CLIMATE CHANGE IMPACTS ON WATER RESOURCES OF INDIA

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Water resource development

- Shall always remain one of the preferred options to cater to
  - Inherent Spatial variability and
  - Temporal variability of this resource
  - Climate change impacts

Implications of Development -(or Interventions)

- Water resource is finite (within natural variability)
- Any development big or small involves in moving the water around (more often upstream)
- Thus every intervention has an associated impact

What are the issues & concerns?

- No mechanism in place to arrive at tradeoffs between the competing demands
  - No mechanism to decide the extent of watershed management
  - Promoting rainwater harvesting without setting the limits
- Ignoring the environmental demand
- Ignoring the hydrological health (interaction between surface and ground water)
- Ignoring the water quality issues

Sustainability

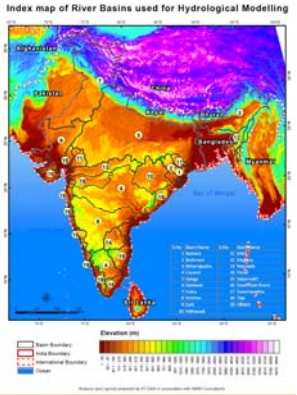
- This brings us to the question of sustainability
  - Which is about maintaining the hydrological and environmental health of the drainage system
- IWRM philosophy has been the scientific option available but seldom used
  - Watershed being the natural system where water balance can be resolved and thereby impacts of the manmade interferences quantified

India's National Communications to UNFCCC

- Coordinated by MoEF
- The first communication was made in 2004
- It was a multidisciplinary effort
  - Work on water Resources was entrusted to IIT Delhi
- Second National Communication was made in April 2012 and IIT Delhi again lead the Water Resources work

NATCOM – MoEF

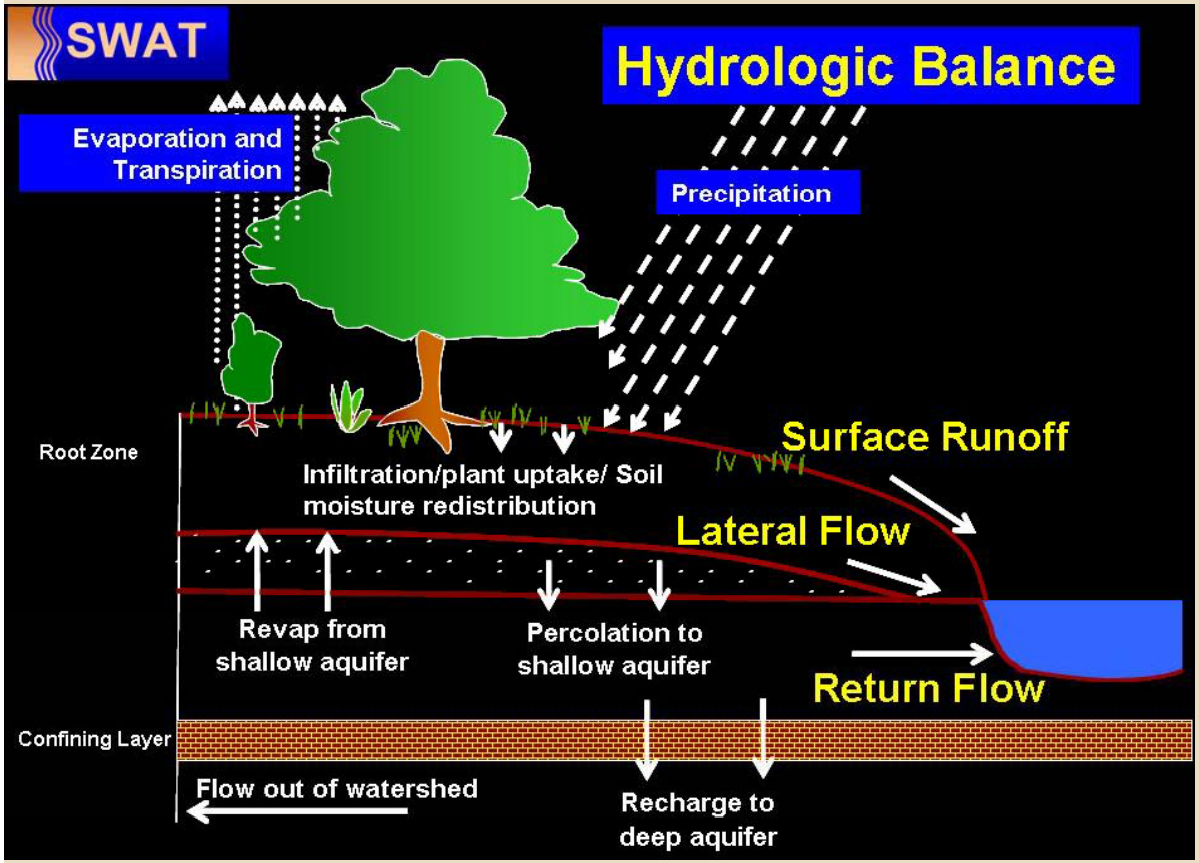
Climate Change and its Impact on Water Resources of India



River Basins Modelled for Climate Change Impact Assesment

- Tools used
  - Modelling: SWAT (Soil and Water Assessment Tool)
  - GIS framework: acts as a pre-processor for the distributed modelling and for visualization of the outputs/results in terms of V & A
- Data used
  - Digital Elevation Model: SRTM 90 m
  - Land use: Global data, 1:2M USGS
  - Soil: Global data, 1:5M FAO
  - Drainage: 1:250,000
  - Weather: IPCC SRES A1B, A2, B2, Hadley Centre U.K. at a resolution of 0.44° X 0.44° latitude by longitude grid points obtained from IITM, Pune
- Impacts Studied
  - Impact on annual water availability
  - Impact on seasonal water availability
  - Impact on inter annual water availability
  - Regional Variability of Water availability
  - Extreme events – Floods and Droughts

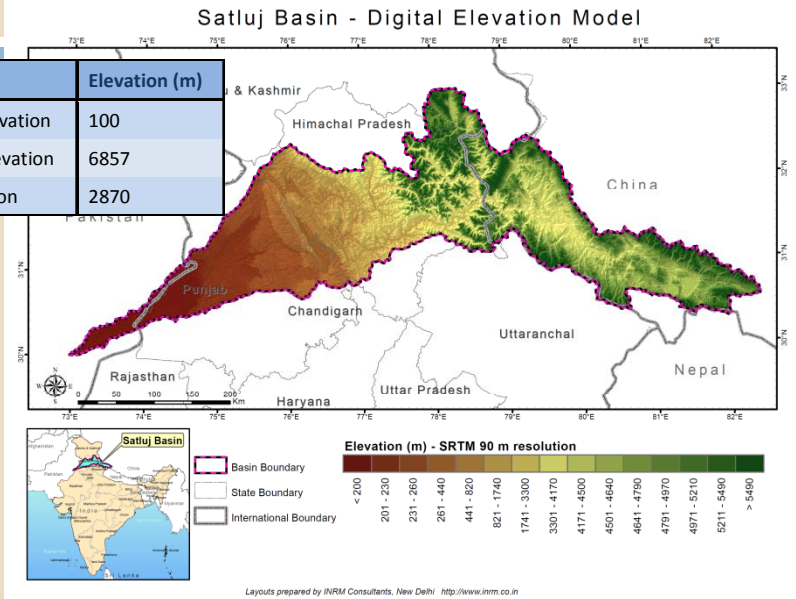
SWAT (Soil and Water Assessment Tool) - Model



