Impacts of climate change on water quality: from local to global scale

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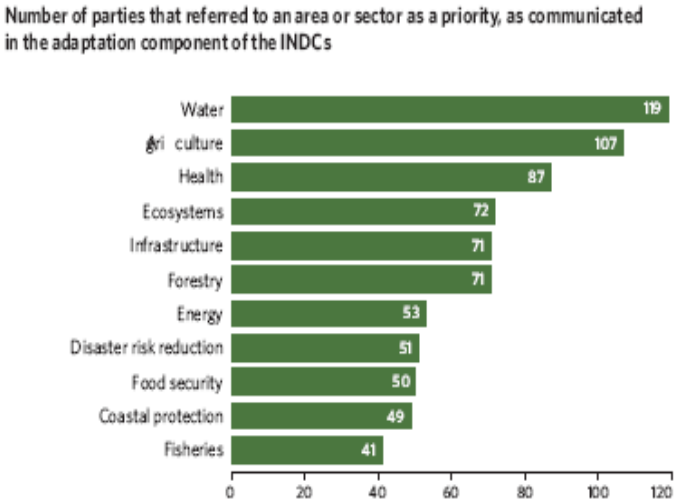
Climate Change: The Biggest threat to Sustainable Development

Climate change presents a major threat to development, and its widespread, unprecedented effects disproportionately burden the poorest and the most vulnerable.

