Comparison of Satellite Based Precipitation Products for Streamflow Simulation in a Data Scarce Watershed of Pakistan.

by

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DEPARTMENT OF CIVIL ENGINEERING

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DEDICATION

We are dedicate this project to our parents and our beloved teachers and also dedicate this project for our university and our country.

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In the name of Allah the most benefit and the most merciful .We will thankful to Engr. M Ehtisham and also thanks to Kuldeep Singh Rautela for give information related to this project. We also thanks to Lucca Brroca for giving SM2RAIN satellite precipitation data.

ABSTRACT

The problem is to Study Flash flood in that area by using gauge data and on ArcSwat model. If any area has no gauge data then we can use satellite data for generating run-off at any area.

In this research, a study of semi distributed modelling of watershed of Pakistan by using Arc swat model, In balancing equation major inflow generated by precipitation. satellite precipitation products (SPP's) i.e. SM2RAIN, NASA(Meera-2), Persian-CDR and Persian and also Ground precipitation data. We have prepare weather data such as; **Temperature**, **Sun Radiation** ,**Humidity** and **Wind Speed**(NASA). The objective of this research is to simulate the stream flow in Harro data scarce watershed of Pakistan. Our main object is to compare the results of satellite on the bases of **coefficient determination** (R^2), **Nash Sutcliffe Efficiency** (NS), **Sum of Squared Residual** (SSQR), **Percentage bias** (PBIAS), **King Gupta efficiency** (KGE), **Root Mean Square Residual** (RSR).

In this research work on the precipitation data from 2010 to 2022, the time period of 2010 to 2014 as warm-up period and from 2015 to 2018 calibration time period and from 2019 to 2022 was time period of validation in Swat cup by using sufi-2 method.

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Chapter :1

Introduction

Pakistan is under development country therefore there is high gauge density. Pakistan metrological department (PMD) install 97 gauges throughout the Pakistan, collecting precipitation data from these gauges. Pakistan has a total area of 0.80394 Million Km^2[18]. The 97 gauges is not fair representation too much large area.

Precipitation estimates provided by high-resolution real-time Satellite Based Precipitation Products (SBPP's) have been under spotlight in scientific and engineering communities globally. The demand of rainfall estimation through satellite-based precipitation products is further highlighted in areas with high gauge density. SBPP's can play a vital role in flash flood monitoring, efficient water resources management and drought management in areas with sparse ground based metrological observatories.

Mona A.Hagras worked on Arc-SWAT modeled the Harro watershed [14]. Peng bai worked on UYA and UYE basins located in Tibetan Plateau simulate the stream flow HEC-HMS model [4]. Khalil-ur-Rehman worked on Potohar Plateau Pakistan to performance on SWAT modelling merging precipitation Datasets by two method and simulate daily streamflow [2].

In this study we use satellite precipitation products (SM2RAIN, PERSIANN, PERSIANN-CDR, NASA (MEERA-2)) use for hydrological modeling in Pakistan watershed harro for the period 2010 to 2022.

Hydrologic models are popular tools for effective and efficient assessment and management of water resources at the watershed level**.**[2]

The European Water Framework Directive requires that all surface and groundwater must achieve at least a "good" status by 2015. Therefore, the directive requires the development of management strategies to restore rivers and lakes to a "good" status. set a time Simulation models are important tools for assessing the potential consequences of proposed strategies and facilitating management decisions. One of the most common watershed models is Arc-SWAT, which is a combination of the SWAT simulation model with GIS.[3]

Hydrological models are important tools for understanding hydrological processes in a watershed characterized by spatial variability and effective decision-making tools for sustainable management of water resources.[4]

Pakistan is classified as one of the highly water stressed countries in the world. Pakistan's agriculture uses more than 95 percent of fresh water resources, and the irrigation system suffers serious losses. Rapid and unsustainable development has also polluted and disturbed several large water bodies and floodplains. The objective of this study is to model the hydrology of the Haro basin and calibrate the hydrological processes of Khanpur. This improves the knowledge of the hydrological cycles of the watershed. It is useful for the development and management of water resources for irrigation and transportation. It is also a starting point for studying climate change and fluctuations in various parameters of hydrological cycles, as well as for managing water balance, agriculture and environmental flows. Spatially distributed modeling would improve understanding of watershed hydrologic patterns. From this perspective, the Soil and Water Assessment Tool (SWAT) was chosen. Because soil, land use, and land cover and topography affect hydrology, it is useful to manage the hydrological patterns of water bodies.[14]

In recent years, the development of SWAT models has gained international recognition as a robust interdisciplinary model of watersheds. SWAT is currently in use worldwide and is considered a versatile model that can be used to integrate multiple environmental processes to support more effective watershed management and the development of more informed policy decisions.[6]

One of the most important variables in hydrological models is precipitation data, which allows models to be grouped according to the way the data is used. Models can be classified as either semi-distributed or distributed, and the rainfall data used as input to hydrological models can be monthly, daily and hourly. Monthly data are used in historical precipitation and climate change analyses. Hourly data can be used for extreme event analysis and storm analysis. Daily precipitation data can be used in all of these applications: historical analysis, climate change analysis, extreme event analysis and storm analysis.[7]

1.1 Types Of Hydrological Models

Classification of hydrological model as follows.

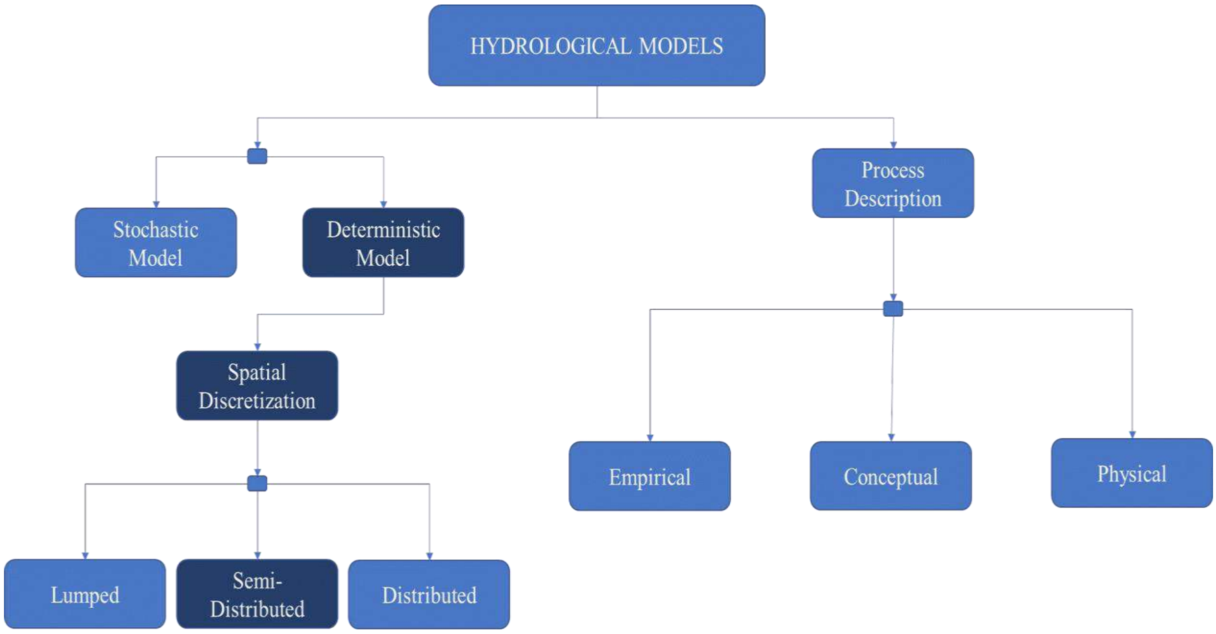


Figure 1 Types Of Models

Our Arc-swat model is semi-distributed hydrological model.

1.2 Needs Of HYDROLOGICAL MODELLING

Watershed modeling is a challenging task for a water resources engineer to predict the impact of natural and human-induced changes on watersheds. Hydrological modeling is also used to understand the behavior of surface and subsurface layers that affect stream flow. Knowledge of past hydrological data would help predict future flows, which would help decision makers and hydrologists make better forecasts. Watershed hydrologic modeling is also used to predict the "change." Change means significant changes in the main characteristics of the catchment area that most affected it, such as land cover, climatic conditions, etc. The erosion rate of the watershed was also predicted with the help of model parameters used in hydrological modeling. Semi-distributed models can be used to efficiently simulate complex hydrological modeling. [3]

1.3 USES OF GIS Tools

In this scenario, a GIS tool is used for data collection, which provides primary and reliable data for hydrological modeling. Remote sensing provides gridded spatial information on databases such as precipitation, snow cover, soil moisture, evaporation, and water quality, etc. However, satellite images provide physical characteristics of the watershed such as topographic information, drainage network, geomorphometric parameters, etc. In semi-distributed hydrological models; precipitation is a key component of the hydrological cycle, and GIS tools can provide the desired precipitation datasets for these enormous data captures, both daily and monthly, for catchments where rain gauges have not yet been installed. Several hydrological models and GIS interface are currently being developed to ensure smooth and fast data analysis. SWAT and the ArcGIS user interface provide a user-friendly interface for solving hydrological problems. ArcGIS can be used to link spatial data such as DEMs, land use maps, soil maps, and slope data to an interface model. [3]

1.4 Objectives

i. To simulate the daily run-off by using Arc-Swat model by using satellite-based precipitation products (SBPP’s) and also ground precipitation data.

ii. Comparing the satellite precipitation data with ground precipitation data.

iii. Comparing the observed run-off data with simulated Arc-Swat Data Determine the Accuracy of Satellite Based Precipitation Products (SBPP’s).

Chapter :2

Literature Review

Engr. MUHAMMAD Ehtsham et al(2020) [1]

Specifically, this effort is focused on the Pakistan region, which spans the coordinates 23.5°-37°N and 61°-77°E, has an elevation range of 0-8,611 meters, and covers a total area of 796096 kilometers. This is based on a comparison of SM2RAIN, TRMM, and IMERG rainfall estimates with the corresponding ground-based gauge observations from 2014-03-12 to 2017-12-31 using a variety of datasets, such as the ASCAT dataset, TRMM-TMPA 3B42-V7, and IMERG V.05, among others.

Khalil Ur Rahman(2020) [2]

Pakistan's northern Punjab region, known as the Potohar plateau, is where the research takes place. The research region, totaling 22,254 km2, is located in western Pakistan, along the border with the Khyber PakhtunKhwa and Azad Kashmir provinces. Data from a variety of sources, including rain gauges (RGs), weather stations, and flow meters, provide the backbone of this approach. In addition, this research delves into the topic of combined satellite precipitation data sets. This research uses the Soil and Water Assessment Tool (SWAT) to compare the results of two MPDs in simulating daily streamflow on the Potohar Plateau in Pakistan.

Kuldeep Singh Rautela(2021) [3]

The Kuttiyadi river catchment is a 449.50 km2 region in Kerala, in the southern portion of India. The sensitivity of the calibrated model's parameters and the ability to accurately quantify streamflow were tested using Arc SWAT (Soil and Water Assessment Tool) in this study. Daily and monthly simulations of streamflow and weather conditions are provided starting on January 1, 2001, and ending on December 31, 2017.

Peng Bai(2018) [4]

The river basin on Tibetan plateau with two gauge scarce are UYE and UYA having area of 121,972 sq km .In this study there are five satellites are used on tibetan plateau under the period of 1998 – 2012. Those satellites are CHRIPS, CMORH, PERSIAN-CDR, TMPA 3B42, MSWEP. The total area is accounted for ~10.4% of tibetan plateau.

Oliver Saavedra(2022) [5]

Bolivia is a large nation, covering 1,098,006 square kilometers, with an elevation range of just 200 to 5,000 meters above sea level. This research suggests compiling daily precipitation data across Bolivia using Satellite-Based Precipitation (SBP) products and local rain gauge data. GSMaP_Gauge v6, CHIRPS, and GMET were the tools used.

N. Mararakanye(2020) [6]

The catchment region under investigation is the lower section of the Vaal River. The overall area covered by the research is around 27 077 km2. Conventional gauge weather data from the SAWS and the ARC was used in one model, while CFSR data was used in the other. The models were calibrated and validated using the SUFI-2 algorithm of the SWAT- CUP at five stream gauge locations, utilizing data collected from 2003 to 2008 and 2009 to 2013.

Mulugeta Musiea(2019) [7]

Located in the Ethiopian Central Rift Valley basin, Lake Ziway has an average depth of 4 meters and an area of around 435 km2; it is 1638 meters above sea level and is a component of the Great East African Rift Valley. In the research community, the CFSR, CHIRPS, PERSI-ANN-CDR), and TRMM 3B42 Version 7 (3B42V7) are the four most well-known products. The TRMM - 3B42V7 dataset covered the years 1998-2004, whereas the other datasets covered the years 1985-2004.

Birhanu(2007) [8]

The catchment drains an area around 101 km2 in size, between the coordinates 37.25°E and 37.33°E and 3.08°S and 3.16°S. The WeruWeru watershed, located in Northern Tanzania at the base of Mount Kilimanjaro, was modeled using SWAT (Soil and Water Assessment Tool), a GIS-based hydrologic model. The temporal calibration approach and long-term global water balance simulation (1972–1986) formed the basis for the Rainfall-Runoff modeling.

Prof. Dr. Ruediger Anlauf(2008) [9]

Agricultural land (AGRL), pasture land (PAST), coniferous forest (FRSE), deciduous forest (FRSD), forest (FRST), soil pits and lakes (WATR), and towns and cities (URBN) are the eight categories of land use. A three-year window, from 2001 to 2003, was employed for the water discharge calibration. The best fitting model was ran over the decade between 1997 and 2006 to verify the results.

Tran, Thanh-Nhan-Duc(2023) [10]

Quantification of Gridded Precipitation Products for the Streamflow Simulation on the Mekong River Basin Using Rainfall Assessment Framework: A Case Study for the Srepok River Subbasin,in this study he evalute different satellite also include SM2RAIN and compare with ground data.

Alaa Alden Alazzy(2017) [11]

The upper Yalong River area in China's southeastern Qinghai-Tibetan Plateau is the subject of this research. There is around 32,925 km2 of land that the GRB drains. The project's time frame was from January 1, 2000, to December 31, 2012. The purpose of this research is to compare and contrast four different satellite precipitation products—CMORPH-CRT, PERSIANN-CDR, 3B42RT, and 3B42—with data from rain gauges.

Chadli Khalid(2017) [12]

Mikke's River is a tributary of Oued Sebou, and the Sidi Echahed dam controls the flow of water through the region. The plan's ultimate goal is to provide Mekne with potable water for the foreseeable future and to irrigate 1,200 acres of land. It covers around 1600 km2 in area. Topography, soil type, soil physical qualities, land use, hydrologic data, and climatic variables are all examples of such information. Good results in reducing discrepancies between seen and measured data were achieved by calibration utilizing the SWAT- CUP with SUFI-2 method from 1979 through 2007.

Deepak Khare(2014) [13]

The western highlands of the Chamba district in Himachal Pradesh are home to the Barinallah watershed. Two years' worth of watershed discharge data (2002 and 2003) were used to calibrate the model, and 2004's results were used to validate it. Soil and Water Assessment Tool (SWAT) model is used to simulate hydrology; it communicates with Arc GIS. Acquiring information on hydrology, geography, soils, and land use/covers.

Mona A. Hagras(2017) [14]

The Haro river watershed is modeled using the Geographic Information System-based semi-distributed model, Soil and Water Assessment Tool (SWAT), with the goals of simulating stream flow, establishing the water balance, and estimating the monthly volume inflow to the Khanpur dam at the basin outlet. For a decade, 1994–2003, the SWAT model was calibrated, then for seven years, 2004–2010, the model was verified.

Changhui Zhan(2023) [16]

Due to the inhospitable terrain, China Meteorological Administration weather stations are sparsely distributed over the vast western Tibetan Plateau (WTP). Average elevations in the Tibetan Plateau (TP) are far over 4000 meters. In this work, two precipitation products from the Global Precipitation Measurement (GPM) period (IMERG and GSMaP) were compared to gauge data. The IMERG-UC and GSMaP-MVK are the uncalibrated variants, whereas the IMERG-C and GSMaP-Gauge are the calibrated ones. Only quality-controlled data from the 2017-2020 wet season (June-September) was used to assess satellite precipitation products in this research.

For the period of 1996-2007, we drew our weather information from the Haste Campus weather station at the University of Applied Sciences, which is located a short distance to the south-west of the watershed region. The use of GIS and ArcSWAT to this investigation. Flow, Nitrate, and Phosphate content, as well as load, were predicted using the calibrated and validated model at the primary basin outflow. Hydrological fundamentals (such surface slope and water flow pathways) are computed in ArcGIS and utilized in the model. ArcGIS was used to classify slopes into two categories: 2.5% and >2.5%.

Aggarwal Ashish(2019 [17]

Mehsana is a city in the Gujarat state's northwestern corner. Located in the northwest corner of the state, it has an area of 4378.38 square kilometers. The SWAT simulation lasted for 17 years, including a four-year warmup. Monthly and annual estimates of runoff were made for the 14 years (2004-2017) of comparable precipitation.The use of ArcSWAT is the subject of the current investigation. For the model to anticipate the monthly and annual runoff, it takes into account parameters like digital elevation model (DEM), land use land cover (LULC), soil data (FAO soils), and data for temperature, rainfall, relative humidity, sunlight, and the wind speed.

Chapter:3

Methodology

3.1 Problem Statement

Study Flash flood in that area by using gauge data and on Arc-SWAT model. If any area has no gauge data then we can use satellite precipitation data for generating run-off at any area.

3.2 Tentative Methodology

Following is the flow chart of our methodology.

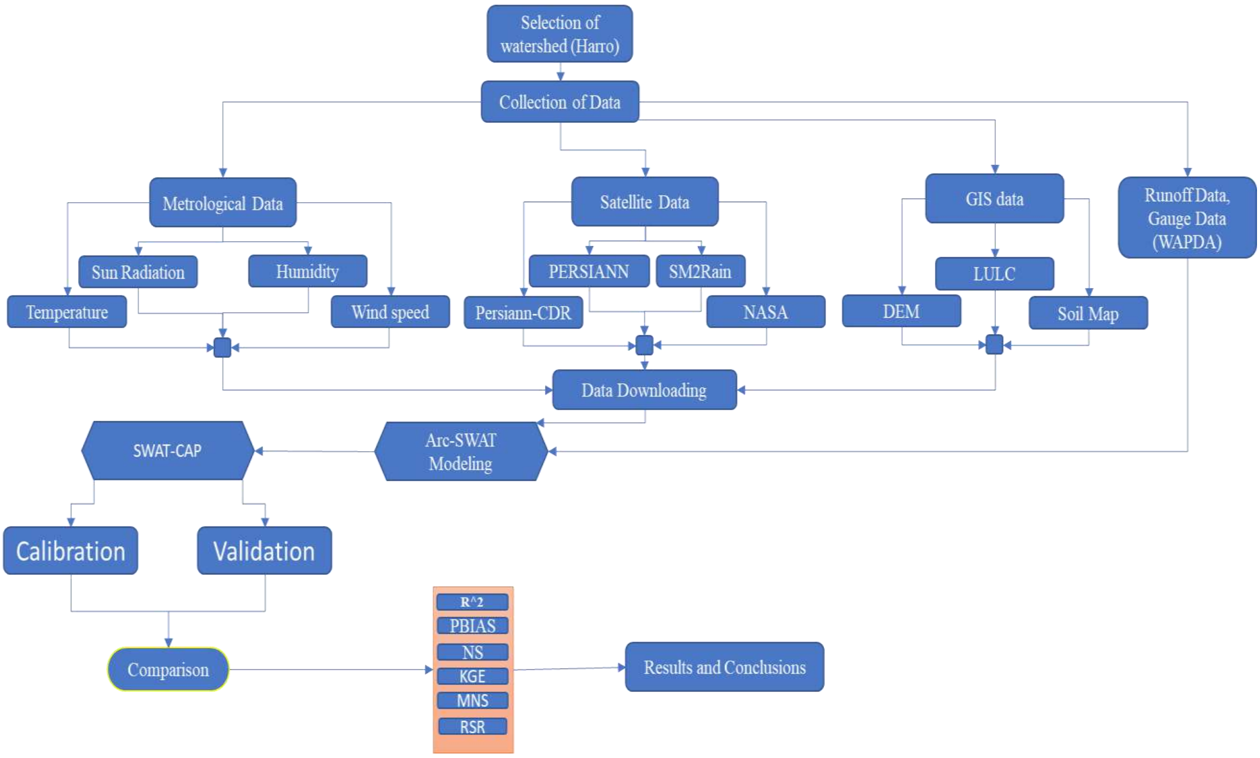


Figure 2 Tentative Methodology

3.3 Selection of watershed.

Watershed	Location	Latitude, Longitude	Distance /Area	Height/capacity of Resovoir
Harro River Watershed	Ayubia, Murree and Margallah Hills, Khyber Pakhtunkhwa (KPK) and Islamabad.	33° 48' 06'' N, 72° 55' 50'' E	Located near distance of 40 Km North West Islamabad in District Haripur. Catchment Area is 800Km^2.	Depth of 167 feet and Reservoirs of 106,000 acre-feet of water.

Figure 3 Selection of Watershed

3.4 Collection of Data

3.4.1 Metrological Data

Following metrological data need Hydrological modeling in Arc-SWAT.

