Isolating the Impacts of Climate Change using QSWAT Model on Uguem River Streamflow at Goa, India

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Structure

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- Results from climate modeling
- Results from hydrological modeling
- Conclusion and Recommendations

Background

- Climate change studies predict impacts on water resources in India
- **Spatial and temporal variation in impacts**
- Impacts include higher annual average rainfall as well as increased drought
- This **can have negative impacts of water supply**
- Primarily the **political and technical adaptation measures** are taken at **local level**
- Hence, **site-specific studies are important** to provide solutions at grass-roots level
- This was the rationale for this study

Objectives of the study

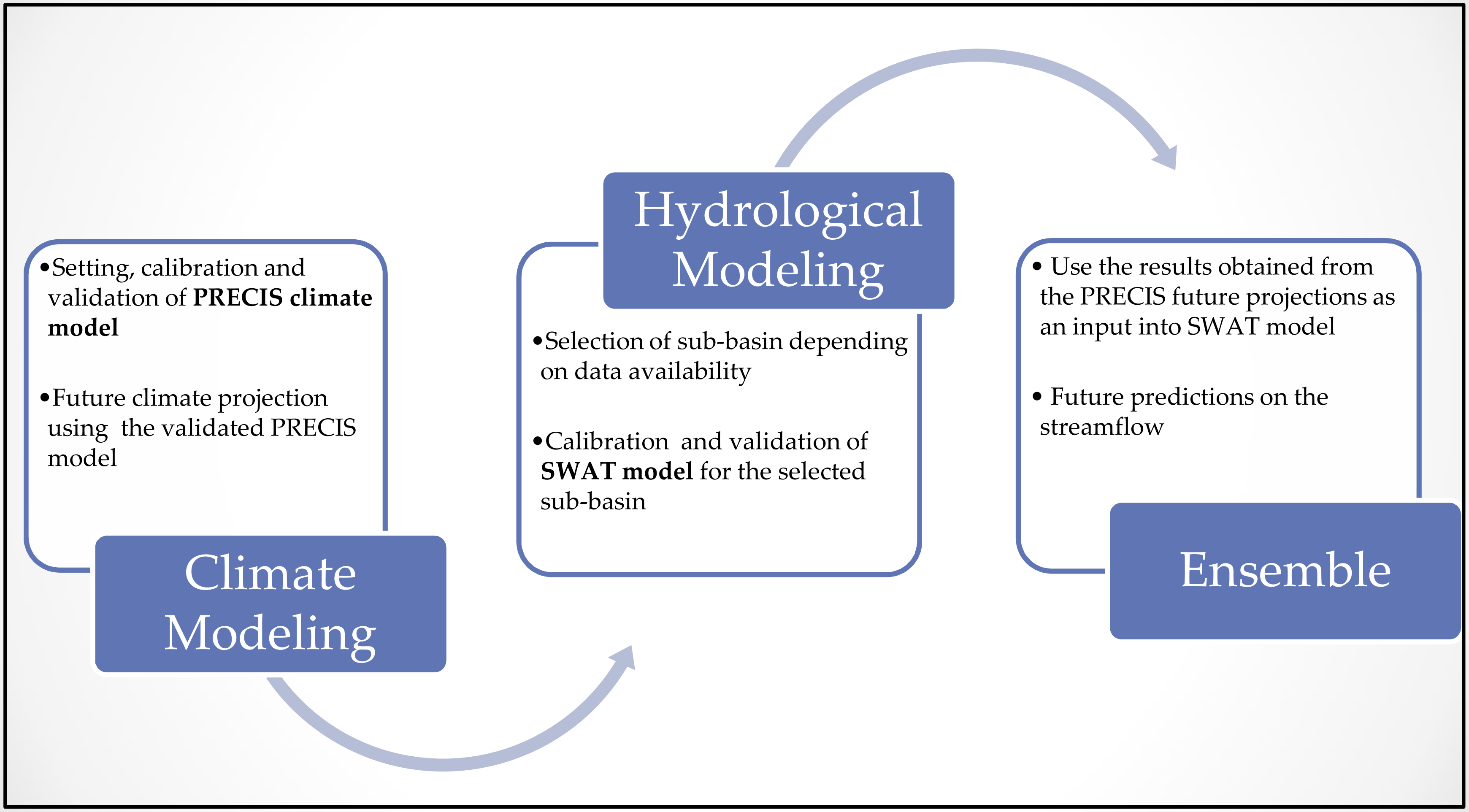
- The **overall objective** for the proposed work was to assess the impact of **the projected climatic changes on the near surface hydrology** across the study area. The specific objectives of the proposed work are:

  - Develop a modelling protocol that couples future climate data for different scenarios with a **hydrologic model simulating stream flow;**

  - Apply the modelling protocol to the study area on the watershed scale. **Calibrate and validate the model for the proposed study area;**

  - Evaluate the **impact of projected climate on water quantity** at watershed level and suggest adaptation strategies.

Methodology: Modeling Protocol

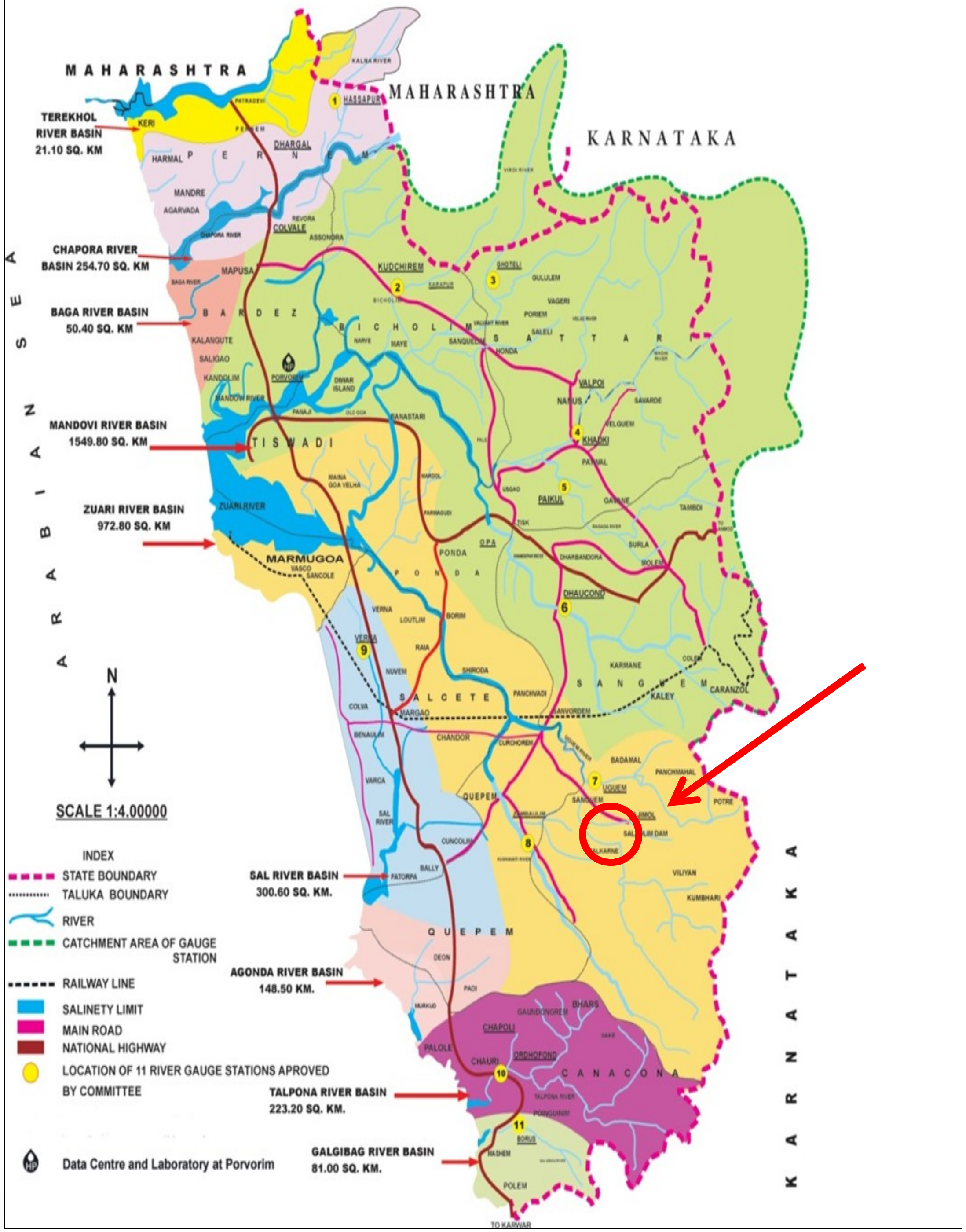


Criteria for site selection

- ❖ availability of consistent and reliable discharge data;
- ❖ size and relevance of the catchment;
- ❖ stakeholder consultations and expert opinion

Study Area

- This study was undertaken at a watershed level and was done for the Uguem river in Sanguem *taluka*, South Goa, India



Description of the study area

LOCATION: Sanguem taluka

VILLAGES: Costi, Uguem, Maulinguem, Valkini colony, Potrem, Dessaiwada, and Bhati