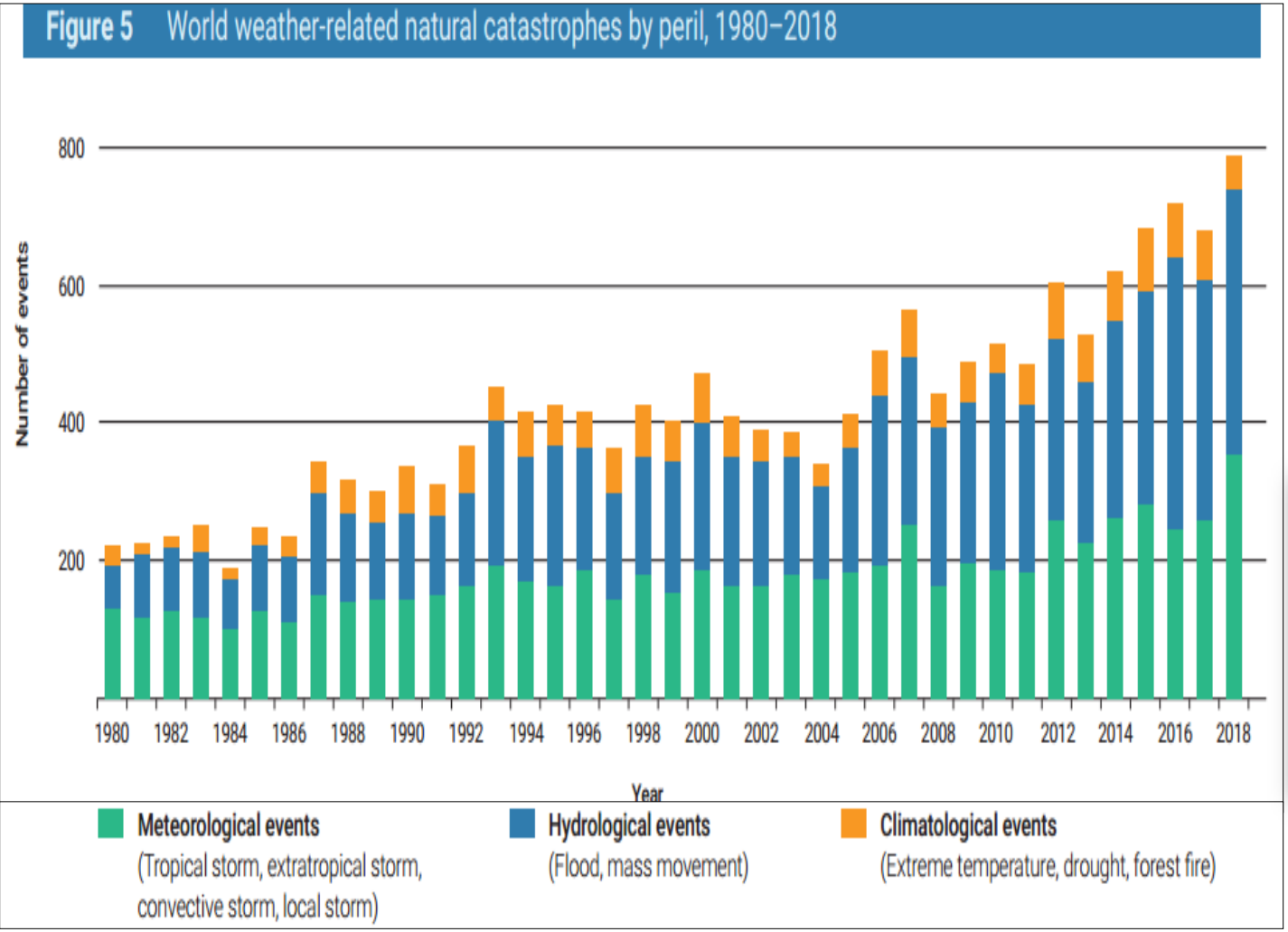


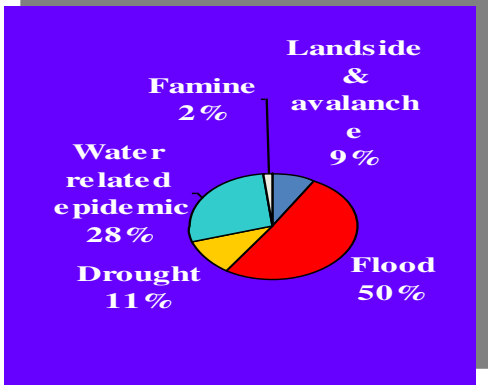
Situation now..

Global Water Crisis

- Over 1 billion people don't have access to clean drinking water; more than 2 billion lack access to adequate sanitation; and millions die every year due to preventable water-related diseases.
- 5 million people – mainly children – die every year from preventable, water-related disease is surely one of the great tragedies of our time.
- Over 34 million people might perish in the next 20 years from water-related disease.
- Hundreds of billions of dollars are needed to bring safe water to everyone who needs it. Since international water aid is sufficient, many experts propose privatization of water services as the only way to help the poor.

Accelerating occurrence of climatic phenomena at the global level





Water and Climate Change

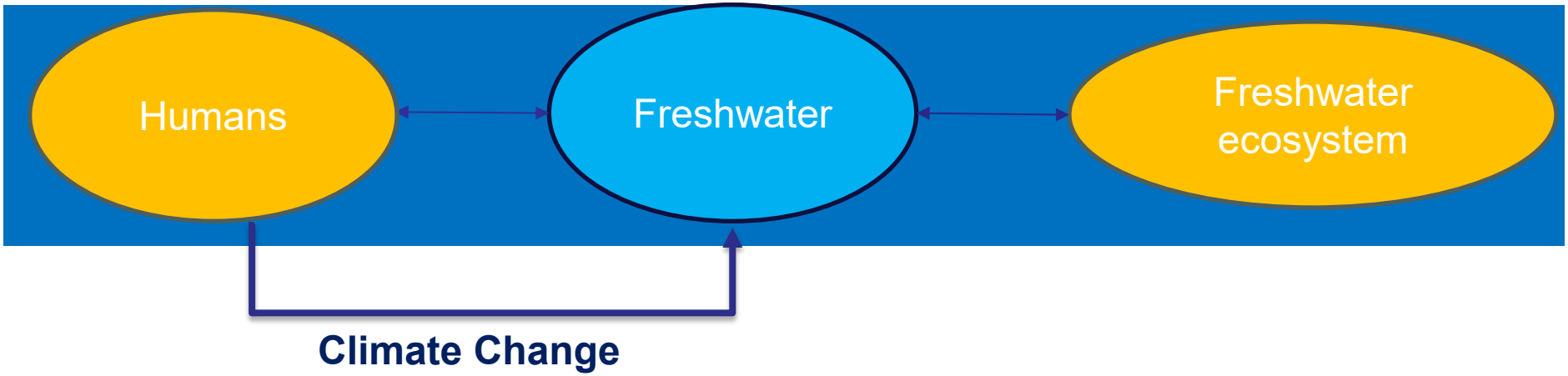
- Climate change will lead to more precipitation - but also to more evaporation
  - Precipitation will probably increase in some areas and decline in others.
- Changing precipitation patterns will affect how much water can be captured.
- The drier the climate, the more sensitive is the local hydrology.
- High-latitude regions may see more runoff due to greater precipitation.
- Reservoirs and wells would be affected.
- New patterns of runoff and evaporation will also affect natural ecosystems.
- Rising seas could invade coastal freshwater supplies.
- Reduced water supplies would place additional stress on people, agriculture, and the environment.
- Improved water resource management can help to reduce vulnerabilities.