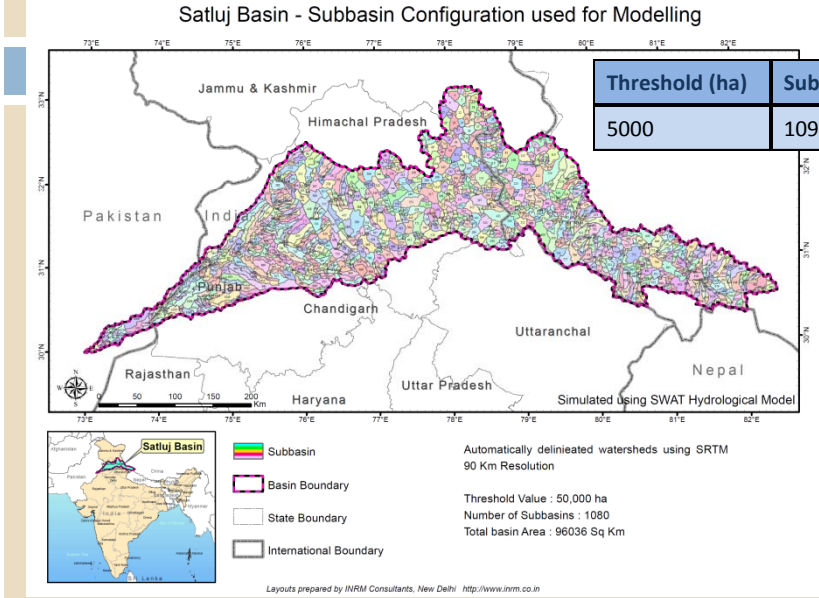
- Features
  - Physically based
  - Distributed model
  - Continuous time model (long term yield model)
  - Uses readily available data
  - Used for long term impact studies

Basic Data layers for modelling

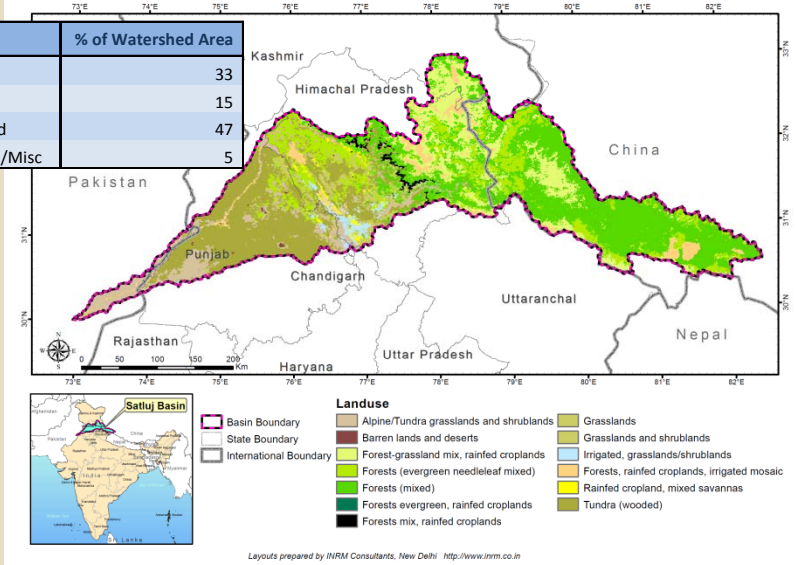
Parameter	Elevation (m)
Minimum Elevation	100
Maximum Elevation	6857
Mean Elevation	2870



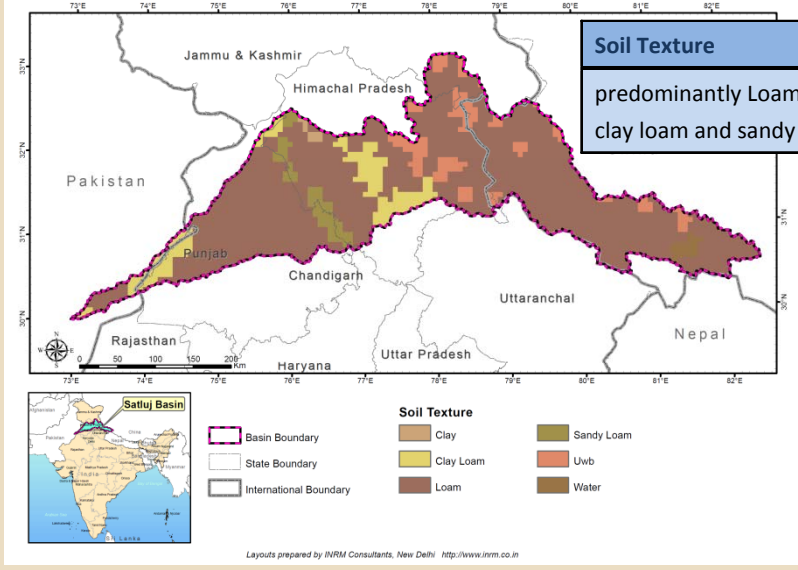
Threshold (ha)	Subbasins
5000	1092



Land Use	% of Watershed Area
Agriculture	33
Forest	15
Range/grassland	47
Water/Wetland/Misc	5

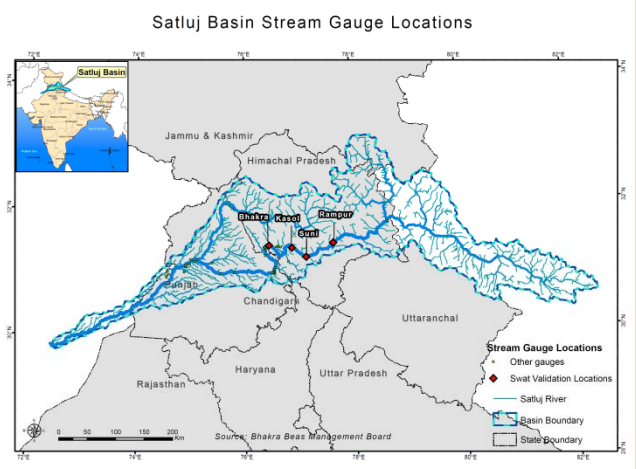


Soil Texture
predominantly Loam
clay loam and sandy loam



SWAT Model Performance for Satluj Basin

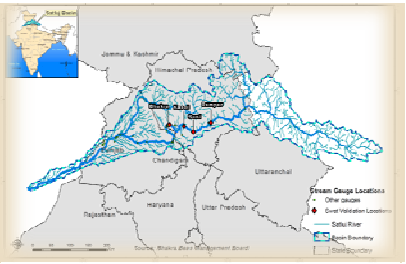
- made using the observed data for the period 1976-2004 at monthly scale
- from four stream flow monitoring stations upstream of Bhakra dam at Rampur, Suni, Kasol and Bhakra

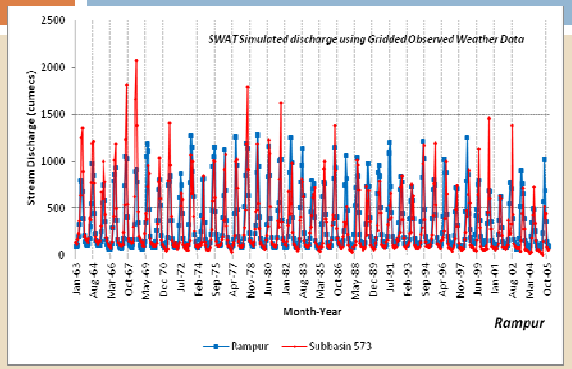


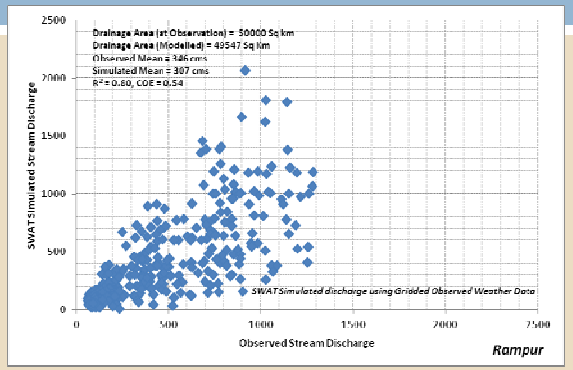
Gauge Site	Catchment Area*(Sq km)	Mean Flow*	Start Year	End Year	COE**	Correlation coefficient	Area Difference (%)	Flow Difference (%)
Rampur	50000 (49550)	345 (390)	1963	2005	0.42	0.83	0.09	-13.04
Suni	NA (51660)	427 (379)	1969	2005	0.52	0.78	NA	
Kasol	NA (52350)	417 (414)	1985	2005	0.62	0.84	NA	
Bhakra	56000 (55310)	458 (427)	1963	2005	0.67	0.87	0.12	6.77

