Building Climate Resilient Water Infrastructure in South Asia

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Enhancing Sustainability & Resilience of Water Infrastructure for Disaster Risk Reduction & Management in South Asia

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How is Climate Resilient Water Infrastructure Different from Conventional Ones?

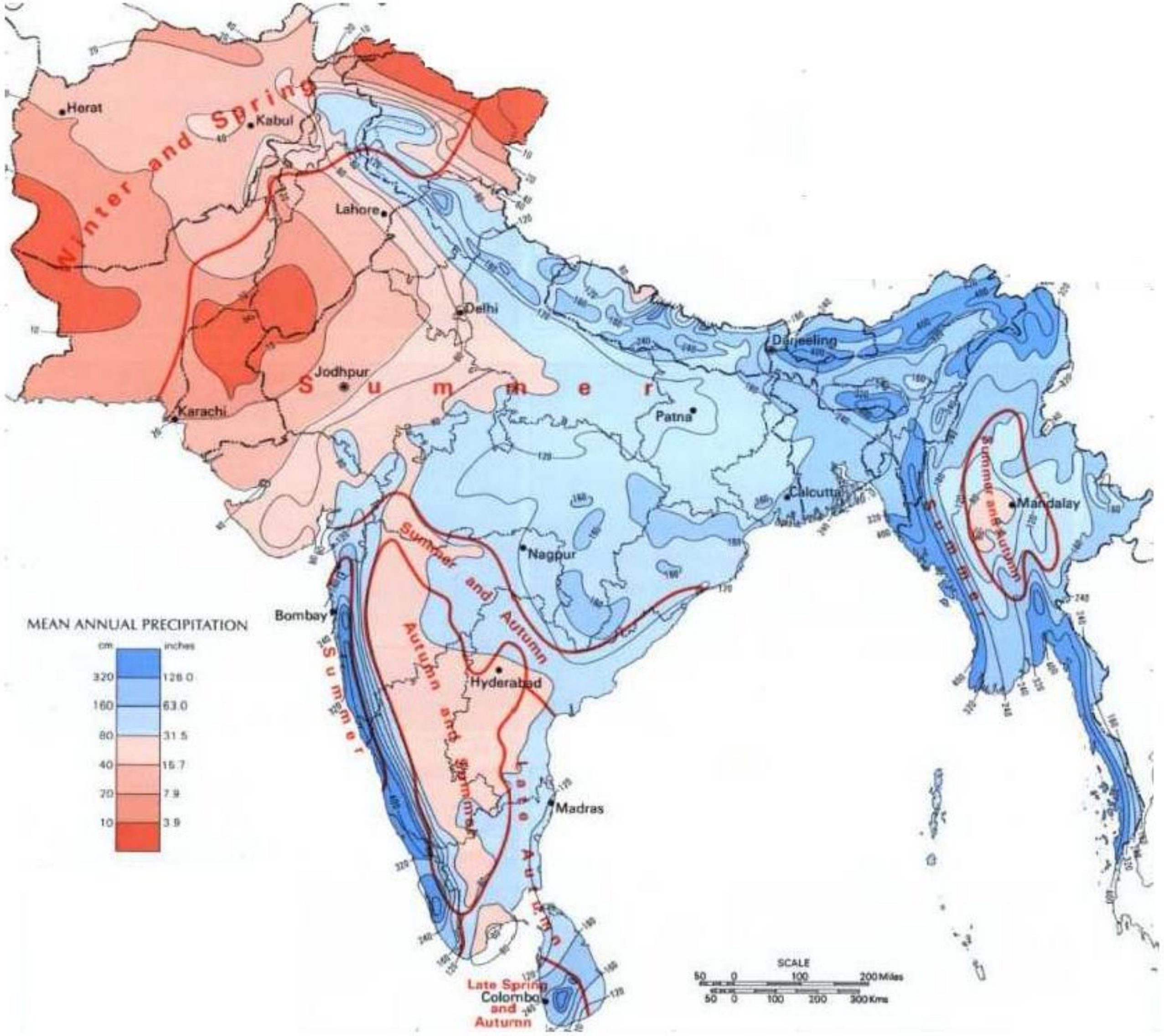
- Conventional water infrastructure (dams, barrages, spillways, water wells, etc.) works under normal conditions, within the range of known variability in hydrology, if schemes are realistically designed
- They are also designed to fail under certain extreme hydrological events that have very low frequency of occurrence
  - Toppling of the dam due to insufficient carrying capacity of the spillway
  - Failure to supply water from a reservoir during extreme drought conditions due to lack of inflows
- Climate resilient water infrastructure is expected to perform under all conditions, including very extreme events that have very low frequency

