Hydrological Modeling of Koshi basin and Climate Change analysis (Nepal)

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2016 International SWAT Conference, Beijing, China

INTRODUCTION

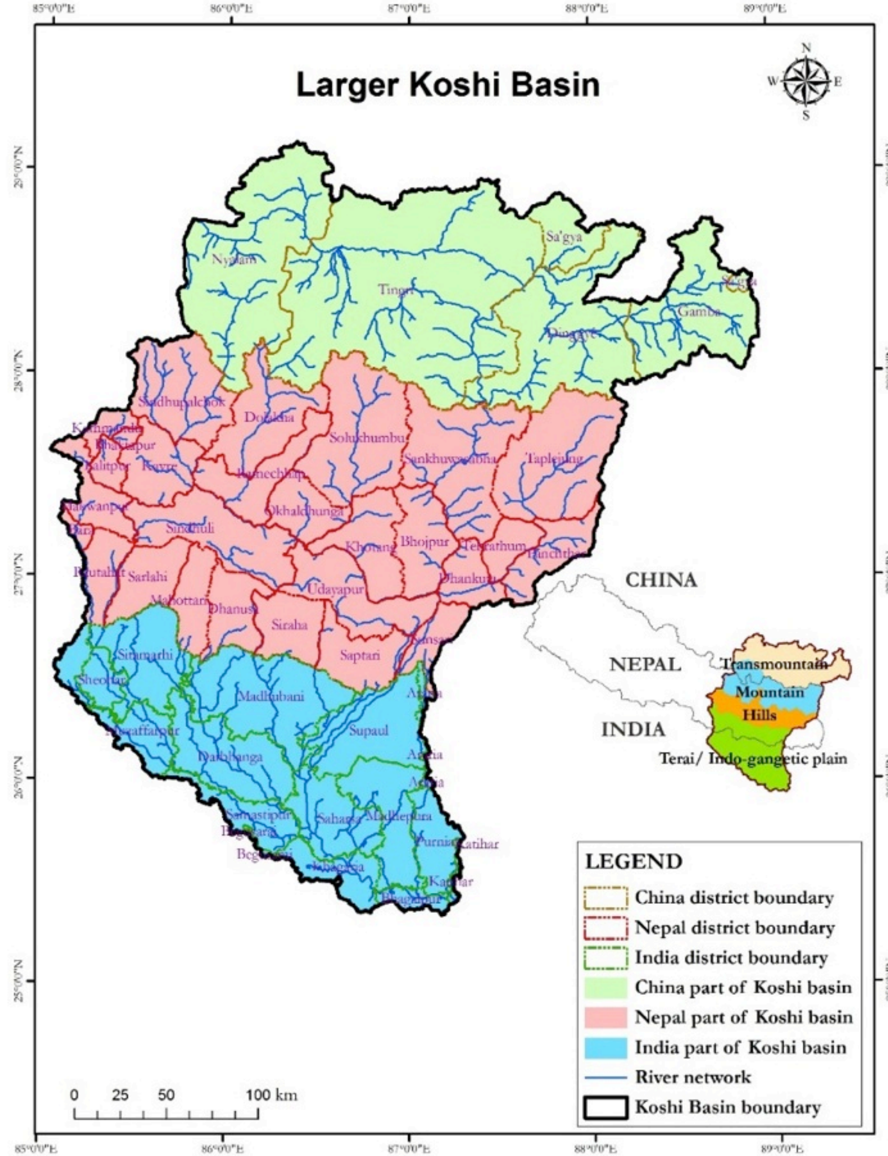
- River basins in Himalayas are still considered data and information vaccuum
- Koshi basin is perceived as having high potential for hydropower and irrigation development
- Currently development plans at individual project levels without focusing on downstream impacts, environmental flows, impact on local livelihoods.
- So there is a need to carry out accurate physical resource assessments, which quantifies both spatial and temporal water availability in the basin
- Also impacts of climate change is important in future planning (infrastructural planning)

OBJECTIVES

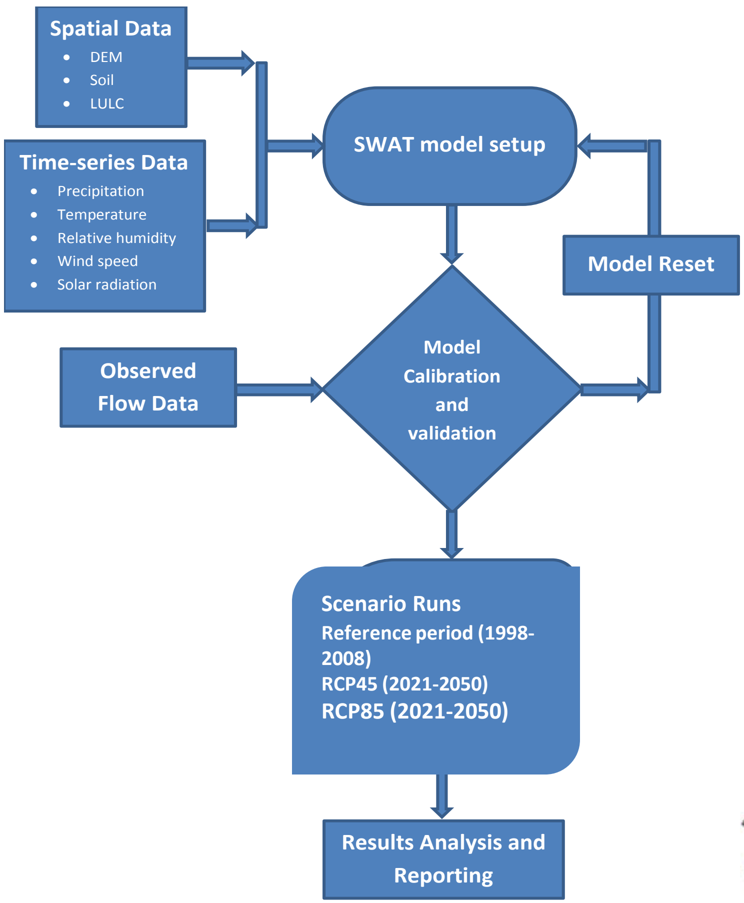
- To assess the spatial and temporal water balances in the Koshi basin (China, Nepal and India)
- Assess the impacts of CC in the hydrology of Koshi basin using SWAT

STUDY BASIN

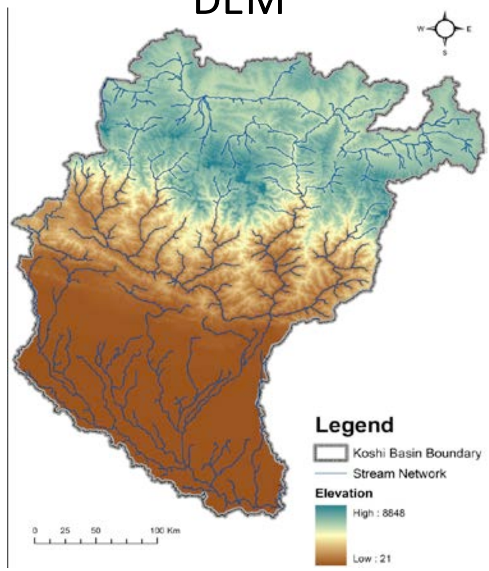
- Koshi Basin (87,311 km^2): Transboundary basin, covering 4 physiographic regions.
- 5 districts in China, 27 districts in Nepal and 16 districts in Bihar, India
- Largest contributor to the Ganges river

