficiency (NSE)=0.81, (PBIAS) = 28%, RMSE observations preferred deviation ratio=0.23 and coefficient of determination (R^2= 0.86 for calibration and NSE = 0.79, PBIAS = 30.

Betrie *et al.* (2011) SWAT was used to assess the impact of various BMPs on sediment reduction in the Upper Blue Nile covering an area of 184560 km^2. The model results for the existing conditions scenario show a good agreement among both daily observed and simulated sediment concentrations as indicated by an NSE greater than 0.83.

Fadil *et al.* (2011) SWAT model was used to understand and determine different drainage basin hydrological processes in the Bouregreg basin, Morocco. Using daily temporal data series the model parameters were analysed ranked and adjusted for hydrologic Modeling purposes. From 1989 to 1997 they were calibrated using an auto-calibration method which is based on a Shuffled Complex Evolution Algorithm and validated from 1998 to 2005. Based on statistical indicators the model demonstrated a strong correlation between observed and simulated monthly average river discharge with R^2 and NSE values around 0.8. These findings indicate that when properly calibrated the SWAT model can be used to support water management policies in semi-arid regions.

Ayana *et al.* (2012) the SWAT model can replicate the sediment generated from the Fincha drainage basin (3251 km^2) in Ethiopia.

The model parameters were calibrated using time series from 1987 to 1996 using the automated calibration process. Using the input parameter set records from 1997 to 2006 have been used to validate the model. The model calibration and validation results showed reliable monthly sediment yield estimates with $R^2 = 0.82$ and NS = 0.80 during the calibration period and $R^2 = 0.80$ and NS = 0.78 during the validation period. This study demonstrated that the SWAT model can predict sediment yields and as a result can be used as a tool for water resource planning and management in the study watershed.

Shi *et al.* (2013) SWAT overall performance for hydrologic Modeling withinside the Xixian basin, China, changed into evaluated. Three techniques of calibration and uncertainty evaluation have been in comparison and used to installation the model sequential uncertainty fitting ,generalized probability uncertainty estimation, and parameter solution. The consequences proven that SWAT plays properly withinside the Xixian river basin, that the hydrological water stability evaluation of the basin discovered that base waft is an essential component of overall discharge withinside the have a look at vicinity and that extra than 60% of annual precipitation is misplaced by evapotranspiration.

Goyal *et al.* (2014) SWAT was used to simulate the hydrologic properties of the Rio Nuevo watershed in Jamaica to assess the availability of stream flow for irrigation supply during dry periods. Because aquiclude rock material makes up approximately 85% of the drainage basin there is little potential for interaction between surface and groundwater. Historical climatic data for the watershed were obtained as well as stream flow data for the Rio Nuevo which drains the drainage system.

Mishra *et al.* (2014) The Damodar catchment specific erosion prone areas were identified using the SWAT model at 2 levels, watershed and hydrological response unit (HRUs). For policymakers identifying and prioritizing critical areas at the HRU level may be a more efficient way to achieve the goal of soil erosion control. According to the HRUs level analysis approximately 67.5% of the Damodar catchment is in critical erosion condition with the integration of sandy loam soil with agriculture and wasteland land use being more prone to soil erosion. The findings of this study also show that erosion is extremely sensitive to land use and soil type within the watershed as well as topography and that specific patches must be identified for effective soil erosion management rather than planning for whole watershed management which may be a more expensive option.

Noor *et al.* (2014) SWAT was used to simulate daily runoff in the Taleghan mountainous drainage basin 800.5 km^2 located west of Tehran, Iran. Particle swarm optimization was used to calibrate the model. The model's performance was assessed visually and statistically and a good relationship between simulated and observed discharge was discovered. The coefficient of determination and Nash-Sutcliffe coefficient values were 0.80 and 0.78, respectively, according to the results. The calibrated model was most sensitive to snowmelt and CN2 levels (Curve Number). The results showed that SWAT can provide reasonable daily stream flow predictions from the Taleghan watersheds.

Hasan *et al.* (2015) SWAT performance and applicability were investigated in the Maybar experimental watershed in Ethiopia. For calibration and validation the following multi-objective function statistics were obtained P-factor (23%, 12%), R-factor (0.63, 0.40), Nash–Sutcliffe efficiency NSE (0.55, 0.53), root mean square error observations standard deviation ratio is (0.67, 0.69), coefficient of determination R^2 (0.55, 0.52), and % bias PBIAS (14.6 %, 0.8 %).

The SWAT is the best management Modeling tool for assessing the hydrological response to different land use land cover, soil types, climate, and land conservation practices. However, because all these parameters differ from basin to basin, an attempt must be made to assess the hydrologic response to the basin current land use land cover, soil types, and climate. The SWAT is the best management Modeling tool for assessing the hydrological response to different land use land cover, soil types, climate, and land conservation practices. However, because all these parameters differ from basin to basin, an attempt must be made to assess the hydrologic response to the basin current land use land cover, soil types and climate.

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CHAPTER 3

MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Location

This research took place in the Bina River Basin which covers an entire catchment area of 2820 km^2. Bina river is a major tributary of river Betwa in Madhya Pradesh Bundelkhand area. It originates in Raisen district Begumganj block and enters Sagar district Rahatgarh block passing through Khurai and Bina tehsils before joining River Betwa nearby Basoda town in Vidisha district. Bina basin is located among 23˚3' to 24˚3' N latitude and 78˚1' to 78˚6' E longitude. Forests, barren terrain and limited rain-fed farmland cover the catchment region which is strongly undulated. The upper watershed has a higher stream density than the lower half of the river.

3.1.2 Climate

The area's average annual rainfall is 1329.56 mm with an average of 28 wet days per year. Only 5.5 percent of yearly rainfall falls during the winter and only 4.5 percent falls during the summer. The month of July has the highest monthly rainfall followed by August. The study area climate is mostly divided into three seasons. The winter season lasts from the middle of November to the end of February, the summer season lasts from March to May and the monsoon season lasts from the second week of June to the end of September. January is the coolest month of the year.

3.1.3 Physiography

According to the broad physiographical classification the research region is part of the Bundelkhand plateau. The area geography ranges from rolling to undulating. Flat topped hillocks describe the land slope. The valley land drains moderately to badly.

Natural drains are scarce in uplands with dendritic drainage patterns and drainage density is low. The district features a large network of rivers most of which are seasonal. Rivers such as the Dhasan, Bebas, Bina, Bamner and Sonar run through the Bundelkhand region.

3.1.4 Soil and crop

The region main soil types are black, alluvial and red soils. Because of its chemical relationship and suitability for cotton black soil is commonly referred to as black cotton soil. This clayey soil has a unique chemical composition and a strong moisture retentive capability (Nayak et al, 2020). When wet the soil becomes extremely sticky and expands dramatically due to excessive water absorption when dry, the soil compresses and develops surface fissures. It does however have a very high fertility rate. Soybean, Urad and paddy are the main crops planted in the Kharif season, whereas wheat and red gram are the main crops farmed in the Rabi season. Linseed, chickpeas, sorghum, oilseeds, and other staple crops are also farmed.

3.2 Data Availability

3.2.1 Meteorological Data

Rainfall data of four rain gauge stations represent the weather pattern of the study area namely Begumganj, Gairatganj, Kurwai, and Gyaraspur in stream flow Modeling using the SWAT model. The daily rainfall data for the period ranging from 1986 to 2008 has been provided by the State data centre, Bhopal. The map showing the location of the rain gauge station is given in Figure.3.1. Day-to-day statistics of temperature (max and min), humidity (comparative and mean), average wind speed, and solar radiation in Sagar station have been used as input data for purpose of Modeling in the Arc SWAT model and the daily data of weather data for the period ranging from 1986-2008 have been provided by the state data centre, Bhopal.

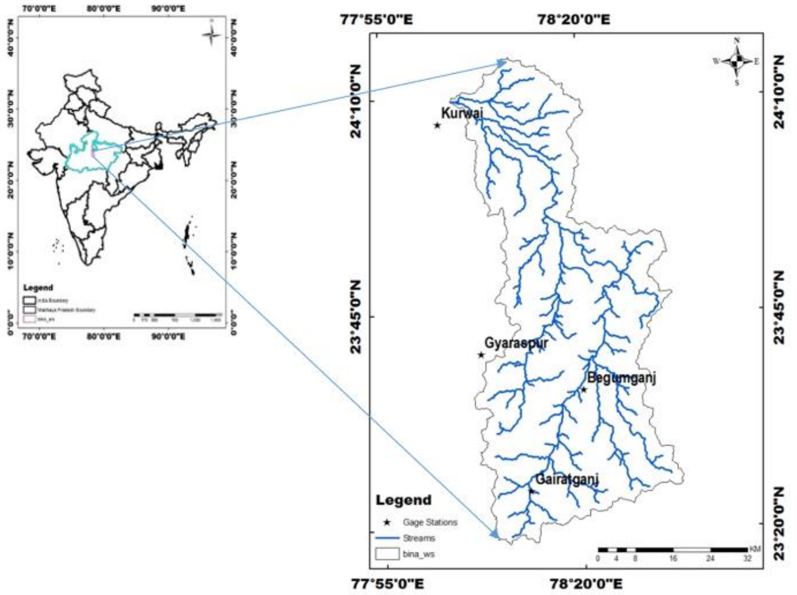

Figure. 3.1: Location map of study area

3.2.2 Hydrological Data

The daily discharge data of the Bina River basin observed at Bina station has been used for stream flow modeling using SWAT models. This observed daily discharge data was also collected from the state data centre, Bhopal.

3.2.3 Land use Land cover and Soil Map

The Landsat 8 Enhanced Thematic Mapper Plus with a 30m resolution downloaded from USGS earth explorer archive. Landsat 8 Enhanced Thematic Mapper Plus satellite images with visual bands with the traditional False Colour Composite were used to make the land use land cover map of the basin for which successive ground truth authentication was carried out by carrying out vast field visits. For the land use land cover supervised classification using a maximum likelihood classifier is used. Soil map extracted from the Food and agriculture organization of the United States.