Factors that Influence the Climate Resilience of Water Infrastructure

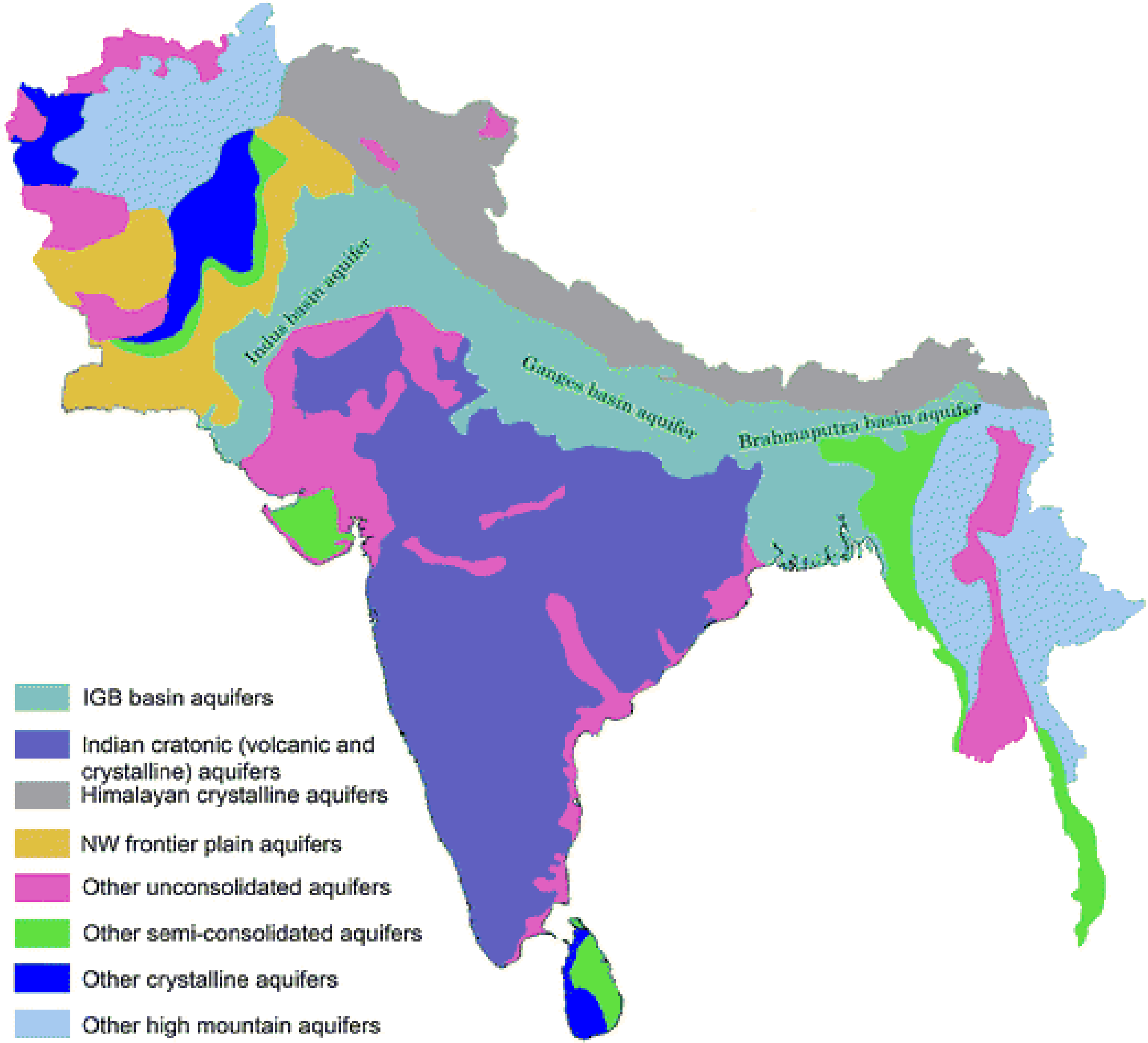
- Predictability of the weather events such as extremely high rainfall occurring over long durations and extremely wet weather conditions
  - Spillways can fail under very high floods, when the reservoir is already full
- Predictability of extremely dry conditions--prolonged droughts
  - Occurrence of extreme events like consecutive droughts are very random, making it difficult to predict the storage conditions in reservoirs and proactively manage them
- Predictability of water availability in aquifers and surface water bodies (lakes, ponds and tanks) on a seasonal basis
  - In hard rock areas, pumping during monsoon & winter for crops determines how much water would be there in aquifer during lean season, and this is hard to predict
- Highly erratic weather conditions, insufficient water stocks and **over-designed schemes** reduce the climate resilience of water infrastructure

South Asia's Precipitation Condition

- Occurrence mostly concentrated in the 3-7 months of monsoon season from May to December
- Remarkable spatial variation in the mean annual rainfall—100mm to 11,000 mm
- Rainfall is very unreliable in low to medium rainfall regions--high inter-annual variability (20% to 80%)
- The entire annual rainfall occurs in very few days in low rainfall regions -10 to 20