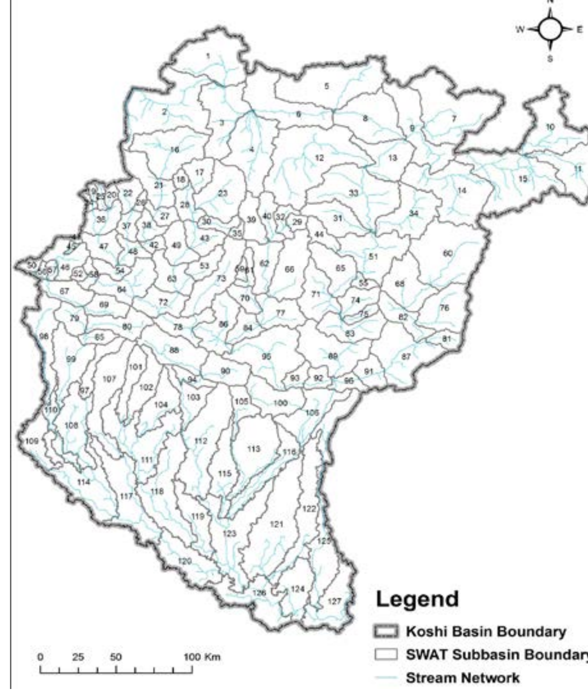


METHODS AND SPATIAL DATA

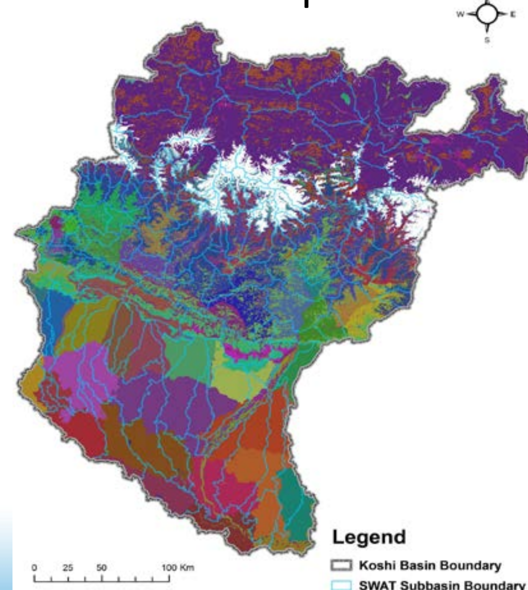


DEM

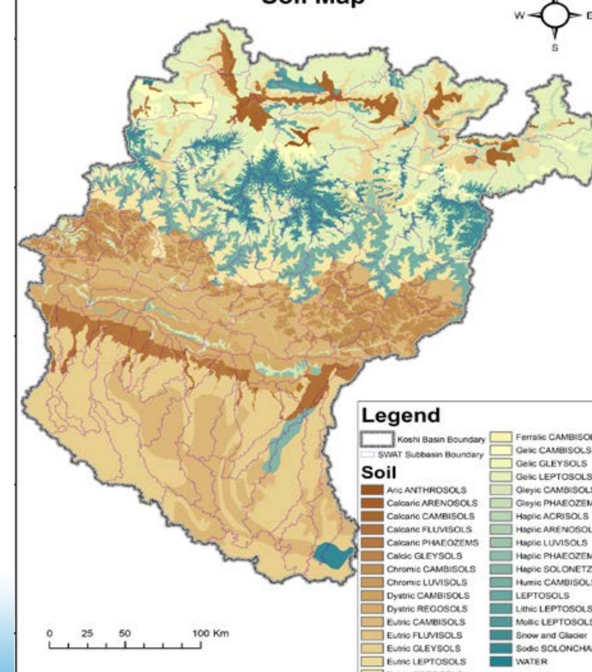




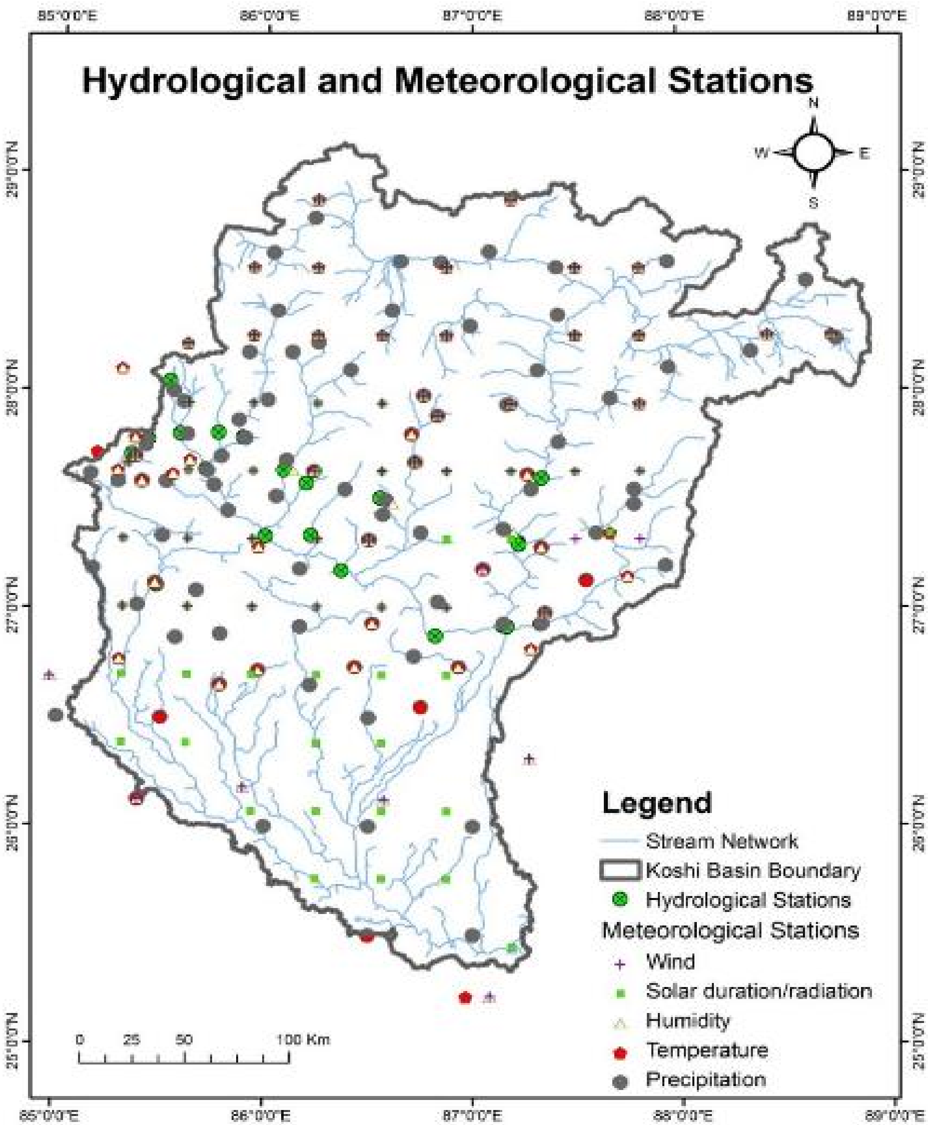
LULC Map

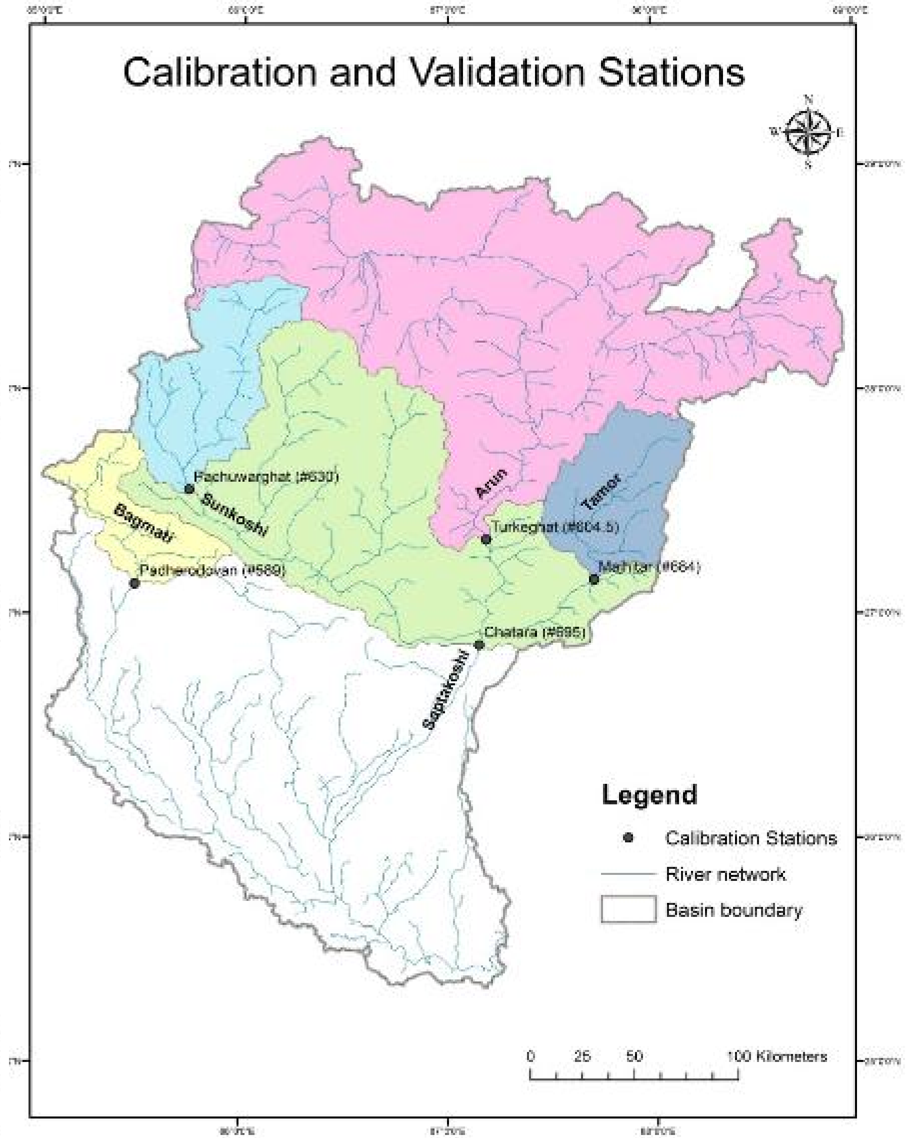


Soil Map



HYDRO-MET AND CALIBRATION STATIONS





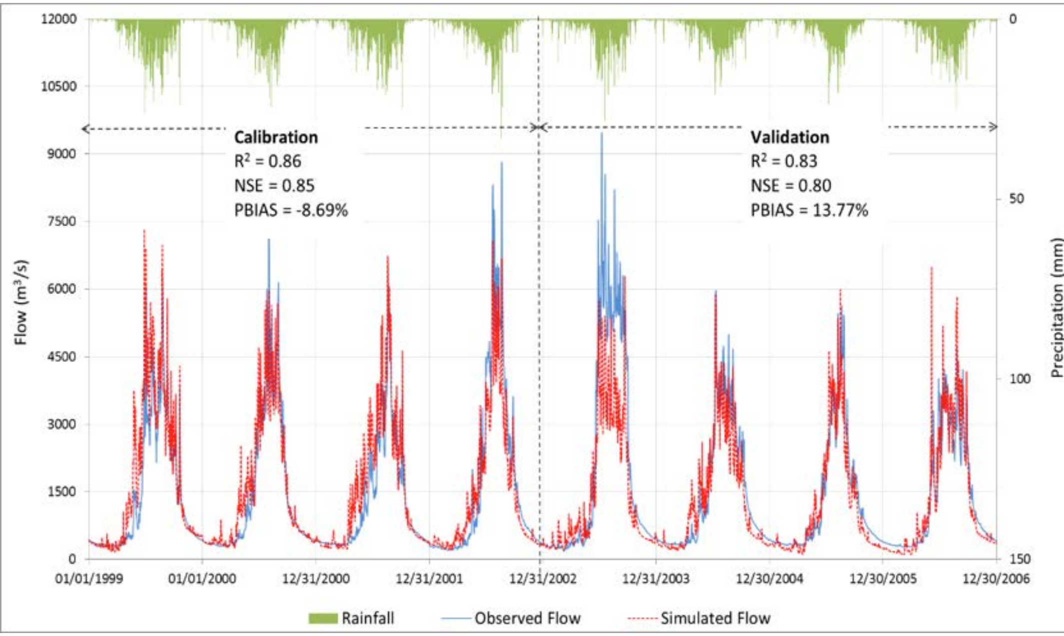
MODEL CALIBRATION

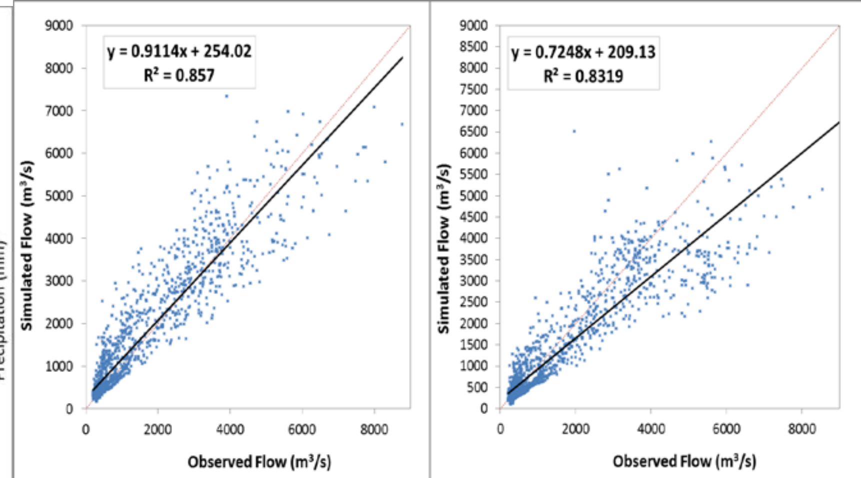
- Sensitivity analysis
- Auto calibration
- Manual calibration

Sensitivity Analysis Ranking	Parameters*	Initial Value suggested by SWAT
1	ALPHA_BF	0.54
2	CH_K2	142.79
3	CH_N2	0.1001
4	CN2	19.129
5	ESCO	0.6208
6	GWQMN	944.35
7	REVAPMN	8.967
8	SOL_AWC	18.17
9	SOL_K	23.45
10	SURLAG	2.35

Arnold et al. 2011

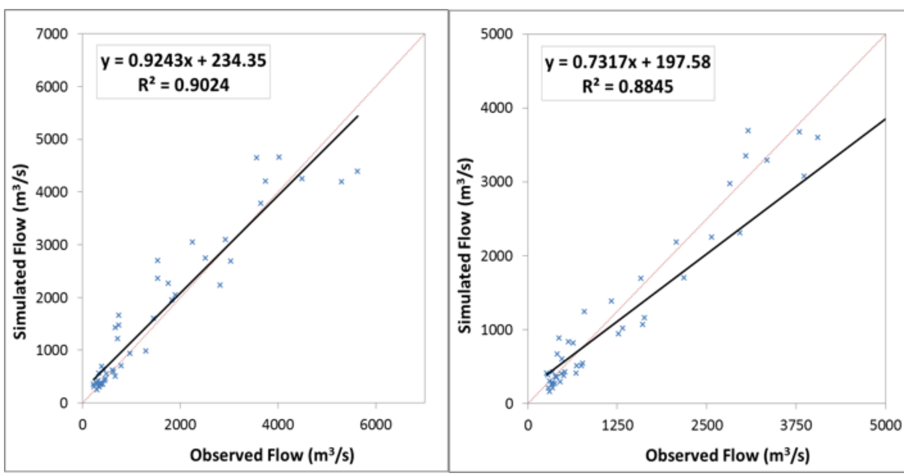
Flow Station	Parameters*	Initial values	Calibrated values