3.2.4 Digital Elevation Model (DEM)

The digital elevation model was downloaded from the USGS earth explorer archive and utilized to delineate the watershed and examine the drainage patterns of the land surface terrain.

3.3 Analysis of Meteorological Data

The rainfall data were collected from various departments and standard techniques were used to fill in missing rainfall data. Tests were also carried out to check the consistency of rainfall. The outliers at individual stations were checked for any systematic or typological errors by comparing them with the time series of rainfall of the surrounding rain gauge stations and daily rainfall data series was created. The daily rainfall data were subsequently summed up monthly to obtain the monthly rainfall time series at each of the four representing rain gauge stations. The seasonal was also subsequently obtained by summing up the monthly times series for each season i.e., Summer from March to May, Monsoon from June to September, Post monsoon from October to November and finally winter from December to the next year of February.

3.4 Software Used

Arc GIS 10.3 software was used for the preparation of a land-use land cover map of the basin. Arc GIS 10.3 is also used for digitizing the soil map and creating, preparing, and managing different layers of maps. Microsoft Excel and Microsoft access were also used for the preparation of input weather data for Arc SWAT. Arc SWAT is the main software that was used for stream flow Modeling.

SWAT-CUP with SUFI-2 techniques was used for calibration and validation of stream flow simulated by SWAT.

3.5 Methodology

3.5.1 Stream Flow Modeling Using Swat Model

Soil and Water Assessment Tool (Arnold et al, 1998) is a useful eco-hydrological model for a wide range of scales and environmental conditions. Create a SWAT model spatially distributed data (GIS input) such as Digital Elevation Model (DEM), soil data, land use land cover, and weather data (precipitation, maximum and minimum temperature, humidity, solar radiation, wind speed) are required. As a result it is based exclusively on data and does not include any prior knowledge of catchment behaviour or flow processes hence the name "black box".

3.5.1.1 Input Data for the Model

SWAT needs the Digital Elevation Model (DEM), soil type, land use land cover, and stream network layers as input data. The streamflow was simulated using day-to-day weather data (PCP, min and max air temperature, relative humidity, average wind speed and solar radiation). The river discharge was also used to calibrate and validate the model.

3.5.1.2 Spatial Data

The Digital Elevation Model, LULC, and soil type layers remained the spatial datasets used in the SWAT model for streamflow modeling. The basin was delineated and the drainage patterns of the land surface terrain were analysed using a 30m resolution DEM acquired from USGS earth explorer archive. Because the model only uses the masked area for stream delineation, we employed a watershed mask put on the DEM. The spatial data on land use and land cover were categorized into SWAT land cover types. The SWAT code for the various kinds of soil and land use land cover on the map was identified using a user lookup table in the required format. The soil map was linked with the user soil database.

3.5.1.3 Weather and Hydrological Data

The streamflow at the catchment outflow was predicted using five years of daily data from the Bina basin on precipitation, air temperature (max and min), relative humidity, average wind speed and solar radiation. Daily weather data and the location of the weather generator were entered into a distinct excel sheet and converted to .dbf structure with Microsoft Access before being imported into the model setup. Hydrological data from 1991 to 1993 was used for calibration, and for validation, data from 1994 to 1996 was used.

3.5.2.1 Model Setup

For hydrological Modeling in the Bina Basin, the Soil and Water Assessment Tool with an interface to Arc GIS 10.3 software was chosen. The watershed has been chosen and the spatial organization of the basin components has been determined to set up a SWAT model run. The spatial data sets were resampled to 30X30-pixel size and projected to UTM 43 North and WGS 1984 datum.

The raster and vector standard world re-project tools in Arc GIS 10.3 were used for re-projection and conversion. The sub-basin structure is the most common in which the basin is divided into sub-basins which are further subdivided into hydrologic response units (HRUs). The HRUs are proportions of the sub-basin area (Gassman et al, 2007). Individual areas with comparable soil, terrain, and land use within a sub-catchment are grouped to form an HRU, even though they are dispersed throughout the subbasin. For HRU's definition, multiple slope discretization with three slope classes was employed, as well as 8 classes of soil and 8 classes of land use land cover categories.

SCS curve numbers were derived from the USDA National Engineering Handbook (USDA-SCS, 1972). The soil permeability, land usage and antecedent soil water conditions all influence the SCS CN.

The SCS curve number approach is a rainfall-runoff model for calculating excess rainfall (direct runoff). Before pondering this method presupposes a first abstraction connected to the curve number. Three antecedent moisture conditions are defined by SCS: I – dry (wilting point), II – average moisture, and III – wet (field capacity). SWAT uses the curve number method to link runoff to soil type, land use, and management. The SCS-CN approach is based on the water balance concept and two basic assumptions (Mishra and Singh, 2002). The first assumption is that the ratio of direct runoff to maximum potential runoff equals the ratio of infiltration to maximum potential retention. The second assumption, the first abstraction is proportional to the greatest retention potential.

The water balance equation and the two assumptions are formally represented as follows:

$$P = I_a + F + Q \tag{3.1}$$

$$\frac{Q}{P} - I_a = \frac{F}{S} \tag{3.2}$$

$$I_a = \lambda S \tag{3.3}$$

P total precipitation (mm), Ia is the preliminary generalization before runoff (mm), F represents collective infiltration after runoff begins (mm), Q represents direct runoff (mm), and S represents possible max retention (mm) and is the preliminary abstraction coefficient. The popular form of the original SCS-CN approach is obtained by combining Equations. (3.4) and (3.5).

$$Q = \frac{(\mathrm{P-Ia})^2}{P - I_a + S} \qquad \text{for P > Ia} \tag{3.4}$$

$$\mathrm{Q} = 0, \qquad \text{for P < Ia}$$

$$S = \frac{25400}{CN} - 254 \tag{3.5}$$

Where the CN is a dimensionless variable with a range of (0 to 100) and it is affected by land use, hydrological soil group, hydrologic circumstances, and antecedent moisture conditions. The following formulae can be used to alter the standard curve number values for drier or wetter antecedent condition

$$CN_1 = CN_2 - \frac{20 * (100 - \mathrm{CN2})}{(100 - \mathrm{CN2} + \exp[2.533 - 0.0636(100 - \mathrm{CN2})])} \qquad (3.6)$$

$$CN_3 = \mathrm{CN2} + \exp[0.00673(100 - \mathrm{CN2})] \qquad (3.7)$$

Where,

CN1 = moisture condition I curve number,

CN2 = moisture condition II curve number,

CN3 = moisture condition II curve number.

SWAT uses standard curve numbers for diverse soils with moisture condition II and a 5% slope. An equation proved by (William 2010) remained used to modify the curve number to varied slopes as shown by Equation 3.8.

$$CN2_S = \frac{\mathrm{CN2} - \mathrm{CN3} *[1 - 2 * \exp(-13.6 * \mathrm{slp})] + \mathrm{CN2}}{3} \qquad (3.8)$$

Where,

CN2s = moisture condition II curve number adjusted for the slope,

CN3 = moisture condition III curve number for default 5 percent slope,

CN2 = moisture condition II curve number for default 5 percent slope.

SLP = average percent slope of the sub-watershed.

Because the watershed is divided, the model can account for changes in evapotranspiration for different crops and soils. The total runoff for the watershed is calculated by predicting runoff separately for each HRU and routing it. This improves precision and supplies a more accurate physical representation of the water balance.

SWAT simulation of the hydrologic cycle is based on the water balance equation:

$$SWt = SWo + (Rday - Qsurf - Ea - wseep - Qgw) \tag{3.9}$$

Where SWt represents the ultimate soil water content (mm), SWo stands for the beginning soil water content (mm), and t represents the period in days. Rday represents the amount of precipitation on the day (mm), Qsurf represents the amount of surface runoff on the day (mm), Ea represents the amount of evapotranspiration on the day (mm), wseep represents the amount of percolation and bypass existing the soil profile bottom on the day (mm), and Qgw represents the amount of return flow on the day (mm).

The Bina catchment simulation was completed with the Arc SWAT interface of Arc GIS 10.3 software, while sensitivity analysis, model calibration, and validation were completed with the SWAT-CUP tool. For the model parameterization and sensitivity analysis, 20 parameters were explored and tested. SUFI-2 uncertainty analysis methodologies were used to evaluate and analyse the model uncertainties.

3.5.2.2 Model Parameters

The parameters are responsible for stream-flow assessment for the Bina catchment, viz. r_CN2.mgt (curve number), v__ALPHA_BF.gw (base flow alfa factor), v__GW_DELAY.gw (groundwater delay time),v__GWQMN.gw (threshold depth of water in shallow aquifer required for return flow), v__GW_REVAP.gw (groundwater ‘revap’ coefficient), v__ESCO.hru (soil evaporation compensation factor), v__CH_N2.rte (manning roughness for the main channel), v__CH_K2.rte (effective hydraulic conductivity in main conductivity), r__SOL_ AWC.sol (soil available water capacity), r__SOL_K.sol (soil hydraulic conductivity) v_RCHRG_DP.gw (Deep aquifer percolation fraction), r_SOL_BD.sol (Moist bulk density), r_SOL_Z.sol (Depth from the soil surface to bottom of the layer), r_SLSUBBSN.hru (Average slope length), r_OV_N.hru (Manning's "n" value for overland flow), CANMX.hru (Maximum canopy storage), v_EPCO.hru (Plant uptake compensation factor), v_SURLAG.bsn (Surface runoff lag time) has been considered for model parameterization and calibration and validation.

3.5.2.3 Objective Function

The five primary purpose functions P-factor, R-factor, bR2, R^2, and Nash-Sutcliffe coefficient were used to measure the model goodness of fit and efficiency. For hydrological applications, the Nash-Sutcliffe efficiency approach is the most used method. The R^2 and Nash-Sutcliffe (NSE) coefficient between the observation and best simulation can be utilized to measure the goodness of fit.