Observed climate change impacts on water quantity

- Lakes and reservoirs: climate change effects primarily due to water temp. variations (climate change or thermal pollution)
- Oxygen regimes, redox potentials, lake stratification, mixing rates, biota development
- Diseases – via drinking water or via consuming crops irrigated with polluted water
- Sea-level rise → increased saline intrusion → reduction in freshwater availability
- Role of decreased stomatal opening of many plant species due to increased CO2

- Lowland inundation and wetland displacement.
- Altered tidal range in rivers and bays.
- Changes in sedimentation patterns.
- Severe storm surge flooding.
- Saltwater intrusion into estuaries and freshwater aquifers.
- Increased wind and rainfall damage in regions prone to tropical cyclones

Drivers of change

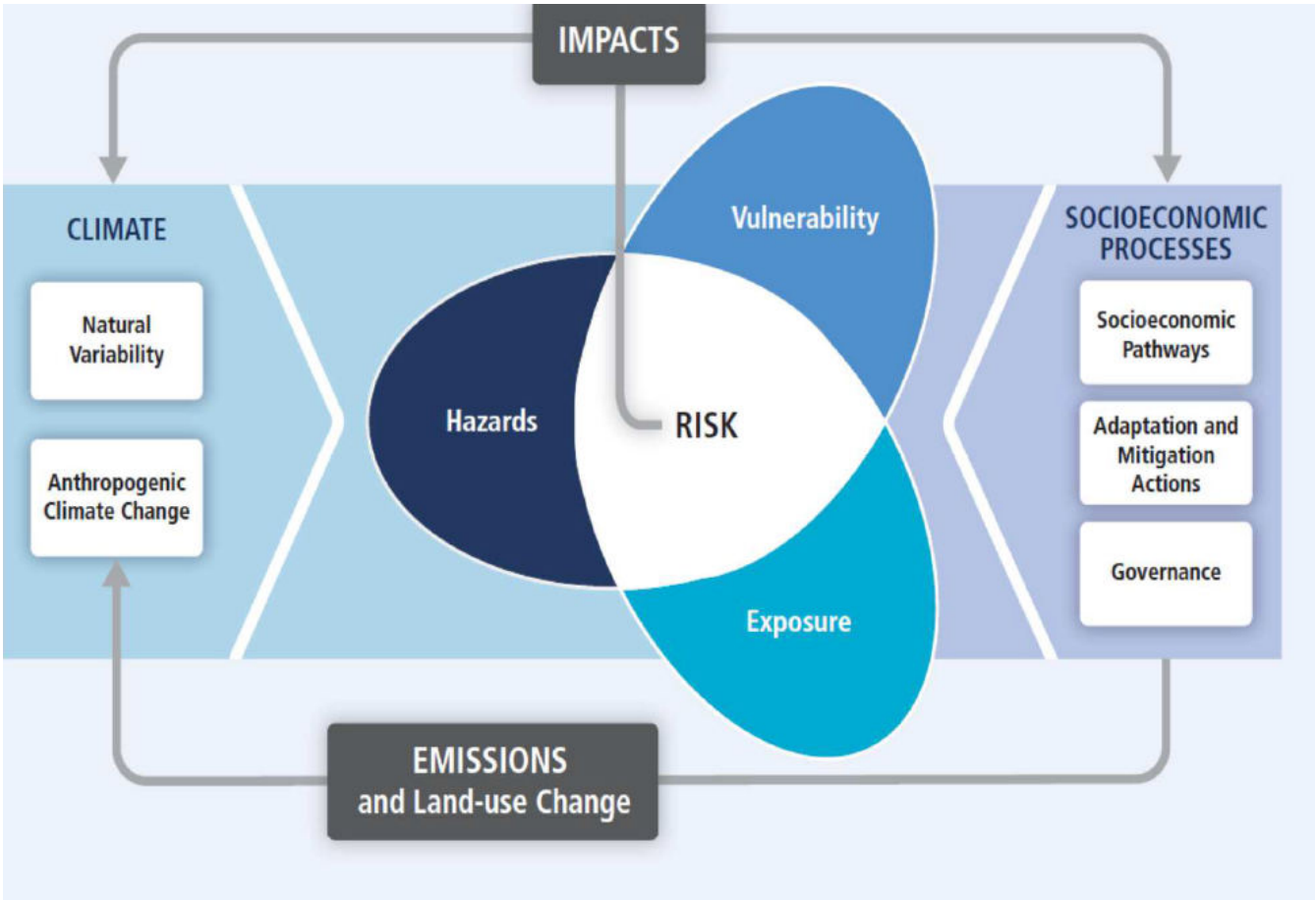


Measures of stress

- Indicators of exposure
  - Numbers affected by flood / drought
- Indicators of access
  - Numbers with access to safe water
- Indicators of availability
  - Resources per capita

Estimating the future risk

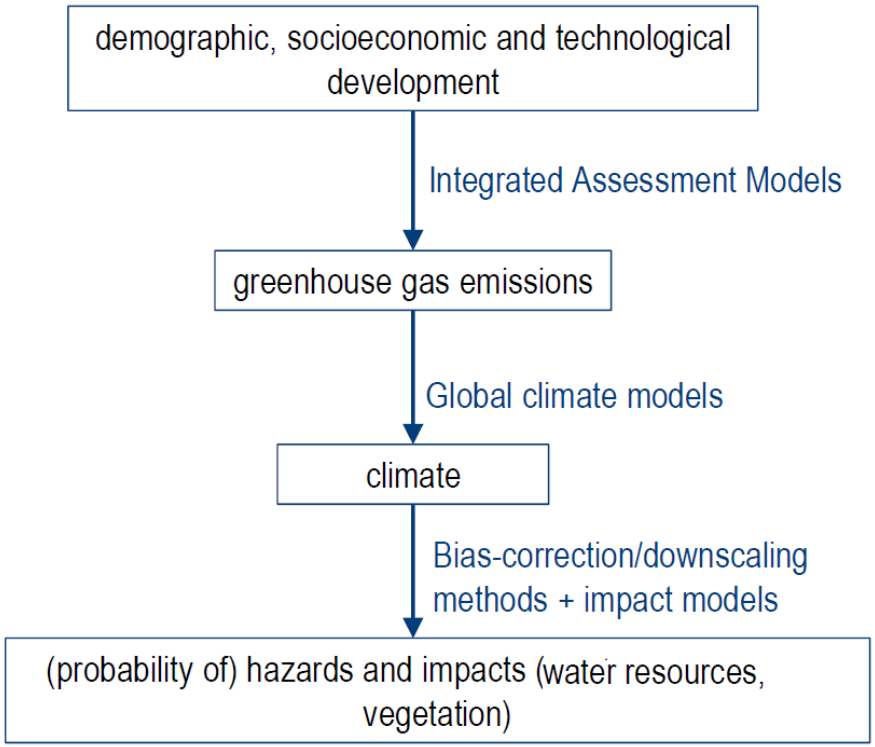
- Future impacts depend on future climate and future exposed population
- Simulate water availability using a macro-scale hydrological model
- Construct climate change scenarios from global climate models
- Construct consistent scenarios for change in exposed population



Risk = possibility of negative impacts = probability of occurrence of hazardous **events or trends** multiplied by the impacts if event or trend occurs

IPCC WG

Model of future risks of impacts



What to look for specifically?

- Precipitation amount
- Precipitation frequency and intensity
- Evaporation and transpiration
- Changes in average annual runoff
- Natural variability
- Snowpack
- Coastal zones
- Water quality
- Water storage
- Water demand

Precipitation amount

- Will increase as global temperatures rise
- Evaporation potential will increase because warmer atmosphere can hold more moisture
- For a one-degree Celsius increase in air temperature, the water-holding capacity of the atmosphere increases by 7 %

What goes up – must come down

- How much global average precipitation will increase?
  - Models suggest 1-2 percent per degree Celsius
- Does not mean it will get wetter everywhere and year-round; some get less; some get more
- More rain over high-latitude land areas; less over equatorial regions;

Precipitation frequency and intensity

- On average: less frequent; more intense → floods and droughts; consequences for water shortage

Why?