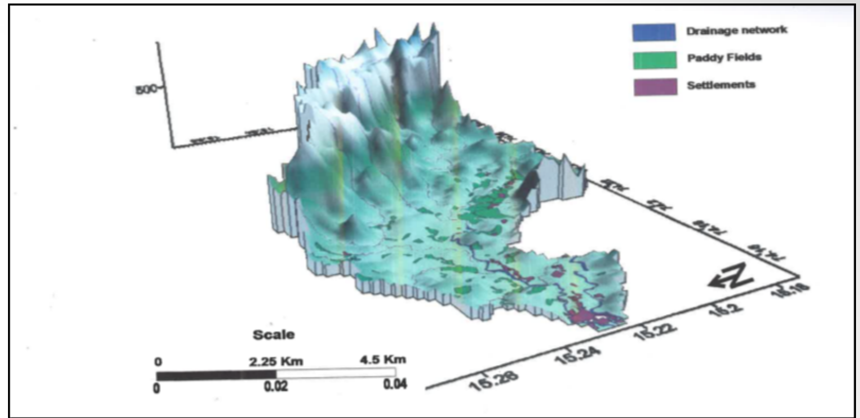
OCCUPATION: Agriculture

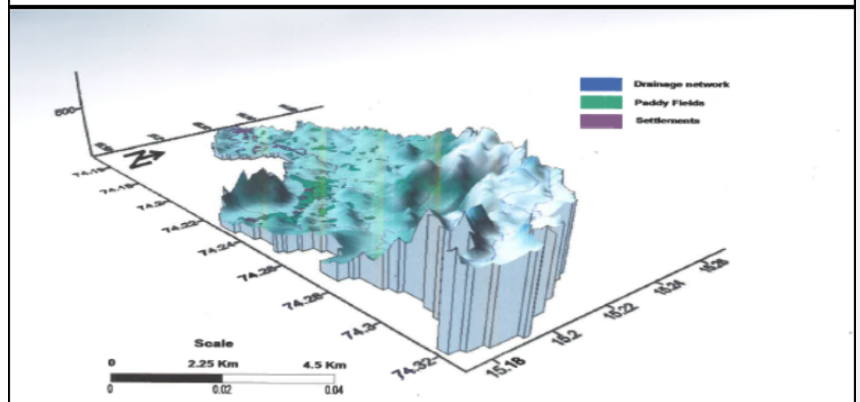
MAJOR CROPS: Paddy, Cashew, coconut, sugarcane, areca nuts

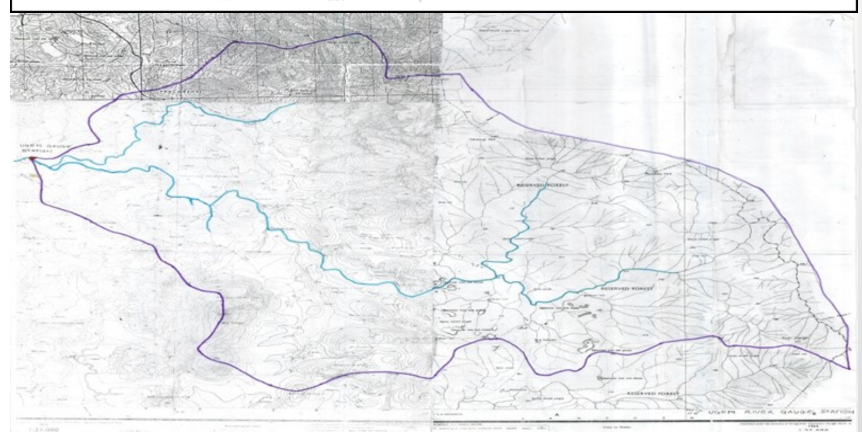
CLIMATE: Warm and humid, annual rainfall of about 4000-4500 mm mainly from Southwest (SW) monsoon during June to September.

Physiography

- Major part of the area has dendritic drainage pattern. First order streams seen owing to steep slope
- **Low lying areas** in the **west** and **Western Ghats** on the **east**
- **Elevation** range **17- 670 m**, original topography altered in the centre due to mining
- Netravali **Wildlife Sanctuary** in South and Bhagwan Mahaveer Sanctuary in North
- **Lateritic soil dominant.** Underlying lithologies includes are weathered quartz-chlorite, Granite Gnesiss, Metabasalts, Manganese , Iron ore,







Source and types of input data sets

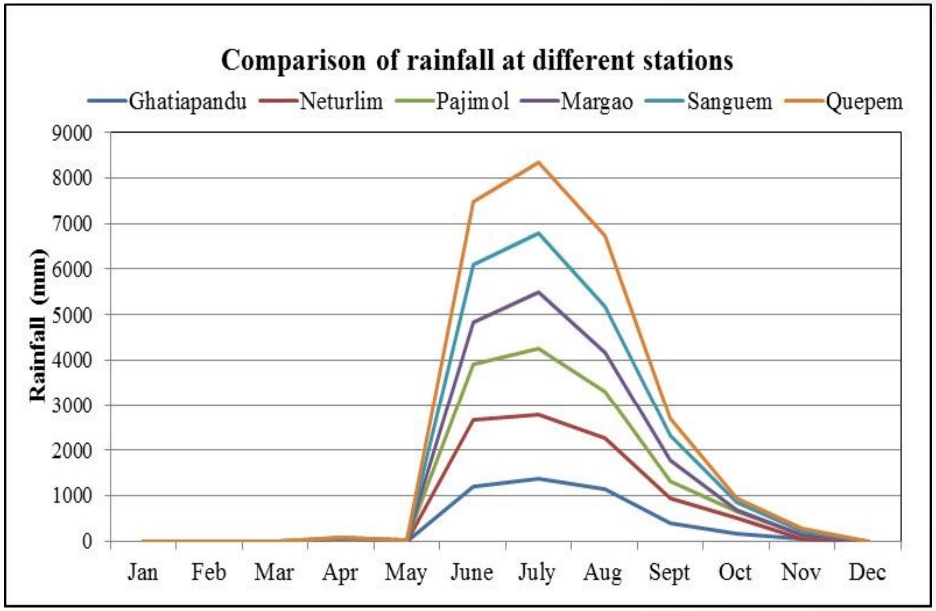
Data	Year of survey/time period	Format	Scale/Resolution	Source
Historical weather data	2009 – 2014	text format	Weather station	Indian Meteorological Department (IMD), Water Resources Department, Government of Goa
Future weather data	2000 - 2060	PP binary data format	50x50 km	PRECIS Climate model runs
Streamflow data	2010 – 2014	Tabular format	Gauging station	Water Resources Department, Government of Goa
Topography	2000	DEM	30m	USGS EROS Data Center
Soil data	2000	GIS Vector	1:500,000	FAO Digital Soil Map of the World
Land use	2014 - 15	GIS Raster	1:250,000	National Remote Sensing Centre, ISRO

Rainfall data

- 3 WRD rain gauging in the vicinity of Uguem river discharge monitoring station at Neturlim, Ghatiapandu and Pajimol

- IMD stations at Margao, Sanguem and Quepem

- It was observed that the annual rainfall measured at Ghatiapandu station is higher by 1.62% and that measured at Sanguem is higher by 0.6% as compared to Pajimol station.



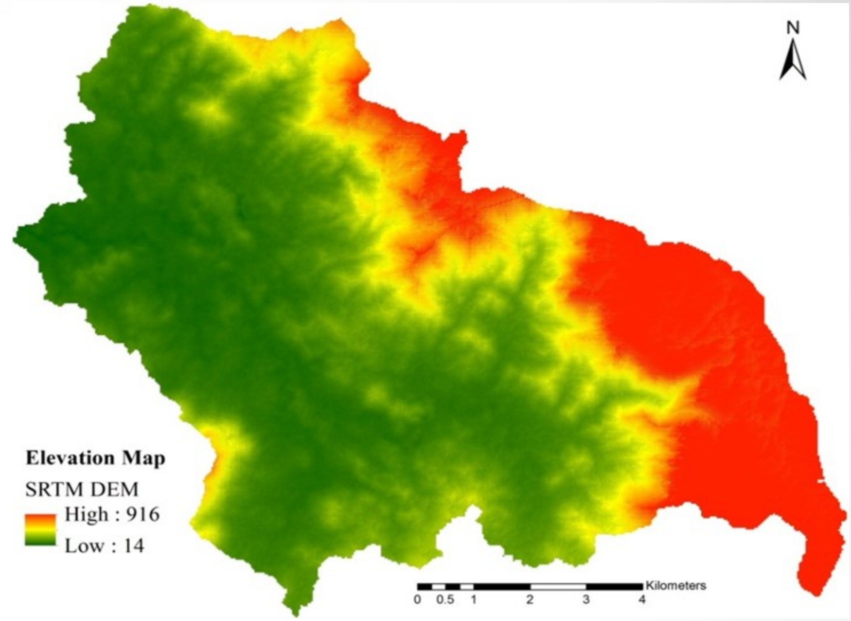
•Since, it is a negligible difference, the rainfall data at Pajimol was used for the modelling exercise because it had other required data