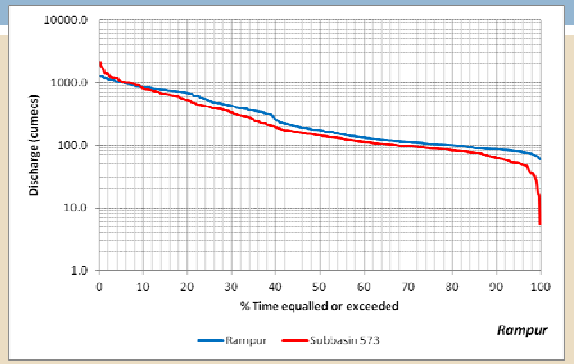
* Model parameter is shown in bracket, ** Nash-Sutcliffe coefficient

SWAT output comparison Locations and model efficiency parameters

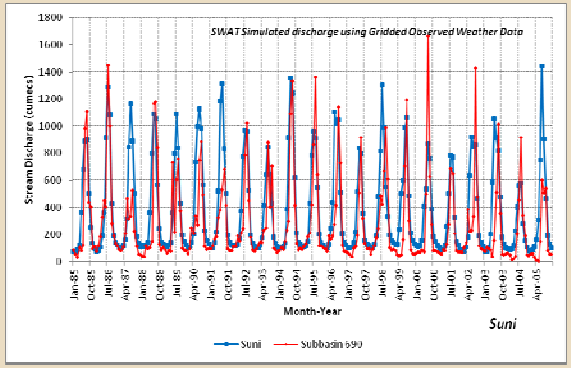


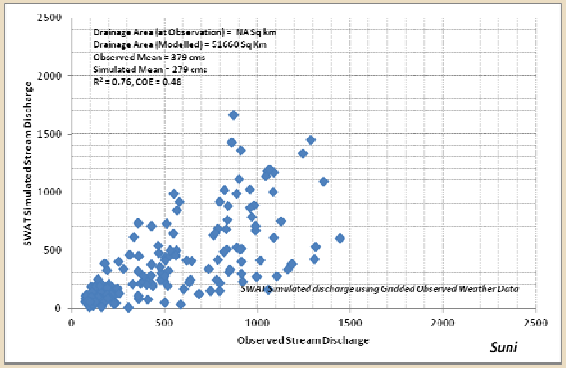


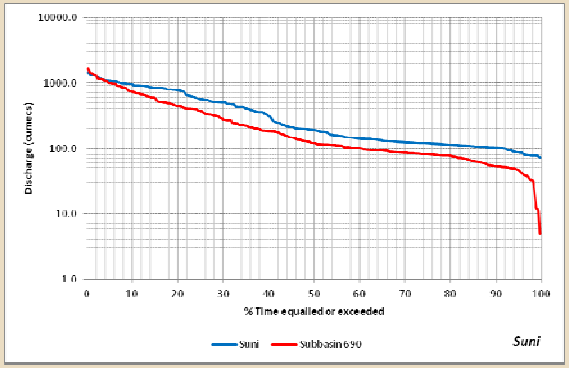




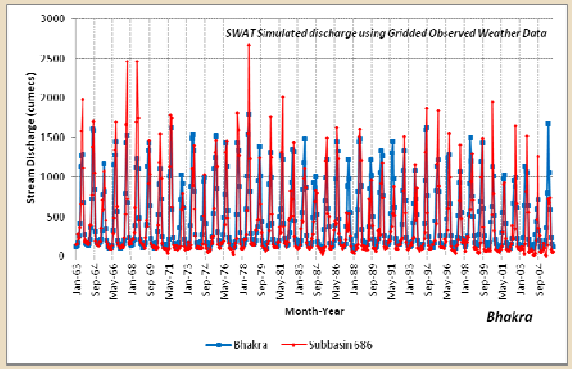
Rampur

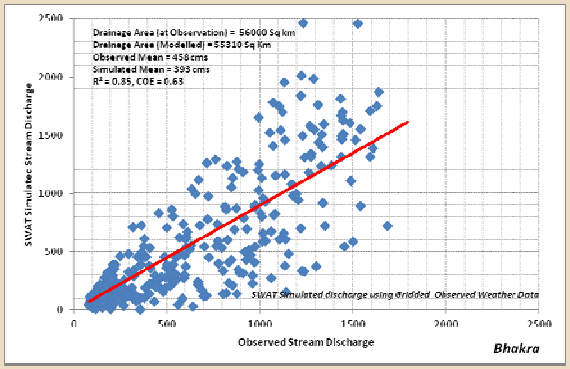


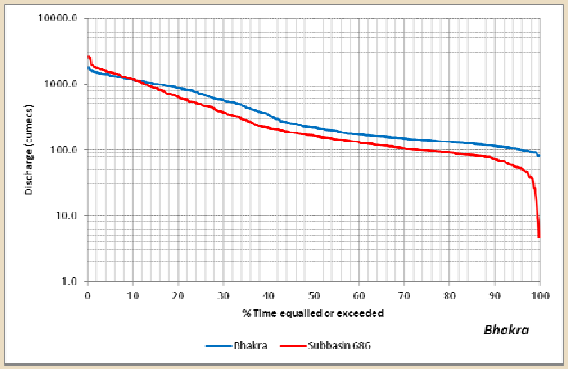




Suni





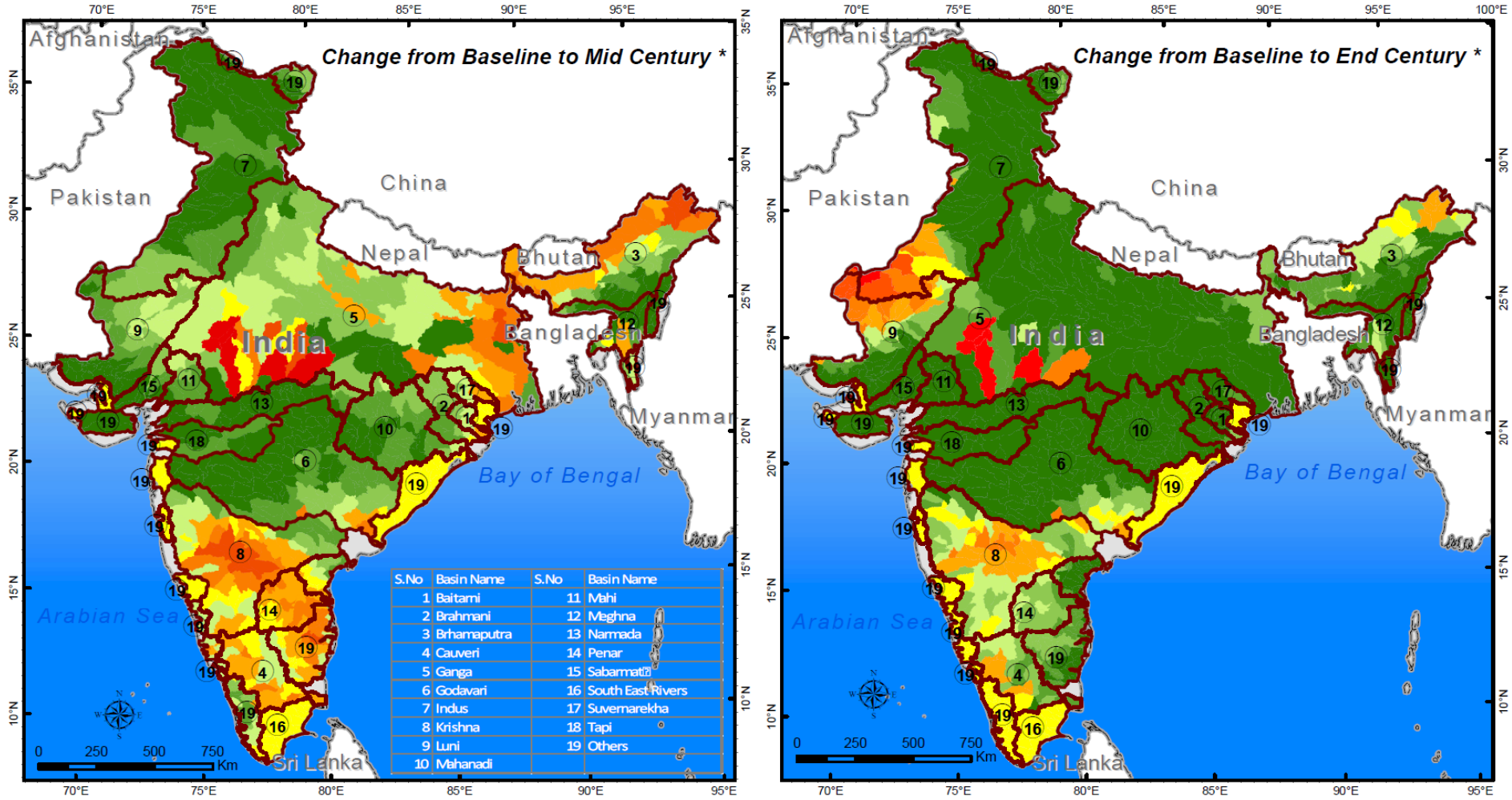


Bhakra

Vulnerability Assessment Procedure

- Palmer Drought Severity Index (PDSI) widely used index
  - incorporates information on rainfall, land-use, and soil properties in a lumped manner
- PDSI value
  - below 0.0 indicates the beginning of drought situation
  - A value below -3.0 as sever drought condition
- Soil Moisture Index to monitor drought severity using SWAT
  - output to incorporate the spatial variability

