Assessing Climate Change Impacts on Water Resources in the Beas Basin
&

Possible lessons for future management of the Ganga

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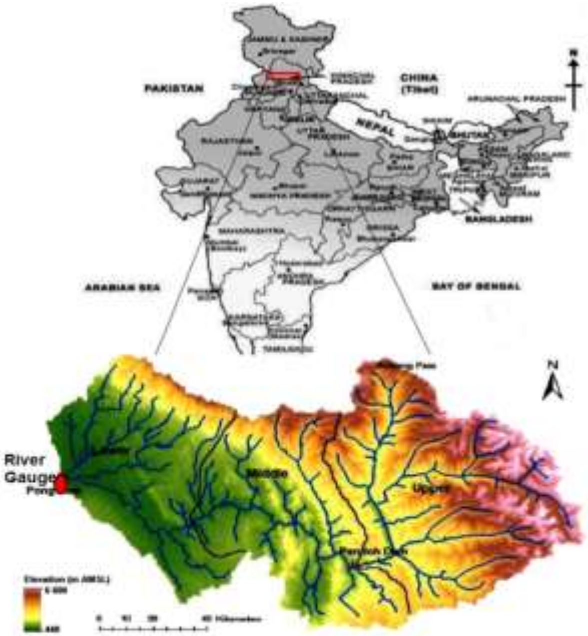
MICCI: Overview of Beas Basin Study

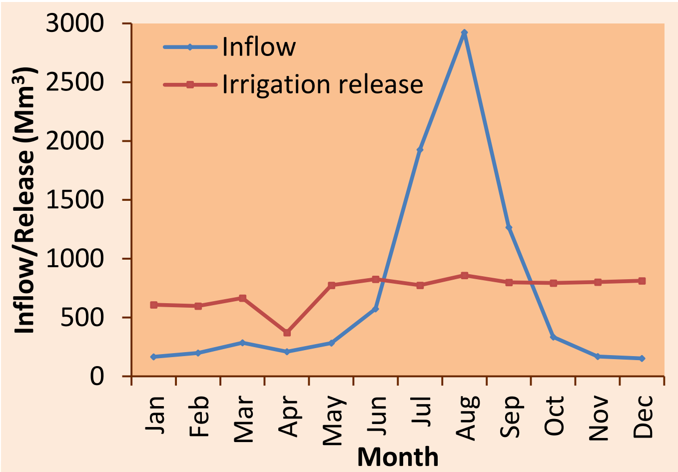
- Projected Climate Change (CC) will influence Temperature, Rainfall & ET with implications for:
  - Irrigation Water Supply/Demand
  - River's Discharge & Reservoir's Inflow
  - Performance of Water Infrastructures e.g. Reservoirs
- Hence, study has included:
  - Assessment of climate change effects and uncertainty on Beas river flows & Pong Reservoir performance in irrigation water supply.
  - Assessment of climate change effects on crop yields in the basin.
  - Field experiments to characterise crop-soilwater interactions.

Beas River Basin & Pong Reservoir

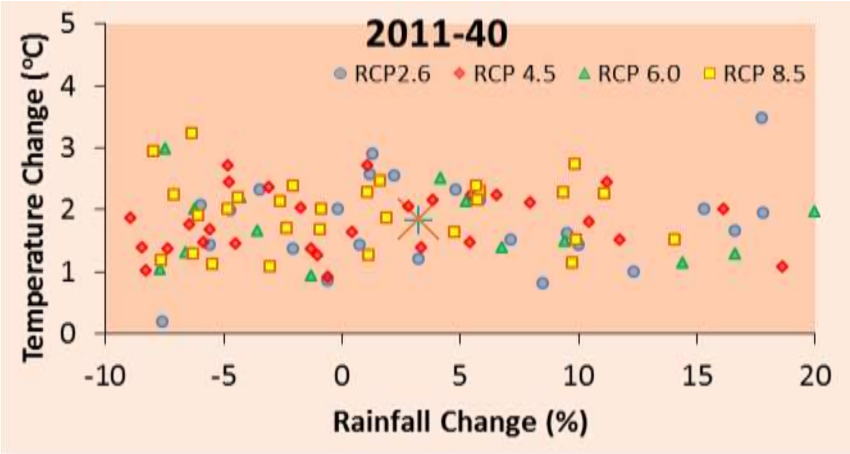


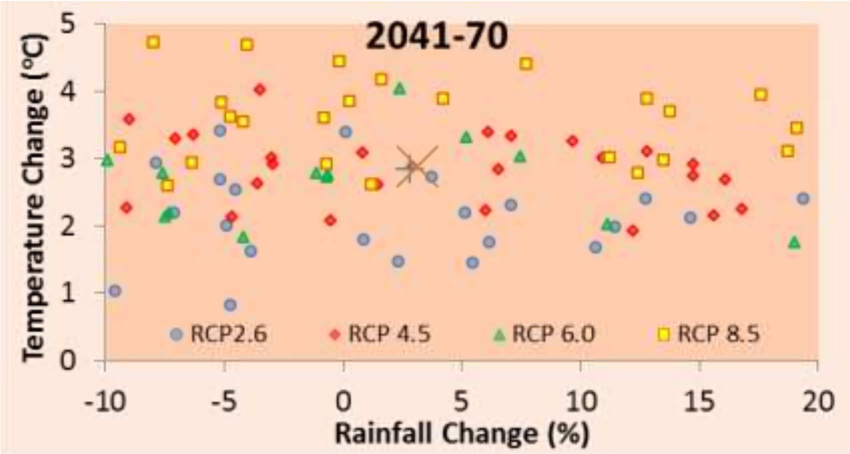
Catchment area	12561 km^2
Snow catchment	780 km^2
Active storage capacity	7291.22 Mm^3
Use	Hydropower (396 MW), Irrigation (1.38 Mha)