3.4.2 Temperature

Temperature datasets from NASA website with resolution of 0.5x0.5degrees. We get data from NASA and assigned data to Arc-SWAT for showing temperature condition for hydrological modelling. We download data on daily temporal scale. Then prepare according to Arc-SWAT format in .txt files.

3.4.3 Sun Radiation

Sun Radiations datasets from NASA website with resolution of 0.5x 0.5degrees. We get data from NASA and assigned data to Arc-SWAT for showing sun radiation condition for hydrological modelling. We download data on daily temporal scale. Then prepare according to Arc-SWAT format in .txt files.

3.4.4 Wind Speed

Wind speed datasets from NASA website with resolution of 0.5x0.5degrees. We get data from NASA and assigned data to Arc-SWAT for showing wind speed condition for hydrological modelling. We download data on daily temporal scale. Then prepare according to Arc-SWAT format in .txt files.

3.4.5 Humidity

Humidity datasets from NASA website with resolution of 0.5x0.5degrees. We get data from NASA and assigned data to Arc-SWAT for showing wind speed condition for hydrological modelling. We will give information to SWAT how much is humidity in our catchment. We download data on daily temporal scale. Then prepare according to Arc-SWAT format in (.txt) files.

3.5 Satellites

A counterfeit satellite is an item deliberately positioned into space in space. Communication relay, weather prediction, GPS navigation, broadcasting, scientific study, and Earth observation are just a few of the many applications for satellites. Satellites used for collection of hydrological data are;

3.5.1 NASA(MEERA-2)

We get data of precipitation from NASA(MEERA-2) of resolution is 0.5x0.5degrees. We download data on daily temporal scale. Then prepare according to Arc-SWAT format in .txt files.

3.5.2 SM2RAIN

We have get data from mailing the locca burroca and get data in csv file. Resolution of data is 0.1x0.1degrees. We download data on daily temporal scale. Then prepare according to Arc-SWAT format in .txt files.

3.5.3 PERSIANN

We have got data from OHAS data portal and get data in CSV file. We can get data of any location on earth. We take data spatial resolution of 0.25x 0.25degrees. We download data on daily temporal scale. Then prepare according to Arc-SWAT format in .txt files. We extract the data similar location points as location of NASA (MEERA-2).

3.5.4 PERSIANN-CDR

We have gotten data from OHAS data portal and get data in CSV file. We can get data of any location on earth. We have got any resolution data from this portal. We take data spatial resolution of 0.25x 0.25degrees. We extract the data similar location points as location of NASA (MEERA-2).

3.6 Gauge data.

We have got data from authorities which is controlling the data on khanpur dam because khanpur dam is outlet of harro watershed. The authority name is WAPDA, LAHORE.

3.7 GIS data

3.7.1 DEM (USGS)

Digital elevation model is taken from USDS website. It is a digital representation of ground surface, topography and terrains in swat modelling. Below figure show our model properties like stream, sub-basin and outlets etc.

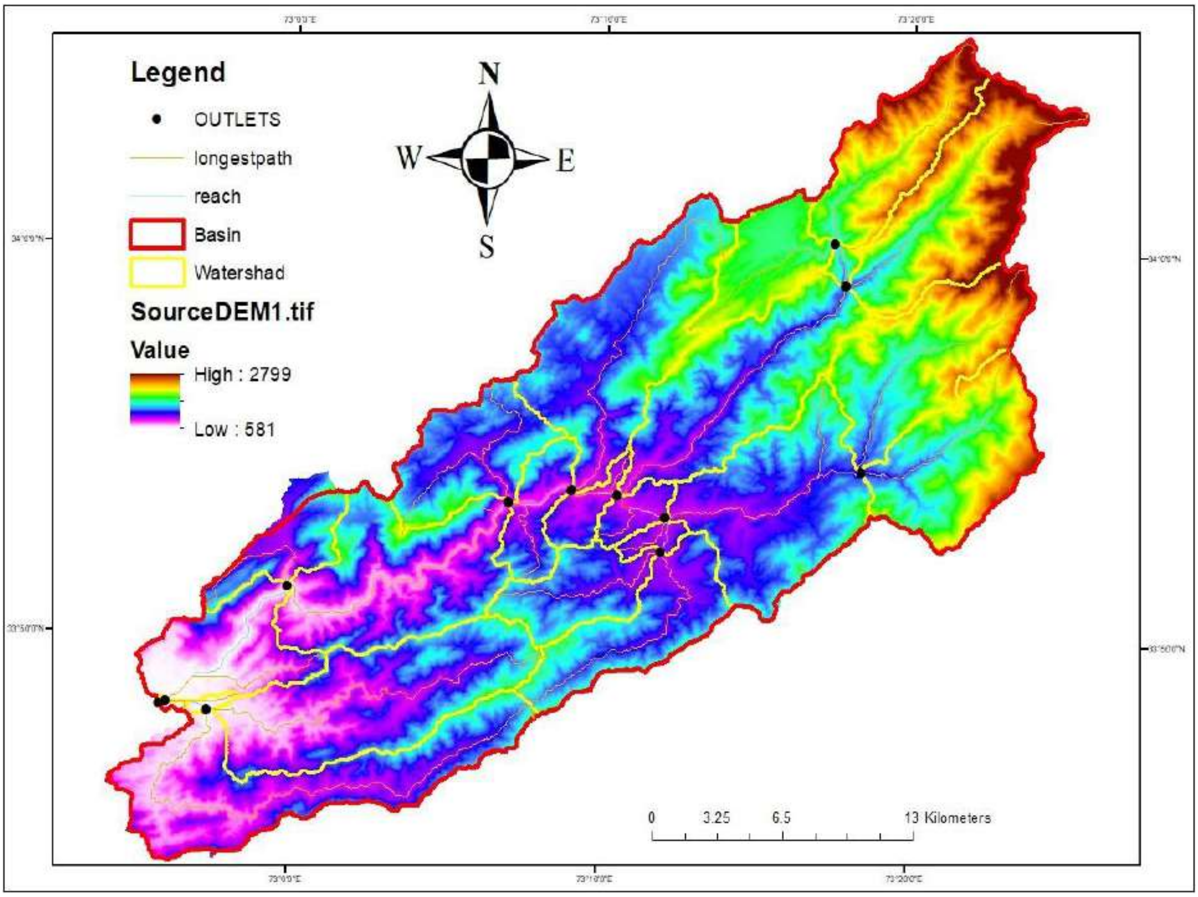


Figure 4 DEM

3.7.2 Land used/land cover (LULC)

We have made lookup table for LULC map. This map is used for define the Arc-swat for which purpose is used for land Classification i-e, forest, agricultural or any other purposes according to their use. Below figure show our catchment LULC map. Our map has 6 classes.

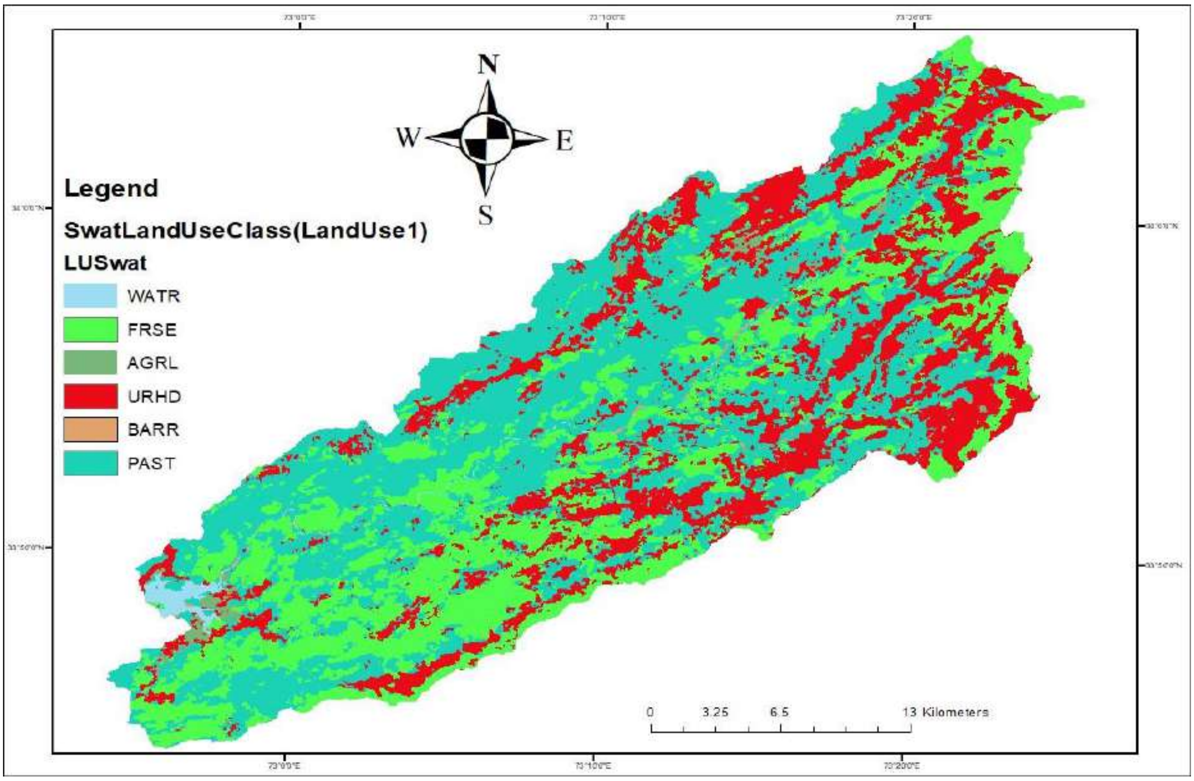


Figure 5 LULC MAP

3.7.3 Soils Map FAO (Food/Agriculture)

This map defines SWAT which type of soil properties in this catchment. Our catchment has two classes of soil. We are download FAO soil map from DEVI GIS whole Pakistan.

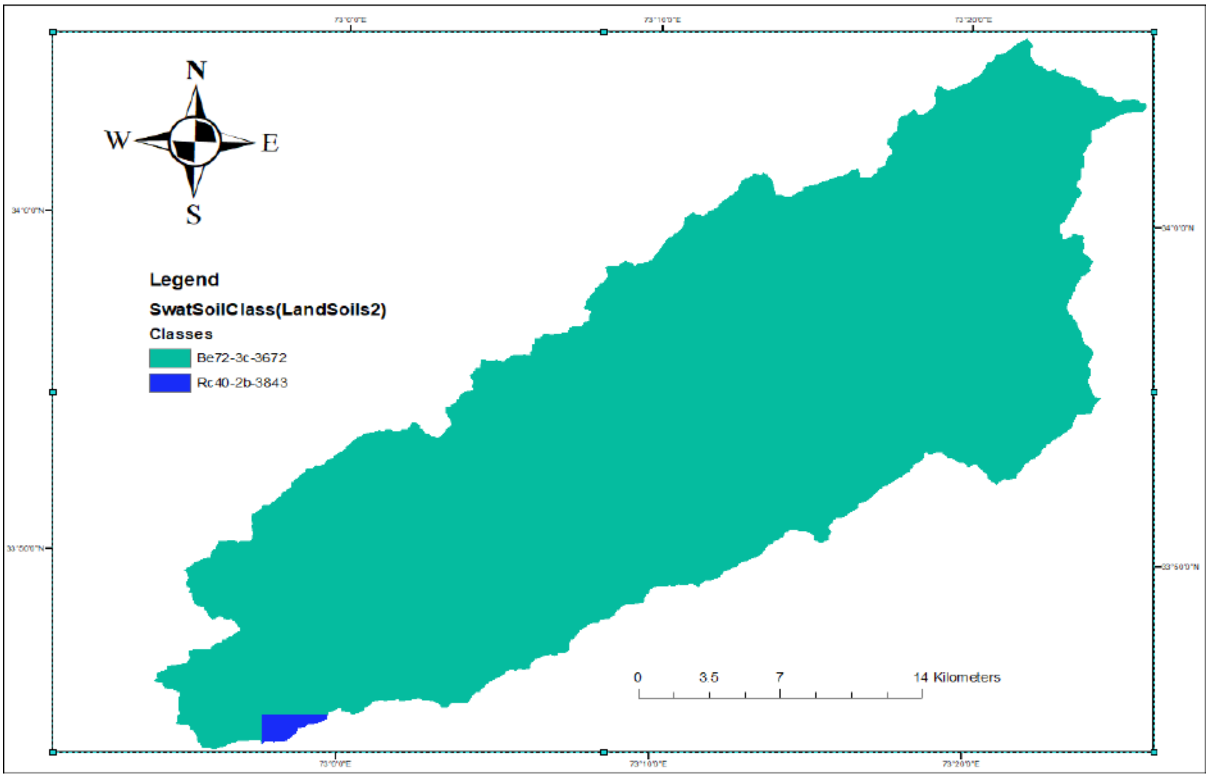


Figure 6 SOIL MAP

3.7.4 Slope map

Arc-SWAT create slope classes from 1 to 5 and slope interval are select accordingly. Following is our catchment slop map.

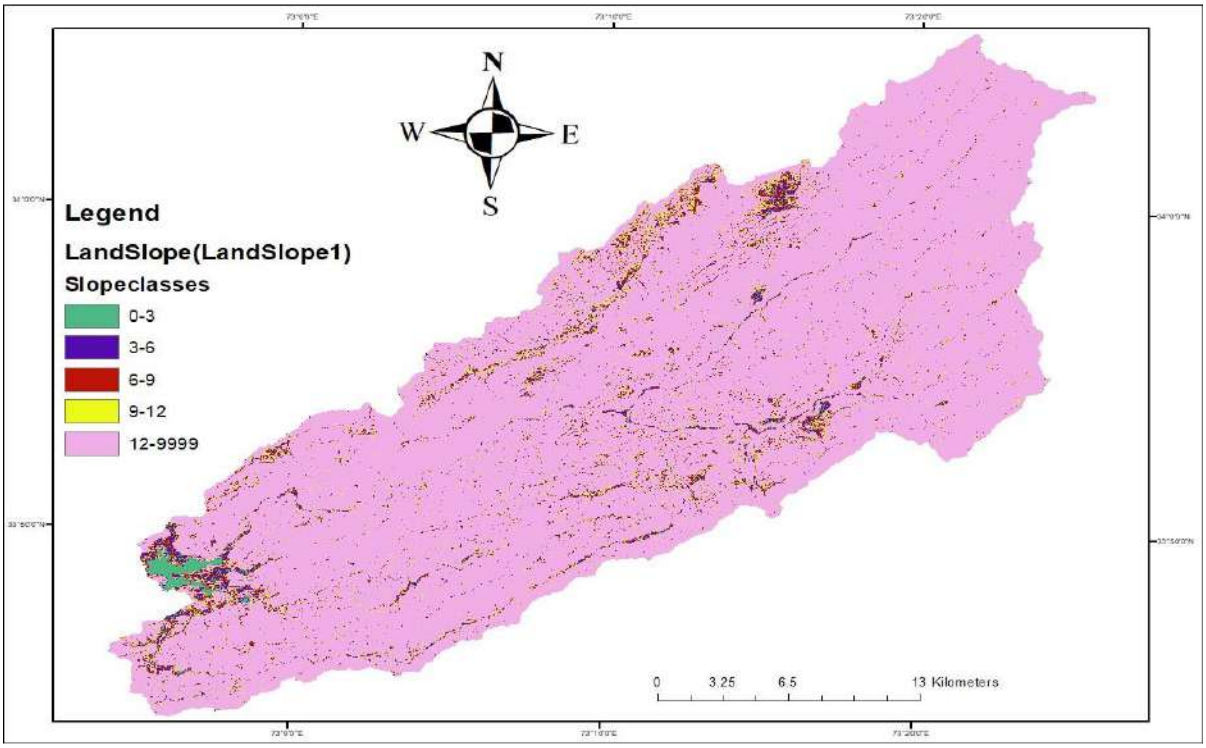


Figure 7 SLOPE MAP

3.8 COMPARISION

3.8.1 R^2

It is coefficient of determination it shows variation in observed and simulated run-off.

- R2 Values ranges from 0 to 1.
- Higher the better the performance

value of R2 can be find by using equations:

$$R^2 = \frac{\left[\sum_i (Q_{m,i} - \bar{Q}_m)(Q_{s,i} - \bar{Q}_s)\right]^2}{\sum_i (Q_{m,i} - \bar{Q}_m)^2 \sum_i (Q_{s,i} - \bar{Q}_s)^2}$$

Where Q_m , $Q_{m,i}$ is measured, Q_s , $Q_{s,i}$ is simulated, $\acute{Q}_m$ is mean of measured $\acute{Q}_s$ is mean of simulated.

3.8.2 NS/NSE

Measure model efficiency.

The NSE ranges from negative infinity to 1, where a value of 1 indicates a perfect match between the model predictions and the observed data, and values below zero indicate that the model performs worse than using the mean of the observed data.

Here's a general interpretation of NSE values:

- NSE > 0: A positive NSE indicates that the model predictions are better than simply using the mean of the observed data. Higher positive values of NSE (closer to 1) indicate better model performance.
- NSE = 0: An NSE value of 0 suggests that the model predictions are as accurate as using the mean of the observed data. It indicates no improvement in model performance.
- NSE < 0: Negative NSE values indicate that the model predictions perform worse than using the mean of the observed data. Lower negative values indicate poorer model performance.

Values ranges from – infinity to 1.

Value of NS can be finding by using equations:

$$NS = 1 - \frac{\sum_i (Q_m - Q_s)_i^2}{\sum_i (Q_{m,i} - \overline{Q}_m)^2}$$

Where Q_m , $Q_{m,i}$ is measured, Q_s , $Q_{s,i}$ is simulated, $\acute{Q}_m$ is mean of measured $\acute{Q}_s$ is mean of simulated

3.8.3 SSQR

Values ranges from +infinity to 0

Since the squared differences are always positive, the sum of squared residuals is also always positive or zero. A value of zero indicates a perfect fit between the model and the observed data, where the predicted values match the observed values exactly. Higher values of SSQR indicate larger discrepancies or residuals between the model predictions and the observed data, suggesting a poorer fit.

Value of SSQR can be find by using equations:

$$SSQR = \frac{1}{n}\sum_{i=1}^{n}[Q_{i,m} - Q_{i,s}]^2$$

Where Q_m , $Q_{m,i}$ is measured, Q_s , $Q_{s,i}$ is simulated, $\acute{Q}_m$ is mean of measured $\acute{Q}_s$ is mean of simulated

3.8.4 PBIAS

It's percent bias. Values ranges from – 100 to +100.

- PBIAS<0 shows overestimate
- PBIAS>0 shows underestimate

Value of SSQR can be find by using equations:

$$PBIAS = 100 * \frac{\sum_{i=1}^{n}(Q_m - Q_s)_i}{\sum_{i=1}^{n} Q_{m,i}}$$

Where Q_m , $Q_{m,i}$ is measured, Q_s , $Q_{s,i}$ is simulated, $\acute{Q}_m$ is mean of measured $\acute{Q}_s$ is mean of simulated.

3.8.5 KGE

It is know as King Gupta Efficiency it also use measure the efficiency of model.

The KGE value ranges from negative infinity to 1, where:

- KGE = 1 indicates a perfect match between the simulated and observed values. It represents a model that reproduces the observed data exactly in terms of correlation, bias, and variability.
- KGE > 0 indicates a positive performance of the model, with higher values indicating better model performance. A KGE value of 0 suggests that the model performs equally well as using the mean of the observed data.
- KGE < 0 indicates that the model performs worse than simply using the mean of the observed data. Lower negative values indicate poorer model performance.

Value of g can be find by using equations:

$$KGE = 1 - \sqrt{(r-1)^2 + (\alpha - 1)^2 + (\beta - 1)^2}$$

Where r is linear regression coefficient

$$\alpha = \frac{\sigma_s}{\sigma_m} = \frac{\text{Standard daviation of simulated}}{\text{standard daviation of measured}}$$

$$\beta = \frac{\mu_s}{\mu_m} = \frac{\text{Mean daviation of simulated}}{\text{Mean daviation of measured}}$$

3.8.6 RSR

It is known as root mean square ratio.

- It ranges from 0 to infinity
- Lower values indicate better model fit

Value of g can be found by using equations:

$$RSR = \frac{\sqrt{\sum_{i=1}^{n}(Q_m - Q_s)_i^2}}{\sqrt{\sum_{i=1}^{n}(Q_{m,i} - \overline{Q}_m)^2}}$$

Where Q_m , $Q_{m,i}$ is measured, Q_s , $Q_{s,i}$ is simulated, $\acute{Q}_m$ is mean of measured $\acute{Q}_s$ is mean of simulated

3.9 Links

Metrological data

NAME	LINKS
HUMIDITY	(https://power.larc.nasa.gov/)
WIND SPEED	Same as Above
SUN RADIATION	Same as Above
TEMPERATURE	Same as Above

Table 1 Metrological data

GIS Data

NAME	LINKS
DEM	(https://earthexplorer.usgs.gov/)
LULC	https://www.arcgis.com/home/item.html?id=fc92d38533d440078f17678ebc20e8e2
SOIL(FAO)	https://www.diva-gis.org/gdata

Table 2 GIS Data

SATELLITES DATA

Name	Links
PERSIAN	(https://chrsdata.eng.uci.edu/)
SM2RAIN	(luca.brocca@irpi.cnr.it)
NASA(MEERA-2)	(https://power.larc.nasa.gov)
PERSIAN-CDR	(https://chrsdata.eng.uci.edu/)

Table 3 SATELLITES DATA

Runoff Data (WAPDA)

By physically meet with WAPDA persons.

