Response of Streamflow under Climate and Land Cover Change Scenarios in the Upper Beas Basin

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BACKGROUND

- Global combined land and ocean surface temp has increased to 0.89°C during 1901-2012 & about 0.72°C during 1951-2012. (IPCC, 2013).
- Warming affects the components of earth system
- Climate change (alter the temporal and spatial patterns of precipitation) will alter the hydrological cycle in many ways.
- Changes in river flow regimes

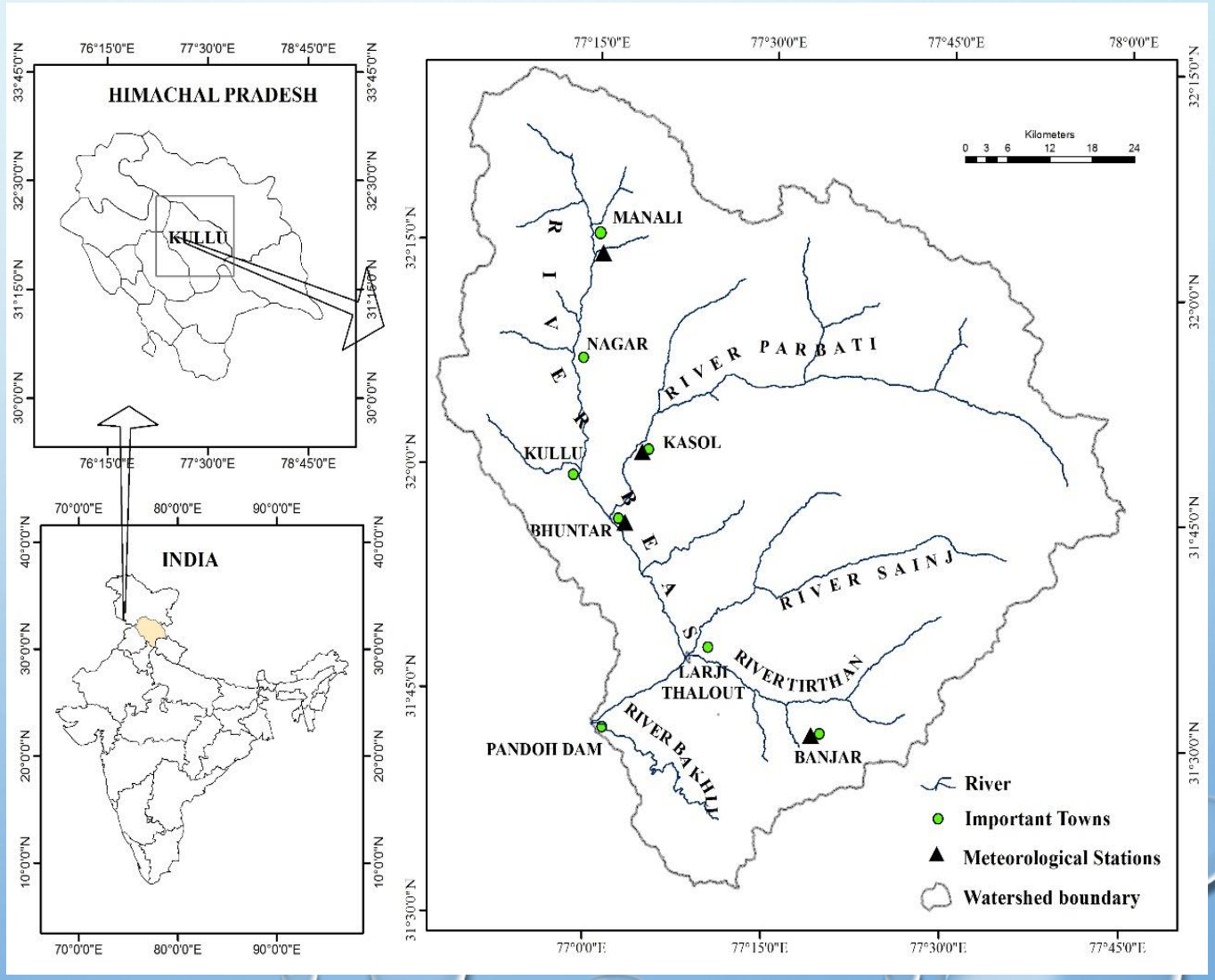
AIM OF THE STUDY

To assess the response of streamflow in the basin under different climate and land cover change scenarios by mid-century

Study Area

Beas River originates ***at the Beas Kund, Kullu district (H.P.)*** at an altitude of 4085 m a.m.s.l. total length = **460 km** & catchment area = **20,303 sq. km**

- upper Beas river basin up to Pandoh dam
- Length =**116 km,** 25% of the total river length
- Catchment area = **5300 km²** 26% of the total river area
- Altitude = **802 m-6600 m** a.m.s.l
- Permanent snow area **15%**
- Annual **avg snow cover Area=31-35%**



a.m.s.l=above mean sea level

Data & Sources

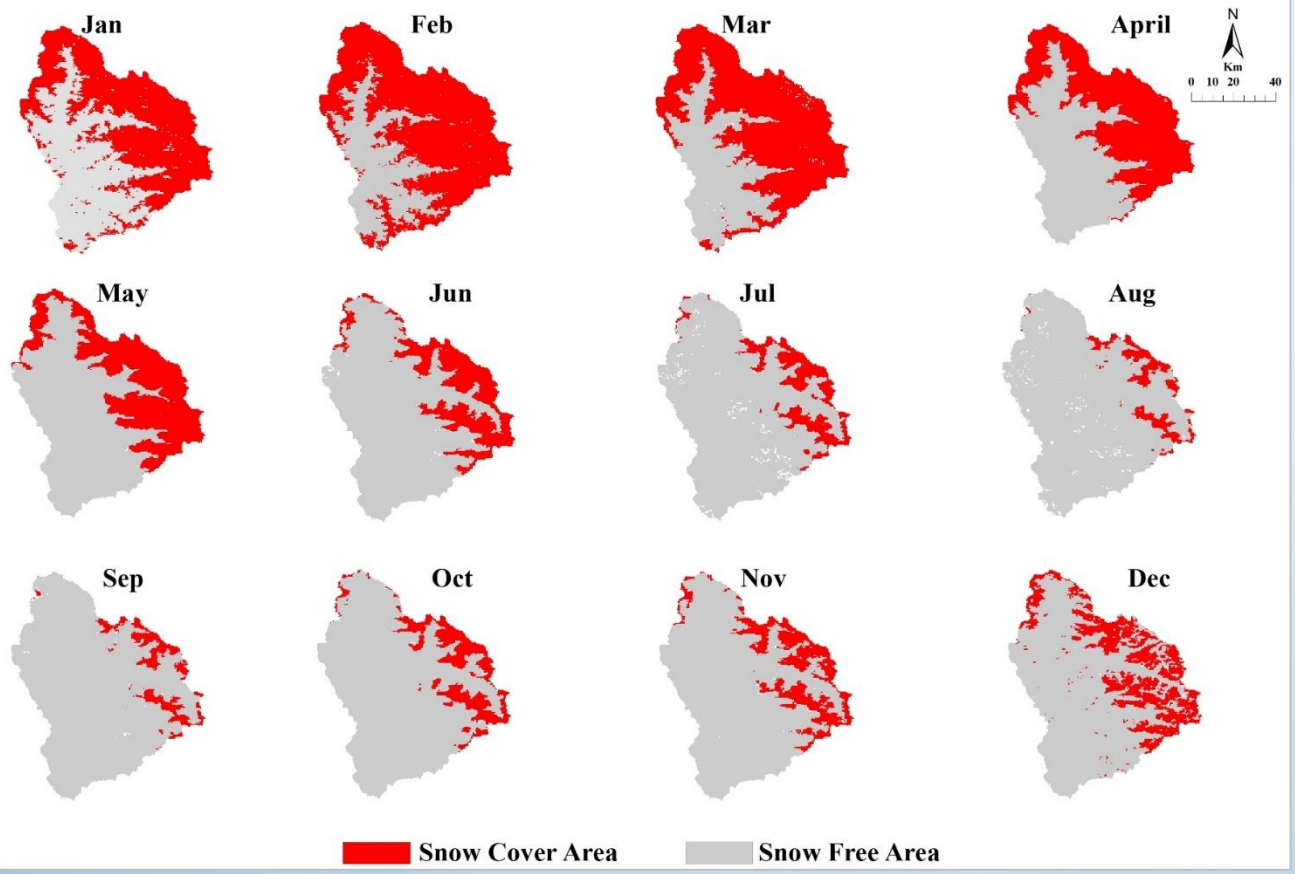
Data	Sources
Daily mini and max air temperature (^{0}C) Daily mini and max RH (%)	IMD ((Manali, Bhuntar) 1969-2010
Daily rainfall (mm) Daily average wind speed (m/s)	& IARI (Katrain) 1985-2014
Discharge of Thalout station (1971-2002)	Ghorpa HEP Report, HPSEB
Digital Elevation Model (DEM)	Catrosat Dem http://bhuvannuis.nrsc.gov.in/bhuvan/web/
Snow Cover Area (SCA) MOD10 A1 2000-2015	The Moderate Resolution Imaging Spectroradiometer (MODIS), Data Pool at National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC)
Satellite Images	Landsat Data from USGS Global Visualization Viewer (GloVis)[2]
Soil	SLUSI

