Linking Climate to Water Security: Case Studies from the Western Desert of Egypt and the Ganges Delta Region of Bangladesh

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Introduction

- Effects of climate change
  - Temperature
  - ET
  - Rainfall
  - Sea level

→ Threat to Freshwater availability

Affects societal growth

- Water demand is increasing
  - Population
  - More food
  - Industrial growth

→ Water Stress

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Two Regions with Different Climatic Conditions

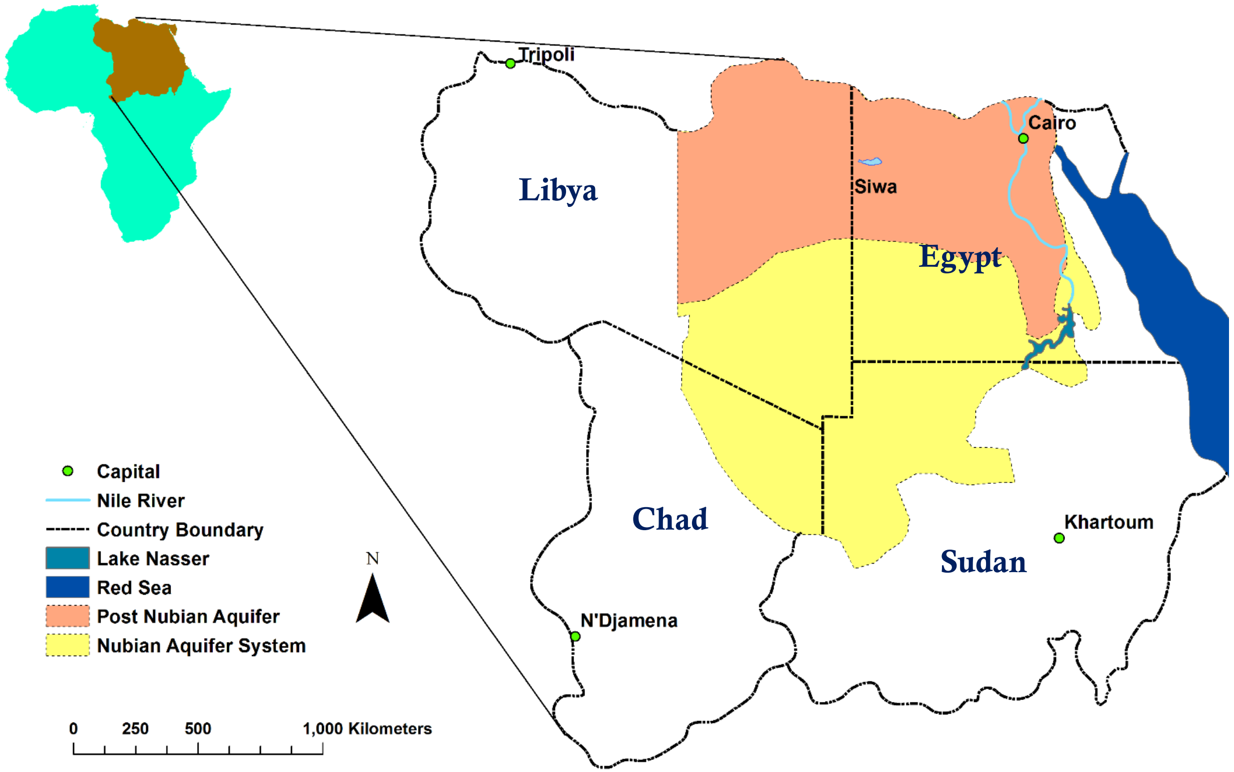
- Arid climate in Siwa Oasis, Egypt (Western Desert region of Egypt)

- Monsoon sub-tropical climate in Ganges Delta of Bangladesh

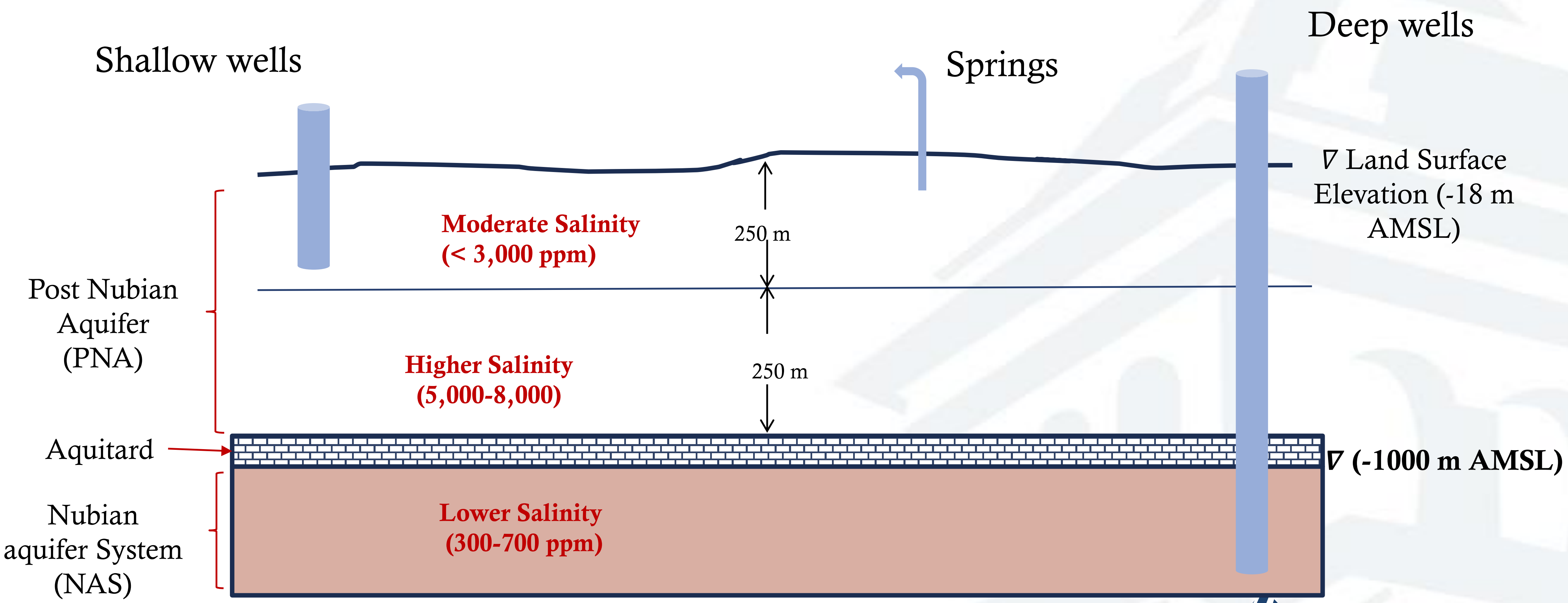
Effects of Climate Change in Siwa Oasis

Siwa Oasis, Western Desert, Egypt

- Located in northwest of Egypt with an area of 1,200 km^2
- Elevation from 0 to -25 m from MSL
- Agriculture is primary activity with olives and date palms as cash crops
- Only source of water is <u>**non-renewable**</u> Nubian Sandstone Aquifer System (NSAS)
- Absence of groundwater management since 1960 caused excess water use
- Six salty lakes formed (73 km^2 in 2000)



