Effect of dynamically varying zone hedging policies on surface water reservoir operational performance during climate change

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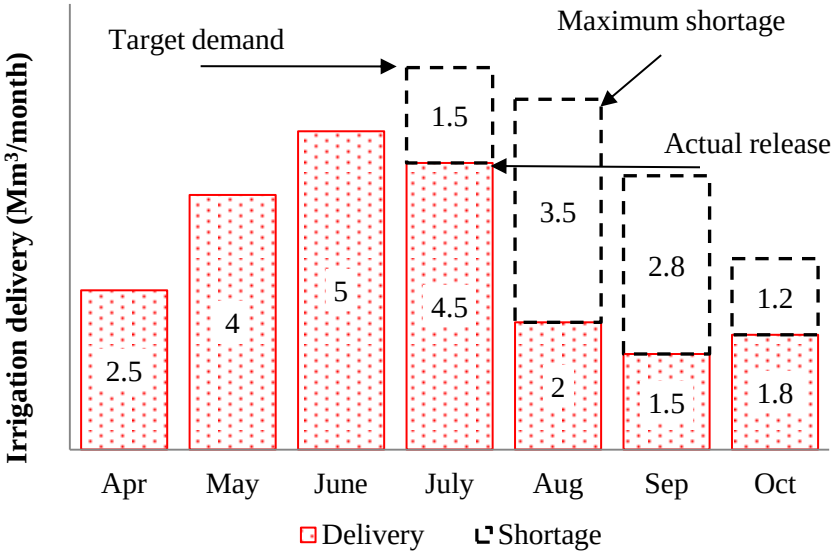
Overview

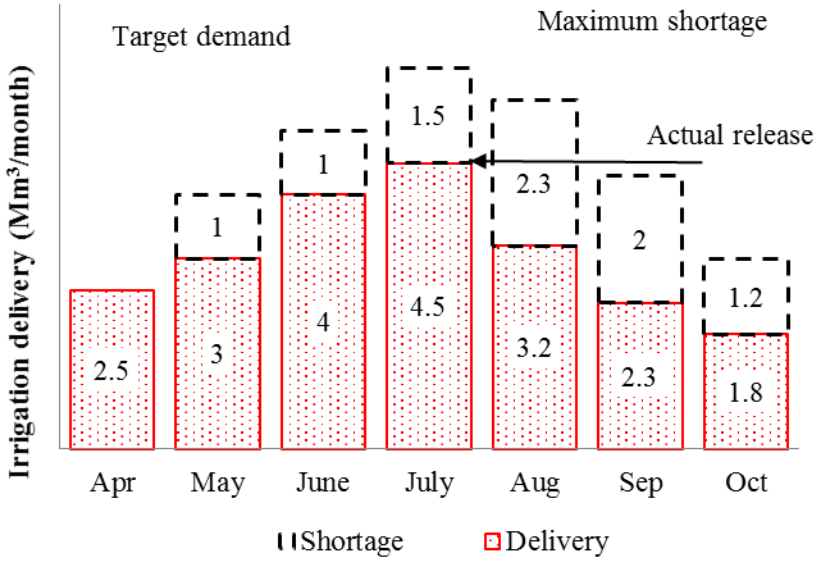
- Projected Climate Change (CC) will influence Temperature, Rainfall & ET with implications for:
  - Irrigation Water Supply/Demand
  - River's Discharge & Reservoir's Inflow
  - Performance of Water Infrastructures e.g. Reservoirs

- Where reservoirs are involved
  - Hedging (or deliberate water rationing during normal operation) can stem performance deterioration

Illustration: Hedging effect on system vulnerability



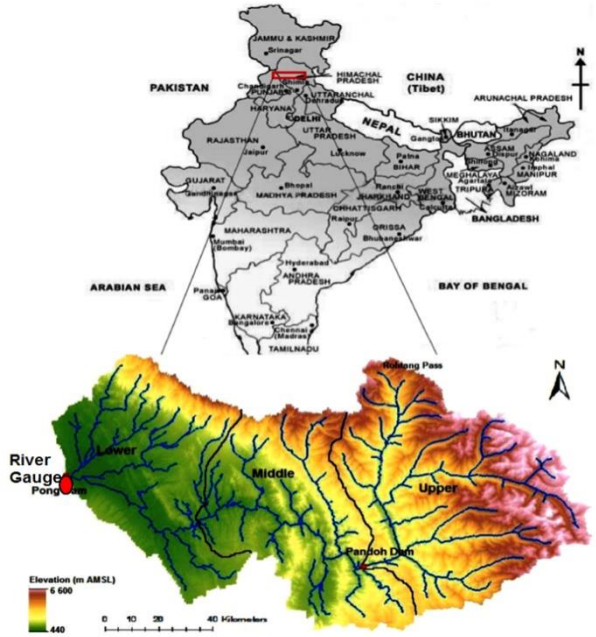
a) without hedging policy



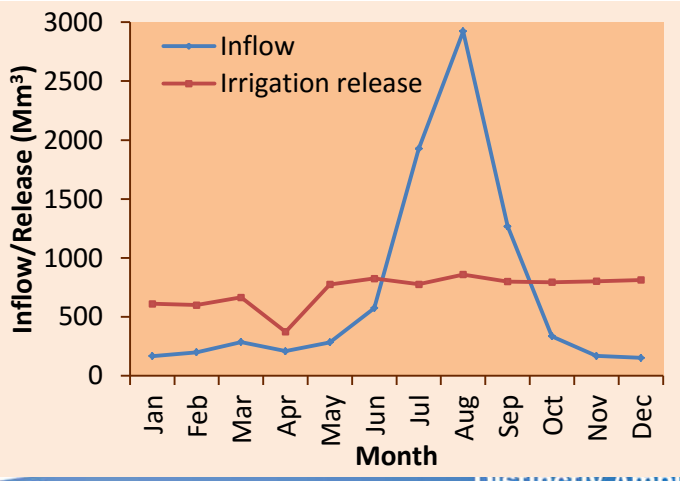
a) with hedging policy (Bower et al., 1966)

Maximum shortage comparison (a) 3.5 units (b) 2.3 units

Application: Beas River Basin & Pong Reservoir (INDIA)