Chapter :4

Procedure

The model involves following steps are

4.1 ARC-SWAT

- **Swat Project setup**

Put "Set Project Path". Put satellites data. Project is started.

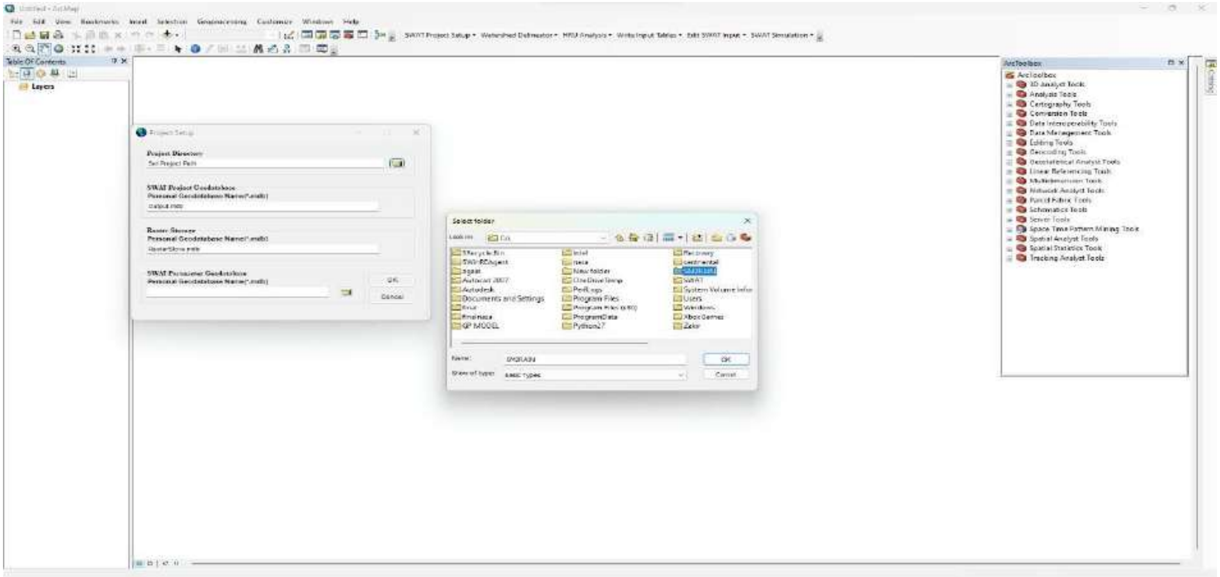


Figure 8 ARCSWAT 1

- **WATERSHED DELINATION**

Put data according to your project all these data is provided which is required for watershed delineation.

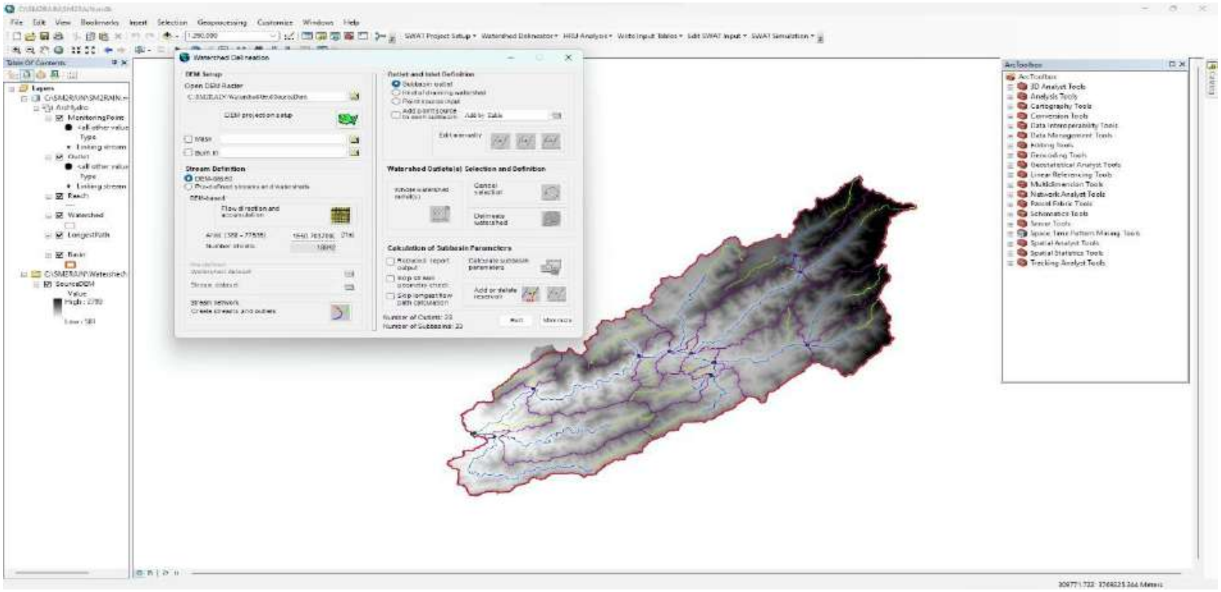


Figure 9 ARCSWAT 2

• Assign data for lulc map.

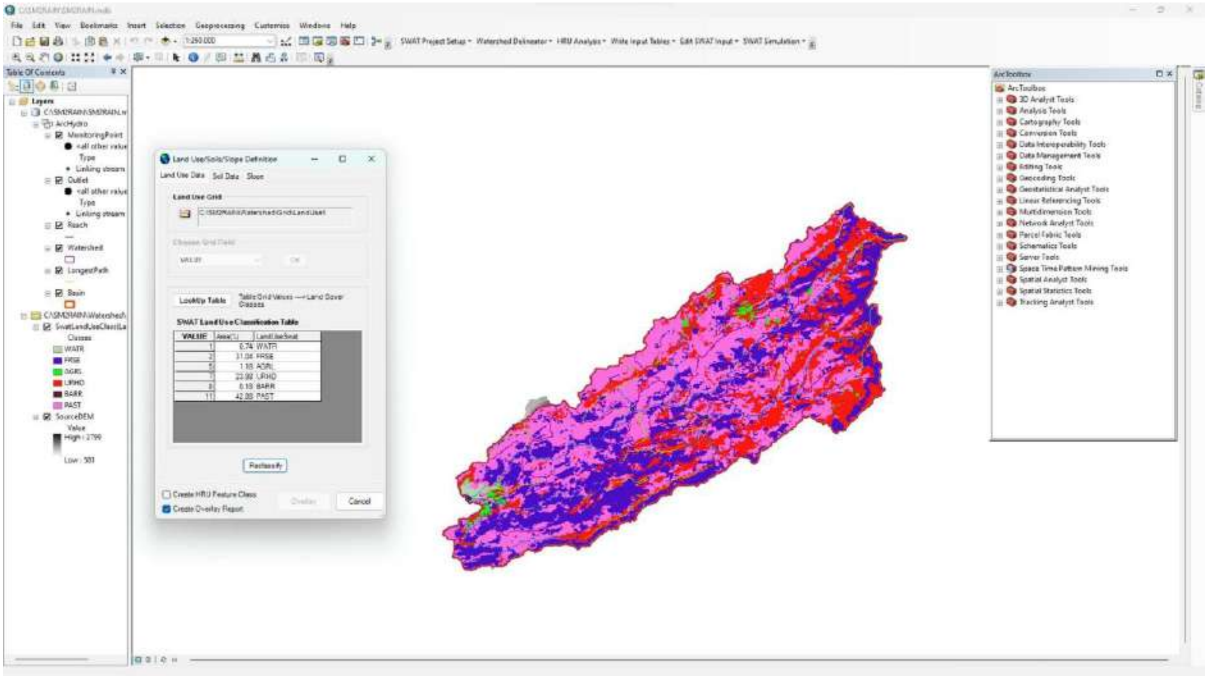


Figure 10 ARCSWAT 3

• Assign soil map of watershed.

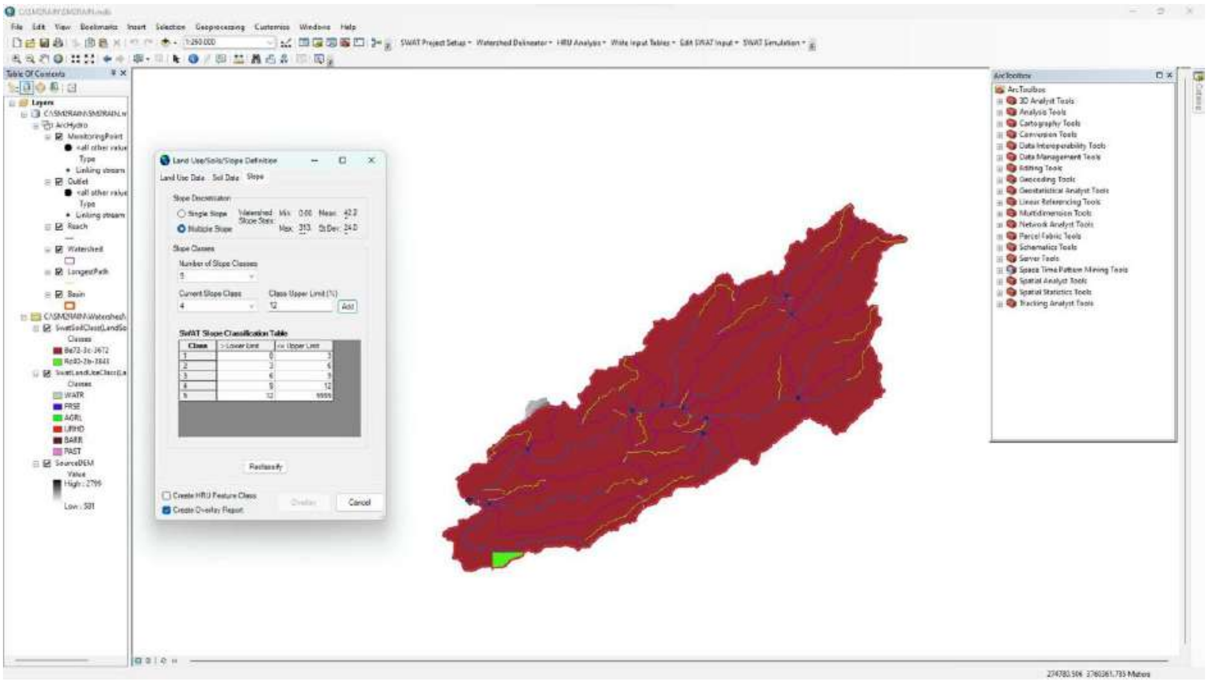


Figure 11 ARCSWAT 4

- **HRU Analysis**

Put data of HRU.

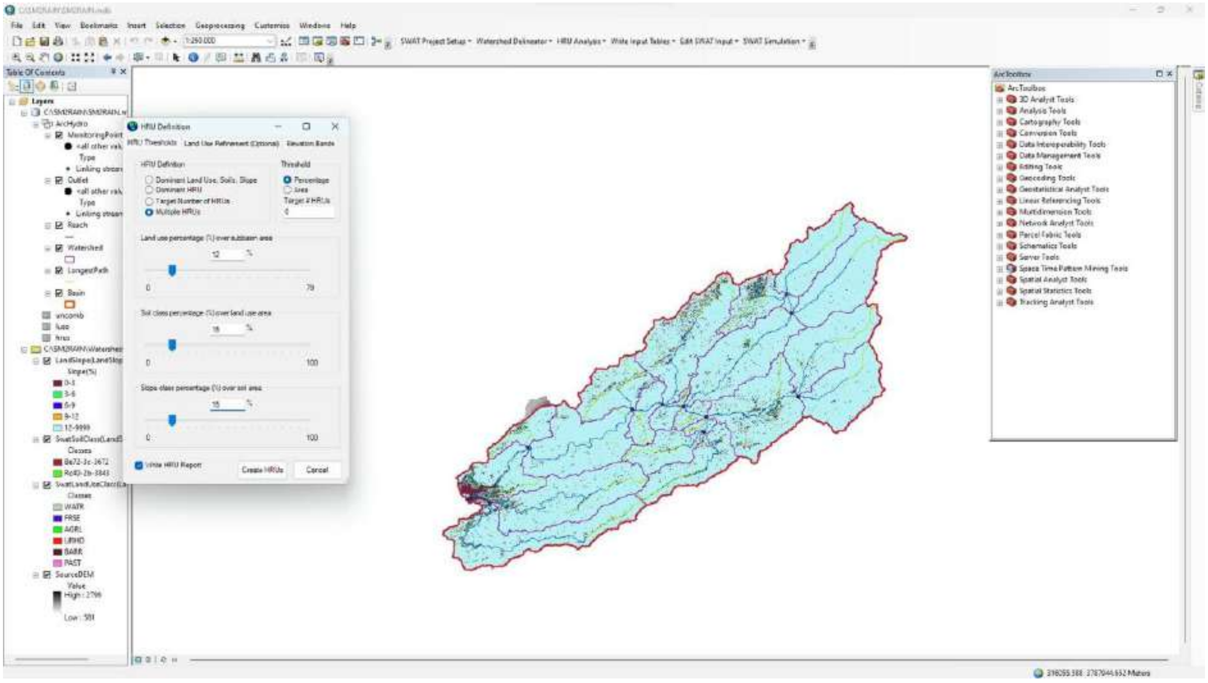


Figure 12 ARCSWAT 5

- Assign weather data rain fall, temperature, sun radiation, wind speed relative humidity and weather data from WGEN_CFSR_WORLD from SWAT cup website

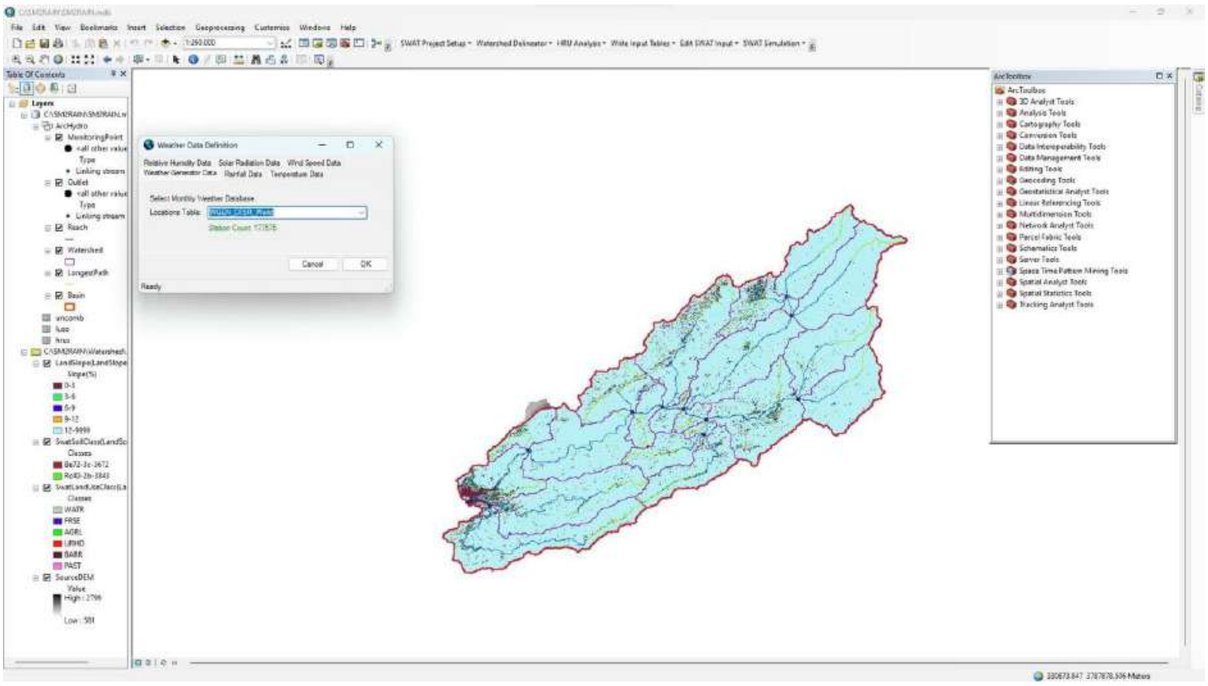


Figure 13 ARCSWAT 6

- **Write Input Tables.**

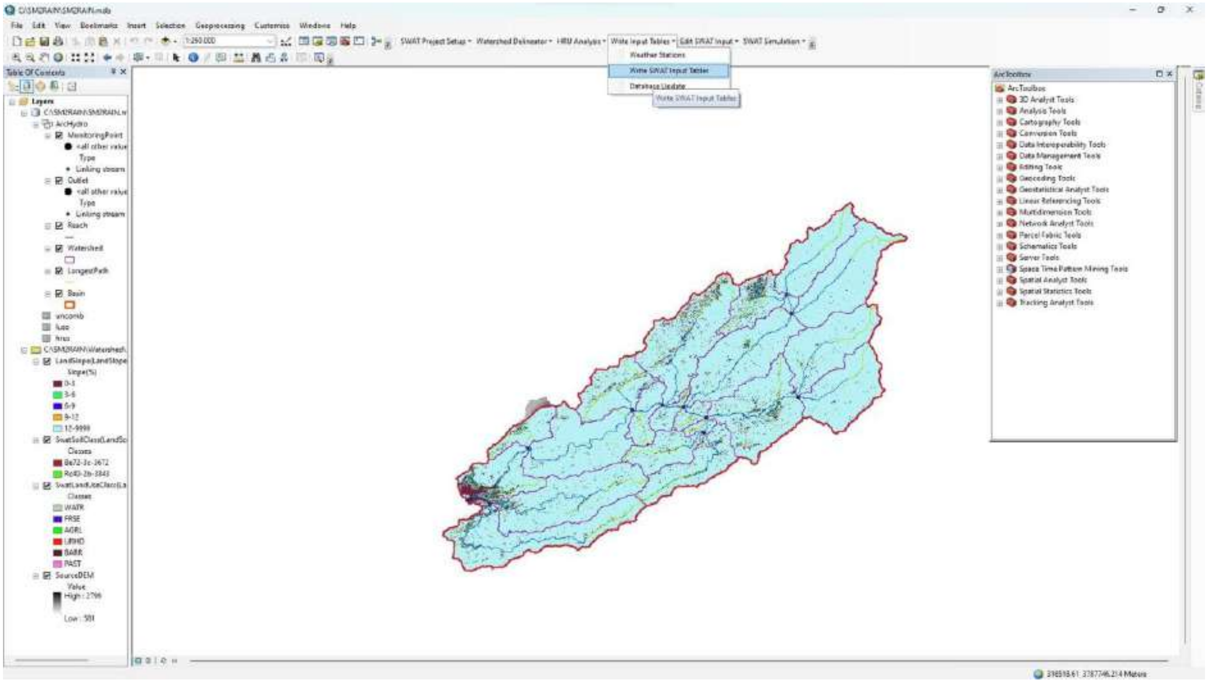


Figure 14 ARCSWAT 7

- **Edit SWAT Input**

Write SWAT database tables.

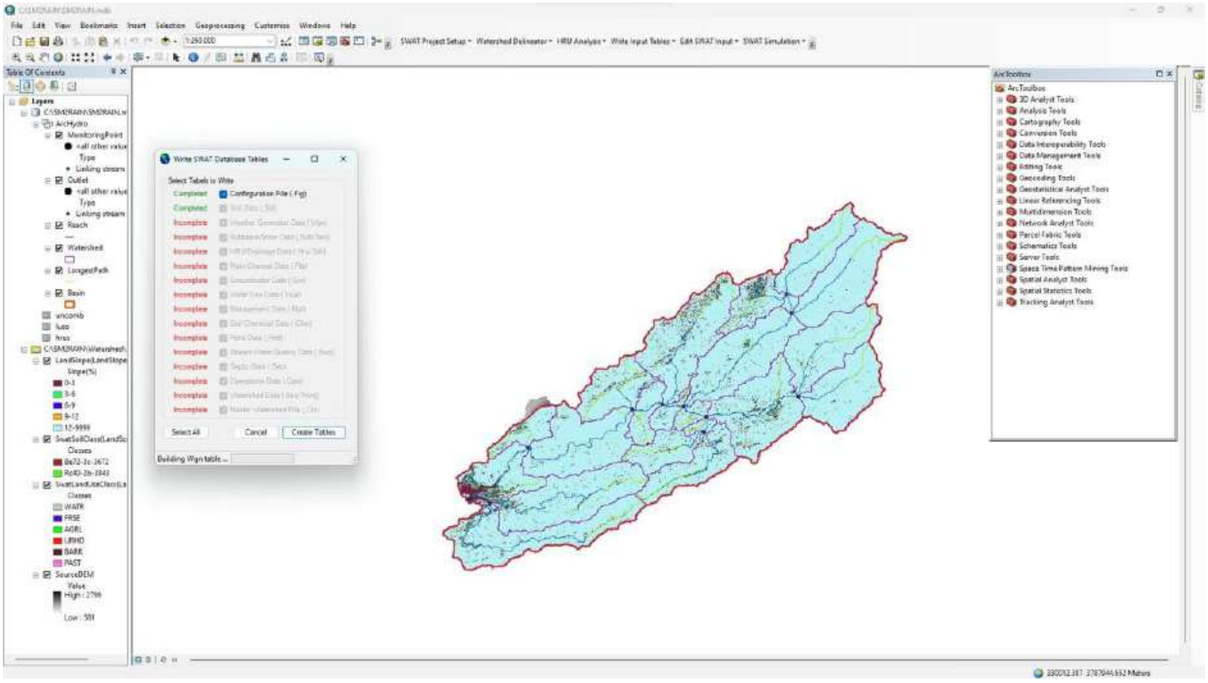


Figure 15 ARCSWAT 8

- **SWAT SIMULATION**

Click Run SWAT.