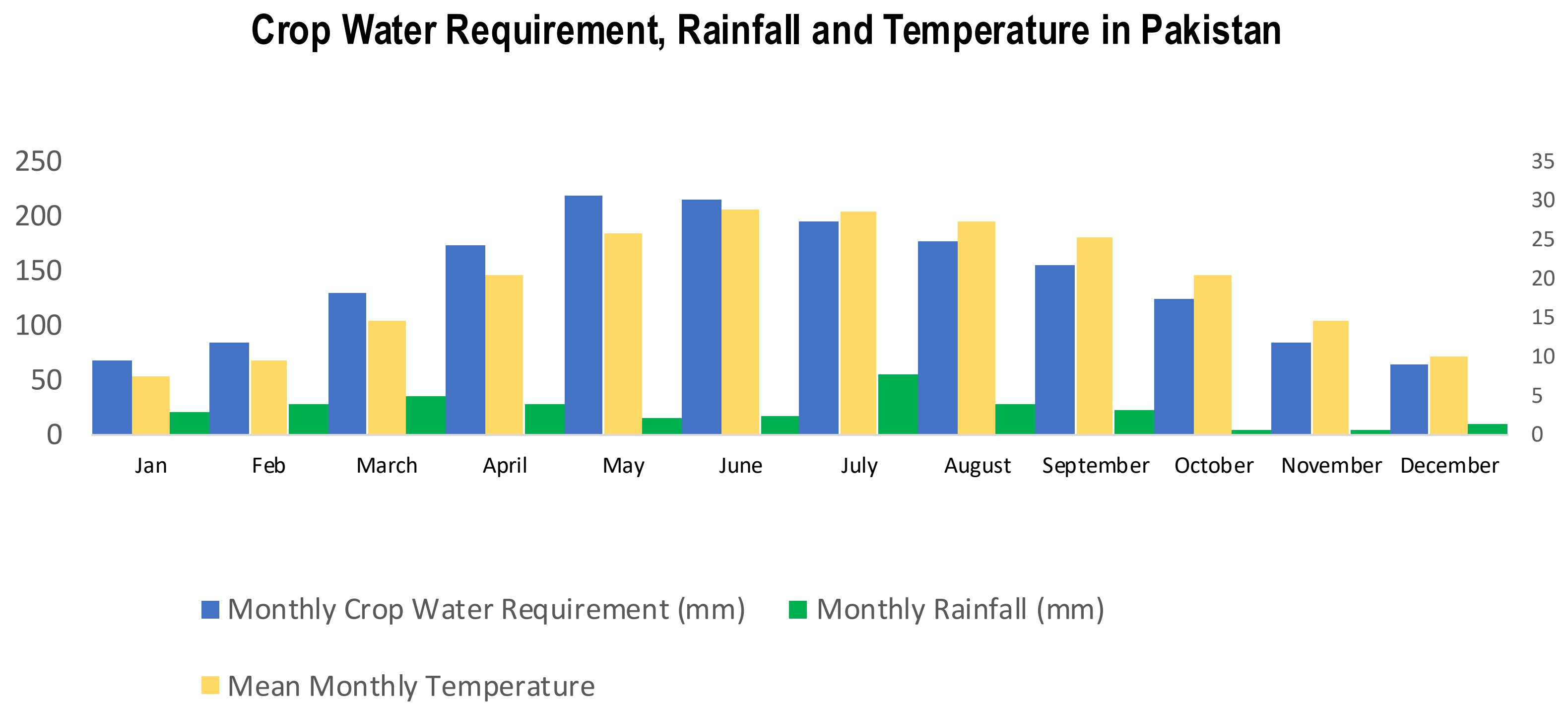


Groundwater in the Indian Sub-continent



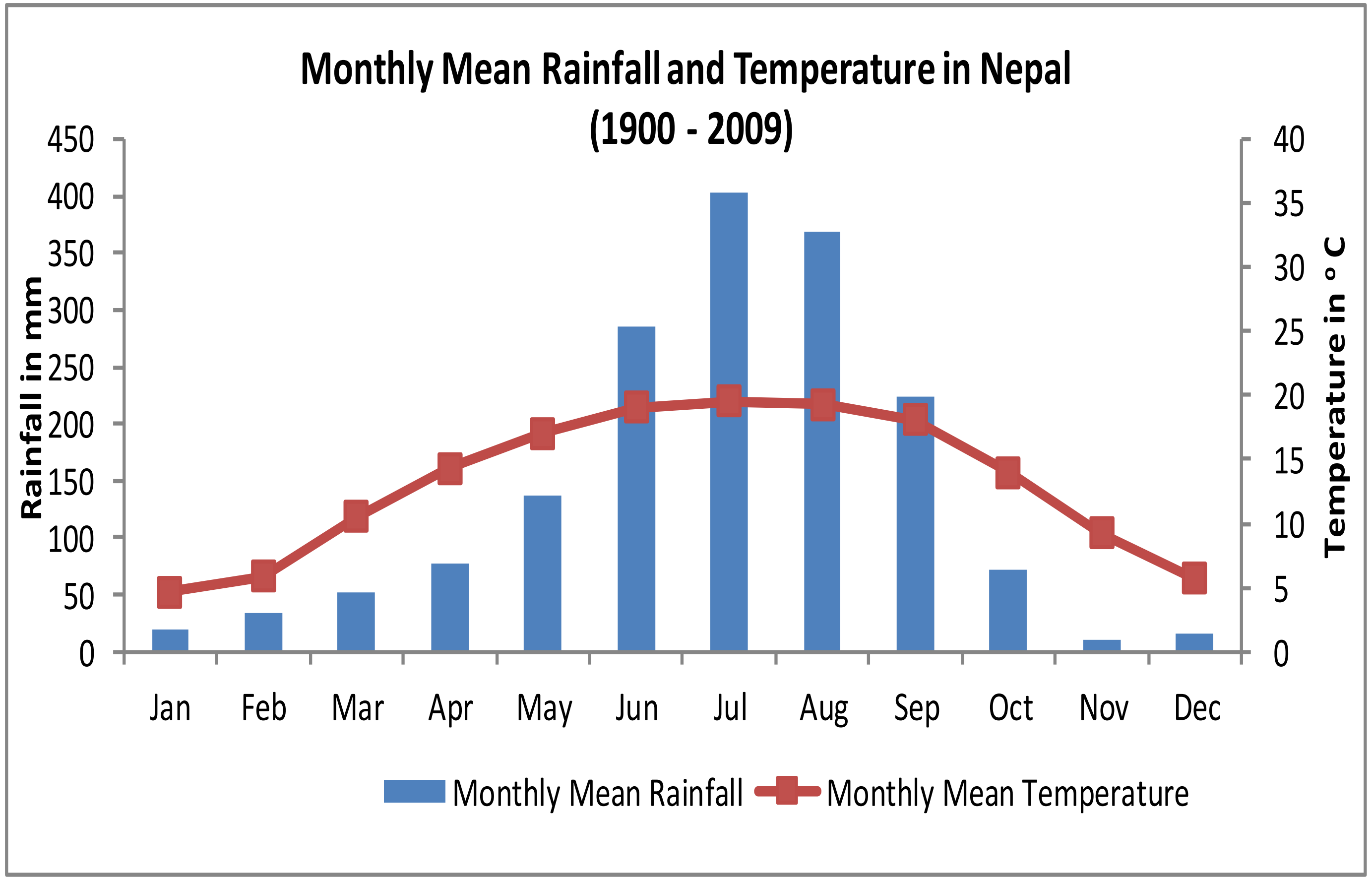
- Most of the groundwater is in the IGP-- Indian Punjab, Haryana, UP, Bihar, WB, Assam; Punjab & Sindh of Pakistan, most of Bangladesh, and Nepal Tarai
- The western, peninsular and central India is underlain by hard rocks with very little recharge and no groundwater stock, with the exception of coastal strip and Cambay basin (Gujarat)
- Recharge in this region fluctuates on annual basis depending on monsoon rains
- The NE and WG have little or no groundwater, except in the valley portions
- Sri Lanka has very little groundwater resources

Mean monthly rainfall, monthly mean temperature and ET_0: Pakistan



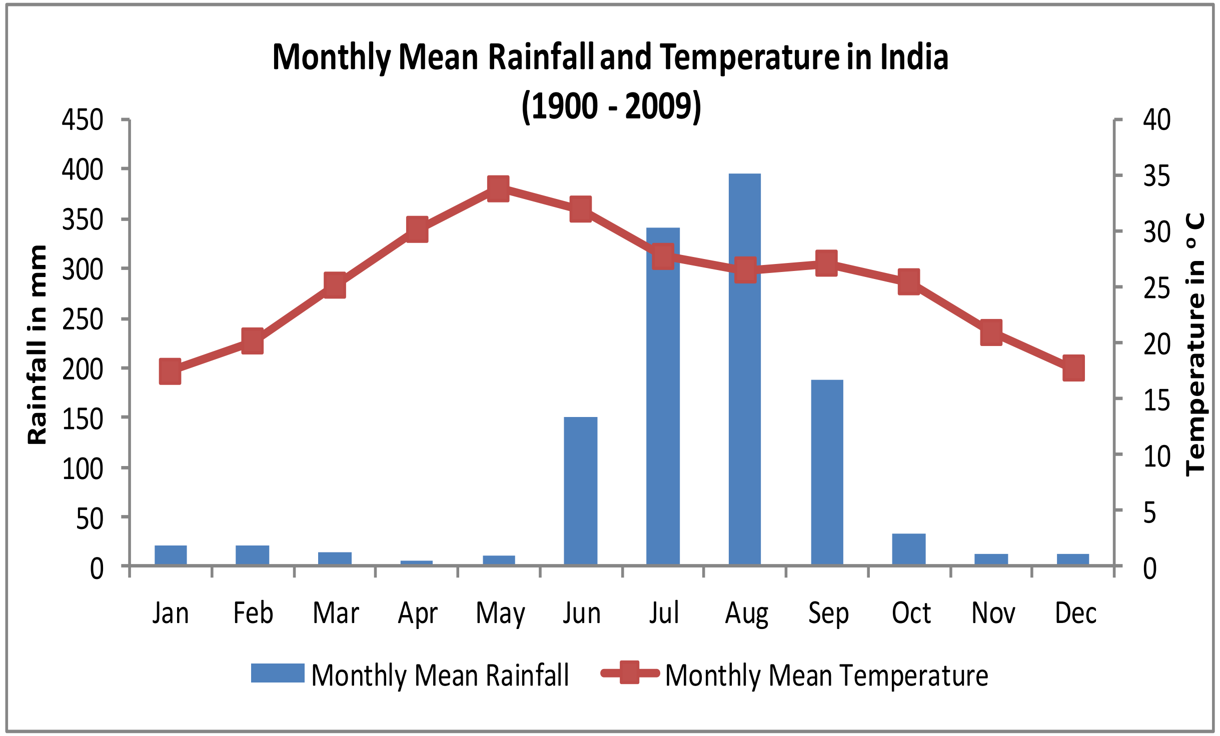
Higher the difference between pattern of occurrence of rainfall and pattern of temp. variation, greater will be the challenge of managing crop water demands. Though rainfall is quite low in comparison to CWR Pakistan, the IBIS is well developed, irrigating around 14 m. ha. There is groundwater stock underlying the Indus basin. It is yet not fully utilized, though groundwater salinity is a major concern.