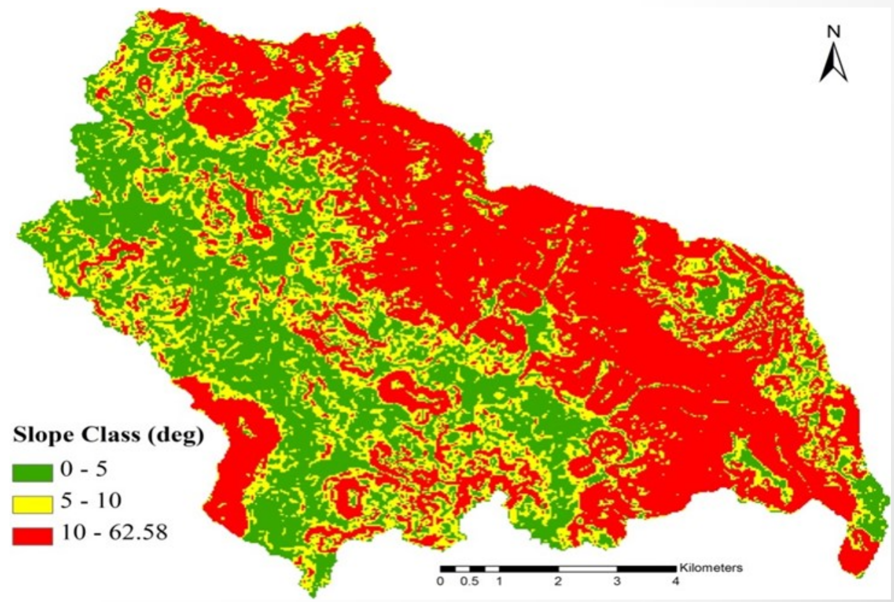
Data Pre-Processing

- The SWAT model requires **all input parameters** to be fed into the model **in a specific format** as it does not take the data in its raw format
- A **common projected coordinate system** (UTM Zone 43N and WGS 84) was used for all spatial data based on the location of the study watershed
- All **spatial data** (DEM, soil and land use) were re-sampled to **30mx30m to match the DEM resolution.**

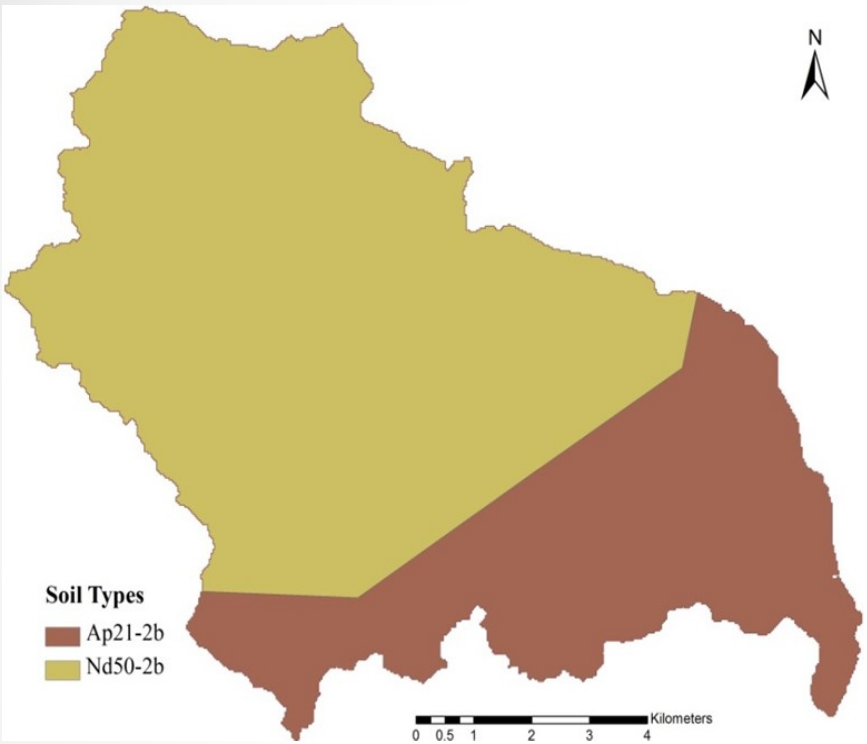
Topography

- **Topography has greater influence on the runoff** and infiltration processes. Flat terrains experience more infiltration and are less favourable to runoff
- The **topography range**: 0^0 - 62.58^0
- Being **located** in the **Western Ghats** region, the terrain is generally **undulating**
- The **slope map indicates** that there will likely be **more runoff** in the **western part of the basin**.





Soil



❑The soil database developed by FAO-UNESCO was used to prepare soil data layer required for the SWAT model

❑The soil parameters were classified according to SWAT model geo-database

❑The main soil types that fall in the Uguem basin are PlinthicAcrisols, DystricNitosols and DystricRegosols

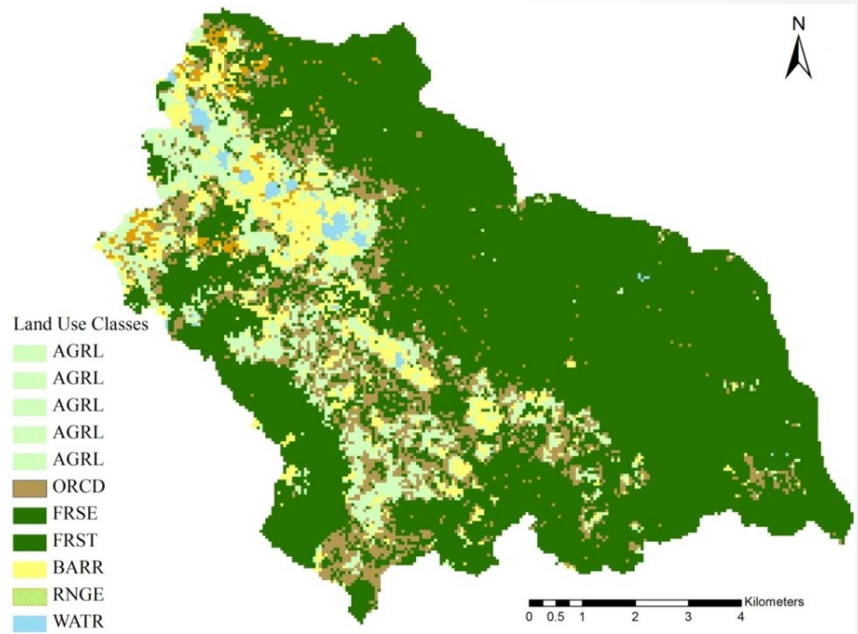
❑Most regions have medium soil texture

Land-Use

- Land use determines the extent of runoff, soil erosion and evapotranspiration

- The land use map of Uguem river basin was obtained from National Remote Sensing Centre (NRSC)

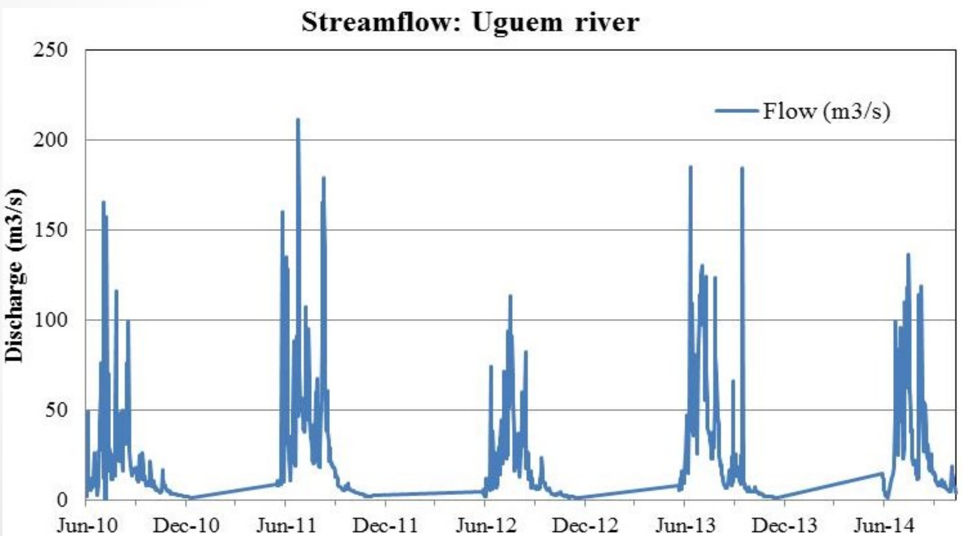
- The land use information was cross checked using SoI map with a scale of 1:250,000



Land-use classification

Land use	Area (ha)	% Watershed
Agriculture	942.10	9.98
Orchard	992.14	10.51
Evergreen Forest	2429.10	25.74
Deciduous Forest	3935.71	41.71
Barren	635.44	6.73
Range (Grasslands/Pastures)	92.02	0.98
Water bodies	83.79	0.89
Other	325.9	3.46
TOTAL	9436.2	100