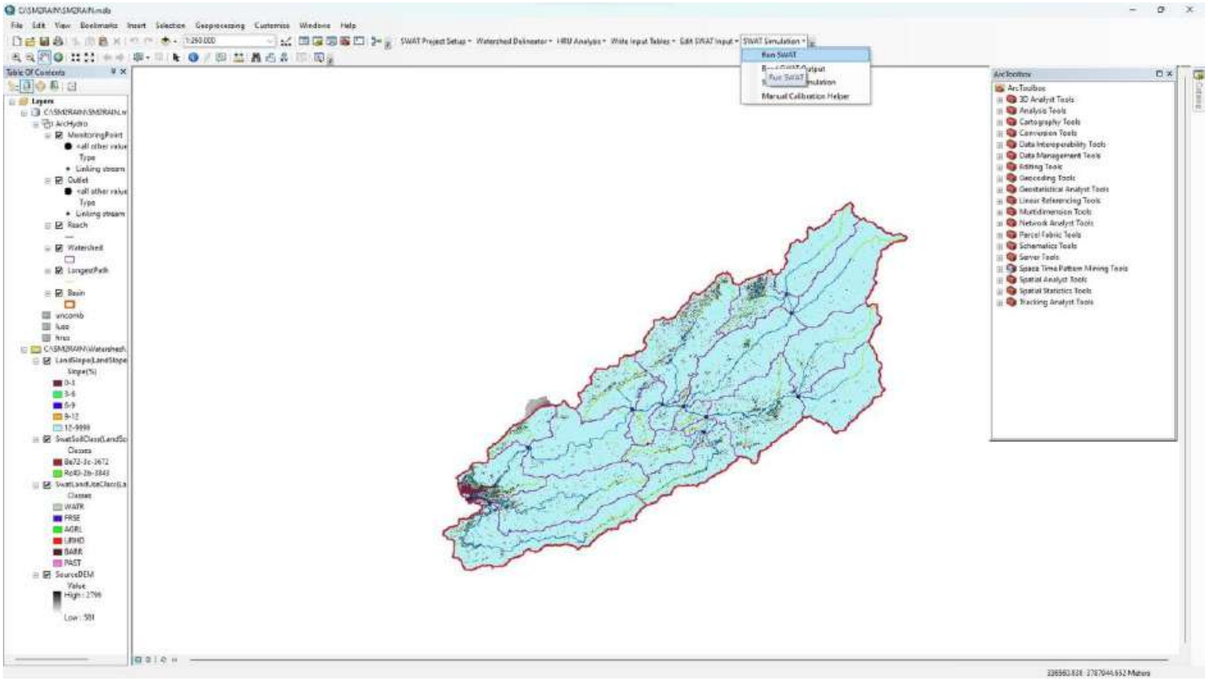


Figure 16 ARCSWAT 9

- Give the SWAT simulation period and click daily.

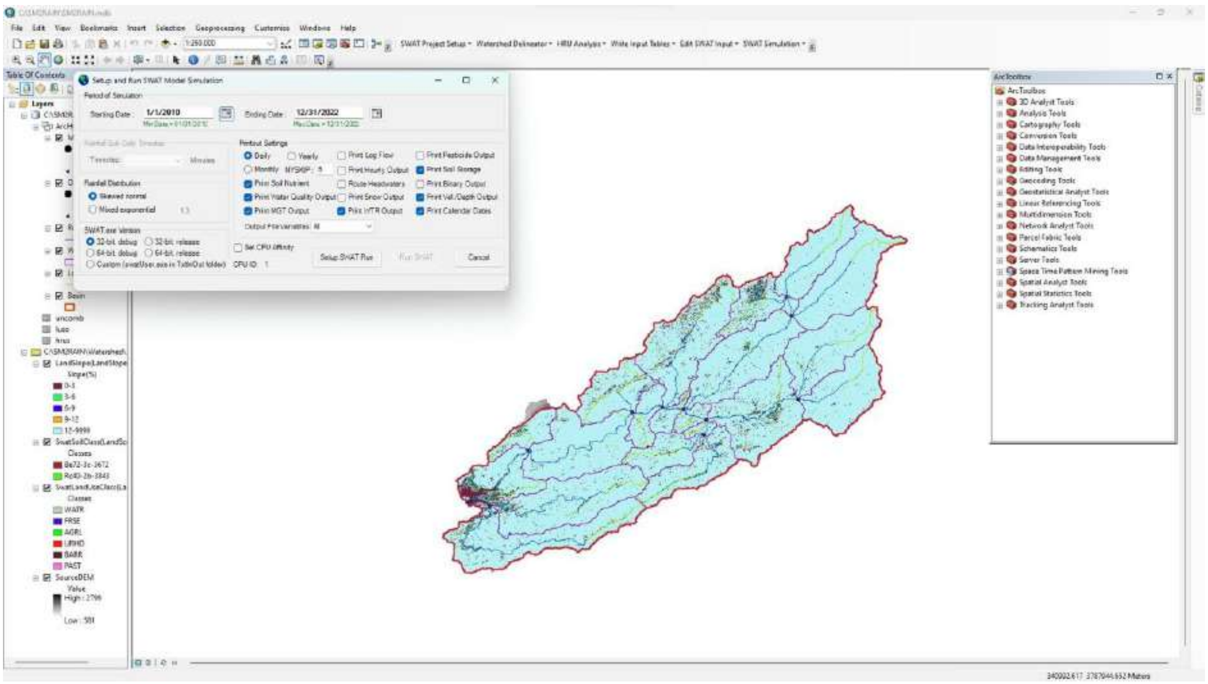


Figure 17 ARCSWAT 9

- Import files to Database.

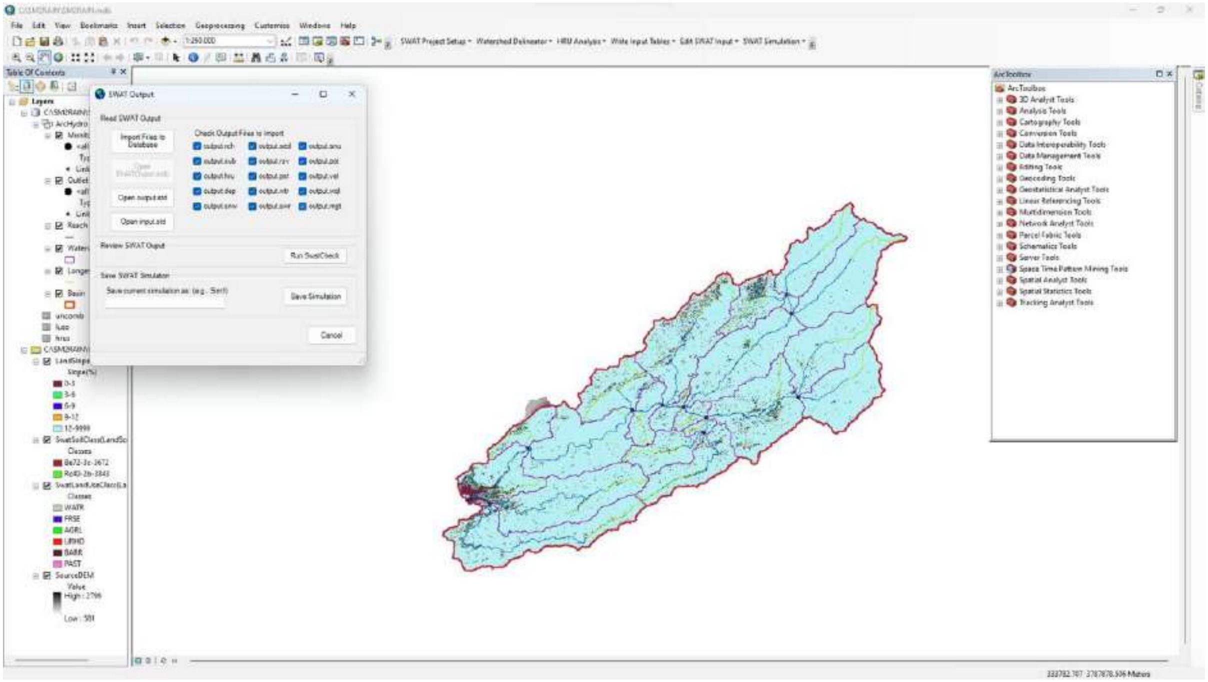


Figure 18 ARCSWAT 10

4.2 SWATCUP Procedure

- Open SWATCUP for calibration and validation. then click NEW.

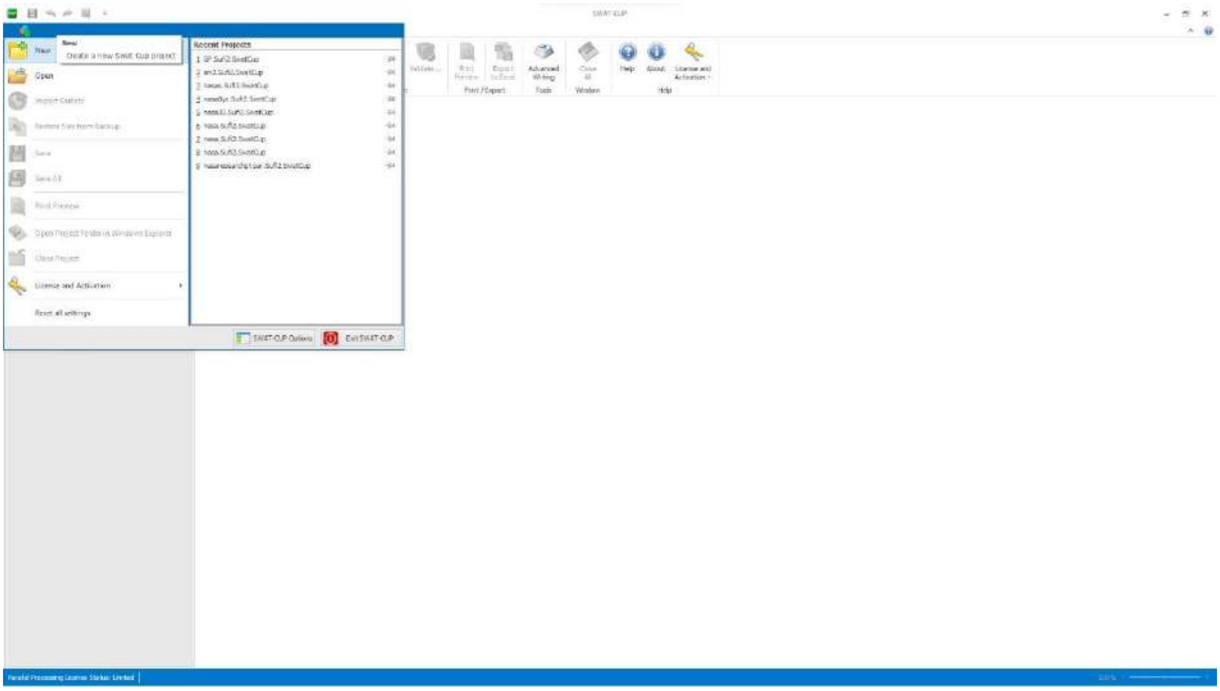


Figure 19 SWAT CUP 1

- Assign swat results file of Particular satellite.

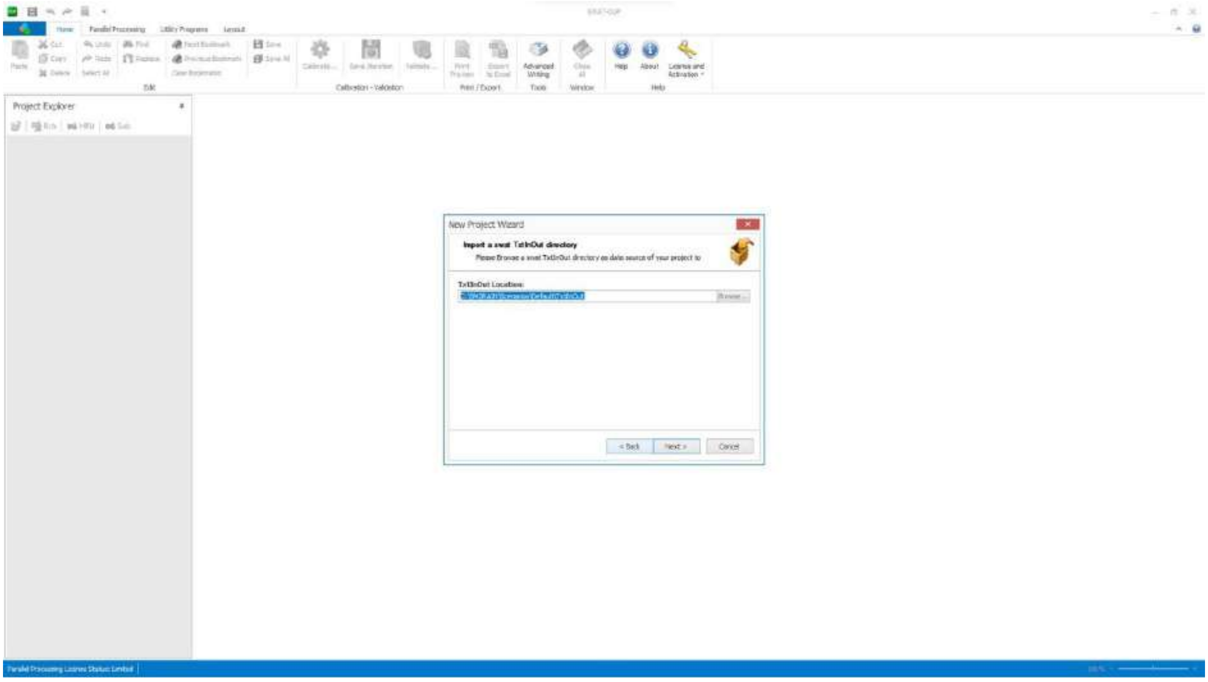


Figure 20 SWATCUP 2

- Select SWAT version and processor Architecture

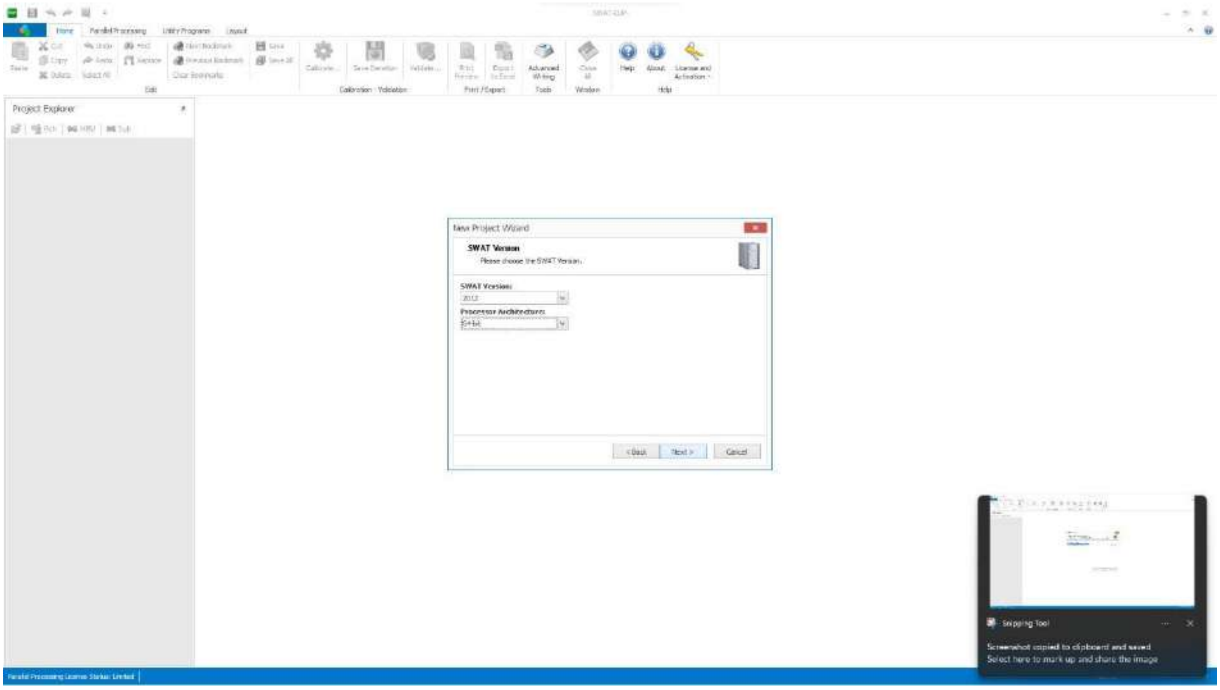


Figure 21 SWATCUP 3

- Sufi-2 method use for calibration and validation which more use in research work.

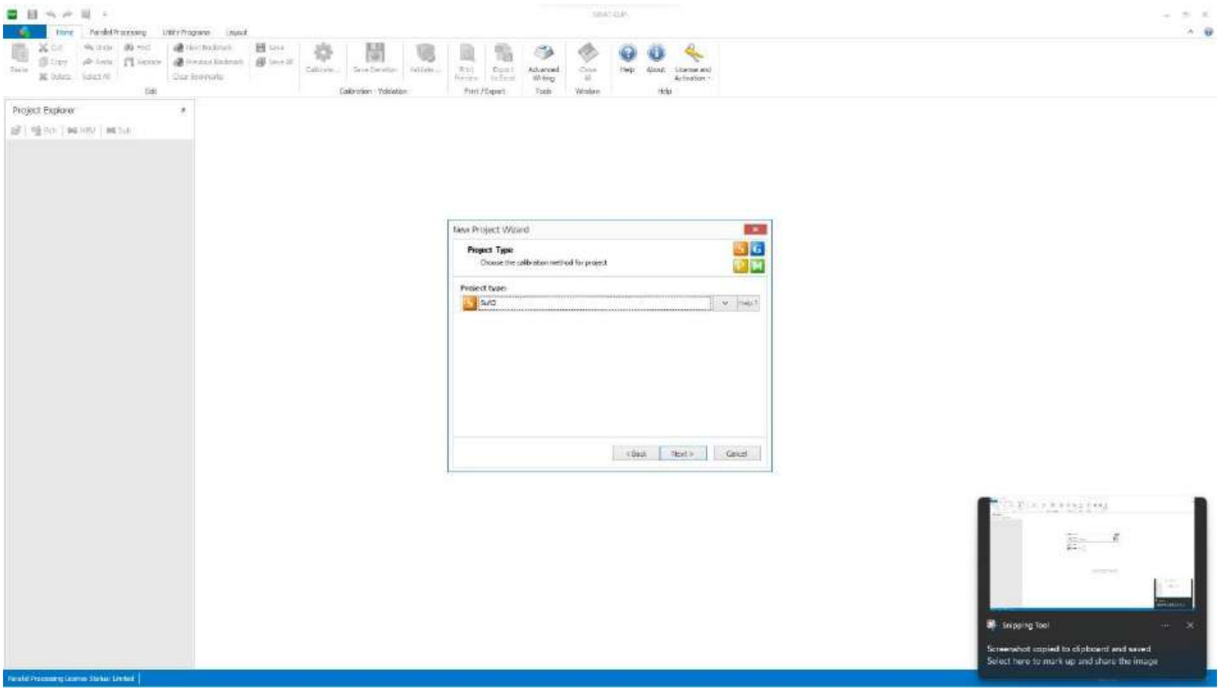


Figure 22 SWATCUP 4

- Give file name and Select location of output file.