Turkeghat	TLAPS	-5.6	-3.8
	PLAPS	-50	5.8
	CN_2	Varies	0.8 (Ratio)
	SOL_K	Varies	0.8 (Ratio)
	GW_DELAY	31	120
	ALPHA_BF	0.048	0.55
	ESCO	0	0.7
	LATTIME	1	1
	SOL_Z	300	600
	GWQMN	0	550
	SURLAG	10	1
	SFTMP	1	1
	SMTMP	0.5	0.9
Majhitar	GW_DELAY	31	85
	CN_2	Varies	0.8 (Ratio)
	ESCO	0	0.5
	SOL_Z	300	800
	SOL_K	Varies	0.75 (Ratio)
	SOL_AWC	Varies	0.95 (Ratio)
	GWQMN	0	415
	CH_N2	0.014	0.035
Pachuwarghat	CN_2	Varies	0.75 (Ratio)
	GW_DELAY	31	90
	ALPHA_BF	0.048	0.09
	GWQMN	0	500
	SOL_Z	300	600
	SOL_K	Varies	0.7 (Ratio)
	SOL_AWC	Varies	1.167 (Ratio)
	ESCO	0	0.7
Padherodovan	CN_2	Varies	1.35 (Ratio)
	GW_DELAY	31	90
	ALPHA_BF	0.048	0.015
	SOL_AWC	Varies	1.135 (Ratio)
	SOL_K	Varies	0.56 (Ratio)
	ESCO	0	0.075
	GW_REVAP	0.02	0.05
	CH_K2	0	6.21
	CH_N2	0.014	0.211
Chatara	GW_DELAY	31	100
	ALPHA_BF	0.048	0.5
	CN_2	Varies	0.65 (Ratio)
	LATTIME	1	4