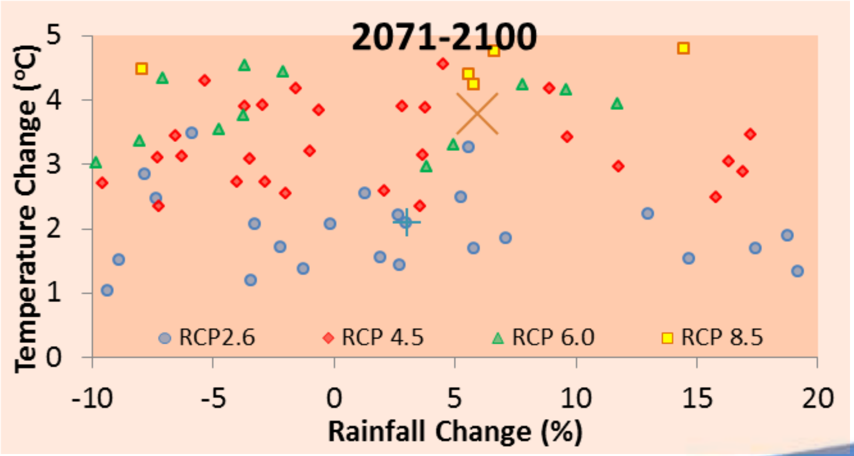
- Runoff highly influenced by the snow melt from the Himalayas
- Pong Reservoir - Major water infrastructure for irrigation water supply to Himachal Pradesh, Punjab, Haryana & Rajasthan



Climate Change: GCM Projections for Beas basin







CMIP5 Projections of Rainfall and Temperature changes

No. of GCM Experiments (Total = 127)

RCP 2.6: 29
RCP 4.5: 38
RCP 6.0: 22
RCP 8.5: 38

Distinctly Ambitious
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Climate Change: GCM Projected changes

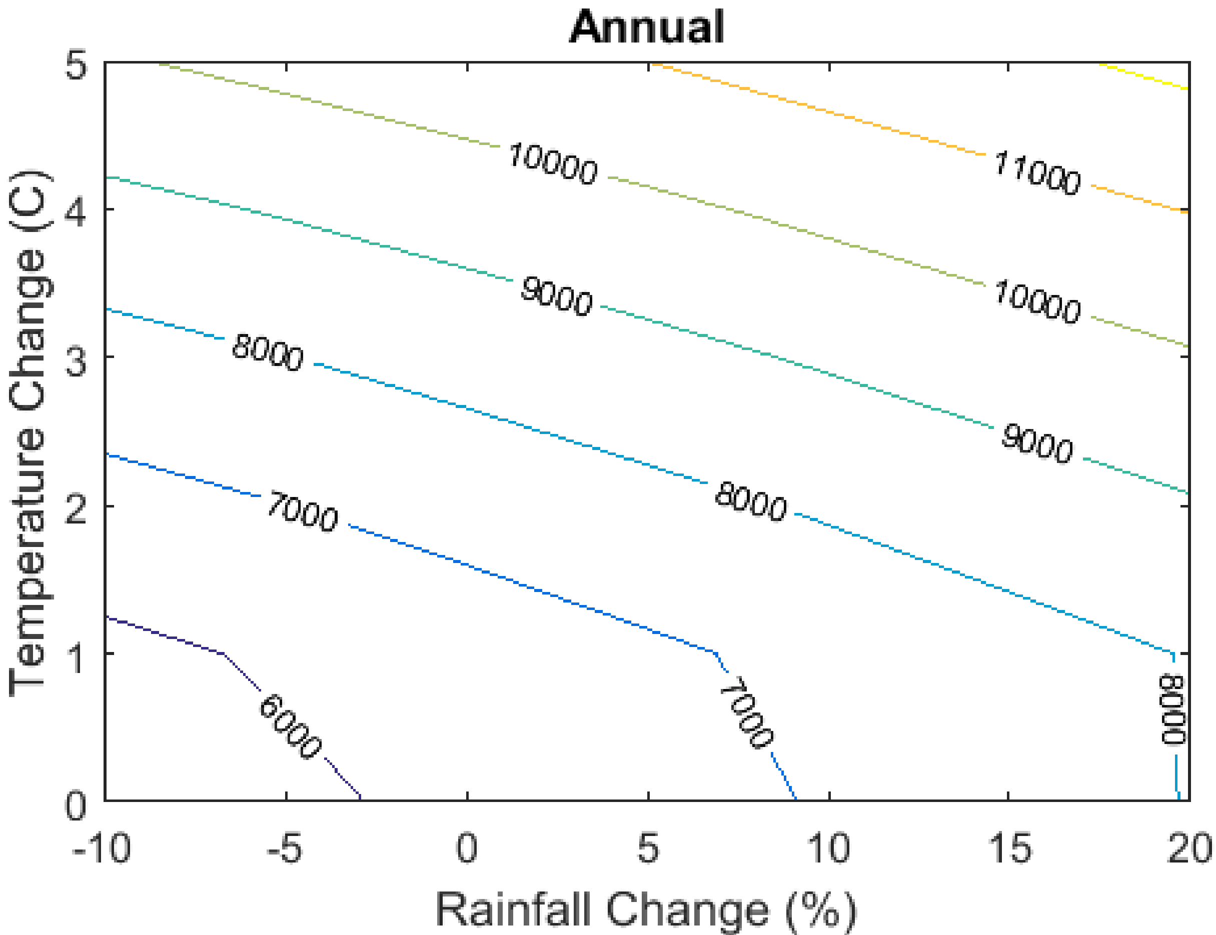
Time slice	Mean (& SD) of change		95% limits	
	ΔT (^oC)	ΔP (%)	ΔT (^oC)	ΔP (%)
2011-2040	1.84 (0.66)	2.84 (13.02)	[1.73, 1.96]	[0.58, 5.10]
2041-2070	2.94 (0.96)	2.77 (14.33)	[2.77, 3.11]	[0.28, 5.26]
2071-2100	3.90 (1.67)	5.51 (15.90)	[3.61, 4.19]	[2.74, 8.29]