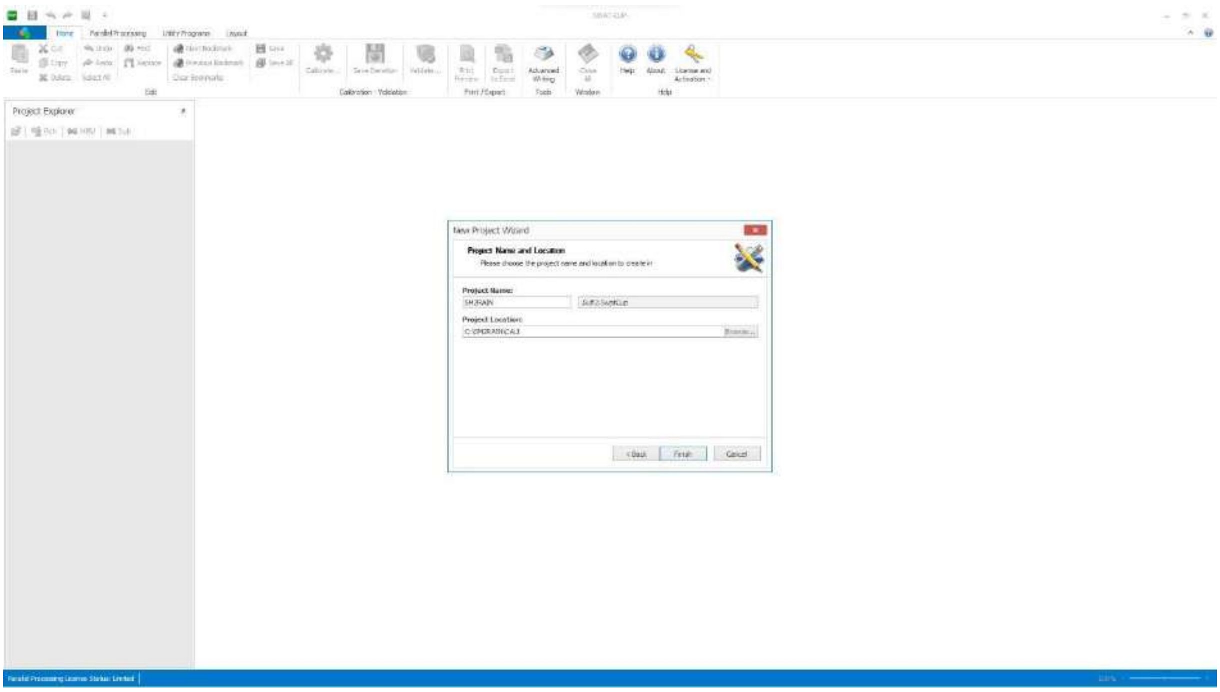


Figure 23 SWATCUP 5

- Then we 14 parameter which we take from research that already [2]. Simulation 500

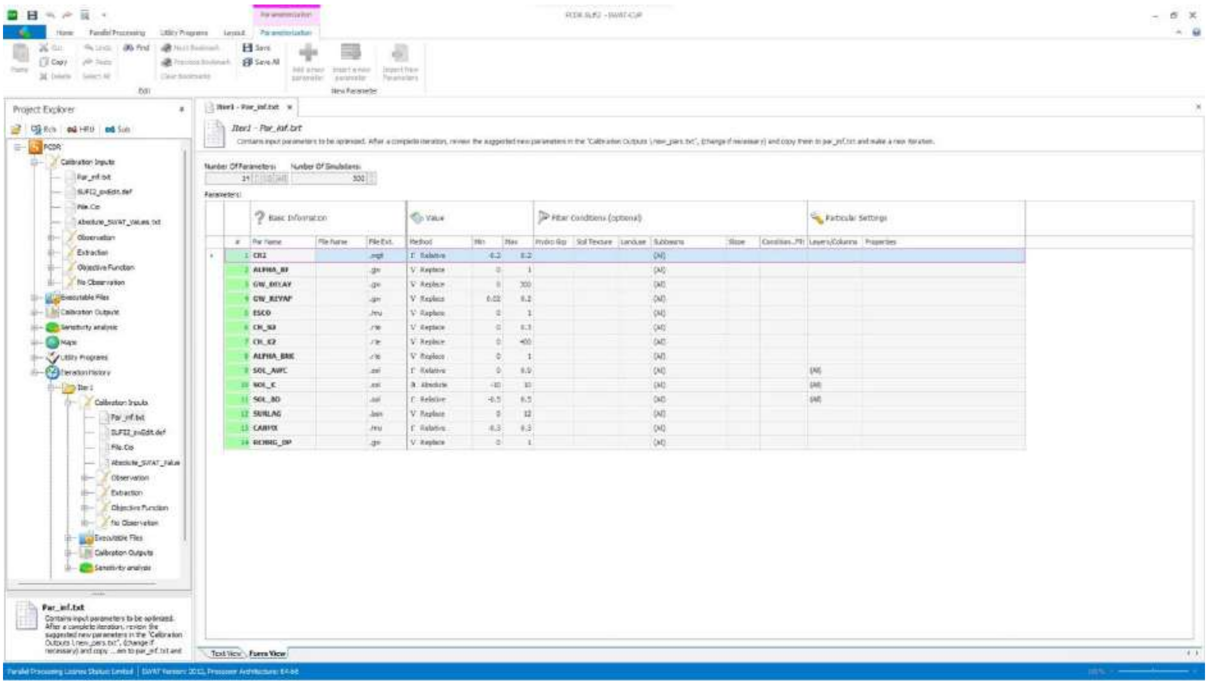


Figure 24 SWATCUP 6

- Match this with our Arc-SWAT when we setup swat

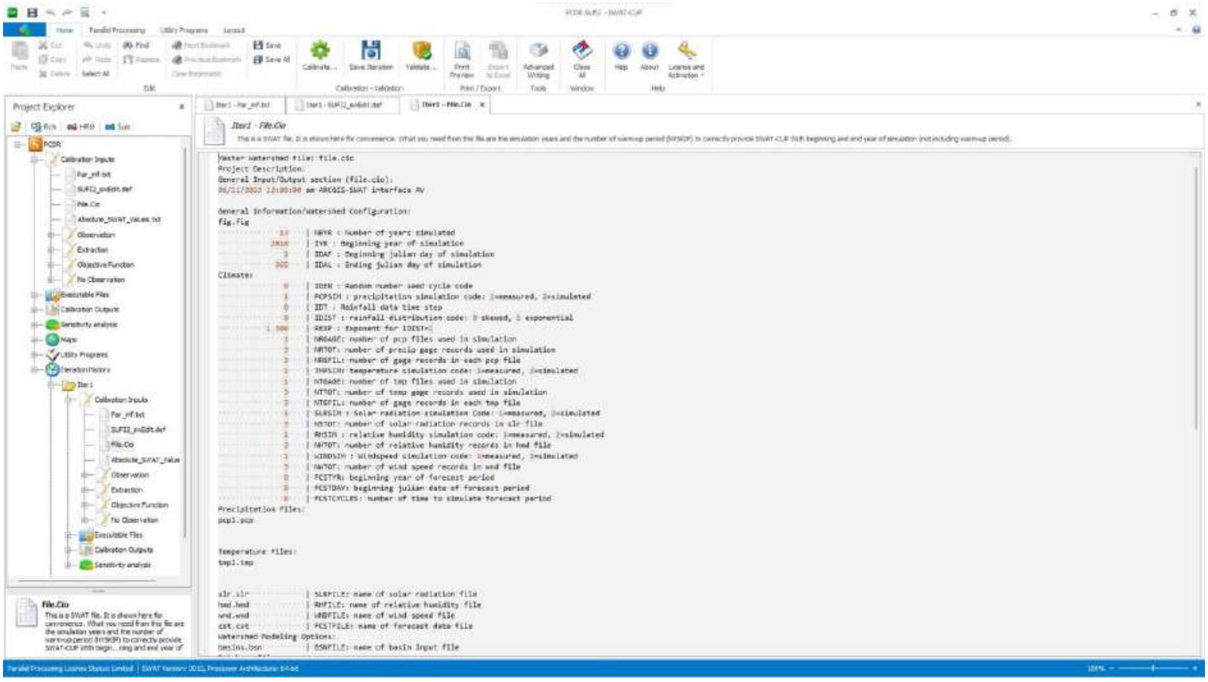


Figure 25 SWATCUP 7

- Then we prepare our observed as "Sr. no, FLOW_OUT_DAY_YEAR" in excel and paste in it.

- Observed variable is 1 because we only calibrate discharge for others variable
- Flow_out_20 is the last outlet no on which the whole catchment discharge in it.
- 1461 is the how much days in calibration

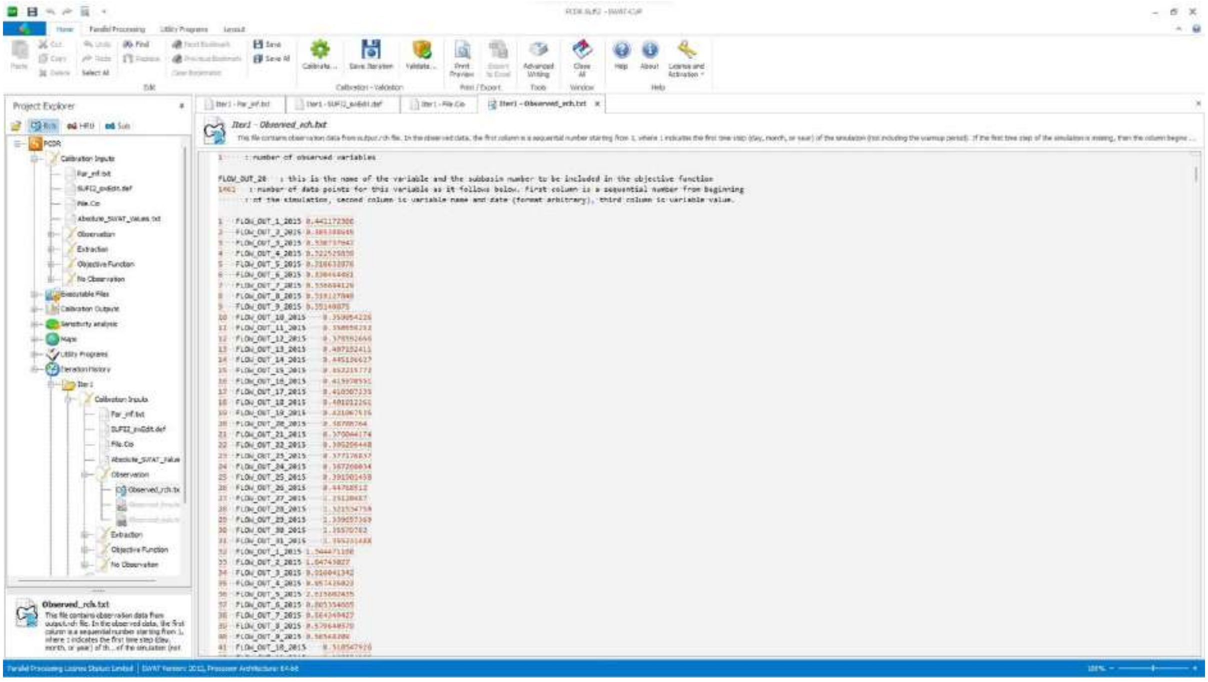


Figure 26 SWATCUP 8

- Then we add watershed properties how many out, which outlet calibrated for variable, no. reach calibrated for variable and for daily temporal scale 1.
- 8 is column in output file

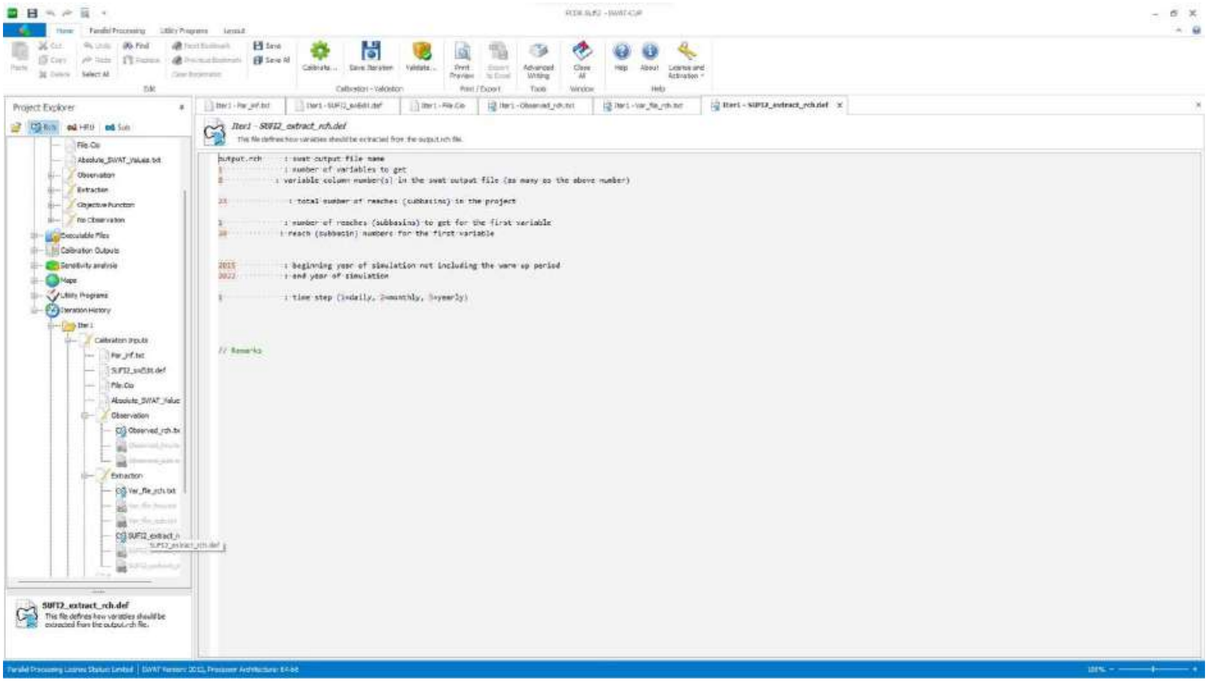


Figure 27 SWATCUP 9

• It is similar to observed.txt.rch but only difference provide minimum threshold of objective function and prefer which objective function.

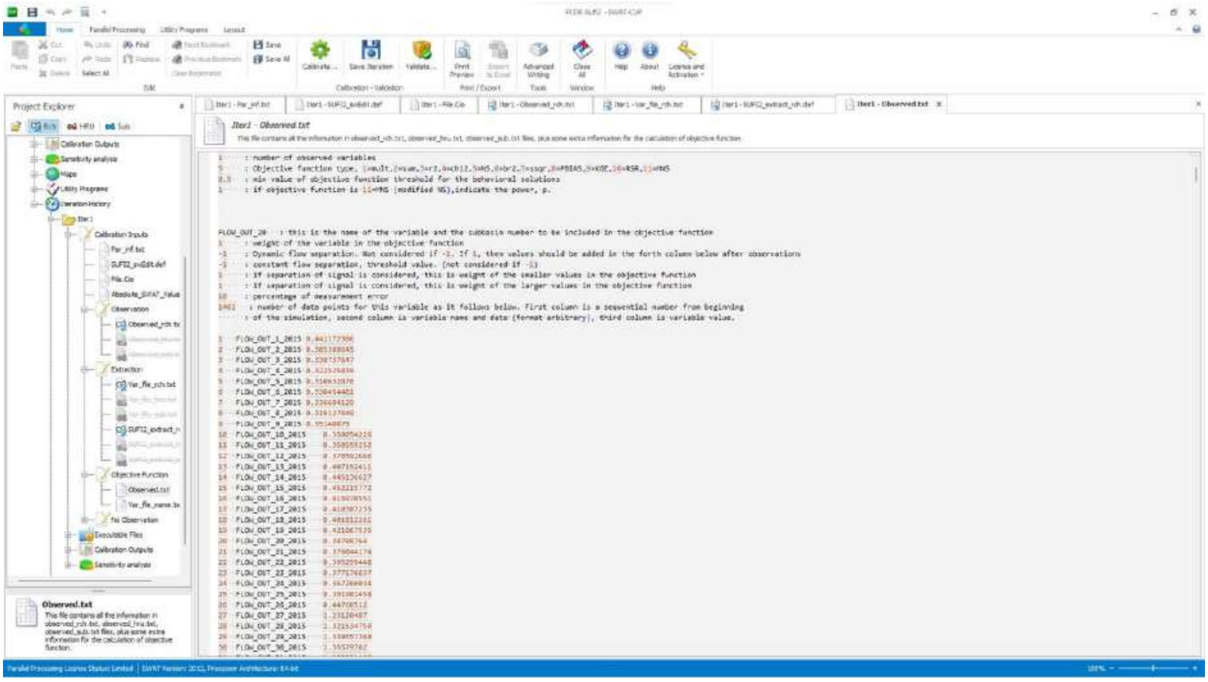


Figure 28 SWATCUP 10

• Flow_Out_20 is Out let No. on which the whole catchment discharge water on it.

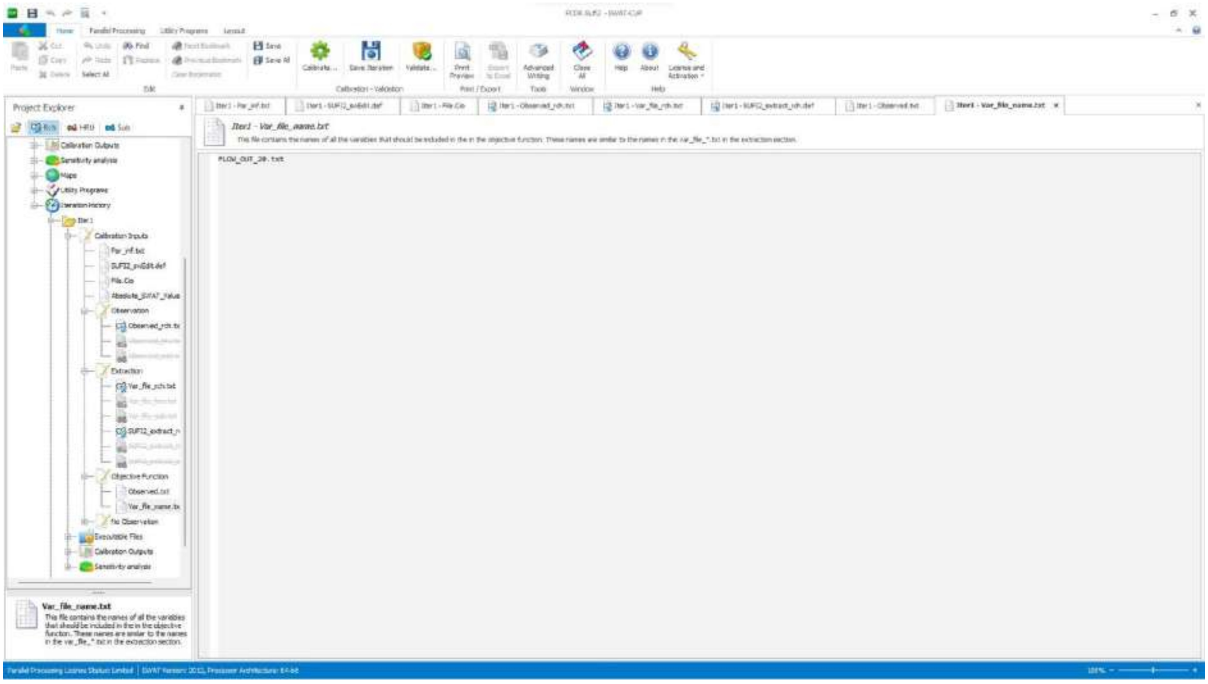


Figure 29 SWATCUP 11

- Outputs of swat cup after calibration 95ppu file.

