RAINFALL-RUNOFF MODELLING OF BETWA BASIN USING SWAT TOOL

A MAJOR PROJECT REPORT

Submitted in partial fulfillment of the requirement for the award of a degree

of

MASTER OF TECHNOLOGY

in

HYDRAULICS AND WATER RESOURCES ENGINEERING

By

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Under The Guidance

Prof. Rakesh Kumar

BONAFIDE CERTIFICATE

This is to certify that the project report entitled " **RAINFALL - RUNOFF MODELLING OF BETWA BASIN USING SWAT TOOL** " is a record of bonafide dissertation work carried out by me, Mayur Jain, towards the partial fulfillment of the requirement for the award of the degree of Master of Technology in Hydraulics & Water Resource Engineering.

Also, I do hereby state that I have not submitted the matter embodied in this thesis in any other university / institute for the award of any degree as per my knowledge and behalf.

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Date: June, 2021 **MAYUR JAIN**

Place: Delhi Roll No. 2K19/HFE/06

ABSTRACT

The hydrologist is under stress that how to analyze the catchment so that it could manage it properly and develop water resource project. To reduce their complexity in analyzing various engineering problems like reservoir storage, flood protection, forecasting, drainage system design

Hydrologists used hydrological modeling so that he could give a solution to the difficult problem. To find runoff from Betwa basin which comes under the Ganga basin, ArcSWAT software have been used along with ArcGIS software

In Actual, SWAT is distributed parameter model which be used to find surplus water, erosion, residue from land.

In this study, we delineate our catchment area by the use of DEM (Digital Elevation Model) and we got 33 sub-basin in our study area. After the creation of Land use map, soil map and slope map in swat model, we got 271 HRU (hydrological response unit) and have given 25 years of daily rainfall, minimum and maximum temperature data

Model is simulated for 25 years in which calibration have been done from 1990 to 2000 and taken two year as warm-up period which gives result R^2 = 0.89 , NS = 0.58 and validation have been done from 1999 to 2013 and taken two years as warm-up period which give result R^2 = 0.90 and NS = 0.34.

Keywords: Hydrological modeling, SWAT, ArcSWAT, GIS, Digital Elevation Model, HRUs

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ABBREVIATION NOTATION AND NOMENCLATURE

SWAT	Soil and Water Assessment Tool
HRU	Hydrological Response Unit
DEM	Digital Elevation Model
LULC	Land Use Land Cover
SRTM	Suttle Radar Topography Mission
UTM	Universe Transverse Mercator

CHAPTER 1
INTRODUCTION

1.1 GENERAL INFORMATION

Water is valuable for all living matter, We are estimating surface runoff so that we can increase yield of a catchment, and plan conservation measures like ground water recharge and reduction of the flooding hazard. So there is a need for SWAT software to get information accurately

But in practical, it is difficult and expensive to determine most of the parameter that interplay in hydrological process. Variables like runoff, sediment load, evaporation is very difficult to measure in the field.

The software used in our study is ArcSWAT 10.3.1 with ArcGIS 2012 interface and catchment area is delineated using projected DEM (Digital Elevation Model) and then had got 33 Sub basin in our area

For preparation of Land use map, Landsat 8 image C2 L1 was downloaded from the USGS Earth Explorer website and soil map was downloaded from Food and Agriculture organization website for entire globe and extracted for our study area .

Sub-basin was further divided into 271 HRU (Hydrological Response Unit) . By use of 24 years of daily rainfall data, daily maximum and minimum temperature data, Swat simulation was done for estimating runoff. Calibration and Validation was also done.

1.2 OBJECTIVE

The Specific Objective :

1- Calculate Runoff for a catchment for a given rainfall
2- Flood forecasting using SWAT model
3- Estimating groundwater recharge rate
4- Assessment of soil erosion risk using swat software
5- SWAT is used to simulate the discharge of sediment and pesticides
6- Water quality modeling using SWAT
7- Modeling of nitrous oxide emission from soil using swat model

1.3 ORGANIZATION OF THESIS

A list of the chapter contains given below :

1- Introduction - discussed swat model along with its objective
2- Literature Review - contain various studies conducted using SWAT
3- Study Area - give details for study area, which we use in this study
4- SWAT Model Description - given history of model, improvement in models.
5- Input data and model setup - give information of all input data which are used in this study
6- Result - In this section, we get result of project along with calibration, validation result.
7- Reference - In this section, we listed references which we used in our study

CHAPTER 2
LITERATURE REVIEW

LITERATURE REVIEW

In this chapter, we had given only those, whose previous work was related to my work.

(1) Nagraj S Pati, Rajkumar V Raikar, Manoj S (2014) In this study they done rainfall - runoff modeling of Bhima river, delineated the watershed by the use of DEM image of watershed and created land use map, soil map and slope map and then had given rainfall, temperature data (minimum and maximum). They simulated the project and checked the accuracy of result with observed and simulated data. Calibration was done monthly from 1974 to 1978. Validation was carried from 1979 to 1983. The calibration result $R^2 = 0.89$, NSE = 0.81. For validation, the R^2 was found to be 0.74 and NSE was estimated as 0.77.

(2) Rohtash, Dr. L. N. Thakural, Dr. M.K. Choudhary, Dipti Tiwar (2018)
In this study, they do rainfall-runoff modeling of chaliyr basin Kerala which had catchment area 2013.4 km². Delineated the watershed and got 15 sub-basin and created land use map, soil map and slope map and 103 HRU was generated for entire basin and had given rainfall , temperature data (minimum and maximum). they simulated the project and checked the accuracy of result with observed and simulated data. Calibration was done from 2003 to 2007 on monthly basis . Validation was carried from 2008 to 2011. The calibration result $R^2 = 0.77$, NSE = 0.75. For validation, the R^2 was found to be 0.765 and NSE was estimated as 0.73.

(3) Leelambar Singh a , Subbarayan Saravanan (2020) In this study they do rainfall-runoff modelling of IB basin . Delineated using the dem of study area. created land use map, soil map and slope and had given rainfall, temperature data (minimum and maximum). they simulated the project and checked the accuracy of result with observed and simulated data. Calibration was done monthly from 1993 to 2003. Validation was carried from 2004 to 2011. The calibration result R^2 = 0.77, NSE = 0.75. For validation, R^2 was found to be 0.80 and NSE was estimated as 0.55.

(4) Asmita K. Mistry, Bankim R. Joshi (2014) rainfall-runoff modeling of Shakkar basin had catchment area 2223 km^2. They delineated the watershed and had got 23 sub-basin and created land use map, soil map and slope map and 223 HRU was generated for entire basin and then by giving rainfall, temperature data (minimum and maximum) . SWAT simulation was done for daily basis for 21 years data and a good R2 value 0.8019.

(5) Ashok Mishra, Philip Gassman (2007) The SWAT model had been applied for Banha watershed to simulate sediment transport. The model predicted surface runoff and sediment transport on daily and monthly basis, had R^2 value in range between 0.77 and 0.99. NSE value in range from 0.58 to 0.99 indicated in daily timeframe and SWAT performance was not good for surface runoff and sediment loss. For installing check dam in an area, we had given priority to those sites where current check dam was already placed. Three check dams had install in catchment reduces 50 % of sediment concentration and during the monsoon seasons overall sediment loads was reduced almost 64% for the duration of 1996 - 2001. Results confirm that model applicable to small watersheds with monsoon dominated climatic condition

(6) SU WAI THIN, KOICHIRO OHGUSHI & TOSHIHIRO MORITA (2019) Bago basin, Myanmar had catchment area of 4883.1 km^2. Delineated using the Dem of study area. created land use map, soil map and slope and then had given rainfall, temperature data (minimum and maximum) they simulated the project and checked the accuracy of result with observed and simulated data. Calibration was done for daily basis from 2010 to 2013. Validation was carried from 1/1/2014 to 31/12/2014. Calibration result NSE = 0.76. For validation, NSE = 0.56. The relation was best fitted with observed and simulated data

(7) **K. N. Loukika, K. Venkata Reddy, K. H. V. Durga Rao and Amanpreet Singh (2019)** The study area was taken at Chintalapudi village, andrapradesh By Using DEM, LULC map, Soil map, rainfall data, aquifer parameters we estimate groundwater recharge . In this SWAT and MODFLOW model, both was used. By creating a grid in modflow along with Dem, aquifer data, and permeability data and by it was simulated from 1990 to 2005 to get groundwater rate result

(8) Anurag Bandi , Y. R. Satyaji Rao , Sanjeet Kumar (2020) On Sarada river basin SWAT model was applied. Sub-basin in which outlet was located they compared both observed discharge & SWAT simulated discharge. 13 years from 1996 to 2008 data was used for simulation and for calibration 1999 to 2005 data was used, which had R^2 value = 0.8312 and NSE = 0.83 and for validation from 2006 to 2008 data was used having R^2 value = 0.855 and NSE value = 0.66 . It had given good result

(9) Manoj Jain, Survey Daman Sharma (2014)) Vamsadhara basin was delineated using the Dem of study area having area of 10,830 km^2. input variables like rainfall, temperature data (minimum and maximum, land use map, soil map, slope map, DEM etc. they simulate the project and check the accuracy of result with observed and simulated data. calibration was done monthly having $R^2 = 0.89$. Validation was carried monthly having $R^2 = 0.91$.

(10) Subhadip and Sneha (2017) they find the actual runoff obtained in Ajay catchment. Our area was delineated by the use of DEM and got 19 sub-basins in our area and then they divided area into 223 small units called HRU . After by using daily data of our rainfall for 30 years and 30 years of daily max and min temperature data . SWAT obtained result in monthly basis and R^2 value obtained was 0.9419.

CHAPTER - 3

DESCRIPTION OF SWAT MODEL

3.1 DEVELOPMENT HISTORY OF SWAT MODEL

Before the development of swat model many model came, and by knowing the limitation in each model, swat model were prepared. SWAT model is created around 1990 and it is developed by merging many model like SWRPB, ROTO, GIS Interface.

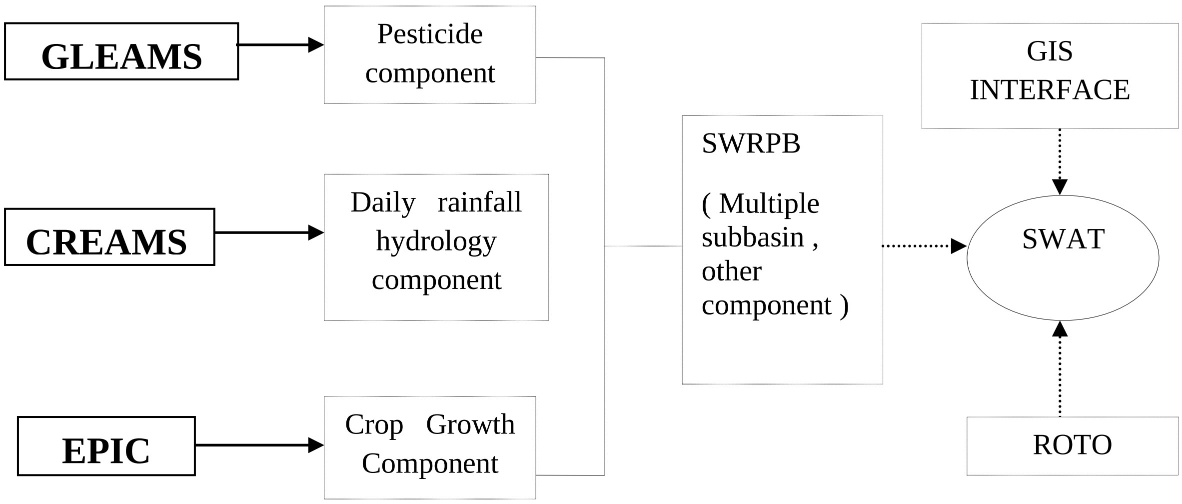

FIG 3.1: SWAT Development History

After the initial development of SWAT, it goes for modification and many models release with time

Model release:

SWAT 94.2: Multiple hydrologic response units (HRUs) is considered

SWAT 96.2: Auto - fertilization and auto-irrigation added; storage of water is added; Crop Growth Model Co2 component is added; potential evapotranspiration equation added; lateral flow of water in the soil is added; water quality equations added

SWAT 98.1: water quality equation is improved; tile flow drainage added, Nutrient cycling routines is added

SWAT 99.2: improvement in Nutrient cycling routines, wetland routine improved, nutrient removal by settling added; water storage is added; Equation from SWMM added

SWAT 2000: infiltration added; improvement in inputs of weather generation; Inputs like solar radiation, relative humidity, and wind speed is added; calculating ET values for catchment area ready; simulate an unlimited number of reservoirs; Muskingum routing method added

SWAT 2005: weather forecast scenarios added; precipitation data is added on a daily and sub-daily basis; CN calculation is added

SWAT 2009: Increasing weather data upto 300 years. Some updates in Watershed Delineation, HRU Analysis and SWAT 2009.mdb Database.

3.2 OVERVIEW OF SWAT

SWAT (Soil & Water Assessment Tool) is continuous time model, public domain software and it is used to predict runoff on our watersheds.

The model is physically based, computationally efficient, and capable to find result for long periods. The watershed is divided into multiple sub-basin, which is further subdivided into hydrologic response units (HRUs).

Individual HRUs represents land use, soil type and slope within the sub-basin . After creating HRU and adding input like rainfall, maximum and minimum temperature etc. model is simulated. The figure given below is a hydrologic cycle image in SWAT software for better understanding the result obtained after simulation

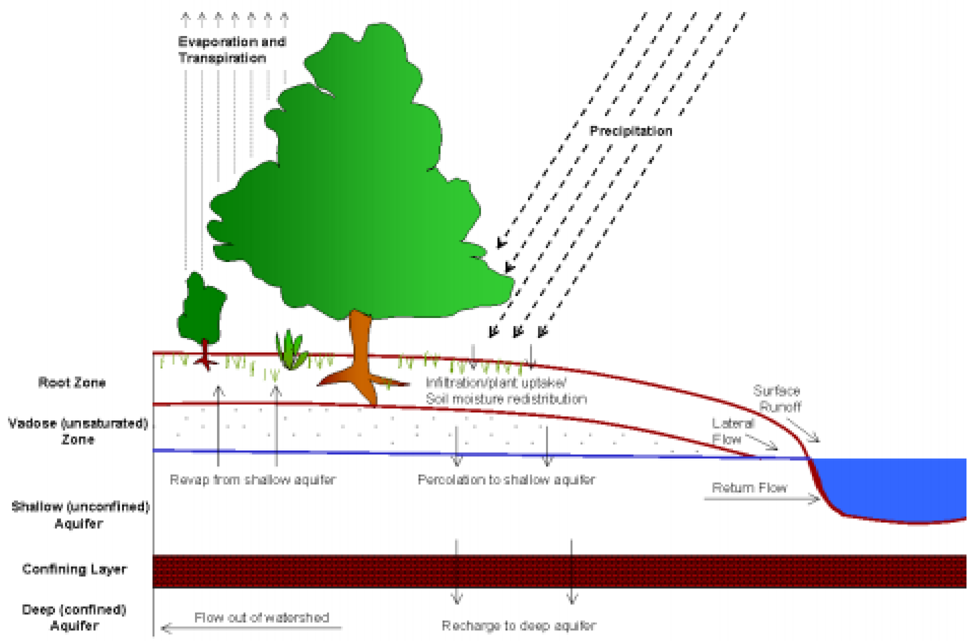

FIG 3.2: Hydrologic Cycle

Equation on which hydrologic cycle is based :

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

Where SW_t is final soil water content, SW_0 is initial soil water content of day, t is the time, R_{day} is the amount of precipitation on day i, Q_{surf} is the amount of surface runoff on day i, E_a is the amount of evapotranspiration on day i, W_{seep} is the amount of water entering the vadose zone from the soil profile on day i, Q_{gw} is the amount of return flow on the day i

All the component of the hydrological cycle is summarized in next section

3.2.1 PRECIPITATION

For input, user should provide precipitation value on daily timeframe to swat model. SWAT distribute rainfall according to the rain gauge station location in sub basin and created monthly report of every sub basin having precipitation value

We go for skewed rainfall distribution and find the amount of rainfall on that day by an equation :

$$R_{day} = \mu_{mon} + 2.\, \sigma_{mon} . \left(\frac{[\left(SND_{day} - \frac{g_{mon}}{6}\right)\left(\frac{g_{mon}}{6}\right) + 1]^3 - 1}{g_{mon}} \right)$$

Here R_{day} represent quantity of precipitation occurred for given day. μ_{mon} is the average value of the month for daily rainfall data, σ_{mean} is standard deviation value of month by using daily rainfall data, SND_{day} is the standard normal deviate value of our day and g_{mon} is the monthly coefficient value by using daily precipitation value

3.2.2 EVAPOTRANSPIRATION

Evapotranspiration is the sum of evaporation from ground and evaporation from leaves in plant . In swat, there are three methods to calculate evapotranspiration but due to the limitation of data we had chosen the Hargreaves method as it takes only temperature data.

The equation used by this method is :

$\lambda E_0 = 0.0023\ H_o\ (T_{mx} - T_{mn})^{0.5}\ (T_{av} + 17.8)$

Where λ is the latent heat of vaporization, E_0 is the potential evapotranspiration, H_0 is the radiation, T_{mx} is maximum temperature obtained for a day, T_{mn} is min temperature obtained for a day, T_{av} is the average temperature of the day

3.2.3 PERCOLATION

Percolation means movement of water in soil in downward direction, it only happen when the water content is in excess to the required field capacity of soil.

Our software calculates the percolation of water at every layer in the soil profile beneath the ground and does the sum and calculate total percolation of water in-ground

Infiltration is calculated by using the field capacity formula

Percolation is founded by an equation at each layer on the soil profile and it is given below :

$$W_{perc,ly} = SW_{LY,excess} \cdot \left(1 - \exp\left[\frac{-\Delta t}{TT_{perc}}\right]\right)$$

Where $W_{perc,ly}$ is the value of percolating water in the ground to beneath soil layer for a day, $SW_{LY,excess}$ is the volume of water drained soil layer for a day, Δt is the same time change value in hours, TT_{perc} is the time taken for water to percolate in ground

For each layer, we calculate our travel time of water in the soil by using

$$TT_{perc} = \frac{SAT_{ly} - FC_{ly}}{K_{sat}}$$

Where TT_{perc} is the travel time for percolation (hrs), SAT_{ly} is the amount of water in the soil layer when completely saturated, FC_{ly} is the water content of the soil layer at field capacity, K_{sat} is the saturated hydraulic conductivity for the layer (mm hr^{-1})

3.2.4 REVAP FROM SHALLOW AQUIFER

Revap is simply water coming out from aquifer to saturated zone The maximum amount of water that be removed from aquifer is given by :

$$W_{revap,mx} = \beta_{rev} . E_0$$

Where $W_{revap,mx}$ is the maximum amount of water moving into the soil zone, β_{rev} is revap coefficient, E_0 is the potential evapotranspiration for the day

The actual amount of revap for a day is given by an equation :

$$W_{revap} = 0 \quad \text{if} \quad aq_{sh} \leq aq_{shthr,rvp}$$

$W_{revap} = W_{revap,mx} - aq_{shthr,rvp} \quad if \; aq_{shthr,rvp} < aq_{sh} < (aq_{shthr,rvp} + W_{revap,mx})$

$W_{revap} = W_{revap,mx} \quad if \; aq_{sh} \geq (aq_{shthr,rvp} + W_{revap,mx})$

Where W_{revap} is the actual amount of water moving into the soil zone , $W_{revap,mx}$ is the maximum amount of water moving into the soil zone , aq_{sh} is the amount of water stored in the aquifer at the beginning of the day, $aq_{shthr,rvp}$ is the threshold water level in the shallow aquifer for revap to occur

3.2.5 SURFACE RUNOFF

Surface runoff means excess rainfall which is not infiltrated in ground, so that excess water flow over the surface and the river or stream.