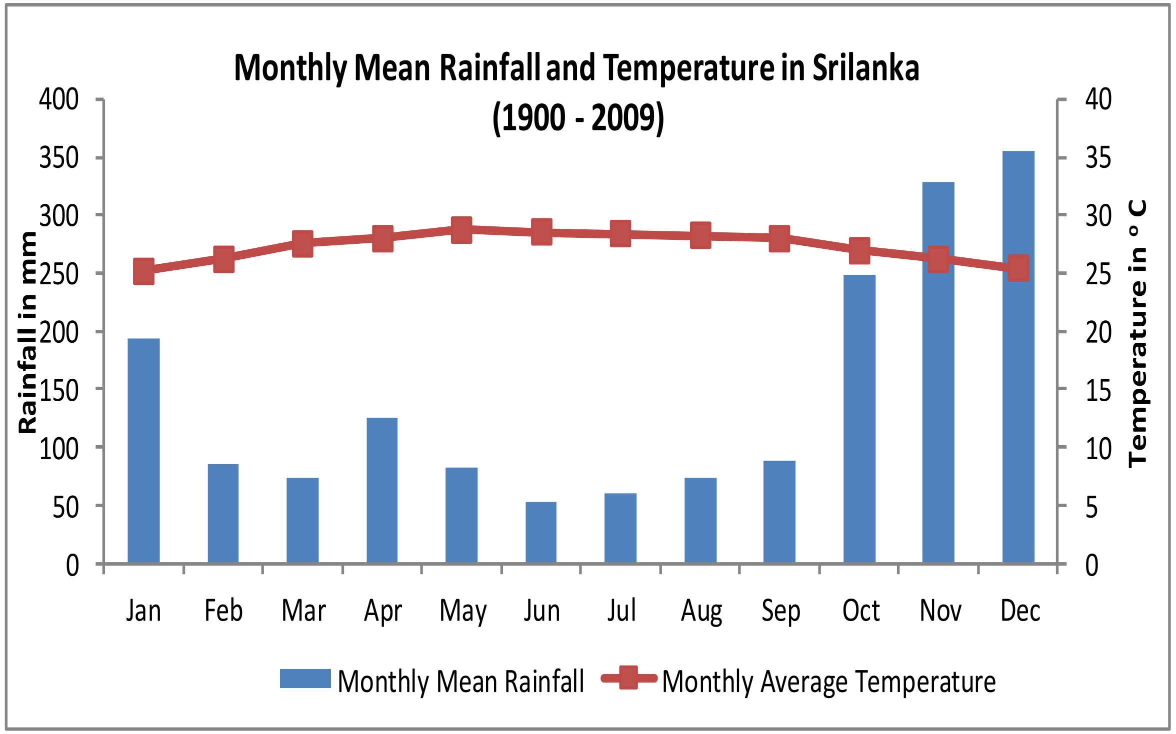
Mean Monthly Rainfall and Monthly Mean Temperature in Nepal



- The monthly reference evapotranspiration (ET_0) ranges from a lowest of 55mm in the coldest month of January to the highest of 170mm in the hottest month of May
- Precipitation occurs even in the hottest months--March to May

Mean monthly rainfall and monthly mean temperature: India and Sri Lanka





Challenge of managing crop water needs is bigger in India as compared to Sri Lanka, Nepal and Pakistan. In India, irrigation demand is **excessively high during summer**, **relatively less during winter**, and very low during the monsoon season. But droughts can upset the situation, as water demand can go up steeply during rainy season