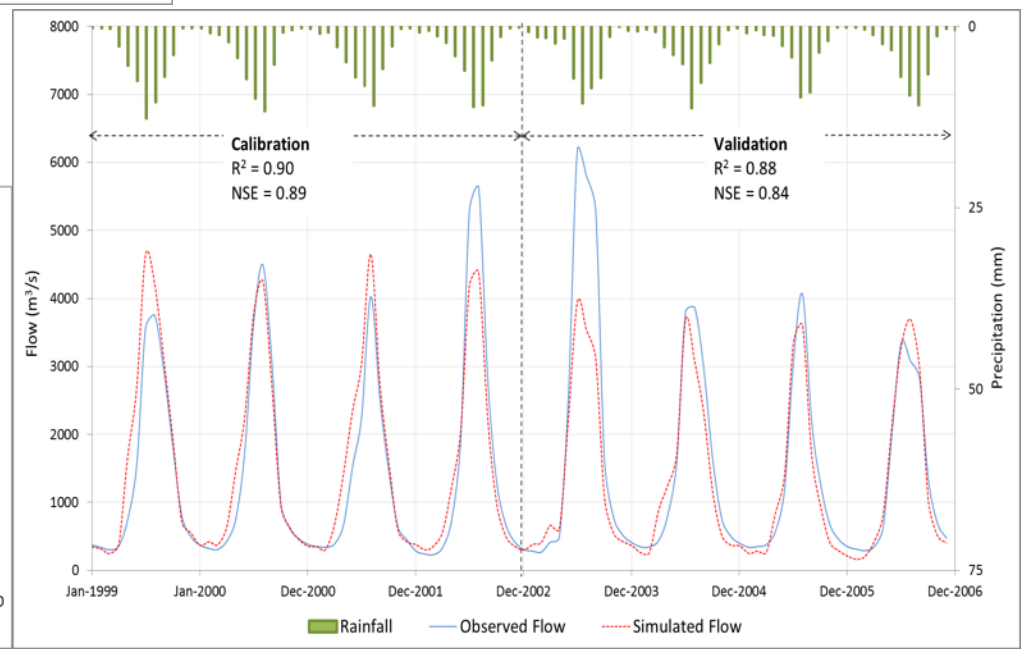




VALIDATION

CALIBRATION





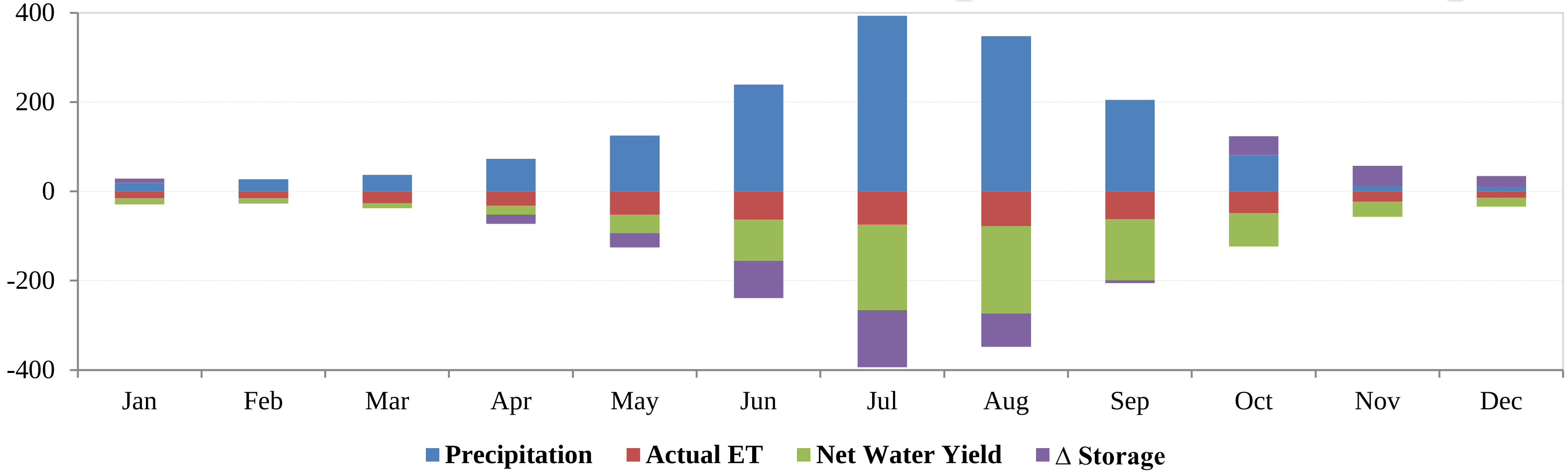
Calibration and Validation of flow at Chatara #695

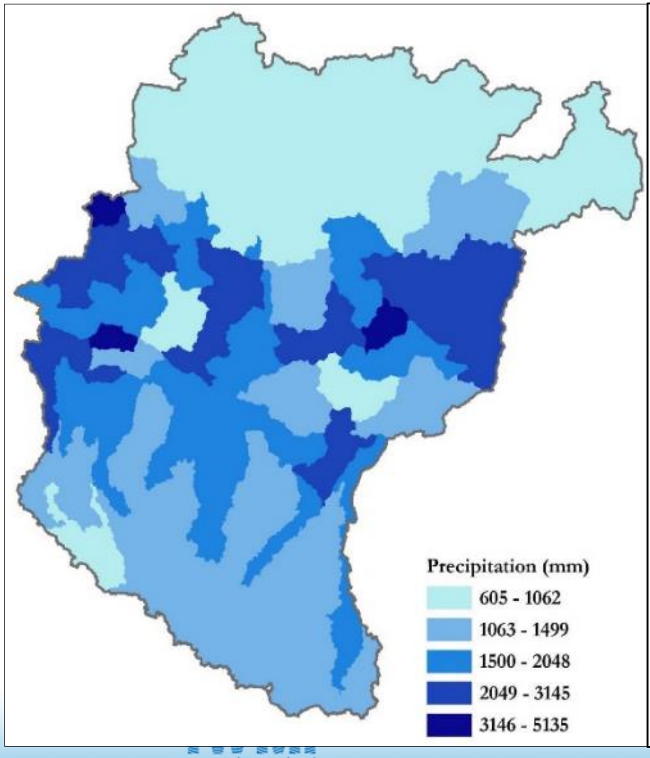
CALIBRATION AND VALIDATION (CONTD..)

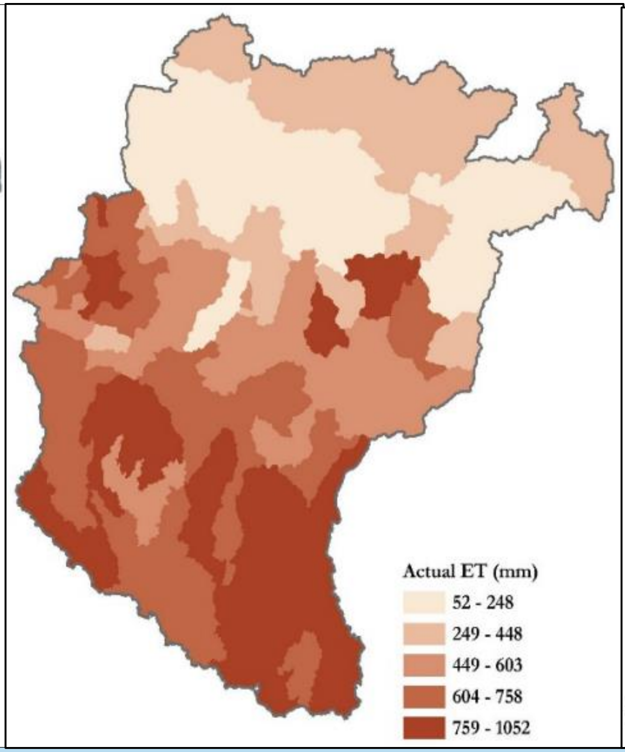
River	Station (Index no.)	Index	Daily		Monthly	
			Calibration	Validation	Calibration	Validation
Arun	Turkeghat (#604.5)	R^2	0.81	0.67	0.95	0.75
		NSE	0.81	0.61	0.94	0.66
		*Performance			Very Good	Satisfactory
Tamor	Majhitar (#684)	R^2	0.66	0.67	0.91	0.95
		NSE	0.65	0.58	0.85	0.95
		*Performance			Very Good	Very Good
Sunkoshi	Pachuwarghat (#630)	R^2	0.74	0.71	0.93	0.94
		NSE	0.72	0.65	0.93	0.93
		*Performance			Very Good	Very Good
Bagmati	Padherodovan (#589)	R^2	0.71	0.70	0.93	0.95
		NSE	0.71	0.67	0.92	0.82
		*Performance			Very Good	Good
Saptakoshi	Chatara (#695)	R^2	0.86	0.83	0.90	0.88
		NSE	0.85	0.80	0.89	0.84
		*Performance	0.39	0.44	Very Good	Good

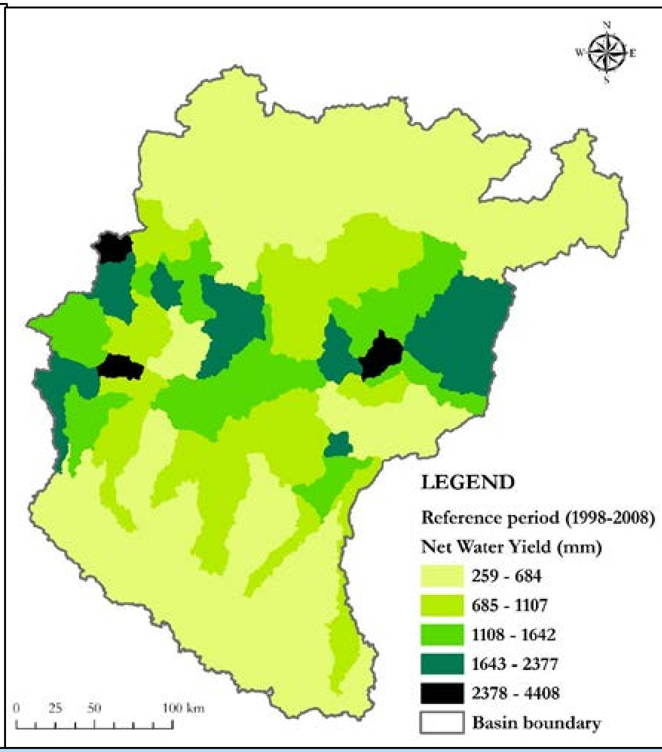
Guidelines proposed by Moriasi et al. (2007)

WATER BALANCE (1998-2008)