Cross-Sectional View of NSAS in Siwa



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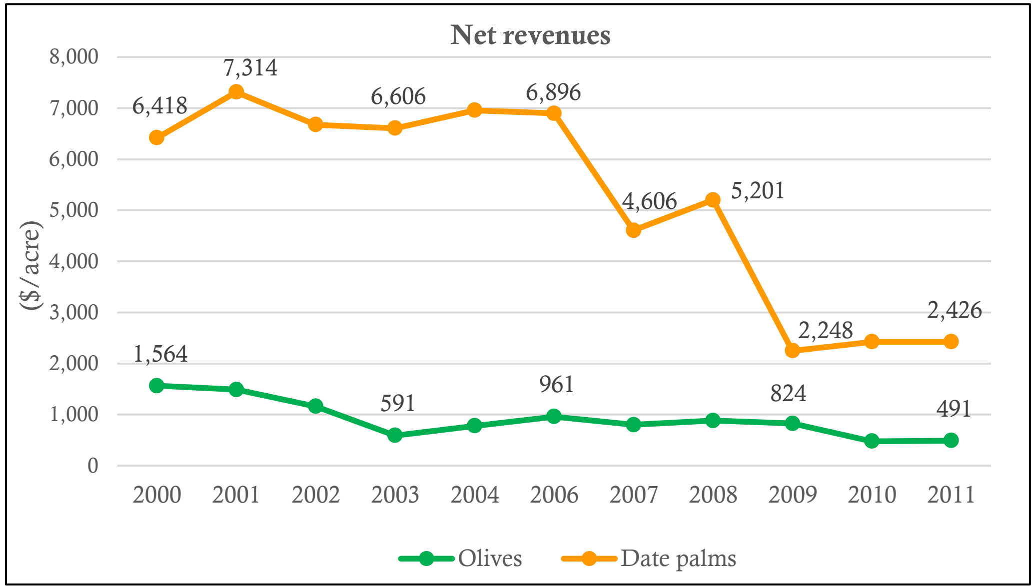
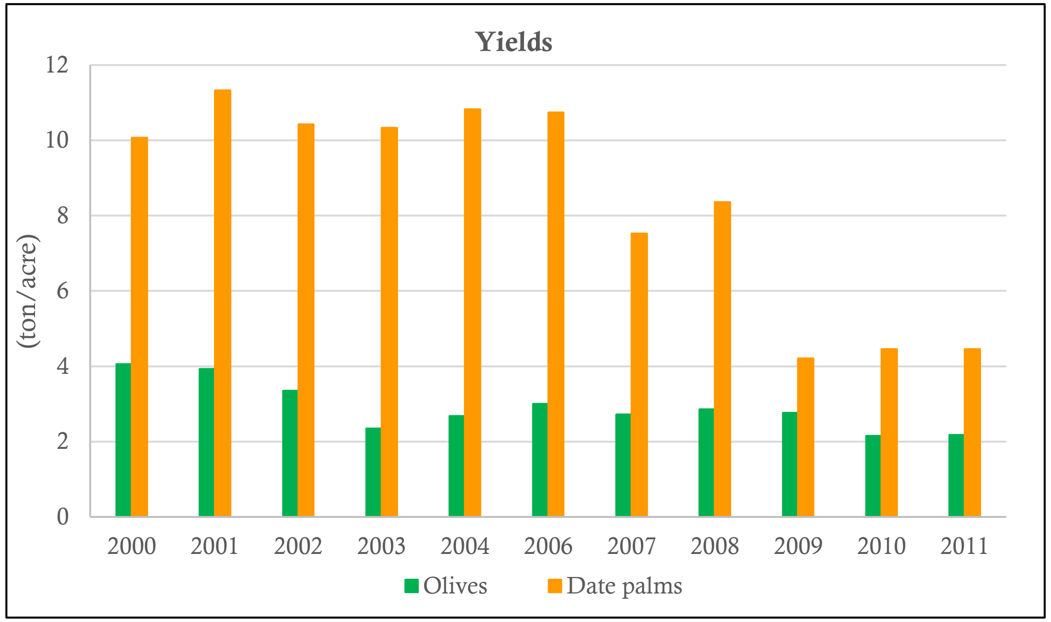
Problems in Siwa Oasis

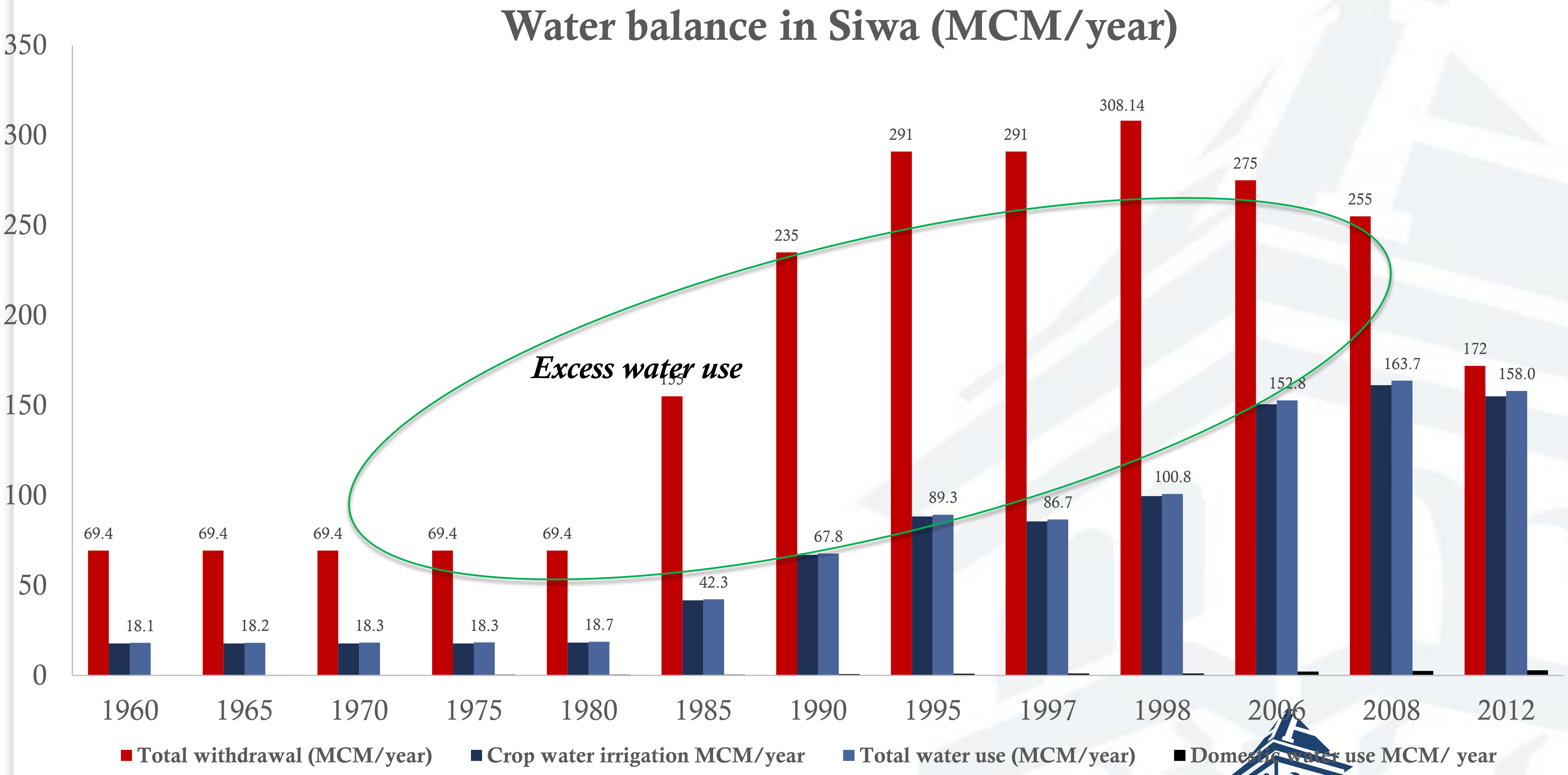
- Increased salinity in groundwater from Nubian Sandstone Aquifer together with excess crop water use

- Decreased revenue





In 2015 dollars



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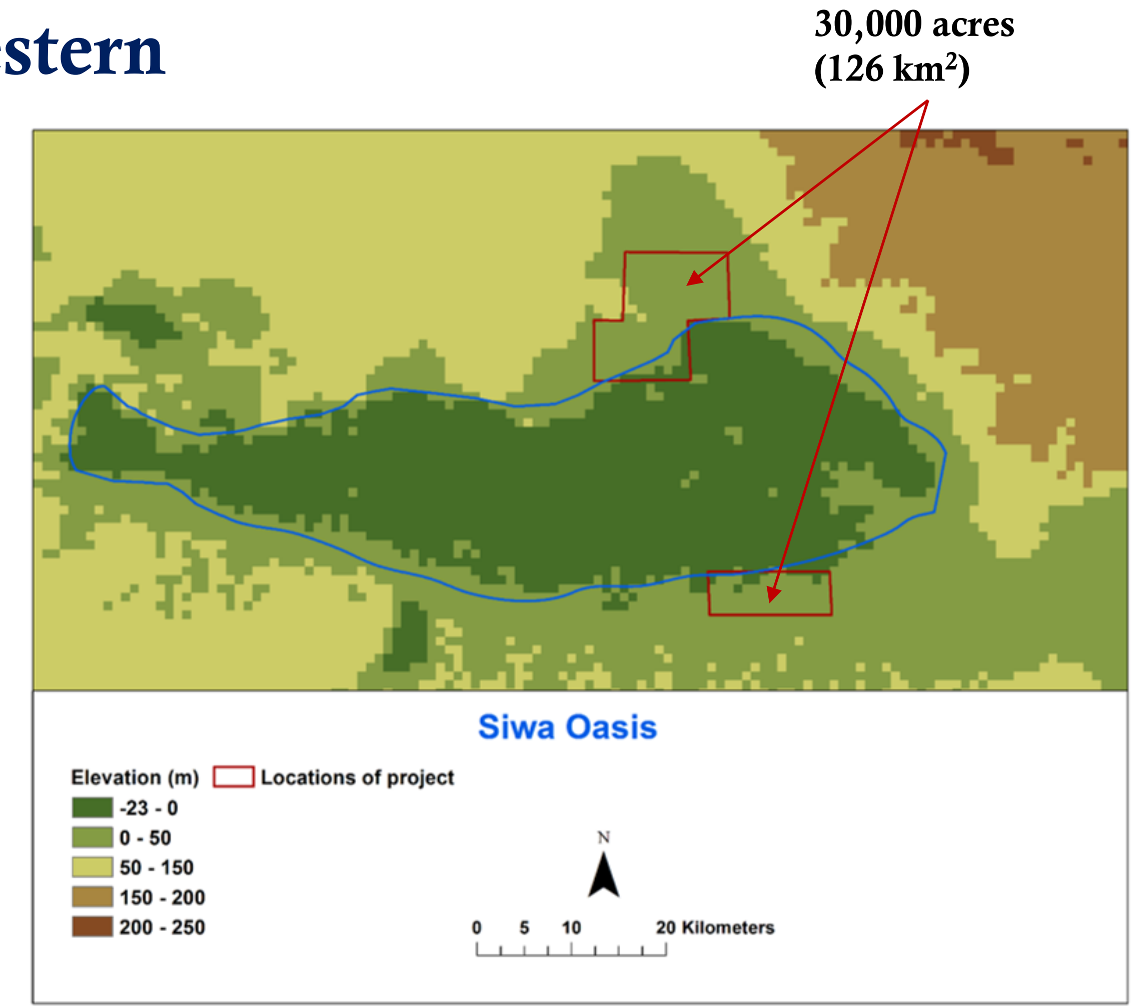
Egyptian Government Initiative (2016): Reclaim 1.5 Million Acres in the Western Desert