Investigation ΔT : 0 to +5^{o}C

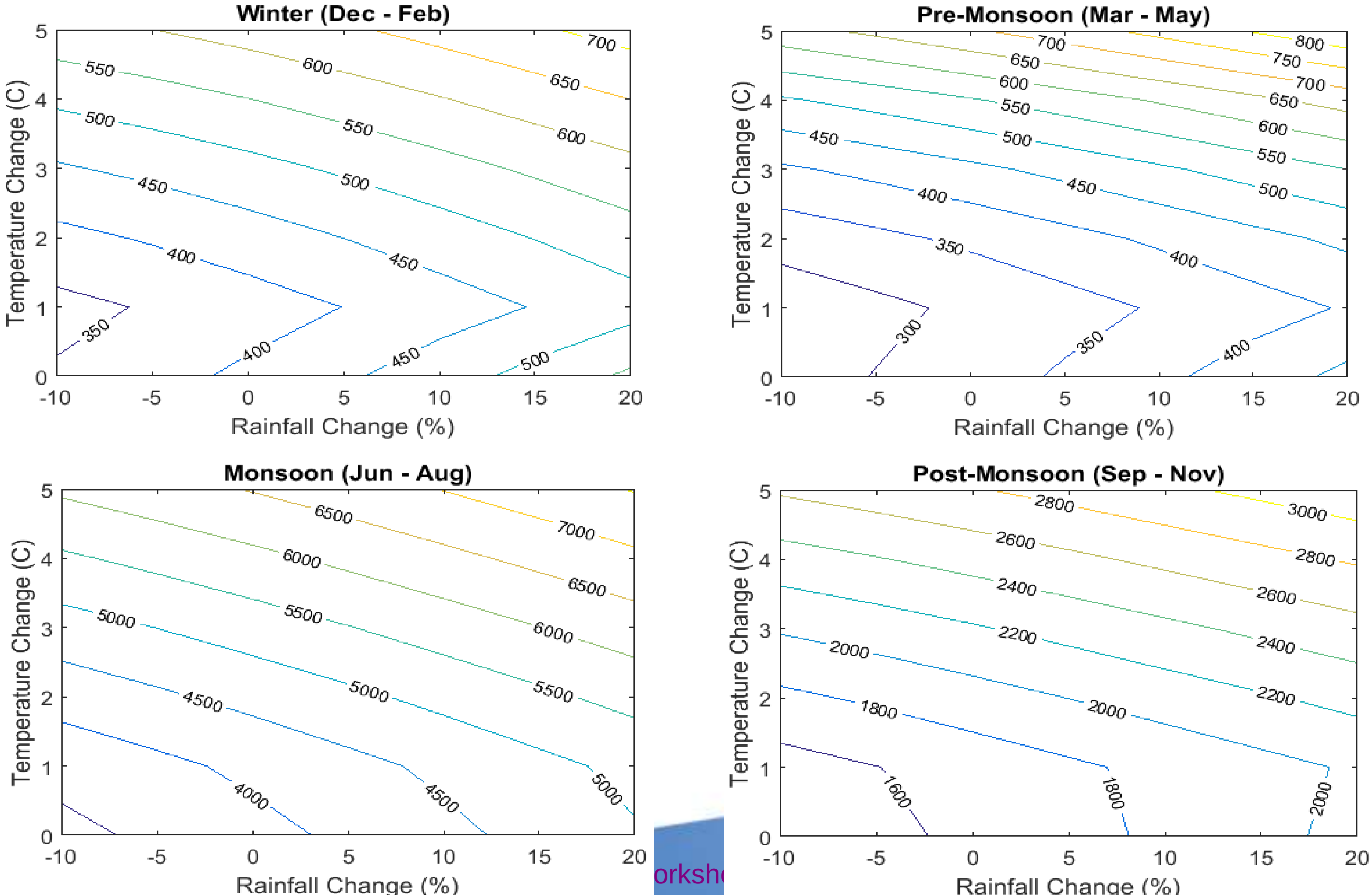
ΔP : -10 to +20%

CMIP5

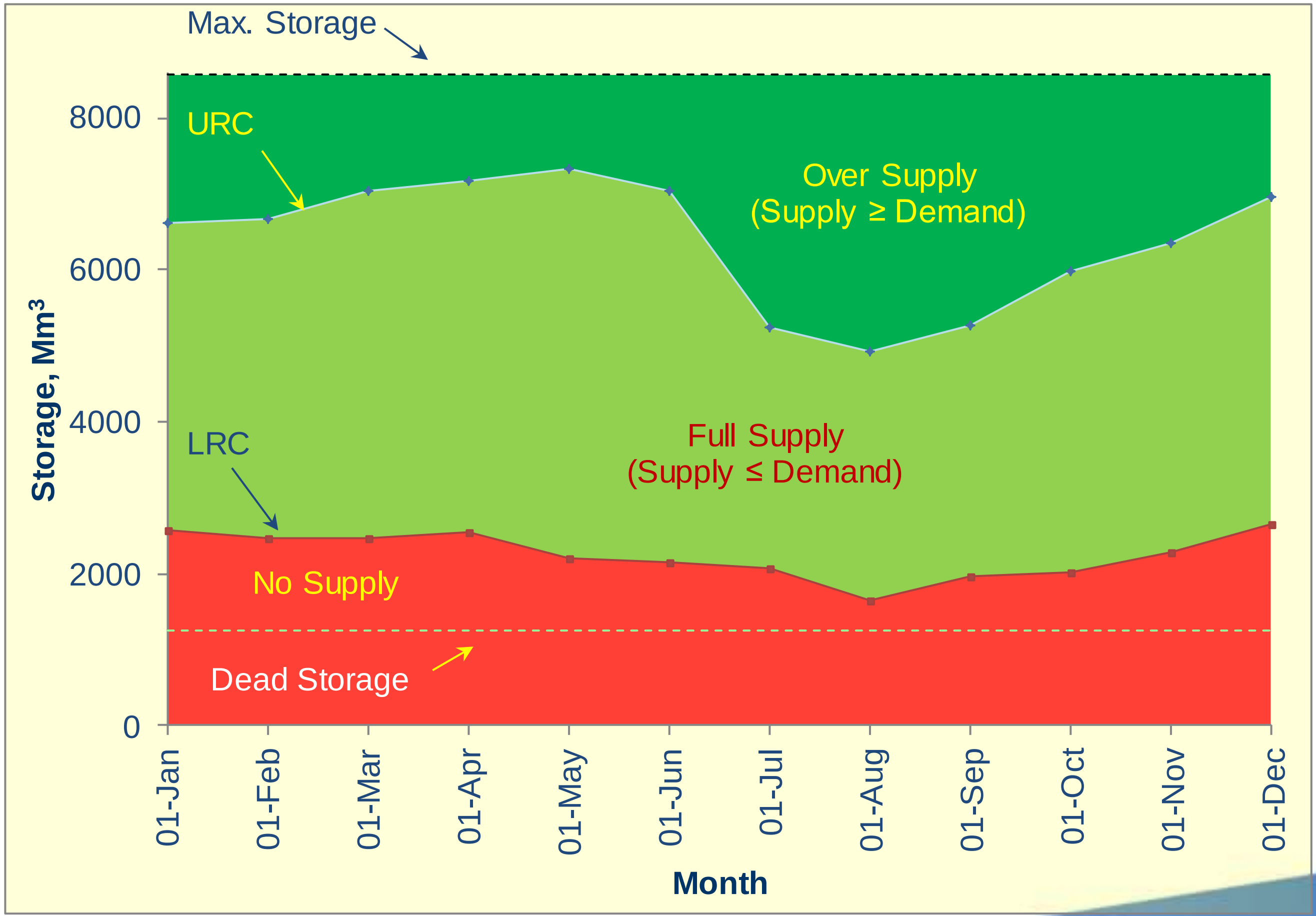
HYSIM Simulated Climate change Impacts: Annual Runoff (MCM)