Percent Change in Precipitation across India



S.No	Basin Name	S.No	Basin Name
1	Baitarni	11	Mahi
2	Brahmani	12	Meghna
3	Brhamaputra	13	Narmada
4	Cauveri	14	Penar
5	Ganga	15	Sabarmati
6	Godavari	16	South East Rivers
7	Indus	17	Suvernarekha
8	Krishna	18	Tapi
9	Luni	19	Others
10	Mahanadi		

Change % in Precipitation

Basin Boundary

International Boundary

Ocean

Increase from baseline

< -15%

-14% - -10%

-9% - -5%

-4% - -1%

-1% - 0%

Decrease from baseline

0 - +1%

+1% - +5%

+6% - +10%

+11% - +15%

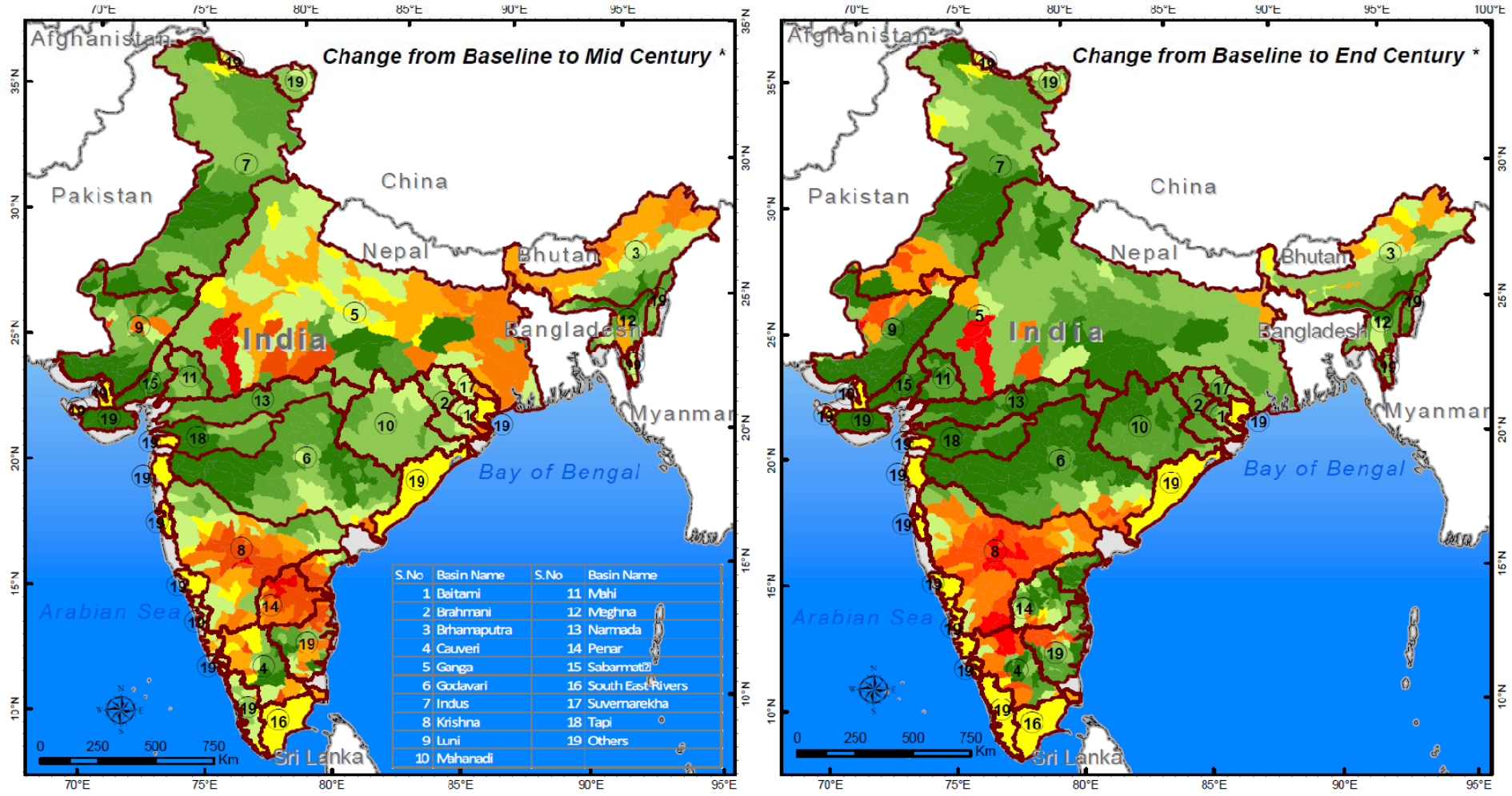
> +15%

SWAT hydrological model results simulated using PRECIS RCM daily weather datasets provided by the Indian Institute of Tropical Meteorology, Pune*

** IPCC SRES A1B Scenarios (Q14 QUMP ensemble) - Baseline (1961–1990), Mid Century (2021-2050) & End Century (2071-2098)*