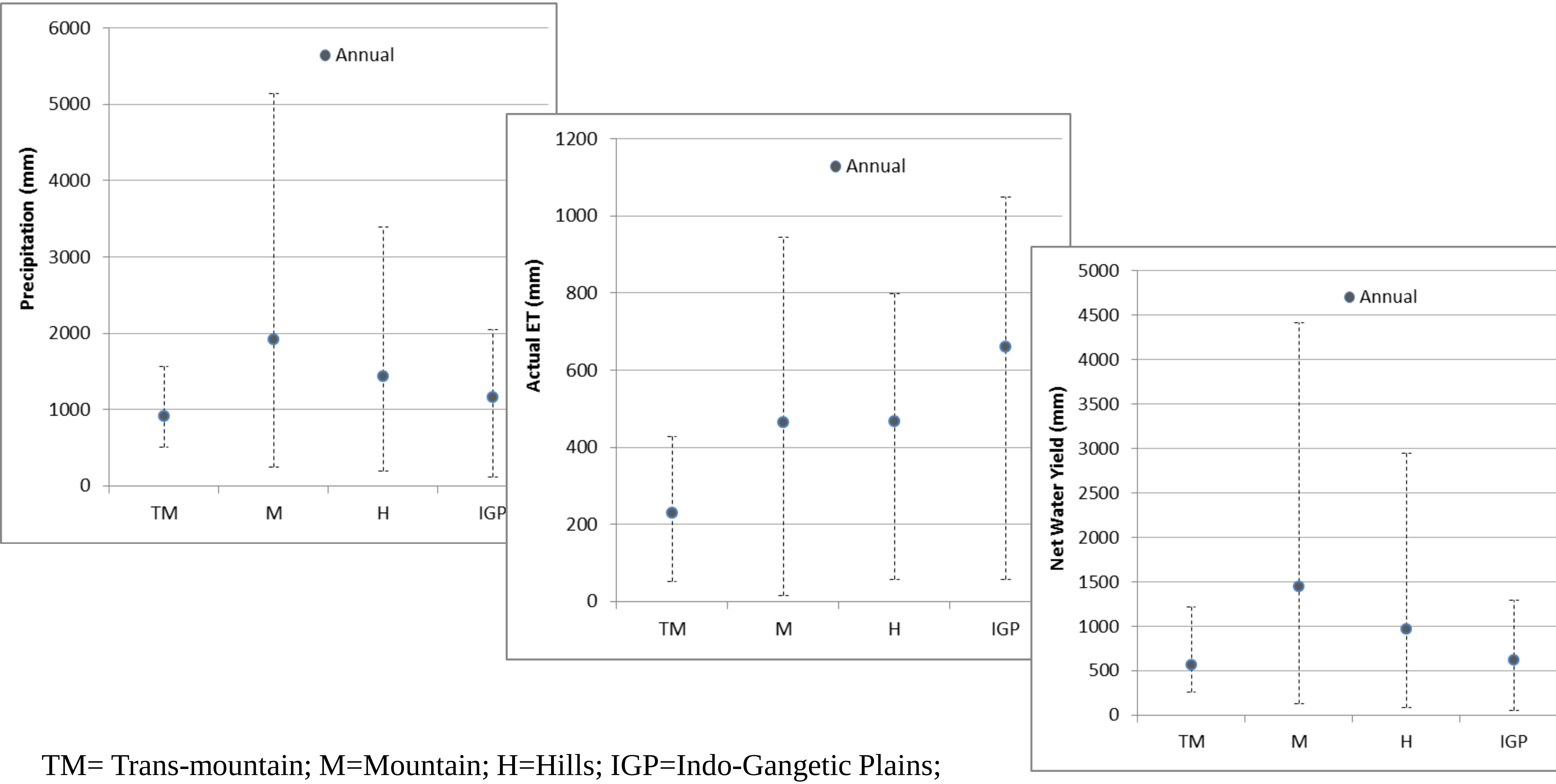








PHYSIOGRAPHIC REGION WISE WATER BALANCE



TM= Trans-mountain; M=Mountain; H=Hills; IGP=Indo-Gangetic Plains; error bars show the maximum-minimum range

FUTURE CLIMATE SCENARIOS

"…A new set of scenarios, the ***Representative Concentration Pathways (RCPs)****, was used for the new climate model simulations carried out under the framework of the Coupled Model Intercomparison Project Phase5 (CMIP5) of the World Climate Research Programme…"*

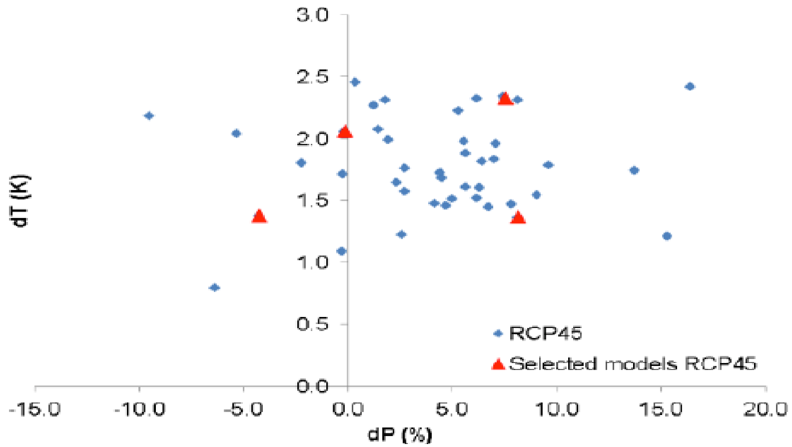
✓ RCPs are identified by their approximate total radiative forcing in year 2100 relative to 1750: 2.6 W/m^2 for RCP2.6, 4.5 W/m^2 for RCP4.5, 6.0 W/m^2 for RCP6.0 and 8.5W/m^2 for RCP8.5

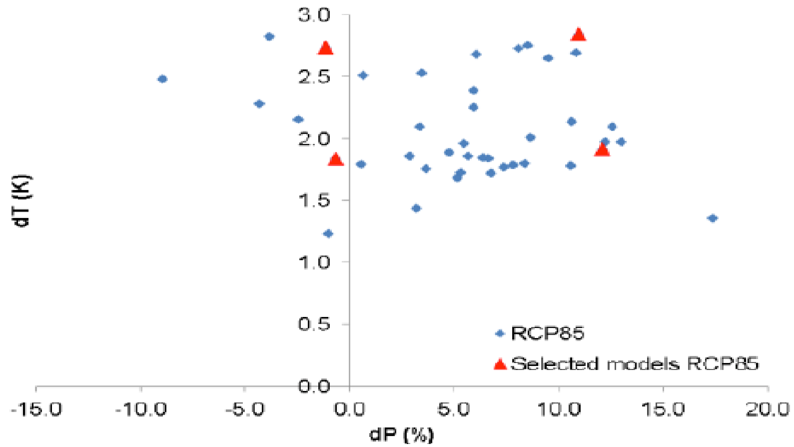
- **RCP2.6 : mitigation scenario leading to a very low forcing level**
  - Radiative forcing peaks and declines by 2100
- **RCP4.5 and RCP6.0 : stabilization scenario**
  - Radiative forcing stabilizes by 2100
- **RCP8.5 : very high GHG emissions**
  - Radiative forcing does not peak by 2100

Source: IPCC, 2013

Climate change downscaling method

Selection of GCM





Description	RCP	dP (%)	dT (K)	Selected Model
DRY, COLD	RCP45	-1.8	1.4	GISS-E2-R-r4i1p1_rcp45
DRY, WARM	RCP45	-1.8	2.3	IPSL-CM5A-LR-r4i1p1_rcp45
WET, COLD	RCP45	8.9	1.4	CCSM4-r5i1p1_rcp45
WET, WARM	RCP45	8.9	2.3	CanESM2-r4i1p1_rcp45
DRY, COLD	RCP85	-1.1	1.7	GFDL-ESM2G-r1i1p1_rcp85
DRY, WARM	RCP85	-1.1	2.7	IPSL-CM5A-LR-r4i1p1_rcp85
WET, COLD	RCP85	12.1	1.7	CSIRO-Mk3-6-0-r3i1p1_rcp85
WET, WARM	RCP85	12.1	2.7	CanESM2-r4i1p1_rcp85

Climate change downscaling method (Contd…)