And it is being calculated in SWAT using CN Value

Formula is given below:

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

Where S = 25.4 ($\frac{1000}{\text{CN}}$ - 10)

Where R_{day} is a depth of rainfall for a day, S is the retention parameter, CN is the Curve Number for the day

3.2.6 RETURN FLOW

Base flow is sometimes called as return flow as it comes to the main channel through groundwater

In SWAT it is being calculated by an equation :

$$Q_{gw} = \frac{8000.K_{sat} \cdot h}{{L_{gw}}^2}$$

Where Q_{gw} is the base flow, K_{sat} is hydraulic conductivity, L_{gw} is the distance from the ridge, h is the height of the water table

CHAPTER - 4

STUDY AREA AND METHODOLOGY

4.1 STUDY AREA

Our Selected study area was betwa basin which is a sub-basin of ganga basin. Watershed area was 43,751.59 km^2. States which comes under this basin are some part of uttarpradesh and some part of Madhya Pradesh. fourtheen district which comes under betwa basin was ashoknagar, bhopal, chattarpur, hamirpur, jalaun, jhansi, lalitpur, mahoba, raisen, sagar, sehore, shivpuri, tikamgardh, vidisha . In our basin, less than 1% of area was covered by water bodies, and the highest 40% of the land was covered with forest and In our elevation report of our basin, it was seen that it had an elevation range from 76 to 715 above mean sea level

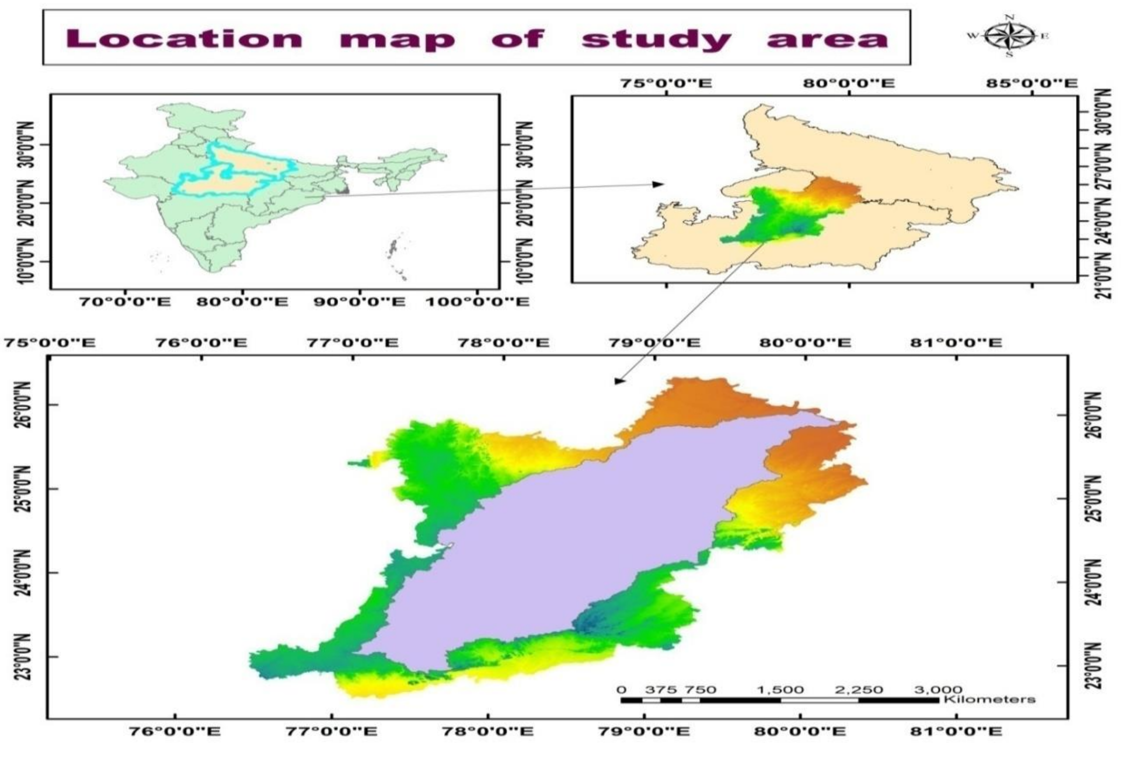

Fig 4.1: Location map of the study area

4.2. METHODOLOGY

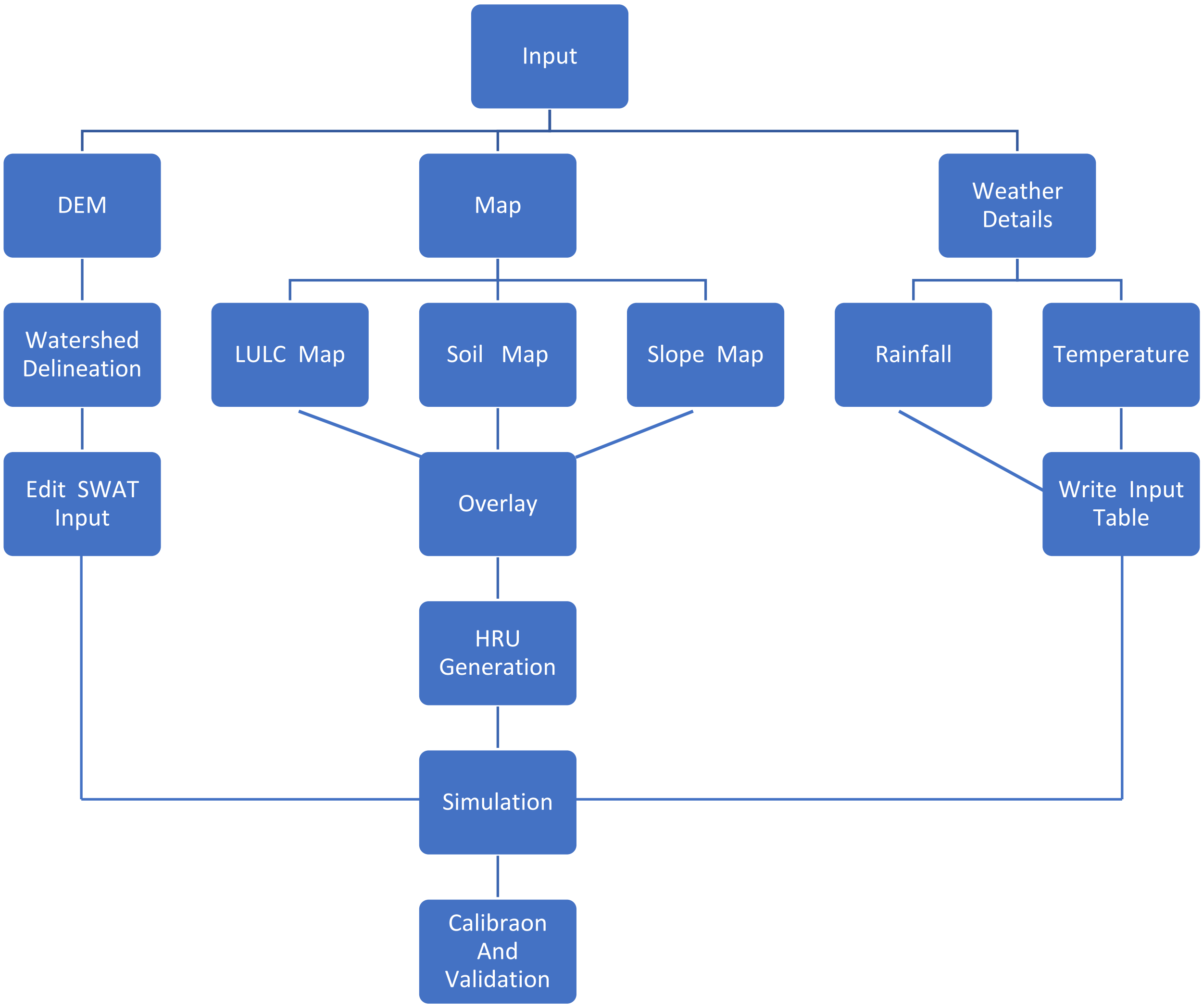

FIG 4.2: Methodology Flow Chart

The picture given above was the flowchart of methodology that tells the steps to complete the project. ArcSWAT 2012 version is used in this project with ArcGIS 10.3.1. The input data required in this project was DEM, LULC map, soil map, slope map and rainfall and temperature data. By using all data we simulated our project and after that, we use SWAT CUP for calibration and validation

CHAPTER - 5

PREPARATION OF INPUT DATABASE AND SWAT MODEL SETUP

In our case, we used SWAT 2012 version and using this version in ArcGIS 10.3.1 version software, which is easily available and free of cost software. Input which required in project was DEM, land use map data, soil map data and meteorological data like precipitation data and minimum and maximum temperature data. Daily temperature and precipitation data which required in this project was from 1-1-1990 to 31-12-2013.

5.1 PRE–WATERSHED DELINEATION PROCESS

5.1.1 FINDING DISTRICT IN THE STUDY AREA

we had to find district come in Betwa basin, for that we need a scanned image of that basin and do georeferencing means assigning coordinate system for that image/ scanned image such that image should be used for ArcGIS software.

Now by selecting a district from India district map and find that district that touches the scanned Betwa basin image and do this in such a way we had got 14 district that comes in my selected basin i.e. ashoknagar, bhopal, chattarpur, hamirpur, jalaun, jhansi, lalitpur, mahoba, raisen, sagar, sehore, shivpuri, tikamgardh, vidisha

So our district selection step was now completed.

5.1.2. DEM

DEM Stands for digital elevation model. DEM is digital representation of land surface elevation with respect to any reference datum.

For creating a DEM of our area, first we had to download SRTM image. For that open Earth Explorer website and search all 14 district one by one and note its latitude and longitude value. After that add all 14 coordinate and get an area and now click on SRTM 1 Arc - Second Global and then click on footprint and select those footstep which touches the area and done in such a way it covers total area and download that footprint. You get an SRTM image

In the Arc Toolbox option in ArcGIS, create a raster
After creating a raster dataset, merge all Srtm images by mosaic option

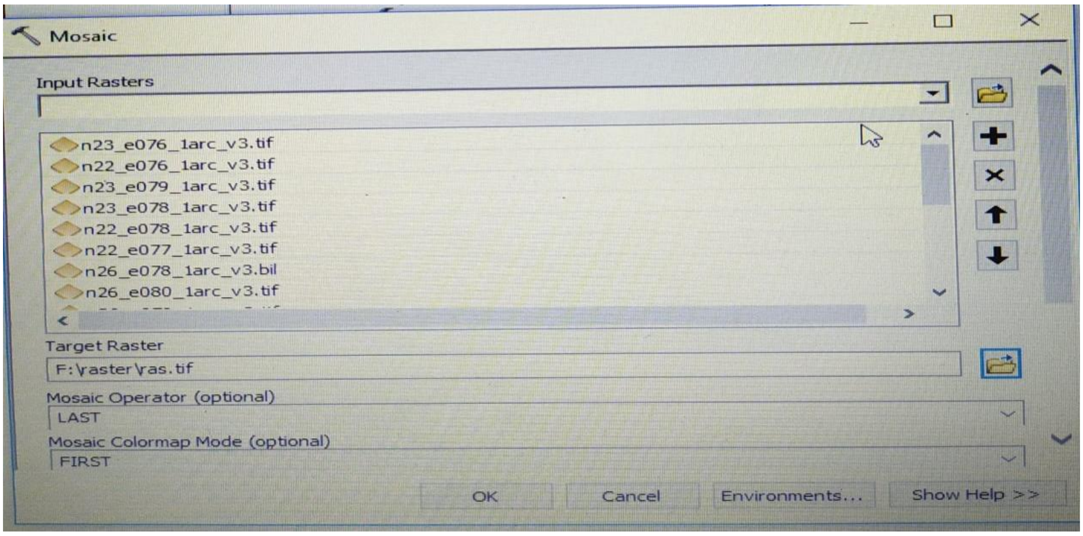

Fig 5.1: Mosaic (merge all SRTM images)

And after that, merged Dem was obtained

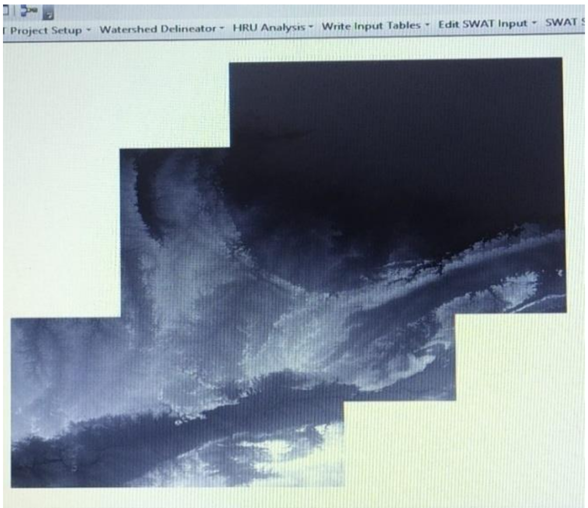

Fig 5.2: Merged DEM

Study area which was formed by click on all 14 districts. And extract our study area from merged DEM by the use extract by mask command

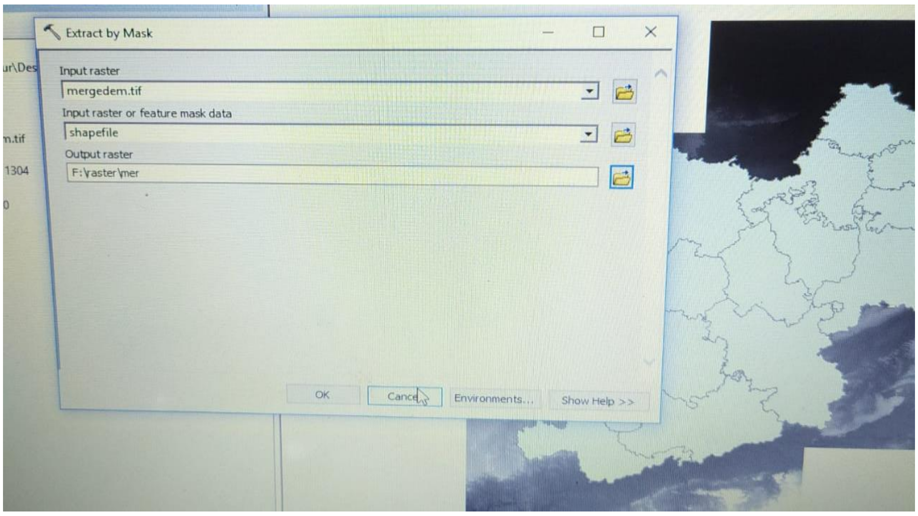

Fig 5.3: Extract study area using Extract by mask option

And obtained the Dem of our study area

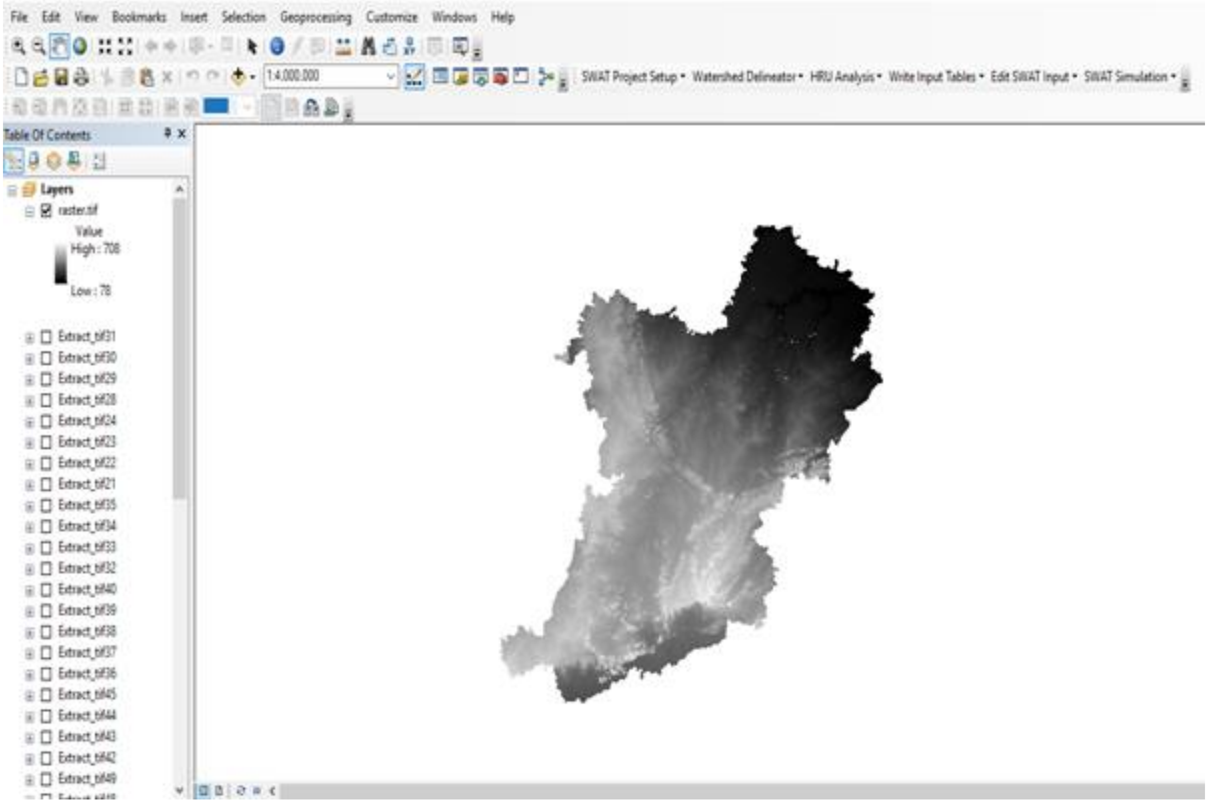

FIG 5.4: DEM of our study area

5.1.3. UTM ZONE IDENTIFICATION AND COORDINATE CONVERSION

Before gone to watershed delineation process, we had changed the coordinate system of obtained DEM. Coordinate system was GCS_WGS_1984 and its unit was in decimal. So we had to convert its unit in meter by converting its coordinate system

So our main aim was to identify in which zone our study area comes. By the use of **Google Earth Pro** and kml of our shape file and utm zone kml. we got our area lies in two utm zone i.e. 44N and 43N. but most of our area lies in UTM Zone 44N. So we converted our coordinate system into WGS_1984_UTM_Zone_44N by using project raster in Arc tool box.