LANDSAT_5	TM	147 /038	11/16/1991
LANDSAT_8	OLI_TIRS	147 /038	10/17/2015

[1] http://glovis.usgs.gov/
[2] ftp://n5eil01u.ecs.nsidc.org/SAN/MOSA/

Methodology

- LULC mapping is done by decision tree
- Climate change scenarios were selected on the basis of available reports of IPCC & IITM
- Land cover change scenarios were decided on the basis of snow cover area in the basin
- Hydrological modeling using **S**oil & **W**ater **A**ssessment **T**ool (SWAT) 2012 .
- Model is calibrated (manual & auto calibration by SWAT CUP SUFI 2) & validated using observed mean monthly flow at Thalout station through coefficient of determination (R^2) and Nash–Sutcliffe efficiency (E_{NS})

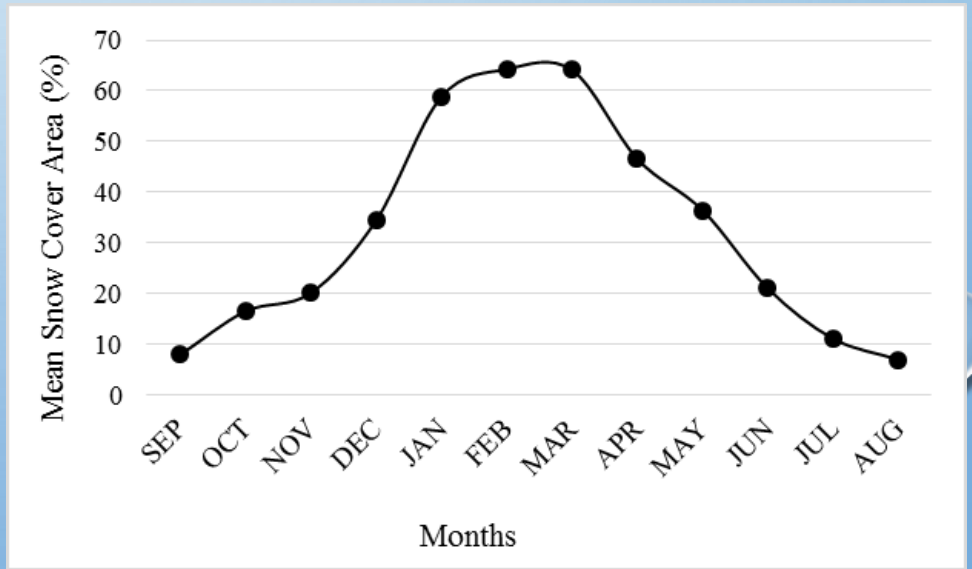


MARCH **64%**

AUGUST **7%**

Seasonal variation in SCA of the study area

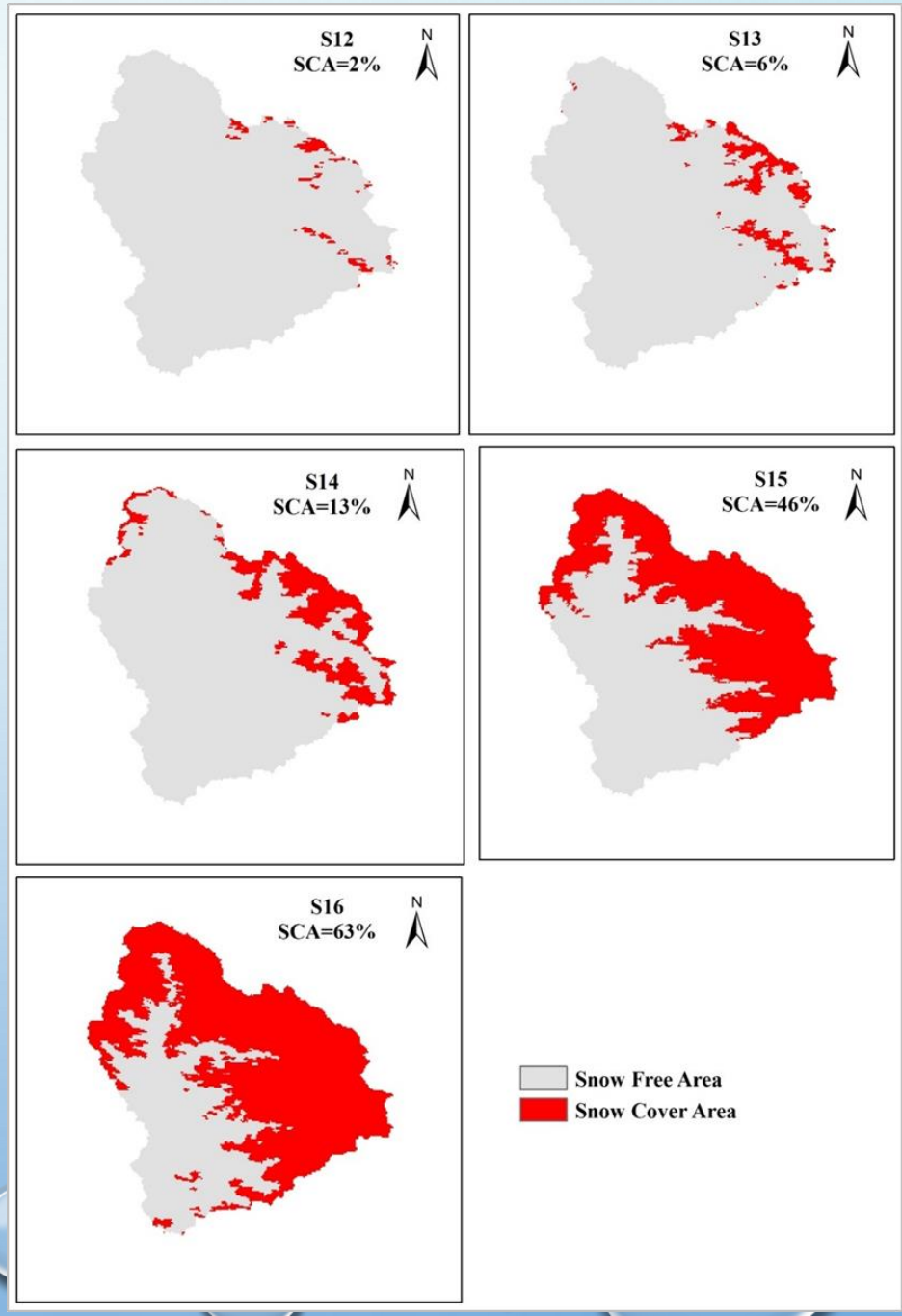
Mean monthly SCA of the study area of 2000-2015