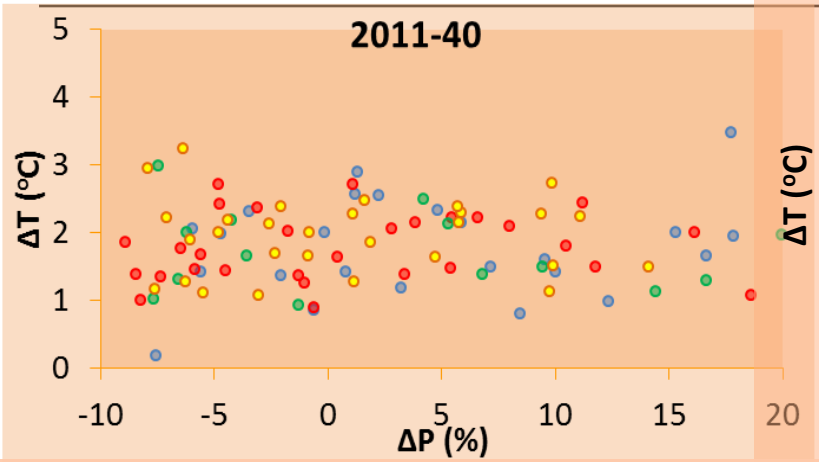


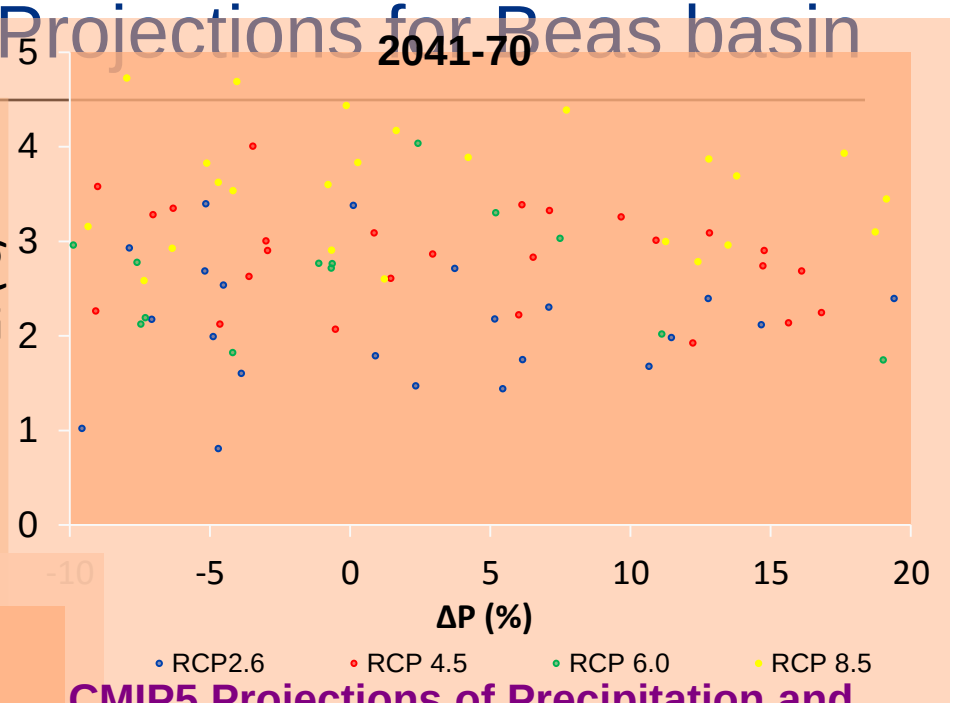
Catchment area	12561 km^2
Snow catchment	780 km^2
Active storage capacity	7291.22 Mm^3
Use	Hydropower (396 MW), Irrigation (1.38 Mha)

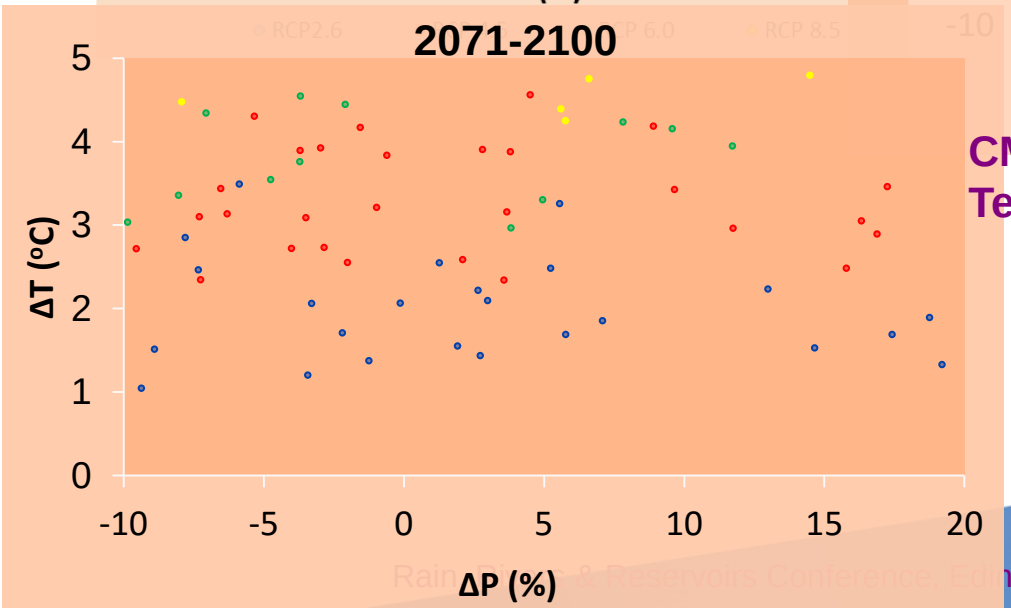


- Runoff highly influenced by the snow melt from the Himalayas
- Pong Reservoir - Major water infrastructure for irrigation water supply to Himachal Pradesh, Punjab, Haryana & Rajasthan