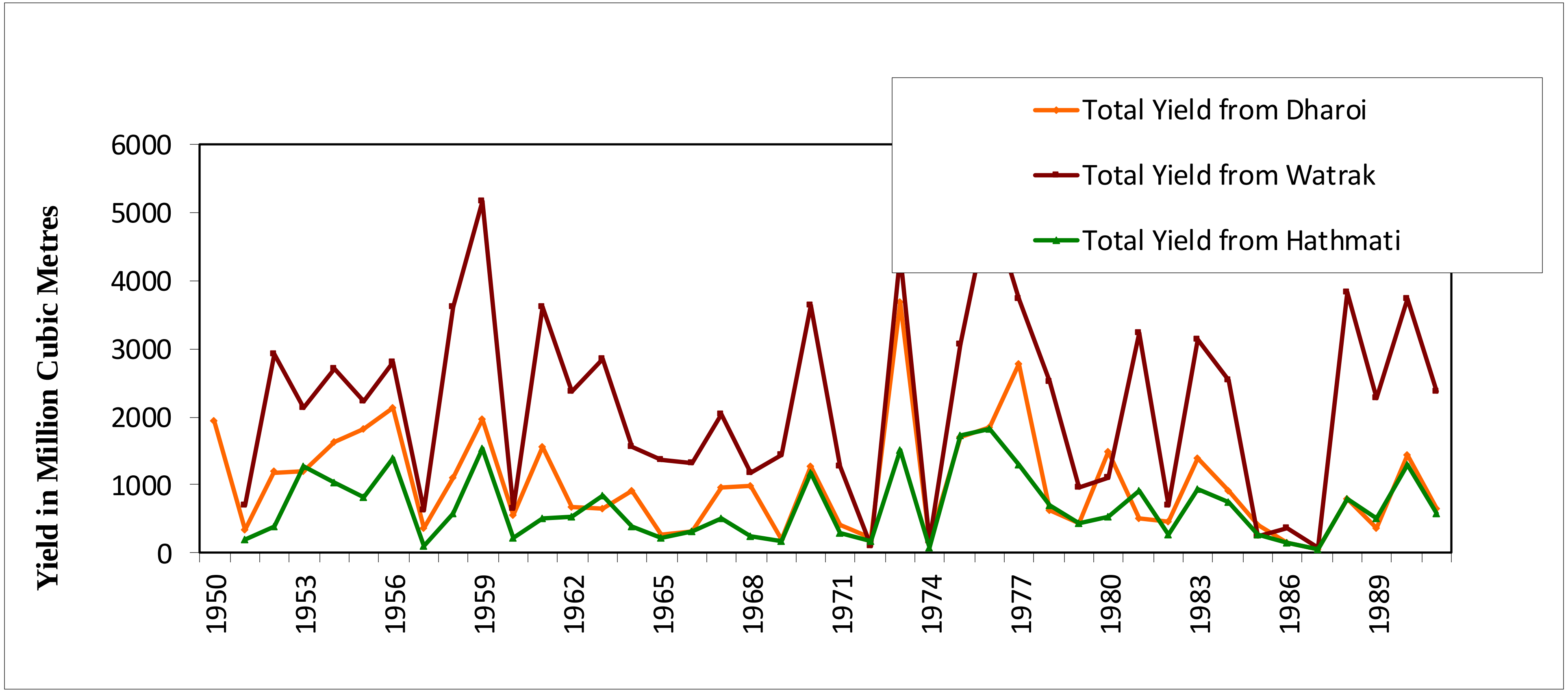
The Climate Reality-India

- Spatial variability in climate is very significant:
  - Hot & arid to hot & humid, to cold & sub-humid to cold & humid
- Within the same river basin, agro climate vary significantly
- Day time and night temperature of a day can vary from year to year with changing rainfall pattern
- Monsoon records for 104 years (1901-2003) do not show any linear trend (Kelkar, 2010)
- Also data for 1813-2006 do not show any uniform trend (Sontakke et al., 2008)

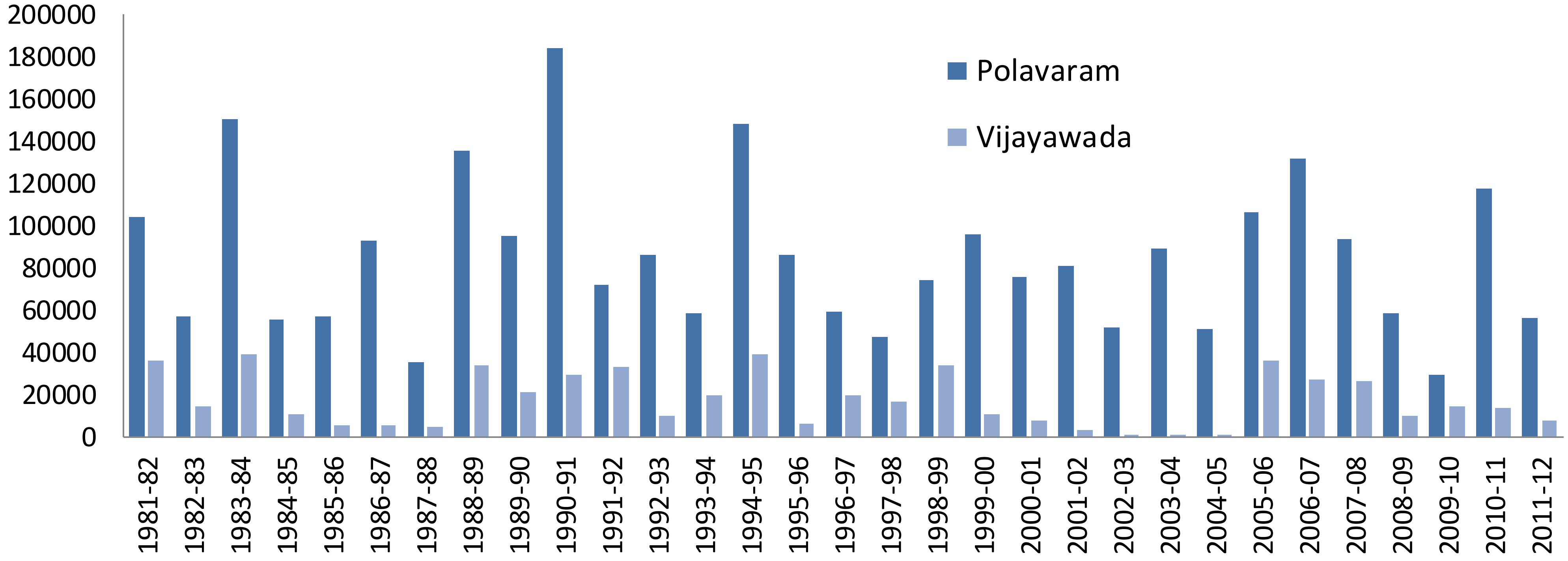
The Climate Reality-India

- Spatial variation in rainfall is remarkable
- So is the variation in number of rainy days
- Regions of low rainfall receive it in very few showers; regions of high rainfall have long wet spells
- Regions of high mean annual rainfall has low inter-annual variability and vice versa
- Regions experiencing fewer days of rains experience high variability in number of rainy days between years

Annual Yield of three Sub-basins of Sabarmati River Basin



Gauge Discharge of Godavari & Krishna rivers (MCM)



Water availability and water demand scenario

- Regions of low water endowment are characterized by high water demand
  - High per capita arable land
  - Low to medium rainfall and high aridity
- Regions of high water endowment are characterized by low water demand
  - Low per capita arable land
  - High rainfall and low aridity
  - Agro ecological problems due to floods and poor drainage

What can be done to improve the Climate resilience of water infrastructure?

- Use **long-term historical datasets of annual rainfalls, stream flows, max. daily rainfall and rainfall intensity** for hydrological simulations and hydraulic computations
- Design schemes (irrigation, drinking water supplies) for yields of high dependability--75% for irrigation and 90-95% for drinking water supplies
- This means, the design command area of irrigation schemes and service area of drinking water supply schemes should be strictly based on the **assured supplies from the reservoirs,** with the predetermined dependability
- **Multi-annual storage in large reservoirs**: In regions/river basins that experience very high inter-annual variability in runoff, provision is made in the reservoirs for storing the excess flows from excessively wet years and the same be carried over to the next year instead of releasing to meet the demands of extended areas.
- **Groundwater Banking**: Provision is made to divert and store the excess flows from catchments that otherwise goes uncaptured to decentralized surface storages and depleted aquifers--the Australian, Western US and north Gujarat examples