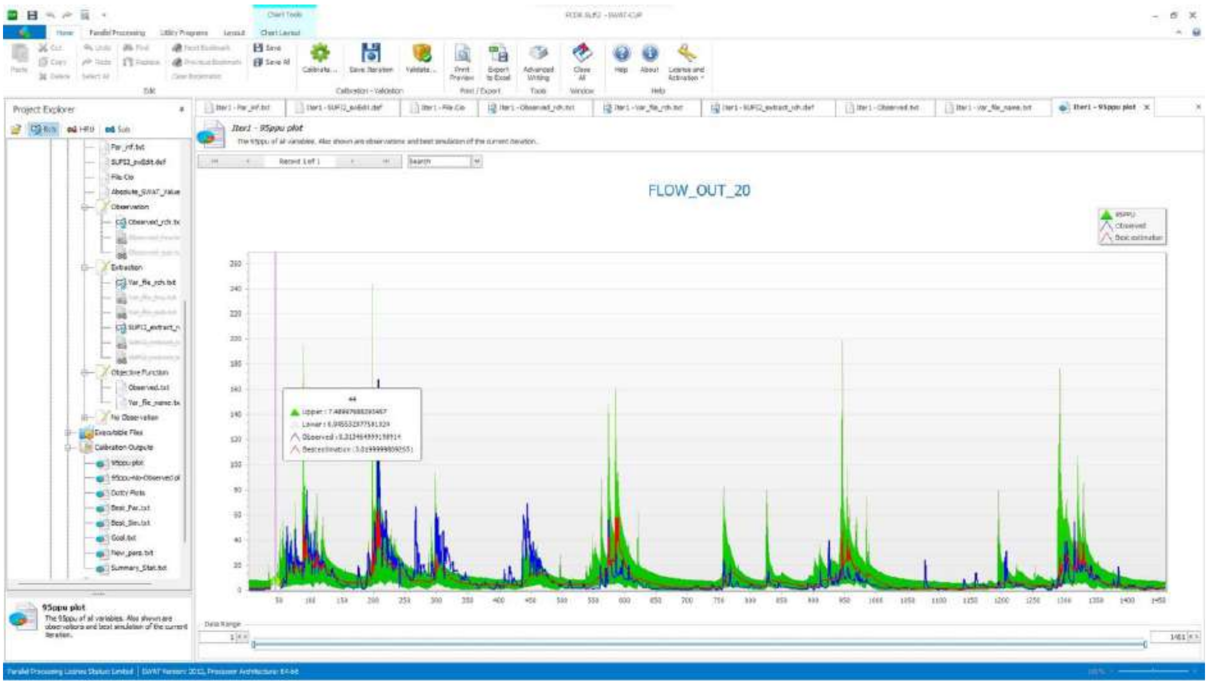


Figure 30 SWATCUP 12

- Best simulation result

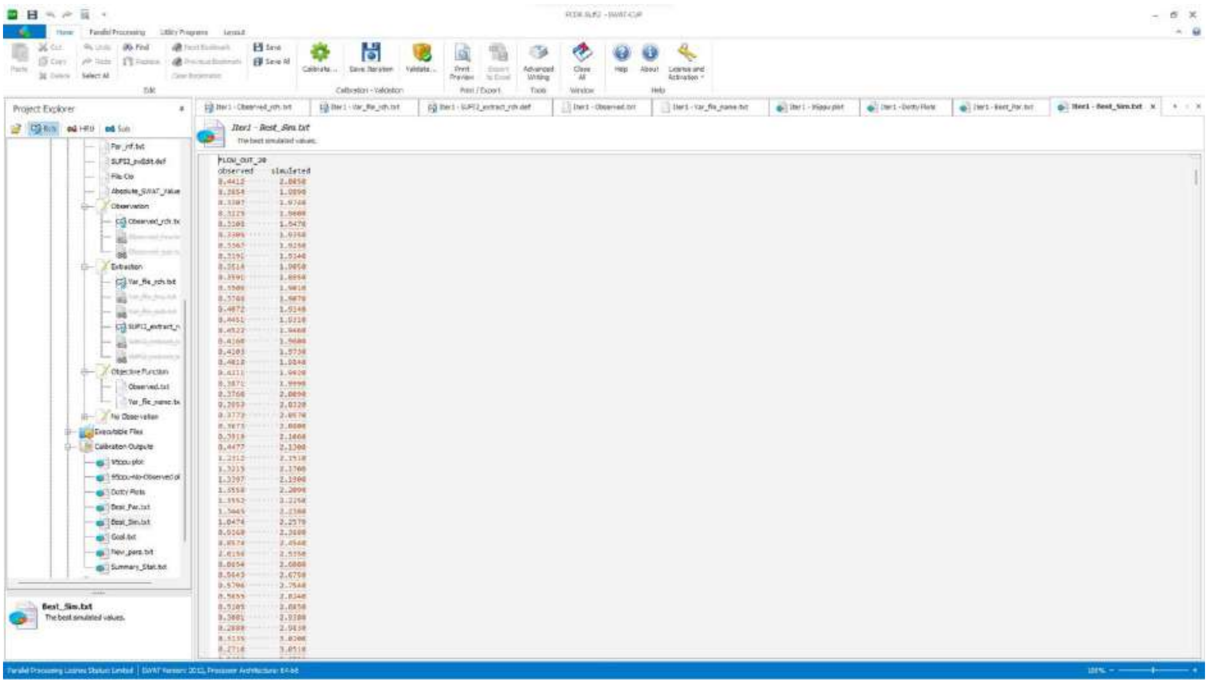


Figure 31 SWATCUP 13

- Statically parameter result by SWAT-CUP

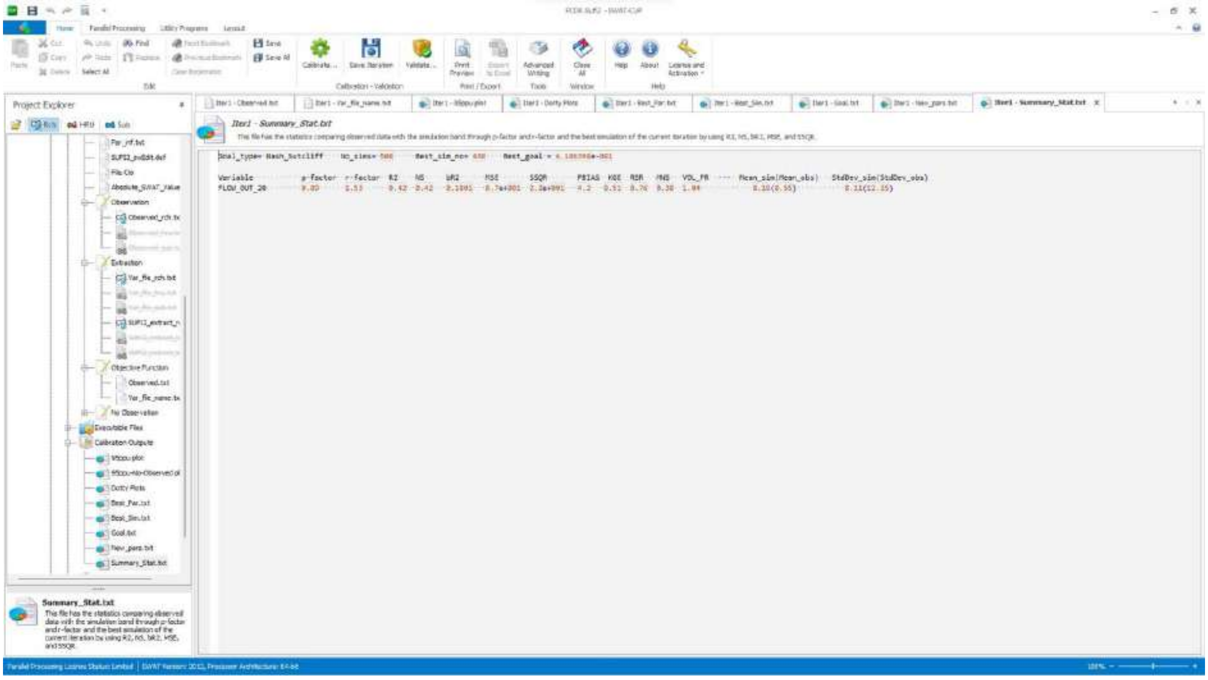


Figure 32 SWATCUP 14

Chapter :5

Results and Discussion

In our research there are the following objects

iv. To simulate the daily run-off by using Arc-Swat model by using satellite-based precipitation products (SBPP’s) and also ground precipitation data.
v. Comparing the satellite precipitation data with ground precipitation data.
vi. Comparing the observed run-off data with simulated Arc-Swat Data determine the Accuracy of satellite-based precipitation products (SBPP’s).

in this research we run Arc-swat for following five precipitation data

i. Ground precipitation data
ii. SM2RAIN
iii. NASA (MEERA-2)
iv. PERSIANN
v. PERSIANN-CDR

And following statically methods for stream flow simulation.

i. R^2

ii. NS
iii. PBIAS
iv. KGE
v. SSQR
vi. RSR

For precipitation comparison i.e. for objective no. 2 only on the bases of R^2.

Statically parameter ranges and indication are given below table

Figure 33 RANGES

Representation	Stand for	Ranges	Indication
R2	Coefficient of Determination	0 to 1	Higher values indicate better model fit
NS	Nash-Sutcliffe Efficiency	-∞ to 1	Higher values indicate better model fit
KGE	Kling-Gupta Efficiency	-∞ to ∞	KGE<0 Poor performance, KGE>0 well performance, KGE=1 perfect match
SSQR	Sum of Squared Residuals	0 to ∞	Lower values indicate better model fit
RSR	Relative Squared Residual	0 to ∞	Lower values indicate better model fit
PBIAS	Percent Bias (%)	-100 to 100	Lower values indicate overestimate and Higher values indicate under estimate

Table 4 Statically parameter Indication

SM2RAIN precipitation R^2 Graphs

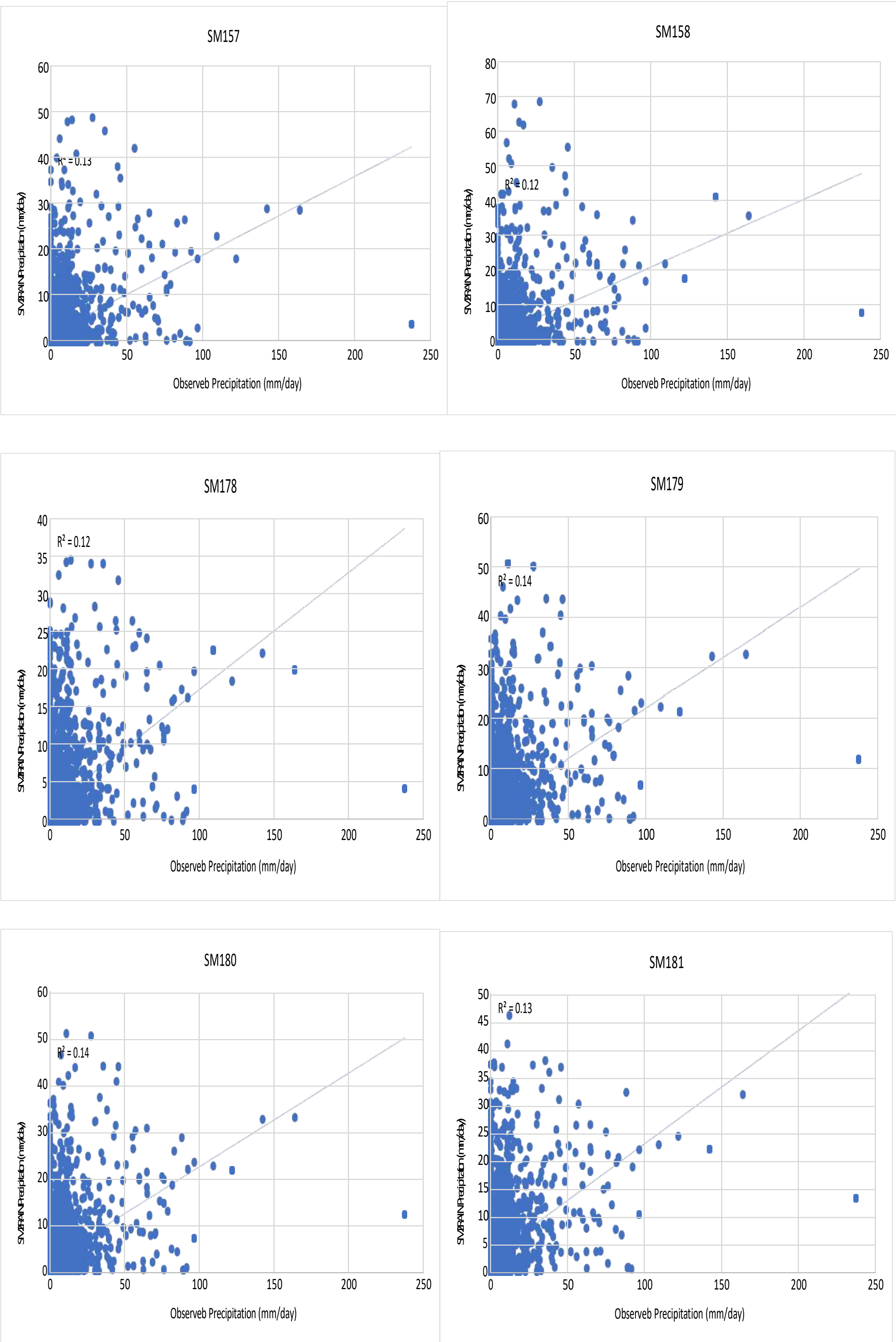
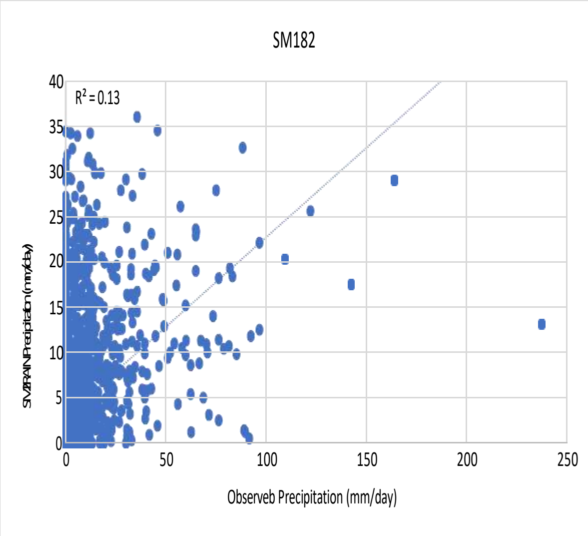
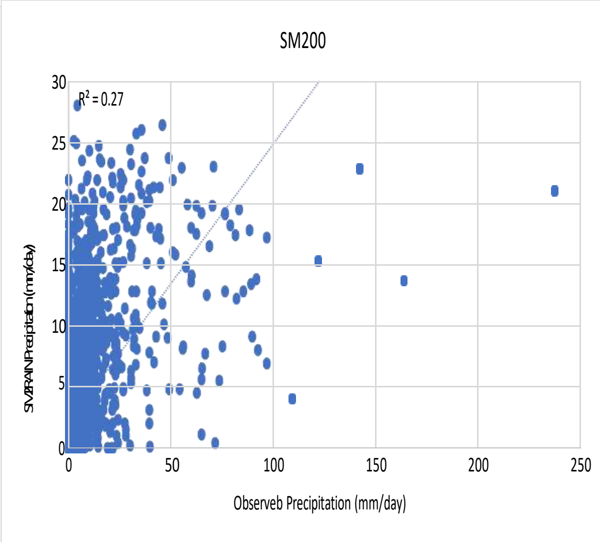
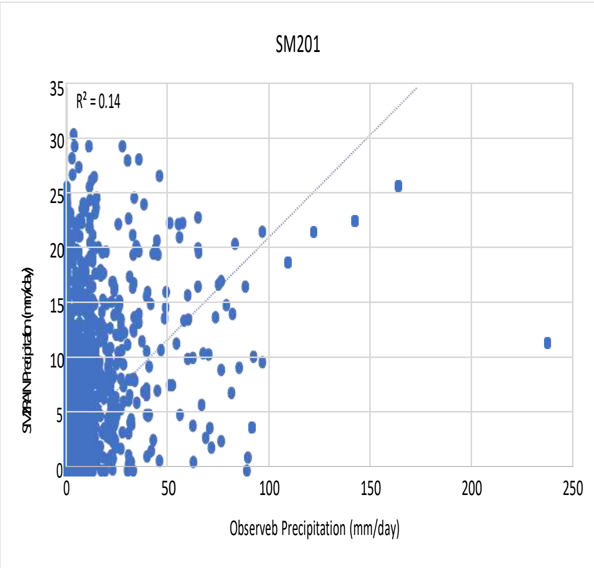


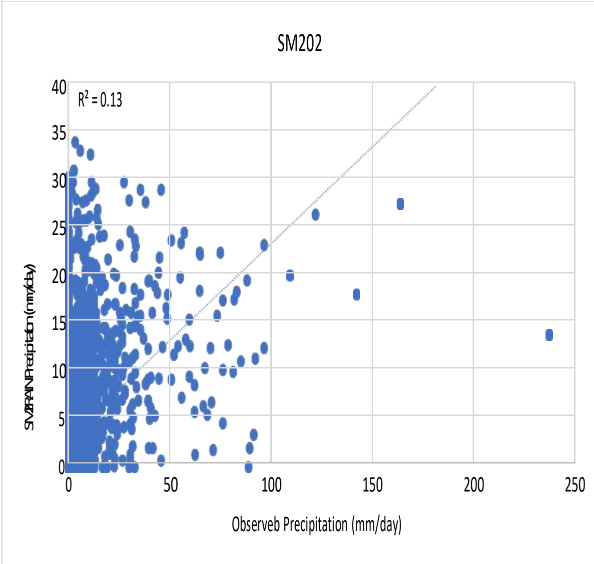
Figure 34 SM2RAIN GRAPHS 1

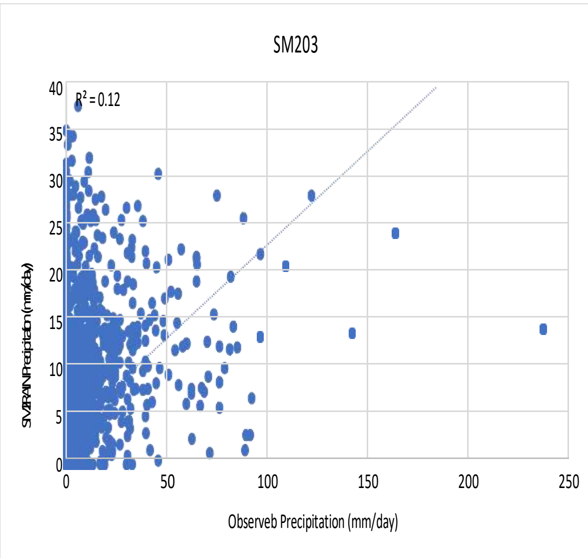
SM2RAIN precipitation R^2 Graphs (continue)











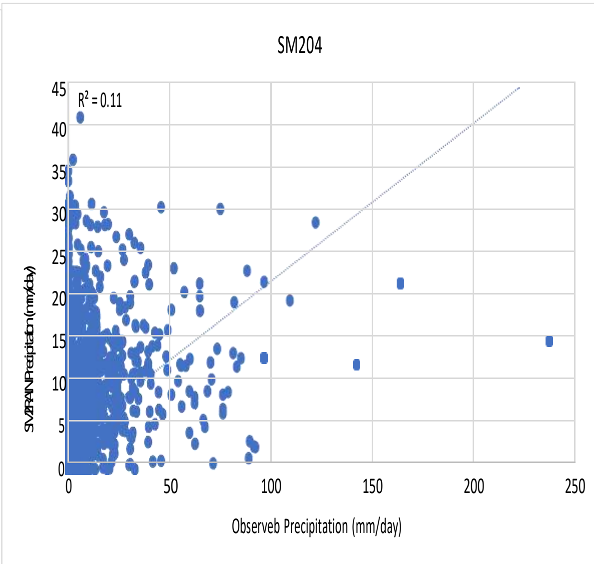


Figure 35 SM2RAIN GRAPH 2

SM2RAIN precipitation R^2 Graphs (continue)

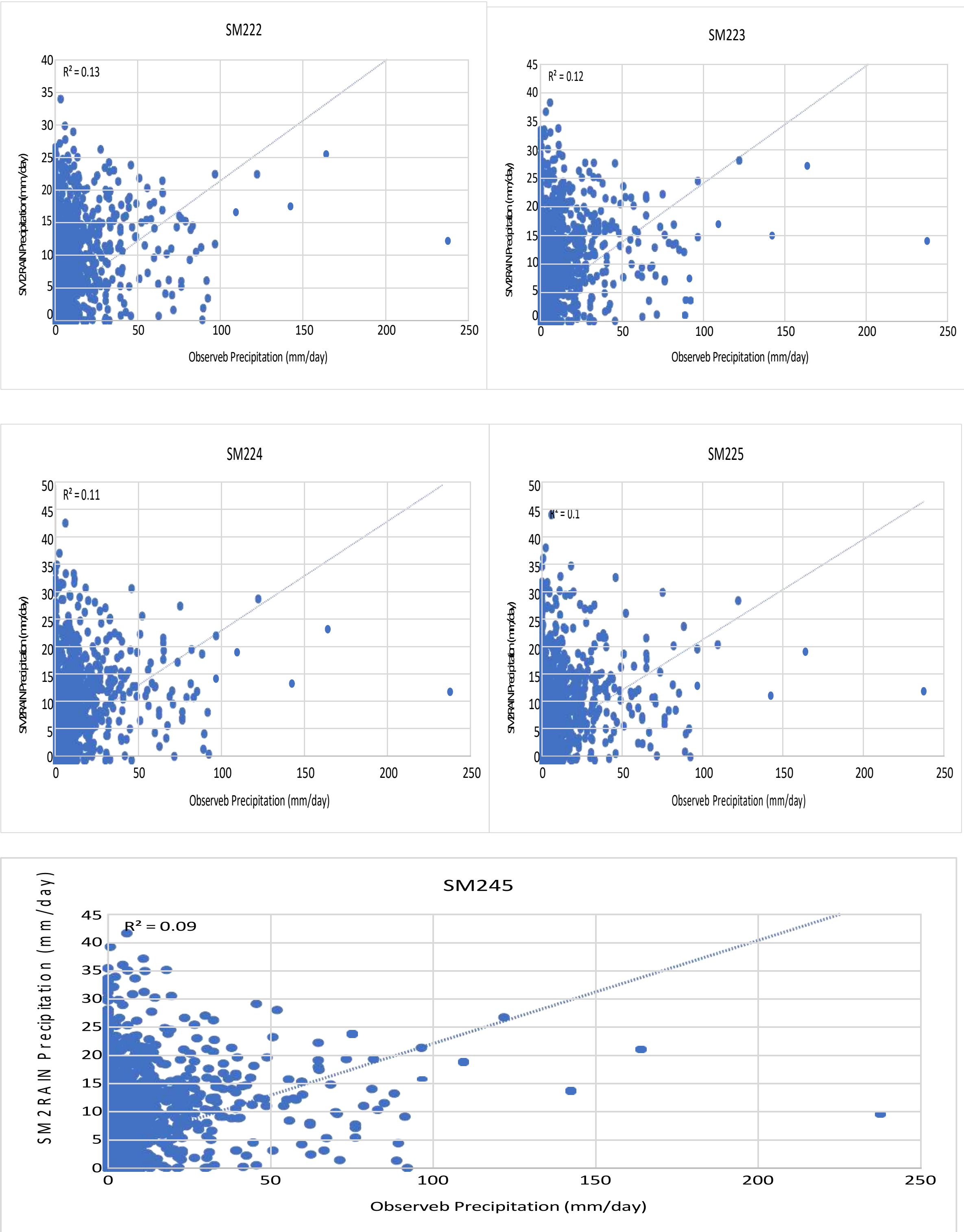
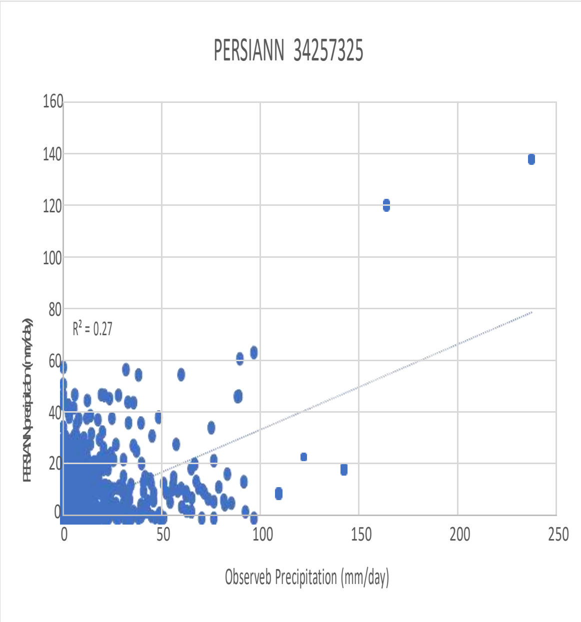
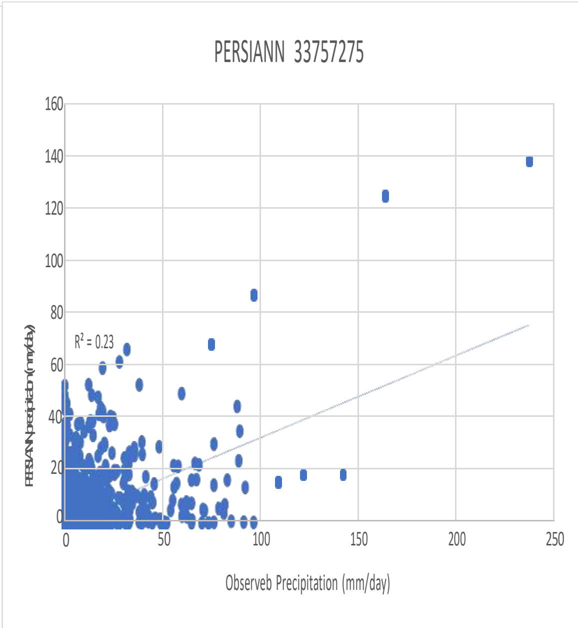


Figure 36 SM2RAIN GRAPHS 3

By comparing the precipitation data SM2RAIN with ground precipitation data on the bases of R^2 we see that the SM2RAIN overestimate the precipitation because the vertically disperse i.e. SM2RAIN data shows precipitation values when there no observed ground values. There are 17 SM2RAIN gauges cover our catchment area as show in figure and all gauges R^2 graph are also shown above. We see that the value of R^2 ranges from 0.09 to 0.27.