Streamflow



❑The **observed discharge** or streamflow data was collected from the **WRD**

❑The **data was available** for the period of **2010-2014**

Results: Climate Modeling

PRECIS

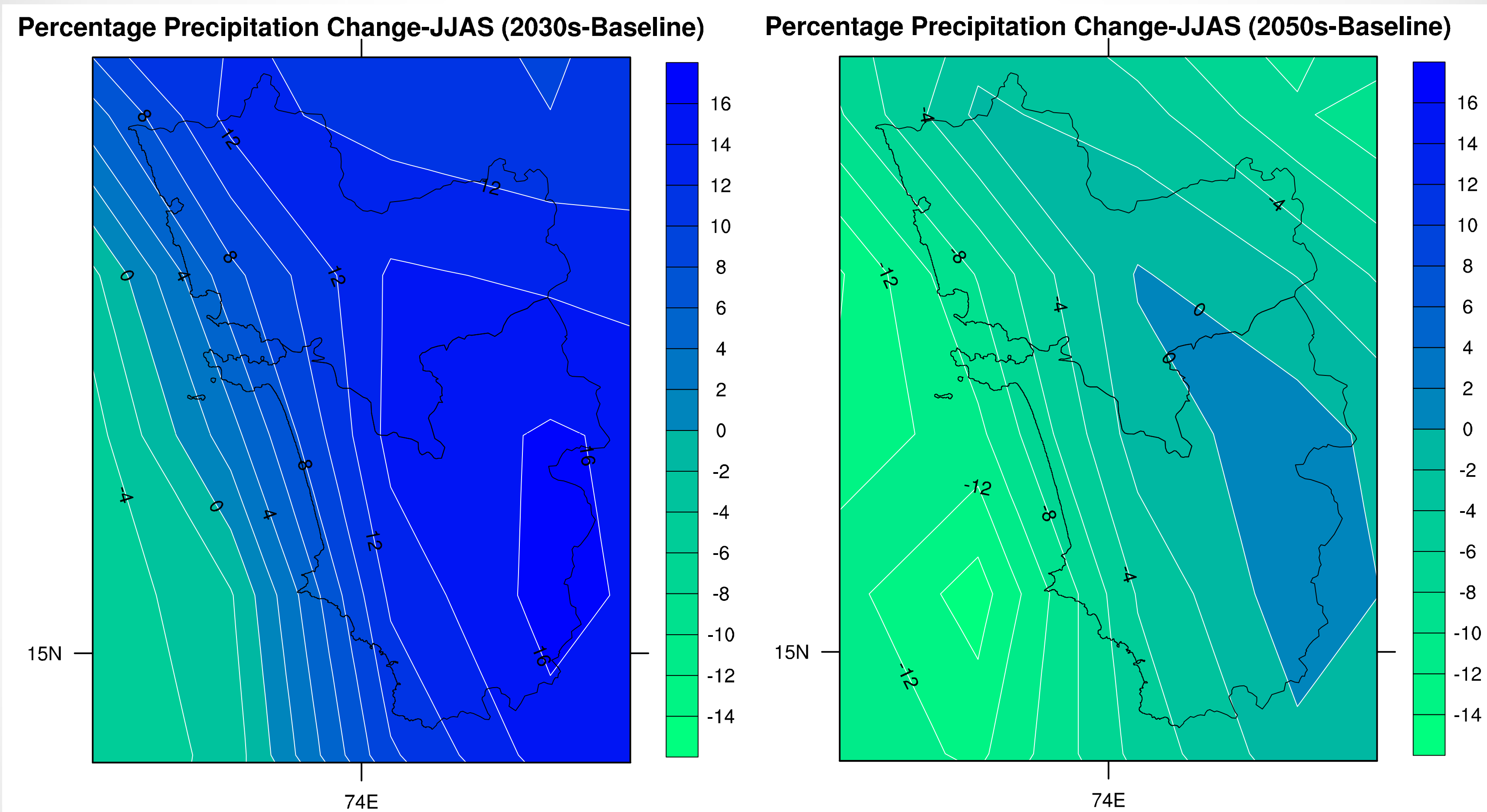
- Climate scenario used was A1B SRES
- Resolution was a horizontal grid of 25 X 25 km
- Baseline period used: 1970-2000
- Future Period: 2020 - 2060

PRECIS Modeling

- Daily temperature and precipitation data from the **output of PRECIS** model for the **future time period** of 2030 and 2050 were used

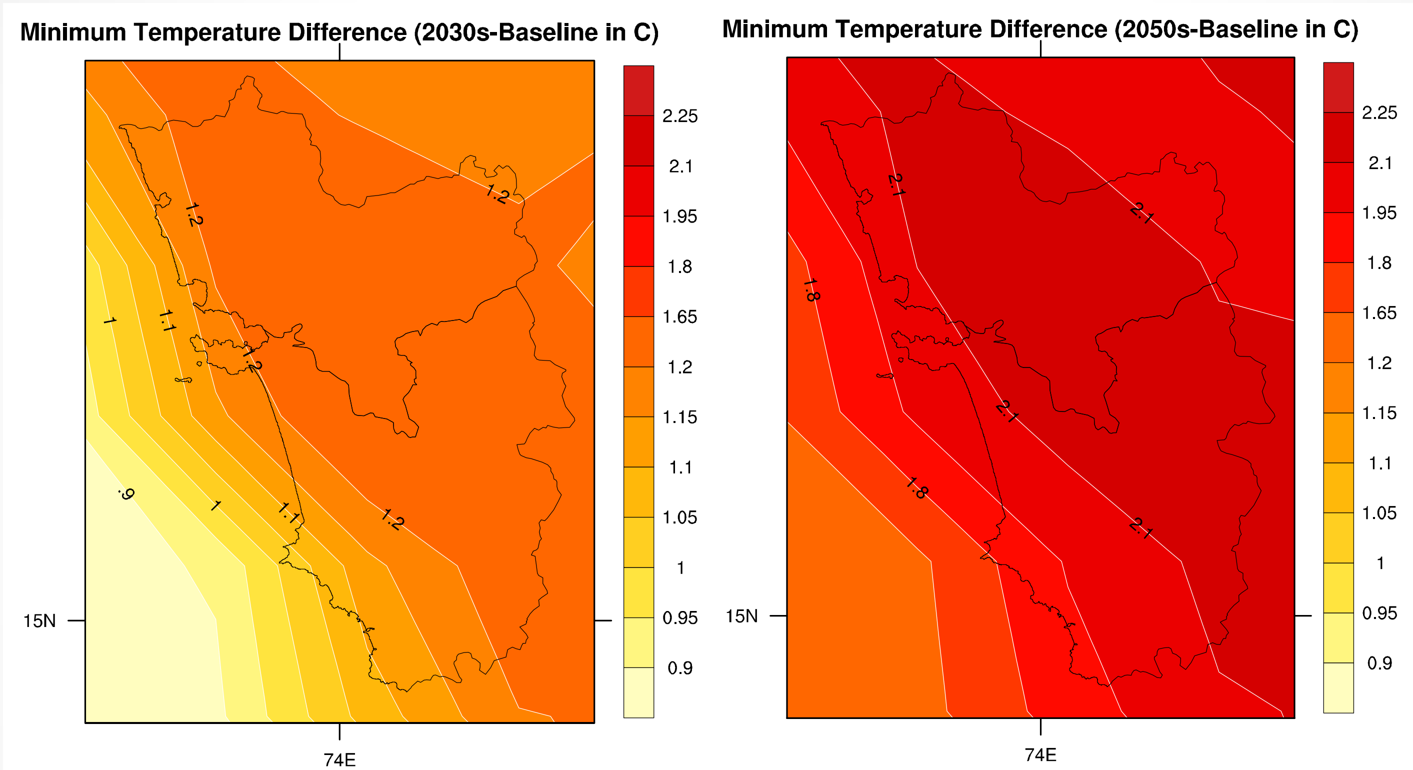
- **SWAT input files** (which would include daily precipitation, minimum and maximum temperature, solar radiation, relative humidity and wind speed) **were prepared** using the **PRECIS output**