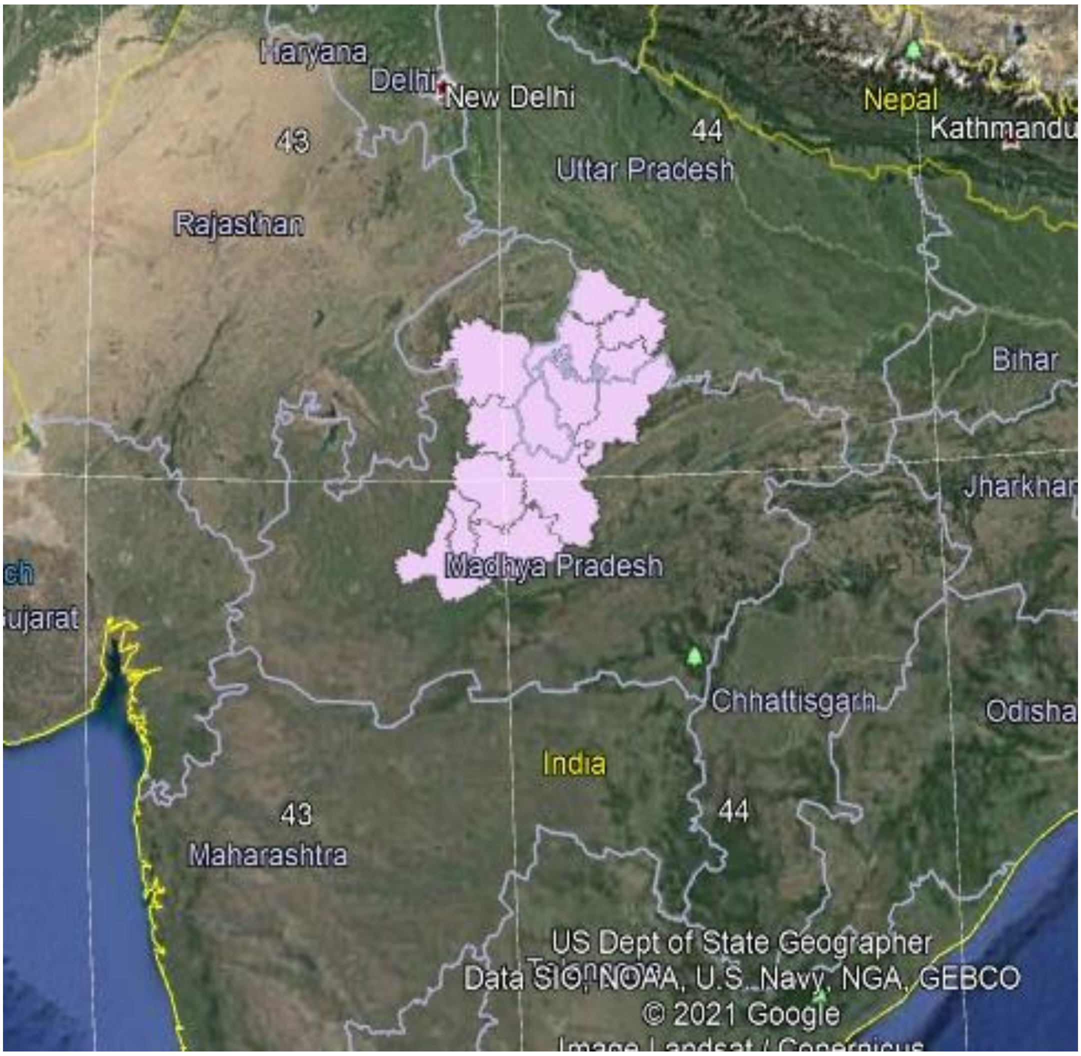

FIG 5.5: Identification of UTM Zone in goggle earth pro desktop app

For converting the coordinate system in WGS_1984_UTM_Zone_44N we had used the project raster option in the arc toolbox

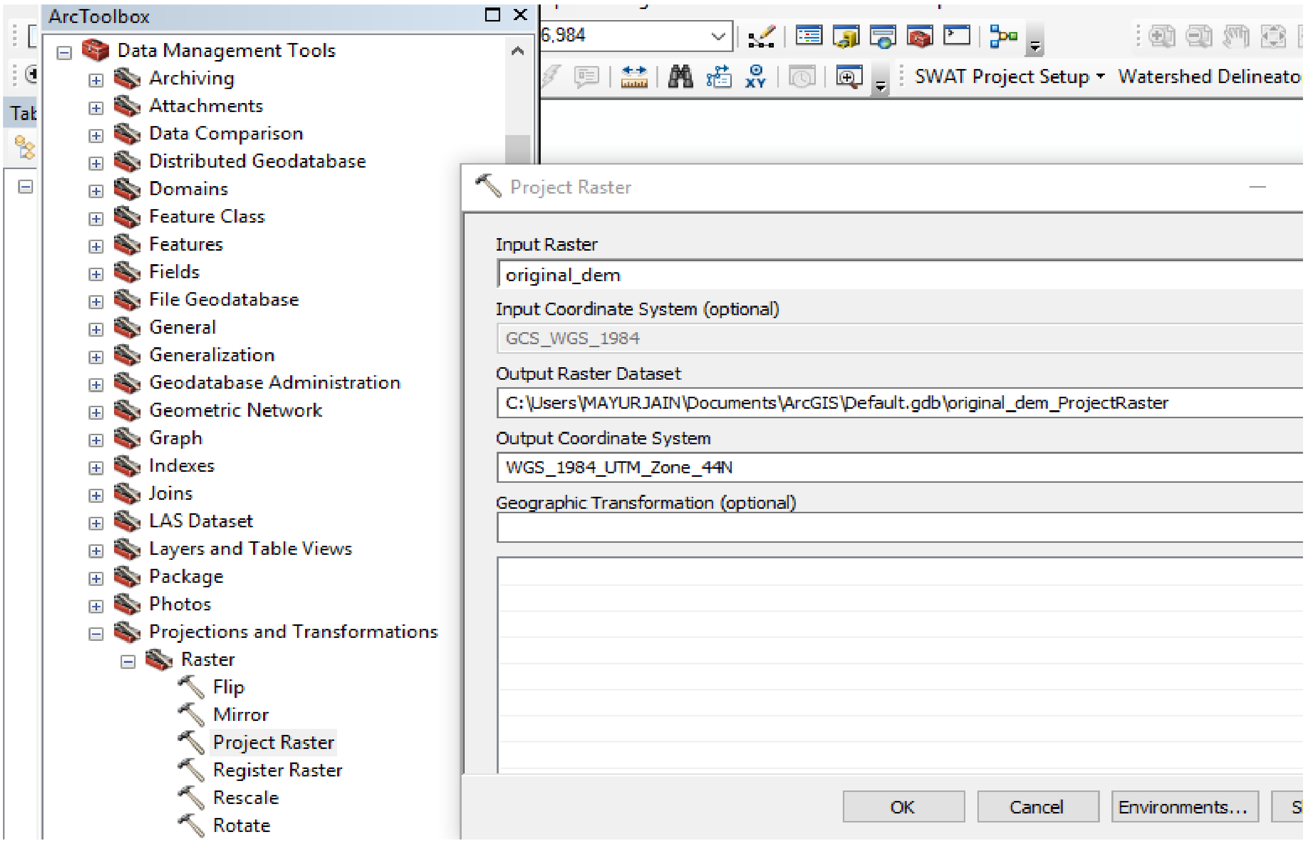

FIG 5.6: Conversion of the coordinate system

5.2. WATERSHED DELINEATION

Watershed delineation means creating a boundary that represents the contributing area for a particular river outlet.

Our converted DEM in meter format and now spatial reference of DEM was WGS_1984_UTM_ZONE_44N

Now In the watershed delineation step, it accept our converted DEM

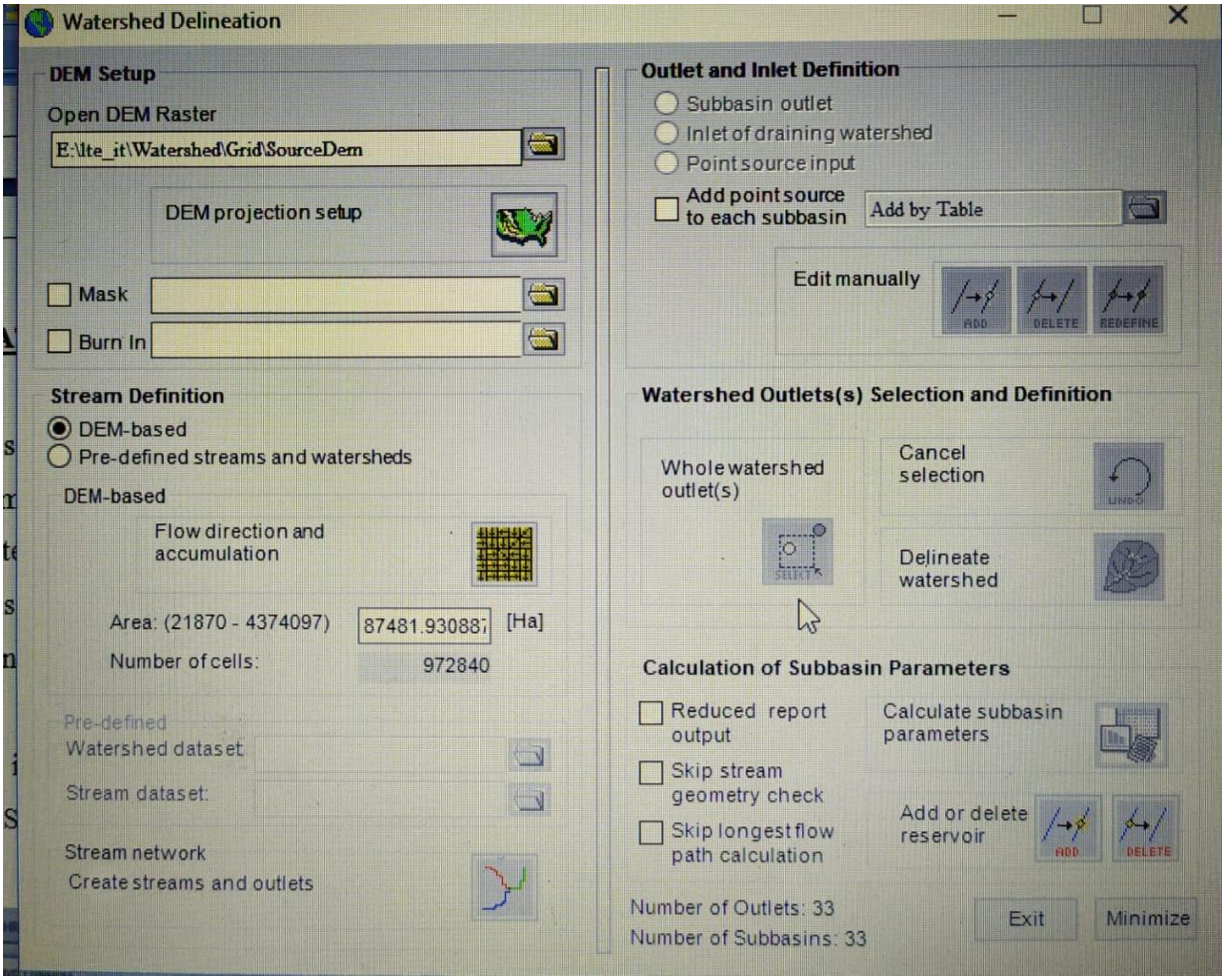

FIG 5.7: Watershed Delineation Window

We had assigned the unit in meter in DEM projection setup option

We had delineated our watershed by DEM

After using flow direction and accumulation option

Area obtained should be in range

After created stream network and we had to assign an outlet

We had to assign outlet for the whole watershed

Watershed Delineation step was completed

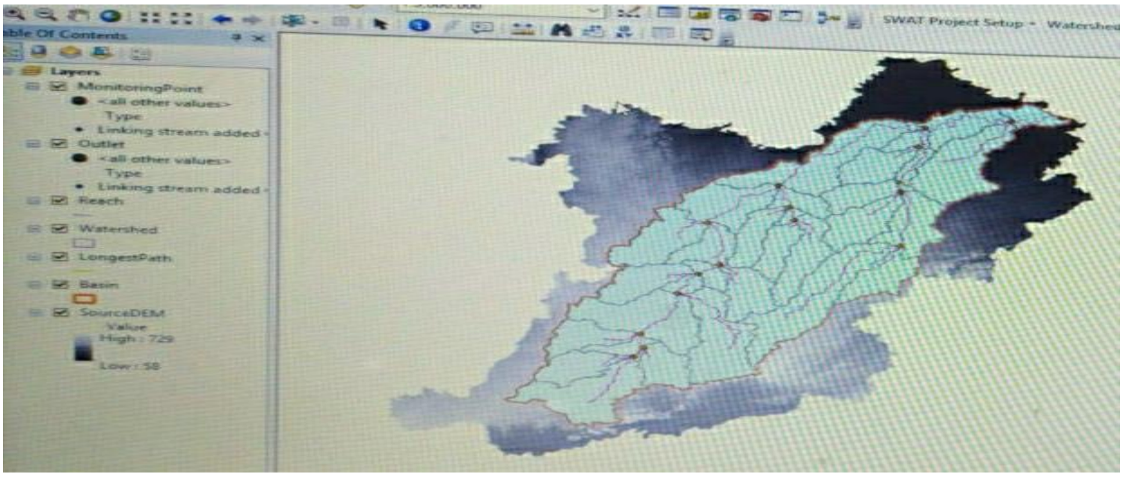

Fig 5.8: Delineated Watershed (blue image)

In our area we got 33 sub-basin and we got topographic report in which each sub basin elevation details was there. Elevation of our area lies between 76 to 715

5.3. PREPARATION OF LAND USE MAP AND SOIL MAP FOR HRU GENERATION

HRU (Hydrologic Response Unit) is the smallest unit of SWAT to calculate the Hydrological properties of catchment

Individual HRUs represents land use, soil type and slope within the sub-basin

Our aim was to create lulc map , soil map and slope map for making hru report.

5.3.1 LULC MAP

For creating land use map, we need a land image which was captured from satellite i.e. Land sat 8 satellite takes 30 m spatial resolution image and it was downloaded from the USGS Earth Explorer website

Search all 14 district one by one in Earth Explorer website and note its latitude and longitude value. After that add all 14 coordinate and get an area and now click on Land sat 8 OLI / TRIS C2 L1 and then click on footprint and select those footstep whose cloud cover was less than 10 % for clear picture of our land area and touches the area and done in such a way it covers total area and download that footprint. You get land sat image.

Now do band composite for every footprint by using composite band option in arc toolbox and after completing all image do mosaic such that a single band composite image of our study area was obtained

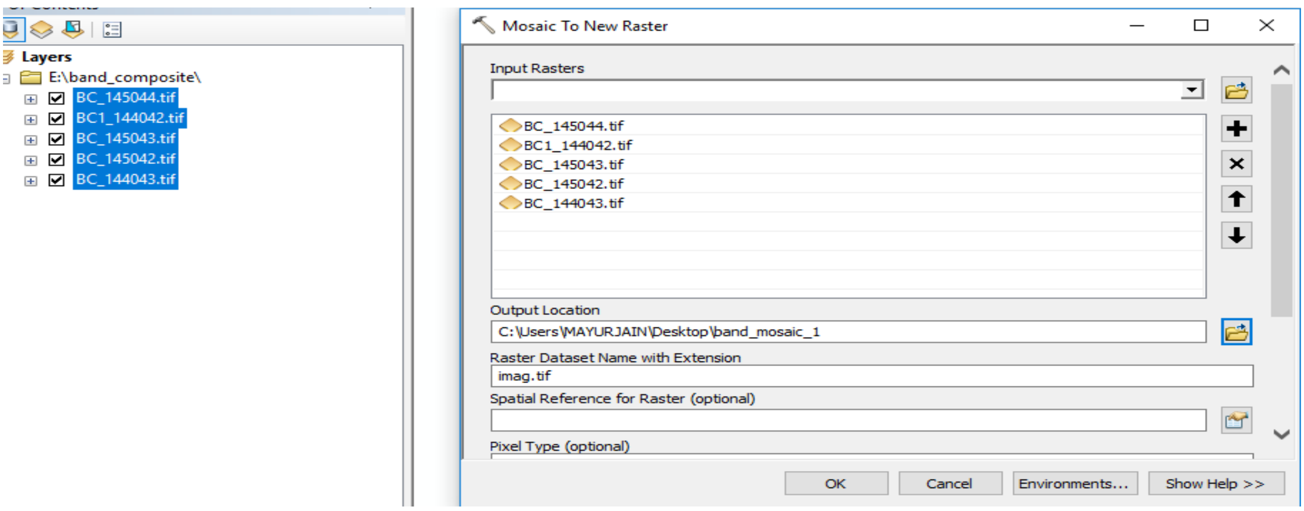

FIG 5.9: Mosaic window for single-band composite

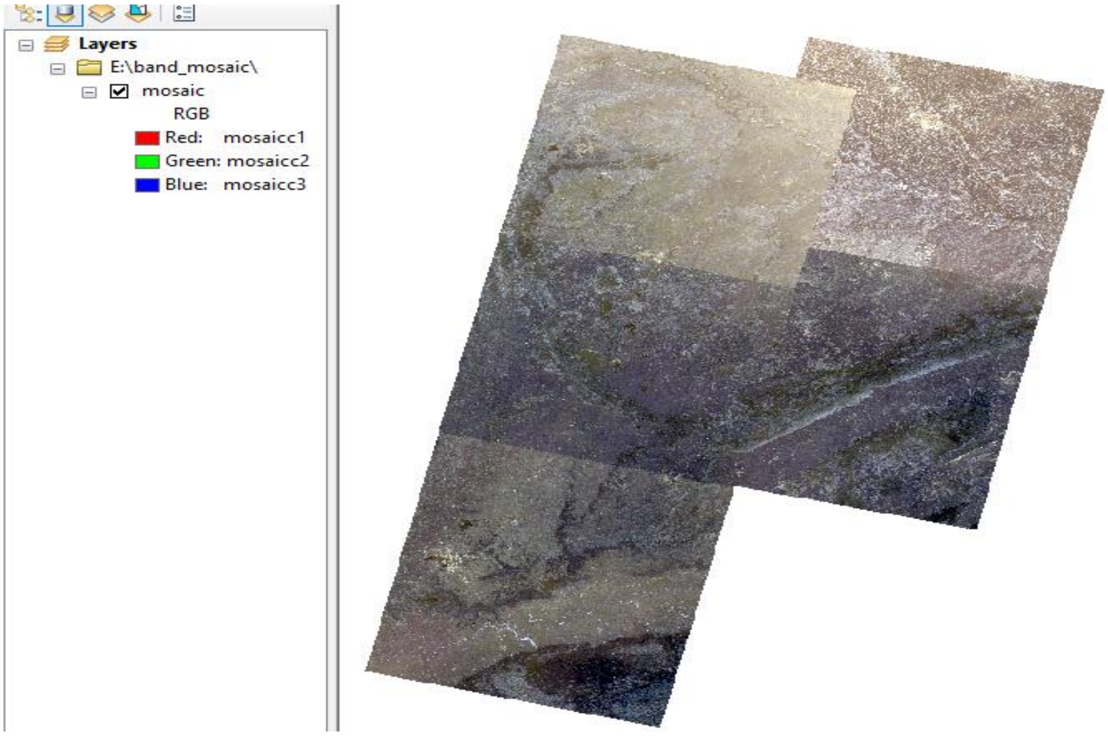

FIG 5.10: Mosaic of our band composite

Now do extract by mask operation we get our study area

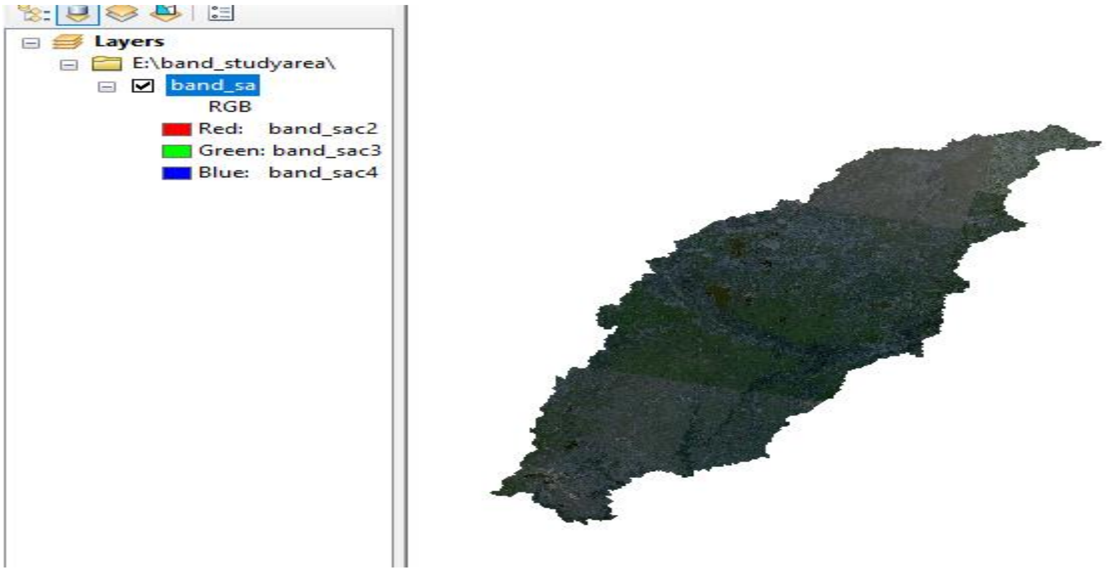

FIG 5.11: Study area band composite

And by using the image classification option we had create a training sample

To create training sample, identification is necessary whether Our land was barren, had water bodies, etc by adding base map in band composite mosaic image and now it is easily visible what the land was and we had created a signature file and do maximum likelihood classification