PERSIANN precipitation R^2 Graphs





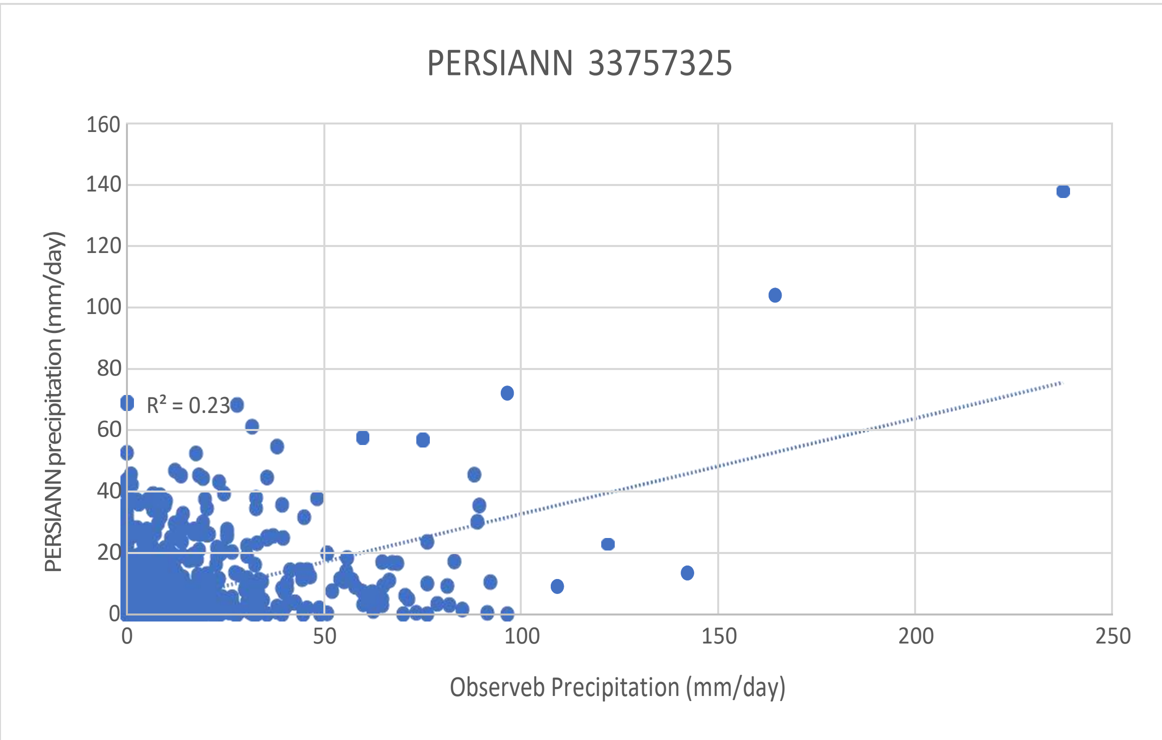


Figure 37 PERSIAN GRAPH 1

There are 3 PERSIAN gauges cover our catchment area as show in figure and all gauges R^2 graph are also shown. We see that the value of R^2 ranges from 0.2276 to 0.2692. By comparing the precipitation data PERSIANN with ground precipitation data on the bases of

R^2 we see that the one PERSIANN 33757325 Gauge underestimate the precipitation and because the horizontally disperse i.e. PERSIANN data shows precipitation values when there observed ground values and other two are vertically dispersed and also horizontally disperse i.e. when observed data shows high precipitation but PERSIANN shows less precipitation and vice versa.

NASA (MEERA-2) precipitation R^2 Graphs

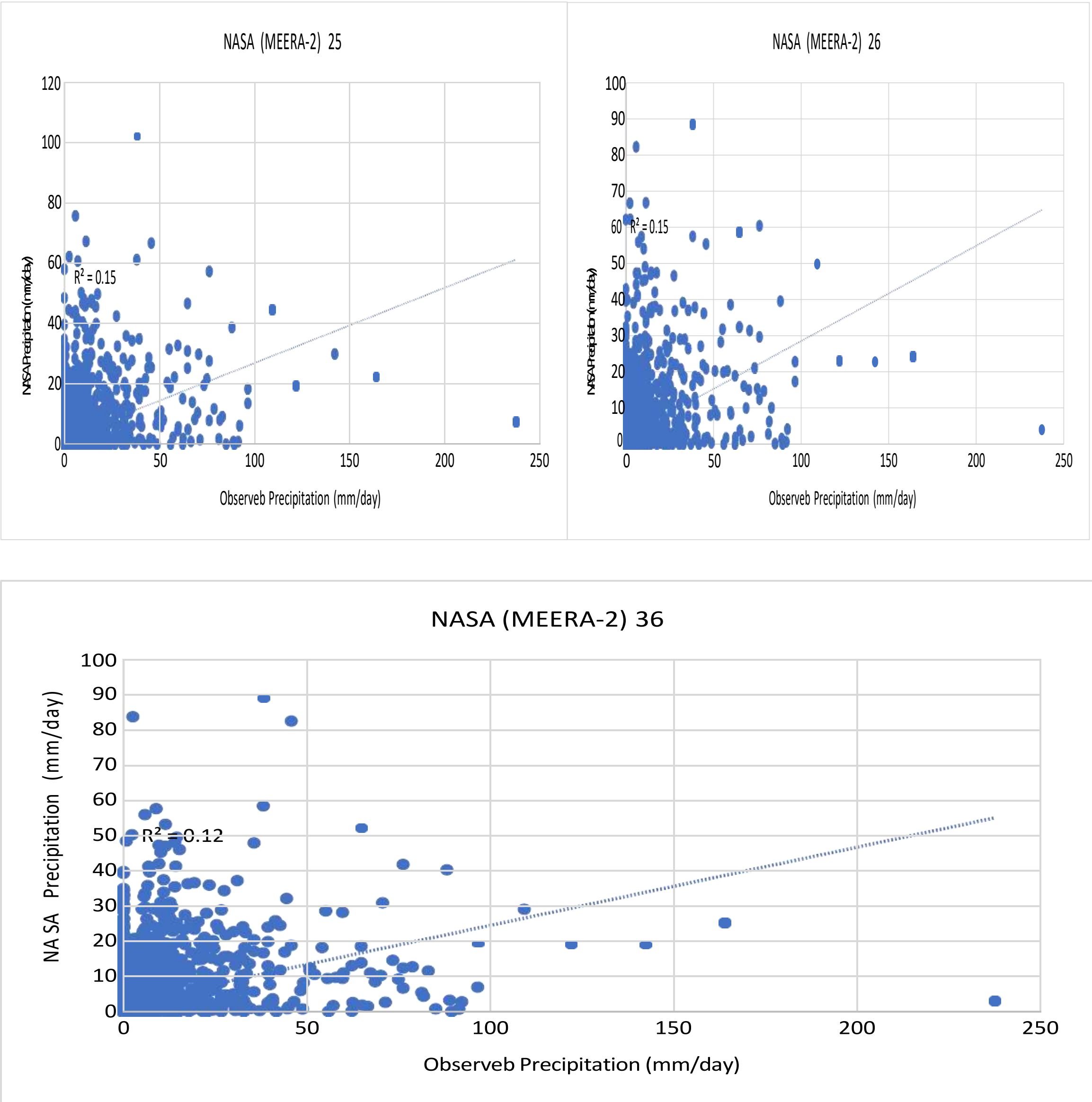
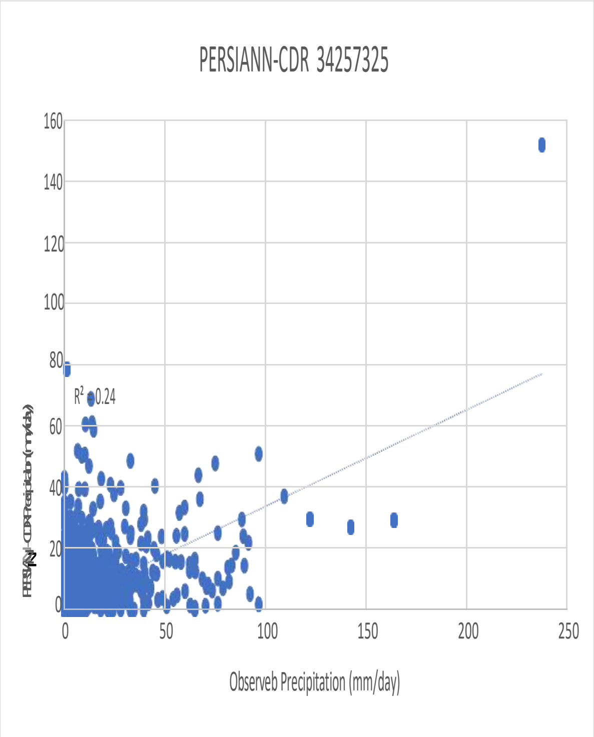
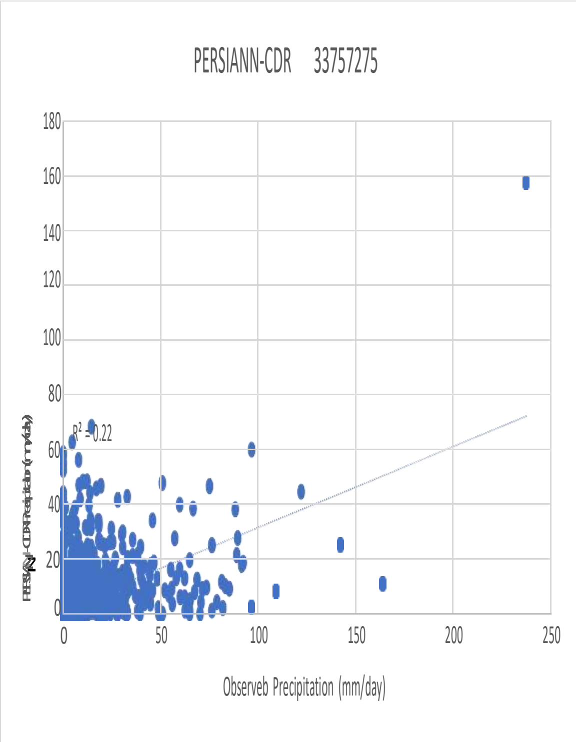


Figure 38 MEERA-2 GRAPHS 1

By comparing the precipitation data NASA (MEERA-2) with ground precipitation data on the bases of R^2 we see that the NASA (MEERA-2) overestimate the precipitation because the vertically disperse i.e. NASA (MEERA-2) data shows precipitation values when there no observed ground values and in NASA (MEERA-2) heavy outlier are present in this after 2018. There are 3 NASA (MEERA-2) gauges cover our catchment area as show in figure and all gauges R^2 graph are also shown. We see that the value of R^2 ranges from 0.1206 to 0.1499.

PERSIANN-CDR precipitation R^2 Graphs





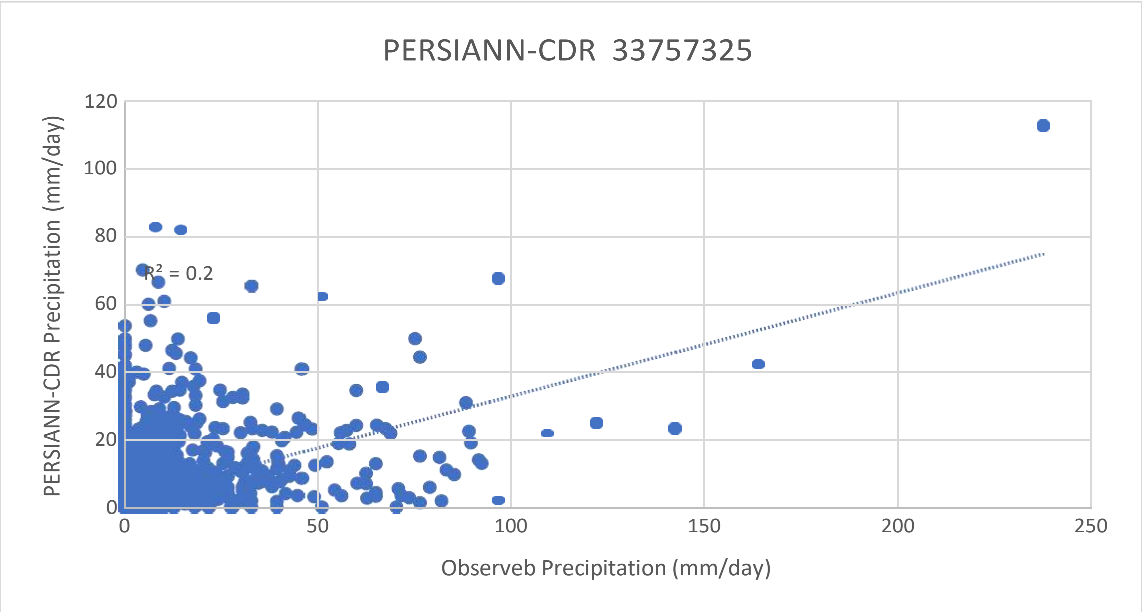


Figure 39 PERSIAN-CDR GRAPHS 1

There are 3 PERSIAN-CDR gauges cover our catchment area as show in figure and all gauges R^2 graph are also shown. We see that the value of R^2 ranges from 0.1997 to 0.2425. By comparing the precipitation data PERSIAN-CDR with ground precipitation data on the bases of R^2 we see that the two PERSIAN-CDR Gauge underestimate the precipitation and because the vertically disperse i.e. PERSIAN-CDR data shows precipitation values when there no observed ground values and one is vertically disperse and also horizontally disperse i.e. when observed data shows high precipitation but PERSIAN-CDR shows less precipitation and vice versa.

Hydrographs of Gauge Data

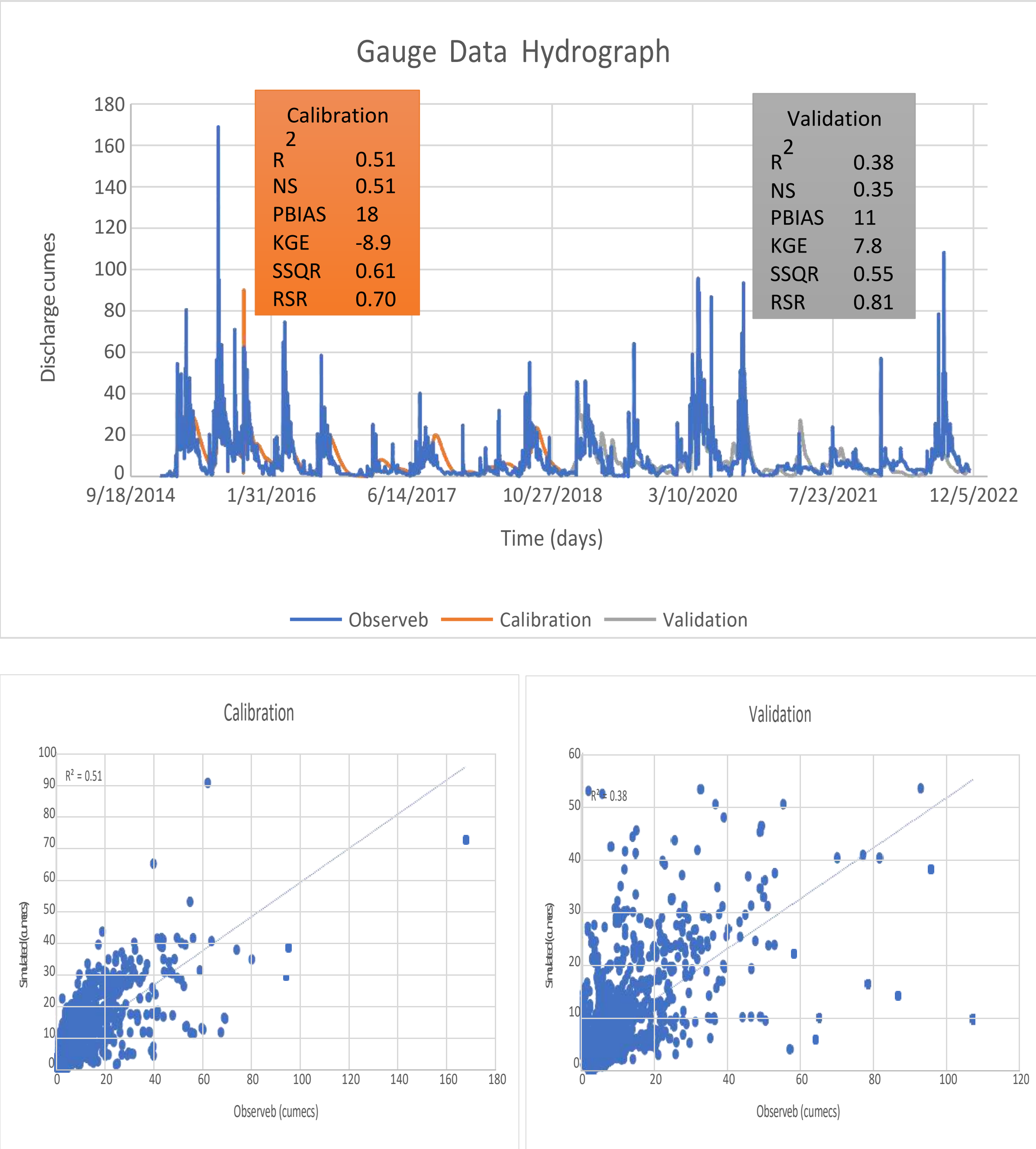


Figure 40 RESULTS 1

While comparing the run-off data by using Ground precipitation with observed ground data the values of statically parameters in calibration period 0.51, 0.51, 18, -8.9, 0.61, 0.70 in validation period 0.38, 0.35, 18, -5.6, 0.57, 0.72 of R^2, NS, PBIAS, KGE, SSQR, RSR respectively.

In calibration period model perofmance is well as we see in R^2 graph the discharge value are near to trend line with some outliers but in validation period not performe very well as compare to calibration there are heavy outlier and little overestimate the discharge values.