- Attract people from over-populated areas
- Cultivate strategic crops to address food security concerns
- Cultivate economic crops for export as source of income
- Increase investment and job opportunities
- 30,000 acres to be cultivated in Siwa with best management practices



Questions

- What is the irrigation water demand in Siwa under climate change?
- Is this amount sustainable based on water availability in the non-renewable Nubian Aquifer System?

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Cultivated Crops

Cash Crops

Olives – 20%

Date Palms – 20%

Food Security

Alternate crops – 60%

Summer

Maize and vegetables

Winter

Wheat, Barely, Bean, Onion, and vegetables

Crop Water Irrigation

Crop water demand with leaching allowance to minimize salinity

$$IR = \frac{ET_c - R}{(1 - LR) * E}$$

IR - irrigation requirement (mm/day)

ET_c - crop evapotranspiration (mm/day)

R - effective rainfall (mm/day)

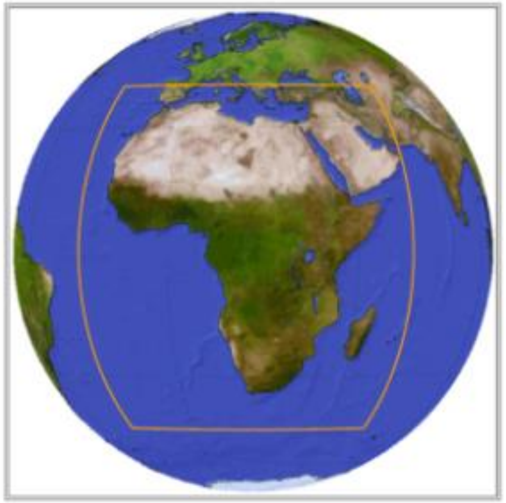
LR - leaching requirement

E- irrigation efficiency

Data

- Monthly meteorological data from Coordinated Regional Climate Downscaling Experiment (CORDEX)
- Four models to project water use from 2020 to 2100
- Two emission scenarios; RCP 4.5 and RCP 8.5

Region 4: Africa



Ref: Description of the CORDEX domains (23/06/2015 version)

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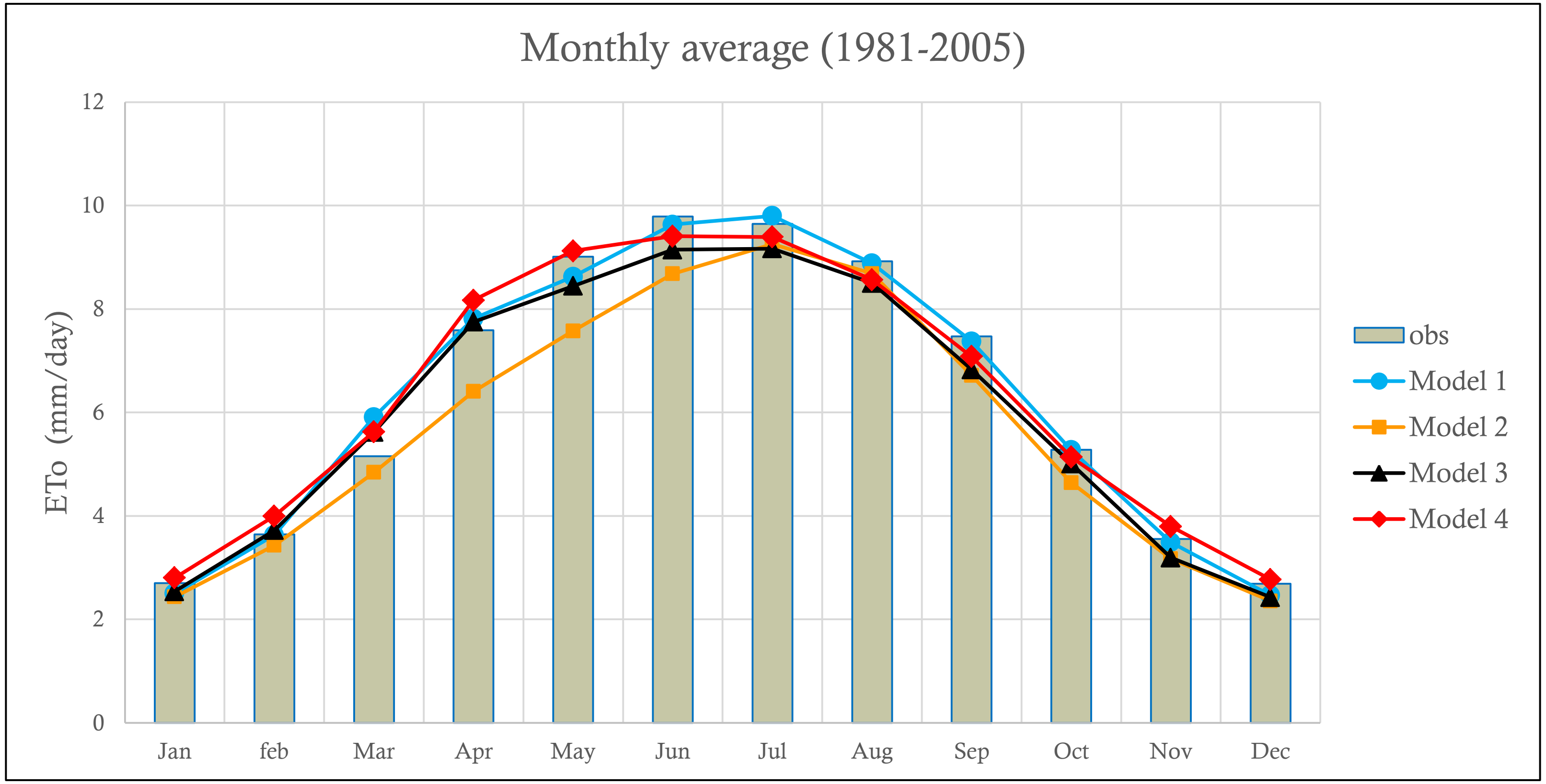
Downloaded models for RCP 4.5 and RCP 8.5

Institute	Regional Climate Model (RCM)		Global Climate Model (GCM)		Model
	Model name	Resolution	Model name	Resolution	
Swedish Meteorological and Hydrological Institute (SMHI)	Rossby Centre regional climate model (RCA4)	50 km	Centre National de Recherches Météorologiques (CNRM-CM5)	155 km	1
Koninklijk Netherlands Meteorological Institute (KNMI)	Regional Atmospheric Climate Model (RACMO22T)	50 km	EC-EARTH consortium (EC-EARTH)	120 km	2
Swedish Meteorological and Hydrological Institute (SMHI)	Rossby Centre regional climate model (RCA4)	50 km	EC-EARTH consortium (EC-EARTH)	120 km	3
Swedish Meteorological and Hydrological Institute (SMHI)	Rossby Centre regional climate model (RCA4)	50 km	Max Planck Institute for Meteorology (MPI-ESM-LR)	210 km	4