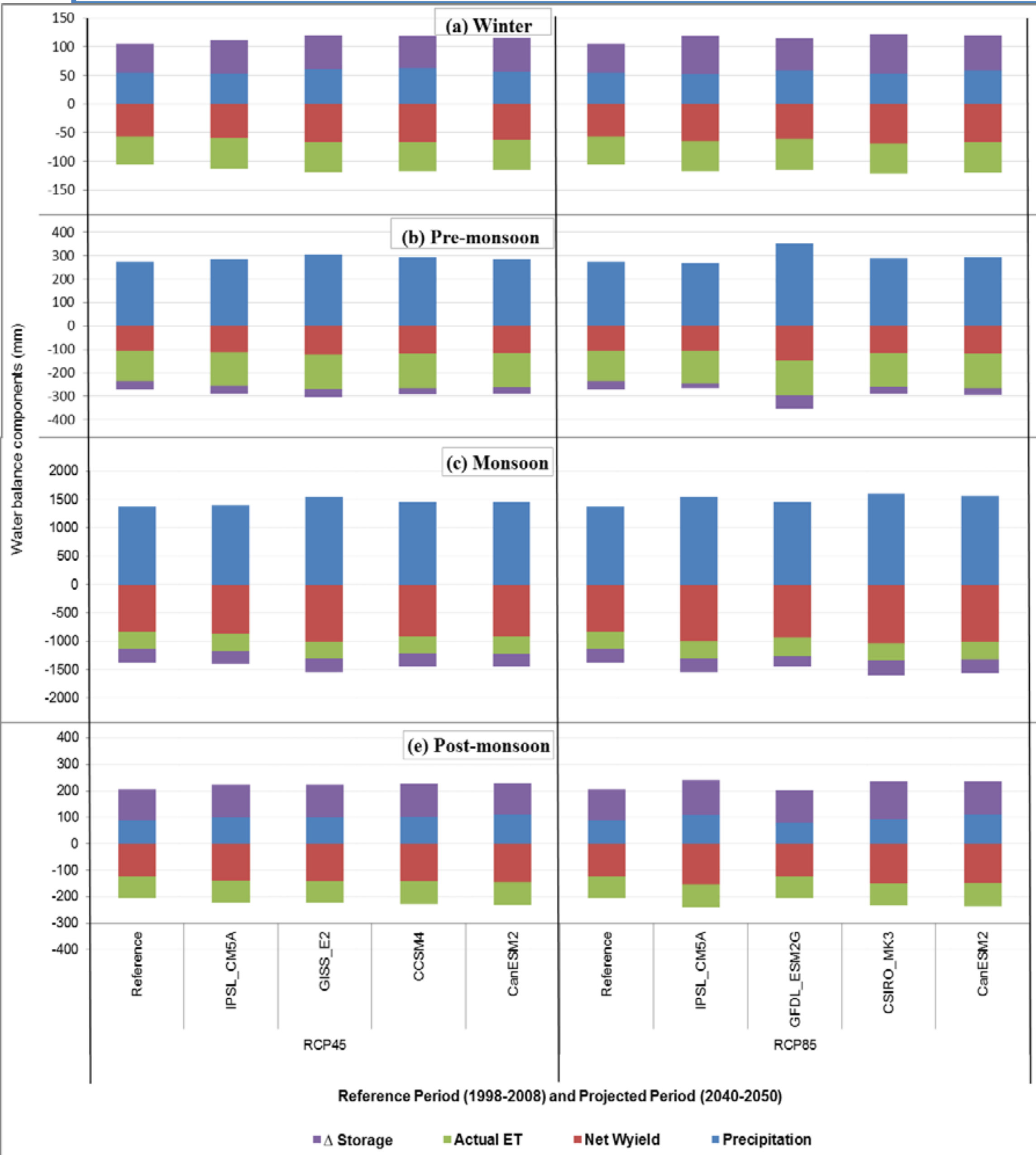
Delta Change Approach

- **Grids with monthly delta change data for the future was provided (**Immerzeel et al. 2012**)**

- **Daily future time series climate data (precipitation, maximum temperature and minimum temperature) for 2021 to 2050 was generated by applying monthly delta change value in random years in reference period (1998-2008).**

Specifications of provided dataset	
Extent (WGS 1984)	Long: 66.00° to 99.00° E Lat: 21.25° to 37.50° N
Spatial Resolution	0.25° x 0.25°
ΔT units	Kelvin (K)
ΔP units	Percent (%)
Format	ASCII grid
Total no of grids	192

Future Water Balance (Seasonal)

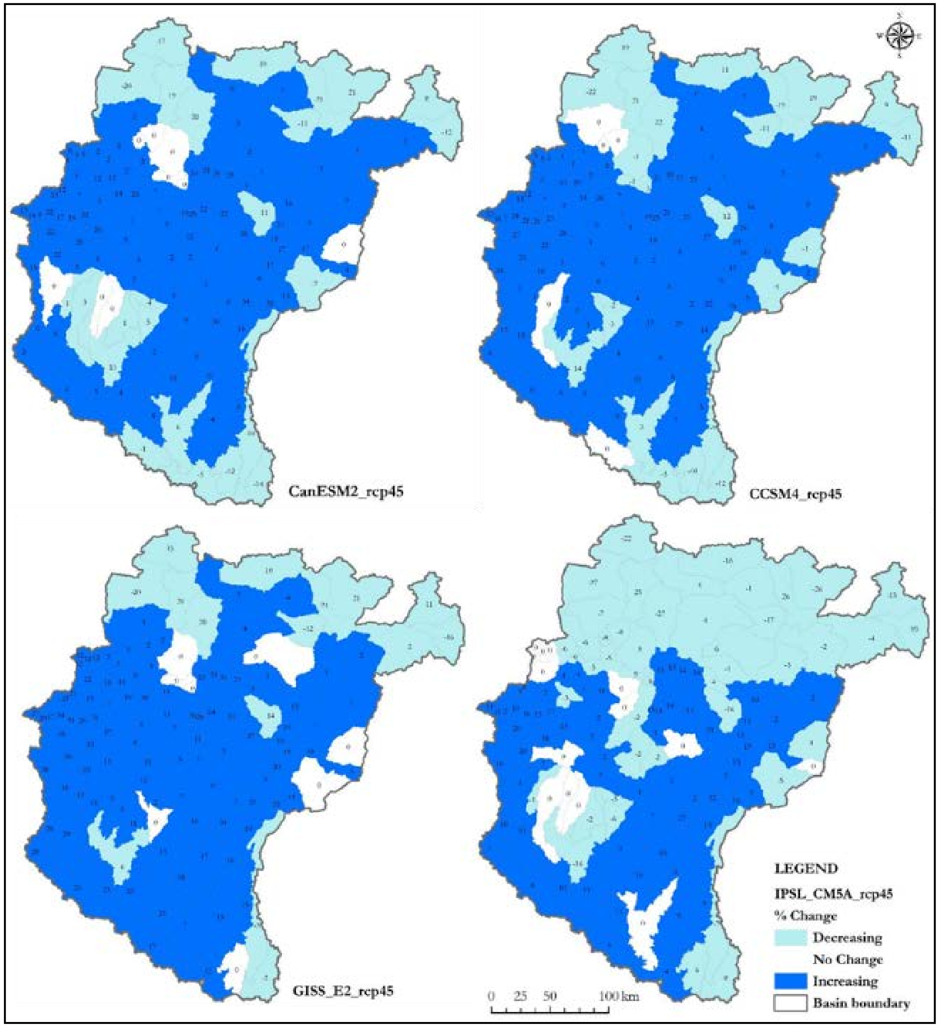


Absolute change in annual average water balance components from reference period

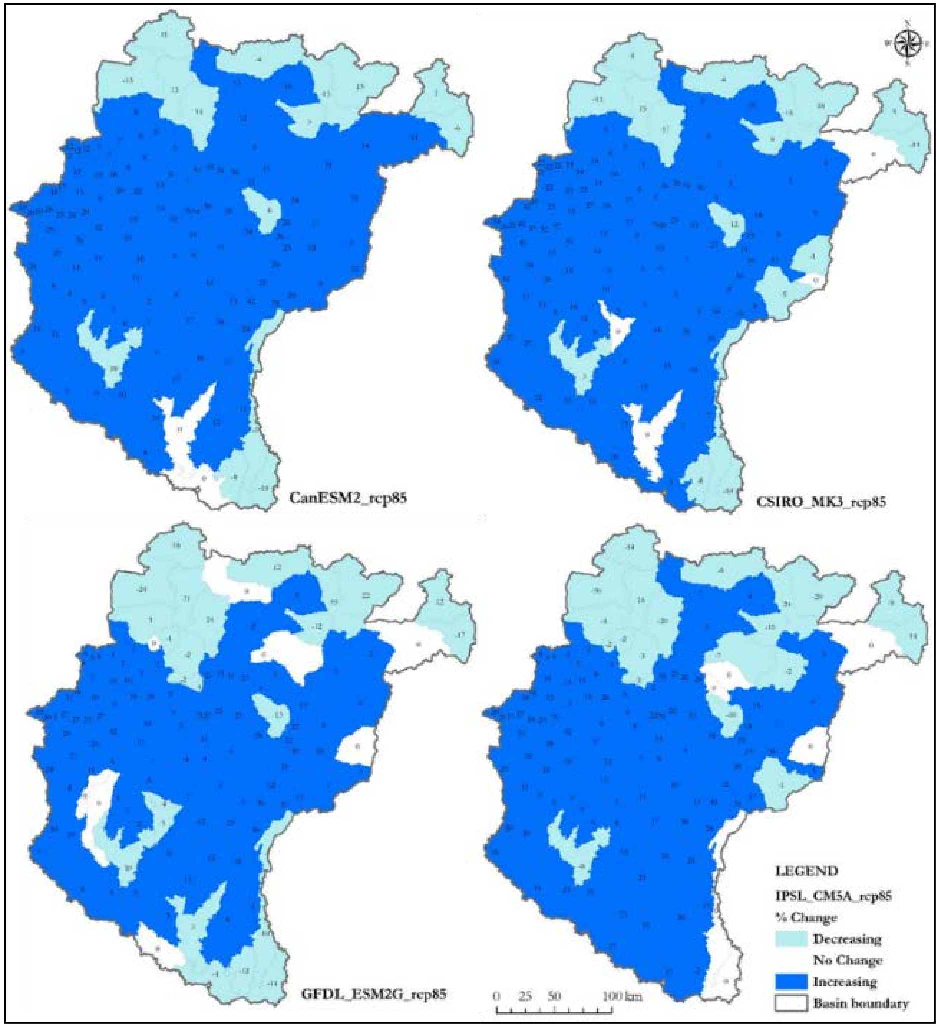
	Winter	Pre-monsoon	Monsoon	Post-monsoon
		Precipitation		
IPSL_CM5A_rcp45	-1	15	29	11
GISS_E2_rcp45	7	32	176	10
CCSM4_rcp45	8	21	88	14
CanESM2_rcp45	1	15	82	21
IPSL_CM5A_rcp85	-2	-6	182	21
GFDL_ESM2G_rcp85	4	80	87	-9
CSIRO_rcp85	-2	16	234	6
CanESM2_rcp85	4	21	187	22
		Net Water Yield		
IPSL_CM5A_rcp45	3	8	31	13
GISS_E2_rcp45	9	17	168	16
CCSM4_rcp45	9	15	77	18
CanESM2_rcp45	6	11	76	20
IPSL_CM5A_rcp85	8	-1	159	28
GFDL_ESM2G_rcp85	4	43	89	-1
CSIRO_rcp85	12	12	196	26
CanESM2_rcp85	9	14	168	24
		Actual ET		
IPSL_CM5A_rcp45	4	12	14	4
GISS_E2_rcp45	5	15	16	3
CCSM4_rcp45	4	14	13	4
CanESM2_rcp45	4	13	17	5
IPSL_CM5A_rcp85	5	10	18	6
GFDL_ESM2G_rcp85	-3	43	50	-43
CSIRO_rcp85	5	9	14	4
CanESM2_rcp85	6	15	23	6