Analysis and Layouts prepared by IIT Delhi in association with INRM Consultants

Percent Change in Water Yield across India



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10	Mahanadi		

Basin Boundary

International Boundary

Ocean

Change % in Water Yield

Increase from baseline

< -50%

-49% - -25%

-24% - -10%

-9% - -1%

-1% - 0%

Decrease from baseline

0 - +1%

+1% - +10%

+11% - +25%

+26% - +50%

> +50%

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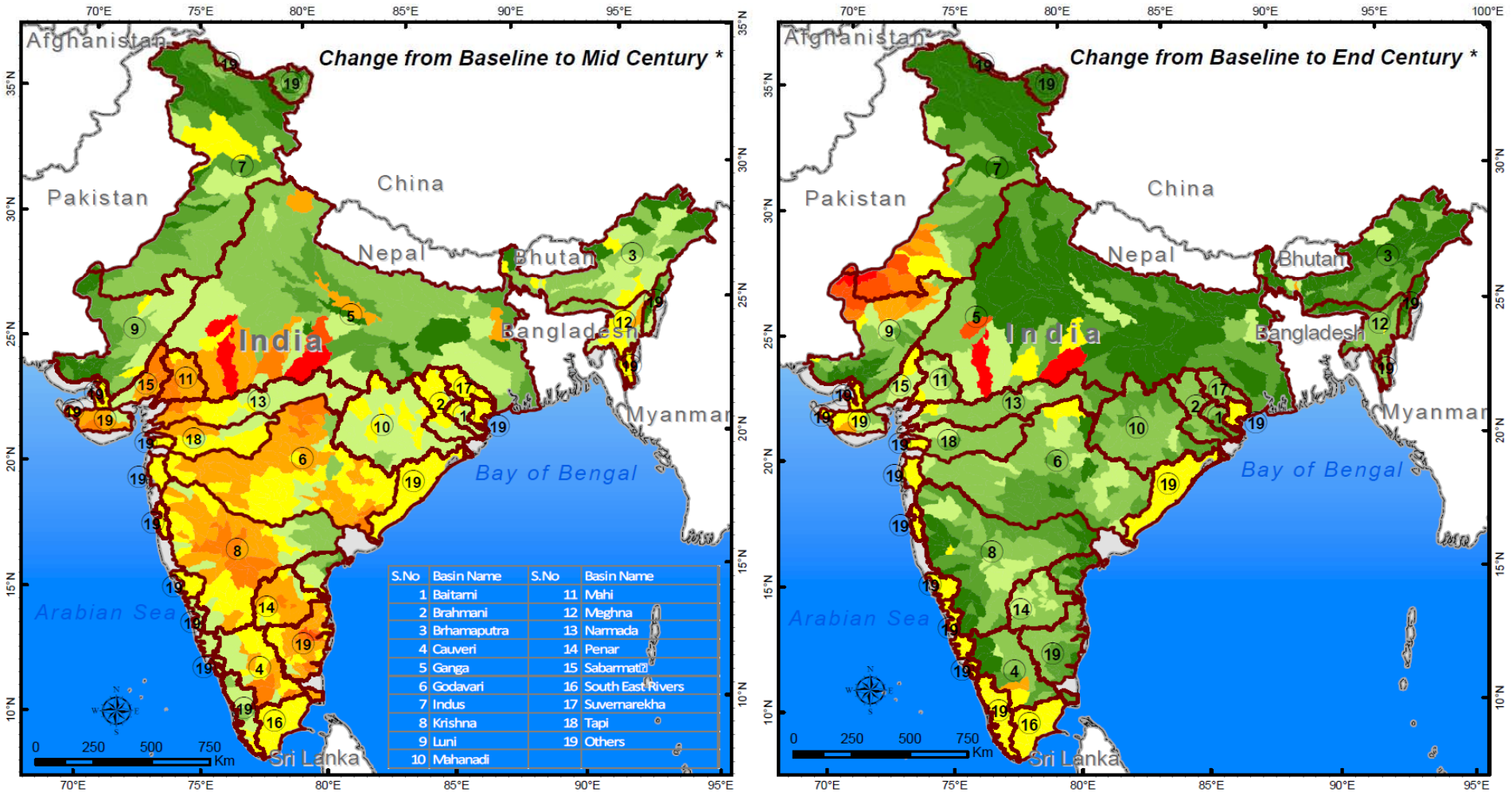
Percent Change in Actual Evapotranspiration across India



Change % in Actual Evapotranspiration

Basin Boundary

International Boundary

Ocean

Increase from baseline

< -15%

-14% - -10%

-9% - -5%

-4% - -1%

-1% - 0%

Decrease from baseline

0 - +1%

+1% - +5%

+6% - +10%

+11% - +15%

> +15%

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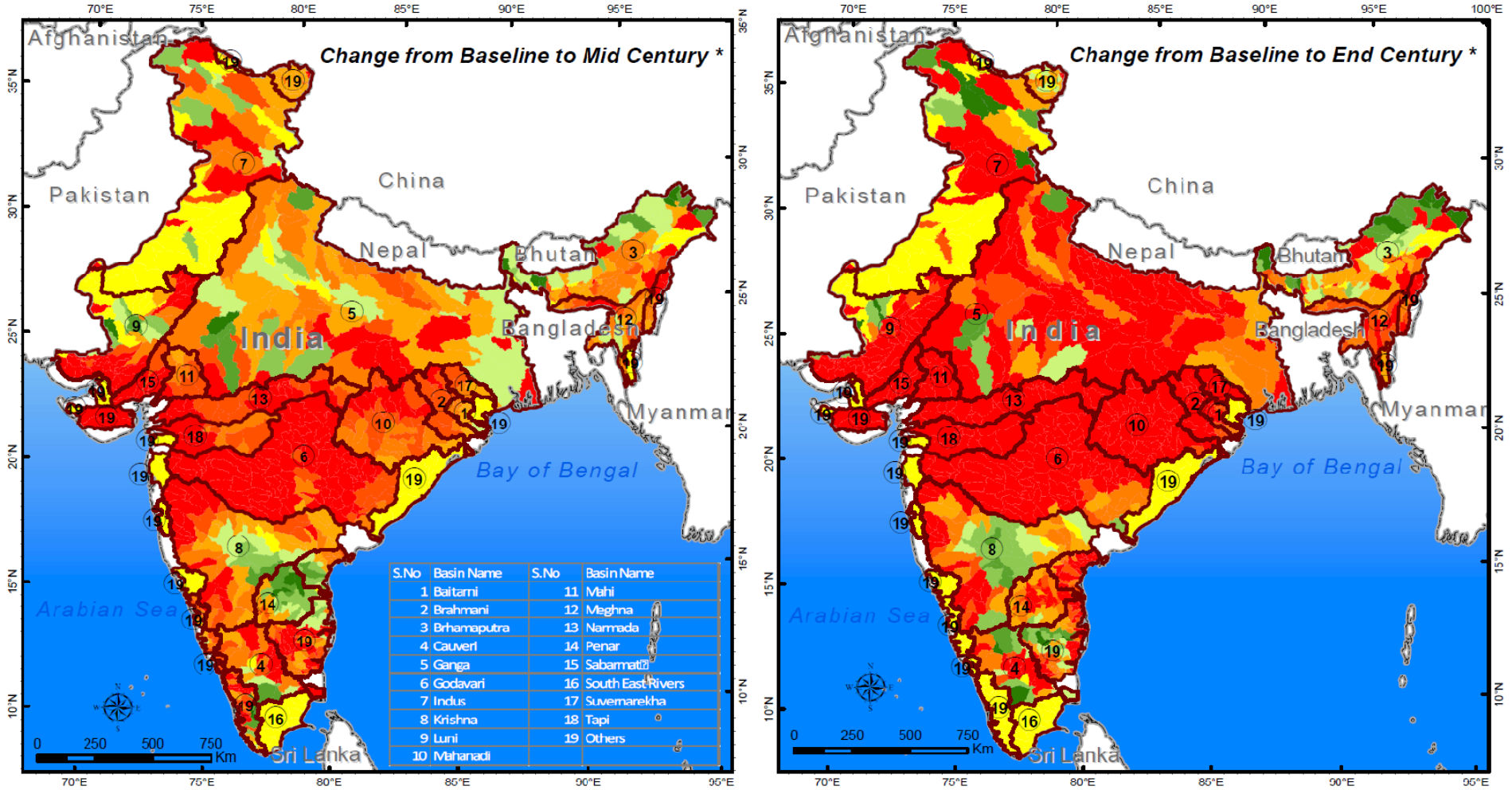
Percent Change in Sediment Yield across India