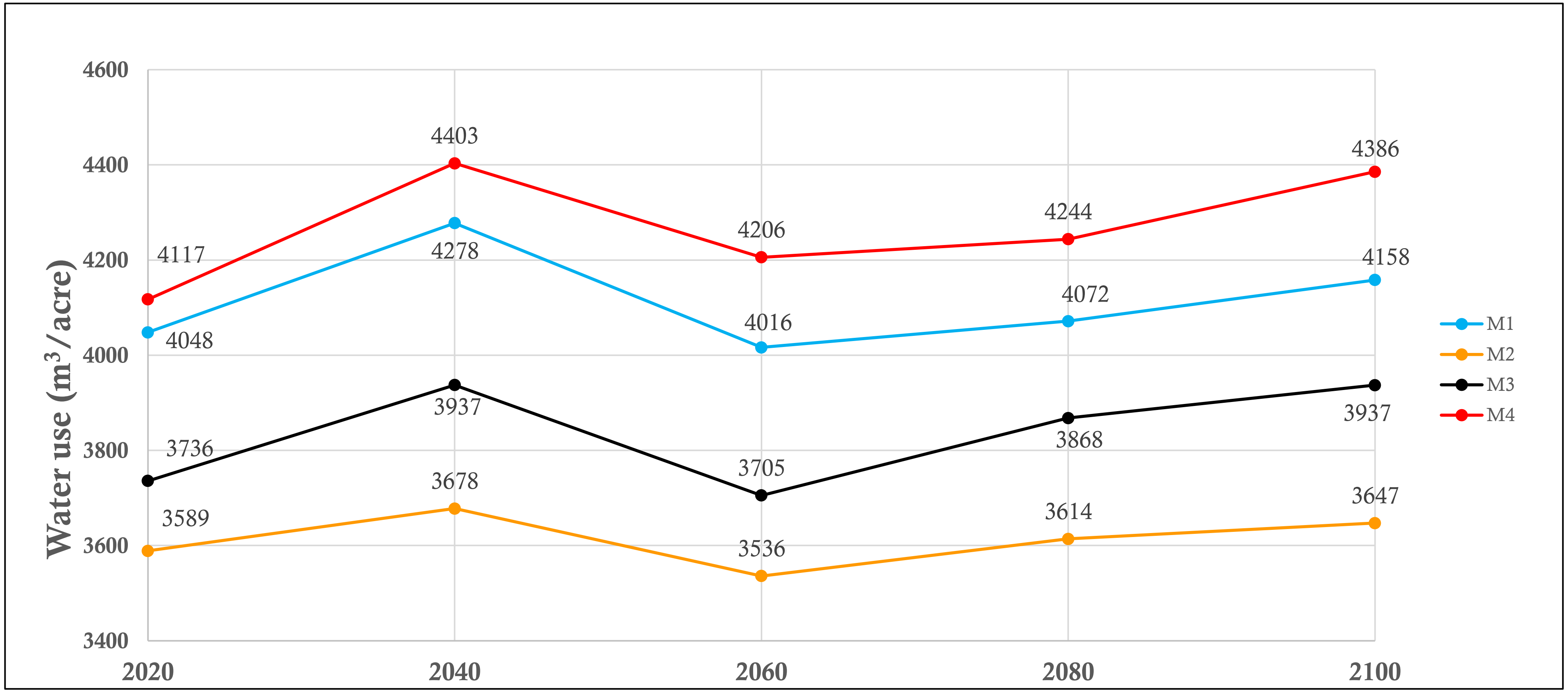
http://www.cordex.org/

Monthly average ETo between historical and observed data (1981-2005)

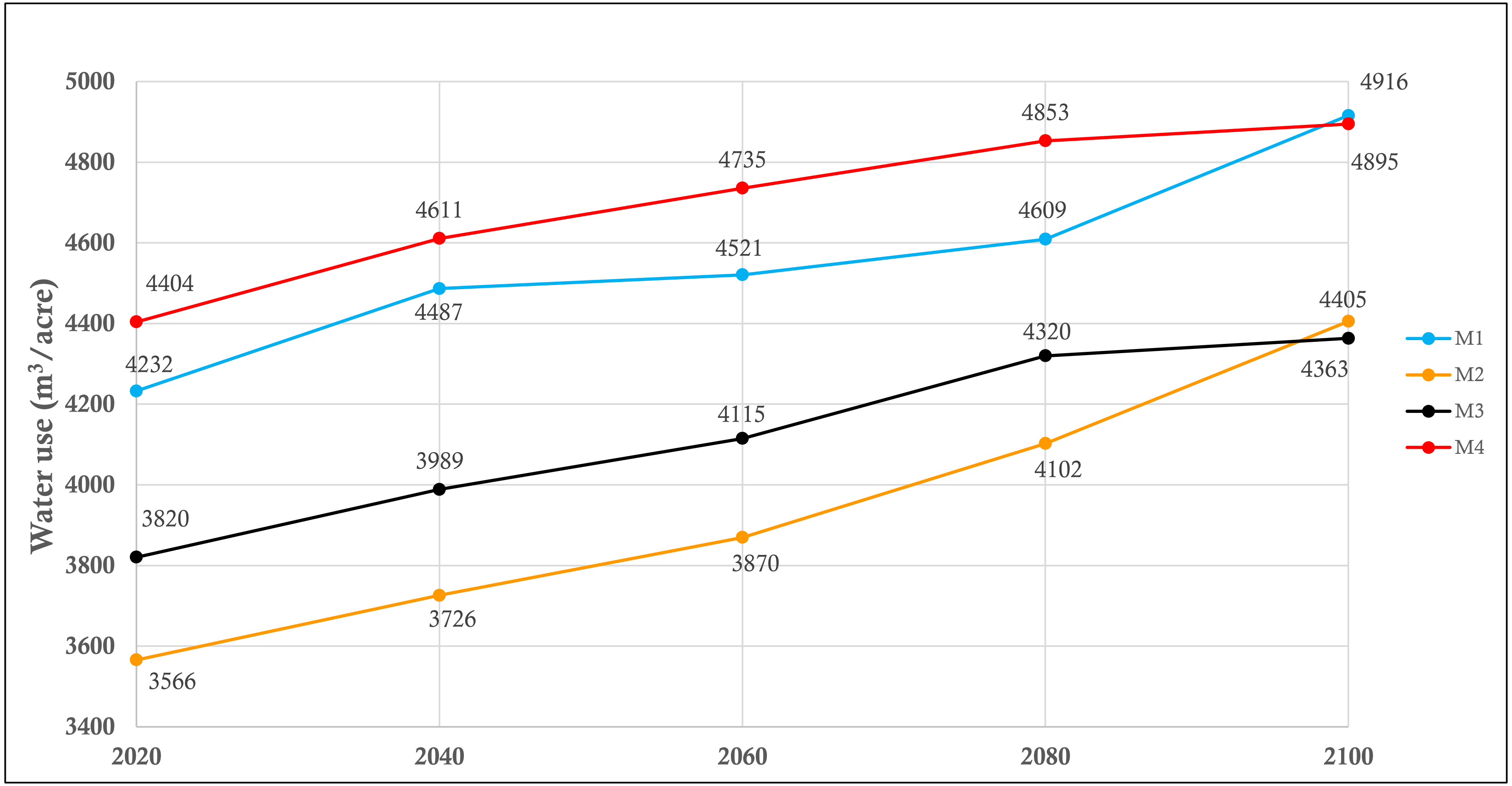


Results

Annual water use (RCP 4.5)



Annual water use (RCP 8.5)



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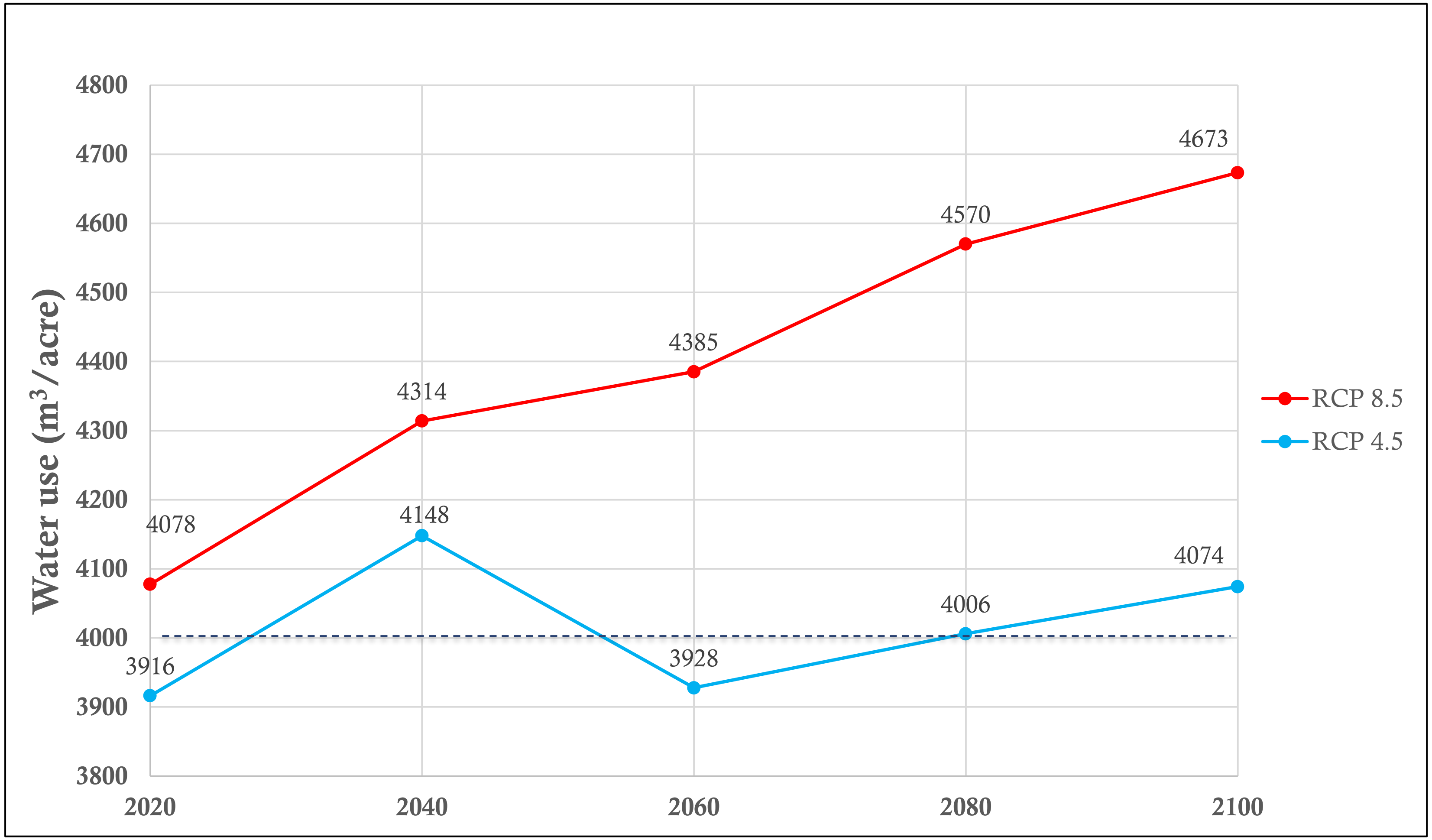
Model Weighted Results