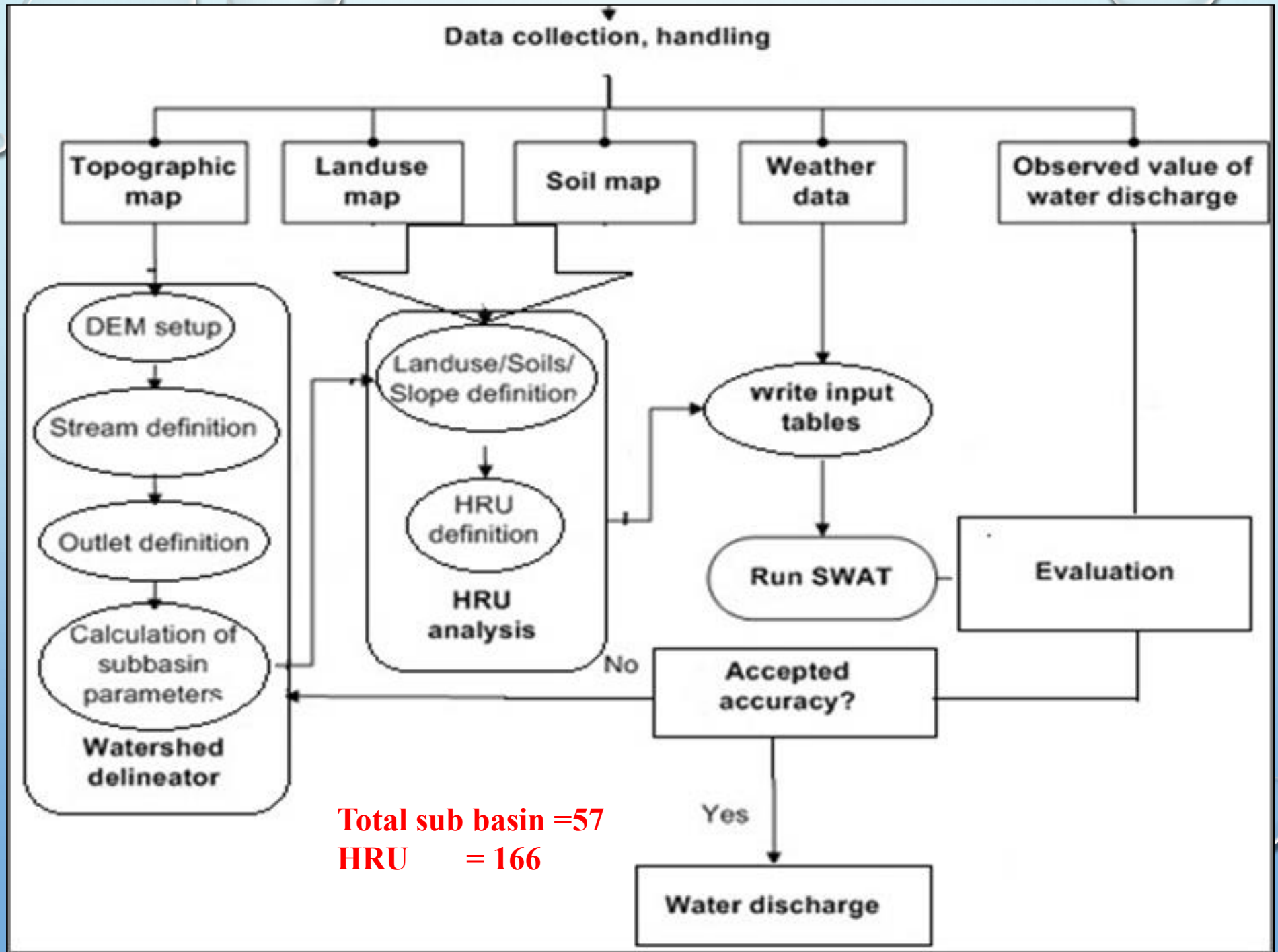


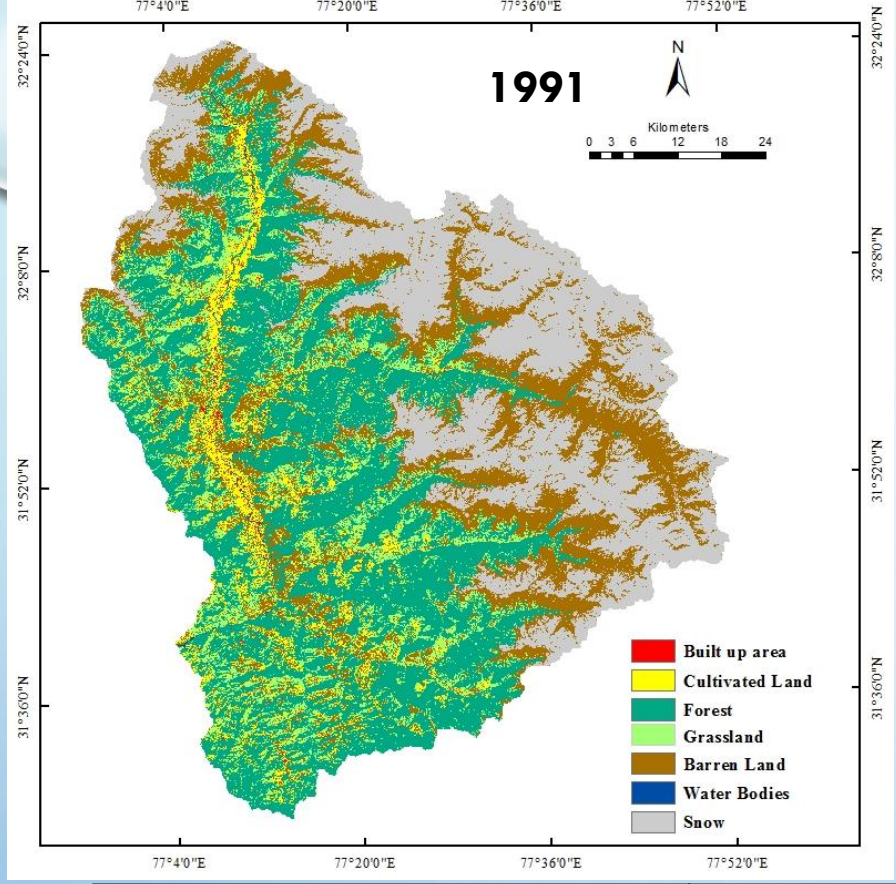
Climate Change Scenarios

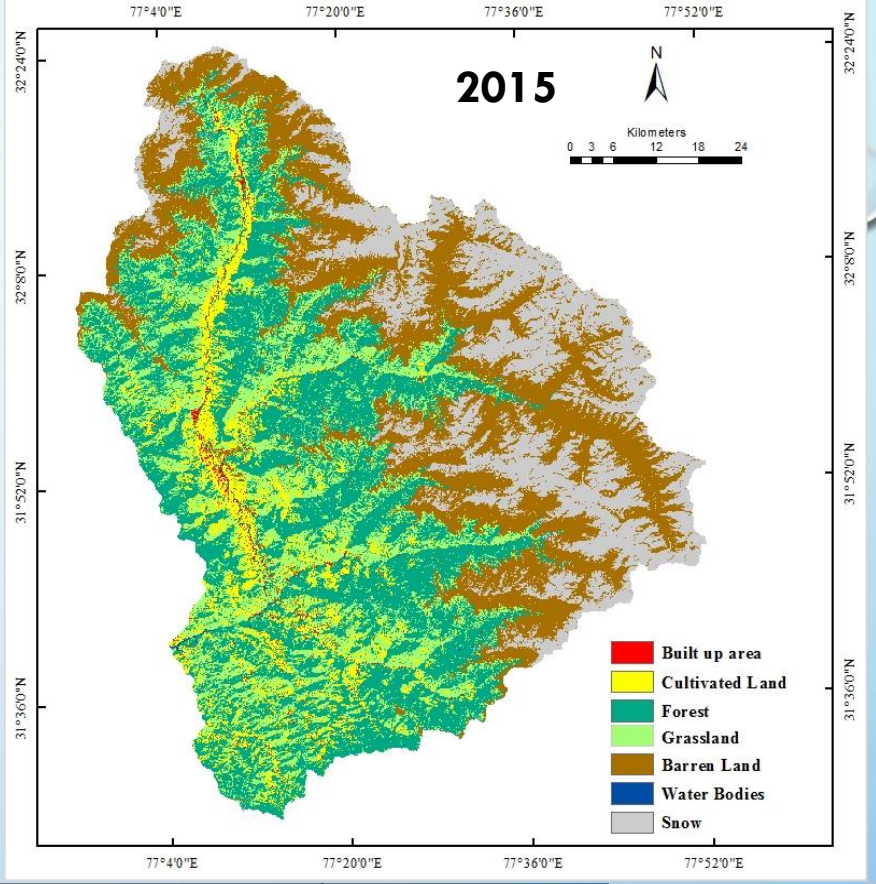
CC Scenarios	Temp change (◦C)	Precipitation change (%)
S1	2	0
S2	3	0
S3	0	5
S4	0	10
S5	0	15
S6	2	5
S7	2	10
S8	2	15
S9	3	5
S10	3	10
S11	3	15

Land Cover Change Scenarios

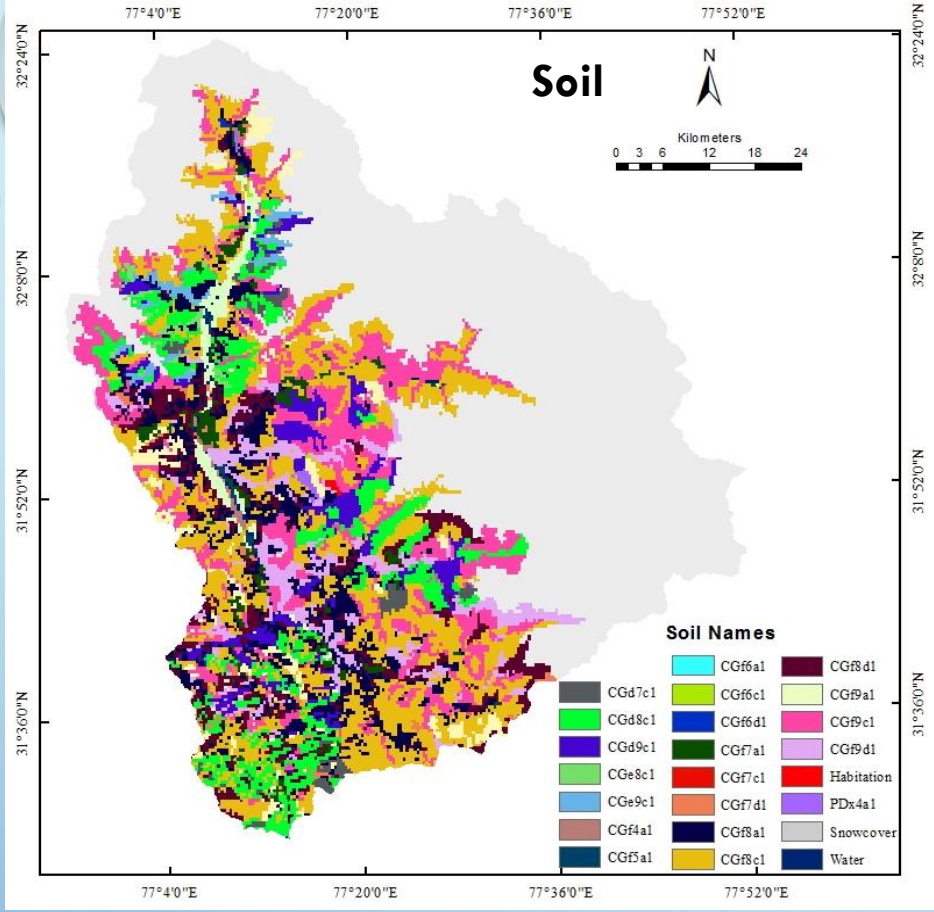


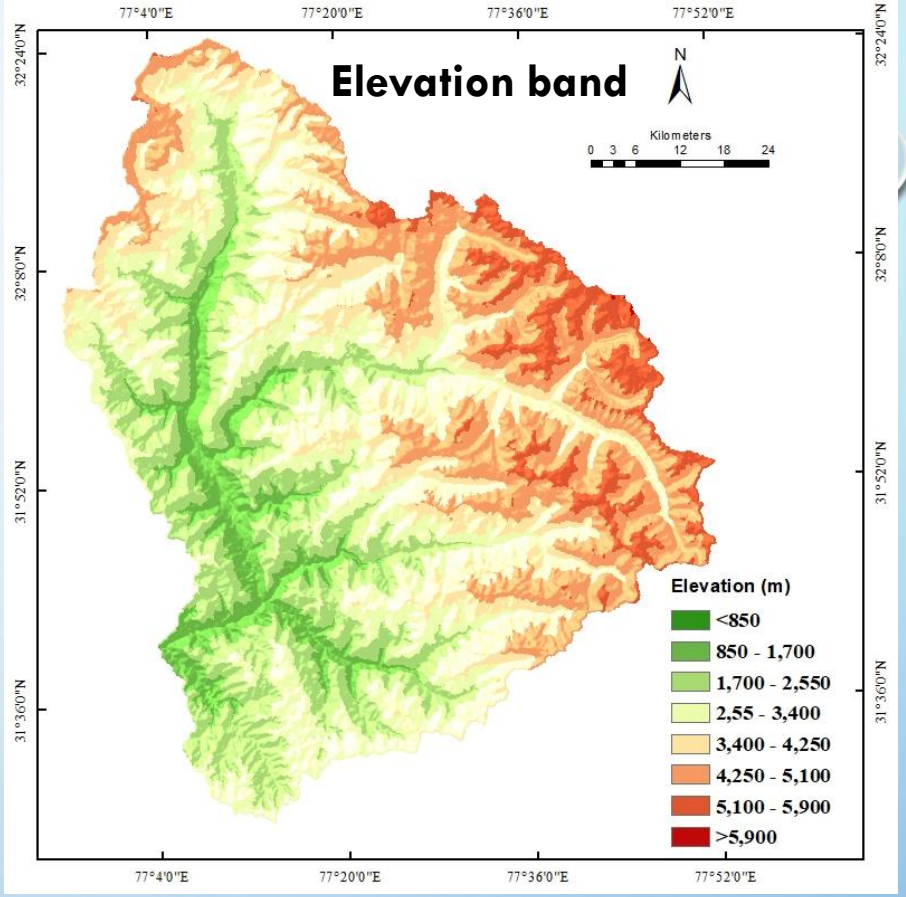

Data collection, handling
Topographic map
Landuse map
Soil map
Weather data
Observed value of water discharge
DEM setup
Stream definition
Outlet definition
Calculation of subbasin parameters
Watershed delineator
Landuse/Soils/ Slope definition
HRU definition
HRU analysis
write input tables
Run SWAT
Evaluation
No
Accepted accuracy?
Yes
Water discharge
Total sub basin =57
HRU = 166