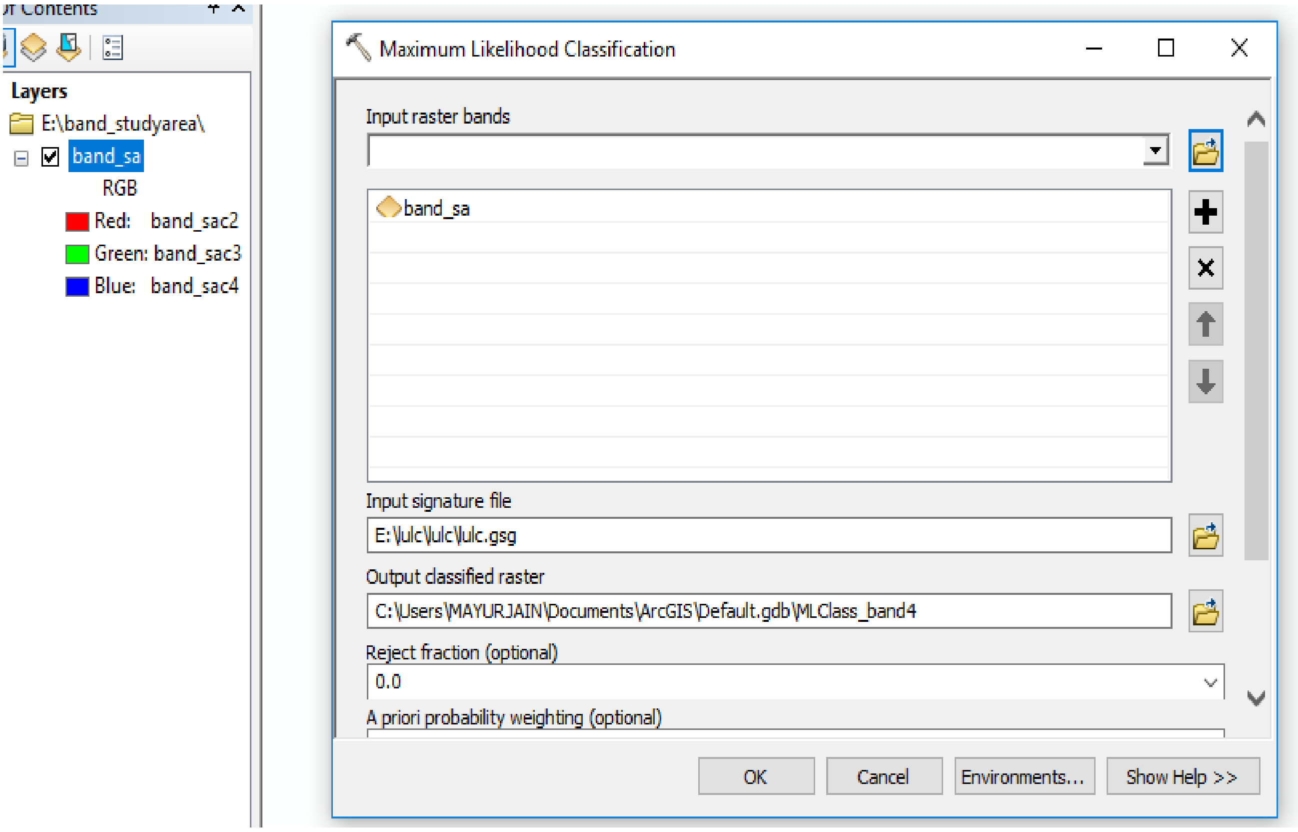

FIG 5.12: Maximum likelihood window

After completing this our LULC Map was prepared

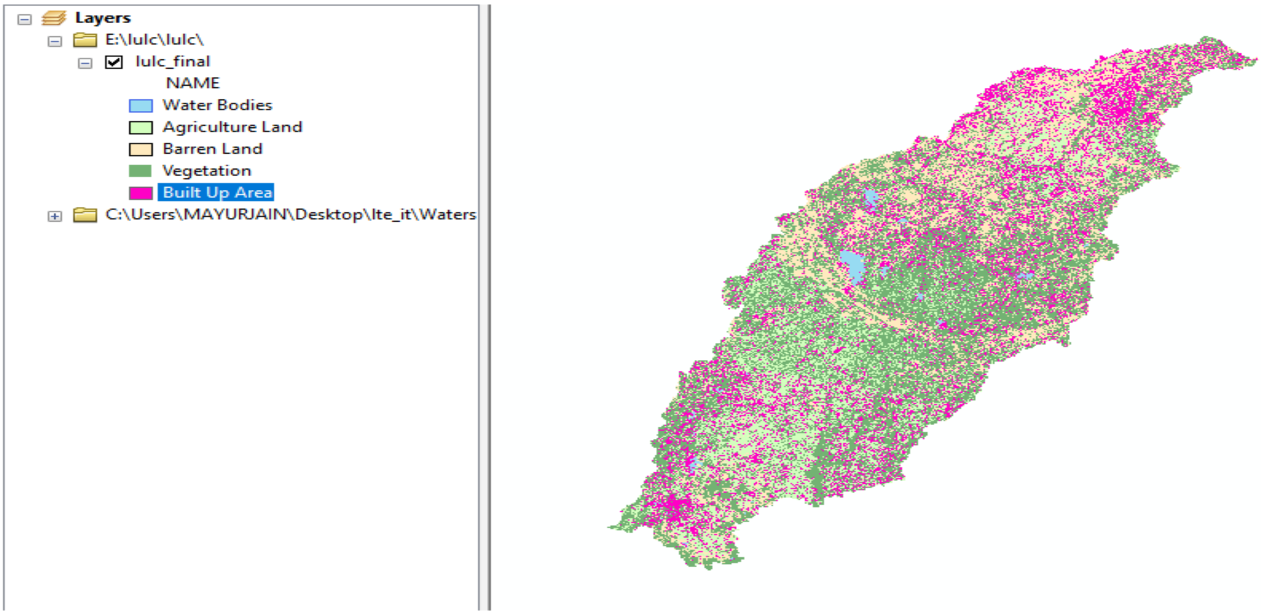

FIG 5.13: LULC Map

5.3.2 SOIL MAP

Download digital soil map of world from FAO website and extract our study area from it. Now we get soil map of our study area

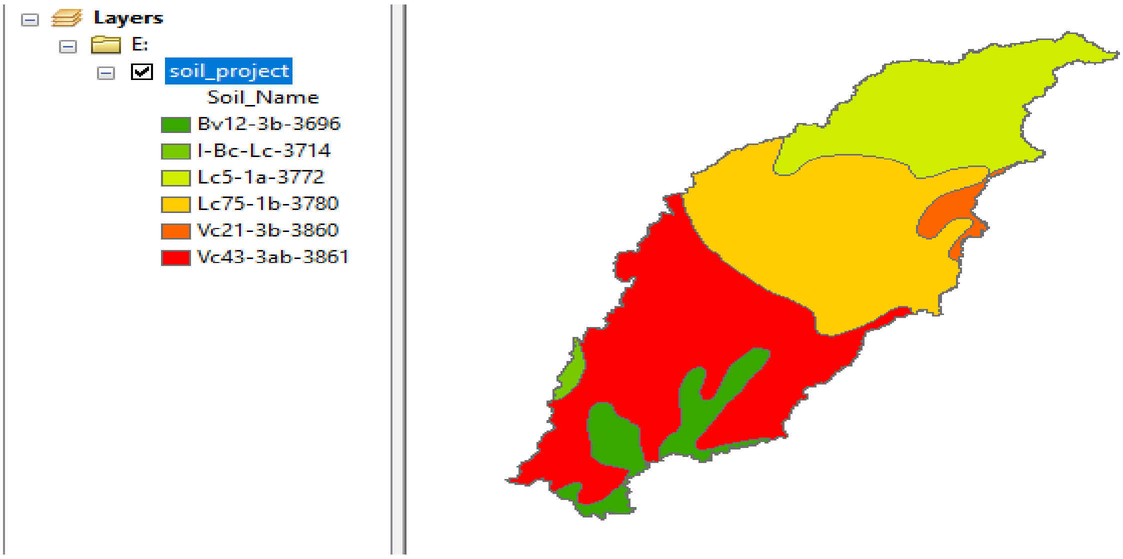

FIG 5.14: Soil Map

5.4. HRU Analysis

5.4.1 LANDUSE / SOIL / SLOPE MAP

After the creation of LULC Map and Soil Map. We go for HRU generation.

We had to create swat land use classification table by use of land-use map which had created previously. So after reclassification, we got land use map

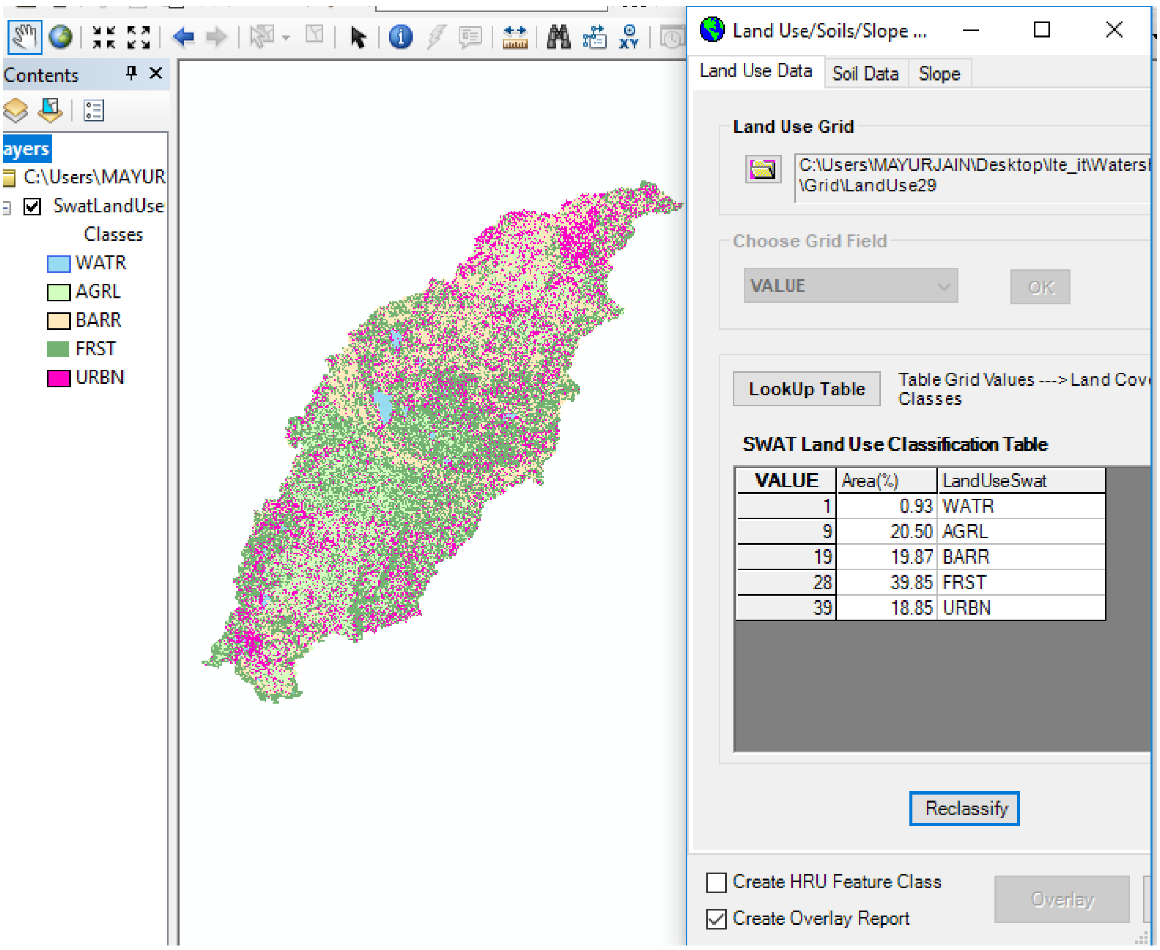

Fig 5.15: Land use map and table in HRU Generation step

We had to create SWAT soil classification table using soil map which we created previously. In this table percentage of area covered by each soil was given and after reclassification, we got soil map of our area

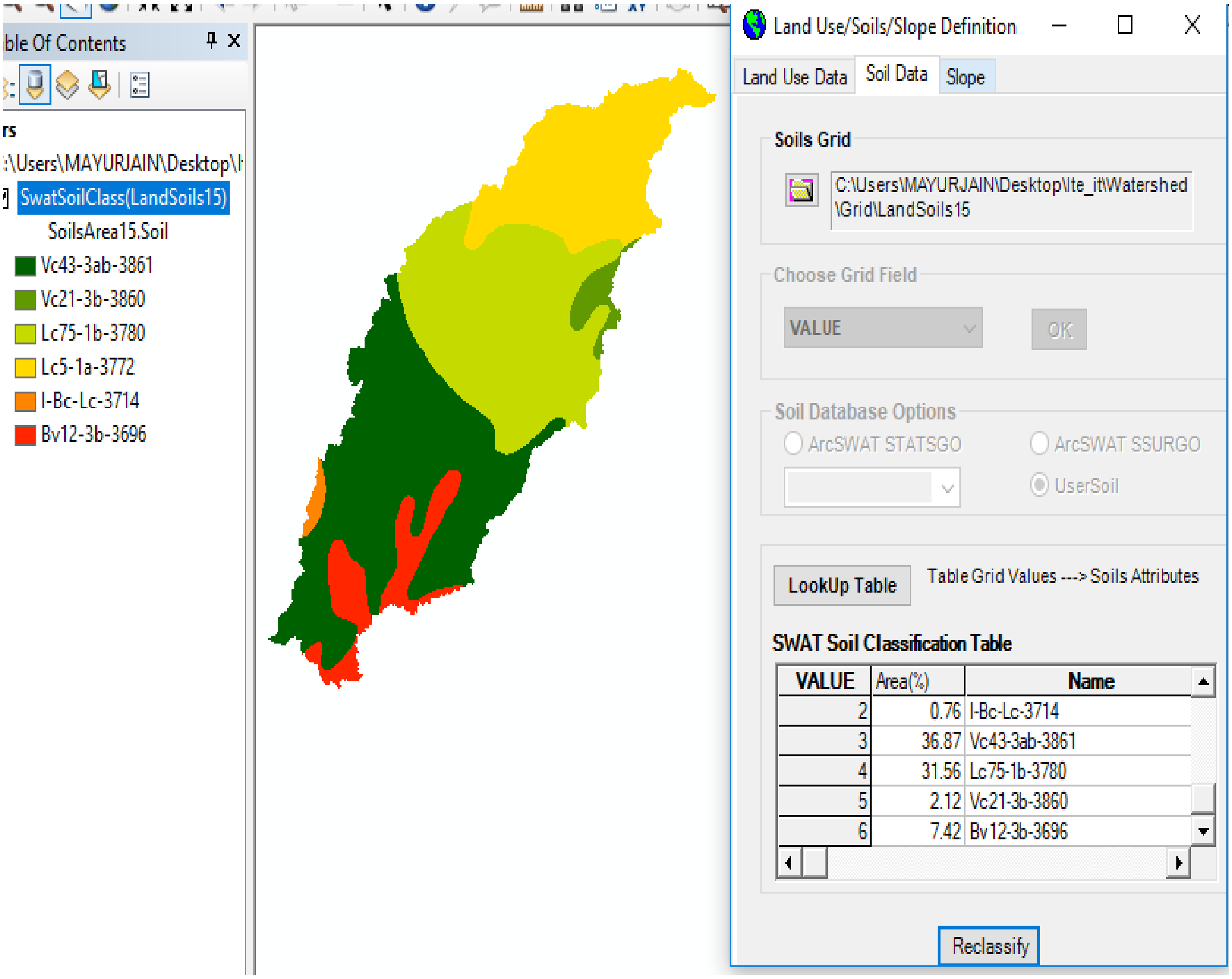

Fig 5.16: Soil map and table in HRU Generation step

For slope map, we had created five classes and in each classes, the lower limit and the upper limit was given and we distribute our slope in the form of multiple slopes and after reclassification, we get a slope map of our area

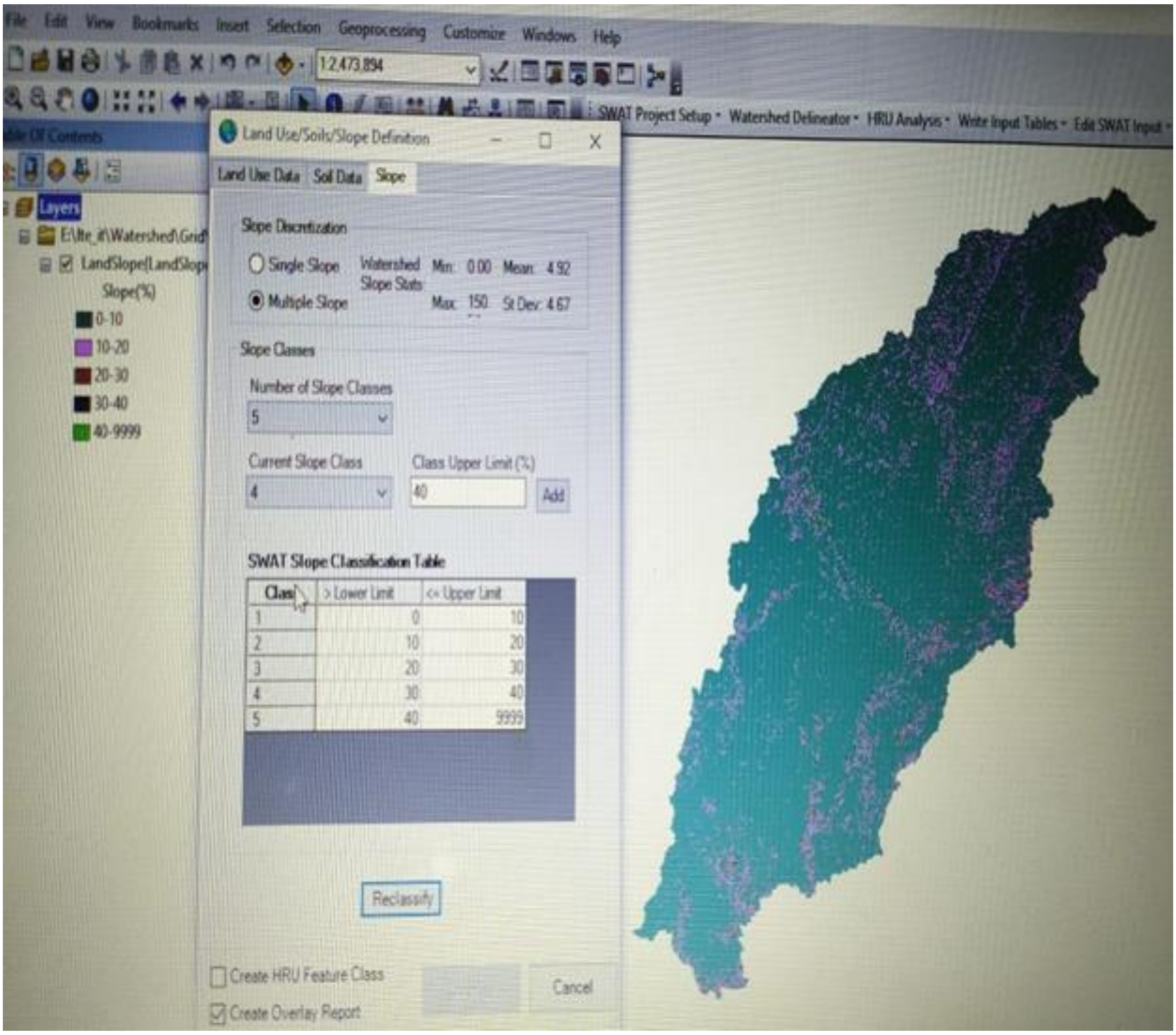

Fig 5.17: Slope map and table in HRU Generation step

After creating all, we want to create a report so this was possible when we overlap the data obtained from land use, soil and slope map