- Crop water use is around 4000 m^3/acre /yr by 2100 - RCP 4.5
- RCP 8.5 shows crop water use increasing to about 4700 m^3/acre/yr by 2100

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Key Findings

- Crop water use from RCP 4.5 scenario shows sustainability with groundwater from the Nubian aquifer
- However, crop water use from RCP 8.5 scenario can affect non-renewable water from Nubian Aquifer increasing water scarcity in this region
- Given the uncertainty, some measures to reduce greenhouse gas emissions is warranted in the region to minimize potential climate change impacts

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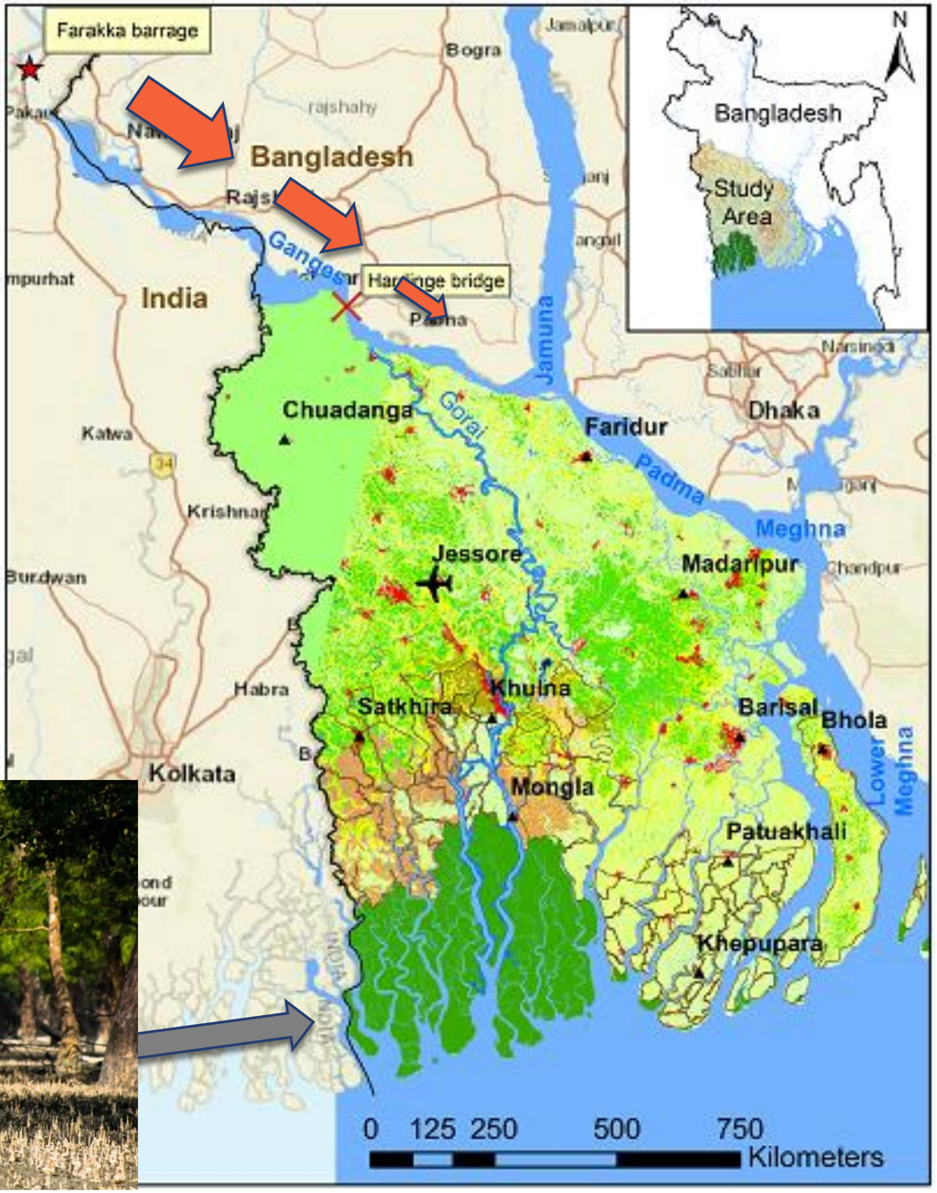
Effects of Climate Variability in the Ganges Delta of Bangladesh

Background

Farakka Barrage: Dry season water diversions



Evaluate freshwater scarcity: lower end of Ganges Delta of Bangladesh

- Area ~42,000 km^2
- Population 32.8 million

Major part of largest Mangrove ecosystem

Experiences water related challenges e.g., drought, flood, cyclones, water logging, river erosion, tidal actions

Limitations in quantity, quality, and timing of available water

Transboundary water issues

Source: Farakka barrage: The Sunday Indian, Feb 17, 2012
Sundarbans: https://prithulmahmud.wordpress.com

Floods and Droughts

Source: Kyle Knight/IRIN

The Daily Star, August 2009

Key Question: How is climate **variability** affecting freshwater scarcity?

Key Variables

- Rainfall, temperature, ET (Bangladesh Meteorological Department)
- Actual ET => Complimentary relationship model
- Pre-barrage period (1949-1974)
- Three post-barrage periods based on treaty