LULC Classes	1991 (%)	2015 (%)	Change
Built up area	0.25	0.61	0.36
Cultivated land	4.9	7.49	2.51
Forest	34.03	30.3	-3.68
Grassland	11.2	16.4	5.17
Barren/unculturable/wasteland	23.4	26.4	3.03
Water bodies	0.12	0.12	0.00
Snow	25.9	18.5	-7.40





31 types of soil found in the basin

Slope (%)	% of total basin area
< 10	7.16
10-15	3.2
15-25	6.93
> 25	82.71

Elevation (m)	% of total basin area
<850	0.02
850-1700	9.10
1700-2550	23.80
2550-3400	22.91
3400-4250	16.87
4250-5100	21.23
5100-5950	6.05
> 5900	0.03

Results and Discussions

Parametrization

Elevation band related parameters

a) Precipitation lapse rate (PLAPS)
b) Temperature lapse rate (TLAPS)
c) snow water content (SNOEB)

Snow related parameters

a) Rain/snow threshold (SFTMP)
b) Maximum melt coefficient (SMFMX)
c) Minimum melt coefficient (SMFMN)
d) Snowpack temperature lag factor (TIMP)
e) Snowpack temperature melt factor (SMTMP)
f) Areal snow coverage threshold CV_{100} (SNOCOVMX)
g) Areal snow coverage threshold CV_{50} (SNO50COV)

Hydrological Parameters	Final Value
a) r__CN2.mgt	-0.150000
b) v__GW_DELAY.gw	11.927000
c) v__SURLAG.bsn	9.610001
d) v__OV_N.hru	4.296410
e) r__HRU_SLP.hru	-1.852000
f) v__GWQMN.gw	23.000000
g) v__REVAPMN.gw	964.500000
h) v__GW_REVAP.gw	0.046970

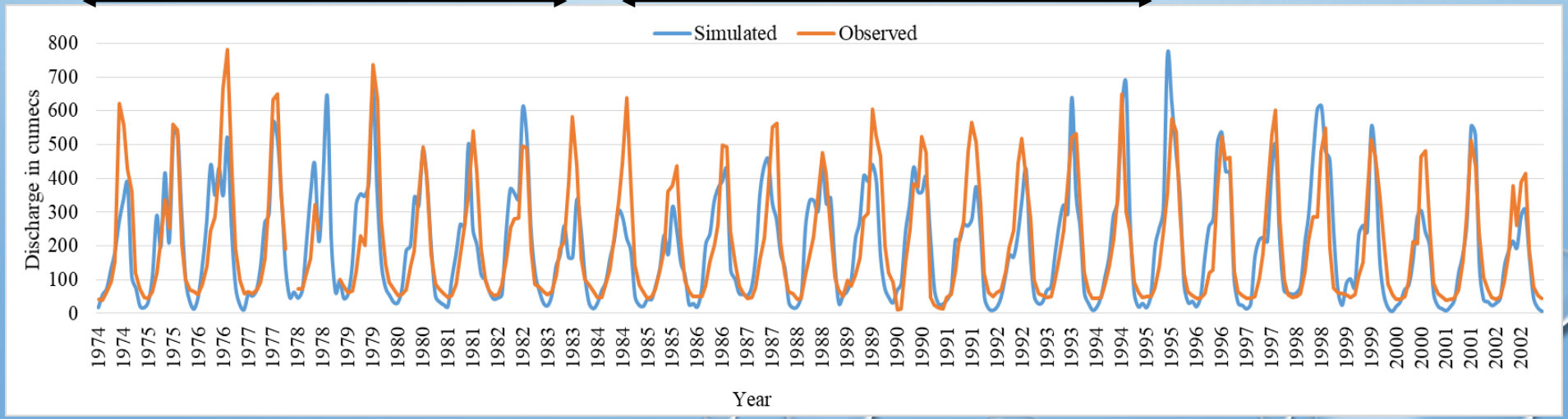
Calibration & Validation

Type	Period	Time Scale	Mean Stream Flow (in cumecs)		R2	NSE
			Observed	Simulated		
Default	1974-2002	Monthly	207	175	0.24	-0.39
Baseline	1974-2002	Monthly	207	198	0.64	0.63
Calibration	1974-1983	Monthly	217	207	0.65	0.65
Validation	1985-1995	Monthly	207	202	0.64	0.61