Change % in Sediment Yield

Basin Boundary

International Boundary

Ocean

Increase from baseline

- < -75%
- -74% - -50%
- -49% - -25%
- -24% - -1%
- -1% - 0%

Decrease from baseline

- 0 - +1%
- +1% - +25%
- +26% - +50%
- +51% - +75%
- > +75%

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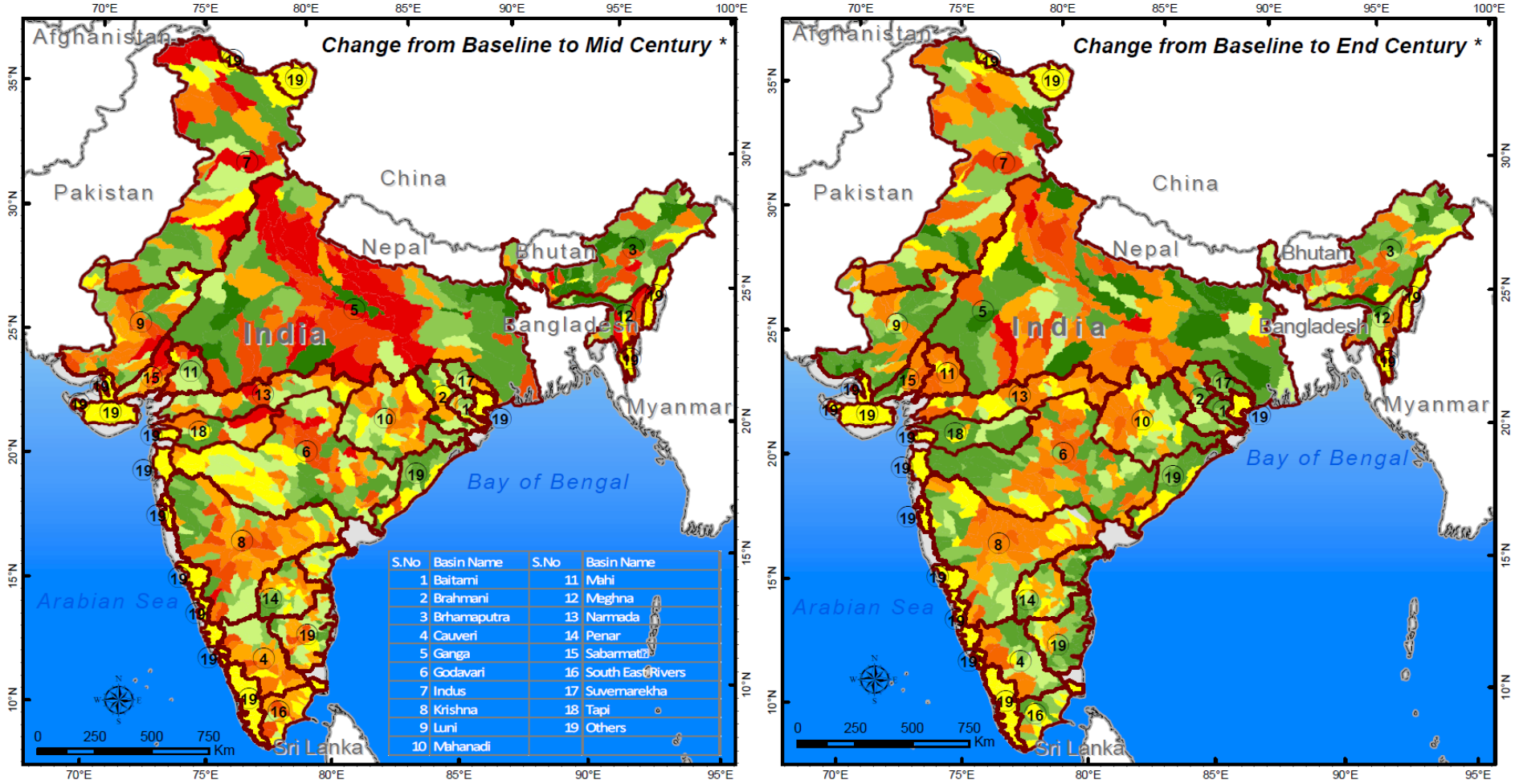
Percentage Change in Drought Weeks (JJAS) across India

Based on Agriculture Drought Index ranging from -2 to -4 (moderate to extreme soil moisture stress during critical growth stages of crops)



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Change % in Drought Weeks (JJAS)

Basin Boundary

International Boundary

Ocean

Increase from baseline

< -25%

-24% - -10%

-9% - -5%

-4% - -1%

-1% - 0%

Decrease from baseline

0 - +1%

+1% - +5%

+6% - +10%

+11% - +25%

> +25%

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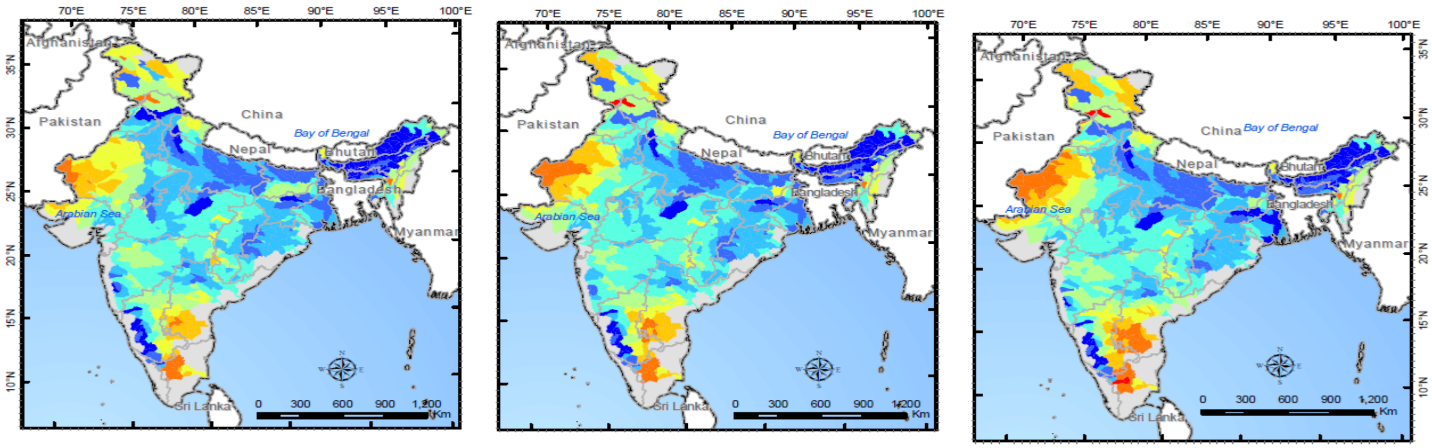
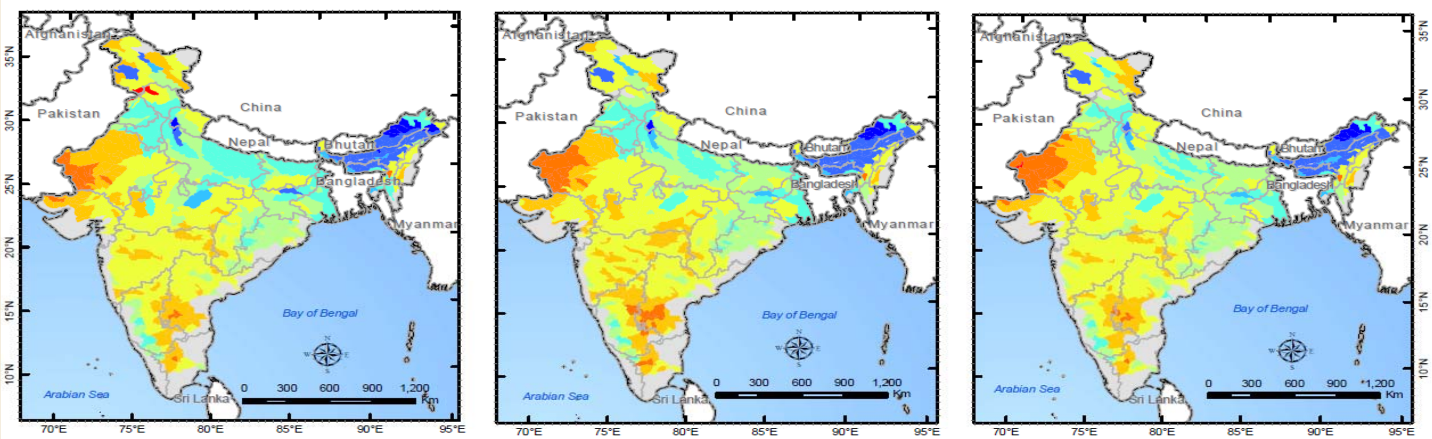
Green Water Storage (mm/yr) - Monsoon period

IPCC SRES Baseline * | **IPCC SRES Mid Century *** | **IPCC SRES End Century ***



Green Water Storage (mm/yr) - Non monsoon period



Green Water Storage (mm/yr)

Green Water Storage (soil water) - Monsoon period (JJAS)
Green Water Storage (soil water) - Non Monsoon period (OND JFMAM)

SWAT hydrological model results simulated using PRECIS RCM daily weather datasets provided by the Indian Institute of Tropical Meteorology, Pune*

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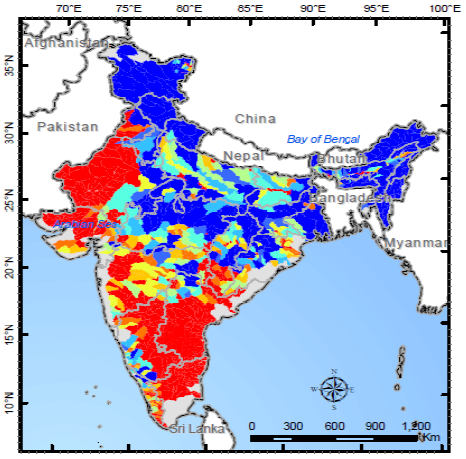
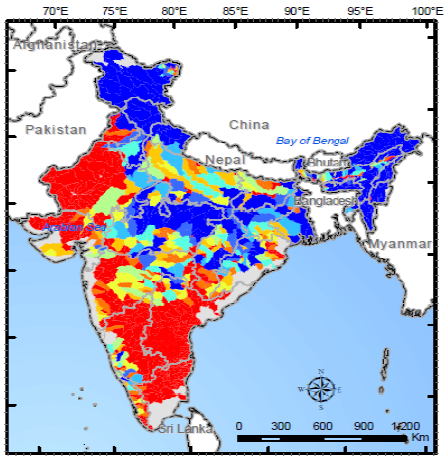
Annual Average Blue Water Flow availability per capita ** (m3/cap/yr)