- Local and regional rainfall rates greatly > evaporation rates and depend on the convergence of regional to continental scale moisture sources
- Rainfall intensity should increase at same rate as increases in atmosphere moisture (7% / degree C)

Evaporation and transpiration

- Evapotranspiration:
  - From open water, soil, shallow groundwater, water stored on vegetation
  - Transpiration through plants
- Consistent prediction: increase total evaporation
- One study: an increase/decrease in precipitation of 20% → runoff changing by ~ 20%; w/ no change in precipitation, a 2 degree C increase in temp -> reduce mean annual runoff by 4 to 12%.
- Thus – if temp increased by 4-degree $^{\circ}$C, precipitation would need to increase by 20% to maintain runoff.

Changes in average annual runoff

- Importance?
- Depend on changes in temp and precipitation
- Global message of increased precipitation does not translate into regional increases in water availability

Natural variability?

- Will not go away

- Water supplies can change dramatically, and for extended periods, even without anthropogenic climate change

Temperature, snowpack, and runoff

- Very likely that a greater portion of winter precipitation will fall as rain rather than snow

- An increase in rain events would increase winter runoff

But

- Result in smaller snowpack accumulations
- Warmer climate likely result in earlier melt season
- Increase in winter or spring flows
- May increase the risk of winter and spring floods

Water quality

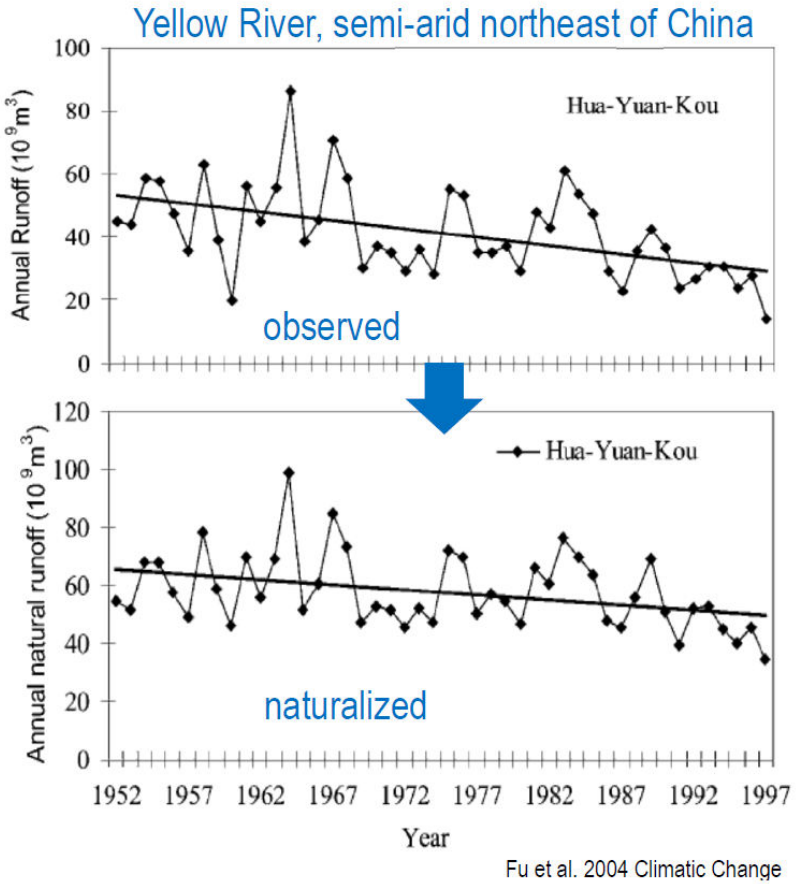
- Flooding…
  - increased sediment and non-point source pollution loadings in watercourses
  - Decline in streamflow and lake levels …
  - nutrients and contaminants become more concentrated in reduced volumes with longer water residence times
  - reducing dissolved oxygen concentrations
  - Cold-water species (salmon, trout) susceptible to warm-water temp
  - increase salinity of surface water

Leaf 'sweat glands' (stomata) to worsen future flooding

- Regulate the amount of carbon dioxide taken up by the plants during photosynthesis
- Absorb and release moisture during transpiration
- Tend to shrink when carbon dioxide levels rice
- So – plants transpiring less → plants consume less water → more water remains in the soil → more water runs into the river
- River flow increased by 3% worldwide
- In the Med and South American: might ease the damage from drought; Not so in Asia, Europe, and North America

Which impacts of climate change on water resources indicators have already been observed?