5.4.2 HRU DEFINITION

In this we create HRU by following standard percentage. After clicked create HRU, it tell you how much HRU was there in your area. 271 HRU was created in our study area along with HRU report

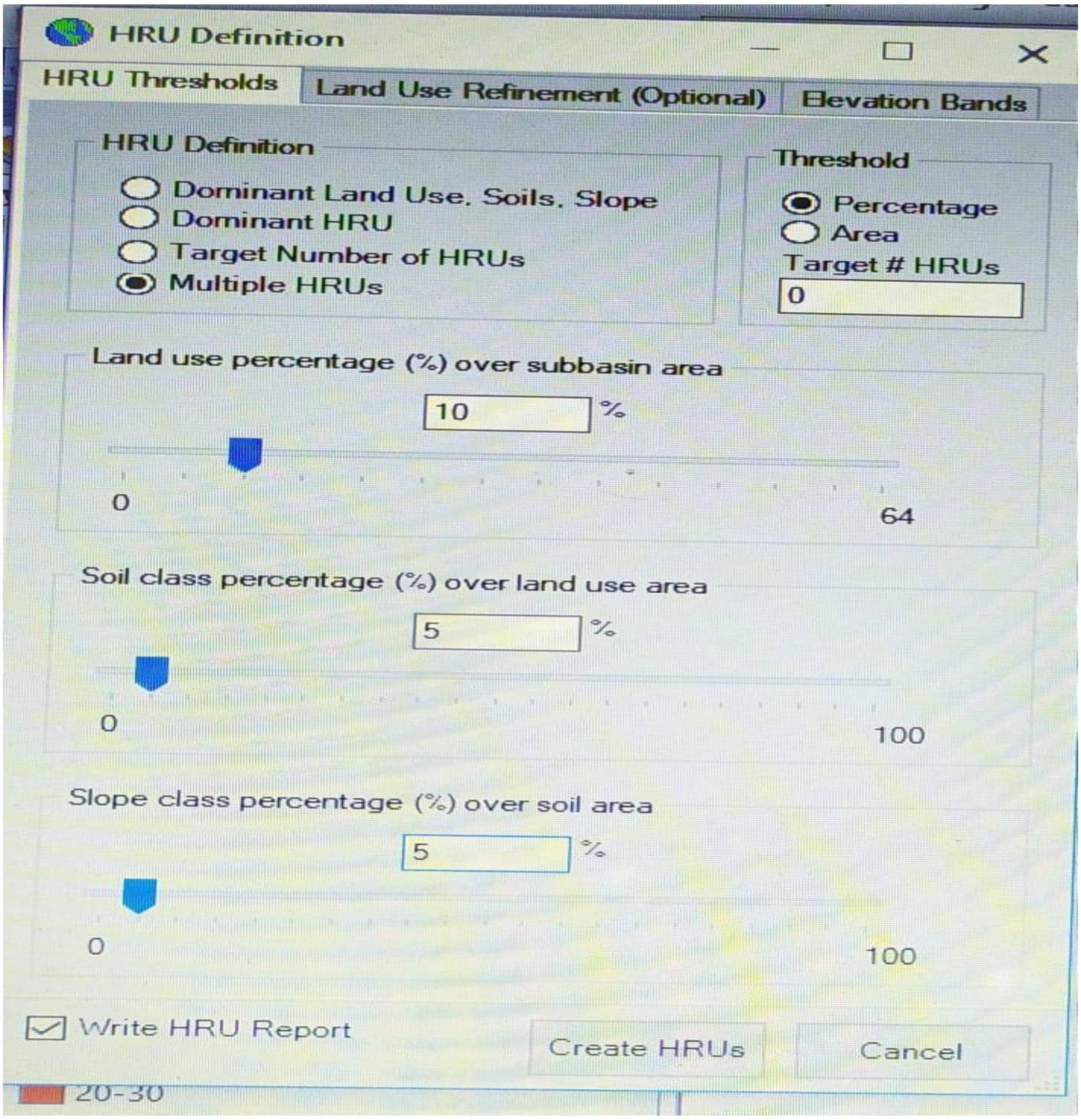

Fig 5.18: HRU Definition step in HRU analysis

5.5 POST HRU ANALYSIS - WRITE INPUT TABLES

5.5.1 CREATING DATA FOR WEATHER DEFINITION

We had to give weather details like temperature, rainfall. So for downloading rainfall and minimum and maximum temperature data from 01-01-1990 to 31-12-2013 on daily basis we had to use global weather data for SWAT given by SWAT website

Got temperature and rainfall data for every station. Now our task was to take data of that station which comes in our study area .

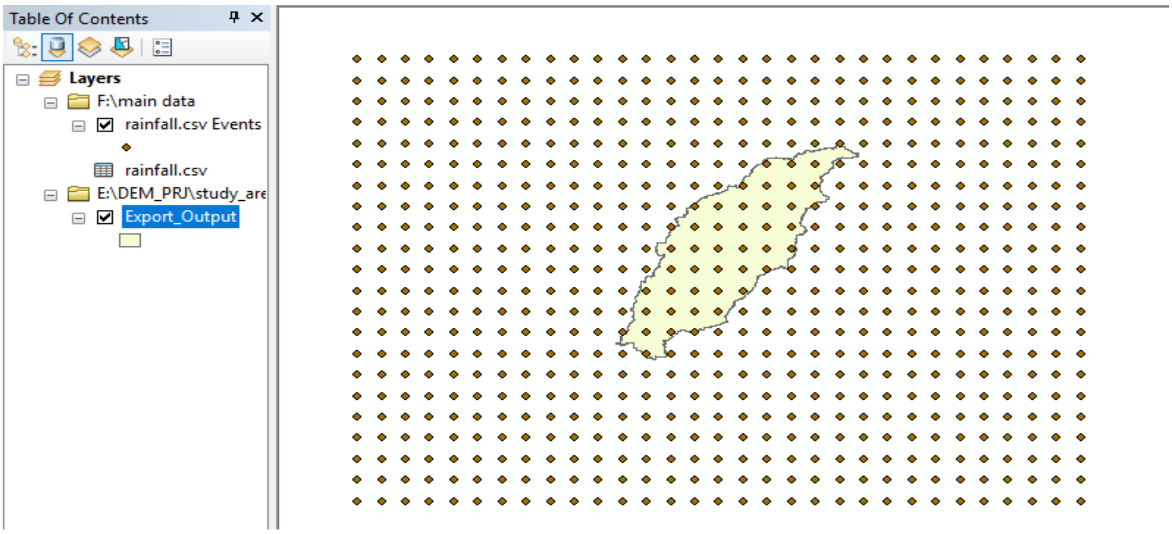

Fig 5.19: rain gauge station inside and outside the study area

Now by extract by clip feature in the arc toolbox, we get the station available in our study area

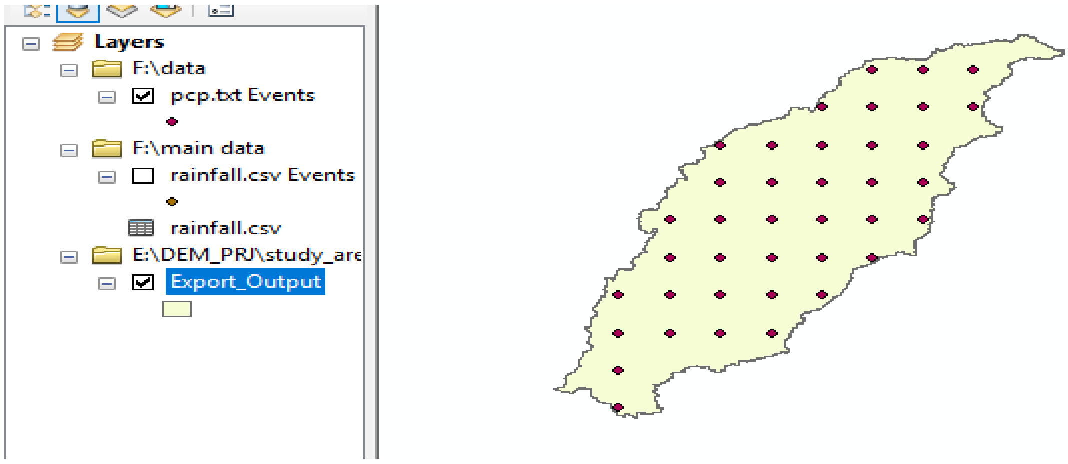

Fig 5.20: Rain gauge station in our study area

Now by seeing in attribute table, get the id of all station in our area and make text file of id available in attribute table for rainfall and temperature. Now our data was created.

5.5.2 USING DATA IN WEATHER DATA DEFINITION

By assigning precipitation time step in a daily time frame and assigning the folder in which rainfall data was present

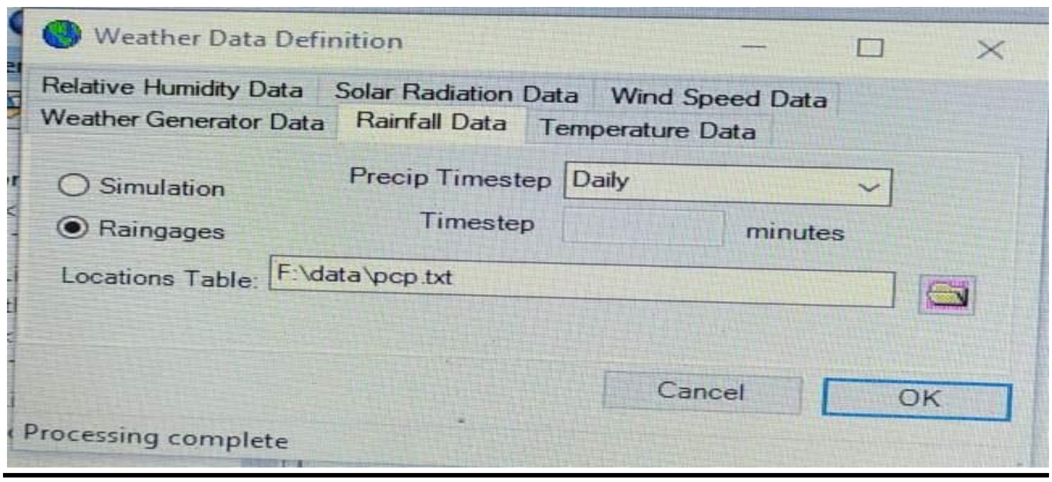

Fig 5.21: Assigning rainfall data in weather data definition window

By assigning the folder in which max and min temperature data was present

Our weather data definition window work got completed

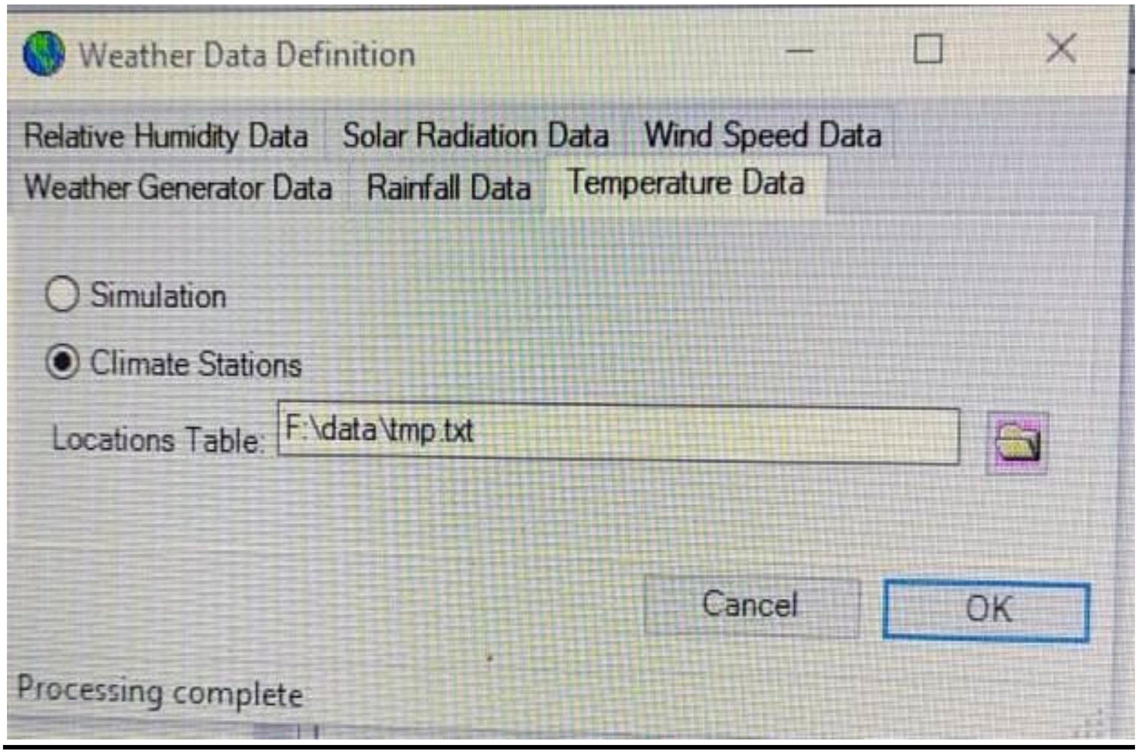

Fig 5.22: Assigning temp data in weather data definition window

5.5.3 WRITE INPUT TABLE FOR SWAT

After clicking on write swat input table in write input tables

We get a window, and now click on select all if all get status-completed then only we create input tables

Now we had to update our input data by clicking on Update data

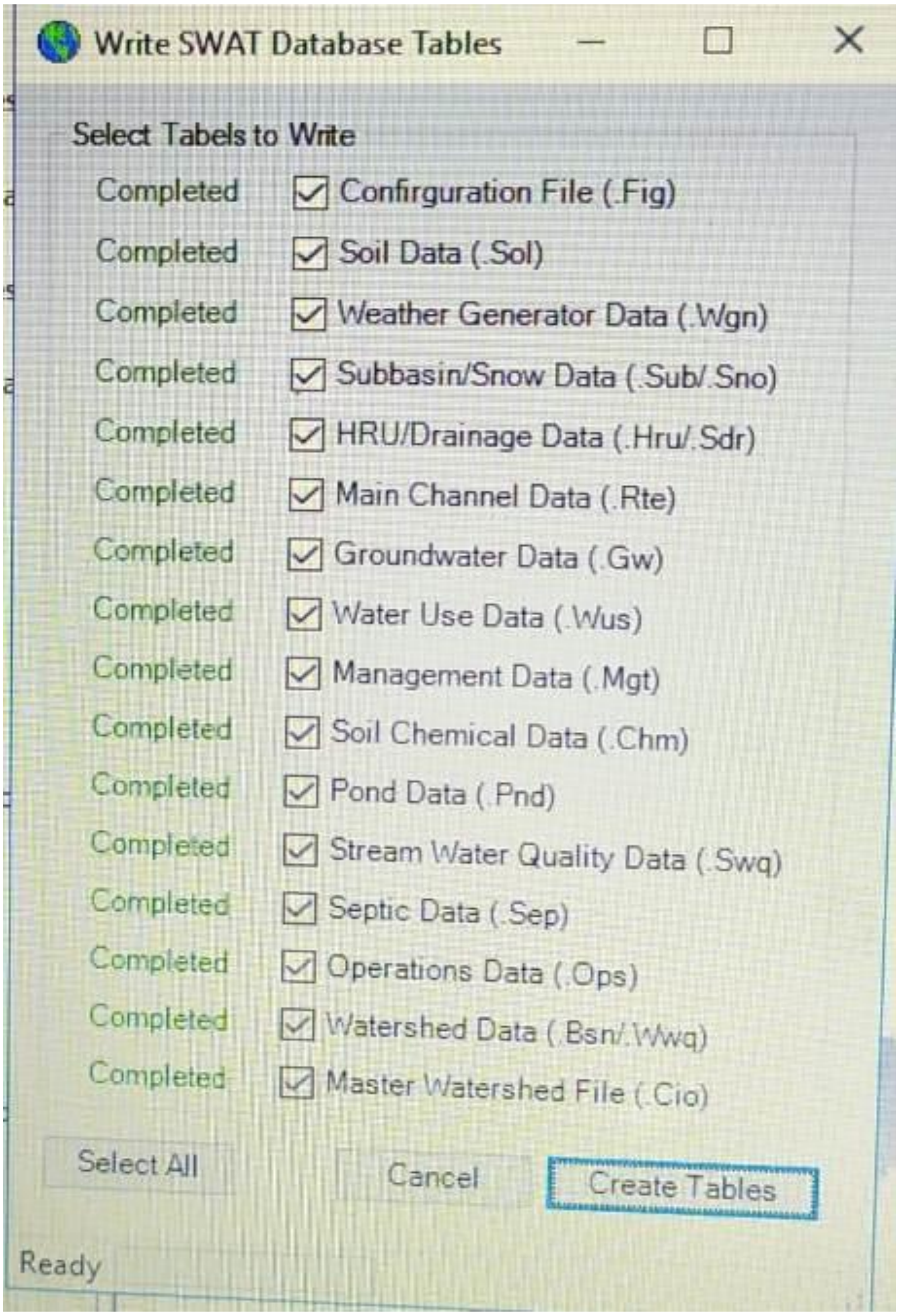

Fig 5.23: Write SWAT Database Tables

5.5.4 DATABASE UPDATE

Now we had to update our input data by clicking on Update data

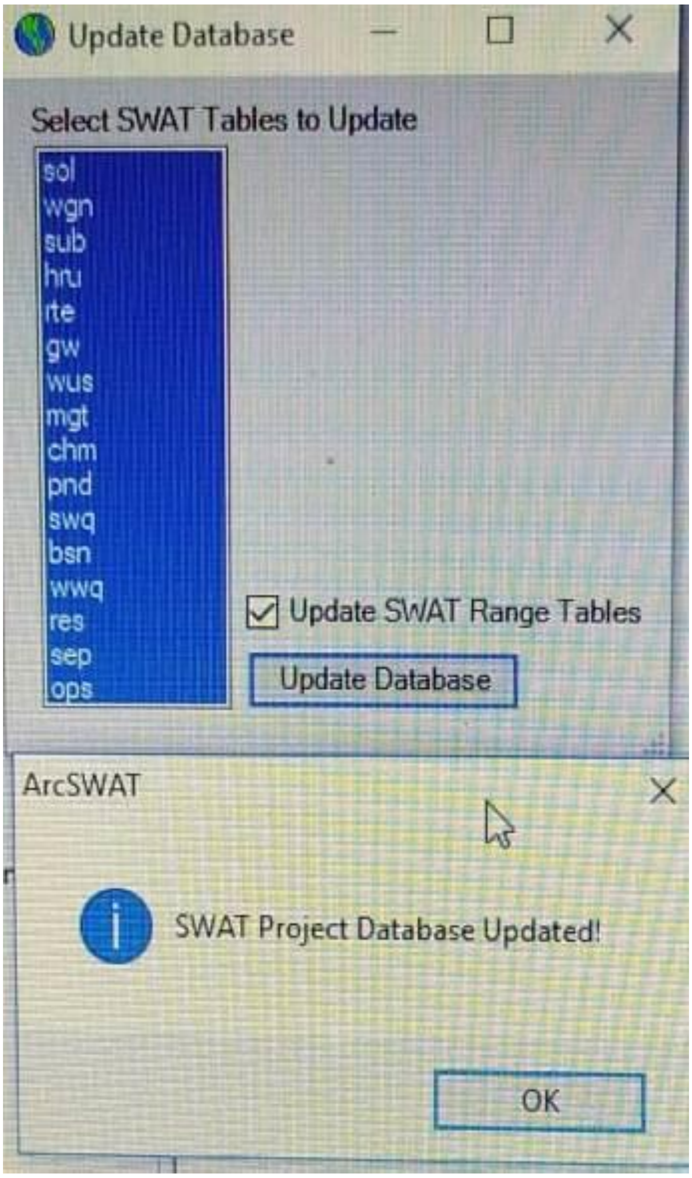

Fig 5.24: Update Database

5.6. POST HRU ANALYSIS - EDIT SWAT INPUT

5.6.1 EDIT GENERAL WATERSHED PARAMETERS

In this we was editing our general data by assigning Potential evapotranspiration method as Hargreaves because we had limited data available precipitation and temperature. So this method is being adopted