Baseline Period

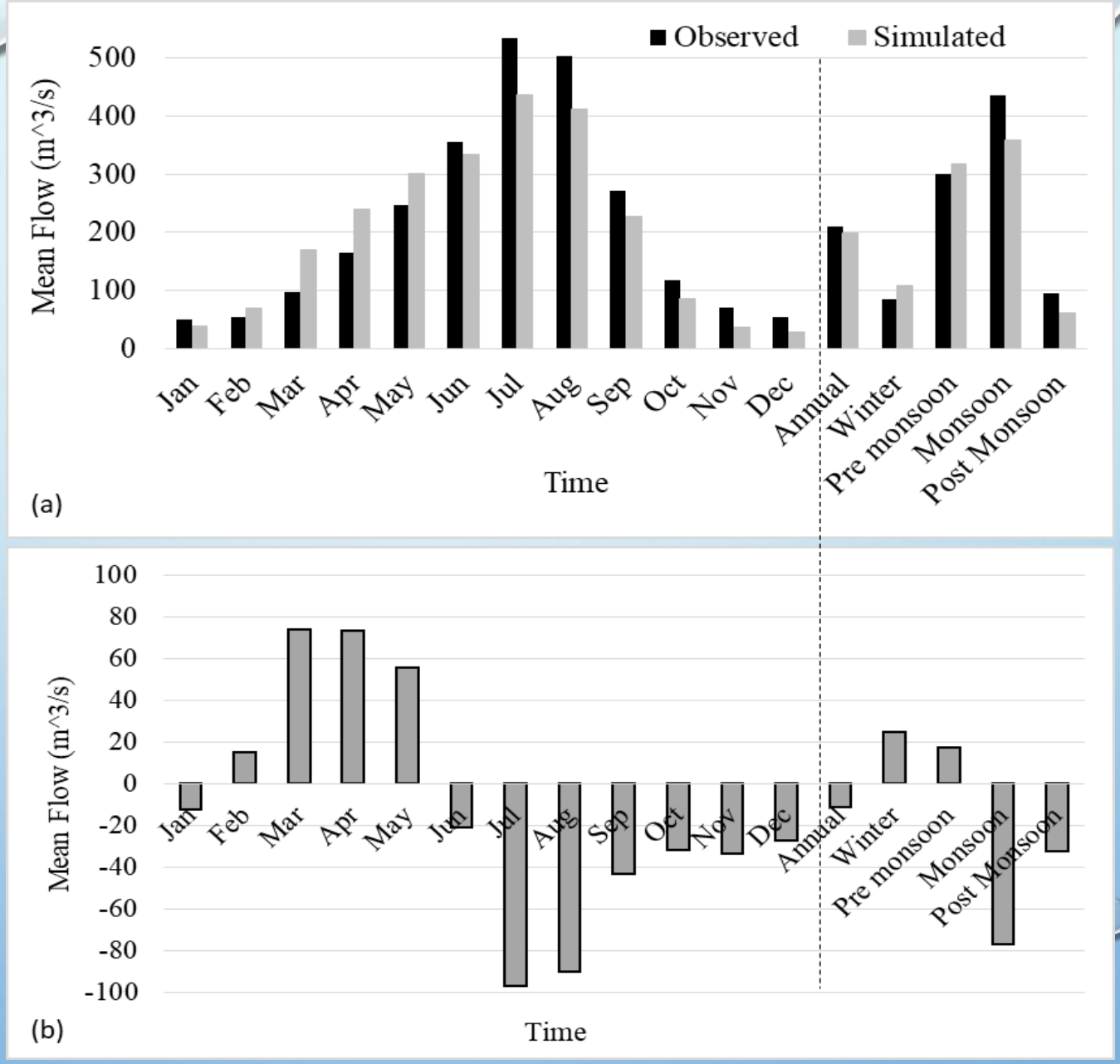
Calibration Period

Validation Period



Overestimaton from jan to jun

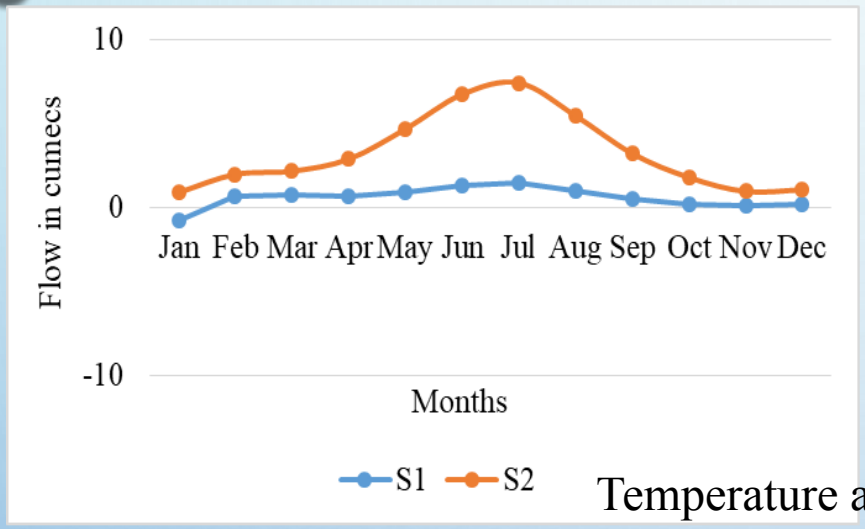
Underestimation from july to sep



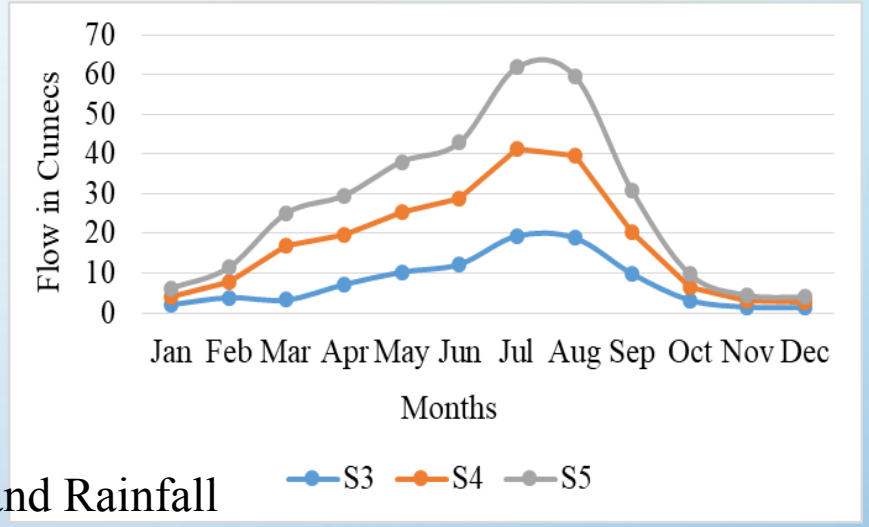
(a) Observed and simulated flow (b) Difference between observed and simulated mean monthly flow for the period 1974-2002

Simulated annual cycle of streamflow by month in response to various changes in temperature & Rainfall

Temperature

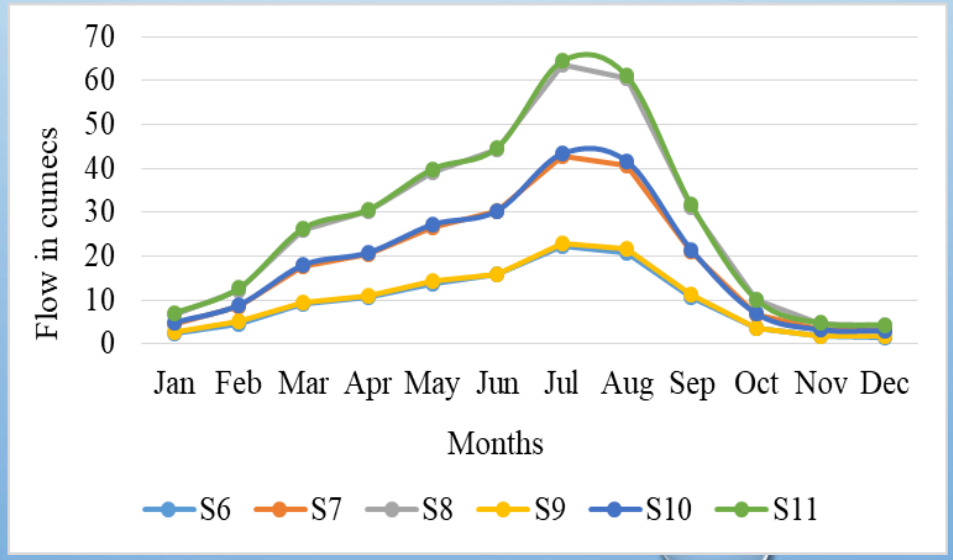


Rainfall



Temperature and Rainfall

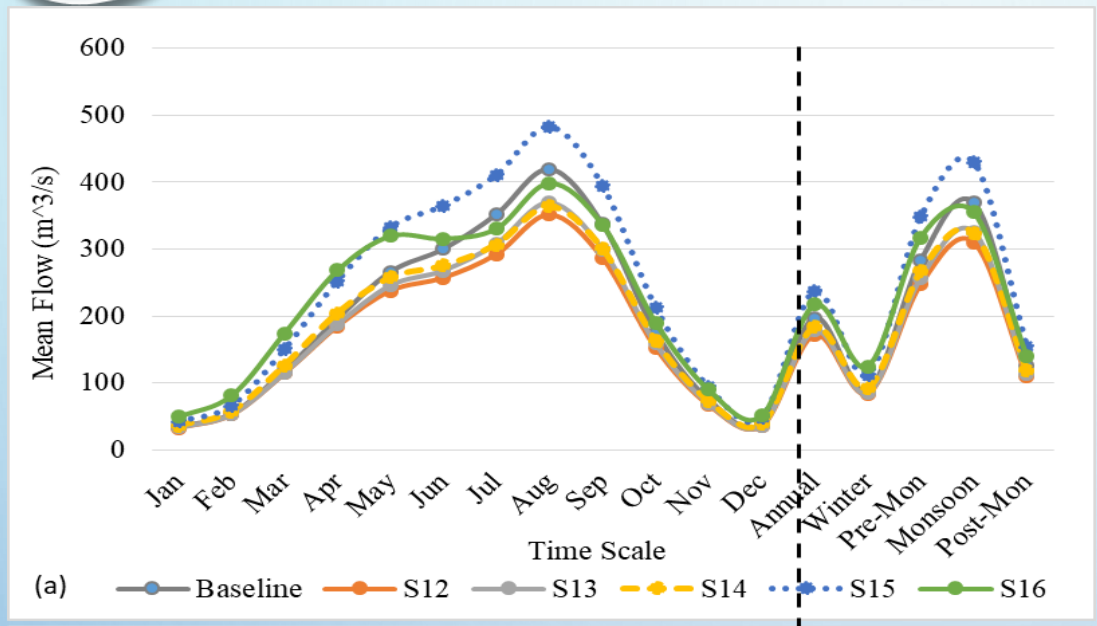
	Temp	Rain
S1	2°C	
S2	3°C	
S3		5%
S4		10%
S5		15%
S6	2°C	5%
S7	2°C	10%
S8	2°C	15%
S9	3°C	5%
S10	3°C	10%
S11	3°C	15%