Mostly to changes in climate variables, not to anthropogenic reasons)



Fu et al. 2004 Climatic Change

- The presence of pathogens in water supplies has been related to extreme rainfall events In the USA, 20 to 40% of water-borne disease outbreaks can be related to extreme precipitation.

- Between July 29 and August 1, 2023, Beijing was soaked with the heaviest rainfall in 140 years. So far, the floods have killed dozens of people across Beijing and Hebei, with many still missing.

- BEIJING (Reuters) - Large areas of south China are suffering from serious drought, with water levels on two major rivers in rice-growing provinces dropping to historic lows, state media said on Tuesday.

- Bangladesh says reaches all cyclone-hit areas Relief workers and the Bangladesh military on Tuesday reached the last remaining pockets of the country devastated by a cyclone that killed nearly 3,500 people along the Bay of Bengal.

List of countries/municipalities that have seen catastrophic flooding in the first 11 days of September 2023

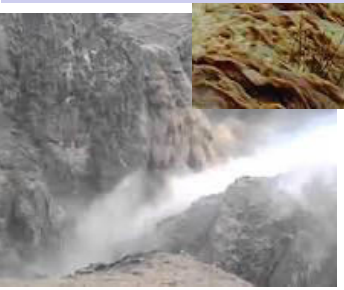
- Greece
- Turkey
- Libya
- Brazil
- Hong Kong
- Shanghai
- Spain
- Las Vegas

Extreme Weather Events on the regional scale

Flooding in /Saudi Arabia, 2021

Flooding in Amman, Jordan on 2011

Flooding in Morocco on 2014



Flooding in Egypt 2020

Flooding in Iraq 2021

Flooding in Sudan 2021

Flooding in United Arab Emirates on 2013

The death toll from natural disasters doubled in the Arab region by 275% in the period (2006-2015) compared to the period (1995-1999), showing that floods are the most frequent disasters and that drought led to an increase in the number of individuals affected by disasters. ((First Arab Sustainable Development Report 2012).

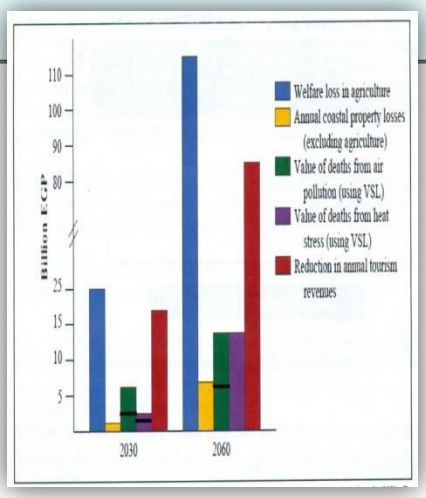
Saudi Arabia

- Depletion of water resources due to climate change.
- Ground water levels dropping very quickly.
- Overall temperature increase of 0.5 to 2 degrees Celsius in desert regions between 1976 and 2000.
- Many deserts will experience a decline of 5 to 10 percent in rainfall in the near future.
- Restrict irrigation agriculture.

Egypt: Nile Delta

- 2.5% of Egypt's land area (Nile delta and Nile valley) suitable for intensive agriculture.
- 50 km wide land strip less than 2 m above sea-level.
- Erosion of sand belt – increased since Aswan dam.
- Rising sea level…
  - Change the water quality
  - Affect more freshwater fish
  - Flood agricultural land
  - Endanger recreational tourism
  - Salinate essential groundwater

Climate Change in Egypt – Sea Level Rise (2030- 2060)



	2030	2060
Agriculture	20-26 billion EGP	41-234 billion EGP
Total Impact	50-55 billion EGP	195-394 billion EGP
GDP	1.6-2.4 % GDP	2.1-6.0 % GDP

Sea Level Rise – 0.5m Potential Impact on Delta Region

Population: 3 800 000
Cropland (Km²): 1 800

Sea Level Rise – 1.0m Potential Impact on Delta Region

Population: 6 100 000
Cropland (Km²): 4 500

- **Water Resources will decrease by 10-30% while, Population will increase by 50-100%**
- **Unprotected against Sea Level Rise (SLR)**
- **Agricultural production will decrease by 8-47%**
- **Food Prices will increase by 16-68%**
- **GDP will decrease by 2-6%/year**

‘There is high confidence that by mid-century "many semi-arid areas, for example the Mediterranean basin, western United States, southern Africa and northeast Brazil, will suffer a decrease in water resources due to climate change.’

IPCC report