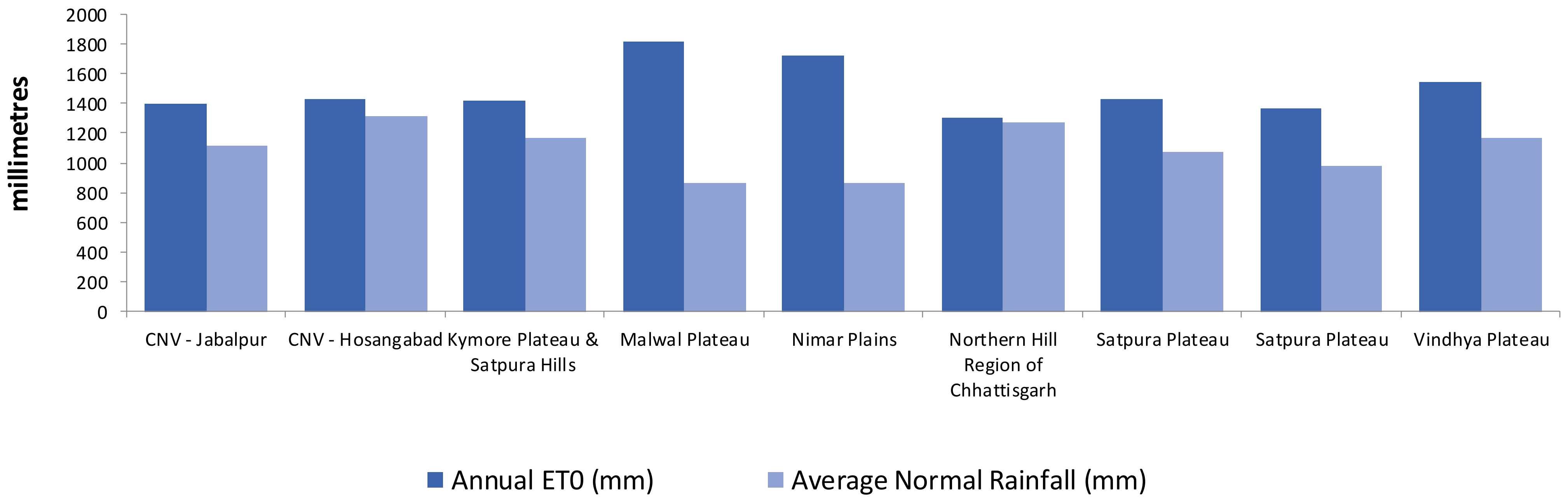
What can be done to improve the climate resilience of water infrastructure?

- In the case of rural drinking water supplies, move to surface reservoirs to reduce the supply risk due to groundwater depletion and drying up of wells caused by uncontrolled withdrawal for irrigation
- Wells shall be used as the source of water supplies in both rural & urban areas, only when the aquifers are rich (unconsolidated and semi-consolidated formations) with a large stock
- Water supply from bore well-based drinking water schemes shall be supplemented by water imported through pipelines from reservoirs—bulk water supply in Gujarat from Narmada canal is a good example
- Link the existing reservoirs and schemes in the semi-arid & arid regions that experience high variability in annual flows to those located in water-rich regions that have highly dependable flows using water transfer canals and pipelines

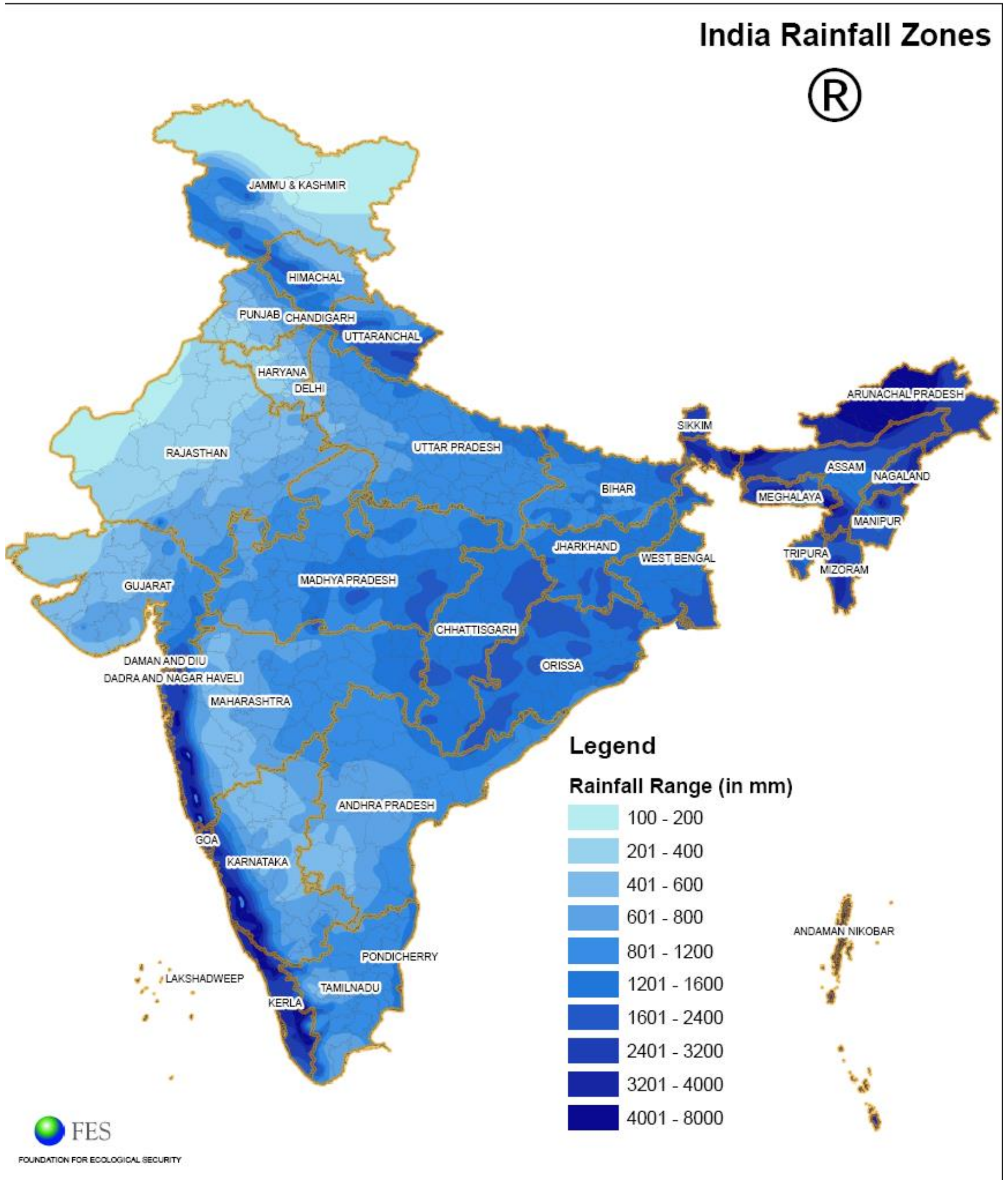
Conclusions

- There are no silver bullets for making water systems climate-resilient
- Building resilient systems is all about understanding the hydrology (the flows and the stocks) and socioeconomic systems (the demands) and how they vary with space and time
- Understanding the flow characteristics--volume, intensity and pattern--, and demand fluctuations, and realistically assessing the extent to which those demands can be met from the water system are crucial
- Large-scale water transfers from water rich basins to water scarce basins, groundwater banking using runoff during wet seasons in high rainfall areas, and reducing the dependence on poorly yielding aquifers for drinking water supplies in hard rock areas are the emerging approaches