HYSIM Simulated Climate change Impacts: seasonal Runoff (MCM)

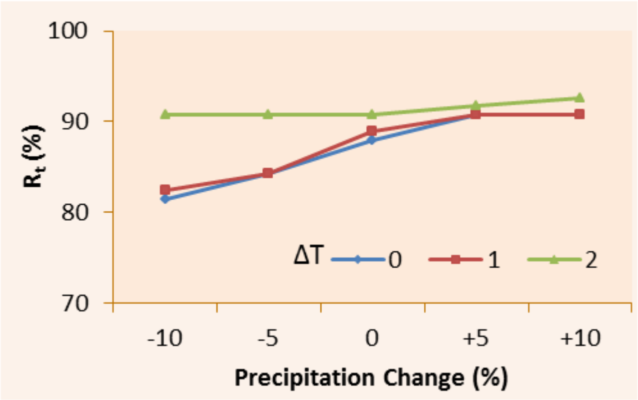


Pong Reservoir: Optimised basic Operational Rule Curves

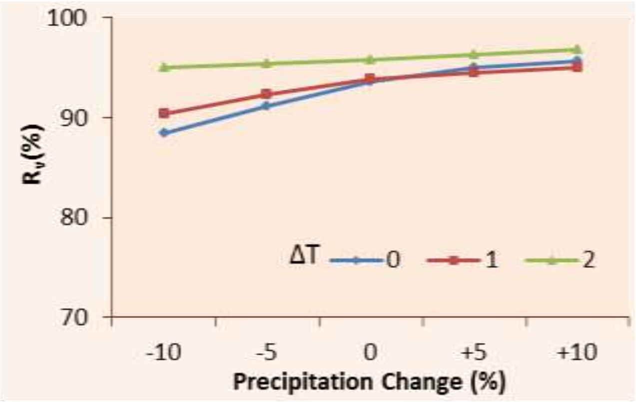


Pong Reservoir: Simulated Performance

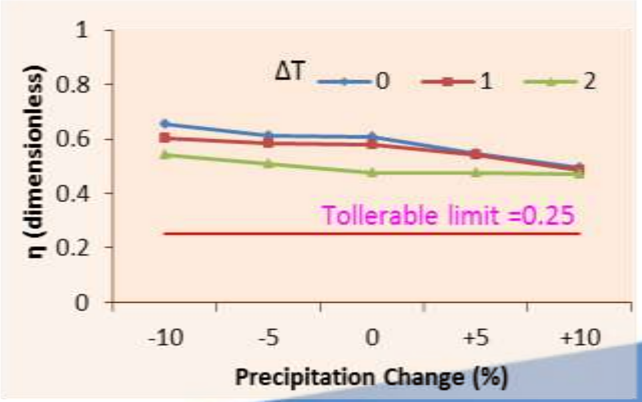
Time Reliability



Volume Reliability



Vulnerability



Adeloye AJ, Soundharajan B, Ojha CSP, Remesan R. (2015) Water Resources Management. DOI: 10.1007/s11269-015-1171-z