The Nash-Sutcliffe coefficient is calculated as follows:

$$N_{SE} = 1 - \frac{\sum_{t=1}^{T}(\mathrm{Qot{-}Qtm})^{2}}{\sum_{t=1}^{T}(\mathrm{Qot{-}Qo})^{2}} \tag{3.10}$$

The coefficient of determination is given by

$$R^2 = \frac{\sum_{t=1}^{T}(\mathrm{Qmt{-}Qm})\,(\mathrm{Qot{-}Qo})^{2}}{\sum_{t=1}^{T}(\mathrm{Qmt{-}Qm})^{2}\,(\mathrm{Qot{-}Qo})^{2}} \tag{3.11}$$

Where,

NSE = Nash-Sutcliffe coefficient

Qo = Observed discharge

Qm = Simulated discharge

Qo = Mean observed discharge

Qt = Discharge at time t

3.5.2.4 Sensitivity Analysis

Latin hypercube regression systems were used to calculate the global sensitivity of streamflow factors. In SWAT-CUP the t-stat and p-value are two parameters used to assess sensitivity. The t-stat provides a measure of sensitivity as absolute values increase, whereas the p-values assess the significance of sensitivity magnitudes with values near zero being more significant.

3.5.2.5 Model Calibration and Validation

five years of streamflow records were utilized for calibration and validation. The data for the periods 1991-1993 and 1994-1996 were used for calibration and validation respectively.

3.5.2.6 Model Evaluation Criteria

The World Meteorological Organization (WMO) and other researchers offered several authentication standards that might be utilized for the assessment models Nash Sutcliffe (Coffey et al, 2004) advised the use of the coefficient of determination (R^2) in conjunction with the Nash-Sutcliffe model efficiency coefficient (NSE). NSE is a tool to evaluate and analyse simulated daily and monthly data. Eq.3.10 defines the NSE value, which is a portion of the model's analytical power. A result of 1 for NSE indicates that the simulated and observed data values are identical. In Eq.3.11 R^2 value indicates how strong the linear correlation among anticipated and noted values.

The Nash-Sutcliffe coefficient is calculated as follows:

$$N_{SE} = 1 - \frac{\sum_{t=1}^{T}(\mathrm{Qot}-\mathrm{Qtm})^{2}}{\sum_{t=1}^{T}(\mathrm{Qot}-\mathrm{Qo})^{2}} \qquad (3.10)$$

The coefficient of determination is given by

$$R^2 = \frac{\sum_{t=1}^{T}(\mathrm{Qmt}-\mathrm{Qm})\,(\mathrm{Qot}-\mathrm{Qo})^{2}}{\sum_{t=1}^{T}(\mathrm{Qmt}-\mathrm{Qm})^{2}\,(\mathrm{Qot}-\mathrm{Qo})^{2}} \qquad (3.11)$$

Where,

NSE = Nash-Sutcliffe coefficient

Qo = Observed discharge

Qm = Simulated discharge

$\overline{\mathrm{Qo}}$ = Mean observed discharge

Qt = Discharge at time t

A perfect linear correlation between simulated and observed data values is likewise shown by an R^2 value of 1. The average propensity of simulated data to be higher or lesser than their studied counterparts is calculated by Percent bias (PBIAS). Percent bias has an ideal value of less than 1 and low scale values reveal accurate model simulation. Positive values reveal underestimation bias in the model whereas negative values indicate overestimation bias in the model. The following Eq.3.12 is used to calculate PBIAS.

$$PBIAS = \frac{\sum_{i=1}^{n}(Y_{i}obs - Y_{i}sim)X(100)}{\sum_{i=0}^{n}(Y_{i}obs)} \tag{3.12}$$

Where PBIAS is the deviation of data being evaluated, expressed as a percentage Yi_{obs} is the observed value; Yi_{sim} is the simulated value and Y mean is the mean of observed standards. In Table 3.1 General performance ratings in for recommended statistics for a monthly time step suggested by (Moriasi et al, 2007)

Table 3.1 Performance rating table

Performance rating	**NSE**	**PBIAS %**
Particularly good	0.75 < NSE < 1.00	PBIAS < ±10
Good	0.65 < NSE < 0.75	±10 < PBIAS < ±15
Satisfactory	0.50 < NSE < 0.65	±15 < PBIAS < ±25
Unsatisfactory	NSE < 0.50	PBIAS > ±25

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CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 SWAT Stream flow Modeling

4.1.1 Hydrological response units (HRUs)

The basin soil has been classified into eight classes, as shown in Table. 4.1 and the basin LULC has also been classed into 8 classes, with the final land use classes agreed to be agriculture, barren land, current fallow, dense forest, open forest, sandy area, settlement, and water body as shown in Figure. 4.2.

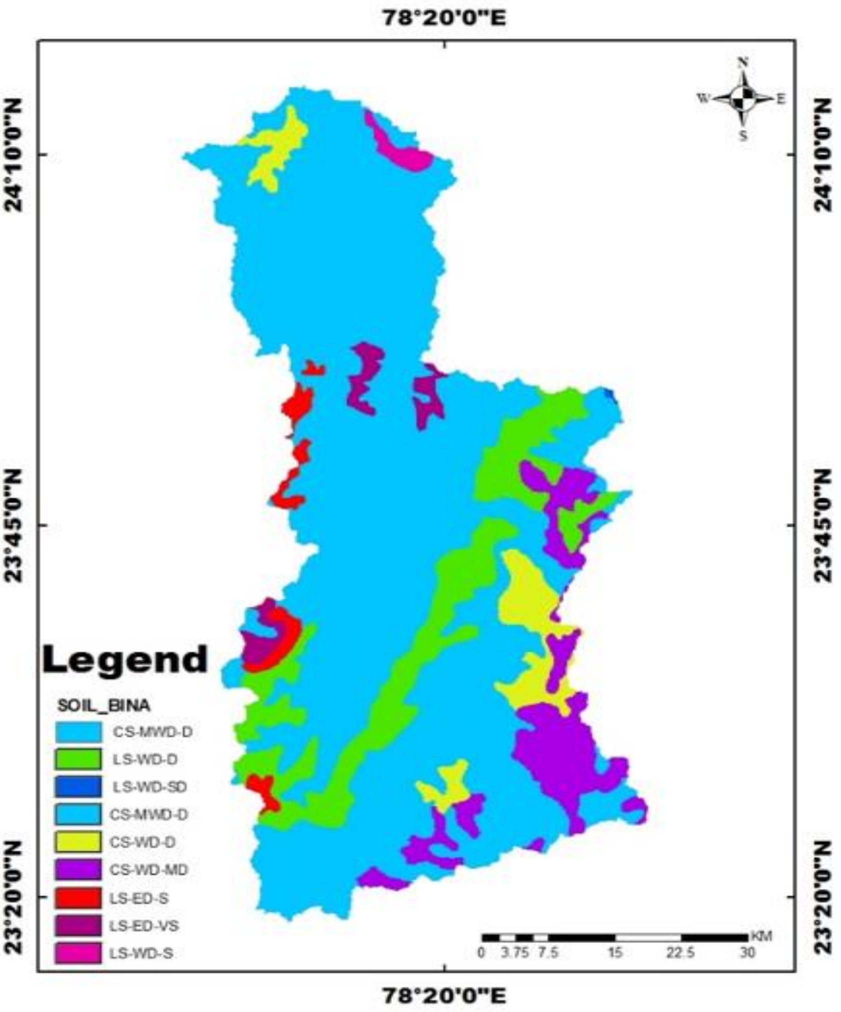


Figure 4.1: Soil Map

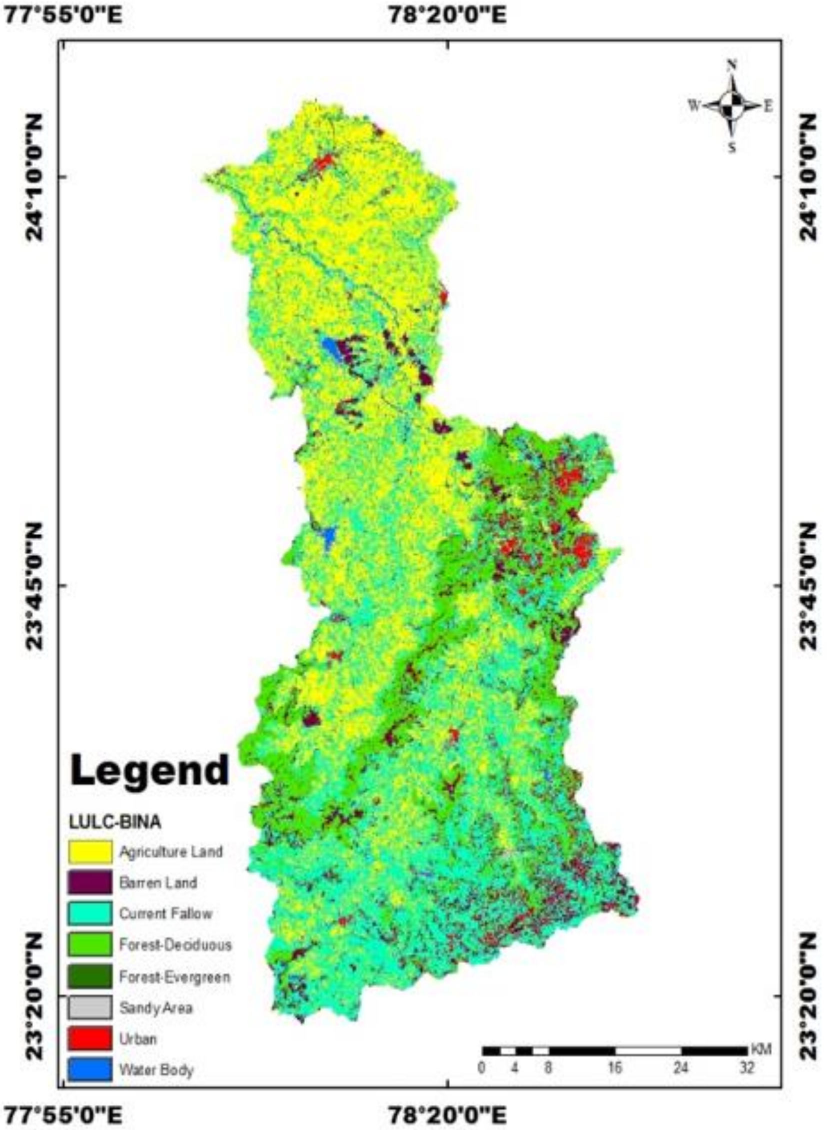


Figure 4.2: Land Use Land Cover Map

As shown in Figure.4.3, the slope of this catchment has been classified into 3 classes: 0-15 percent, 15–30 percent and 20–99.99 percent. As shown in Figure. 4.4, the elevation in the Bina basin ranges from 385 to 710 meters. Figures 4.5 and 4.6 show the DEM and Landsat 8 images of the watershed respectively.