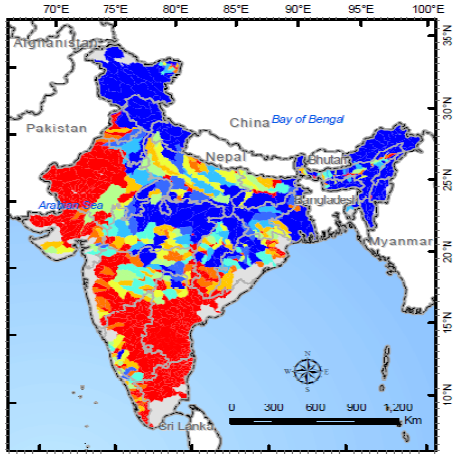
IPCC SRES Baseline *



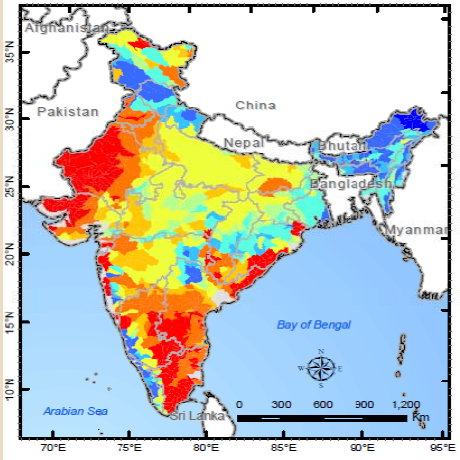
IPCC SRES Mid Century *

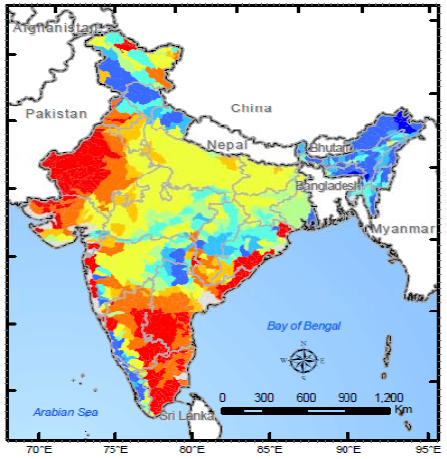


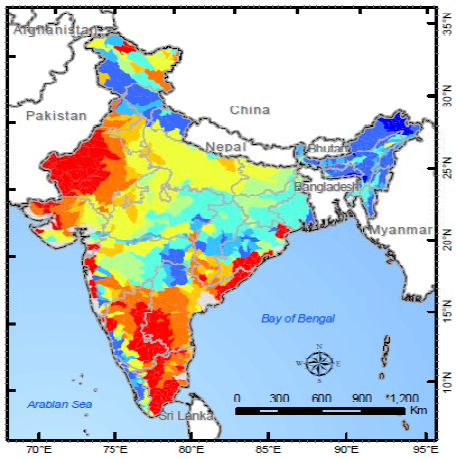
IPCC SRES End Century *



Blue Water Flow (mm/yr)







Blue Water Flow (m3/cap/yr)

- < 500
- 501 - 750
- 751 - 1000
- 1001 - 1250
- 1251 1500
- 1501 - 2000
- 2001 - 2500
- 2501 - 3000
- > 3000

Blue Water Flow (mm/yr)

- < 50
- 51 - 200
- 201 - 350
- 351 - 800
- 801 1000
- 1001 - 1500
- 1501 - 2000
- 2001 - 5000
- > 5000

Blue Water Flow (water yield + deep aquifer recharge)
*** for baseline population of 2001 & for future scenarios, projected population @ 0.93%/yr was used*

SWAT hydrological model results simulated using PRECIS RCM daily weather datasets provided by the Indian Institute of Tropical Meteorology, Pune*

** IPCC SRES A1B Scenarios (Q14 QUMP ensemble) - Baseline (1961–1990), Mid Century (2021-2050) & End Century (2071-2098)*

Possible adaptation options

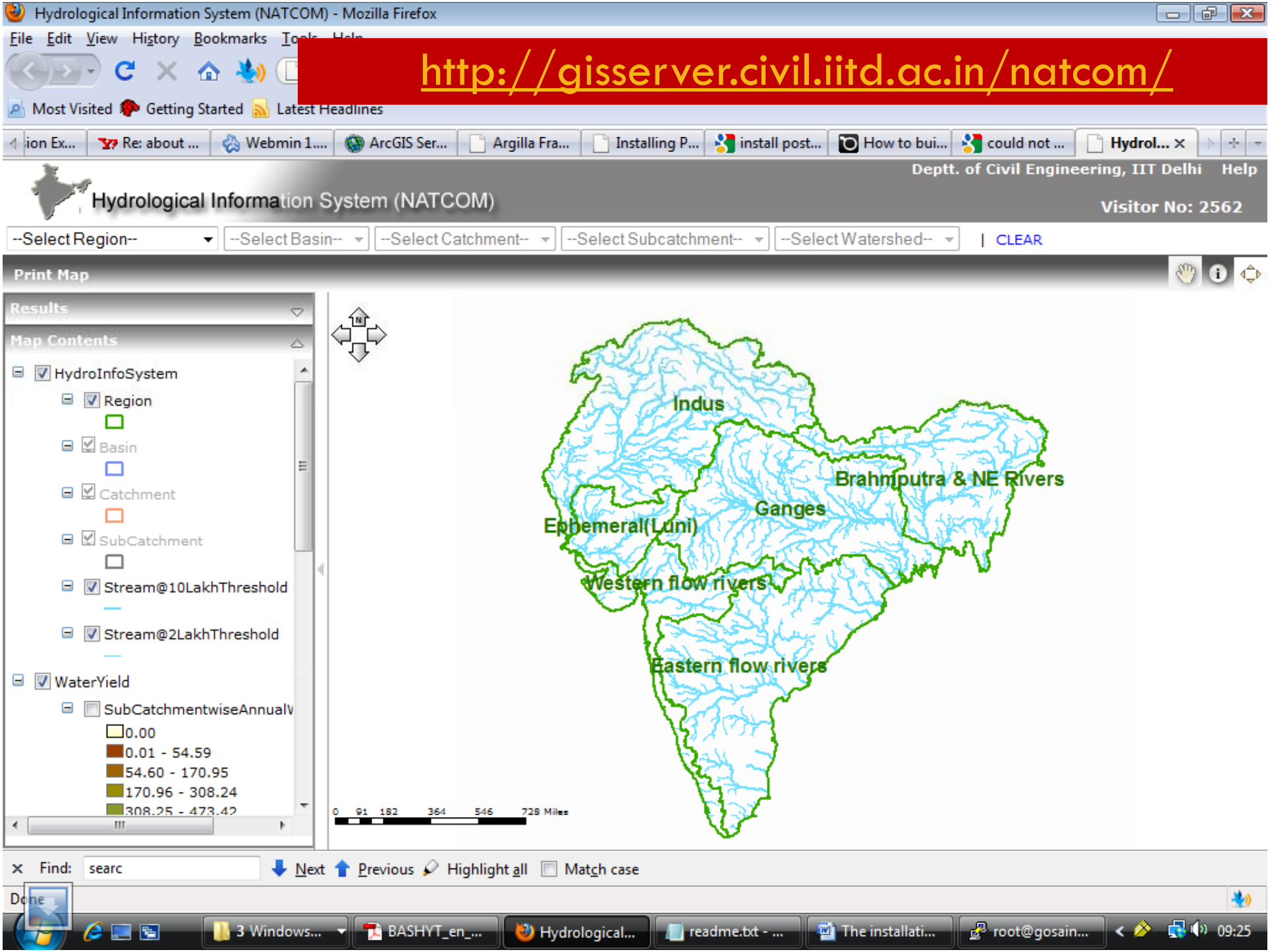
- Enhanced efficiencies
- Surface water Interventions – different scales
  - Big projects – Reservoir or runoff the river scheme
  - Medium & Minor schemes
  - Watershed level – check dams
- Ground water exploitation
  - Shallow wells
  - Deep tubewells