We had to assign PET method which was available in the general data window in the watershed data option

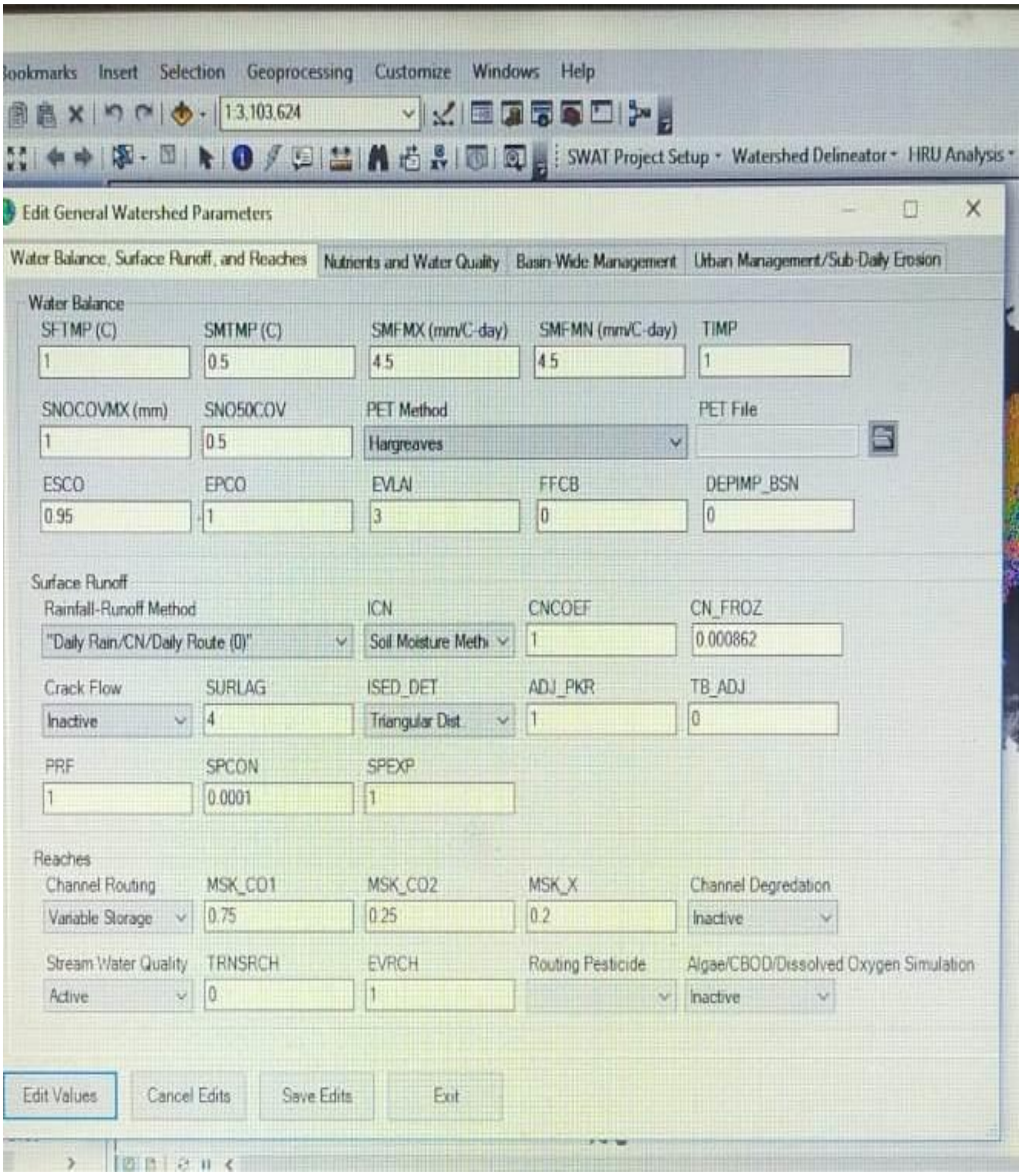

Fig 5.25: General data table

5.6.2 REWRITE SWAT INPUT FILES

We was rewrite our input data by clicking on the select all option And then click on rewrite swat input files

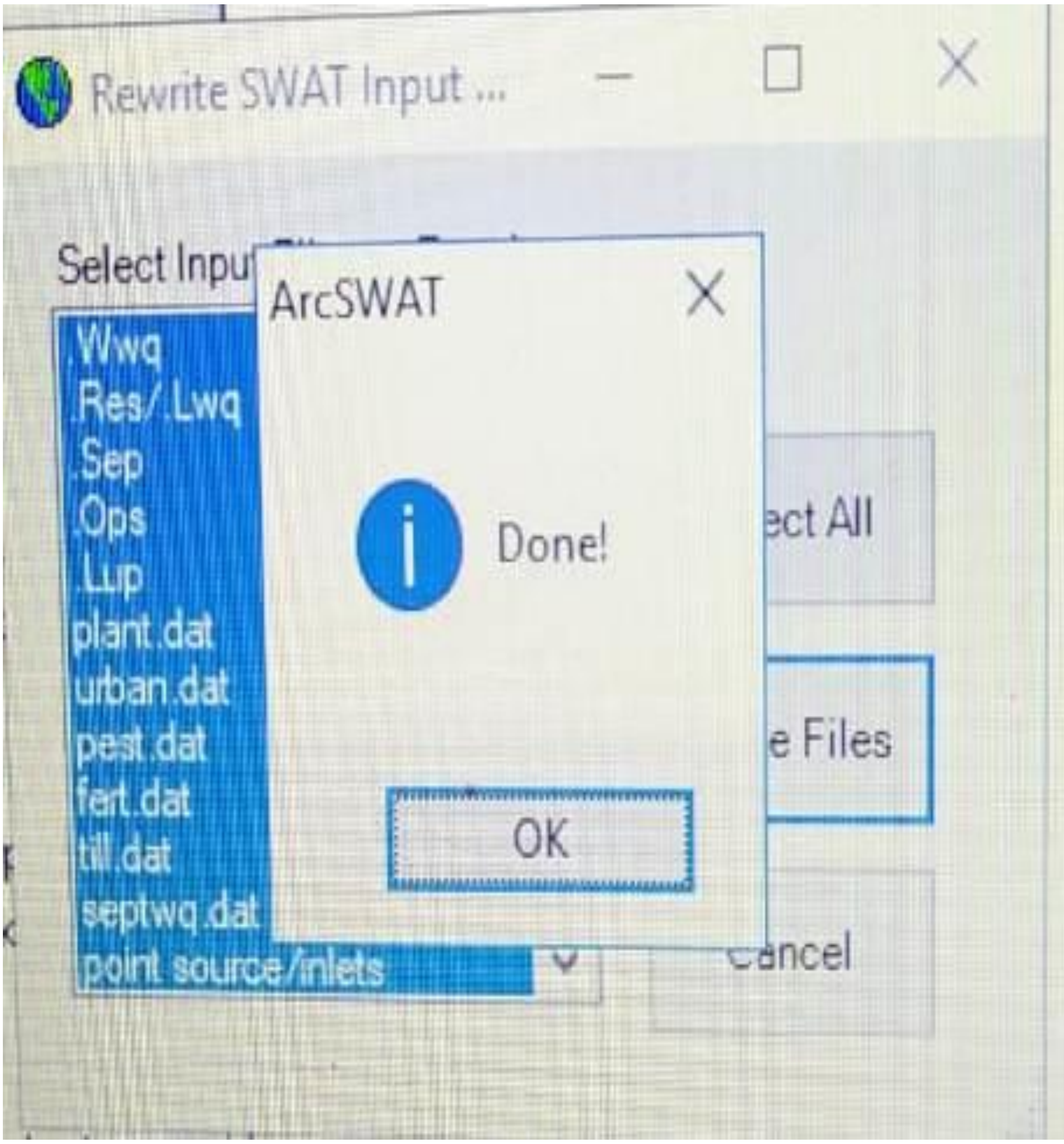

FIG 5.26: Rewrite swat input data

5.7. SET UP FOR SWAT SIMULATION

In this, we had given the period for simulation
Starting date of simulation was 1-1-1990 and the ending date of simulation was 31-12-2013 and give 2 years as warm-up period means In output data it shows from 1-1-1992

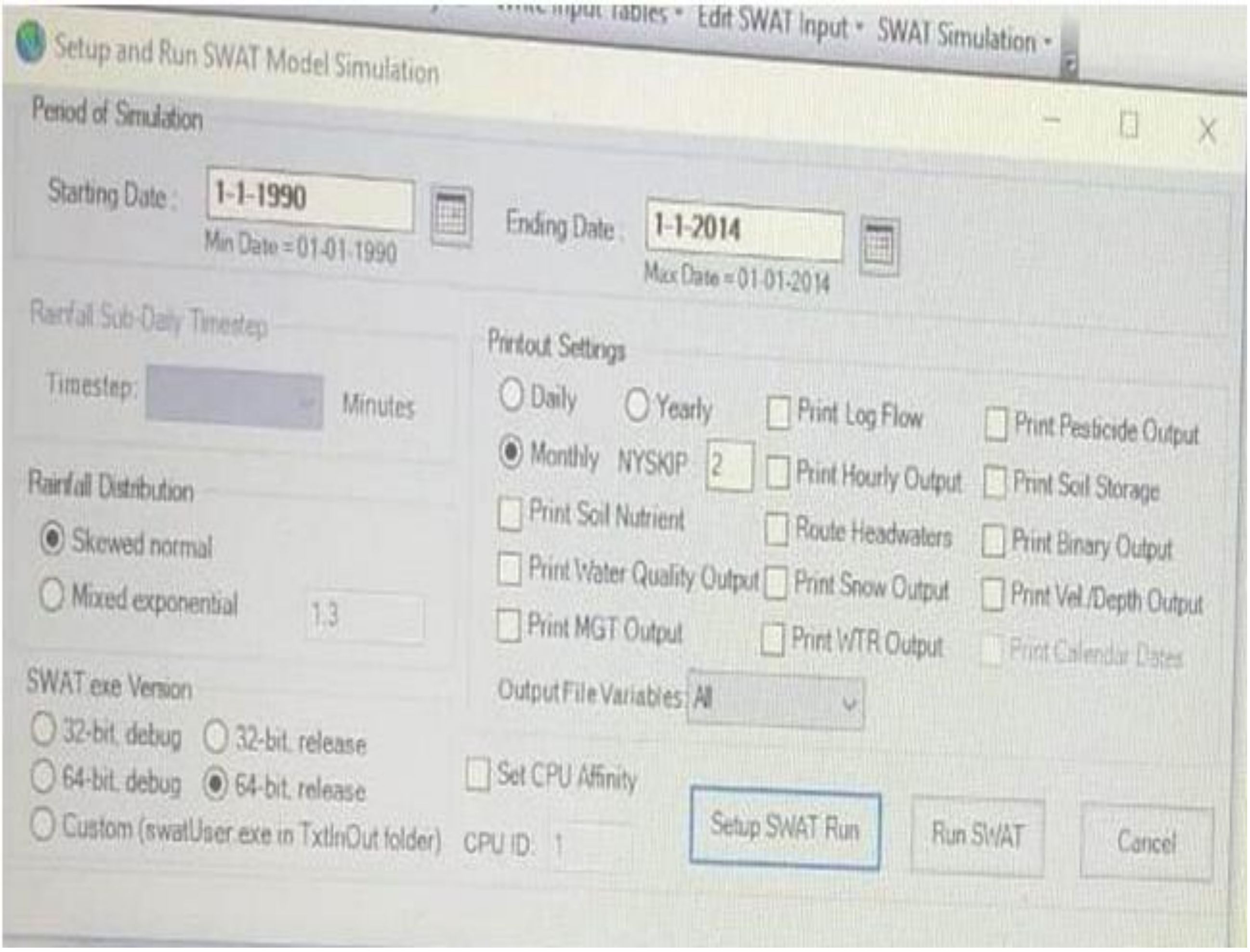

FIG 5.27: Swat Set up window

After clicking on setup swat run. Setup was being completed

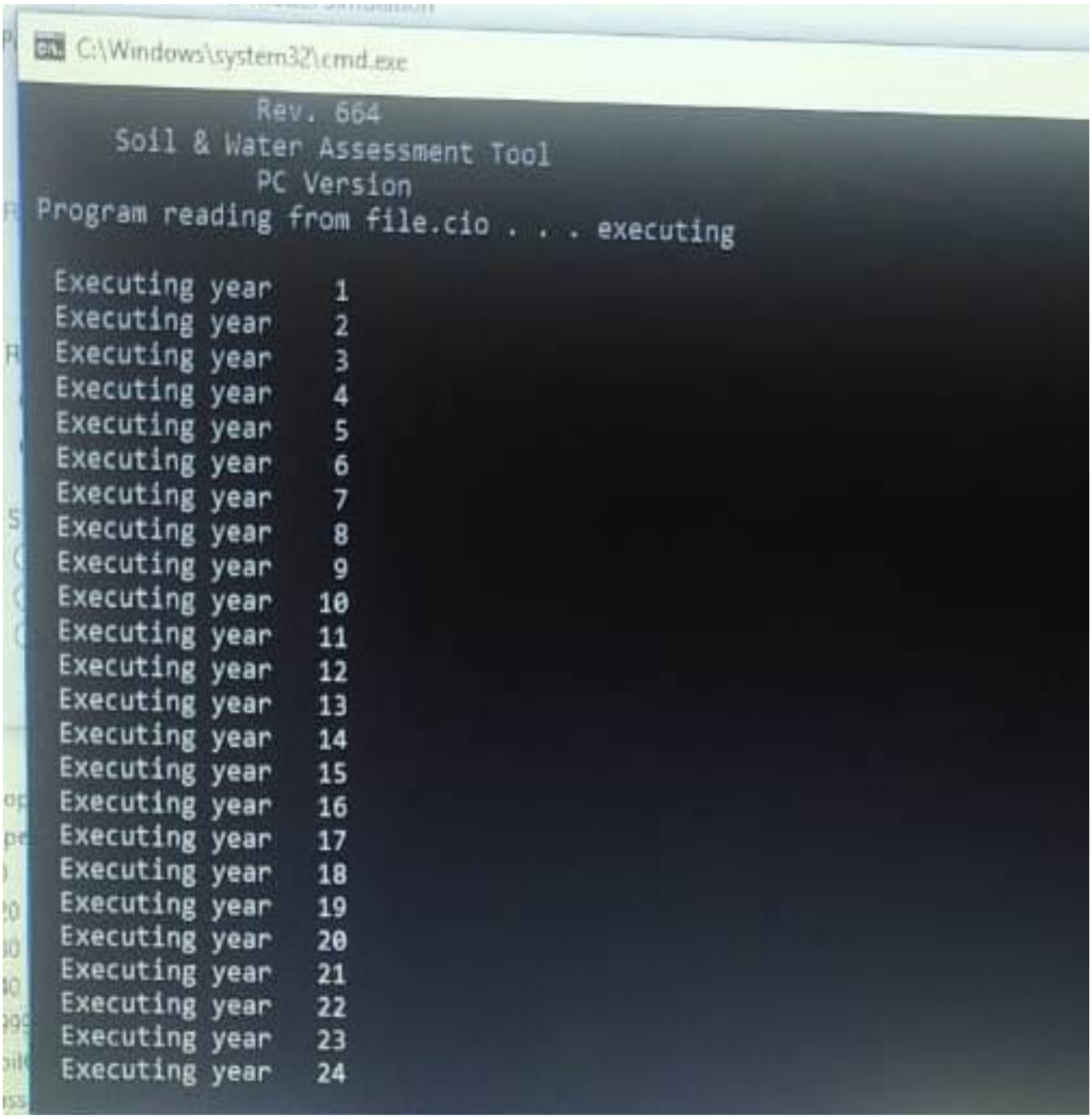

FIG 5.28: SWAT Run was completed

CHAPTER - 6
SWAT SIMULATION

6.1. READ SWAT OUTPUT

In this we had to import our files created till now into database. By Clicked on import files to database