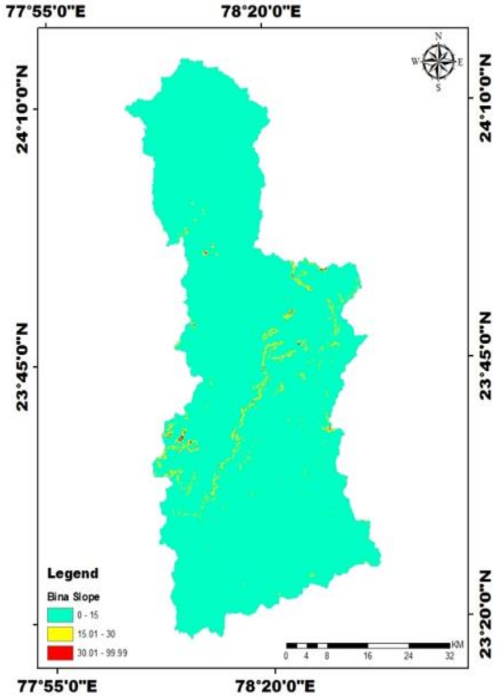


Figure 4.3: Slope Map

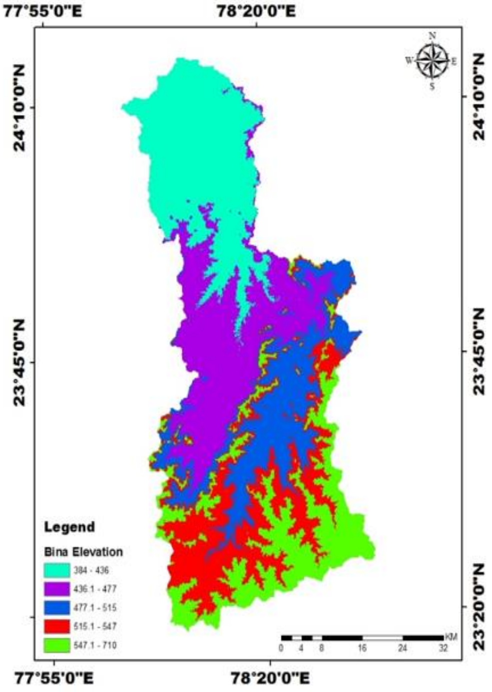


Figure 4.4: Elevation Map

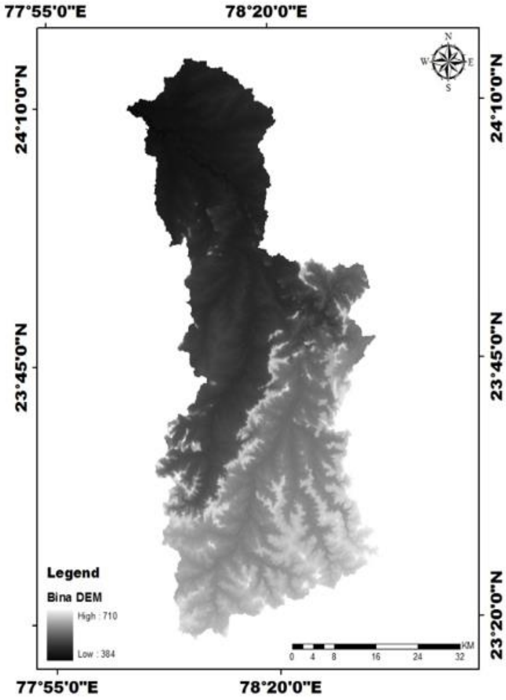


Figure 4.5: DEM

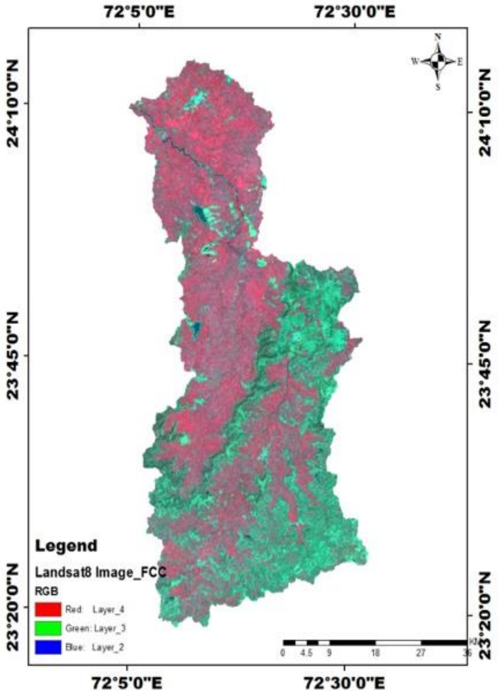
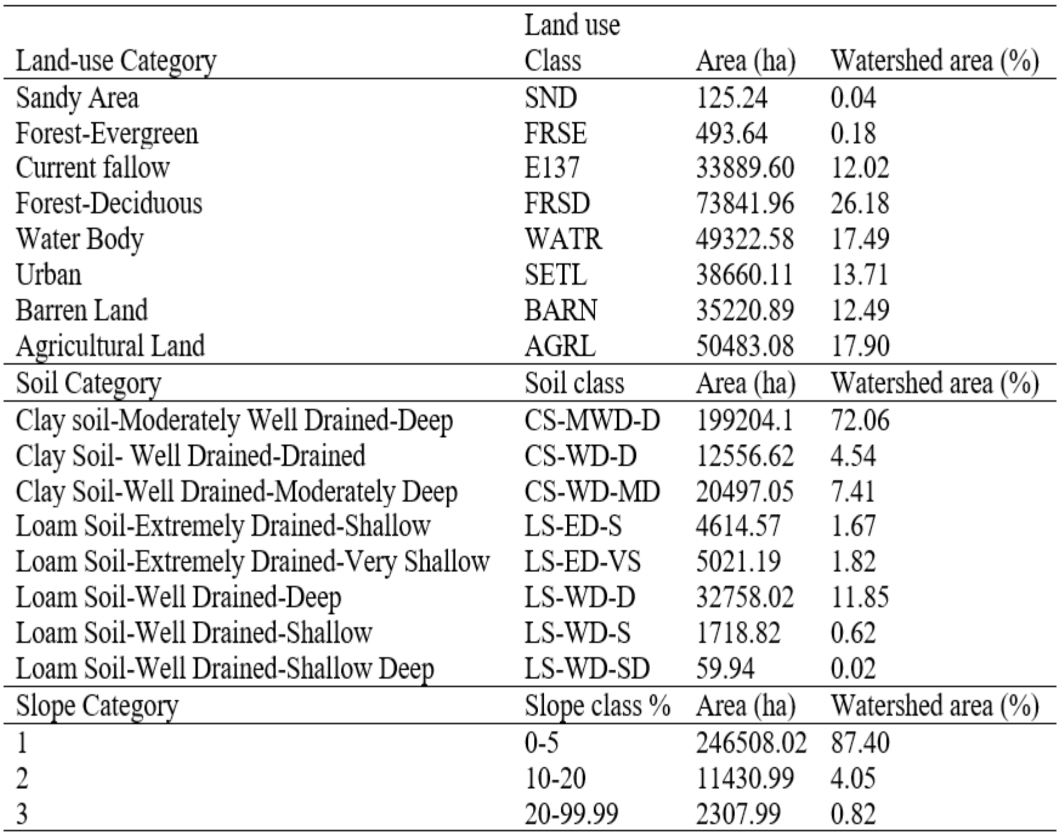


Figure 4.6: Landsat 8 Image (FCC)

Among these classes of LULC, Soil and Slope as shown in Table 4.1 Forest-Deciduous, Agricultural Land-Generic and Waterbody of LULC and CS-MWD-D of soil type are the most dominated classes of the catchment and utmost of the catchment area has a general gentle slope of 0–15 percent and covers approximately 98 percent of the total basin area except for some undulated land.

Table 4.1: Detail of LULC, Soil and Slope



Land-use Category	Land use Class	Area (ha)	Watershed area (%)
Sandy Area	SND	125.24	0.04
Forest-Evergreen	FRSE	493.64	0.18
Current fallow	E137	33889.60	12.02
Forest-Deciduous	FRSD	73841.96	26.18
Water Body	WATR	49322.58	17.49
Urban	SETL	38660.11	13.71
Barren Land	BARN	35220.89	12.49
Agricultural Land	AGRL	50483.08	17.90
Soil Category	Soil class	Area (ha)	Watershed area (%)
Clay soil-Moderately Well Drained-Deep	CS-MWD-D	199204.1	72.06
Clay Soil- Well Drained-Drained	CS-WD-D	12556.62	4.54
Clay Soil-Well Drained-Moderately Deep	CS-WD-MD	20497.05	7.41
Loam Soil-Extremely Drained-Shallow	LS-ED-S	4614.57	1.67
Loam Soil-Extremely Drained-Very Shallow	LS-ED-VS	5021.19	1.82
Loam Soil-Well Drained-Deep	LS-WD-D	32758.02	11.85
Loam Soil-Well Drained-Shallow	LS-WD-S	1718.82	0.62
Loam Soil-Well Drained-Shallow Deep	LS-WD-SD	59.94	0.02
Slope Category	Slope class %	Area (ha)	Watershed area (%)
1	0-5	246508.02	87.40
2	10-20	11430.99	4.05
3	20-99.99	2307.99	0.82

The catchment was delineated into three sub-basins and then further classified into 79 HRUs using Arc SWAT software as shown in Table 4.2. This basin HRUs have been categorized into various classes based on land use land cover, soil type and slope.