  1975-1987, 1988-1996, 1997-2015

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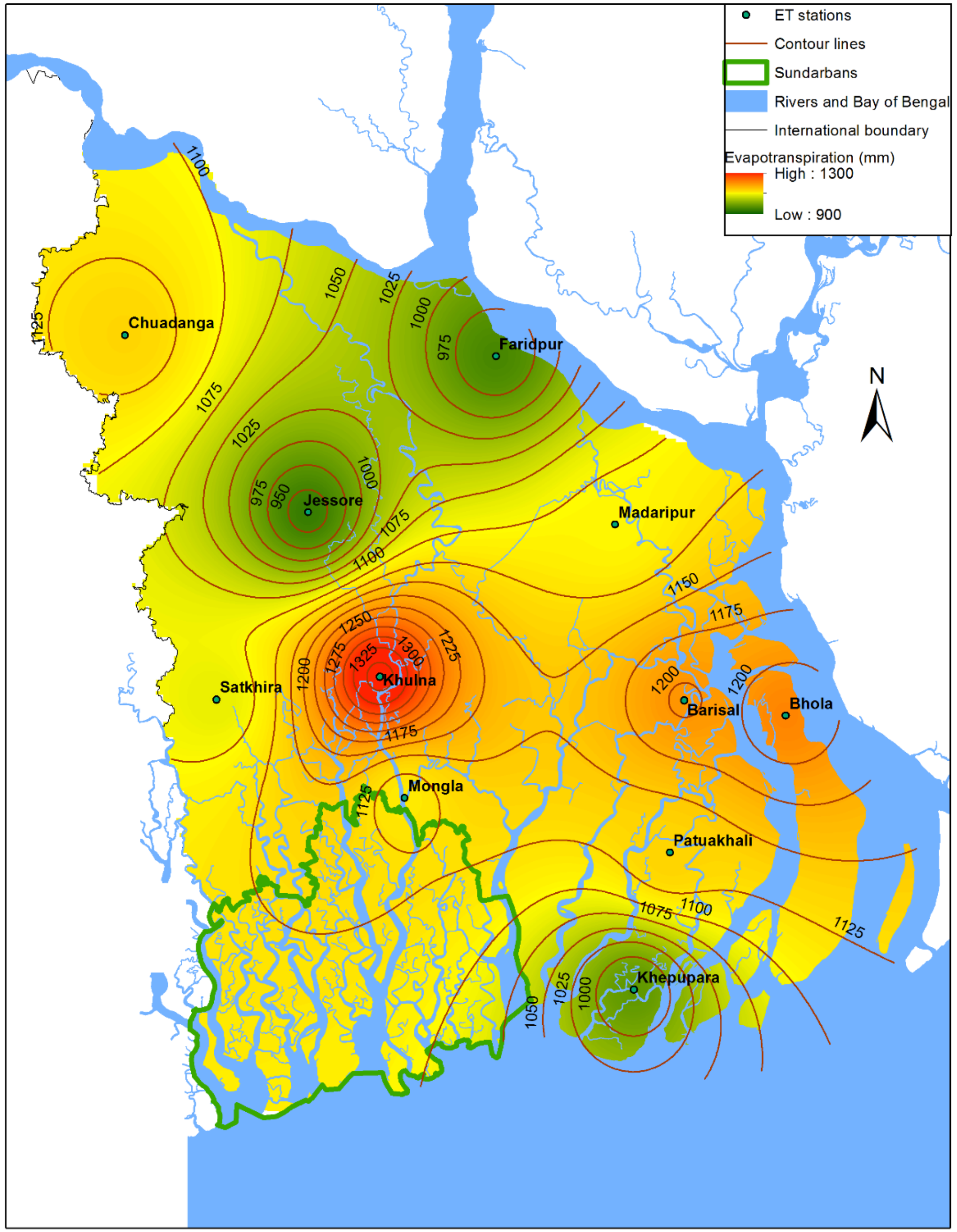
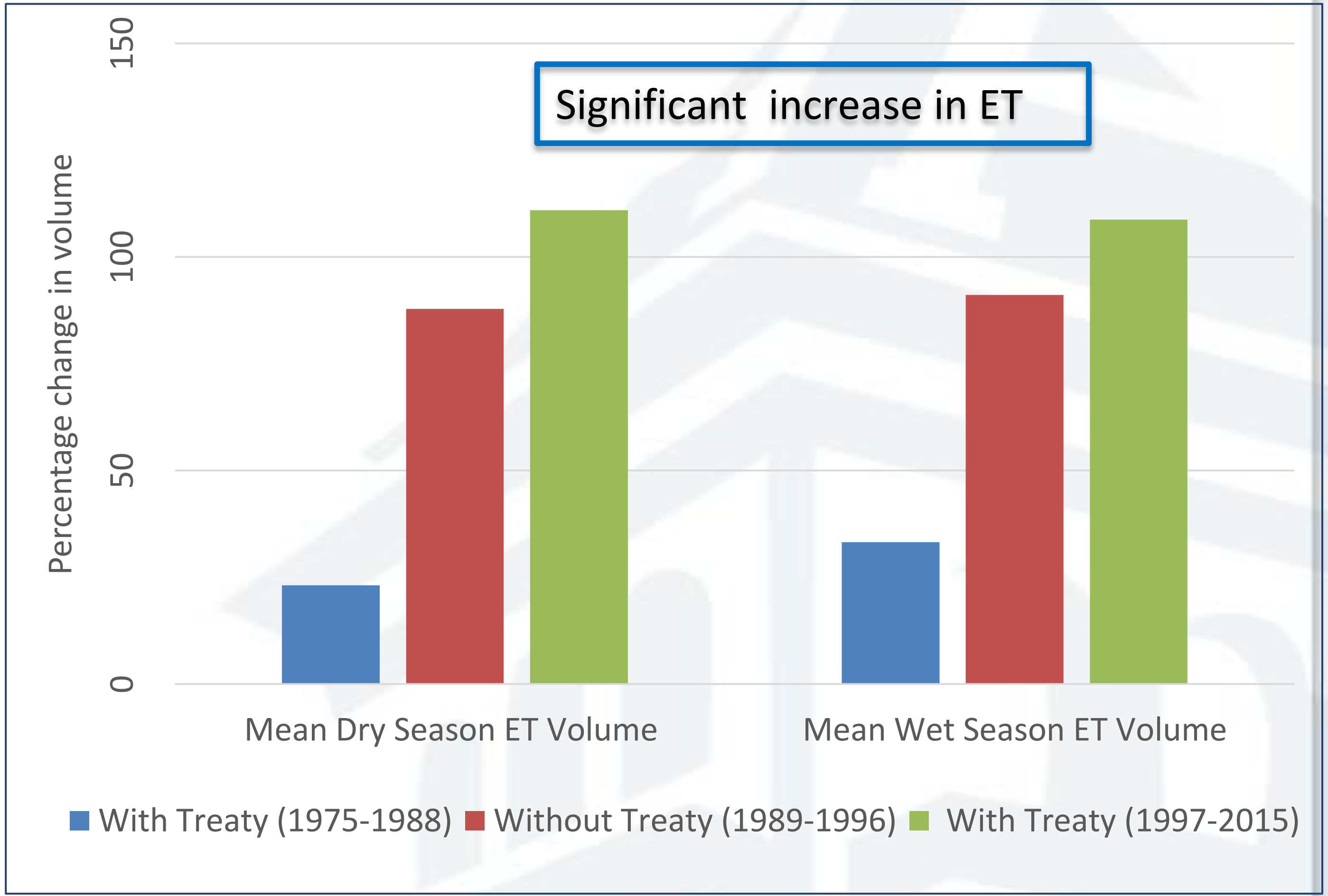
Mean Annual ET



Change in ET volume from **pre-barrage period**



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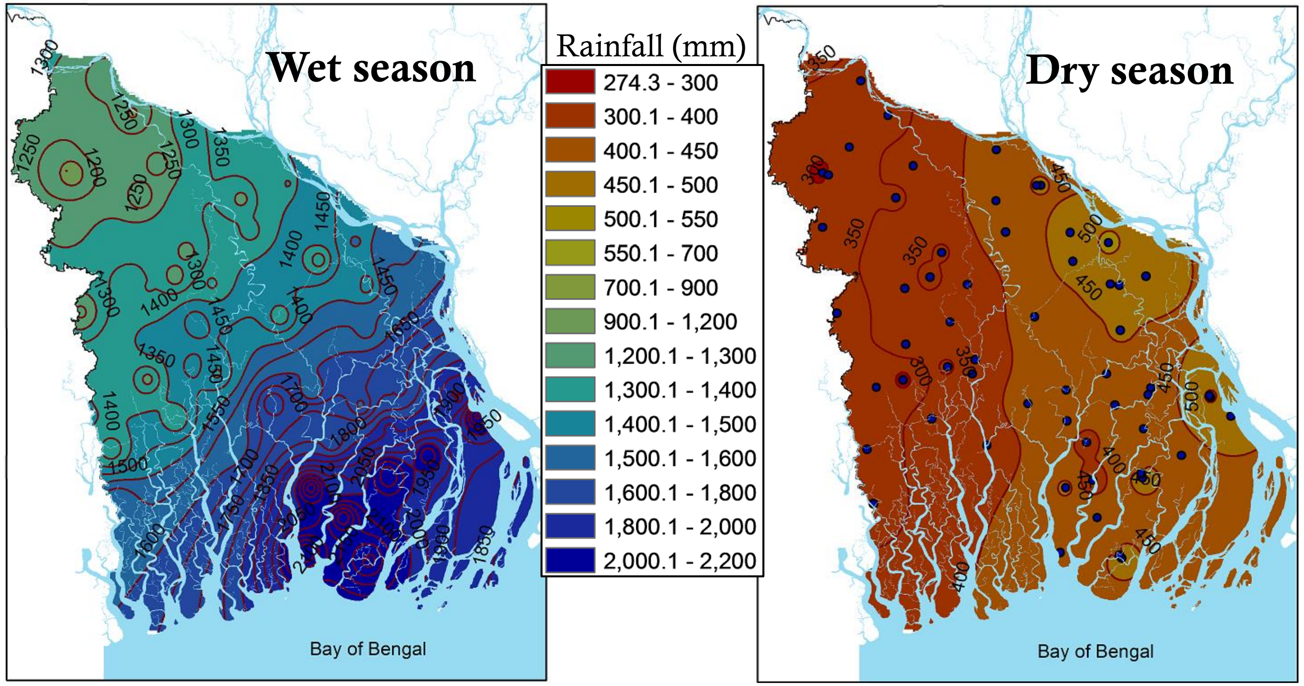
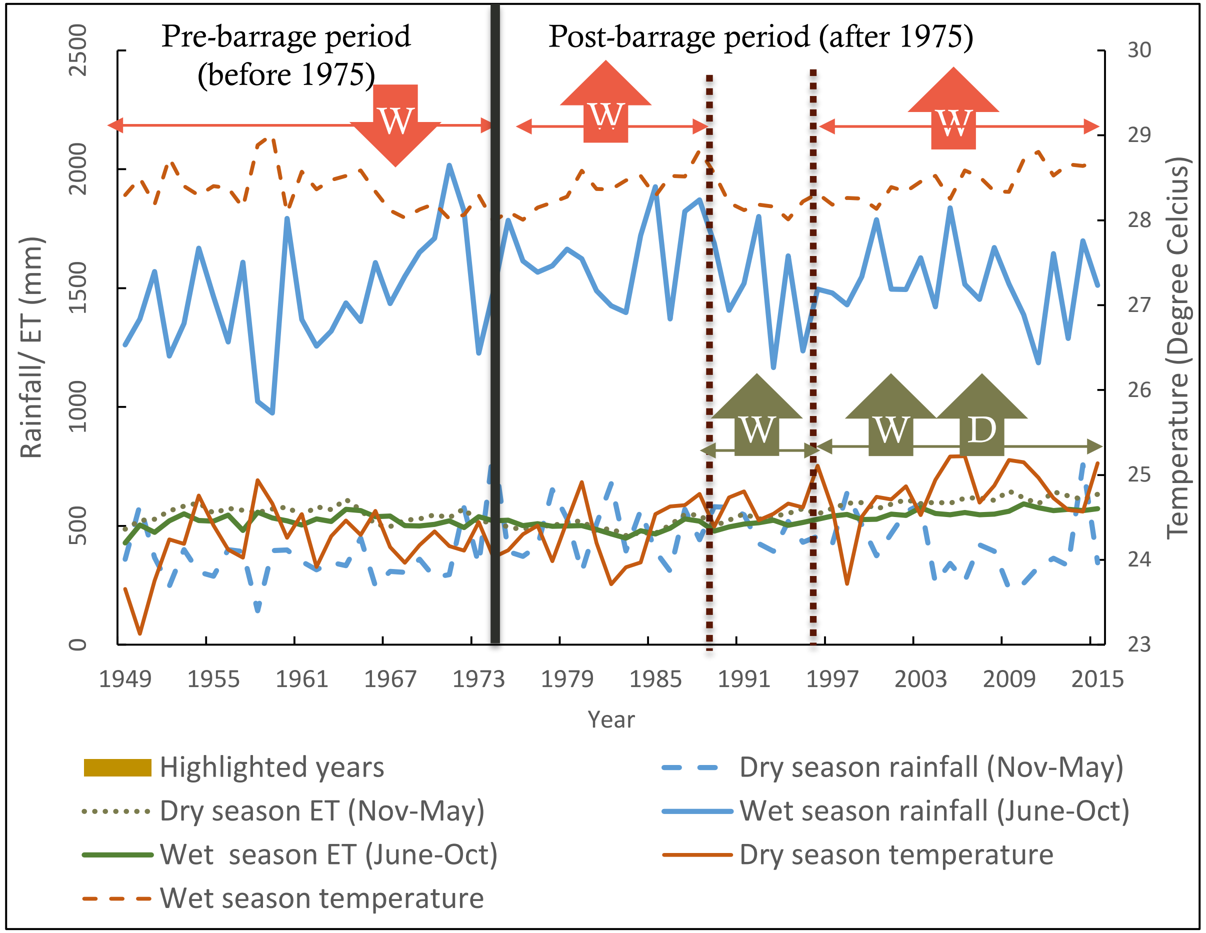
Climate Pattern