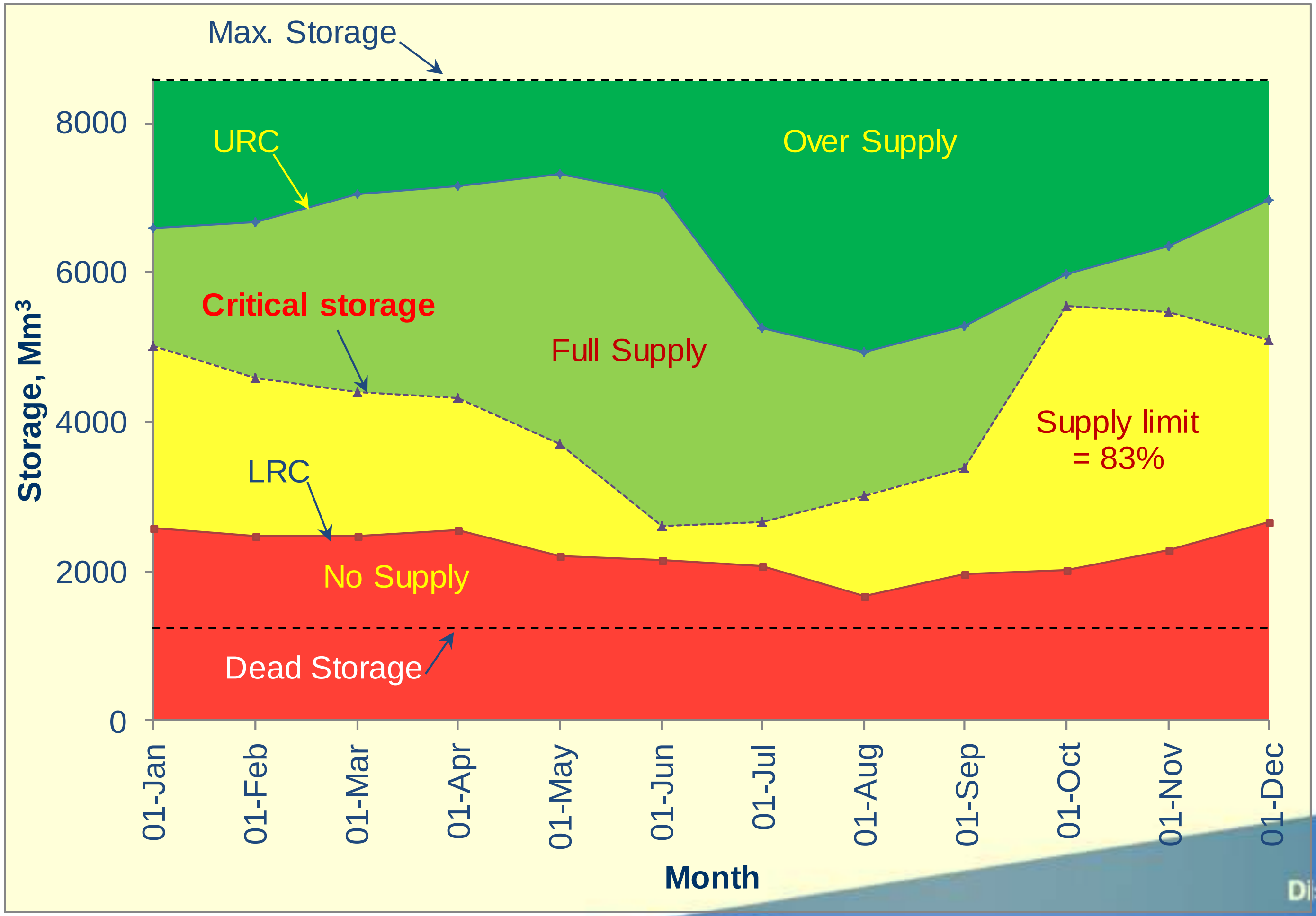
Pong Reservoir: Summary of Simulated Performance & Climate Change

Performance Index	CC causing increased inflow	CC causing reduced inflow	Comments
Time Reliability (R_t)	↑	↓	≥ 80; hence OK
Volume Reliability (R_v)	↑	↓	≥ 88; hence OK
Vulnerability (η)	↓	↑	≥ 0.5; too high and beyond tolerable limit for users.

Pong Reservoir: How to reduce the **Vulnerability?**

- Water Hedging - deliberate reduction in releases during normal periods, which is then used to reduce shortfall (or vulnerability) during low flow periods:
  - Constant, Single stage hedging
  - Constant, 2-stage hedging
  - Seasonally varying, Single stage hedging
  - Monthly varying, Single Stage hedging

Pong Reservoir: Optimised Single stage Hedging-integrated Operational Curves

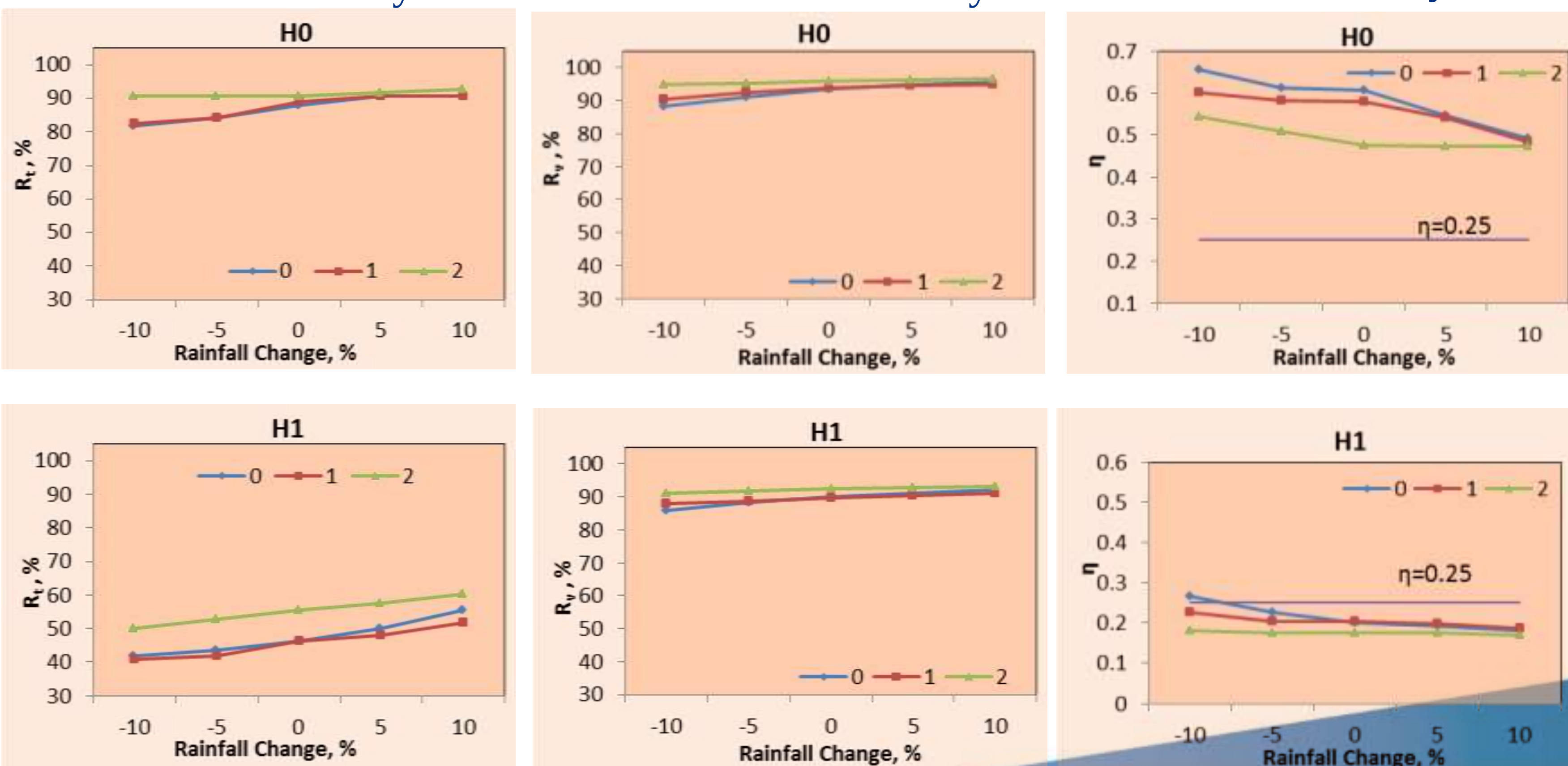


Adeloye *et al*. (2015) Water Resources Management. DOI:10.1007/s11269-015-1171-z