Table 4.2: HRUs Classification

Sub	Latitude	Elevation(m)	HRUs
1	24.07	411	6
2	23.79	449	20
3	23.8	483	19

As shown in Table 4.3 the Bina watershed has an average curve number of 83.33 a higher curve number indicates a higher run-off ability. The curve number is determined by land use, hydrological soil group, hydrologic conditions and antecedent moisture conditions, all of which are impacted by the basin average slope.

Table 4.3: Basin Hydrological value

Sr.no	Hydrological parameters	Value(mm)
1	Precipitation	1210.2
2	Surface runoff	225.8
3	Lateral flow	0.62
4	Groundwater	12.51
5	Evaporation from shallow aquifer	0.82
6	Recharge to the deep aquifer	0.7
7	Total aquifer recharge	14.04
8	Total water yield	237.92
9	Percolation to the shallow aquifer	13.13
10	Actual Evapotranspiration	978.9
11	Potential evapotranspiration	2256.1
12	Transmission Losses	1
13	Average curve number	83.33

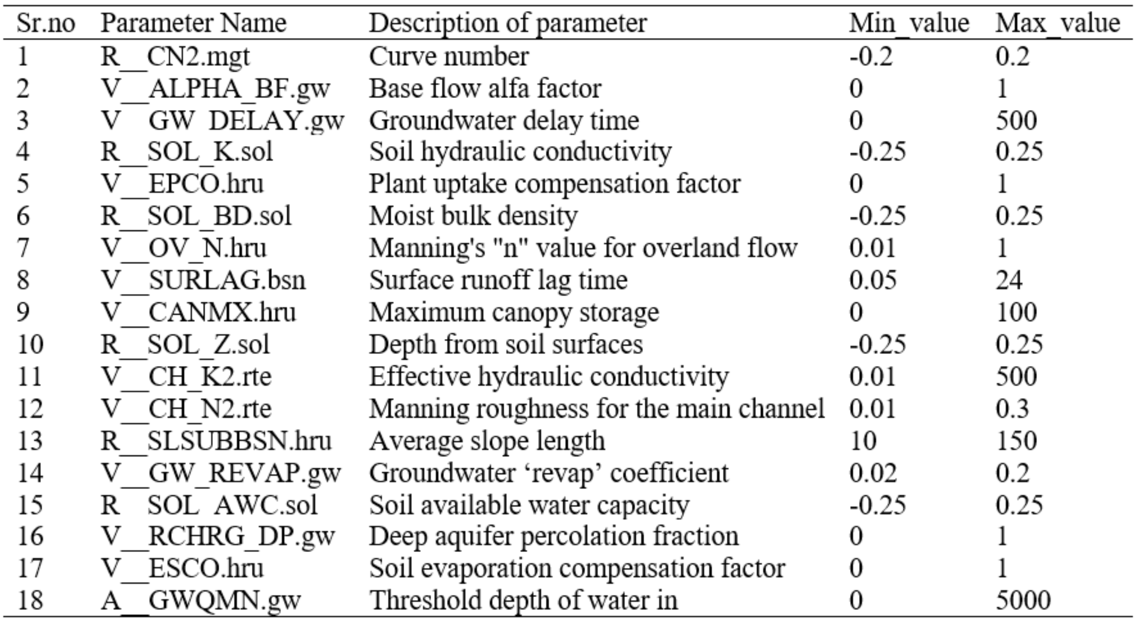
4.1.2 Sensitivity analysis

The Arc SWAT Modeling system contained over 30 parameters in this study. Following a thorough review of the literature on hydrological models, 17 daily parameters and 18 monthly parameters were identified as important and ranked based on their sensitivity.

According to the findings the parameters mainly denoted the channel, runoff, and soil processes. Table 4.4 displays the initial ranges of these selected parameters. Using the fitted parameters and their suitable initial range had a major effect on the stream flow simulation process.

Table 4.4: Selected parameters and their Initial Range

V= Replaced by value, R= (1+multiply by value %) and A = Added on value



Sr.no	Parameter Name	Description of parameter	Min_value	Max_value
1	R__CN2.mgt	Curve number	-0.2	0.2
2	V__ALPHA_BF.gw	Base flow alfa factor	0	1
3	V GW DELAY.gw	Groundwater delay time	0	500
4	R__SOL_K.sol	Soil hydraulic conductivity	-0.25	0.25
5	V__EPCO.hru	Plant uptake compensation factor	0	1
6	R__SOL_BD.sol	Moist bulk density	-0.25	0.25
7	V__OV_N.hru	Manning's "n" value for overland flow	0.01	1
8	V__SURLAG.bsn	Surface runoff lag time	0.05	24
9	V__CANMX.hru	Maximum canopy storage	0	100
10	R__SOL_Z.sol	Depth from soil surfaces	-0.25	0.25
11	V__CH_K2.rte	Effective hydraulic conductivity	0.01	500
12	V__CH_N2.rte	Manning roughness for the main channel	0.01	0.3
13	R__SLSUBBSN.hru	Average slope length	10	150
14	V__GW_REVAP.gw	Groundwater 'revap' coefficient	0.02	0.2
15	R SOL AWC.sol	Soil available water capacity	-0.25	0.25
16	V__RCHRG_DP.gw	Deep aquifer percolation fraction	0	1
17	V__ESCO.hru	Soil evaporation compensation factor	0	1
18	A__GWQMN.gw	Threshold depth of water in	0	5000

Latin hypercube regression systems were used to estimate the global sensitivity of model parameters. Table 4.5 and 4.6 show the extremely sensitive parameters examined after total sensitivity analysis in SUFI-2 for daily and monthly calibration. These tables show that the most sensitive parameters of the model are r SOL BD.sol (moist bulk density), v ALPHA BF.gw (base flow alfa factor), r CN2.mgt (curve number) daily, and r SOL AWC.sol (soil available water capacity), r SOL Z.sol (depth from the soil surface to the bottom of the layer) and It was discovered that comparatively insensitive parameters likened to sensitive parameters did not affect the stream flow simulation process and that variations in their range had not resulted in significant changes in the Latin hypercube regression systems were used to estimate the global sensitivity of model parameters. Tables 4.5 and 4.6 show the extremely sensitive parameters observed after global sensitivity analysis in SUFI-2 for daily and monthly calibration.

These tables show that the most sensitive parameters of the model are r SOL BD.sol (moist bulk density), v ALPHA BF.gw (base flow alfa factor), r CN2.mgt (curve number) daily, and r SOL AWC.sol (soil available water capacity), r SOL Z.sol (depth from the soil surface to the bottom of the layer).

It was discovered that constraints that are relatively insensitive compared to sensitive parameters did not affect the stream flow simulation process and that deviations in their variety had not resulted in important changes in the model result.

Table 4.5: Ranking the sensitivity of flow parameters in Bina Watershed for daily

Rank	Parameters	t-stat	p-value
1	R__SOL_AWC.sol	-0.73	0.47
2	V__OV_N.hru	0.12	0.9
3	V__ALPHA_BF.gw	3.97	0
4	V__CH_K2.rte	1.76	0.08
5	R__CN2.mgt	-3.93	0
6	V__RCHRG_DP.gw	0.62	0.54
7	V__GW_DELAY.gw	1.2	0.23
8	V__EPCO.hru	-0.22	0.83
9	R__SOL_K.sol	1.29	0.2
10	R__SOL_Z.sol	-3.42	0

Table 4.6: Ranking the sensitivity of flow parameters
in Bina Watershed for monthly

Rank	Parameters	t-stat	p-value
1	R__SOL_AWC.sol	1.87	0.06
2	V__OV_N.hru	-0.12	0.89
3	V__ALPHA_BF.gw	14.51	0
4	V__CH_K2.rte	-15.61	0
5	R__CN2.mgt	-6.87	0
6	V__RCHRG_DP.gw	0.33	0.73
7	V__GW_DELAY.gw	0.99	0.31
8	V__EPCO.hru	1.85	0.06
9	R__SOL_K.sol	-1.52	0.12
10	R__SOL_Z.sol	0.58	0.55

4.1.3 Model Calibration and Validation on Daily and Monthly Basis using SUFI-2

After conducting sensitivity analysis the SWAT model for stream flow modeling was calibrated and validated on a day-to-day and monthly basis. User calibrated the results in this study using a SUFI-2 (Sequential Uncertainty Fitting (SUFI-2)) algorithm (Abbaspour et al, 2004). For model calibration and validation examined discharge data from 1989 to 1996 were used on a daily and monthly basis. Initially 2 years of observed discharge data (1989–1990) were used as the warming period followed by 3 years of observed discharge data (1991–1993) for model calibration and the remaining 3 years 1994–1996 for model validation. The most sensitive parameters for the catchment stream flow simulation were found to be 17 parameters used to calibrate daily discharge data and 18 parameters used to calibrate monthly discharge data. Several simulations were carried out to obtain the best model efficiency and goodness of fit between observed and simulated flows.

4.1.4 Model Evaluation Criteria

The model goodness of fit and efficiency were evaluated using the 5 major objective functions.