PRECIS Output: Rainfall



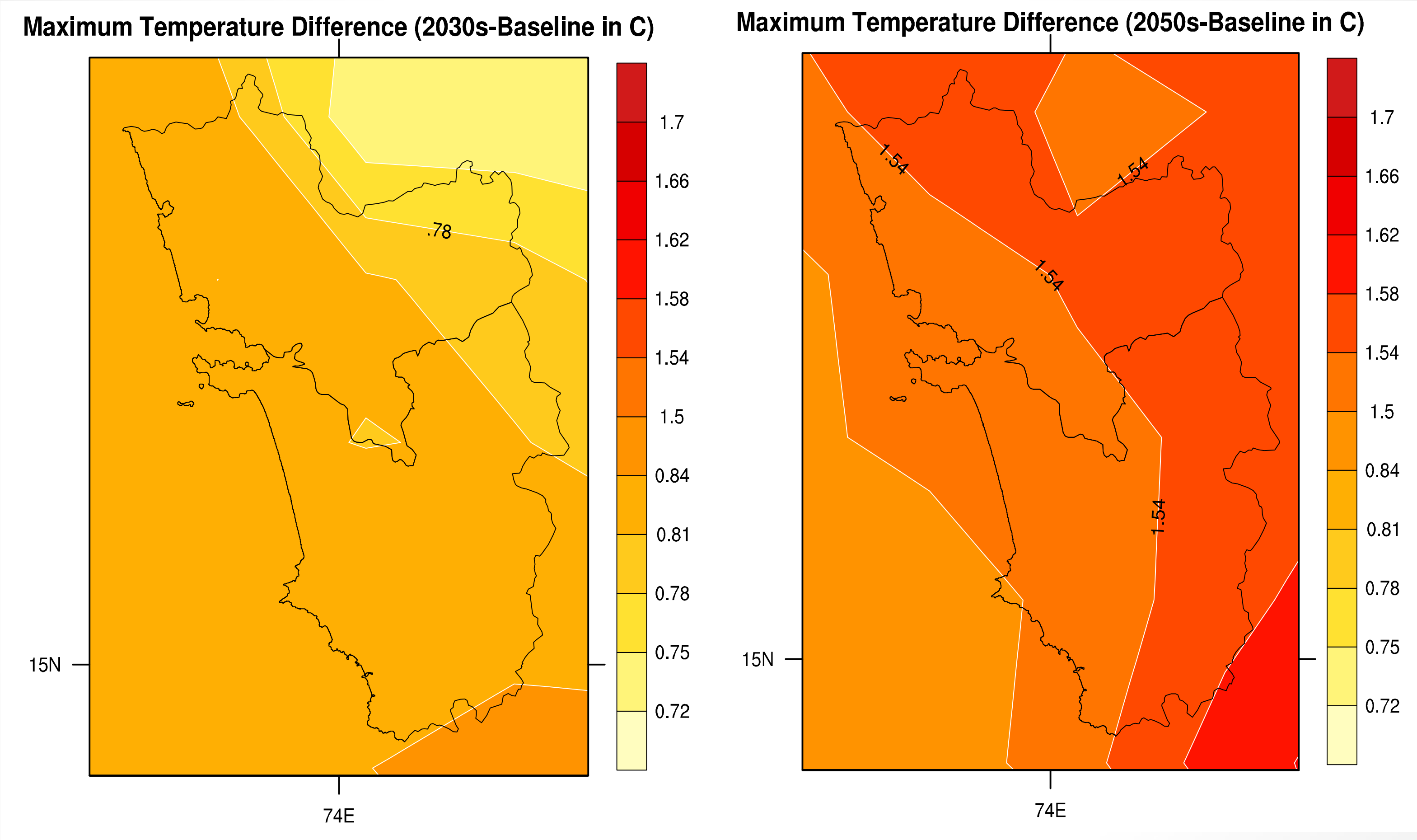
- ❑ Increasing trend in 2030s (4 to16%) as compared to the baseline
- ❑ In 2050s rainfall is predicted to be low -14% to 2% as compared to baseline

PRECIS Output: Minimum Temperature



- Annual mean minimum temperature **increase** in the range of **0.9^0C-1.2^0C in 2030s** and **1.65^0 C- 2.25^0 C** increase in **2050s**.

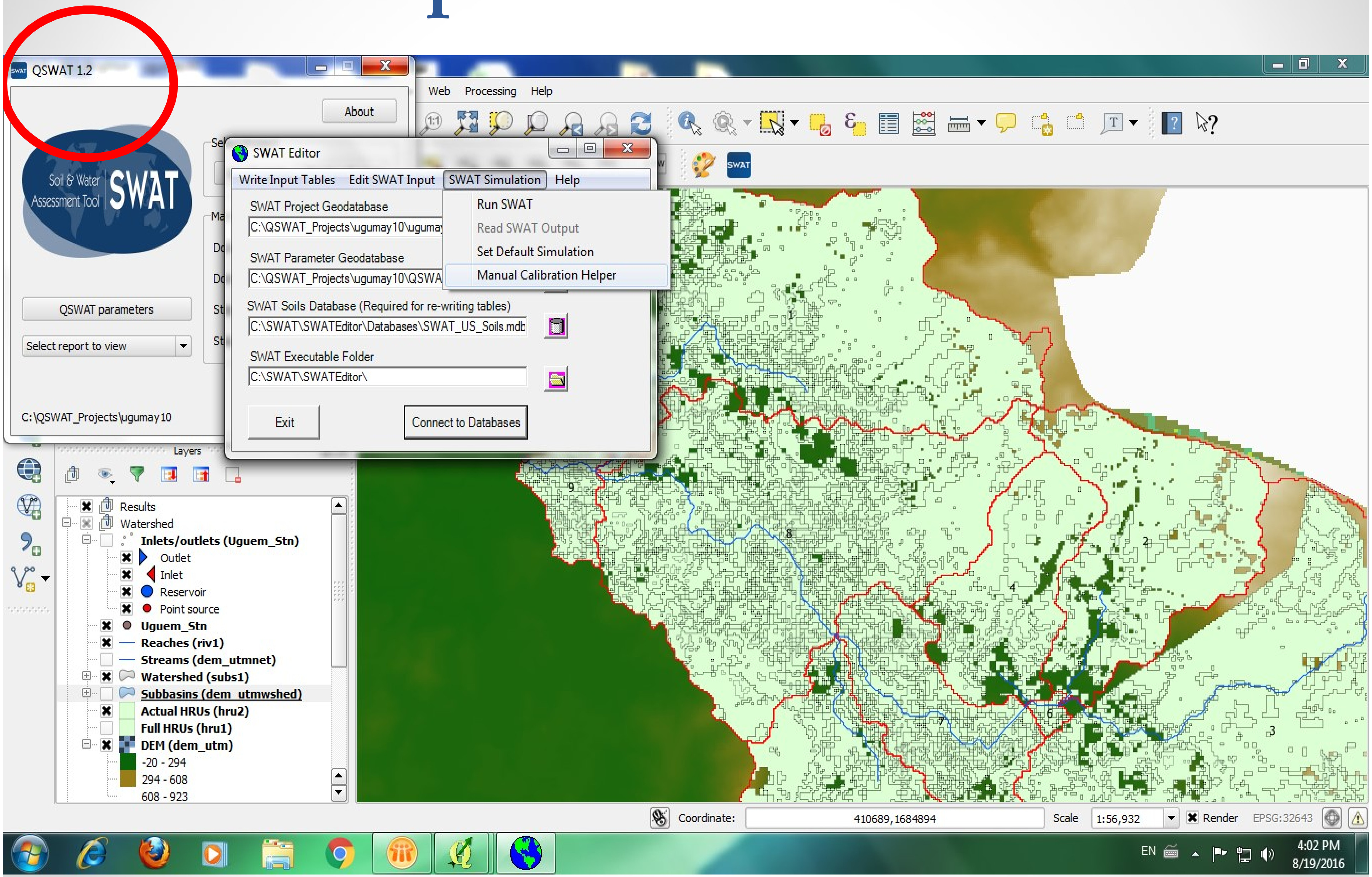
PRECIS Output: Maximum Temperature



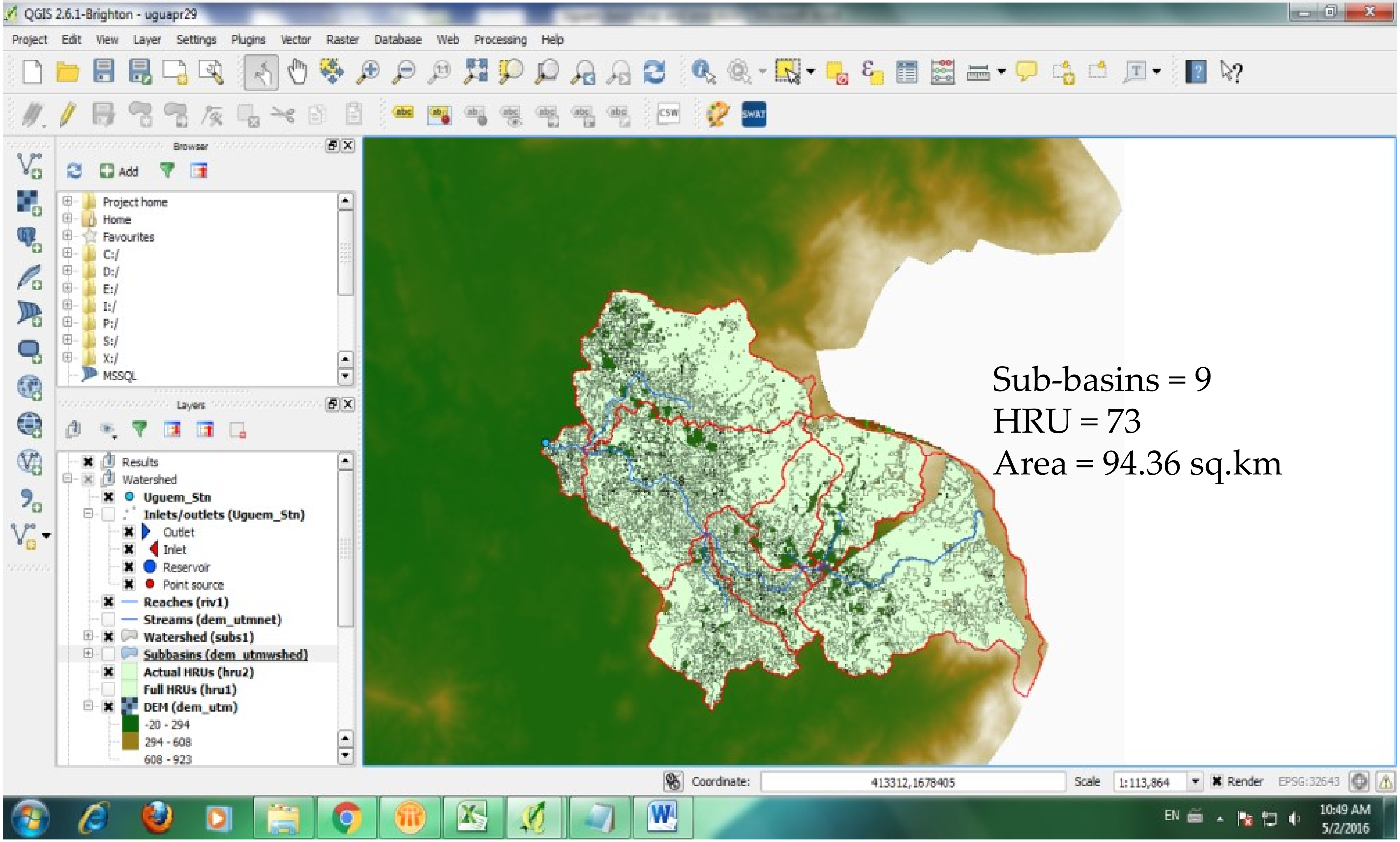
Annual mean **maximum temperature increase** in the range of 0.72^0C- 0.84^0C in 2030s and 1.5^0C-1.7^0C increase in 2050s.