Hydrograph of SM2RAIN

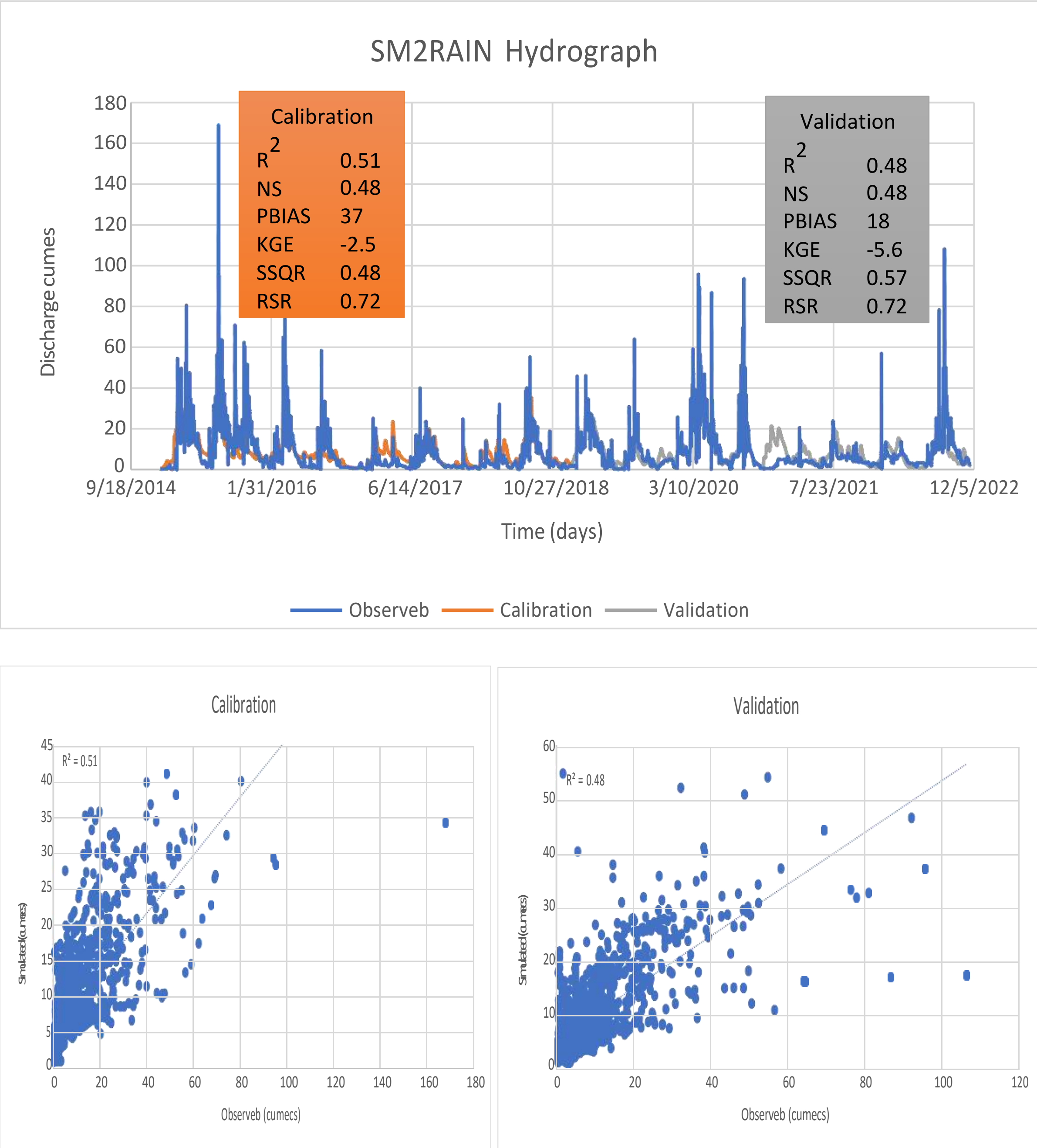


Figure 41 RESULTS 2

While comparing the SM2RAIN run-off data with observed ground data the values of statically parameters in calibration period 0.51, 0.48, 37, -2.7, 0.48, 0.72 in validation period 0.48, 0.48, 18, -5.6, 0.57, 0.72 of R^2, NS, PBIAS, KGE, SSQR, RSR respectively.

In calibration period model perofmance is well as we see in R^2 graph the discharge value are uniformaly distributed above and belove the trend line with only one outliers but in validation period not performe very well as compare to calibration there are heavy outlier but these are also uniformaly distributed above and belove the treand line and little overestimate the discharge values.

Hydrograph of PERSIANN

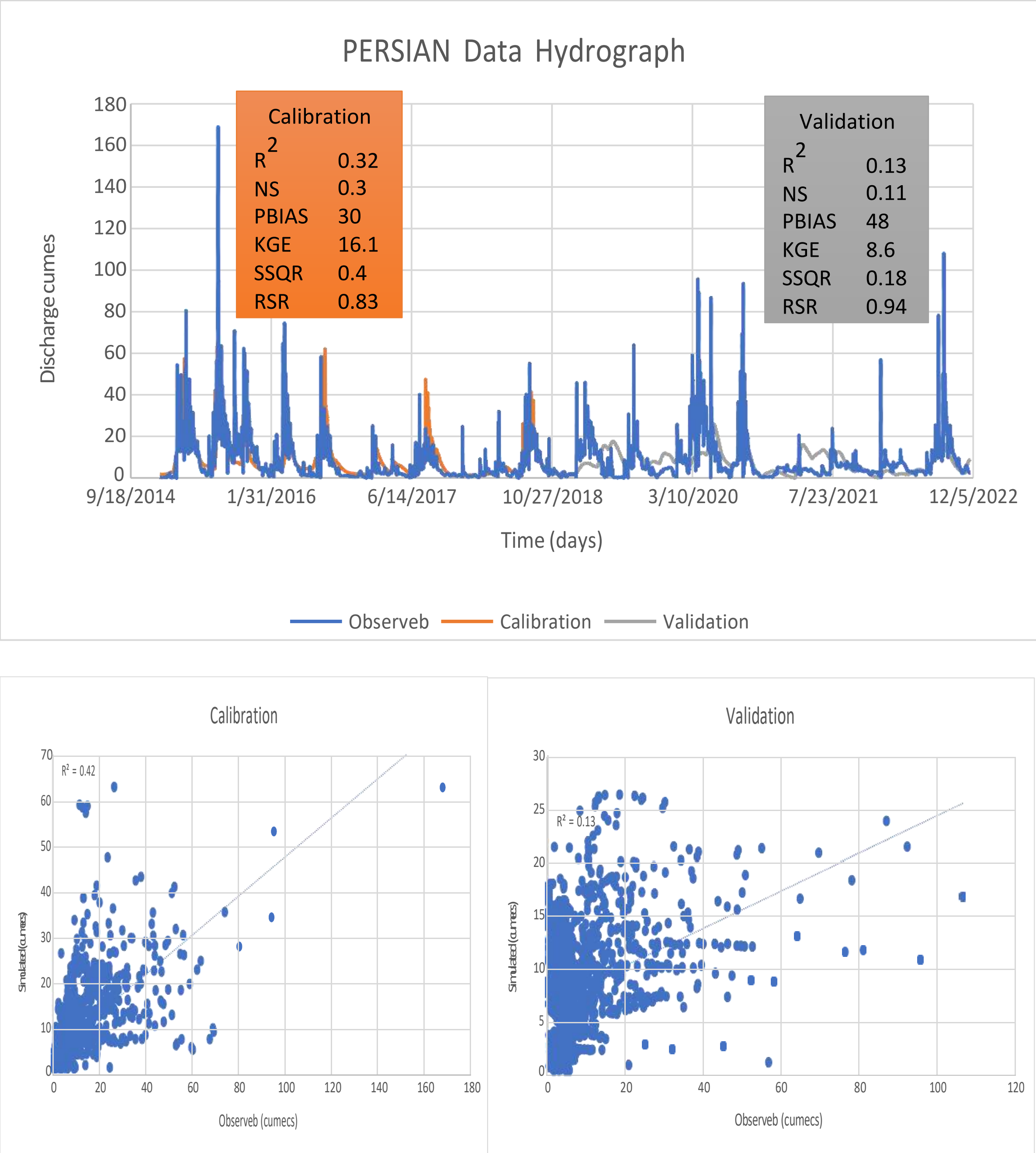


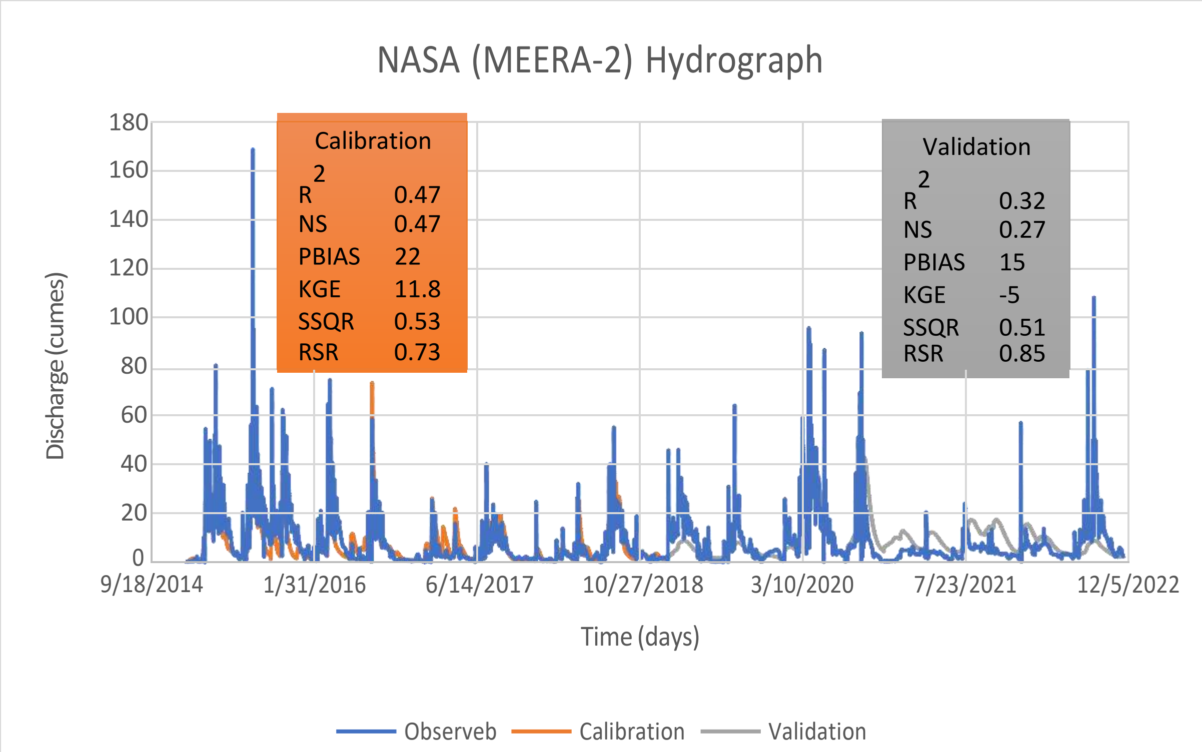
Figure 42 RESULTS 3

While comparing the PERSIANN run-off data with observed ground data the values of statically parameters in calibration period 0.32, 0.30, 30, 16.1, 0.40, 0.83 in validation period 0.13, 0.11, 48, 8.6, 0.18, 0.94 of R^2, NS, PBIAS, KGE, SSQR, RSR respectively.

In calibration period model perofmance is well as we see in R^2 graph the discharge value are near to trend line with some outliers but in validation period show poor performance as compare to calibration there are heavy outlier and overestimate the discharge values i.e. show discharge when there in no ground dicharge values.

As we see PERSIANN hydrograph in calibration it acheved the peak but in validation it not achieved the peak values and it show totally different pattren.

Hydrograph of NASA (MEERA-2)



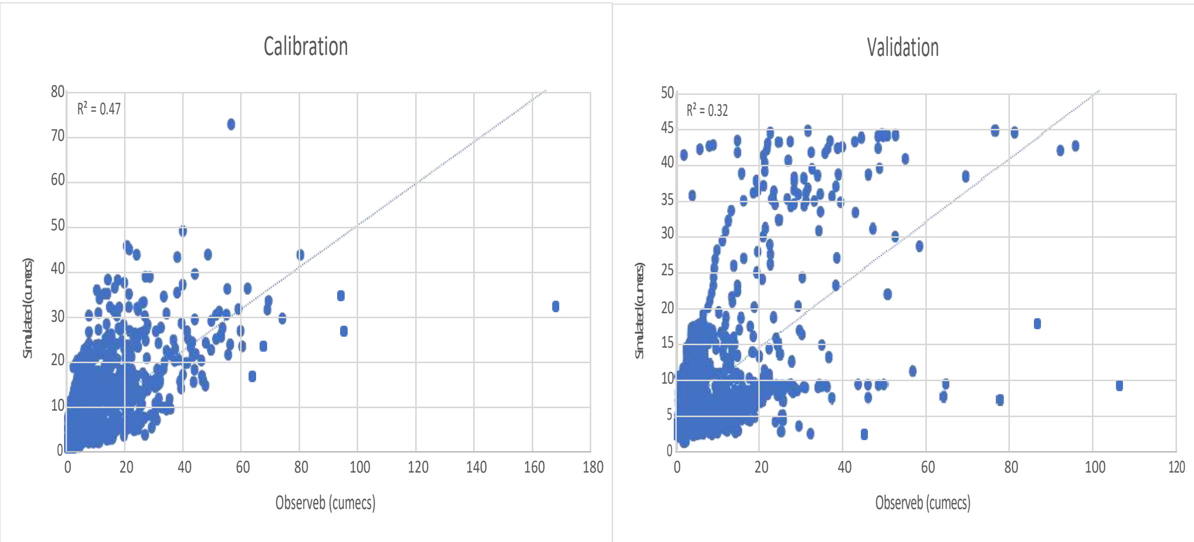


Figure 43 RESULT 4

While comparing the NASA (MEERA-2) run-off data with observed ground data the values of statically parameters in calibration period 0.47, 0.47, 22, 11.8, 0.53, 0.73 in validation period 0.13, 0.11, 48, 8.6, -5, 0.85 of R^2, NS, PBIAS, KGE, SSQR, RSR respectively.

In calibration period model perofmance is well as we see in R^2 graph the discharge value are near to trend line with some outliers but in validation period show poor performance as compare to calibration there are heavy outlier and overestimate the discharge values i.e. show discharge when there in no ground dicharge values. As mention earlier the heavy outlier are present in NASA (MEERA-2) precipitation data after 2018 therefore performance is weak in validation period.

Hydrograph of PERSIANN-CDR

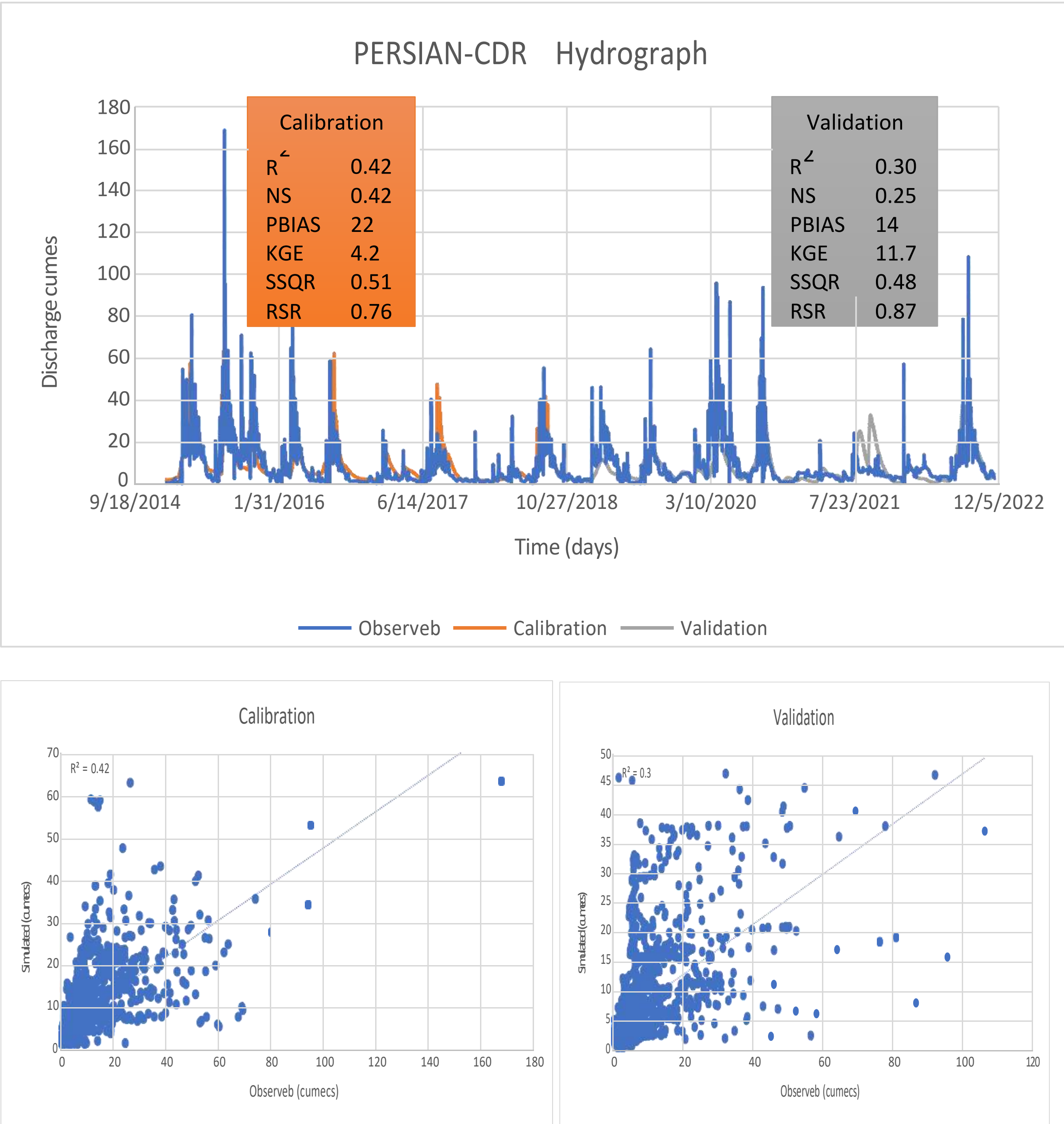


Figure 44 RESULT 5

While comparing the PERSIAN-CDR run-off data with observed ground data the values of statically parameters in calibration period 0.42, 0.42, 22, 4.2, 0.51, 0.76 in validation period 0.32, 0.27, 14, 11.7, 0.48, 0.87 of R^2, NS, PBIAS, KGE, SSQR, RSR respectively.

In calibration period model perofmance is well as we see in R^2 graph the discharge value are near to trend line with some outliers but in validation period show poor performance as compare to calibration there are heavy outlier and overestimate the discharge values i.e. show discharge when there in no ground dicharge values.

As we can see that in calibration period it achieved the peak and in validation it genrate peak but not reach the observed data.

In following are the statical parrameter value our study area

	Calibration						Validation					
	R^2	**NS**	**PBIAS**	**KGE**	**SSQR**	**RSR**	**R^2**	**NS**	**PBIAS**	**KGE**	**SSQR**	**RSR**
Gauge Data	0.51	0.51	18	-8.9	0.61	0.7	0.38	0.35	11	7.8	0.55	0.81
SM2RAIN	0.51	0.48	37	-2.5	0.48	0.72	0.48	0.48	18	-5.6	0.57	0.72
PERSIANN	0.32	0.3	30	16.1	0.4	0.83	0.13	0.11	48	8.6	0.18	0.94
PERSIANN-CDR	0.42	0.42	22	4.2	0.51	0.76	0.3	0.25	14	11.7	0.48	0.87
NASA(MEERA-2)	0.47	0.47	22	11.8	0.53	0.73	0.32	0.27	15	-5	0.51	0.85

Table 5 Results Table

After all comparsion of satllite run-off genrated by Arc-Swat model with observed ground run-off we see that SM2rain perform well in calibration and also in validaion as comparsion other. While the other satellite perform well in the calibration but not well perform in the validation.

Run-off genrated by ground precipitation perform will in calibbration and also in validation.

In the context of past researches

- From letrature we see that SM2RAIN values 0.68, 0.68, -6.94 in calibration, 0.49,0.38, -36.50 in validation of R^2, NS and PBIAS respectively [10]. R^2 and NS values are near to be same but PBIAS different but its temporal scale monthly.
- From letrature we see that PERSIANN-CDR values 0.85, 5.3 in calibration, 0.84,6.6 in validation of KGE and PBIAS respectively [DOI: 10.3390/rs10081316]. PBIAS values are near to be same but KGE different.
- Another paper PERSIANN-CDR values 0.49, 0.45 in calibration, 0.56, 0.48 in validation of R^2 and NS respectively [11].
- From letrature we see that NASA (MEERA-2) values 0.63, 0.59, 21.0 in calibration, 0.57,0.56, 34.30 in validation of R^2, NS and PBIAS respectively [3]. in calibration R^2 and NS values are near to be same but PBIAS different but different in validation due to heavy outlier present in validation period i.e. after 2018.

Chapter:6

Conclusion

The main objective of our research is to comparison of four different satellites on the bases of stream flow simulation using Arc-SWAT model with observed ground stream flow. The second objective compare also precipitation data with gauge data only on R^2 graph bases. After comparing the results following are our findings

i. SM2RAIN and Gauge data perform well in calibration and also in validation but other satellite product perfume well in calibration but not in validation. As we use NASA Power.larc data heavy outlier present after 2018 lead to error in validation period.

ii. By comparing the satellite precipitation data, we see that SM2RAIN and NASA (MEERA-2) overestimate, PERSIANN and PERSIAN-CDR some gauges are over and some are underestimate. PERSIANN and PERSIAN-CDR precipitation show will R^2 then others satellites but not well perform in the in hydrological modelling in validation period.

iii. All Satellites not well perform in precipitation comparison but well perform in hydrological modelling comparison except in validation period of PERSIANN. These perform well in the hydrological modeling due to parametric calibration.

From overall, we conclude that satellite products perform well hydrological modelling but not well direct comparison with gauge data so theses can be use hydrological modeling.

Chapter :7

Future Aspects

In future we are working on that aspects:

- Pakistan is a under-developed country therefore we have low gauge density by using SBPP’s. We have model all over Pakistan for we can create a ARC-SWAT model.
- We can compare developed country watershed by using SBPP’s. Model the American watershed and compare with scarce watershed of under-developed country.

Chapter 7

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