Pong Reservoir: Simulated Performance with hedging

Time Reliability | Volume Reliability | Vulnerability

No hedging / With hedging



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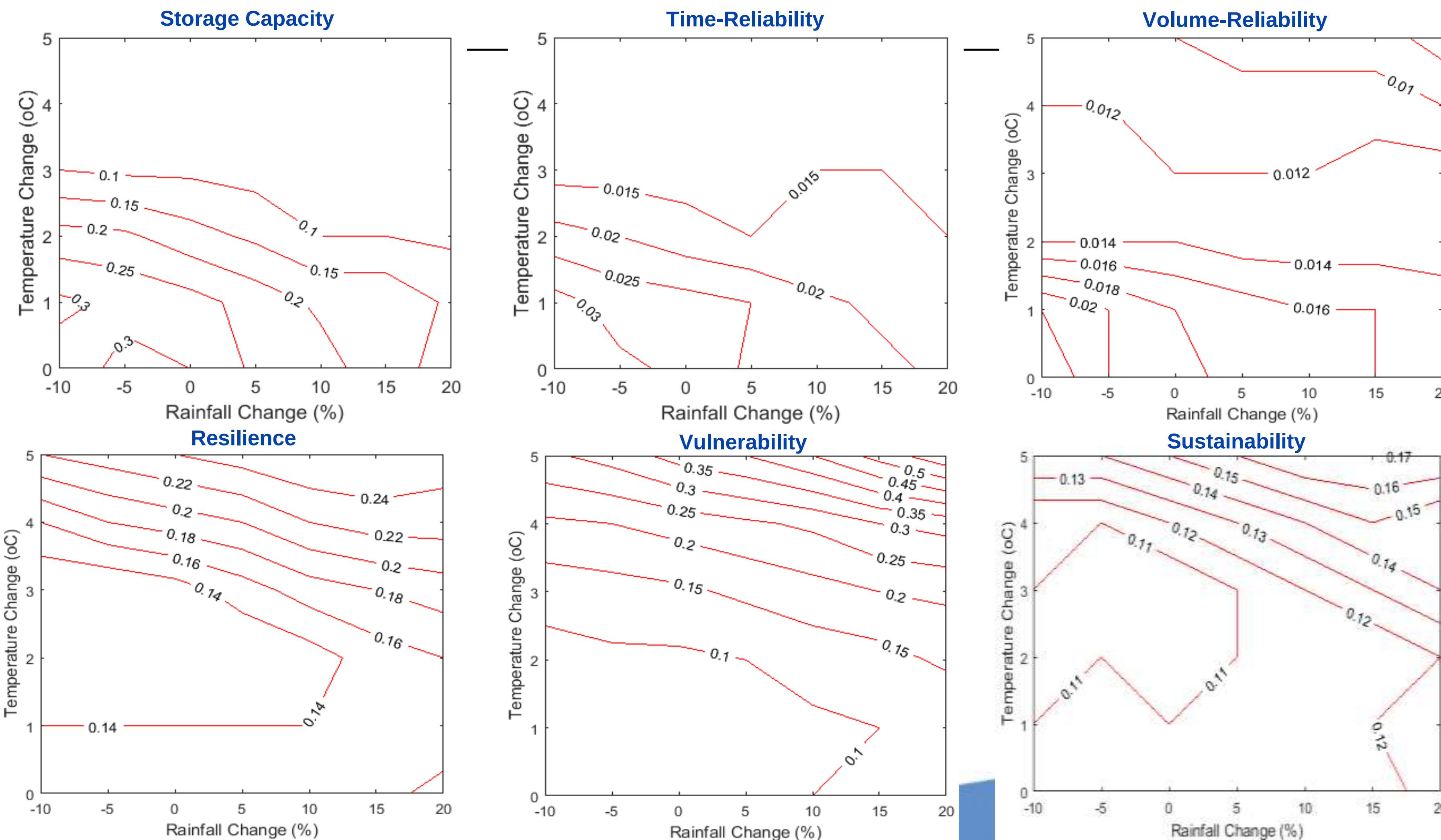
Summary: Effect of Managed Hedging

- Hedging causes the time-based reliability to worsen significantly.
- Hedging causes only very modest reduction in the volume reliability
- Hedging has most profound effect on the vulnerability: All the resulting vulnerability indices were < 0.25 with hedging for all the climate change effects.