These five objective functions have been examined daily and monthly (Table 4.7). The PBIAS daily and monthly periods were within satisfactory limits of 2.2 percent and 18 percent for calibration and 4.5 percent and 3.9 percent for validation respectively. The daily and monthly coefficients of determination R^2 were found to be 0.66 and 0.96 respectively. The estimated R^2 between the simulated and observed flows on both daily and monthly periods shows effective similarity and correlation.

However monthly calibration results are significant in terms of model efficiency. On a daily and monthly basis the Nash–Sutcliffe equation has been used for model testing between simulated and observed flows (Table 4.7). The NS value estimated daily 0.65 was less efficient than the NS value predicted monthly 0.94. The R^2 and NS coefficient is 2 important statistical studies for the evaluation of the results. According to Coffey et al (2004) when R^2 is equal to 1, the regression equation model is considered a perfect fit model meanwhile if the R^2 is lower than 0.5 (near to zero), the model would two significant statistical analyses for evaluating results are the R^2 and NS coefficients. According to Santhi et al (2001) and Coffey et al (2004), when R^2 equals to 1 the regression equation model is considered perfectly fit, whereas if R^2 is less than 0.5 (near zero), the model is considered unsuitable. All the results on both time bases demonstrate the goodness of fit in the study area. The R-factor was used to assess the robustness of the model calibration and uncertainty procedure. On a daily and monthly basis, the R-factor values have been estimated to be 0.22 and 0.52 respectively. The R-factor is calculated by dividing the average thickness of the 95PPU band by the standard deviation of the observed data.

In daily stream flow calibration approximately 49 percent of the information was grouped by 95PPU, whereas in monthly stream flow calibration approximately 42 percent of the data were bracketed by 95PPU. Monthly data show slightly higher prediction uncertainties than daily data. Some mistakes in data input sources data preparation and parameters can account for these model uncertainties.

However, uncertainties can arise because of human and instrument errors during data processing as stated previously the highest percentage of discharge is produced only during the monsoon season in the Bina River basin and there is a restriction on the quality of the discharge data these limitations may also contribute to some uncertainties in the model.

The model efficiency and prognostication uncertainty ability can be improved by improving the discharge data quality. As a result our outcomes agree well with the observed and simulated values.

Table 4.7: Daily and Monthly objective function

		Daily		Monthly	
No	Objective Variables	Calibration	Validation	Calibration	Validation
1	P-factor	0.28	0.32	0.44	0.25
2	R-factor	0.66	0.5	0.52	0.27
3	R^2	0.66	0.53	0.96	0.72
4	NS	0.64	0.52	0.94	0.72
5	bR2	0.3866	0.3525	0.7986	0.52

The time-step data of observed and simulated flows on a daily and monthly basis from 1991 to 1996 for calibration and 1993 to 1996 for validation were plotted for visual comparison to investigate the similarity of peak values resulting from SUFI-2 uncertainty techniques. As illustrated in the Figures 4.7- 4.14.