Change in Future Precipitation

RCP45

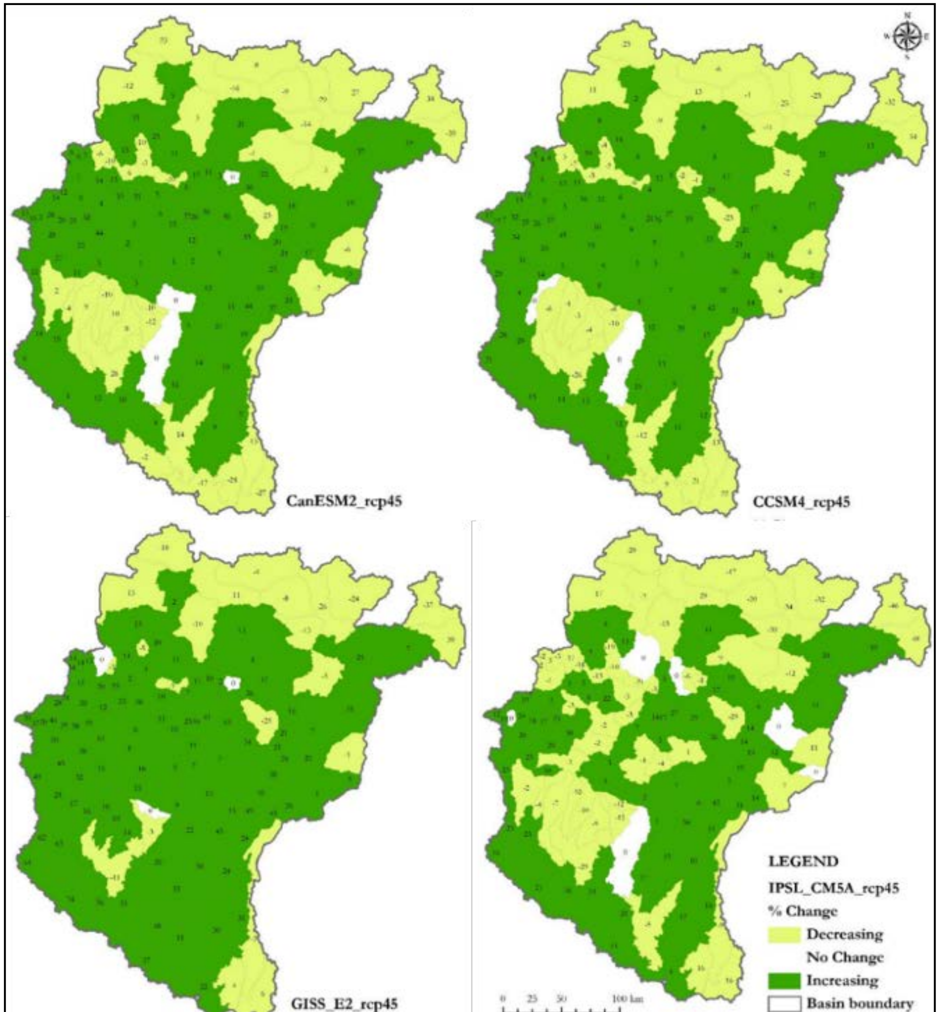


RCP85

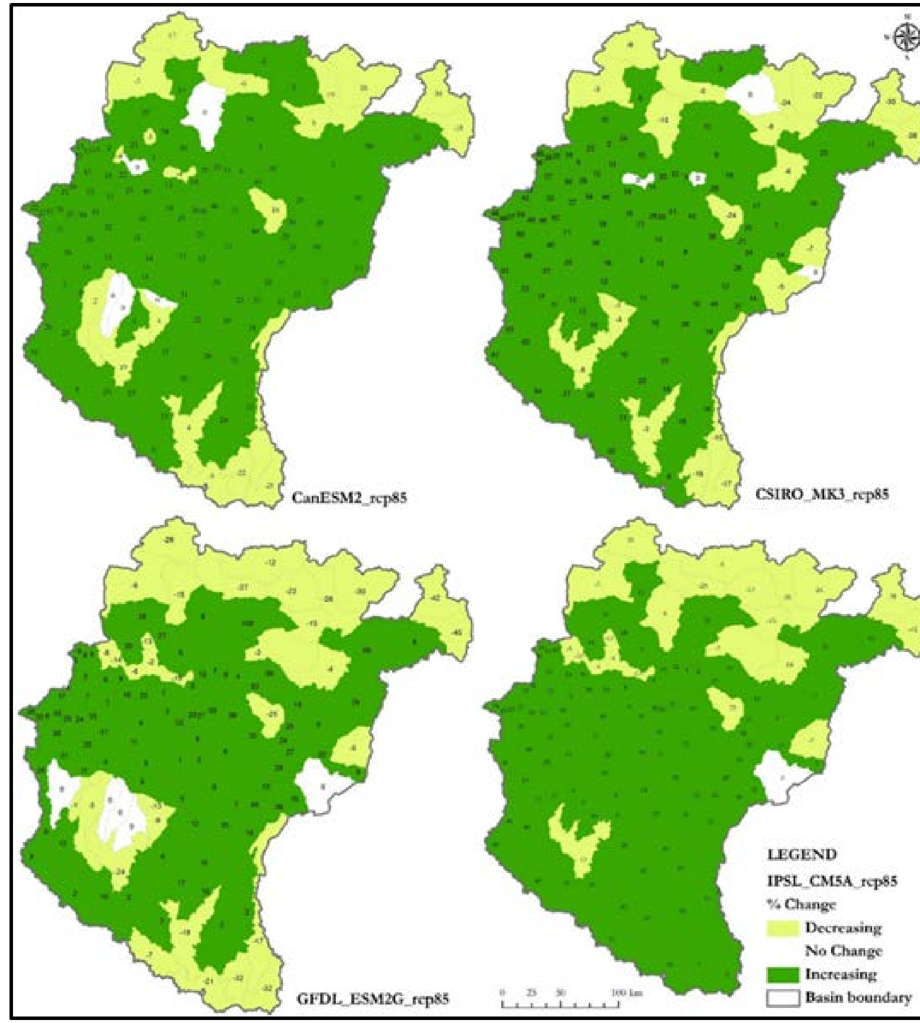


Change in Future Water Yield

RCP45

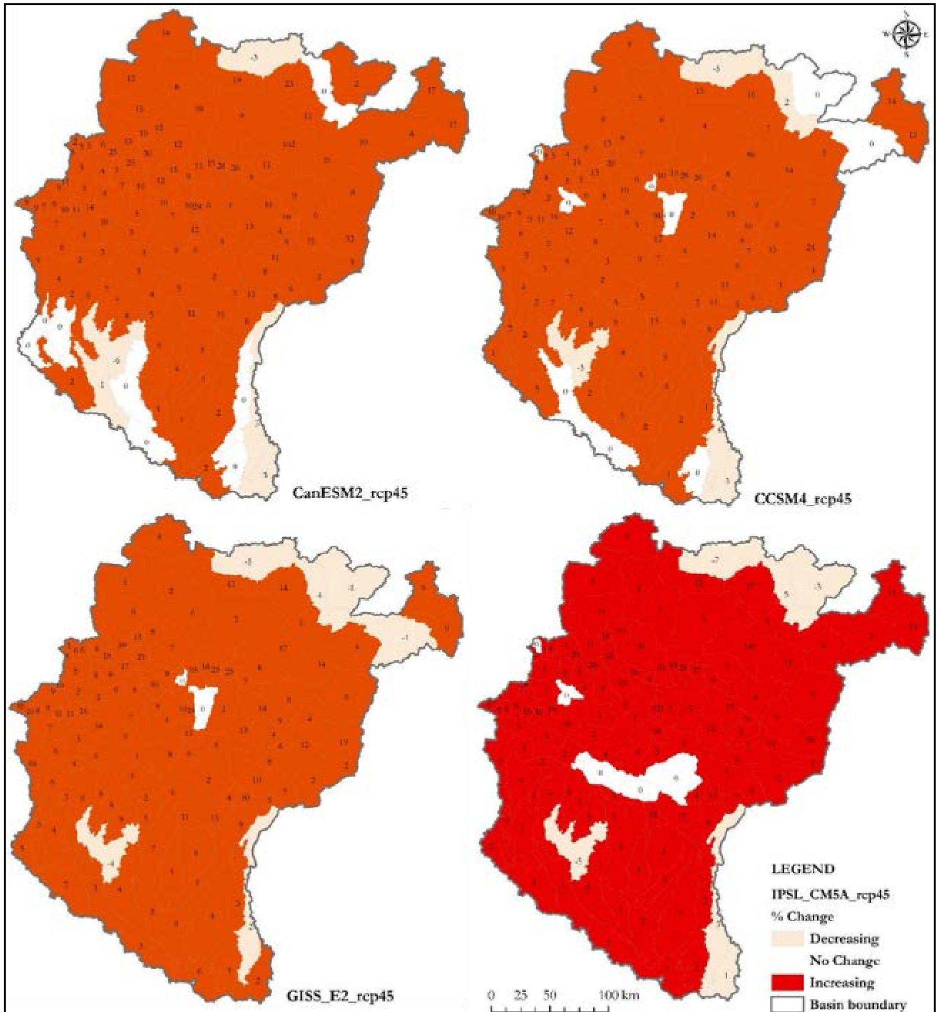


RCP85

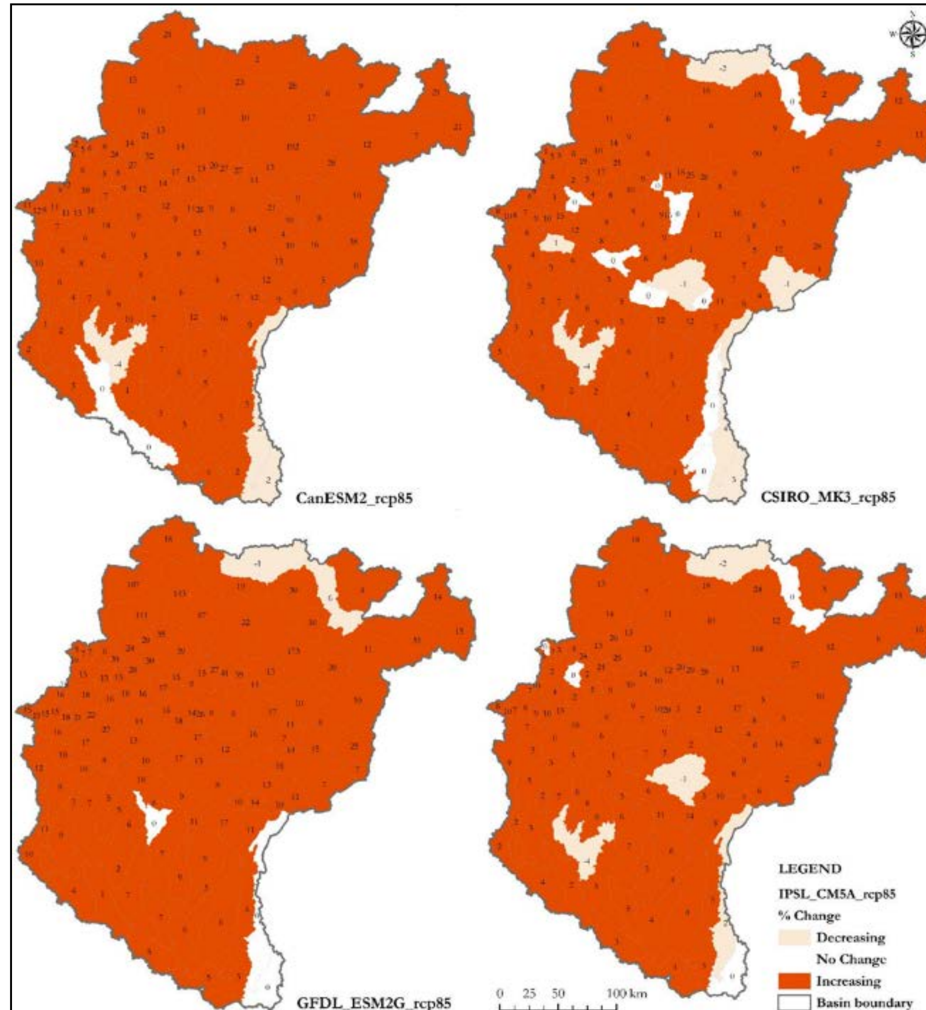


Change in Future Actual ET

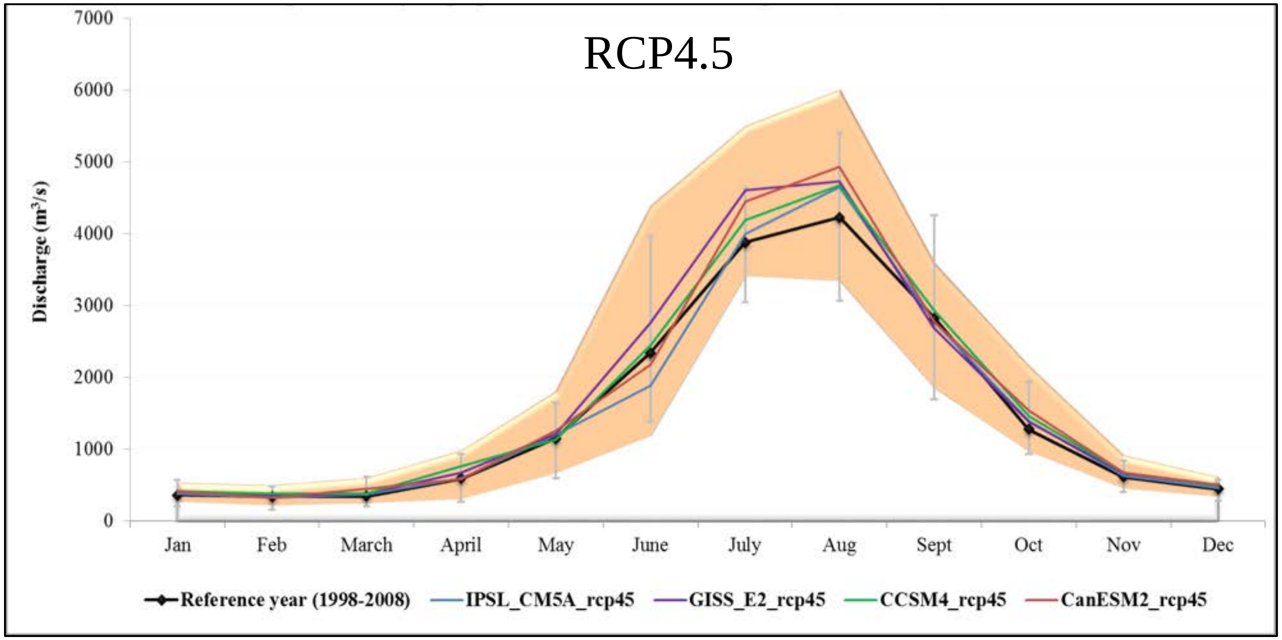
RCP45

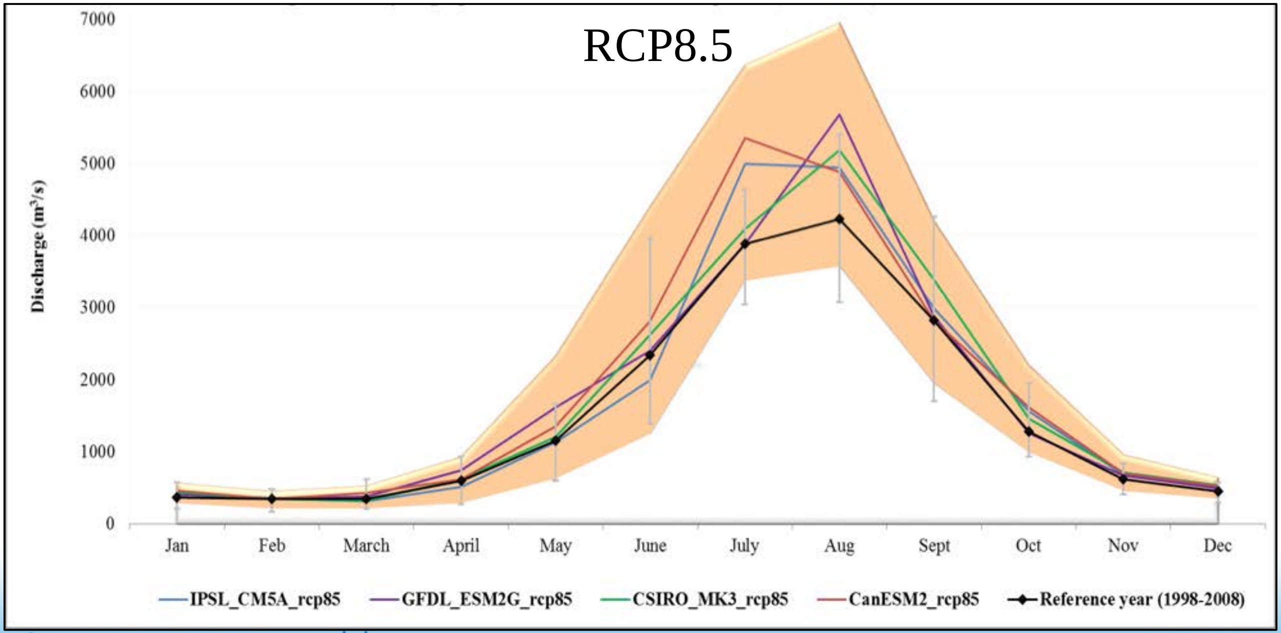


RCP85



CHANGE IN FUTURE DISCHARGE





CONCLUSION

- SWAT can be used as an important tool to assess current and future water resources to aid in future development plans and decision making
- Due to unavailability of the precipitation data and accurate information on snow and glacier in the high mountainous areas of Tibet and Nepal, results from the model have shown a low confidence level for this region
- Remotely sensed data can be used to meet up for the lack of data in the mountainous region however they have to be bias corrected before they can be used
- This model can be used for quantification of irrigation potential (DoI-Irrigation Master Plan)
- If snow/glacier or groundwater need to be analyzed in detail, Snow/glacier models and groundwater models is recommended

THANK YOU

ANY QUESTIONS?