Spatial variation of rainfall



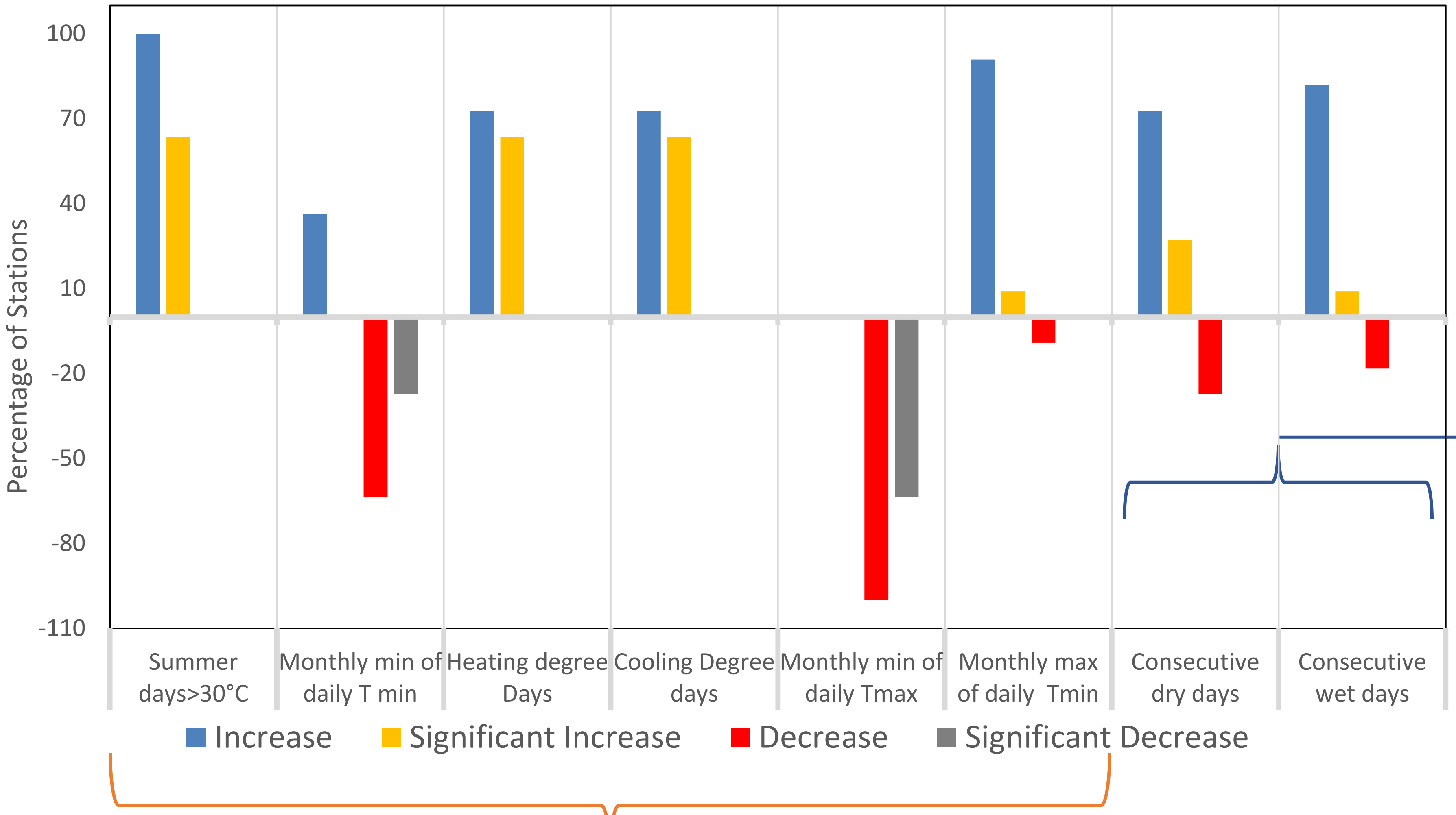
Wet: June – Oct
Dry: Nov-May

Temporal variation of rainfall, temperature and ET



Period 1: Post-barrage with treaties and agreements (1975-1988)
Period 2: Post-barrage without treaty (1989-1996)
Period 3: Post-barrage period after 1996 treaty (1997-2015)