QSWAT Model Runs

Snapshot of the model



Watershed Delineation using QSWAT



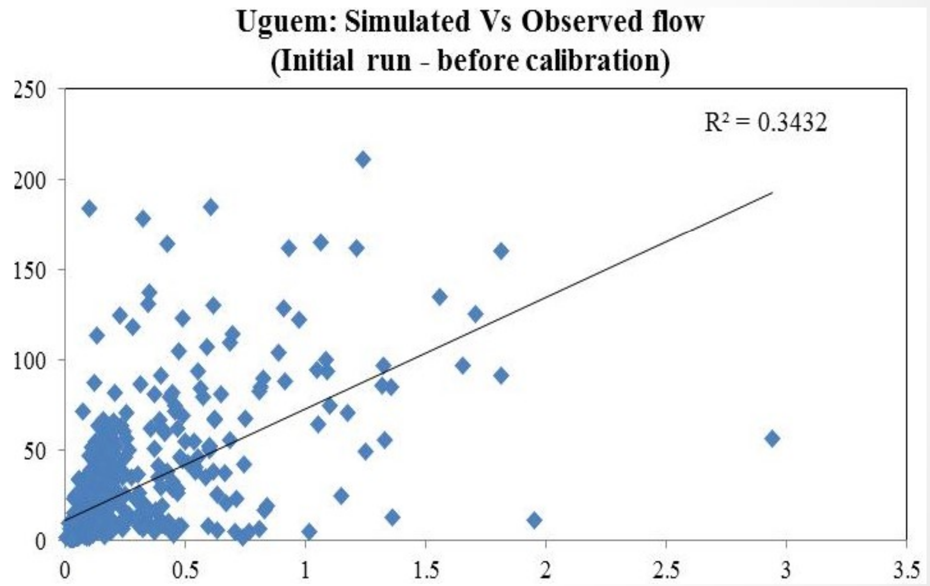
Sensitivity Analysis

- To examine which input parameters have the strongest influence on the model results.

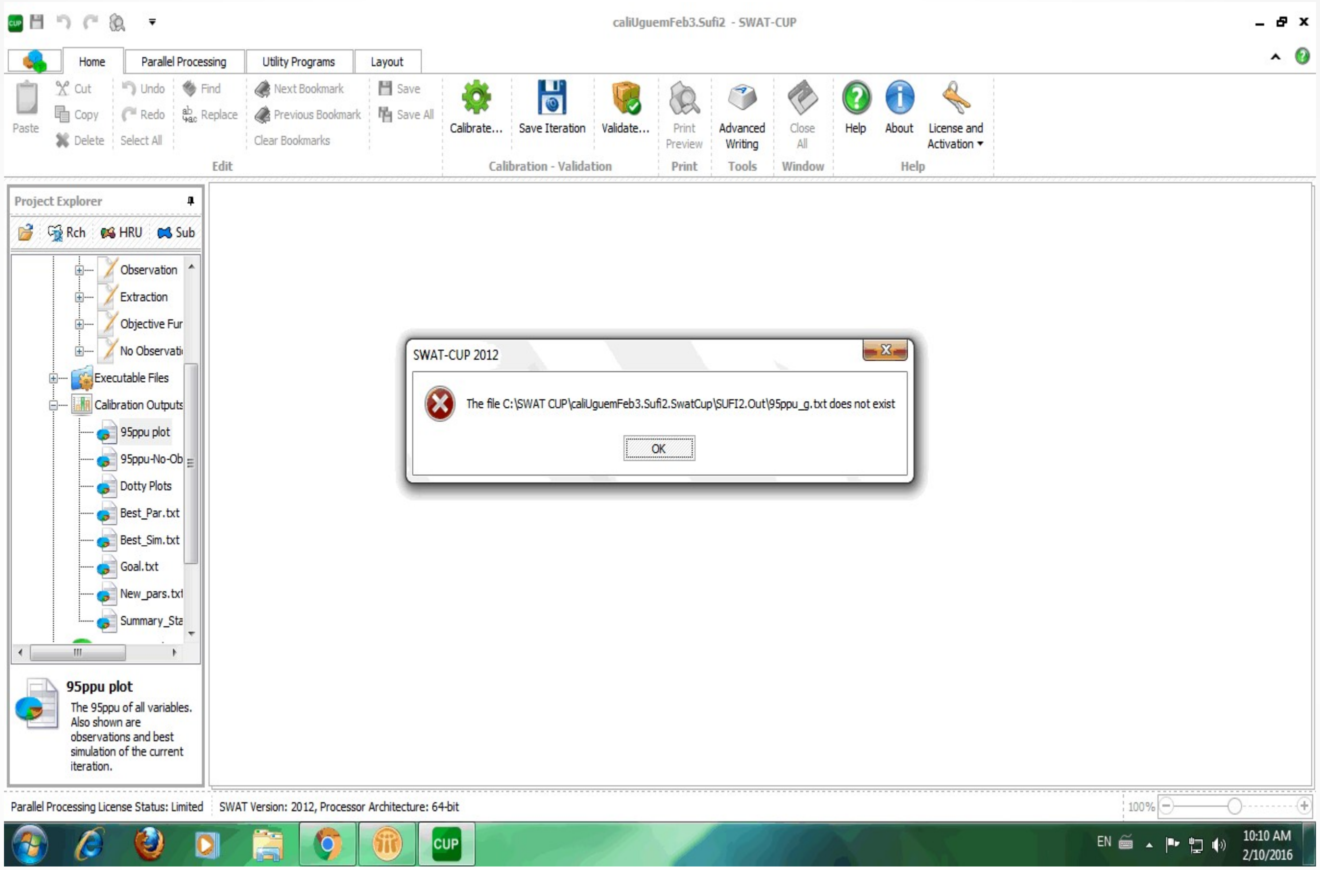
- Once, these input parameters are identified; they are used further for calibration

- **Sensitivity analysis** was carried out **by perturbing a particular parameter x_i by a small amount** Δx_i and computing the corresponding change Δy_i in the objective function y

- A statistical measure called **Sum of Squares Errors (SSE)** was calculated after each run to assess the model performance.



Calibration: SWAT CUP



- Tried using SWAT CUP but ran into issues
- Model ran successfully however on clicking Calibration Outputs to visualize the results got an error message, "95ppu_g.txt does not exist".