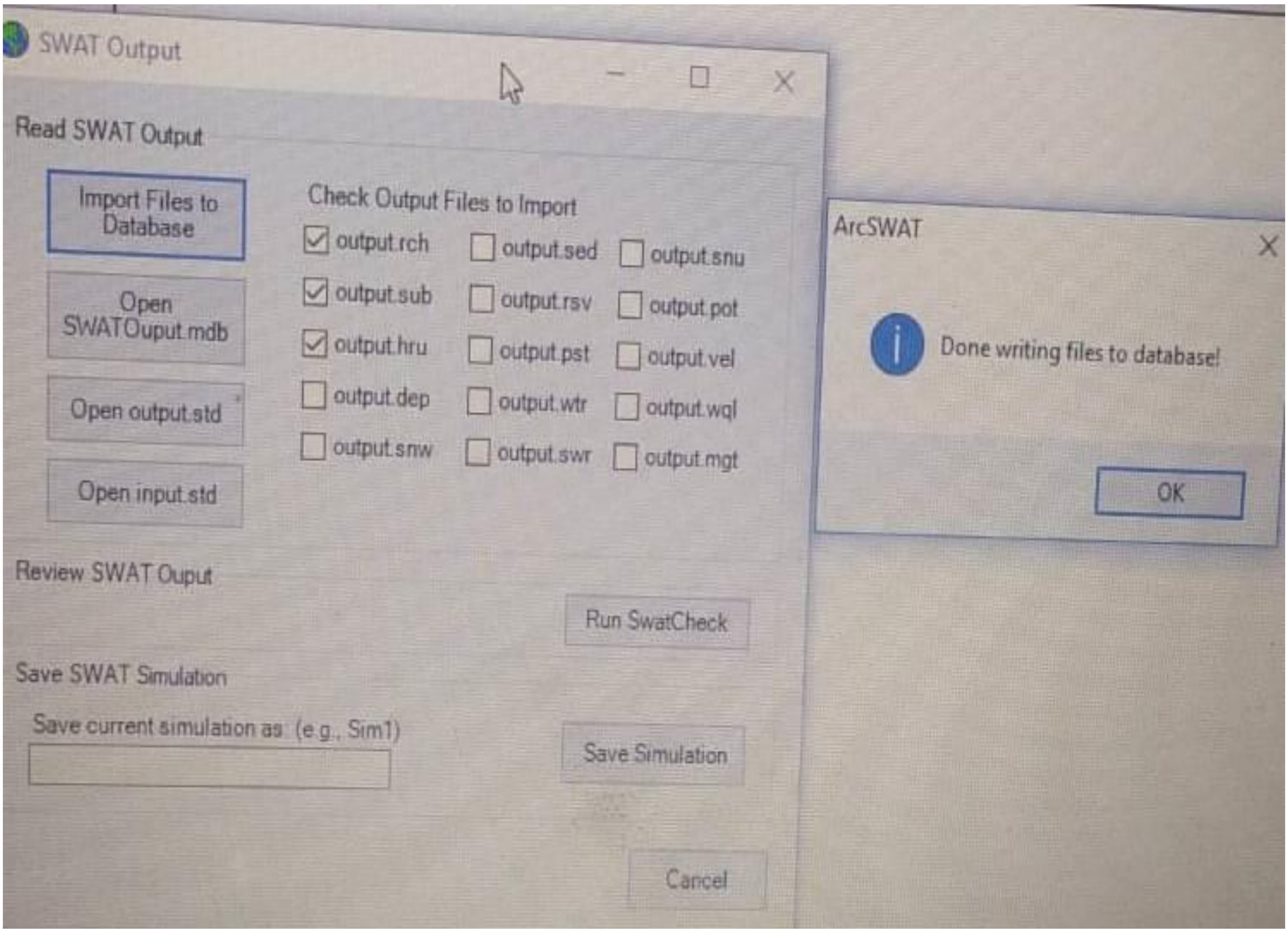

FIG 6.1: Importing Swat File

After this, we had run our swat project by clicking on Run swat check

A new window was appeared then click on examine the model output

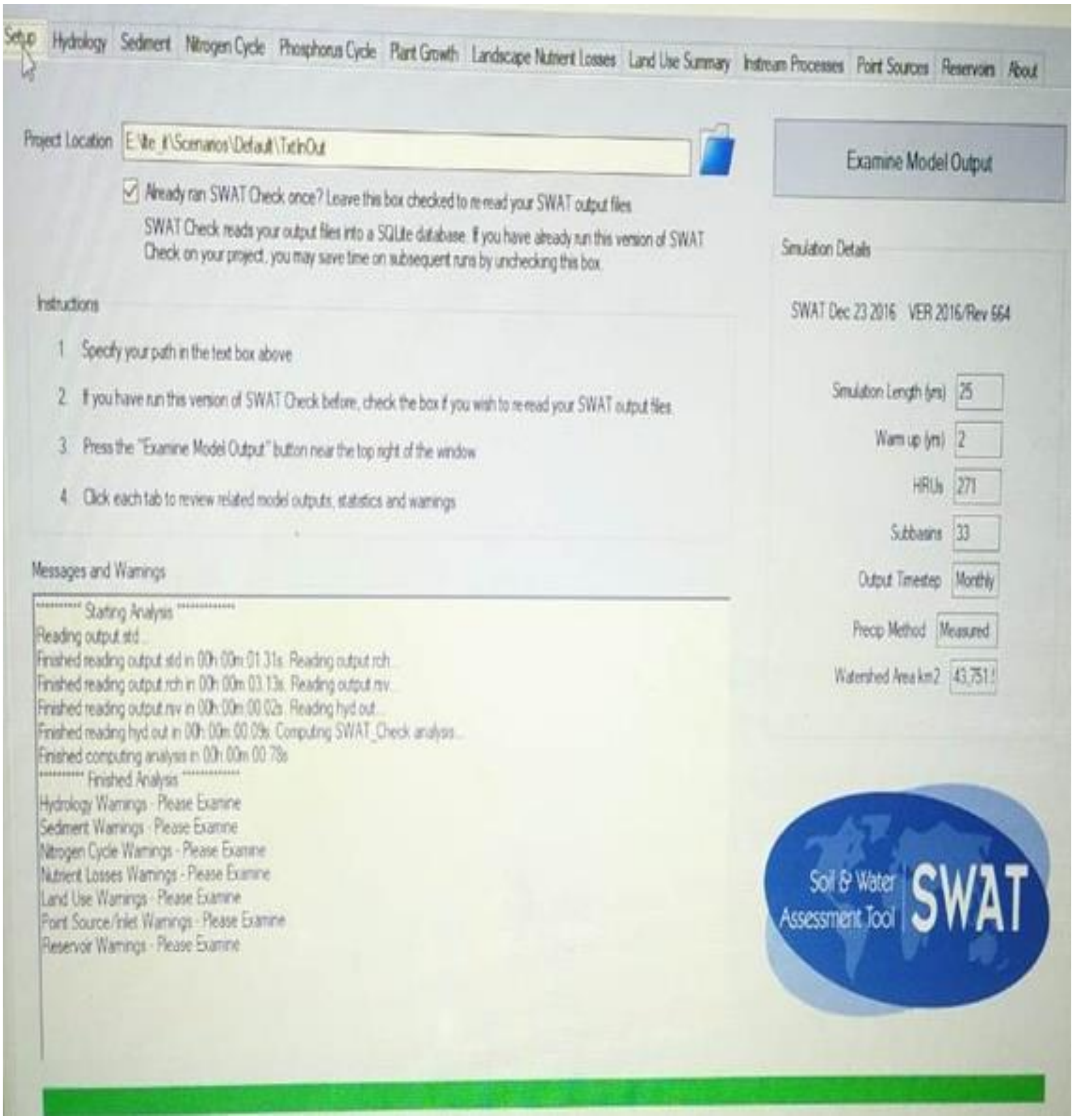

Fig 6.2: Examine the model output

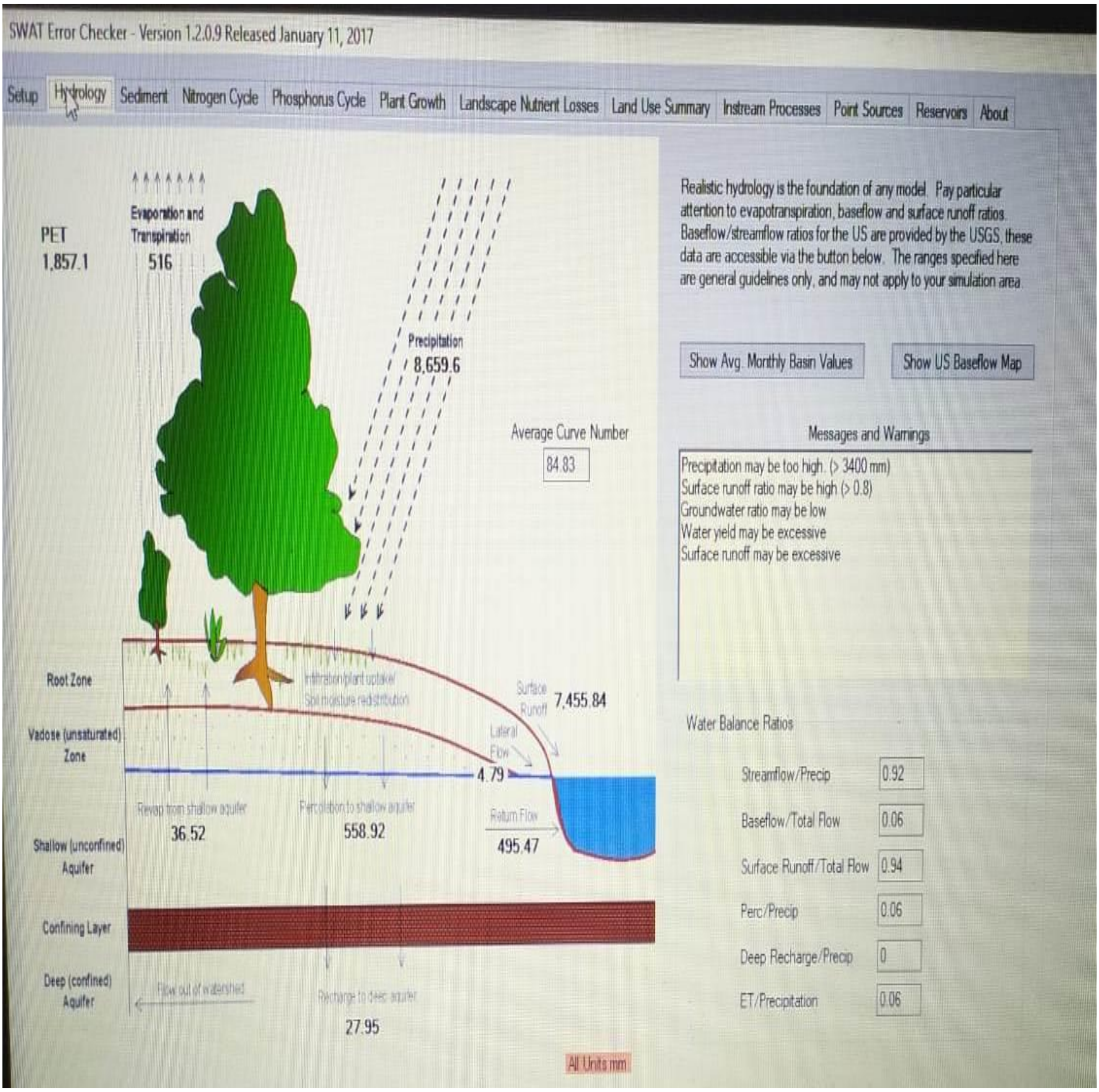

Fig 6.3: SWAT output showing hydrologic cycle with values

In swat output we was getting runoff volume for our study area for given precipitation, min and max temperature value, land, soil and slope map for our area

CHAPTER - 7
CALIBRATION AND VALIDATION

By using the swat app, we get simulated runoff value for each basin for given duration of year at monthly timeframe.
Now we had to compared our simulated runoff value with observed value at site and check accuracy.

we had taken observed value from nautghat station on monthly basis and our station was available in subbasin 4 of our study area and compared with simulated runoff value in subbasin 4

7.1. CALIBRATION

Now we calibrate data from 1990 to 2000 with two years as the warm-up period

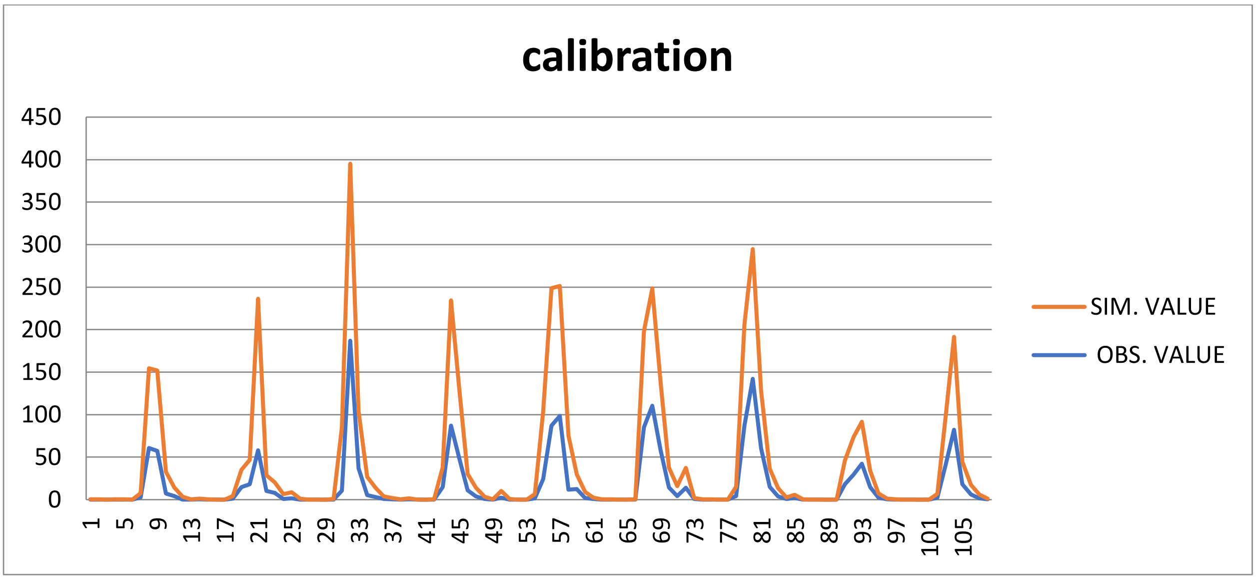

FIG 7.1: Graph between simulated value and observed value for calibration

NS value obtained was 0.58 and the Coefficient of correlation was 0.887 that good . we get 88 percent accuracy

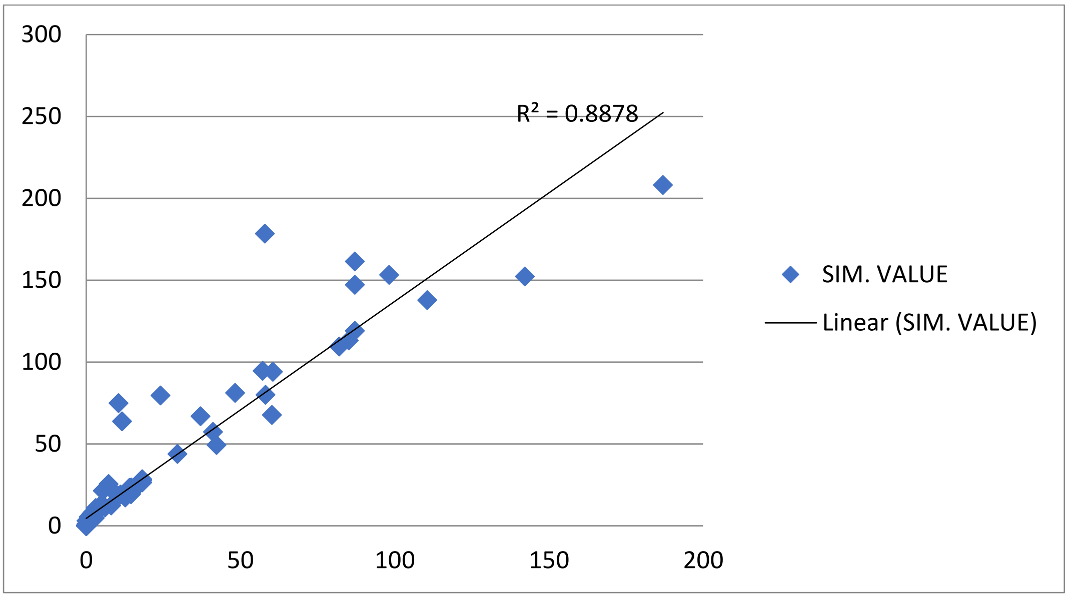

Fig 7.2: R^2 Graph for calibration

7.2. VALIDATION

And for validation, we had taken our data from 1999 to 2013 on monthly basis with two warm-up year

Now we plot a comparison graph between the observed and simulated result

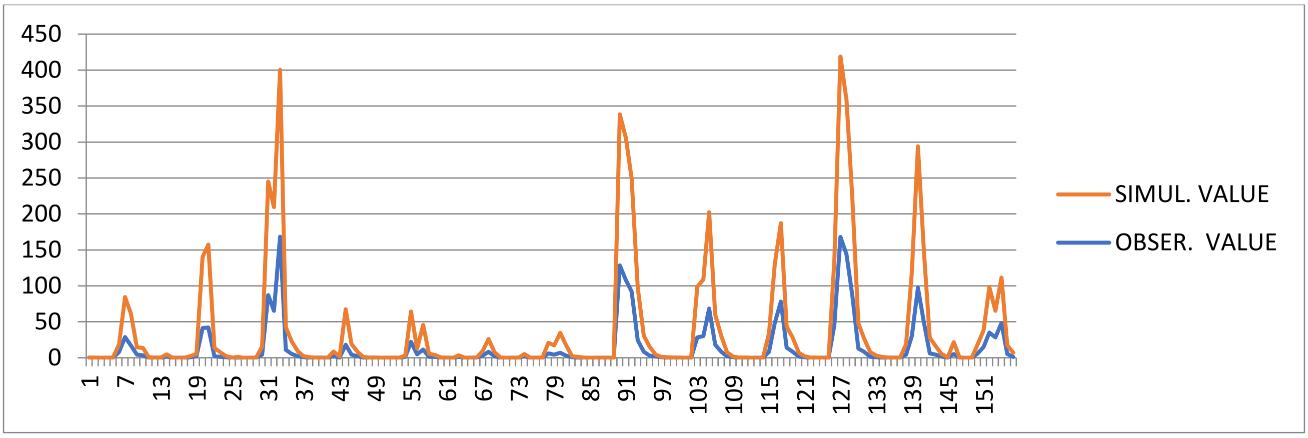

FIG 7.3: comparison graph for simulation

NS value obtained was 0.34 and the Coefficient of correlation was 0.90 that good . We get 90 percent accuracy

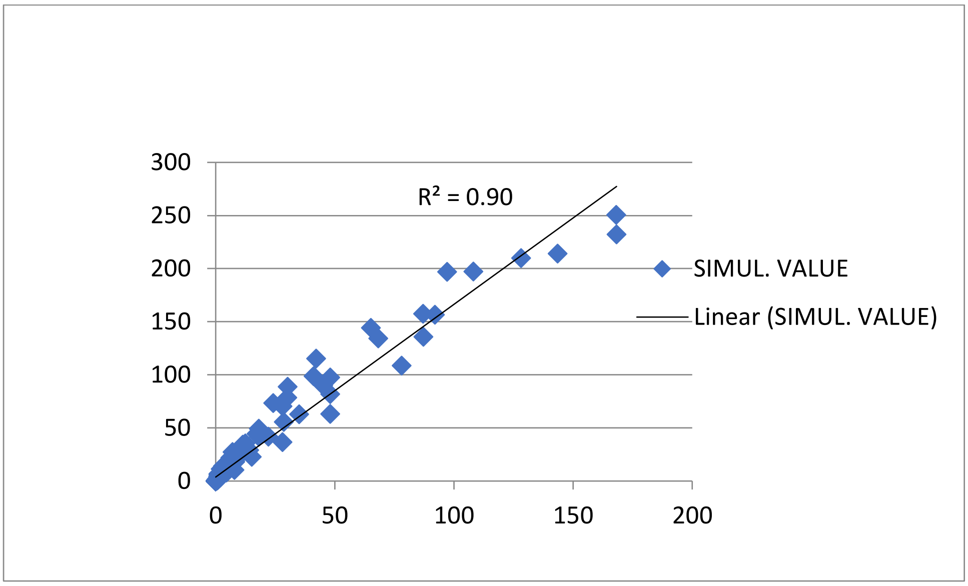

FIG 7.4: R^2 graph for validation

CHAPTER - 8
CONCLUSION

During our study, SWAT model have been used. Rainfall –runoff modeling for betwa basin had basin area 43,751.59 km^2 . It is a helpful tool for applying in water management models in large scale modeling with medium and long time periods.

We had taken observed value from the nautghat station on monthly basis and our station was available in sub basin 4 of our study area and compared with simulated runoff value in sub basin 4

Now we calibrate data from 1990 to 2000 with two years as warm-up period for calibration and for validation we had taken our data from 1999 to 2013 on monthly basis with two warm-up year

Our model was simulated for 24 years . This model gave good and satisfactory results having R^2 value 0.887 for calibration and validation these value was 0.90. The ability of swat model exposed by better match of computer - generated data with observed data.