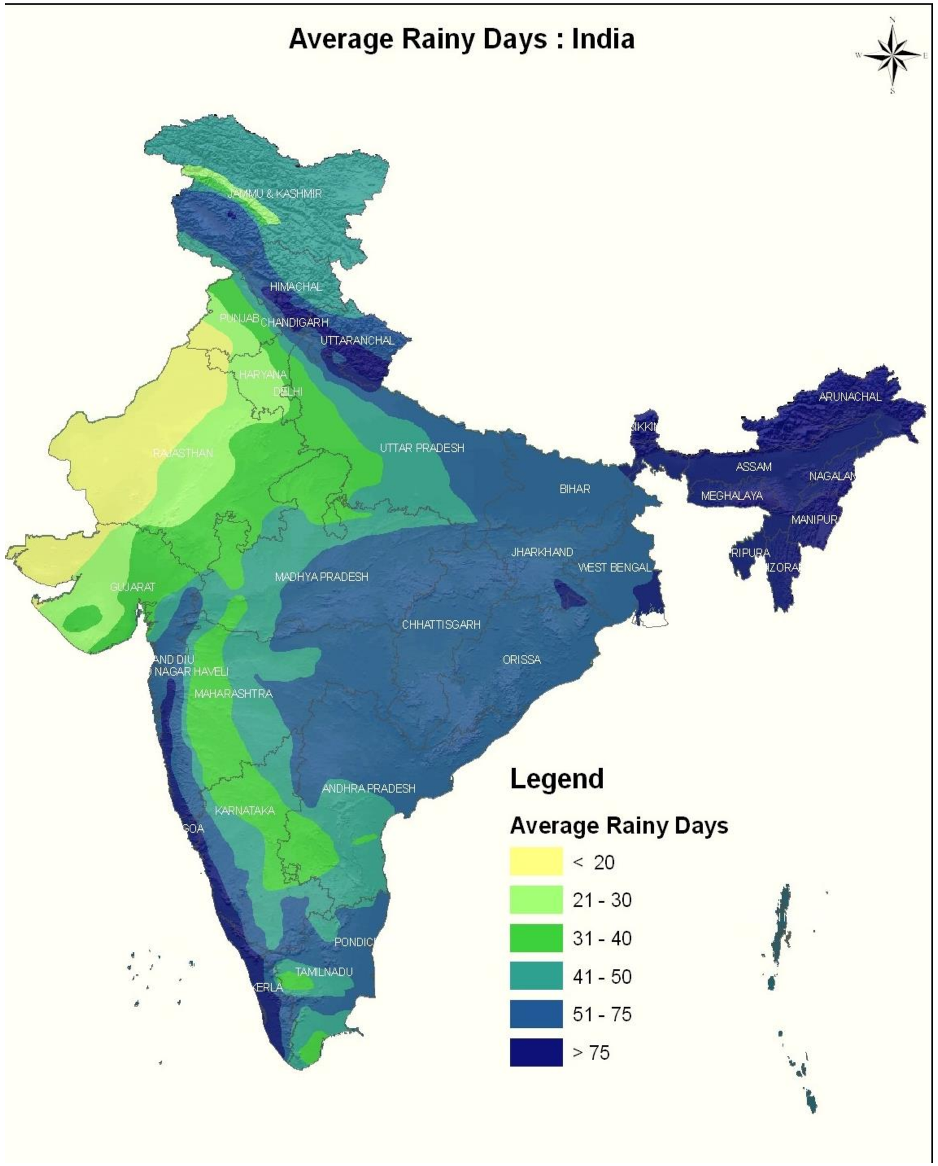
Rainfall and ET_0 in Nine agro climatic sub-zones in Narmada basin