CAUTION: BUT HOW RELIABILE ARE THESE ONE-OFF ASSESSMENTS => UNCERTAINTY CONSIDERATIONS

Pong Reservoir: Uncertainty in Planning Characteristics

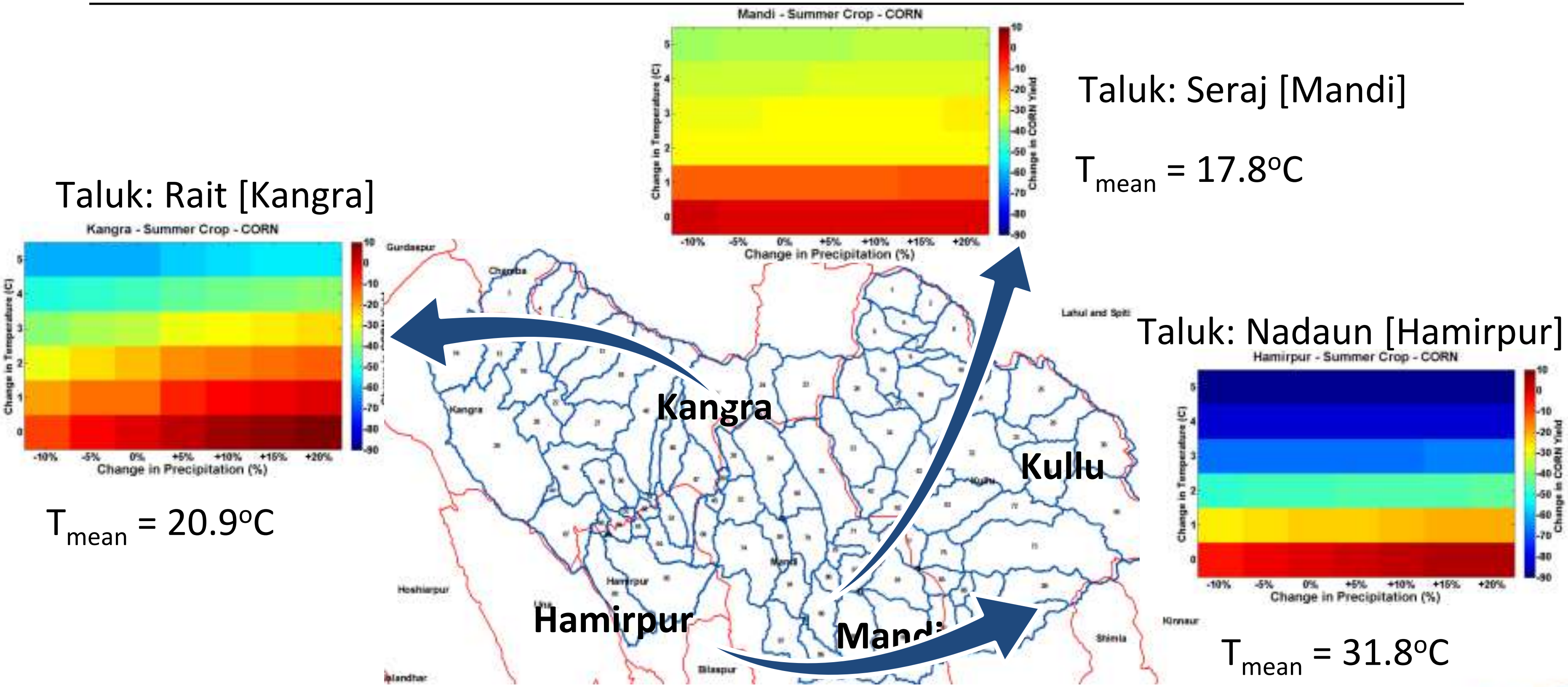


Soundharajan B, Adeloye AJ, Remesan R. (2015) Proc IAHS. DOI: 10.5194/piahs-371-49-2015

Summary: Effect of Uncertainty

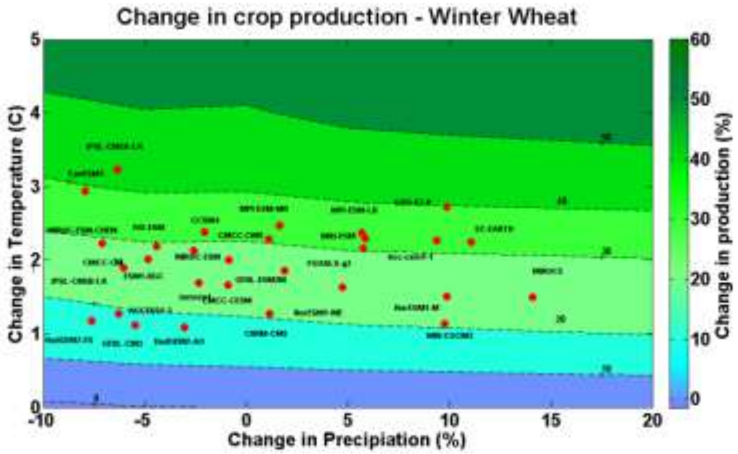
- Reservoir capacity – highly variable under climate change effects.
- Reservoir capacity quantiles for drier scenarios are much larger compared to wetter conditions.
- Performance indices – in general, highly variable, however reliability – least variable.

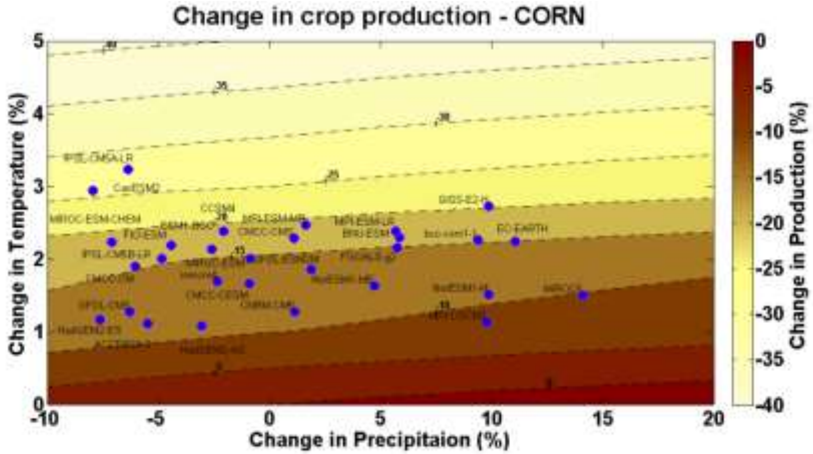
Agriculture: SWAT simulated crop yield (summer corn) – specific regions



❑ The decrease in yield intensifies with increasing mean temperature (i.e. greatest decrease in Hamirpur and smallest in Mandi)

Agriculture: SWAT simulated crop yield (Basin wide)