Climate Change: GCM Projections for Beas basin







CMIP5 Projections of Precipitation and Temperature changes

No. of GCMs

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

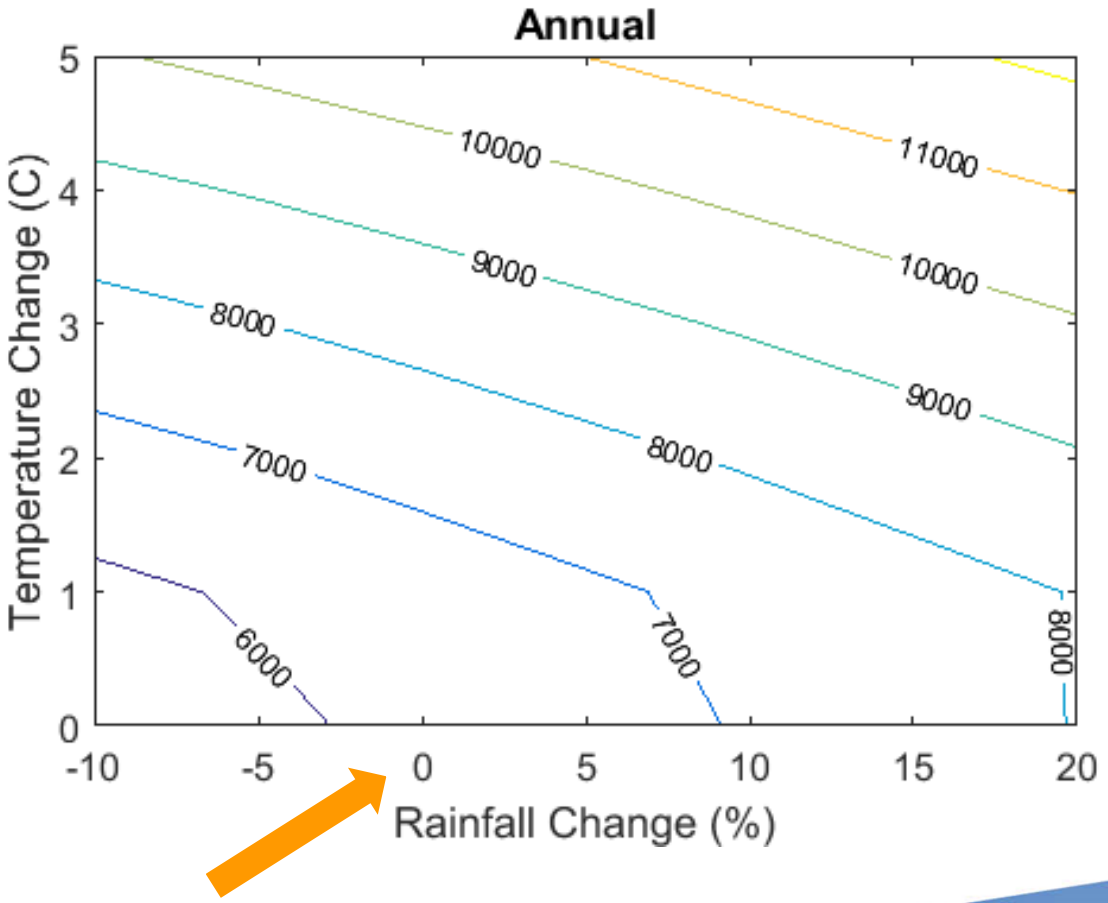
Climate Change: GCM Projected changes

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 +5ºC

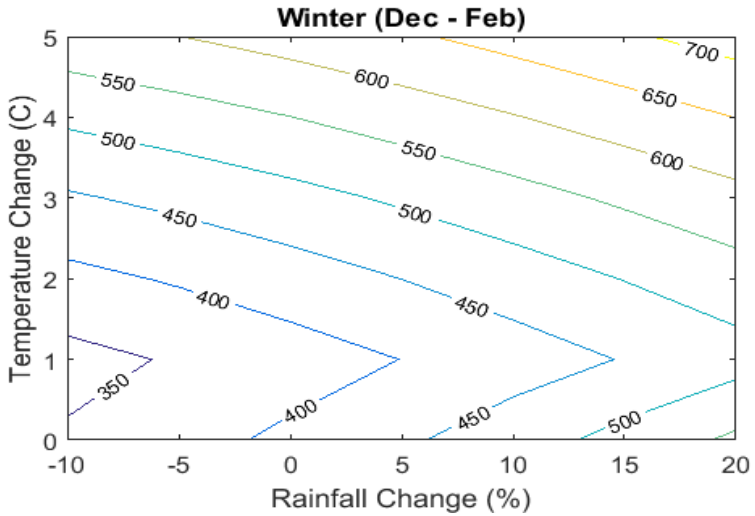
ΔP : -10 to +20%

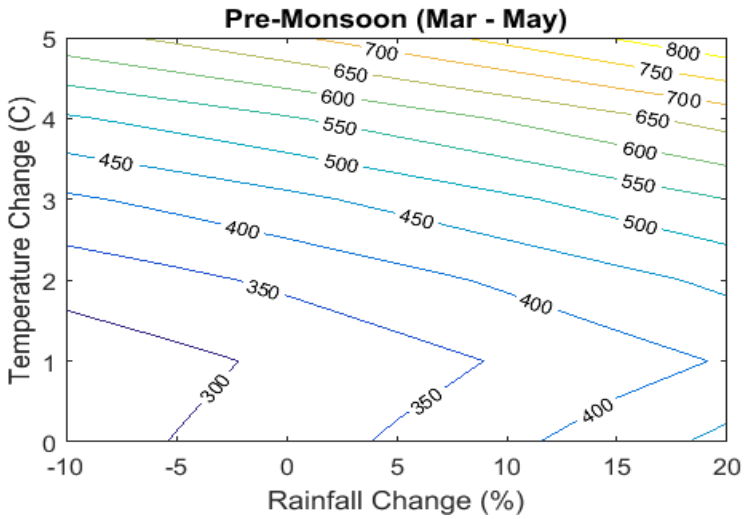
HYSIM R-R Model Simulated Climate change Impacts on Annual Runoff (x 10^6 m^3)

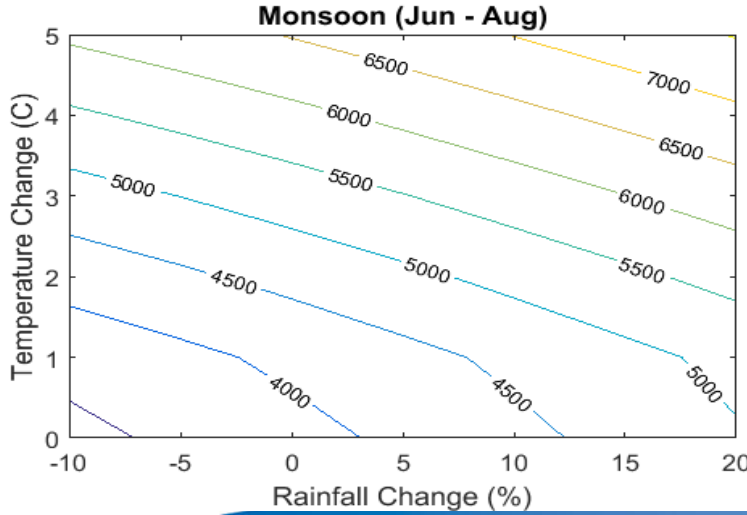


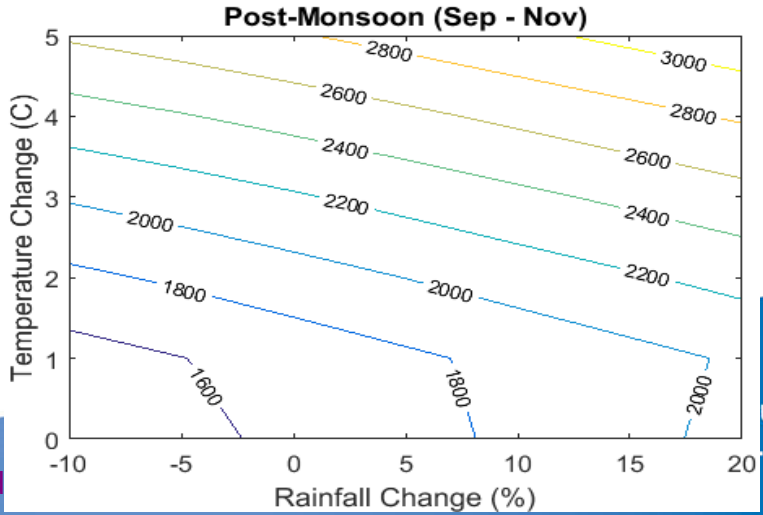
Soundharajan B, Adeloye AJ, Remesan R. *Journal of Hydrology* (2006) doi: 10.1016/j.jhydrol.2016.04.051

HYSIM R-R Model Simulated Climate change Impacts on seasonal Runoff (x 10^6 m^3)