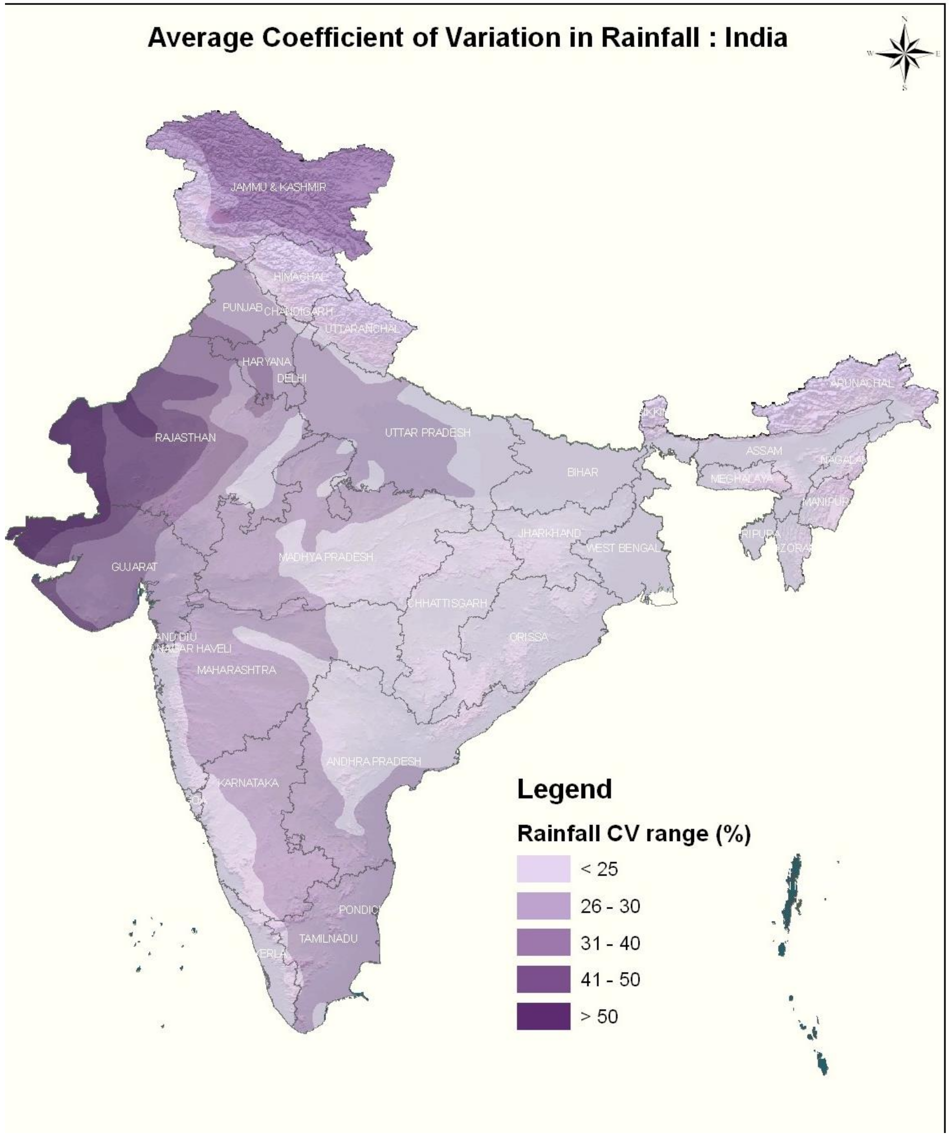
Rainfall variability across regions



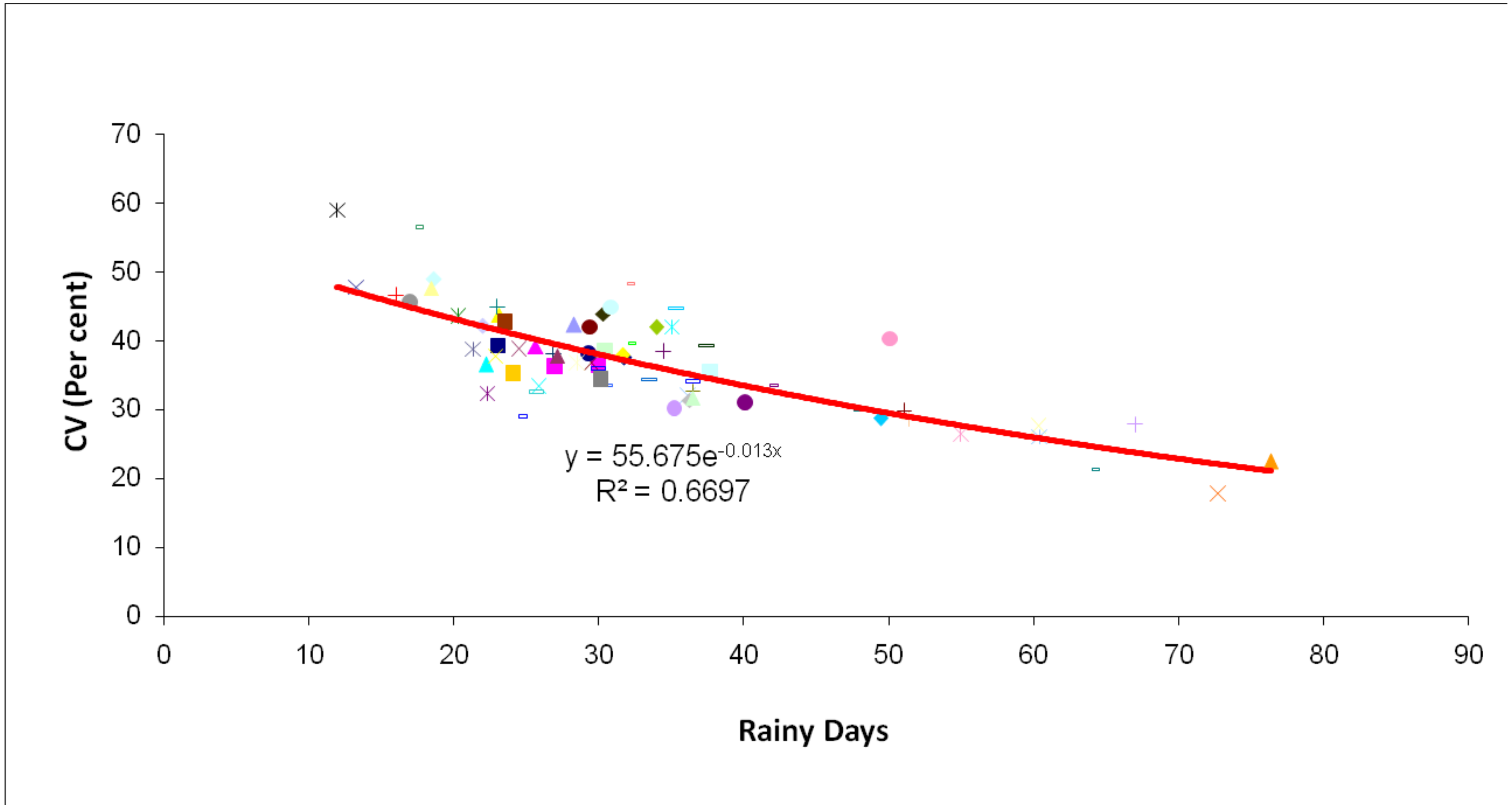
Variability in rainy days



Rainfall variability between years



Variability in rainy days between years



Water-scarce basins & regions

Average Reference Evapo-transpiration Against Effective Annual Water Resources in Selected River Basins in Water-Scarce Regions

Sr. No	Name of the Basin	Mean Annual Rainfall (mm)		Average Annual Water Resources[1] mm)	Effective Annual Water Resource[2] (mm)	Reference Evapo-transpiration[3] (mm)	
		Upper	Lower			Upper Catchment	Lower Catchment
1	Narmada basin	1352.00	792.00	444.70	937.60	1639.00	2127.00
2	Sabarmati basin	643.00	821.00	222.84	309.61	1263.00	1788.80
3	Cauvery basin	3283.00	1337.00	316.15	682.80	1586.90	1852.90
4	Pennar basin	900.00	567.00	193.90	467.80	1783.00	1888.00
5	Krishna basin	2100.00	1029.00	249.16	489.15	1637.00	1785.90

Water-abundant basins & regions

Per capita Renewable Water Resources and Per Capita Water Demand in Agriculture in Three River Basins

Sr. No	Name of the basin	Average Annual Rainfall in the basin (mm)		Average Renewable Water Resources (m^3/capita/ annum)	Effective Renewable Water Resource (m^3/capita/ annum)	Mean Annual Reference Evapotranspiration (mm)		Water Demand for Agriculture (m^3/capita/ annum)
		Upper	Lower			Upper Catchment	Lower Catchment	
1	Ganga	1675.0	1449.0	1179.90	**1399.40**	710.00	1397.00	**721.50**
2	Brahmaputra	2359.0	2641.0	1737.10	**2052.80**	1064.0	1205.00	**1180.62**