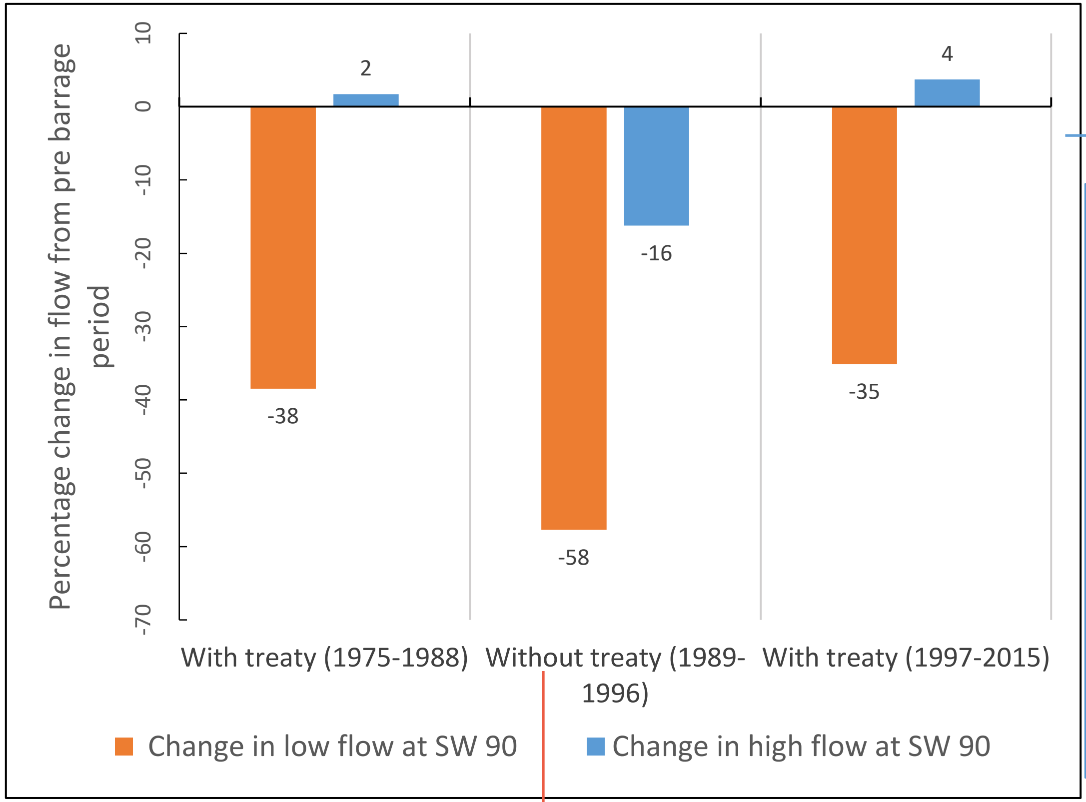
Rainfall and Temperature



Intensifying droughts and floods

Increasing of Extreme temperature

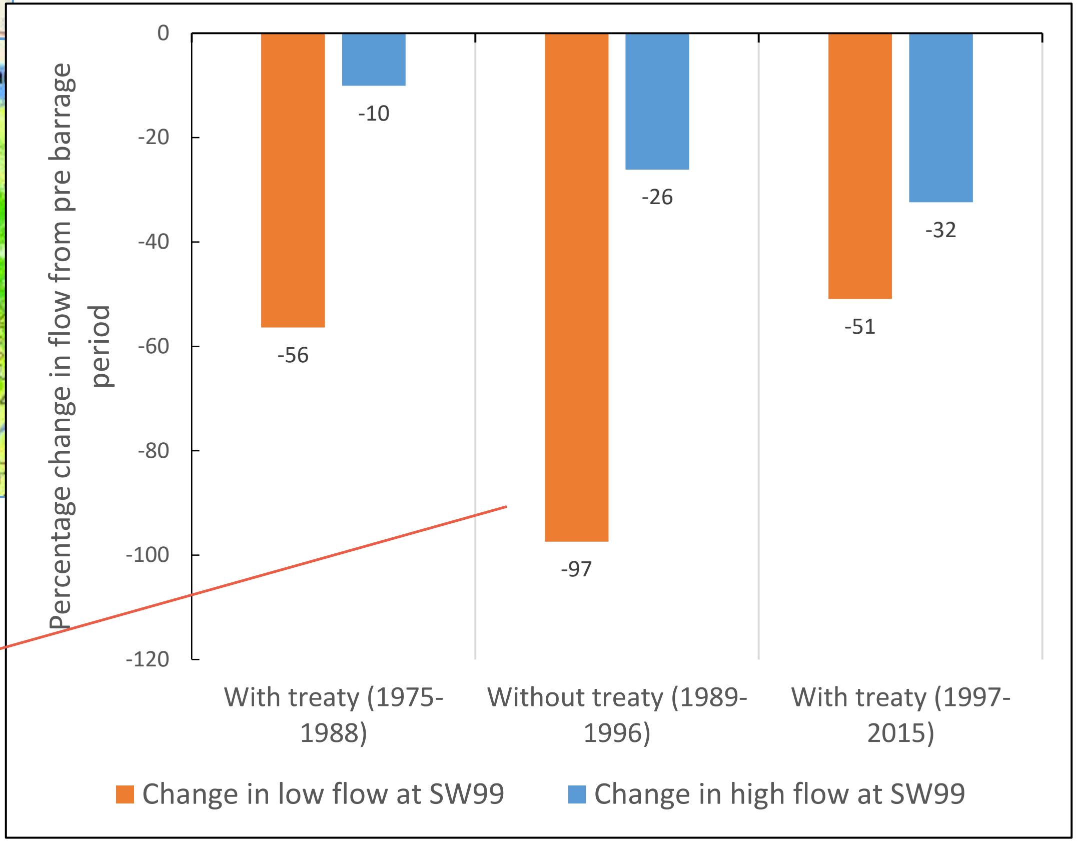
Impact of Farakka Barrage on Stream Flows



Flow duration curve

High flow threshed -20%

Low flow threshed -70%



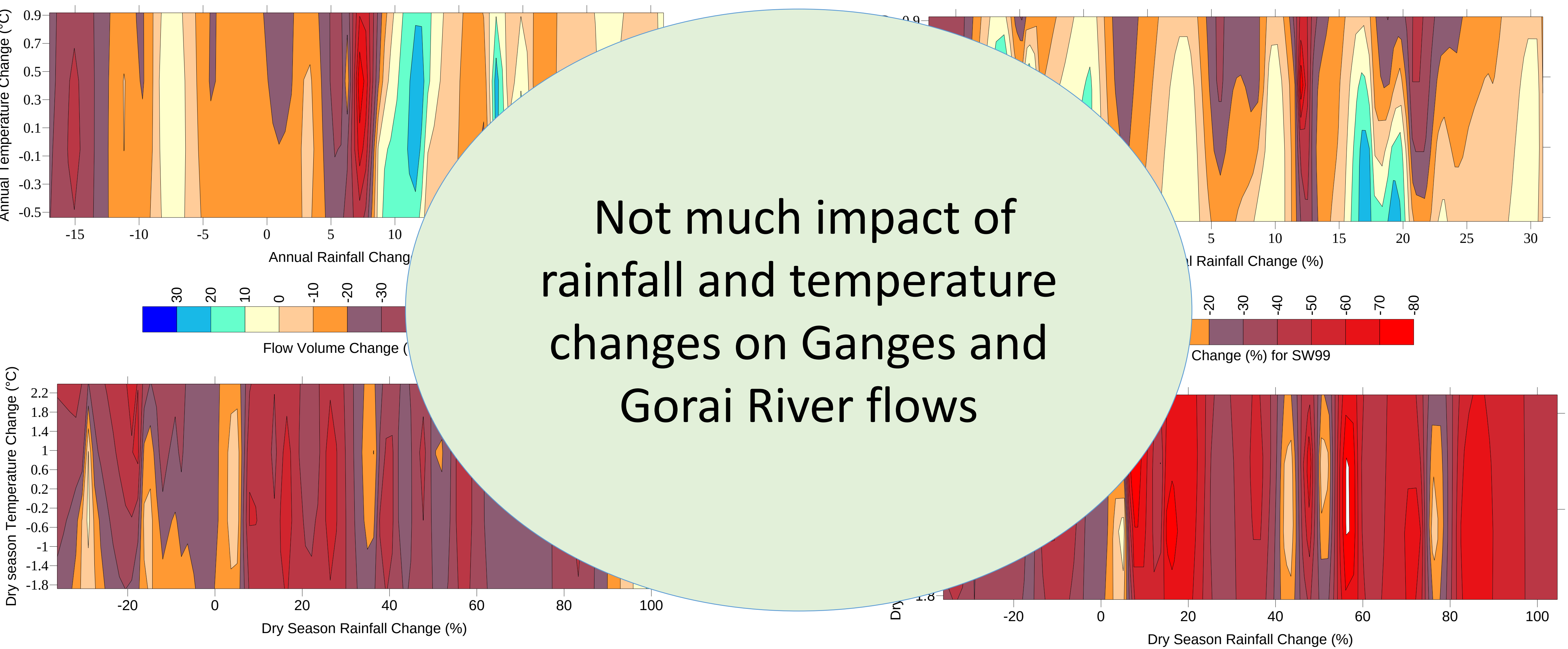
Gorai Bridge, Magura, Source: The Daily Star, 21 Oct, 2014

Dry season flow reduced 58%

Serious concerns in the period without a treaty

Dry season flow reduced 97%

Contour Plot of percentage river flow change as a function of rainfall change and temperature change



Not much impact of rainfall and temperature changes on Ganges and Gorai River flows

Key Findings

- Upper range of temperatures => increasing
- Significant increase of HDDheat and CDDcold => more energy is required to heat and cool the environment
- Increase of overall temperature, along with extreme values => serious influence on increasing ET
- Actual ET in the recent past shows about 110% volume increase compared to the pre-barrage period
- Study area => towards warmer climate => profound impact on surface water availability

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Key Findings

- longer consecutive dry and wet periods => affecting crop production
- Longer successive wet periods => reduce drainage capacity and produce floods

- mean rainfall intensity is decreasing
- high rainfall intensity of short duration is increasing

} water-logged conditions due to limited drainage time.

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Conclusions

Siwa Oasis, Egypt

- High economic activity and growth can increase greenhouse gases and can affect groundwater sustainability
- Moderate to slow economic growth needs to be promoted for sustainable supply of groundwater

Ganges Delta of Bangladesh

- Heading towards warmer climate => affecting water security
- Extreme temperature and rainfalls => increasing
- Vulnerable to droughts and floods