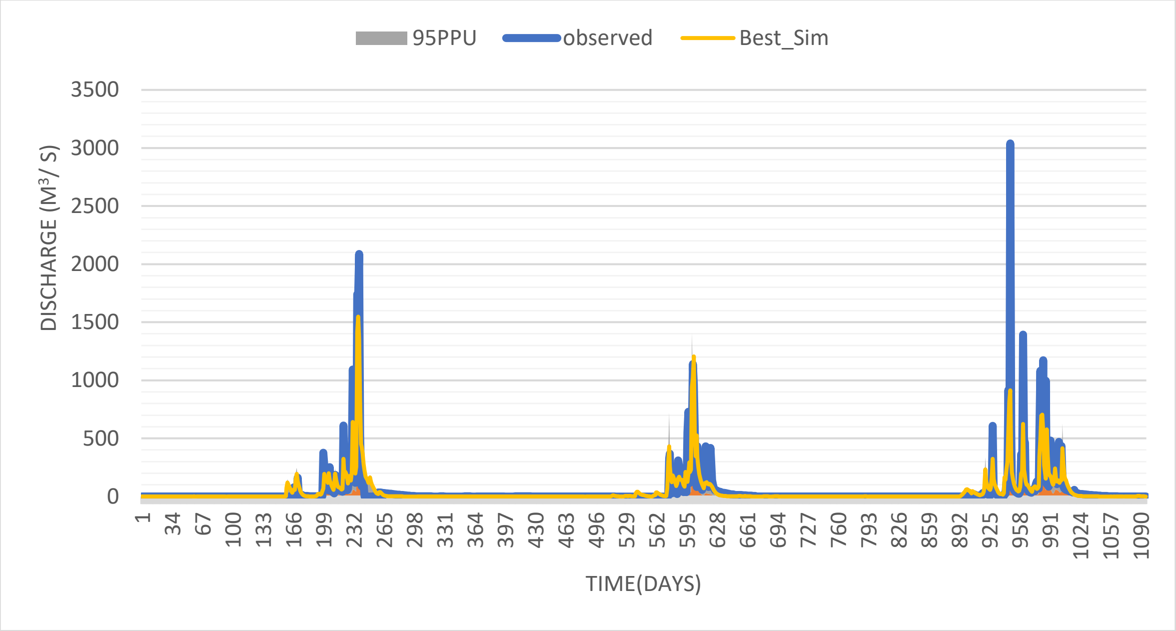


Figure 4.7: Daily Calibration Hydrograph

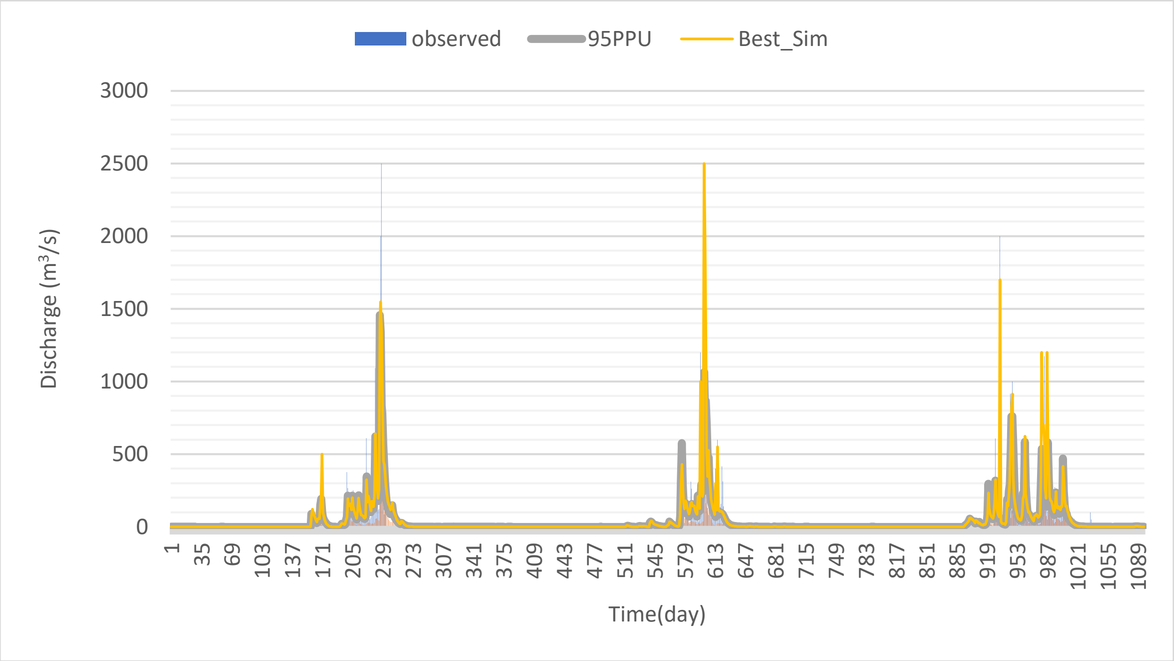


Figure 4.8: Daily Validation Hydrograph

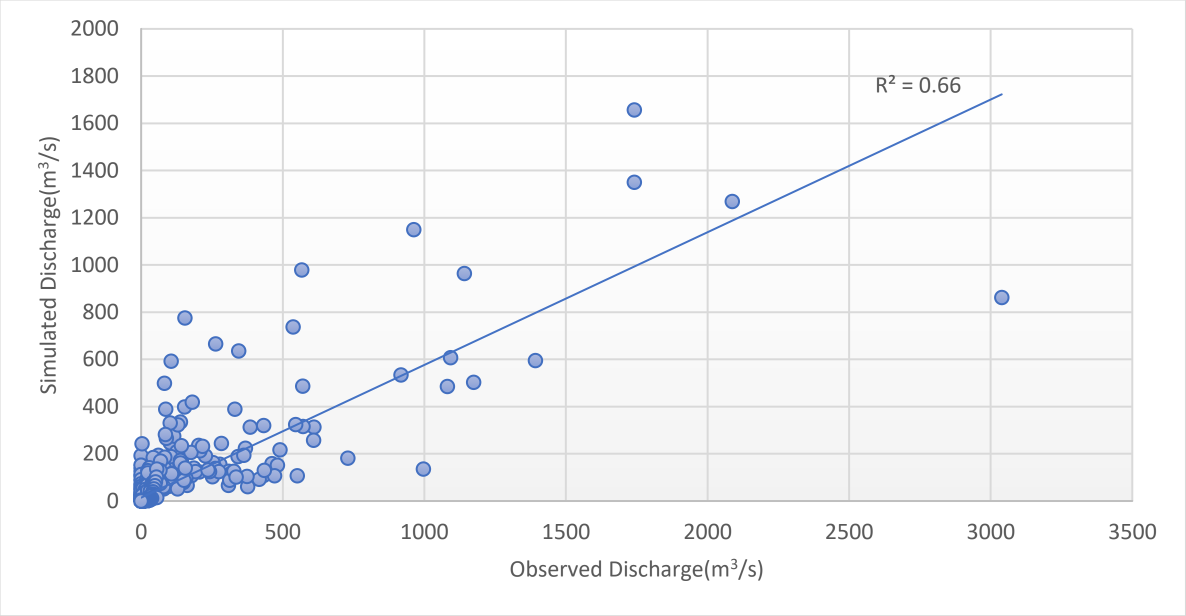


Figure 4.9: Daily Scatter plot for the Calibration period

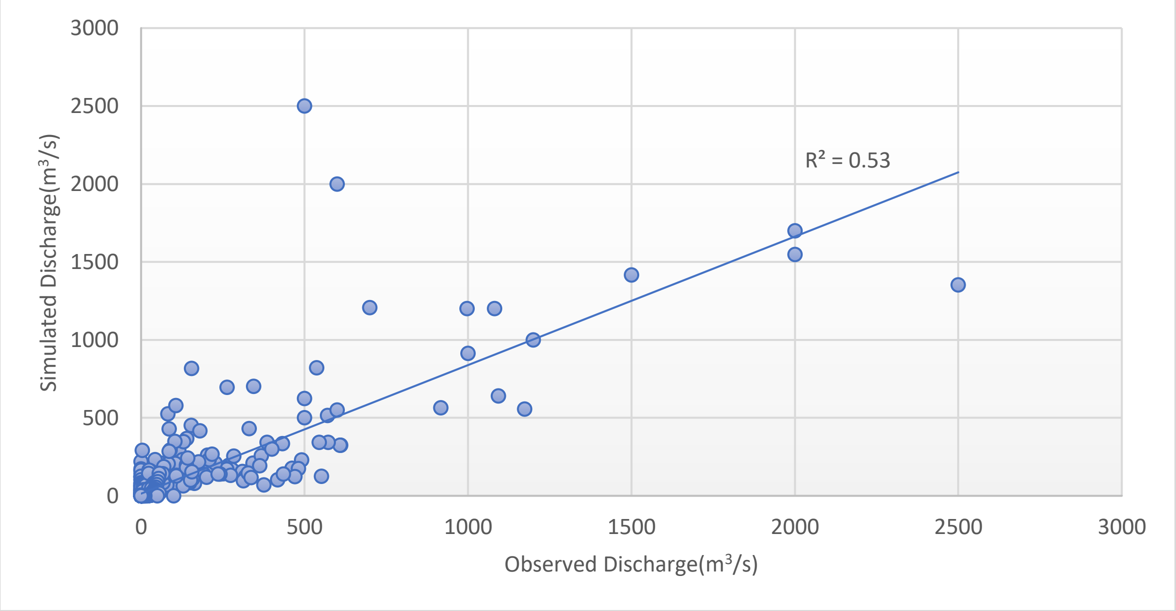


Figure 4.10: Daily Scatter plot for the Validation period

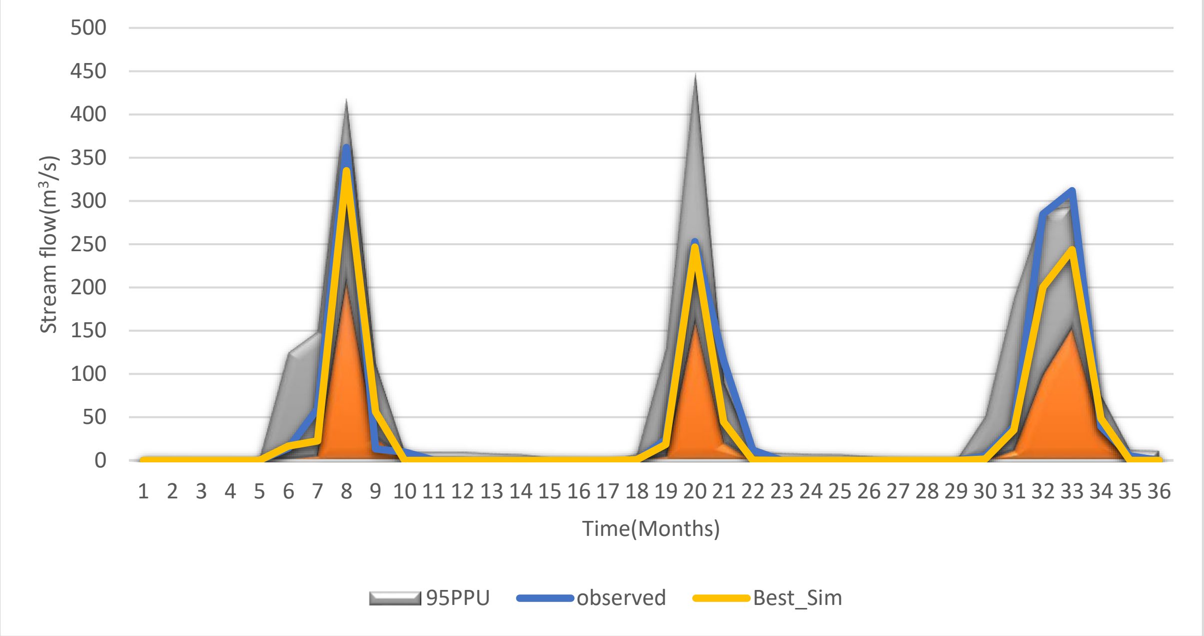


Figure 4.11: Monthly Calibration Hydrograph

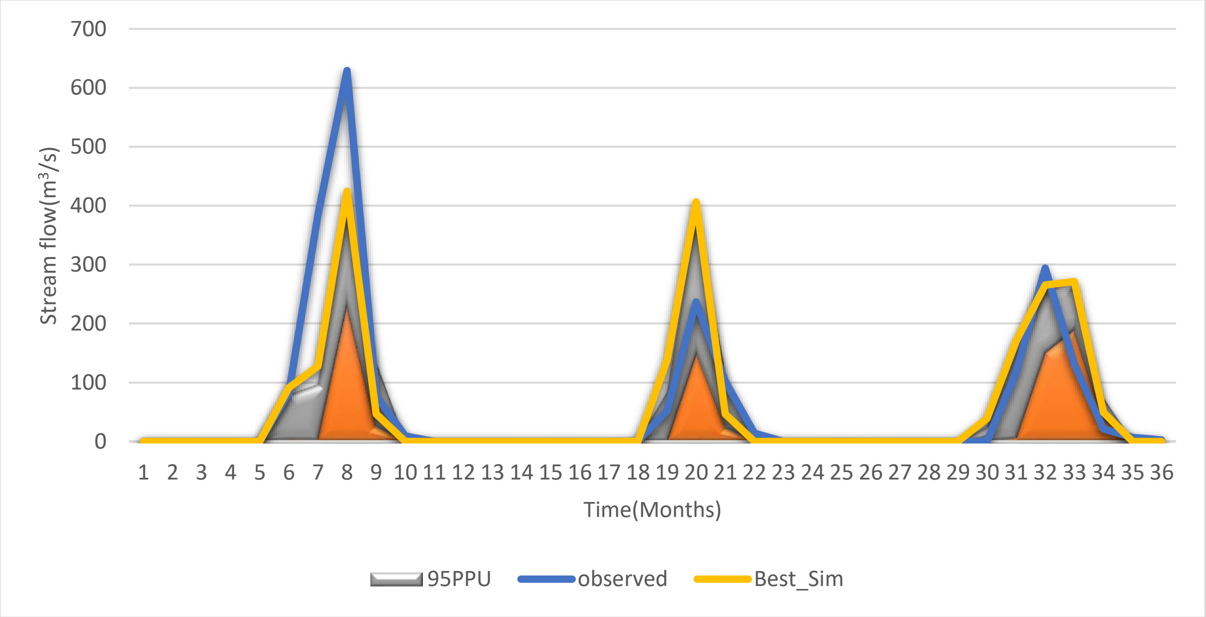


Figure 4.12: Monthly Validation Hydrograph

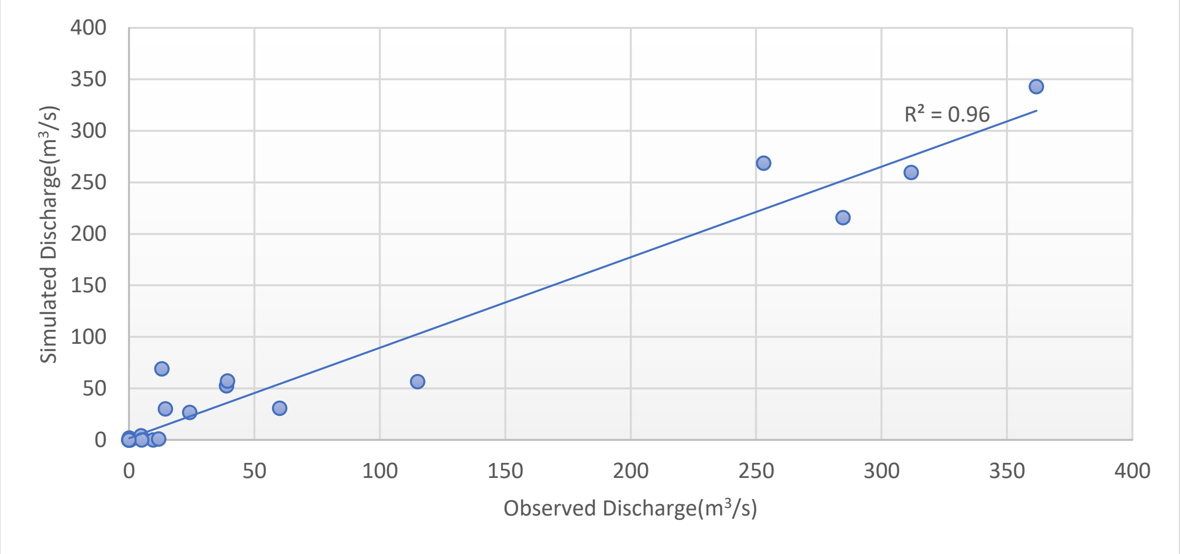


Figure 4.13: Monthly Scatter plot for the calibration period

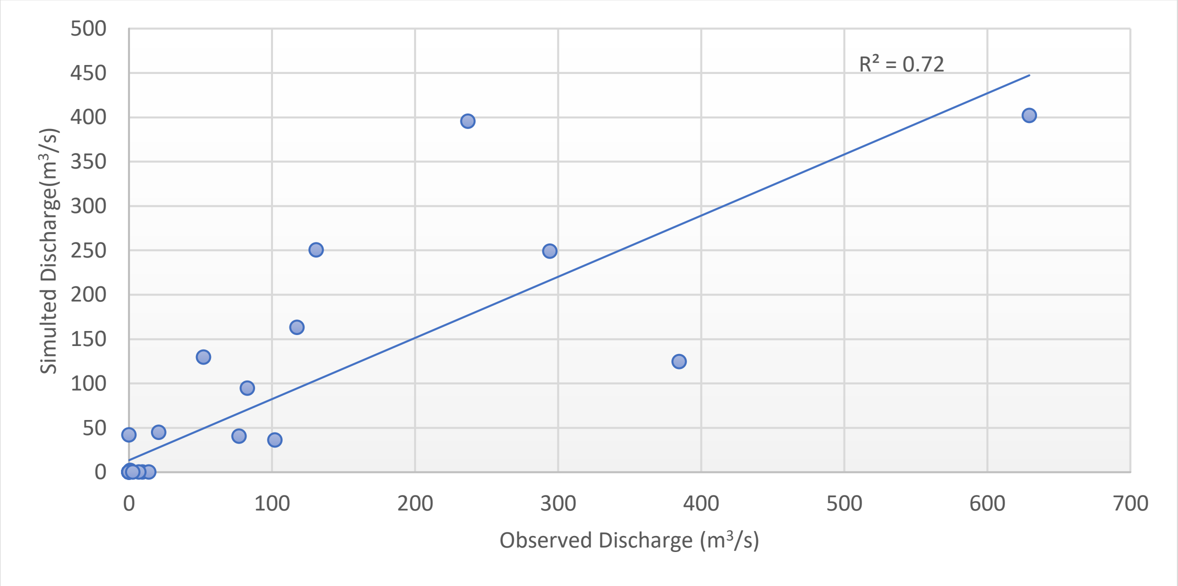


Figure 4.14: Monthly Scatter plot for the Validation period

The best parameters and their range of both periods i.e., daily and monthly have been identified as shown in Table 4.8 and 4.9 below.

Table 4.8: Daily Best Parameters

Sr.no	Parameter Name	Fitted Value	Min_value	Max_value
1	R__SOL_AWC.sol	0.62815	0	0.85
2	V__OV_N.hru	0.15773	0.01	0.85
3	V__ALPHA_BF.gw	0.7704	0	0.8
4	V__CH_K2.rte	134.0067	0.01	400
5	R__CN2.mgt	-0.12125	-0.2	0.15
6	V__RCHRG_DP.gw	0.43602	0	0.78
7	V__GW_DELAY.gw	180.4	0	400
8	V__EPCO.hru	0.42675	0	0.75
9	R__SOL_K.sol	-0.16495	-0.25	0.2
10	R__SOL_Z.sol	-0.20028	-0.25	0.19

Table 4.9: Monthly Best Parameters

Sr.no	Parameter Name	Fitted Value	Min_value	Max_value
1	R__SOL_AWC.sol	-0.1229	-0.1558	0.0814
2	V__OV_N.hru	1.2160	0.4104	1.2316
3	V__ALPHA_BF.gw	326.1514	210.7675	572.4725
4	V__CH_K2.rte	-13.1914	-43.7799	2.0799
5	R__CN2.mgt	0.8876	0.4905	1.4520
6	V__RCHRG_DP.gw	16.6925	-1.1801	46.4801
7	V__GW_DELAY.gw	3.6721	1.9713	20.6612
8	V__EPCO.hru	7.5954	7.4032	20.2188
9	R__SOL_K.sol	5.0864	3.2640	9.7960
10	R__SOL_Z.sol	40.2362	-3.1300	40.6300

This calibrated model was later used to compute the impact of climate change on the river basin's hydrologic runoff response.

4.2 Climate Change Impact on Water Balance Component

4.2.1 Water Balance Components for Current Scenario & Future Scenarios by SWAT model

For studying the water balance of the area it is not enough to compare the river flow. it is essential to analyse the components of river flow.

After Calibration, the SWAT model simulated different climate change scenarios such as Current scenario (1991-1996), RCP 4.5 (2008-2099) and RCP 8.5 (2008-2099). The result obtained from the calculation of different water balance components are shown in Table. 4.10. Water balance elements showed that the major fraction of precipitation is in the form of evapotranspiration, groundwater flow and surface runoff.

In Table 4.10 it is seen that the water balance components in the catchment have also been affected by increase and decrease in precipitation for RCP 4.5 and RCP 8.5 respectively, predicted for the future on account of climate change. Regarding the scenario, average annual runoff was less in RCP 8.5 in comparison of RCP 4.5 hence the river flow is to be affected.

The water balance components exhibit variations between scenarios. Analysis of the results showed that the contribution to evapotranspiration, groundwater flow, and surface runoff was major for current scenario prediction.

Et contributed (646.80 mm) in the Historical scenario while in RCP 4.5 (461.40 mm) and RCP 8.5 it is (317.93 mm). Temperature is considered a major factor controlling evapotranspiration and the rise in temperature and precipitation will result in enhanced evapotranspiration.

Table 4.10: Predicted water balance components (mm)

Water balance components	**Historical**	**RCP 4.5**	**RCP 8.5**
Precipitation	1165.3	1154.2	1138.2
Surface runoff	391.43	369.01	317.93
Groundwater Q	131.42	106.30	179.56
Et	646.80	461.40	460.50

As rainfall and temperature increase results in humidity increases and that resulted in a humid atmosphere which is decreasing the evapotranspiration. The contribution of surface runoff in RCP 4.5 and RCP 8.5 is less than that during the Historical scenario.

This analysis, based on changes in precipitation and temperature tries to illustrate the trend and magnitude of streamflow changes in a river basin which helps to understand the impact of climate change in the future.

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CHAPTER 5

CONCLUSION AND RECOMMENDATION

Climate change is recognized as one of the most serious challenges mankind is facing today. It has a profound effect on the water cycle and water availability at the global, regional, basin and local levels. Changes in temperature and precipitation change the climatic conditions and consequently hydrological and watershed developments in the long run.