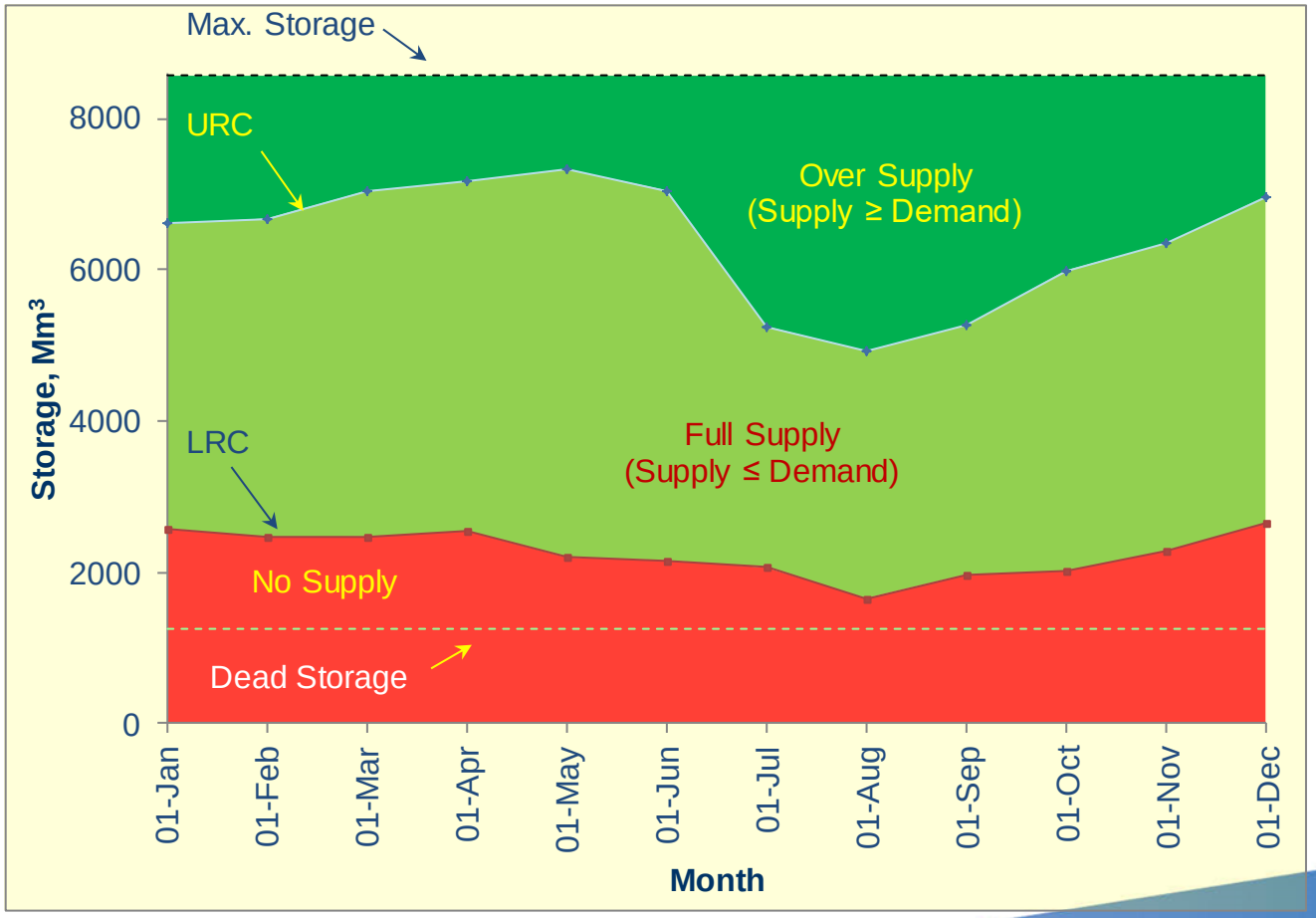






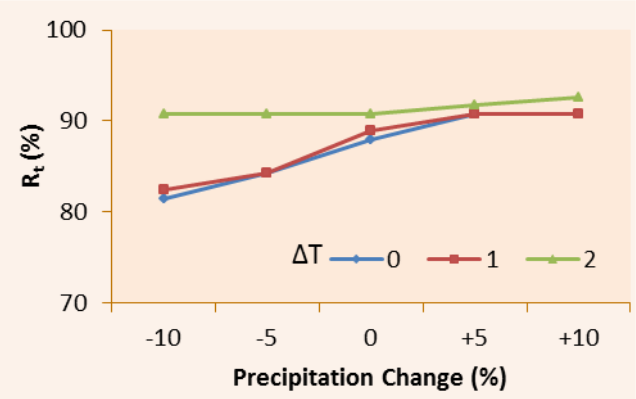


Pong Reservoir: Genetic Algorithms (GA) optimized Rule Curves (No Hedging)

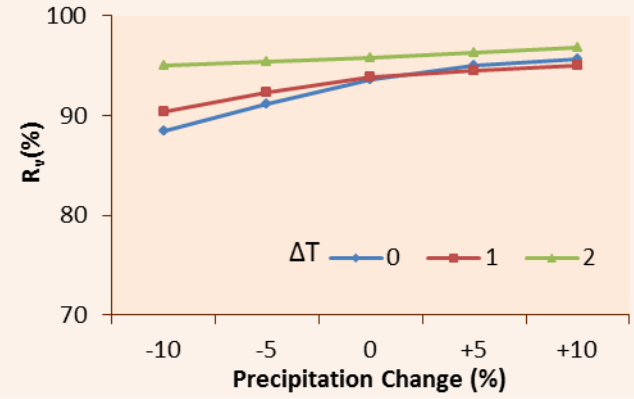


Pong Performance - No Hedging

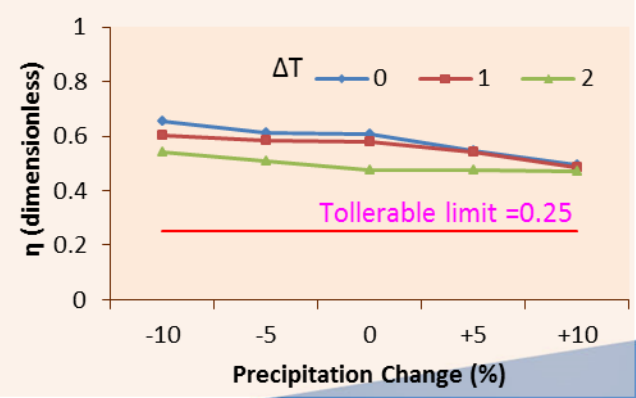
Time Reliability



Volume Reliability



Vulnerability



Adeloye AJ, Soundharajan B, Ojha CSP, Remesan R. (2016) *Water Resources Management doi: 10.1007_s11269-015-1171-z*