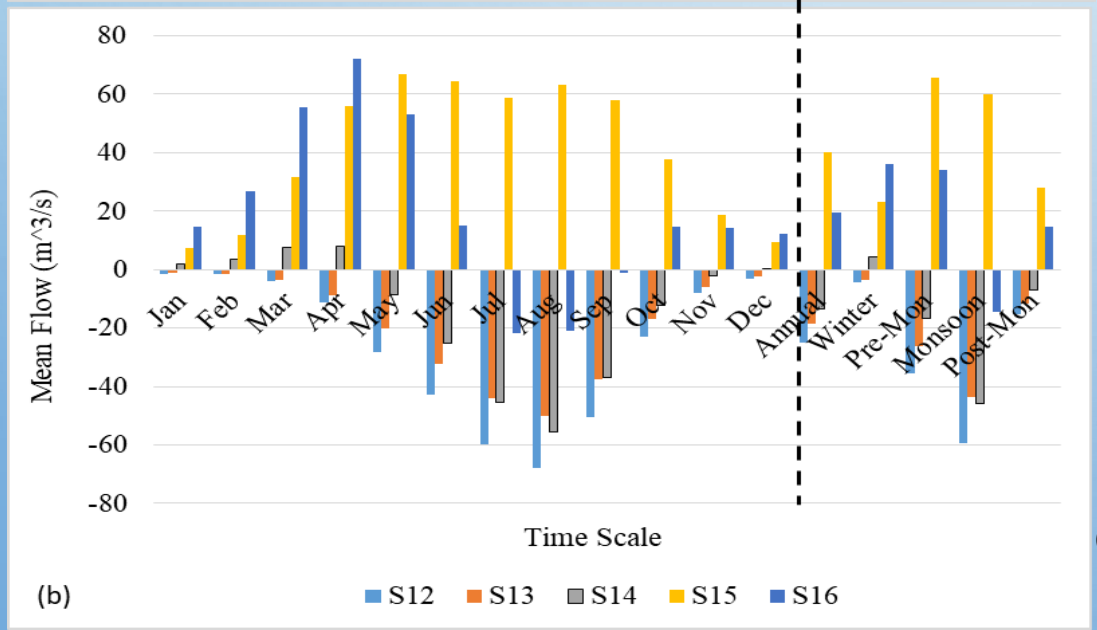


Change in Annual Mean Flow

Scenarios	Annual Mean Flow (m^3/s)	% change
Baseline	198.36	
S1	198.97	0.31
S2	201.65	1.66
S3	206.09	3.90
S4	216.35	**9.07**
S5	**225.32**	**13.59**
S6	208.10	4.91
S7	217.11	**9.45**
S8	226.10	**13.98**
S9	208.47	5.10
S10	217.49	**9.65**
S11	**226.49**	**14.18**

Simulated annual cycle of streamflow by month in response to changes in SCA





SCA

Baseline=26%
S12=2%
S13=6%
S14=13%
S15=46%
S16=63%

(a) Baseline and predicted mean flow
(b) difference between baseline and predicted flow under different land cover scenarios

Change in mean annual flow

Scenarios	Mean Annual Flow (m^3/s)	% Change in Mean Annual Flow
Baseline	198	
S12	172	-13
S13	179	-9
S14	184	-7
S15	238	20
S16	217	10

Conclusions

- Under air temperature scenarios (S1-S2), a major rise in predicted flow is predicted for **pre-monsoon season followed by winter and monsoon**
- under S3-S5, where change in rainfall is considered, rise in flow during **monsoon followed by winter and pre-monsoon** with reference to baseline.
- (S6-S11) where both air temperature and rainfall change simultaneously, a major rise in predicted flow is predicted during **winter followed by monsoon and post monsoon**.
- annual mean flow would vary from 0.3% (S1) to 14.2% (S11)
- impacts of climate change were predicted to be more pronounced for the seasonal variability than the inter-annual variability in the basin

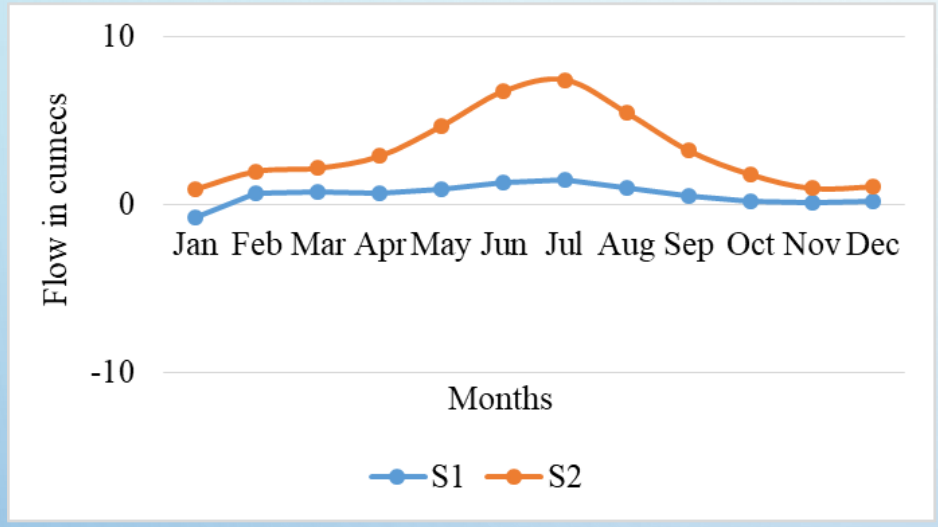
- land cover scenarios from S12 to S16, percentage change in monsoon streamflow would vary from -13% to 23% by mid-century.
- While change in streamflow during pre-monsoon in the basin would vary from -5% to 41%
- Percentage change in mean annual flow would vary from -13% to 20% in the basin.

Overall, the study found that flow regime in the basin is more sensitive towards climate change.

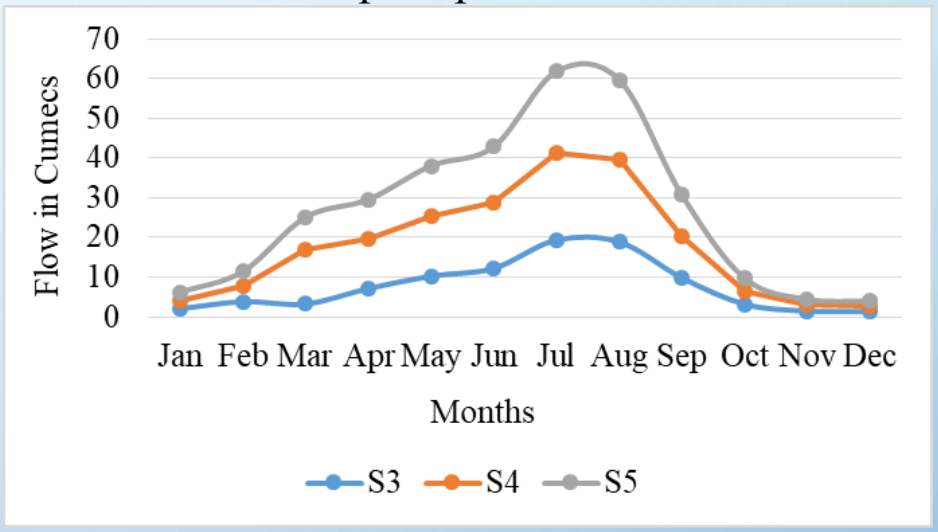
THANKS

simulated annual cycle of streamflow by month in response to various changes in temperature & precipitation