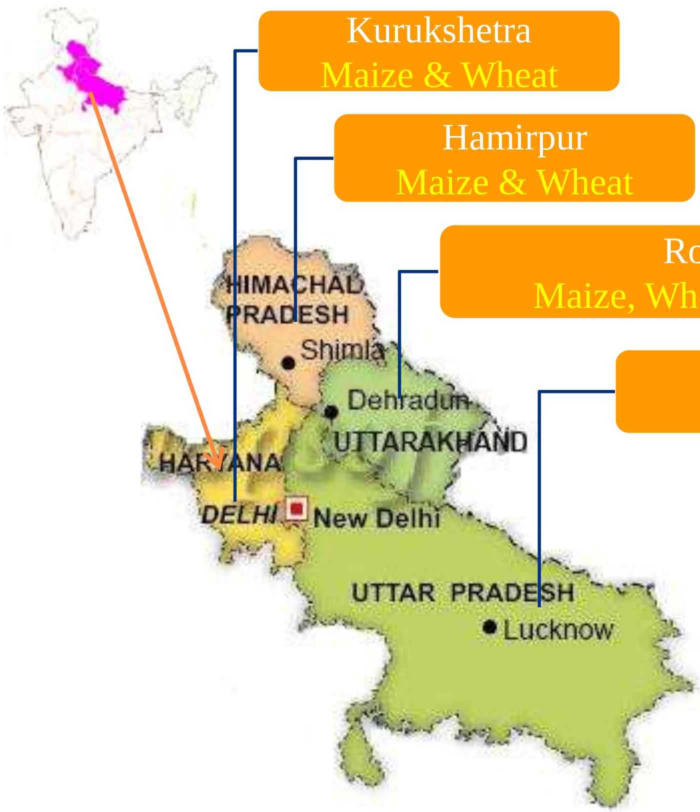




RCP8.5 (2011-2040)

- Summer crop production is decreasing and winter crop is increasing with rise in temperature
- These results highlight the need for farmers to adopt temperature resistant varieties to cope with future climate change or move production to cooler land

Field Experiments: 2012-2015



Parameters observed:

- Moisture depletion in root zone
- root depth
- plant height
- leaf area index
- Irrigation
- meteorological parameters
- Soil characteristics

•To obtain data for evaluation of root water uptake numerical models at different geographical locations.

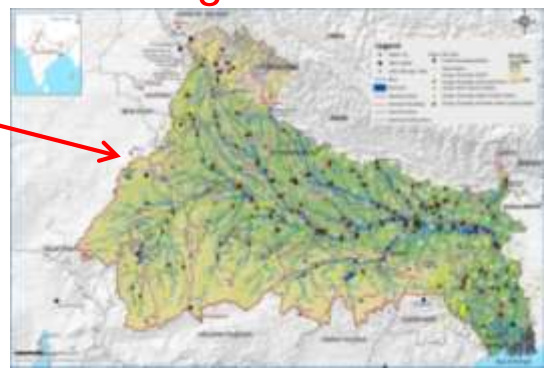
•Calibration & Validation of root water uptake model



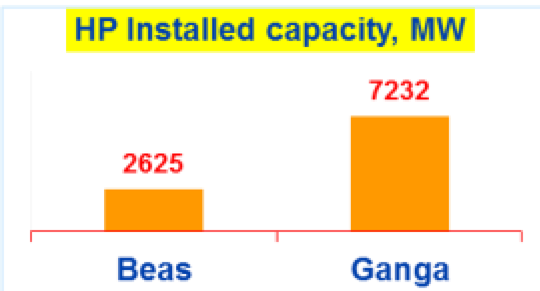


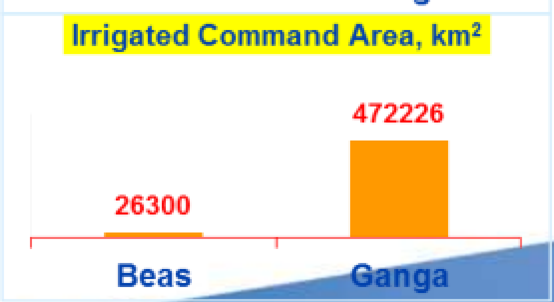

Beas & Ganga River Basins: Facts & Comparison

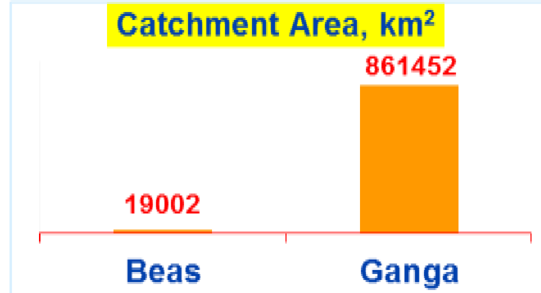
Ganga Basin

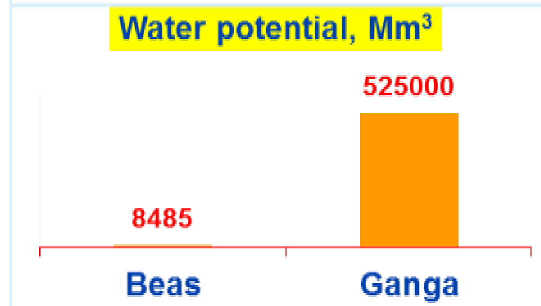


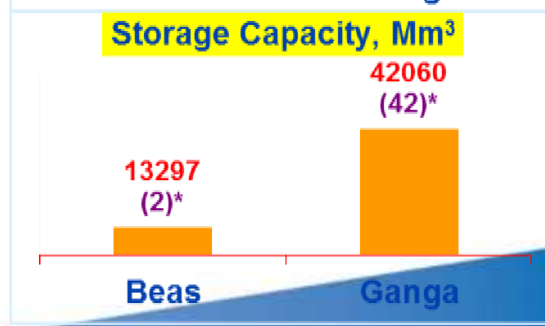
Beas Basin











* Number with storage capacity >100 Mm³

Ganga River Basin: Possible Research Agenda

- Characterising the uncertainties in climate change impacts on the basin water availability for better decision making.
- How much buffering capacity do Ganga water resources systems have for coping with projected climate change effects on water availability for irrigation, and how can this capacity be harnessed?
- Ice/Glaciers: What is the effect of significant/complete disappearance of glaciers in the long-term on the water resources balance of the Ganga?

Ganga River Basin: Possible Research Agenda contd.

- How best can water be conjunctively used for irrigation without compromising/jeopardising either compartment of the hydrologic cycle?
- Water Quality/Pollution: Pollution is a threat to water availability, especially in relation to Arsenic & Nitrate contamination from intensive agricultural practices. Can better predictive tools and/or low-cost treatment options for this be developed?
- Crop yields: How will crop yields be impacted by climate change and water availability in the Ganga Basin?

And finally...

THANK YOU

??Questions??

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Acknowledgements

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