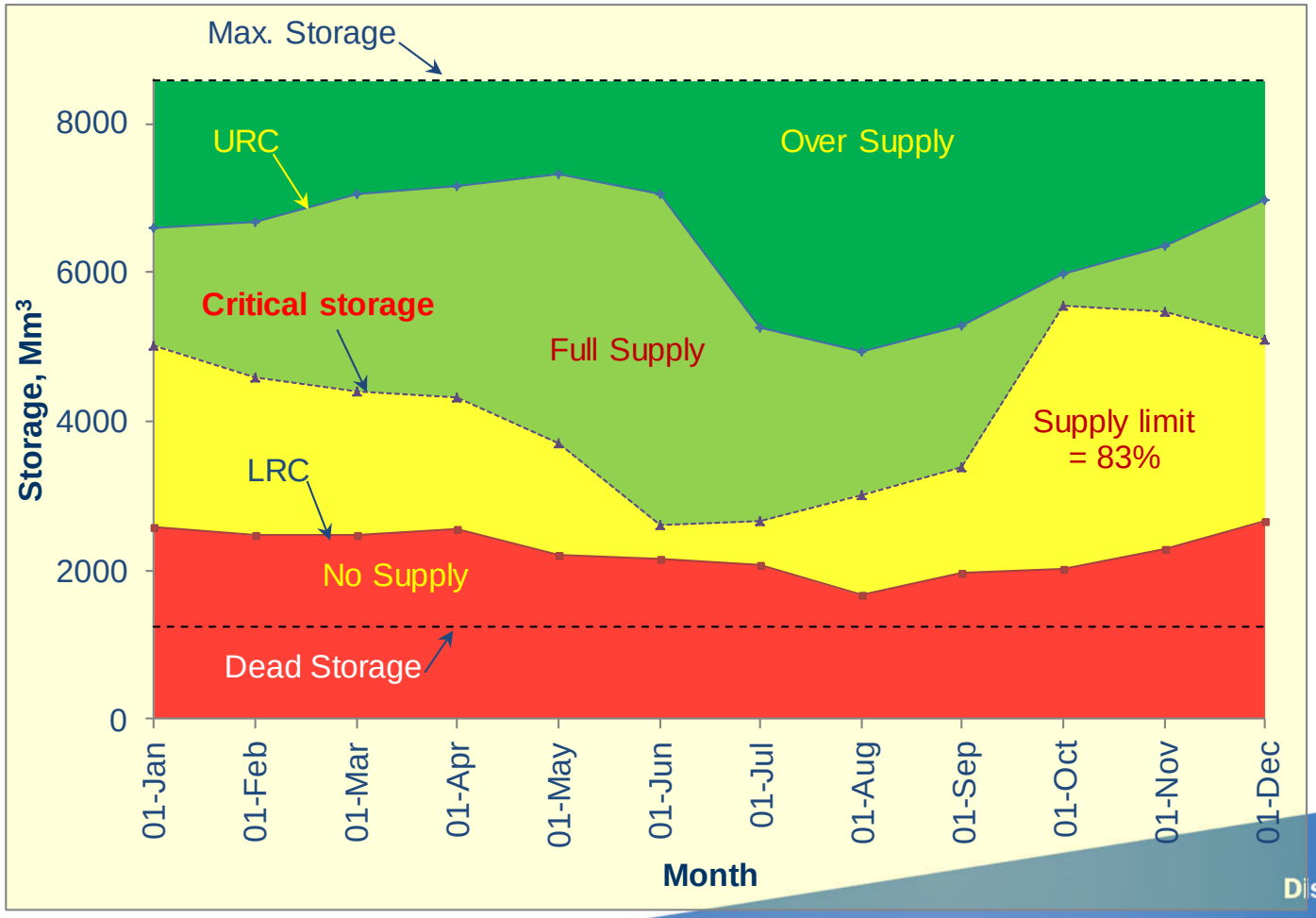
Summary: Climate Change on Performance with no hedging

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.

How to reduce the **Vulnerability?**

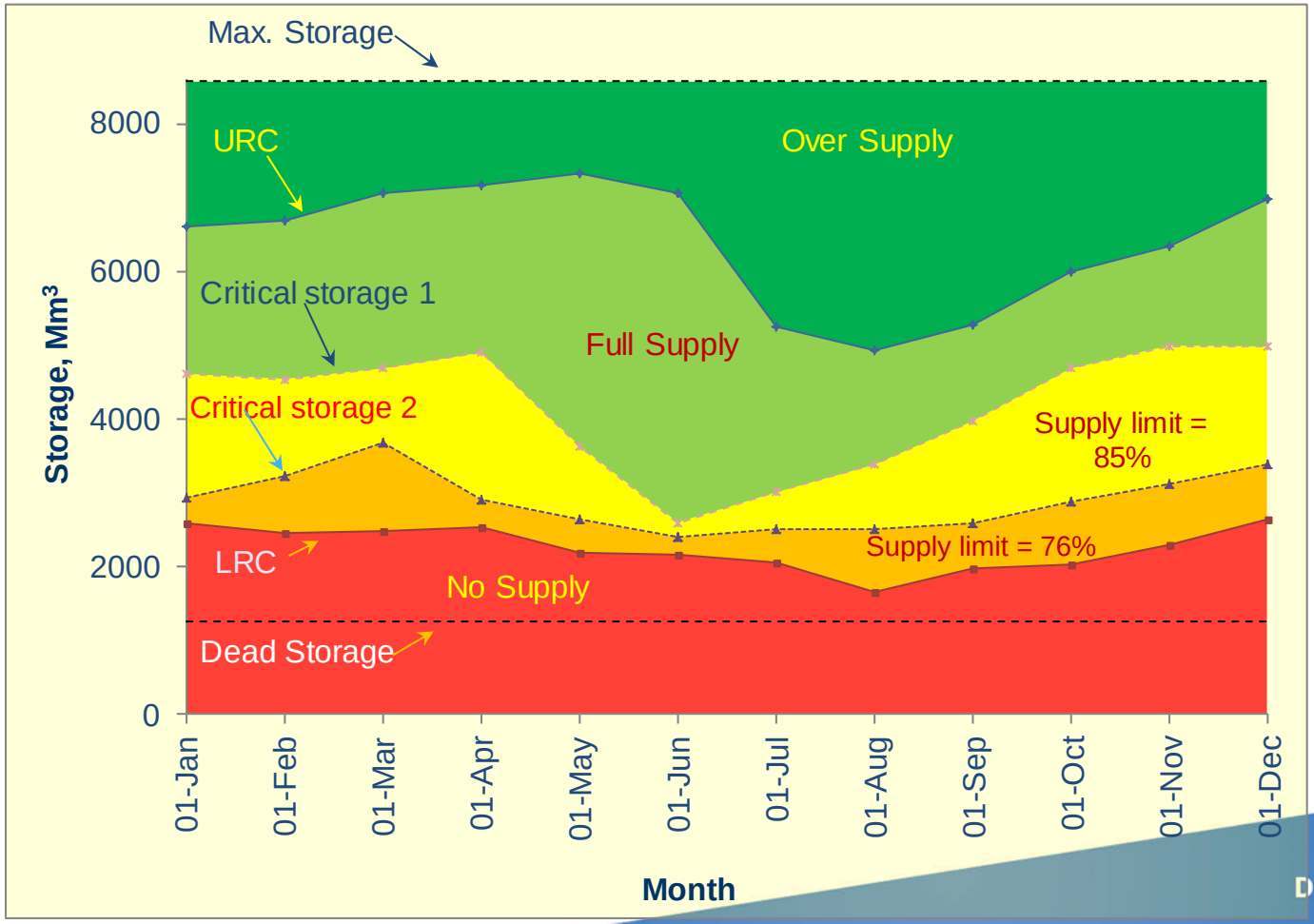
- Water Hedging - deliberate reduction in releases during normal periods, which is then used to reduce shortfall (or vulnerability) during low flow periods:
  - Constant, Single stage hedging
  - Constant, 2-stage hedging
  - Seasonally varying, Single stage hedging
  - Monthly varying, Single Stage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