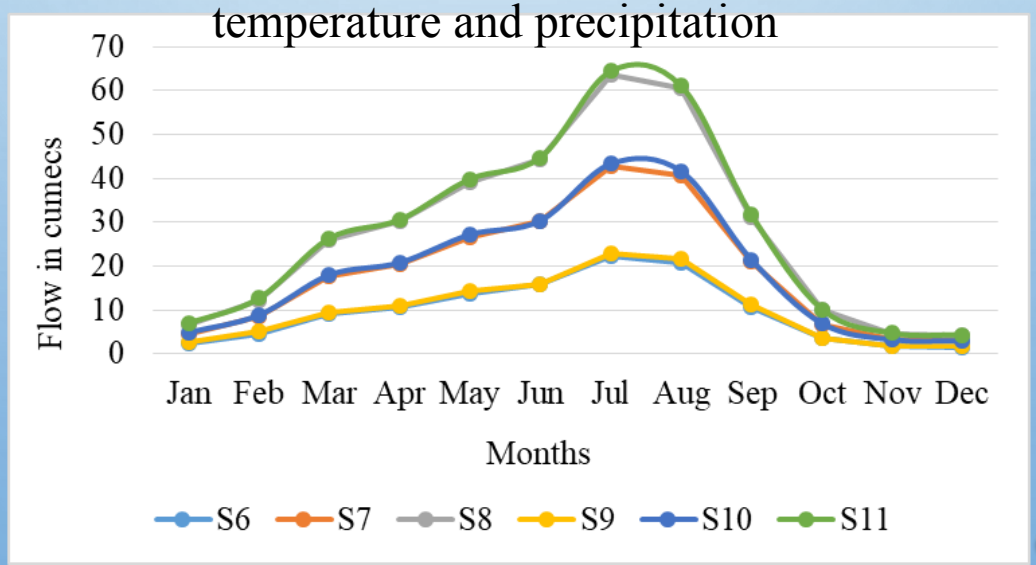
temperature



precipitation

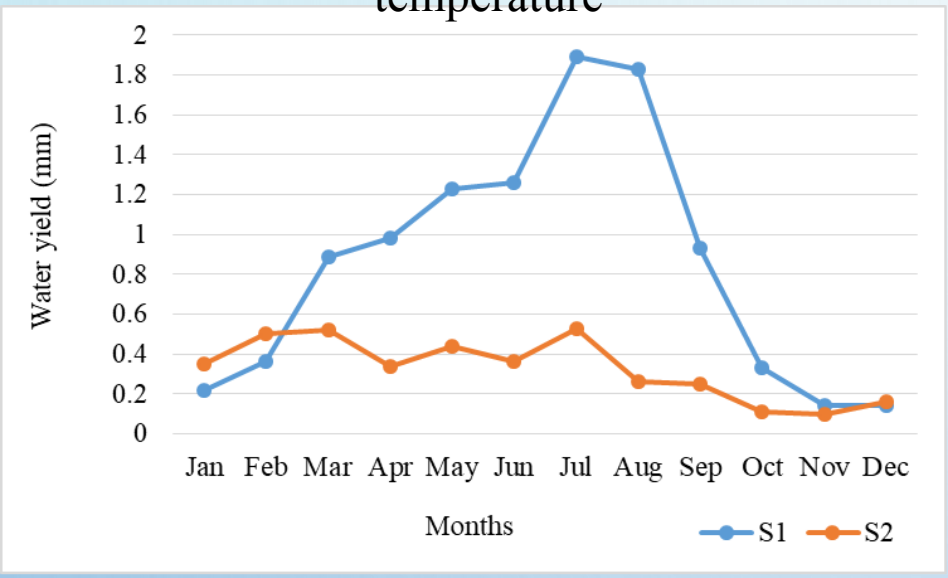


temperature and precipitation

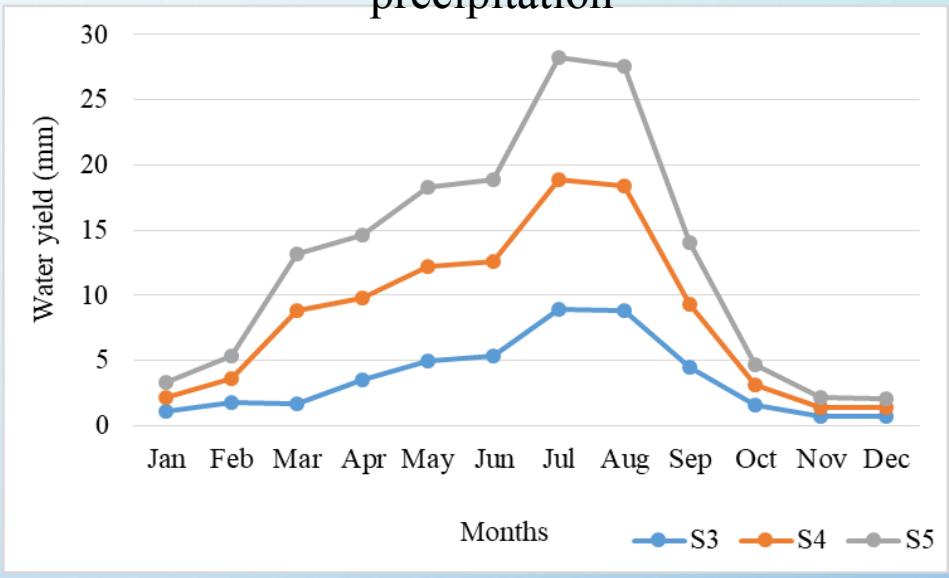


Change in Monthly Water Yield

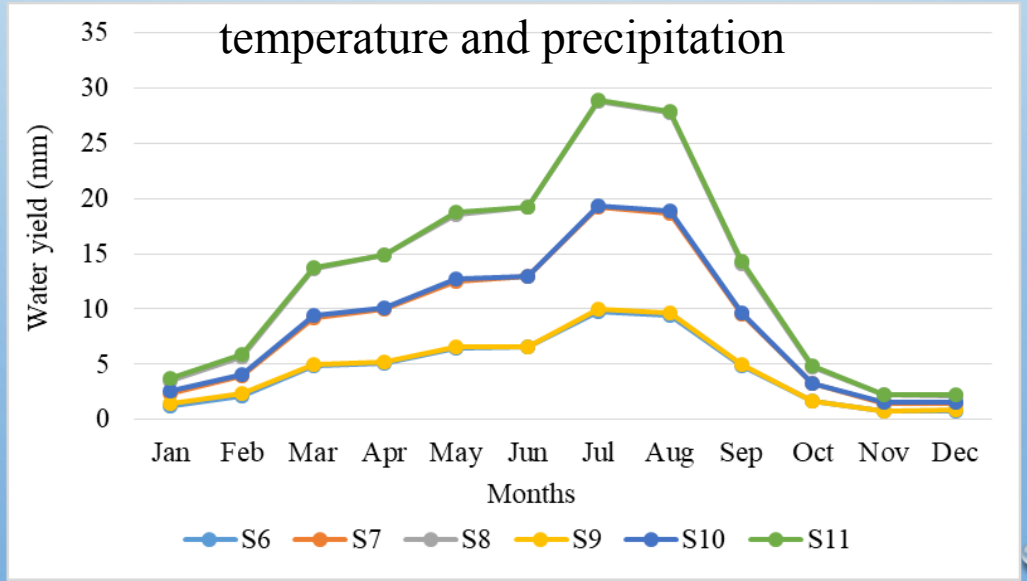
temperature



precipitation



temperature and precipitation



% Change in Average Annual Water Yield

Scenarios	Annual Water Yield in mm	% change
Baseline	90.55	
S1	91.40	0.94
S2	90.87	0.36
S3	94.18	4.01
S4	99.01	**9.35**
S5	103.23	**14.01**
S6	95.02	4.94
S7	99.26	**9.62**
S8	103.49	**14.29**
S9	95.14	5.07
S10	99.38	**9.76**
S11	103.61	**14.43**