CHAPTER -9
SCOPE OF FUTURE WORK

- Simulation of Sediment Yield
- Comparison of evapotranspiraton result obtained from SWAT model and MODIS
- Impact of Land use Land cover change on runoff generation

CHAPTER - 10
REFERENCE

[1] Mistry, Ashmita ., and Joshi , Bankim ., " Rainfall Runoff Modelling of Shakkar River using SWAT Model" IJSTE - Volume 4, Issue 10, April 2018, ISSN: 2349 - 784X, 49-50

[2] Patil, Nagraj., Raikar, Rajkumar., and S, Manoj., " Runoff Modelling for Bhima River using SWAT Hydrological Model" IJERT - Volume 3, Issue 7, July 2014, ISSN: 2278 – 0181, 923

[3] Rohtash., Thakural, L.N., and Chaudhary, Dipti., " Runoff Modeling Using SWAT Model for Chaliyr Basin Kerla " IJSR - Volume 8, Issue 5, May 2019, ISSN: 2319 – 7064, 91-92

[4] Singh, Leelambar., and Saravanan, Subbarayan., " Simulation of monthly stream flow using SWAT model of Ib River Watershed " Keai Hydroresearch , Issue 3, Sep 2020, 95-96

[5] Rostamin, Rokshsare., and Jaleh, Aazam., " Application of SWAT Model for estimating runoff and sediment in two mountainous basins in central iran " Hydrological Science Journal - Volume 53, Issue 5, October 2008, ISSN: 0262-6667, 978-979

[6] Shi, Peng., Hou, Yuanbing., and Chen, Chao., " Application of SWAT model for hydrological modeling in xixian watershed " Journal of hydrologic engineering ASCE, Volume 18, Issue 11, November 2013, 1522-1523

[7] Bandi, Anurag., Rao, Y. R ., and Kumar, Sanjeet., "Rainfall Runoff modeling in Ephemeral river basin using SWAT" Journal Of Critical Review, Volume 7, Issue 13, July 2020, ISSN: 2394-5125, 1589-1592

[8] Tibebe, Mahtsente., and Melesse, Assefa., " Rainfall - runoff relation and runoff estimation for Holetta River , Awash sub basin" International Journal of Water resources and environmental engineering, Voume 9, Issue 5, May 2017, ISSN: 2141-6613, 102-104

[9] Kangsabanik, Subhadip., and Murmu, Sneha., "Rainfall-runoff modelling of Ajay river catchment using SWAT model" IOP Conf. Series: Earth and Environmental Science, Volume 67, April 2017, 1-5

[10] Jain, Manoj., and Sharma, Daman., " Hydrological Modeling of vamsadhara river basin , using SWAT " International Conference on Emerging Trends in Computer and Image Processing , Dec 2014, 82-83

[11] Krysanova, Valentina ., and Arnold, Jeffrey., " Advances in Echo hydrological modeling With SWAT - A Review " Hydrological Science Journal, Volume 53, Issue 5, October 2008, ISSN: 0262 – 6667, 940-942

[12] Visharolia, Umang., Shrimali, Narendra., and Prakash, Indra., " Watershed Delineation of Purna River using Geographical Information System (GIS) " International Journal of Advance Engineering and Research Development (IJAERD), Volume 4, Issue 5, May - 2017, ISSN : 2348 6406, 694-695

[13] Thin, SU., Ohgushi, Koichro., and Morita, Toshihiro.,“Rainfall Runoff Modelling of BAGO River in Myanmar” IAHR World Congress, September 2019 , ISSN : 2521 – 7119 , 3728-3730

[14] Narasayya “ impact of changing Land use - Land Cover Using Swat Model Of Indrayani Watershed ” IJSRCSEIT, Volume 5, Issue 6, November 2019, ISSN : 2456 - 3307, 6-8

[15] Ghadei, S.C., and Singh, P.K., “Hydrological modeling in Ong River basin using SWAT Model” JOSH, Volume 14, Issue 2, 2018, 2-6

[16] Karki, Mohan ., and khadka, Bahadur., “ Simulation of rainfall - runoff of kankai river basin using swat model ” IJRASET, Volume 8, Issue VIII, August 2020, ISSN: 2321-9653, 308-311

[17] Patil, Dipali., and Mhatre, Rutuja., “ Hydrological modeling of Penganga Sub - basin using SWAT ” IRJET, Volume 6, Issue 04, April 2019, ISSN : 2395-0056, 1807-1809

[18] George, Celine., and James, E.J., “ Simulation of stream flow using SWAT tool in Meenachil basin ” SJET, 2013, ISSN 2321 – 4358, 68-69

APPENDIX I

PRECIPITATION AND TEMPERATURE STATION LOCATIONS

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543,p229775,22.949,77.500,546.000
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597,p245778,24.510,77.813,470.000
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641,p245781,24.510,78.125,418.000
643,p248781,24.822,78.125,354.000
645,p251781,25.134,78.125,411.000
679,p236784,23.573,78.438,547.000
681,p239784,23.885,78.438,484.000
683,p242784,24.198,78.438,415.000
685,p245784,24.510,78.438,465.000
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tmp - Notepad

File Edit Format View Help

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```

APPENDIX II

OUTPUT TABLE FOR SUBBASIN IV

SUB	YEAR	MON	AREAkm2	FLOW_INcms	FLOW_OUTcms	EVAPcms
4	1992	1	1200	0.4678	0.3917	0.0761
4	1992	2	1200	0.2995	0.2018	0.0977
4	1992	3	1200	0.2242	0.07978	0.14442
4	1992	4	1200	0.4151	0.2493	0.1658
4	1992	5	1200	0.4547	0.3099	0.1448
4	1992	6	1200	0.1156	0.01052	0.10508
4	1992	7	1200	4.938	4.827	0.111
4	1992	8	1200	94.16	94.05	0.11
4	1992	9	1200	94.85	94.74	0.11
4	1992	10	1200	25.66	25.55	0.11
4	1992	11	1200	10.26	10.18	0.08
4	1992	12	1200	3.248	3.18	0.068
4	1993	1	1200	0.5546	0.483	0.0716
4	1993	2	1200	1.153	1.049	0.104
4	1993	3	1200	0.6291	0.5023	0.1268
4	1993	4	1200	0.175	0.01461	0.16039
4	1993	5	1200	0.1293	0	0.1293
4	1993	6	1200	3.167	3.048	0.119
4	1993	7	1200	20.46	20.32	0.14
4	1993	8	1200	28.69	28.56	0.13
4	1993	9	1200	178.6	178.5	0.1
4	1993	10	1200	18.77	18.66	0.11
4	1993	11	1200	12.49	12.41	0.08
4	1993	12	1200	5.56	5.49	0.07
4	1994	1	1200	7.354	7.286	0.068
4	1994	2	1200	1.191	1.098	0.093
4	1994	3	1200	0.2422	0.09322	0.14898
4	1994	4	1200	0.2138	0.05161	0.16219
4	1994	5	1200	0.1334	0.00001995	0.13338005
4	1994	6	1200	0.7476	0.6266	0.121
4	1994	7	1200	75.02	74.91	0.11
4	1994	8	1200	208.3	208.2	0.1
4	1994	9	1200	67.05	66.95	0.1
4	1994	10	1200	21.53	21.42	0.11
4	1994	11	1200	11.03	10.94	0.09
4	1994	12	1200	2.976	2.903	0.073
4	1995	1	1200	1.627	1.559	0.068
4	1995	2	1200	0.3903	0.2859	0.1044
4	1995	3	1200	1.229	1.1	0.129
4	1995	4	1200	0.2144	0.03705	0.17735
4	1995	5	1200	0.158	0.0001024	0.1578976
4	1995	6	1200	0.3104	0.1741	0.1363
4	1995	7	1200	23.61	23.49	0.12

4	1995	8	1200	147.4	147.3	0.1
4	1995	9	1200	81.33	81.22	0.11
4	1995	10	1200	19.35	19.24	0.11
4	1995	11	1200	10.14	10.05	0.09
4	1995	12	1200	2.682	2.614	0.068
4	1996	1	1200	0.6092	0.5421	0.0671
4	1996	2	1200	8.286	8.195	0.091
4	1996	3	1200	0.7027	0.5656	0.1371
4	1996	4	1200	0.1864	0.01255	0.17385
4	1996	5	1200	0.1373	0	0.1373
4	1996	6	1200	5.017	4.894	0.123
4	1996	7	1200	79.77	79.65	0.12
4	1996	8	1200	161.6	161.5	0.1
4	1996	9	1200	153.4	153.3	0.1
4	1996	10	1200	63.86	63.77	0.09
4	1996	11	1200	17.4	17.31	0.09
4	1996	12	1200	6.992	6.922	0.07
4	1997	1	1200	1.58	1.509	0.071
4	1997	2	1200	0.5729	0.4663	0.1066
4	1997	3	1200	0.4072	0.2655	0.1417
4	1997	4	1200	0.3237	0.1546	0.1691
4	1997	5	1200	0.2383	0.05035	0.18795
4	1997	6	1200	0.4393	0.2846	0.1547
4	1997	7	1200	113.3	113.2	0.1
4	1997	8	1200	137.9	137.8	0.1
4	1997	9	1200	80.1	80	0.1
4	1997	10	1200	23.47	23.37	0.1
4	1997	11	1200	11.77	11.69	0.08
4	1997	12	1200	23.3	23.26	0.04
4	1998	1	1200	1.343	1.281	0.062
4	1998	2	1200	0.5008	0.4117	0.0891
4	1998	3	1200	0.5262	0.4014	0.1248
4	1998	4	1200	0.2834	0.1118	0.1716
4	1998	5	1200	0.1688	0.0008724	0.1679276
4	1998	6	1200	11.12	10.98	0.14
4	1998	7	1200	119.3	119.2	0.1
4	1998	8	1200	152.6	152.4	0.2
4	1998	9	1200	67.92	67.81	0.11
4	1998	10	1200	21.55	21.44	0.11
4	1998	11	1200	9.707	9.627	0.08
4	1998	12	1200	2.092	2.02	0.072
4	1999	1	1200	3.786	3.729	0.057
4	1999	2	1200	0.3319	0.2538	0.0781
4	1999	3	1200	0.2387	0.08993	0.14877
4	1999	4	1200	0.177	0.00344	0.17356

4	1999	5	1200	0.1314	0	0.1314
4	1999	6	1200	0.2011	0.07482	0.12628
4	1999	7	1200	28.03	27.9	0.13
4	1999	8	1200	44.03	43.91	0.12
4	1999	9	1200	49.43	49.32	0.11
4	1999	10	1200	19.43	19.32	0.11
4	1999	11	1200	4.796	4.705	0.091
4	1999	12	1200	0.8963	0.8231	0.0732
4	2000	1	1200	0.2404	0.1618	0.0786
4	2000	2	1200	0.1641	0.06498	0.09912
4	2000	3	1200	0.1231	0.001422	0.121678
4	2000	4	1200	0.09164	0	0.09164
4	2000	5	1200	0.07496	0.00113	0.07383
4	2000	6	1200	4.602	4.491	0.111
4	2000	7	1200	57.5	57.38	0.12
4	2000	8	1200	109.6	109.5	0.1
4	2000	9	1200	26.67	26.54	0.13
4	2000	10	1200	11.48	11.34	0.14
4	2000	11	1200	4.588	4.489	0.099
4	2000	12	1200	0.8256	0.7463	0.0793
4	2001	1	1200	0.3968	0.3164	0.0804
4	2001	2	1200	0.2092	0.09391	0.11529
4	2001	3	1200	0.1516	0.01358	0.13802
4	2001	4	1200	0.1127	0	0.1127
4	2001	5	1200	0.0837	0	0.0837
4	2001	6	1200	10.81	10.7	0.11
4	2001	7	1200	55.79	55.68	0.11
4	2001	8	1200	44.85	44.73	0.12
4	2001	9	1200	10.74	10.61	0.13
4	2001	10	1200	10.51	10.39	0.12
4	2001	11	1200	0.7504	0.657	0.0934
4	2001	12	1200	0.2299	0.1523	0.0776
4	2002	1	1200	0.1596	0.08747	0.07213
4	2002	2	1200	3.064	2.963	0.101
4	2002	3	1200	0.0958	0.0003063	0.0954937
4	2002	4	1200	0.06993	0	0.06993
4	2002	5	1200	0.0516	0	0.0516
4	2002	6	1200	1.603	1.549	0.054
4	2002	7	1200	3.488	3.35	0.138
4	2002	8	1200	98.97	98.87	0.1
4	2002	9	1200	115.5	115.4	0.1
4	2002	10	1200	11.57	11.45	0.12
4	2002	11	1200	6.392	6.301	0.091
4	2002	12	1200	1.306	1.231	0.075
4	2003	1	1200	0.3767	0.3028	0.0739

4	2003	2	1200	0.9805	0.8836	0.0969
4	2003	3	1200	0.1562	0.02241	0.13379
4	2003	4	1200	0.1139	0	0.1139
4	2003	5	1200	0.08465	0	0.08465
4	2003	6	1200	11.18	11.08	0.1
4	2003	7	1200	157.8	157.7	0.1
4	2003	8	1200	144.5	144.4	0.1
4	2003	9	1200	232.3	232.3	0
4	2003	10	1200	31.6	31.49	0.11
4	2003	11	1200	16.88	16.79	0.09
4	2003	12	1200	6.609	6.539	0.07
4	2004	1	1200	1.228	1.161	0.067
4	2004	2	1200	0.5502	0.4473	0.1029
4	2004	3	1200	0.4042	0.245	0.1592
4	2004	4	1200	0.3003	0.1126	0.1877
4	2004	5	1200	0.2229	0.03228	0.19062
4	2004	6	1200	6.694	6.544	0.15
4	2004	7	1200	1.105	0.9694	0.1356
4	2004	8	1200	49.64	49.53	0.11
4	2004	9	1200	15.02	14.89	0.13
4	2004	10	1200	6.478	6.375	0.103
4	2004	11	1200	0.9967	0.9077	0.089
4	2004	12	1200	0.1883	0.1146	0.0737
4	2005	1	1200	0.2059	0.1352	0.0707
4	2005	2	1200	0.1006	0.01232	0.08828
4	2005	3	1200	0.068	0	0.068
4	2005	4	1200	0.04914	0	0.04914
4	2005	5	1200	0.03658	0	0.03658
4	2005	6	1200	1.899	1.837	0.062
4	2005	7	1200	42.16	42.05	0.11
4	2005	8	1200	8.223	8.091	0.132
4	2005	9	1200	34.5	34.4	0.1
4	2005	10	1200	4.492	4.382	0.11
4	2005	11	1200	3.017	2.925	0.092
4	2005	12	1200	0.4687	0.3968	0.0719
4	2006	1	1200	0.1437	0.06262	0.08108
4	2006	2	1200	0.1095	0.003125	0.106375
4	2006	3	1200	2.375	2.27	0.105
4	2006	4	1200	0.06812	0	0.06812
4	2006	5	1200	0.04883	0	0.04883
4	2006	6	1200	0.3904	0.3365	0.0539
4	2006	7	1200	6.736	6.626	0.11
4	2006	8	1200	18.25	18.14	0.11
4	2006	9	1200	5.431	5.312	0.119
4	2006	10	1200	0.2144	0.1204	0.094

4	2006	11	1200	0.05411	0.001051	0.053059
4	2006	12	1200	0.03748	0	0.03748
4	2007	1	1200	0.02702	0	0.02702
4	2007	2	1200	3.485	3.428	0.057
4	2007	3	1200	0.02514	0	0.02514
4	2007	4	1200	0.01659	0	0.01659
4	2007	5	1200	0.01171	0	0.01171
4	2007	6	1200	14.56	14.48	0.08
4	2007	7	1200	13.31	13.2	0.11
4	2007	8	1200	27.67	27.56	0.11
4	2007	9	1200	14.41	14.3	0.11
4	2007	10	1200	1.462	1.345	0.117
4	2007	11	1200	0.8664	0.7704	0.096
4	2007	12	1200	0.2183	0.145	0.0733
4	2008	1	1200	0.1255	0.04829	0.07721
4	2008	2	1200	0.09452	0.007733	0.086787
4	2008	3	1200	0.0711	0	0.0711
4	2008	4	1200	0.05291	0	0.05291
4	2008	5	1200	0.05686	0.002165	0.054695
4	2008	6	1200	210.4	210.3	0.1
4	2008	7	1200	197.4	197.3	0.1
4	2008	8	1200	156.9	156.8	0.1
4	2008	9	1200	73.72	73.61	0.11
4	2008	10	1200	22.59	22.48	0.11
4	2008	11	1200	12.29	12.2	0.09
4	2008	12	1200	2.993	2.92	0.073
4	2009	1	1200	0.8584	0.7848	0.0736
4	2009	2	1200	0.4816	0.3673	0.1143
4	2009	3	1200	0.3492	0.1972	0.152
4	2009	4	1200	0.2593	0.07718	0.18212
4	2009	5	1200	0.1924	0.005248	0.187152
4	2009	6	1200	0.4357	0.2914	0.1443
4	2009	7	1200	70.74	70.61	0.13
4	2009	8	1200	78.7	78.6	0.1
4	2009	9	1200	134.5	134.4	0.1
4	2009	10	1200	41.99	41.89	0.1
4	2009	11	1200	22.1	22.02	0.08
4	2009	12	1200	5.218	5.155	0.063
4	2010	1	1200	0.9767	0.9088	0.0679
4	2010	2	1200	0.4097	0.3109	0.0988
4	2010	3	1200	0.2575	0.1079	0.1496
4	2010	4	1200	0.1913	0.01099	0.18031
4	2010	5	1200	0.142	0.0001365	0.1418635
4	2010	6	1200	0.125	0.01257	0.11243

4	2010	7	1200	26	25.88	0.12
4	2010	8	1200	82.04	81.93	0.11
4	2010	9	1200	109	108.9	0.1
4	2010	10	1200	29.27	29.17	0.1
4	2010	11	1200	19.75	19.68	0.07
4	2010	12	1200	5.616	5.552	0.064
4	2011	1	1200	1.15	1.084	0.066
4	2011	2	1200	0.4458	0.351	0.0948
4	2011	3	1200	0.2827	0.1378	0.1449
4	2011	4	1200	0.2099	0.02696	0.18294
4	2011	5	1200	0.1558	0.0001039	0.1556961
4	2011	6	1200	90.28	90.15	0.13
4	2011	7	1200	250.9	250.8	0.1
4	2011	8	1200	214.5	214.4	0.1
4	2011	9	1200	136.2	136.1	0.1
4	2011	10	1200	35.66	35.54	0.12
4	2011	11	1200	18.56	18.47	0.09
4	2011	12	1200	6.985	6.914	0.071
4	2012	1	1200	2.282	2.221	0.061
4	2012	2	1200	0.6666	0.5677	0.0989
4	2012	3	1200	0.4907	0.3424	0.1483
4	2012	4	1200	0.3642	0.1803	0.1839
4	2012	5	1200	0.2762	0.07617	0.20003
4	2012	6	1200	15	14.82	0.18
4	2012	7	1200	88.97	88.85	0.12
4	2012	8	1200	197.1	197	0.1
4	2012	9	1200	97.89	97.79	0.1
4	2012	10	1200	22.01	21.9	0.11
4	2012	11	1200	11.61	11.52	0.09
4	2012	12	1200	3.534	3.46	0.074
4	2013	1	1200	0.7055	0.6308	0.0747
4	2013	2	1200	16.76	16.67	0.09
4	2013	3	1200	0.3506	0.2155	0.1351
4	2013	4	1200	0.2305	0.05412	0.17638
4	2013	5	1200	0.1694	0.0006181	0.1687819
4	2013	6	1200	12.61	12.48	0.13
4	2013	7	1200	22.88	22.76	0.12
4	2013	8	1200	63.17	63.07	0.1
4	2013	9	1200	37.01	36.9	0.11
4	2013	10	1200	63.26	63.17	0.09
4	2013	11	1200	12.31	12.23	0.08
4	2013	12	1200	5.743	5.675	0.068