Pong: GA Optimised Single stage Constant Hedging

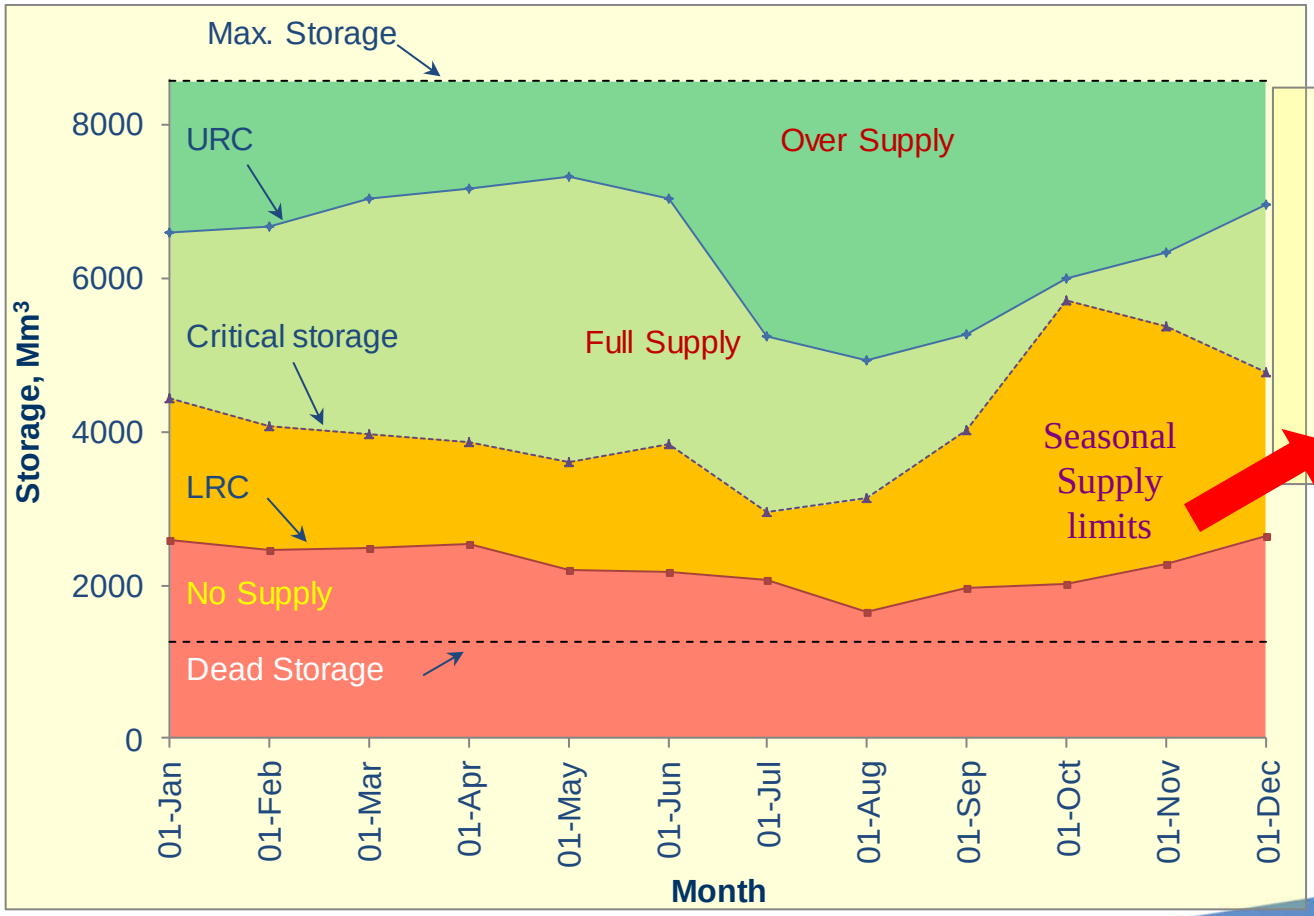


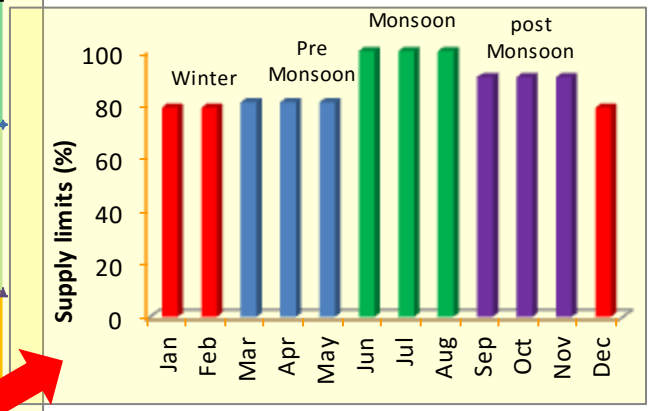
Adeloye *et al*. (2015) Water Resources Management