Calibration

- The process of optimizing the unknown model parameters to improve the model output is known as *Calibration*.
- Calibration was done **manually**
- Calibration period: **2010-2013 data**
- Two criteria for goodness of fit – **Nash Sutcliffe Efficiency (NSE)** and **Linear Regression (R^2) were used for calibration.**
- NSE = 1 indicates a perfect fit between modelled and observed data; values <=0 indicate the model's predictions are not good. A NSE =>0.6 indicate very good calibration and accuracy of the model

Model Performance

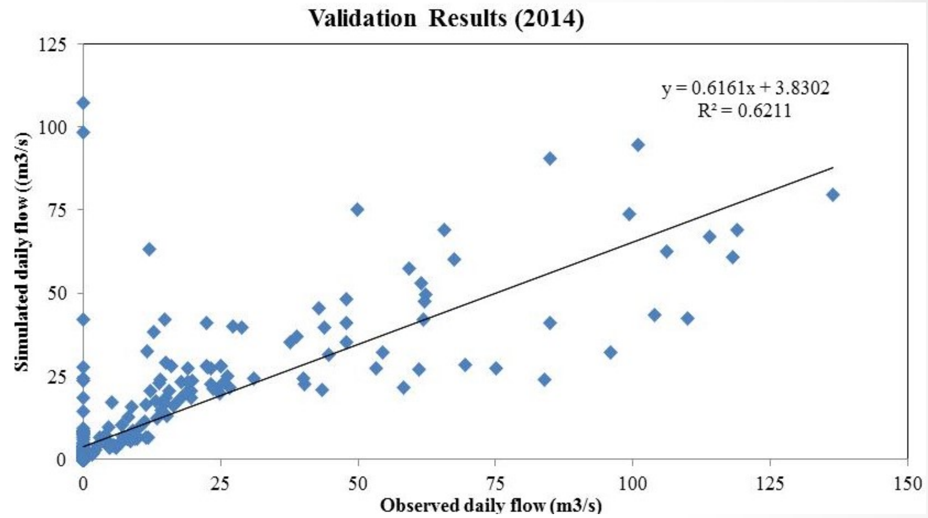
Parameter, Unit / Symbol	Original Value	Calibrated Value
SCS Runoff curve number (CN)	as given in table below	as given in table below
Baseflow recession constant (days) (Alpha_BF)	0.048	1
Soil evaporation compensation coefficient (ESCO)	0.95	1
Delay time for aquifer recharge (days) (GW_Delay)	31	5
Plant uptake compensation factor (EPCO)	1	0.5
Manning's coefficient (Ch_N2)	0.014	0.01
Effective hydraulic conductivity (mm/hr) (Ch_K2)	0	1300
Revap coefficient (GW_Revap)	0.02	0.09
Available water capacity of the soil layer (mm H_2O/mm soil) (Sol_AWC) / (soil Ap21, ND50)	0.104, 0.158	0, 0.01
Nash Sutcliffe Co-efficient Efficiency (NSE)	**0.4**	**0.7**

Calibrated CN values

Land use	Soil	Original CN_2 Value	Changed CN_2 Value
Agriculture	ND50-2b-3819	83	70
Agriculture	Ap21-2b-3656	87	74
Barren	ND50-2b-3819	91	80
Barren	Ap21-2b-3656	94	82
Deciduous Forest	ND50-2b-3819	70	48
Deciduous Forest	Ap21-2b-3656	77	49
Evergreen Forest	ND50-2b-3819	73	48
Evergreen Forest	Ap21-2b-3656	79	49
Orchard	ND50-2b-3819	77	63
Orchard	Ap21-2b-3656	83	67
Range	ND50-2b-3819	79	75

Validation

- The process of comparison of model results with an independent data set without further adjustment is called as *Validation*

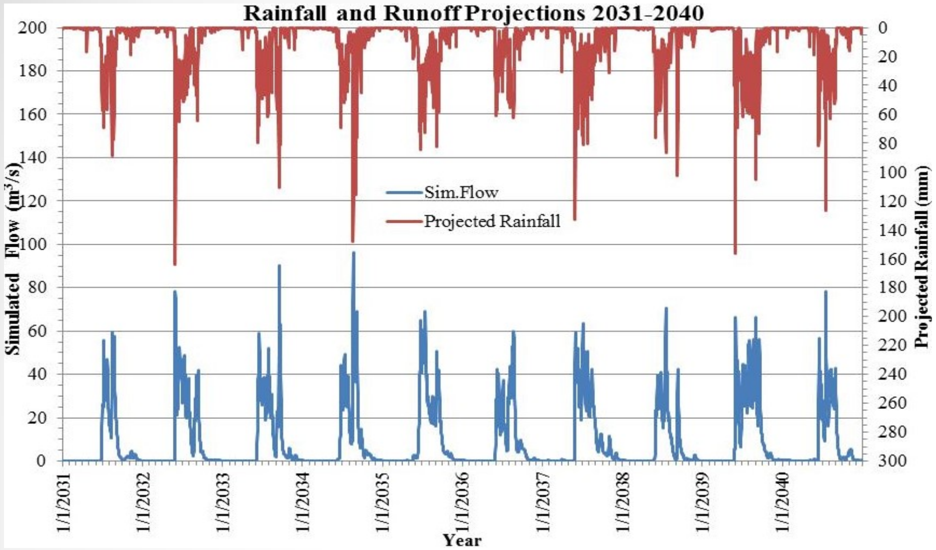


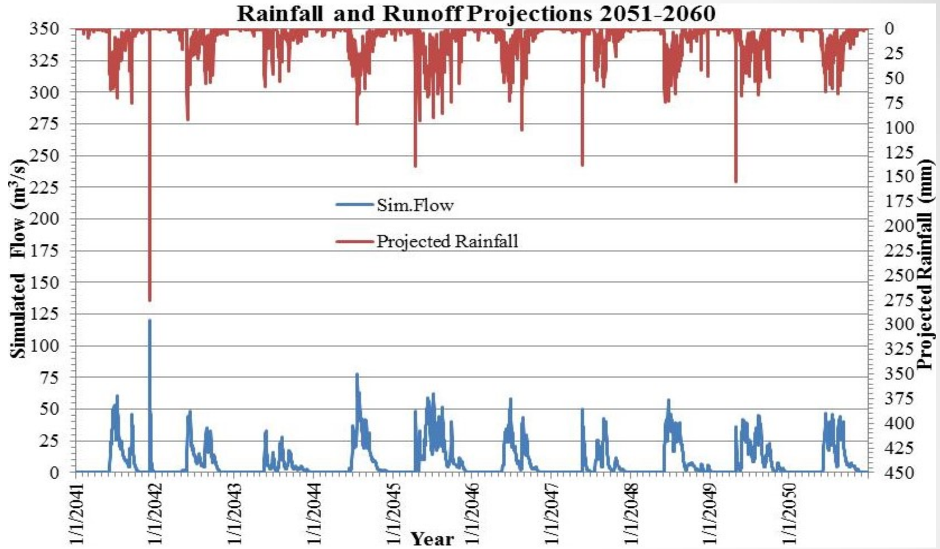
$R^2 = 0.64$, NSE = 0.7

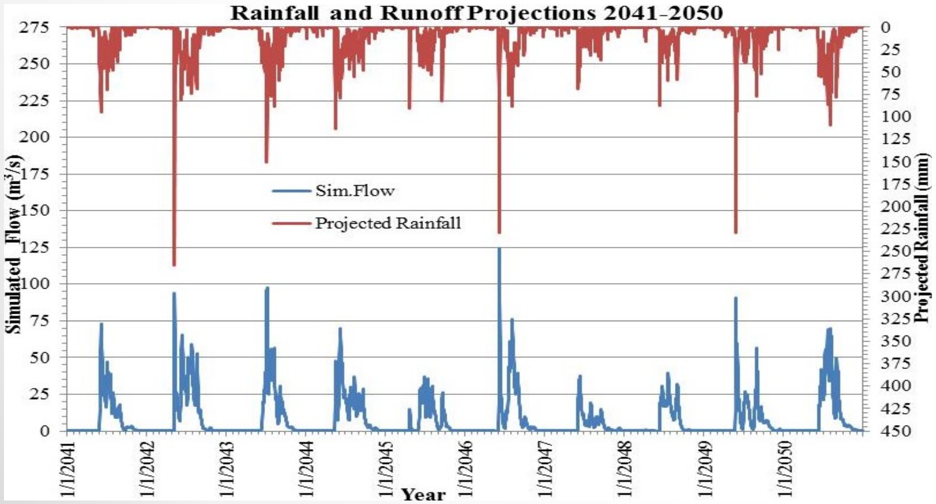
Validation	
Mean of simulated runoff	10.21206
Mean of observed runoff	10.35844
Standard Deviation of simulated runoff	18.24865
Standard Deviation of observed runoff	23.34387

- The model was validated for 2014

Future Predictions







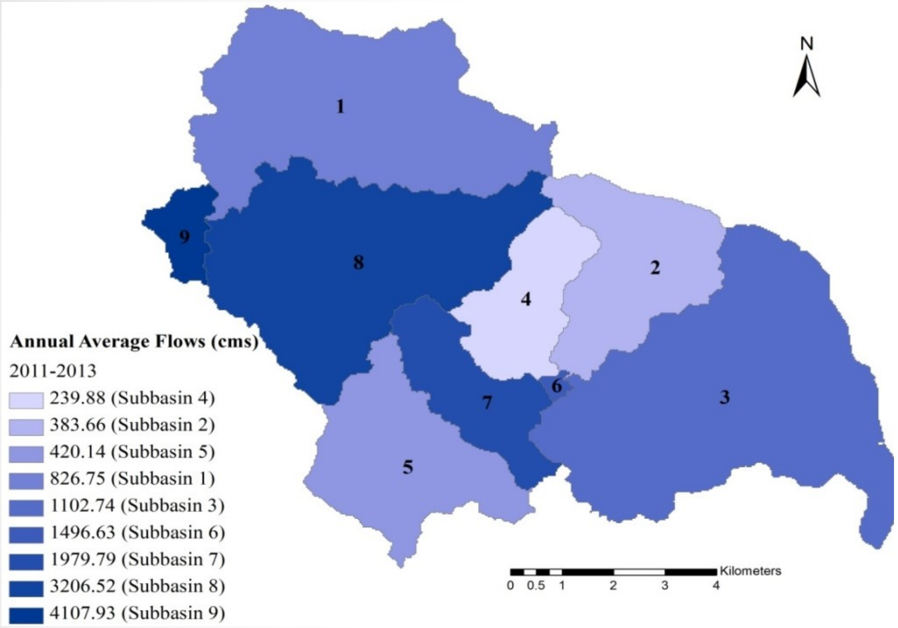
- The peak average rainfall for all future decades is lesser than the observed values during the period of 2010-2014.