Interventions have implications

- Every intervention big or small has associated impact
- Integrated Watershed philosophy was the scientific option suggested
  - Watershed being the natural system where water balance can be resolved and thereby impacts of interventions quantified
  - 'Integrated' implies consideration of all possible usage and interest of all stake holders

The major concern

- Evaluate the implications of climate change by incorporating the baseline
- Adaptation shall require enhanced level of interventions through line departments
  - A common framework is required to provide an integrated information base
  - Procedures for scenario generation and evaluation


Hydrological Information System (NATCOM) - Mozilla Firefox
http://gisserver.civil.iitd.ac.in/natcom/
Hydrological Information System (NATCOM)
Deptt. of Civil Engineering, IIT Delhi
Help
Visitor No: 2562
--Select Region--
--Select Basin--
--Select Catchment--
--Select Subcatchment--
--Select Watershed--
CLEAR
Print Map
Results
Map Contents
HydroInfoSystem
Region
Basin
Catchment
SubCatchment
Stream@10LakhThreshold
Stream@2LakhThreshold
WaterYield
SubCatchmentwiseAnnualV
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0.01 - 54.59
54.60 - 170.95
170.96 - 308.24
308.25 - 473.42
Indus
Ganges
Brahmputra & NE Rivers
Ephemeral(Luni)
Western flow rivers
Eastern flow rivers
0 91 182 364 546 728 Miles
Find: searc
Next
Previous
Highlight all
Match case
Done

SubBasinwise Model Results - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://gisserver.civil.iitd.ac.in/his/swat/mainPage.aspx

SubBasinwise Model Results

Select ID:

0002
0003
0004
0005

Select Parameter:

Water Balance

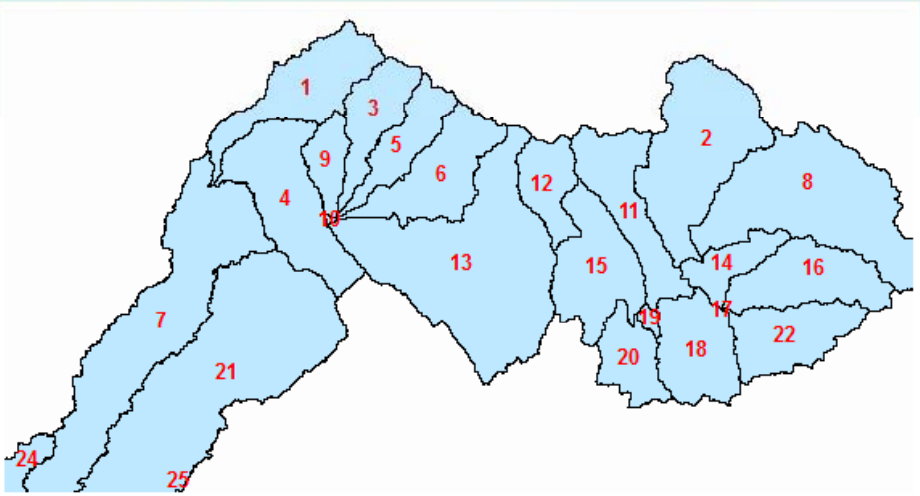
Select Time Range

From: 1996/01/1

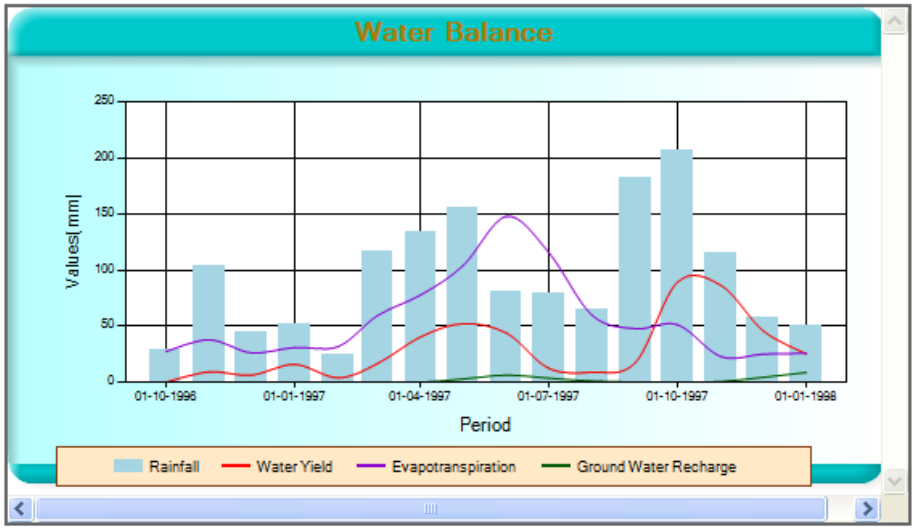
To: 1998/01/1

Show Table

Show Graph



SubBasin Beas



Hydrological Information System (NATCOM) - Windows Internet Explorer

http://gisserver.civil.iitd.ac.in/natcom/

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Basinwise Model Results - Windows Internet Explorer

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Basinwise Model Results (SWAT)

MODEL RESULTS VULNERABILITY ASSESSMENT CLIMATE CHANGE ANALYSIS ADVANCED ANALYSIS

Model Results: Chambal 20322

- (•) Virgin Condition
- ( ) BL Condition

Select Parameter: Discharge

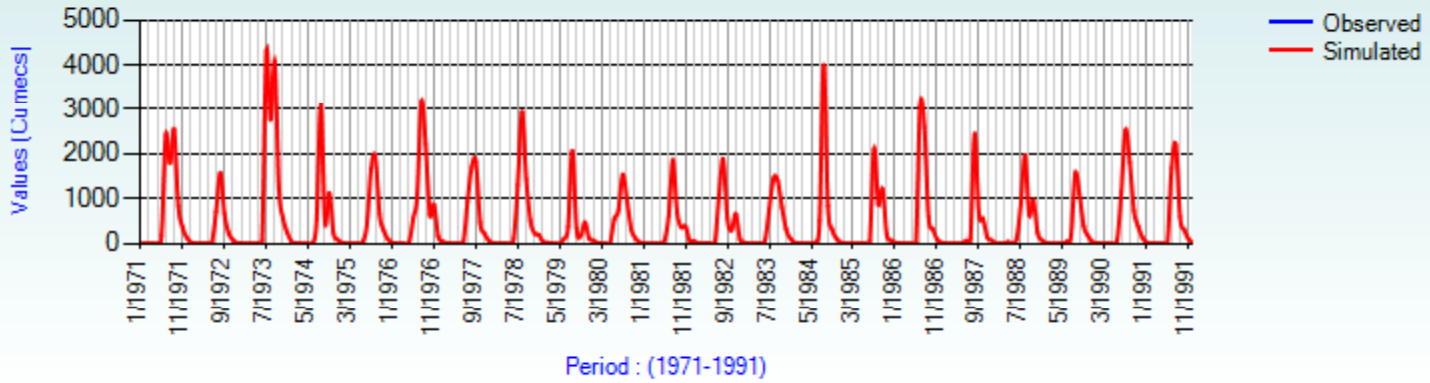
- (•) Run with IMD Grid Data (1971-2005)
- ( ) HadRM3 Baseline (BL) (1961-1990)
- ( ) HadRM3 GHG Scenario (A2) (2071-2100)
- ( ) HadRM3 GHG Scenario (B2) (2071-2100)
- ( ) A1B Baseline Scenario (1961-1990)
- ( ) A1B Mid Century Scenario (2021-2050)
- ( ) A1B End Century Scenario (2071-2098)

Select Period: (Start-End) 1971 1991

Show Graph Show Table

Discharge Graph: Chambal 20322

IMD Grid data: Virgin Condition



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Conclusions

- Integrated water resource development and management framework is required to be adopted
- Creation of sharable information is essential for sustainable use of water resources
- This shall be a good way forward for selecting meaningful adaptation options to development and climate change impacts

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THANK YOU