Pong: GA Optimised 2-stage Constant Hedging

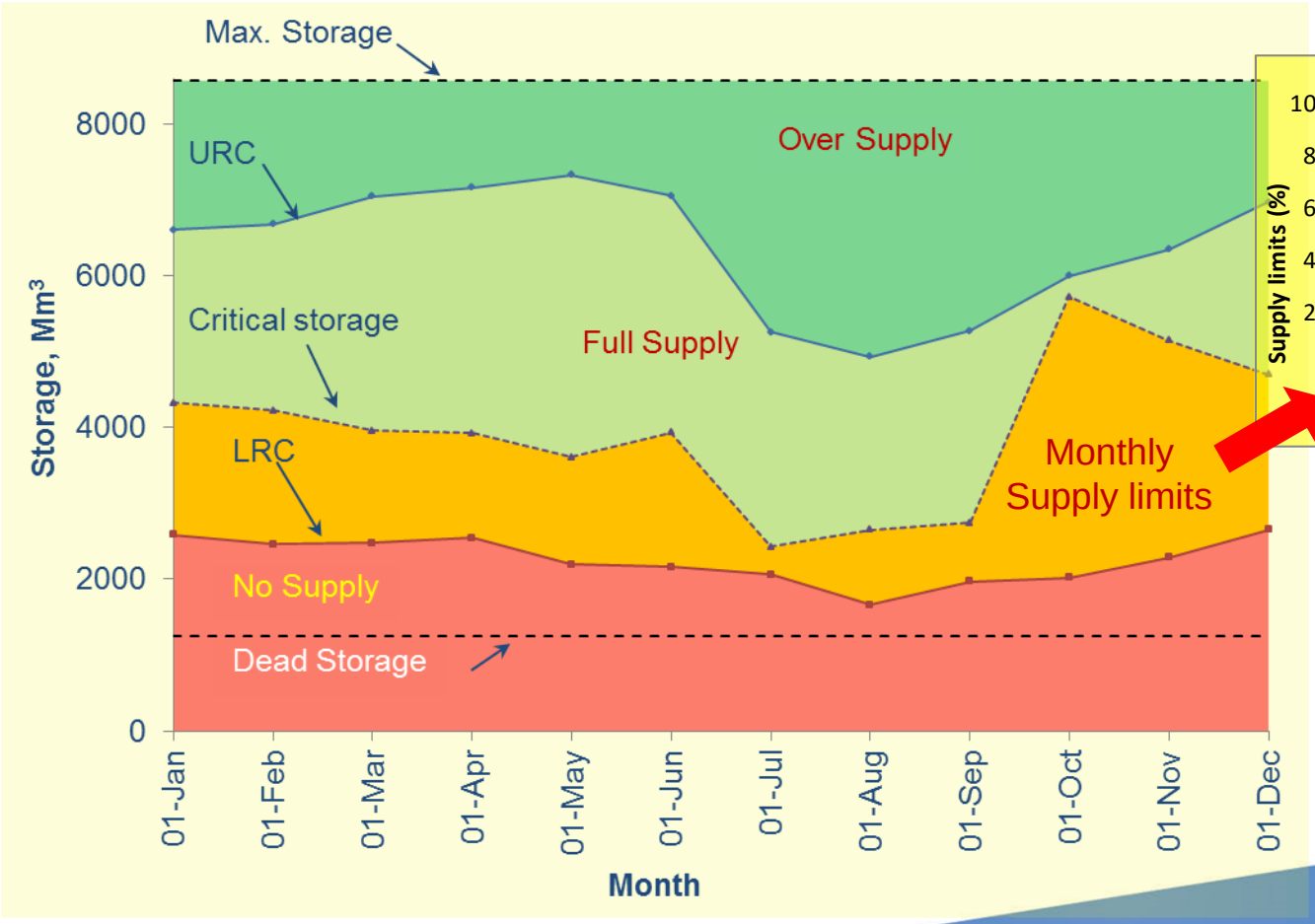


Pong: GA Optimised Single stage Seasonally varying Hedging

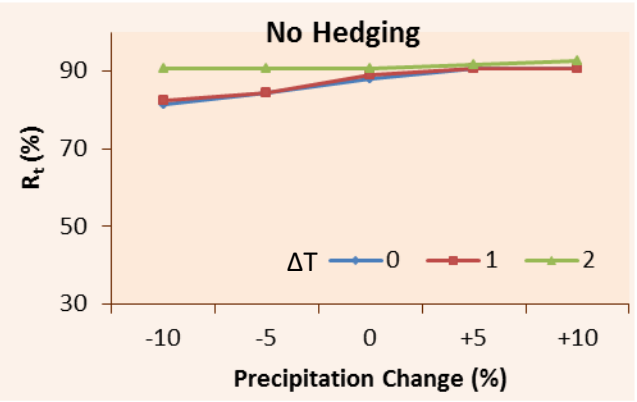


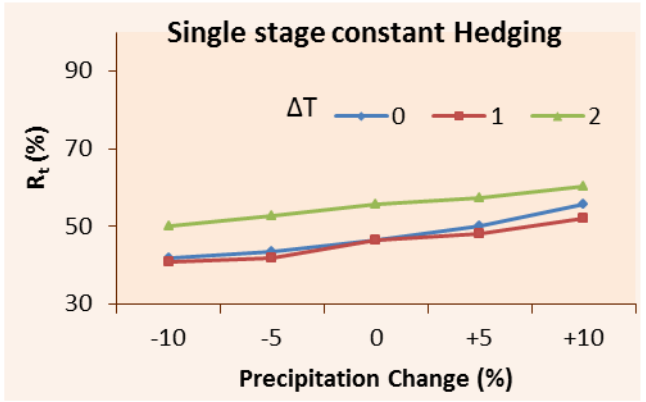


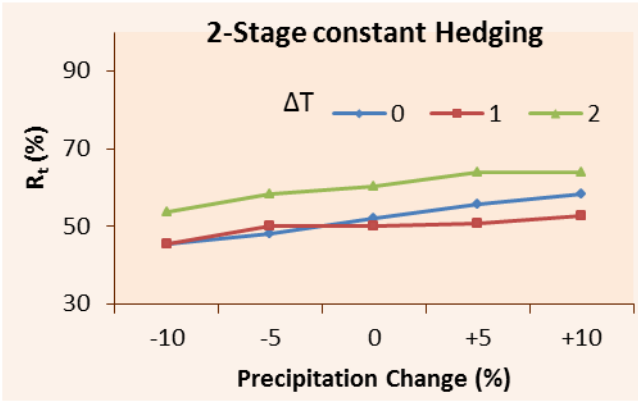
Pong: GA Optimised Single stage Monthly varying Hedging

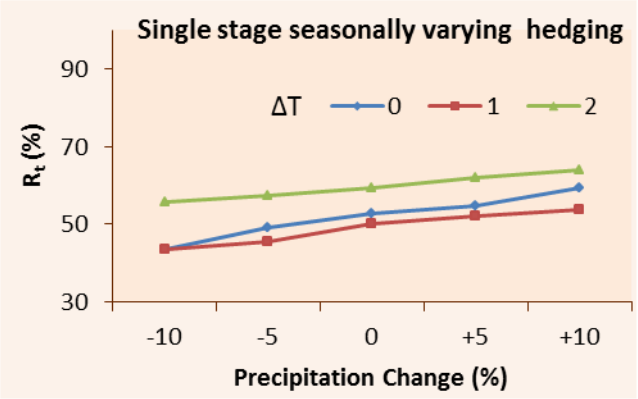


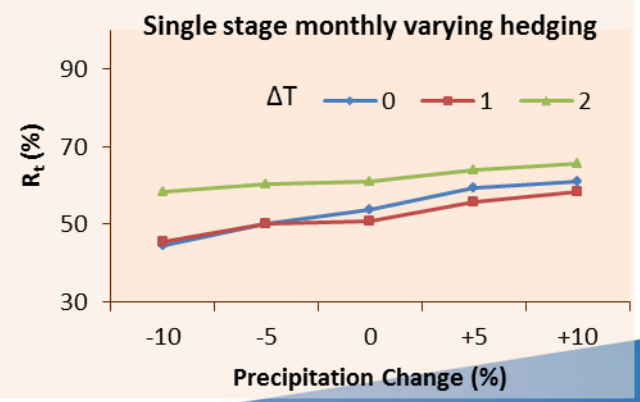
Pong: Hedging effect on Reservoir Reliability (time-based)