- Similarly, the runoff which is dependent on the rainfall is also projected to be decreasing

Future Predictions

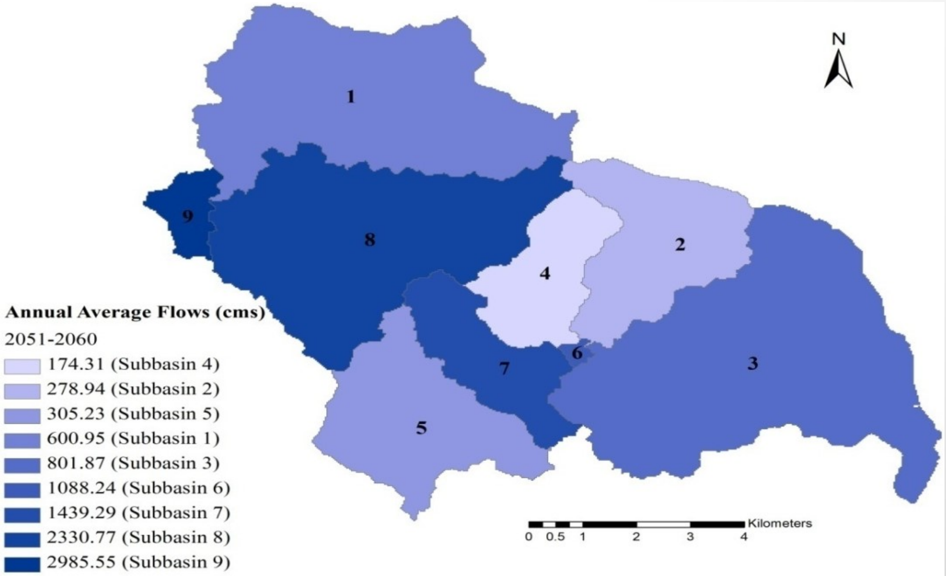
Time period	Runoff Five year Average (m^3/s)	Rainfall Five year Average (mm)
2010-2014 (Observed)	11.69	11.15
2031-2035	8.89	9.07
2036-2040	9.14	9.30
2041-2045	8.41	8.63
2046-2050	7.01	7.37
2051-2055	8.34	8.66
2056-2060	8.01	8.23

Spatial variability in runoff



High slope areas influence the quantum of runoff

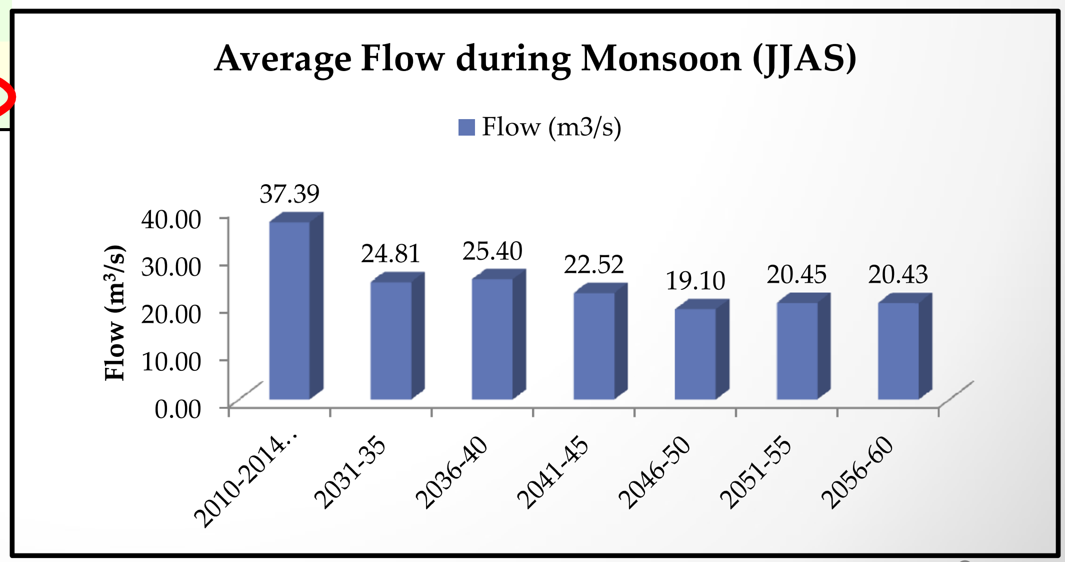
Future period: 2051-2060



Baseline period: 2010-2013

Temporal variability in Peak flow

Year	Peak flow (m^3/s)	Year	Peak flow (m^3/s)	Year	Peak flow (m^3/s)
2031	59.32	2041	73.07	2051	120.3
2032	78.07	2042	94.01	2052	48.75
2033	90.34	2043	90.34	2053	33.11
2034	96.00	2044	148.20	2054	96.10
2035	68.95	2045	68.95	2055	62.39
2036	60.07	2046	60.07	2056	58.28
2037	63.76	2047	63.76	2057	49.98
2038	70.29	2048	102.5	2058	57.09
2039	66.31	2049	66.31	2059	45.16
2040	78.26	2050	78.26	2060	46.56



Dependable Flow Analysis

- The Flow Duration Curve (FDC) is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest
- FDC is one of the most critical pieces of information in any hydrological study
- FDC is one of the most informative means of displaying the complete range of river discharges, from low flows to flood events
- Q_{90} means the flow rate equalled or exceeded for 90% of the time

Use of Flow Duration Percentile

Flow Percentile	Use
Q_{90}	❖ Commonly used low flow index ❖ Monthly value provides stable and average flow conditions ❖ Monthly value gives minimum flow for aquatic habitat ❖ Used to examine discharge –duration patterns of small streams ❖ Threshold warning water managers of critical streamflow levels ❖ Describes limiting streamflow conditions, and is used as a conservative estimator of mean baseflow ❖ Licensing surface water extractions and effluent discharge limits assessment
Q_{50}	❖ Aquatic baseflow policy for water resources planning and management ❖ Used to protect aquatic biota ❖ Used to recommend seasonal minimum discharges for waterpower rivers

Decadal Dependable flow for 2031-2060

% Exceedance (%)	Dependable Flow (m^3/s) 2031-2040	Dependable Flow (m^3/s) 2041-2050	Dependable Flow (m^3/s) 2051-2060
Q_{10}	35.03	26.37	27.88
Q_{20}	19.94	14.88	16.43
Q_{30}	5.43	5.82	7.33
Q_{40}	1.89	1.71	3.51
Q_{50}	0.46	0.39	1.07
Q_{60}	0.25	0.23	0.30
Q_{70}	0.17	0.16	0.21
Q_{80}	0.13	0.11	0.15
Q_{90}	0.09	0.08	0.10
Q_{100}	0.00	0.04	0.05
Q_{mean}	9.01	7.71	8.17

OBSERVATIONS

- The high flow rates (Q_{10}) are likely to gradually decrease over the decades thereby affecting the water availability
- Q_{90} and Q_{50} flows are often used as low flow indices and could be used by the government and the planners to better manage water resource and prioritize its use

Recommendations

- The **stream flow is likely to decrease** in the coming years. This **warrants** for timely **conservation strategies** for better water management
- Some points on the course of the Uguem river, water is being pumped directly by the private people mostly for irrigation and no records are being maintained. There is an over-use and wastage of water since it is not being charged. This needs to be rectified and curtailed
- New water intensive industries in the downstream of the river should be restricted. In case of water guzzling activities/industries, rain water harvesting should be made mandatory and compliance should be checked regularly

Recommendations

- Considering the delivery, conveyance, and **application losses,** actual irrigation will be considerably more, depending upon the type of irrigation method. Hence, agriculture and horticulture activities in these sub-basins need attention

- Water conservation measures such as drip irrigation, system of rice intensification should be encouraged

- **Developing irrigation design and scheduling guide**s for local crops needs to be done to enhance **water-use efficiency of agriculture sector**

- Regulating the use of canal water to avoid wastage and over-use should be looked into. The **functioning of** the existing **Water User's association (WUAs**) needs to be scrutinized and regularised.

Recommendations

- **Future dependable flows may be used** while giving out licenses for surface water extractions and effluent discharges

- While **planning for future development** of the water resources in this watershed, the dependable flow values should also be used to **maintain the minimum environmental flow** required by the river to **support the aquatic habitat**

Conclusions

- PRECIS was able to capture spatial and temporal variability
- Land-use change was not included in this study. These will be corrected in the next study
- Though the amount of available data was low, the projected streamflow patterns are quite indicative and can be integrated into water resources management plans
- Site-specific recommendations are provided

Thank You ☺