Bina river is a major tributary of River Betwa in Madhya Pradesh Bundelkhand area. It originates in Raisen district Begumganj block the upper watershed has a higher stream density than the lower half of the river. This study simulated climate change impact on runoff and other hydrological components such as groundwater flow, baseflow, and evapotranspiration for the Bina River Basin, average annual rainfall is 1165.3 mm, with an average of 22 water stress days per year.

According to the broad physiographical classification the research region is part of the Bundelkhand plateau. The area geography ranges from rolling to undulating. Flat-topped hillocks describe the land slope. The valley land drains moderately to badly. Natural drains are scarce in uplands with dendritic drainage patterns and drainage density is low. The region main soil types are black, alluvial and red soils. Because of its chemical relationship and suitability for cotton black soil is commonly referred. This clayey soil has a unique chemical composition and a strong moisture-retentive capability.

In this regard a stream flow modeling for a basin is of foremost importance for appropriate planning, designing, development and decision making activities of water resources. Simple, logistic and systemic modeling of stream flow is an important and challenging issue in the recent changing environment to properly manage water resources for the socio-economic development of the society in the region. In the present study area a physically based model of SWAT has been applied for modeling stream flow to the Bina basin.

The Soil and Water Assessment Tool having an interface with Arc GIS 10.3 software has been effectively applied for Modeling hydrological features of the Bina basin using the Hydrological Response Unit based approach. The automated watershed delineation at a sub-basin level indicates how the spatial input data such as land use land cover, soil and slope influence the hydrology of the basin. SWAT-CUP advance calibration and uncertainty assessment tools have been used for automatic calibration, validation and sensitivity analysis of streamflow amounts on a daily and monthly basis for the period 1989–1996 using SUFI-2 techniques. The coefficient of determination (R^2) for the daily and monthly runoff was obtained as 0.66 and 0.96 respectively for the calibration period and 0.53 and 0.72 for the validation period. The model gives satisfactory results in the Bina basin. The model shows a few prediction uncertainties, especially in the daily flow data. It is assumed that the model deficiency in the catchment has been examined mainly due to the quality of the discharge data and the seasonality of the river. A comparison of the results from simulation and observation indicates that the model can reproduce well the observed inflow starting time, peak and time base. This static analysis and graphical methods indicated that SWAT using the SUFI-2 technique is a fair model for simulation and calibration for discharge in the Bina River basin.

The model data for RCP 4.5 & RCP 8.5 emission scenarios for the 2008-2099 periods were selected for the study based on the availability of data and to get a long-term trend of the impact studies. The annual average basin value data for RCP 4.5 & RCP 8.5 emission scenario for periods 2008-2099 showed that there is a decrease in rainfall for both future periods.

The results found can be utilized in preparing future water resources management plans and for evaluating the impact of climate change in the area using hydrologic models.

Furthermore, the water balance components of the Bina River basin predicted by the model have been estimated for the simulation period (1991-1996) from the output files. It is found that outflow from the basin is summation of evapotranspiration (646.80mm), groundwater flow (131.42mm), surface runoff (391.43mm). Average annual precipitation in RCP 4.5 was found greater than RCP 8.5 which resulted in higher runoff in RCP 4.5 and lower value of runoff in RCP 8.5.

Water balance components discover that the major portion of precipitation is in the form of evapotranspiration, surface runoff and groundwater flow. Finally, it is suggested that the concerned body and water resources development planners in the region should design strategies and plans by taking into consideration of spatial and temporal distribution and changing patterns of meteorological and hydrological parameter.

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