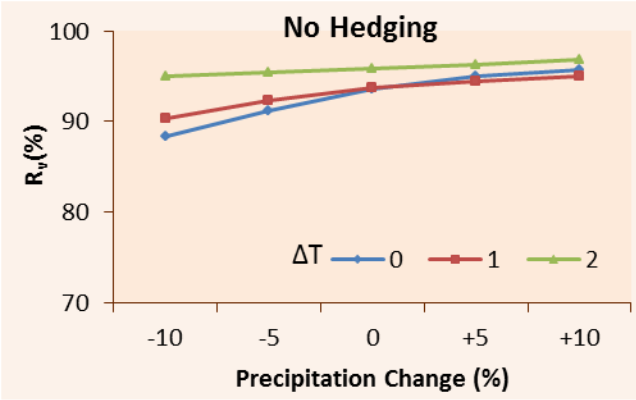


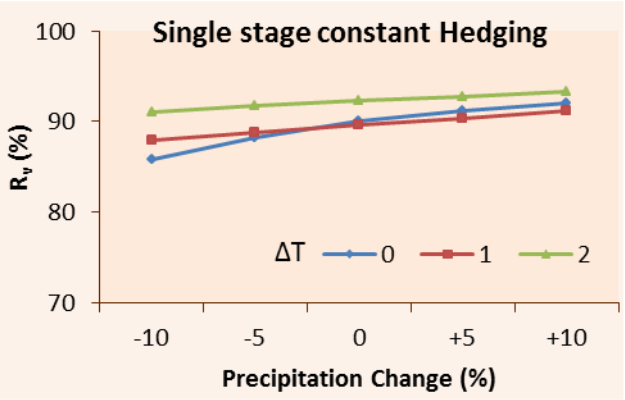


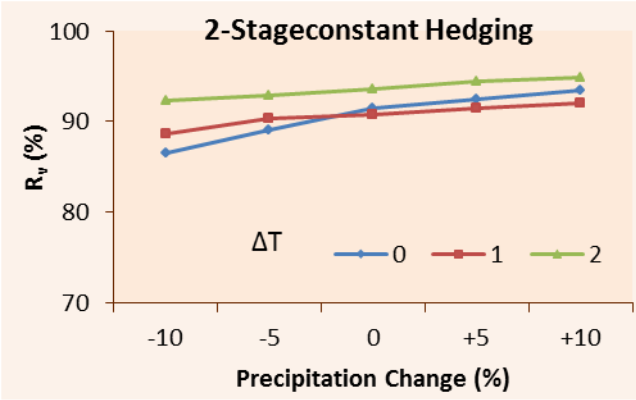


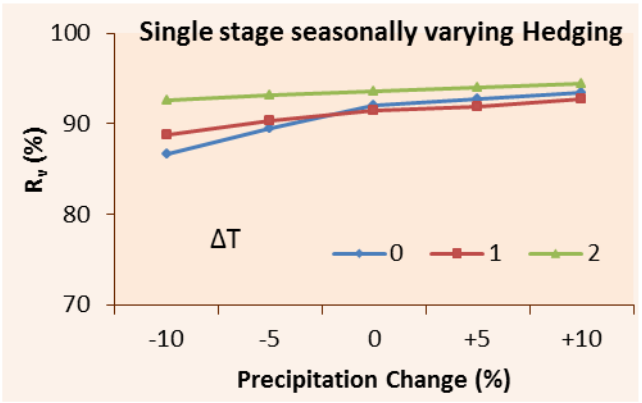


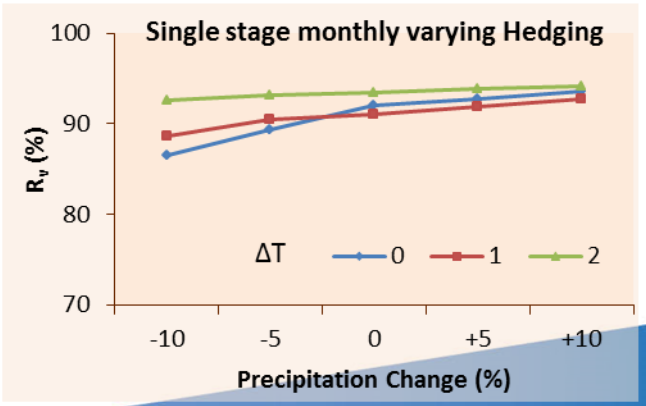
Pong: Hedging effect on Reservoir Reliability (volume-based)



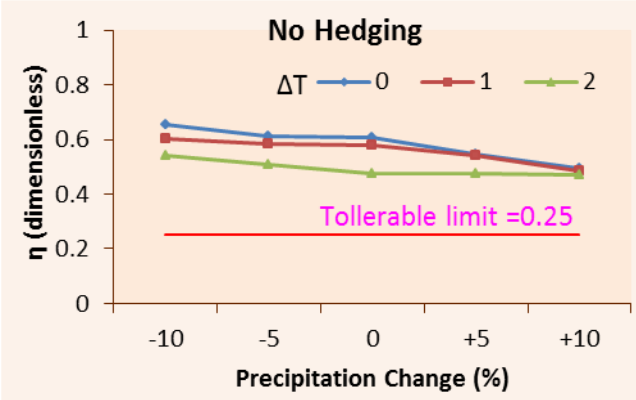


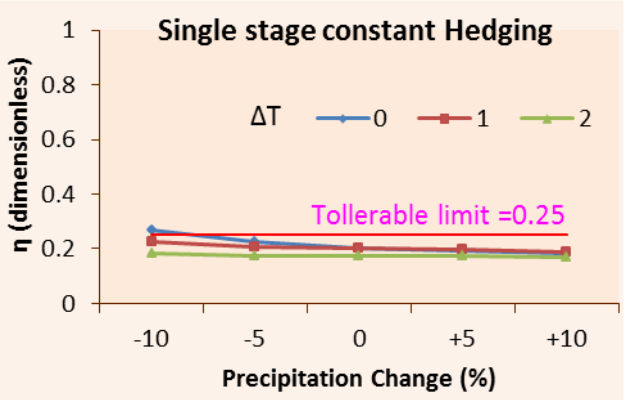


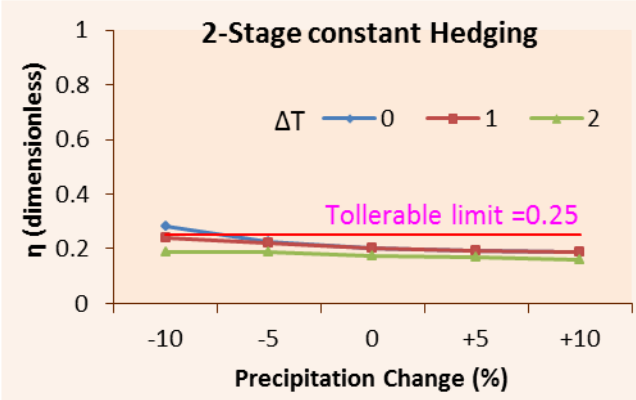


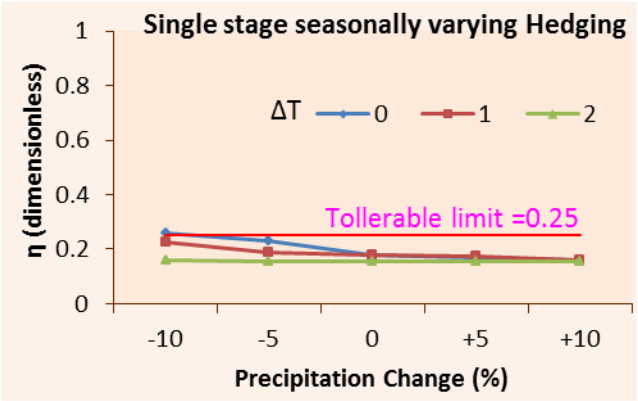


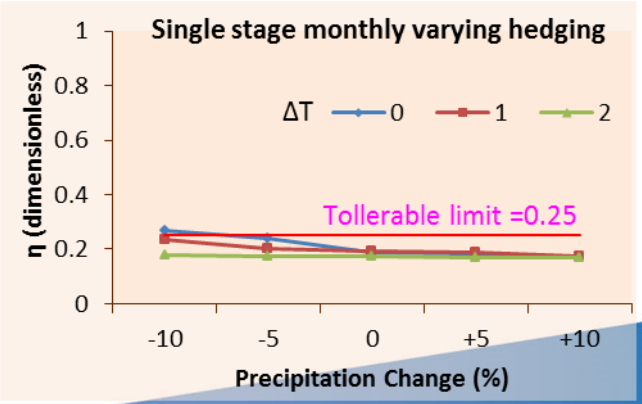
Pong: Hedging effect on Reservoir Vulnerability











Summary: Effect of Managed Hedging

- Hedging causes the time-based reliability to worsen significantly.
- Hedging causes only very modest reduction in the volume reliability (a plus)
- Hedging has most profound effect on the vulnerability:

  All the resulting vulnerability indices were < 0.25 with hedging for all the climate change effects.

- Simple single stage hedging with constant rationing ratio is as effective as any of the more complicated hedging schemes.

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Thank You

???Questions???