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A Look at 20th Century Droughts

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A LOOK AT THE 20TH CENTURY DROUGHTS

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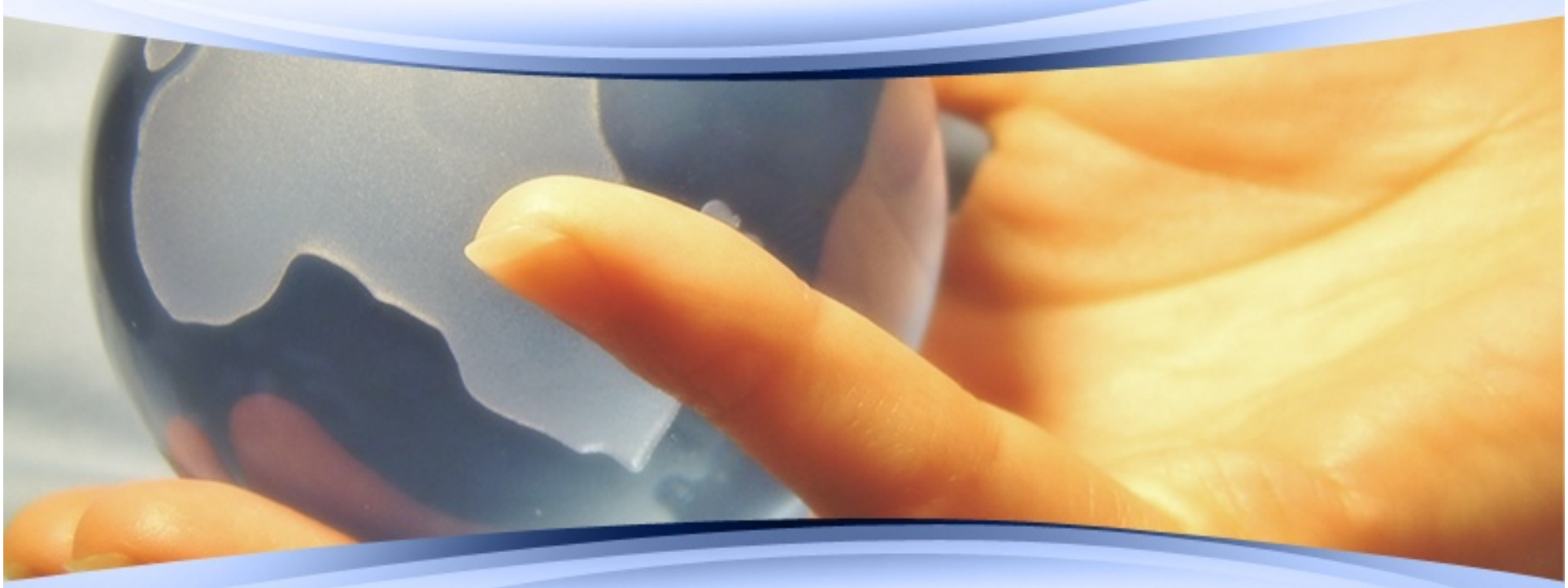
Department of Biological & Agricultural Engineering &

Department of Civil & Environmental Engineering



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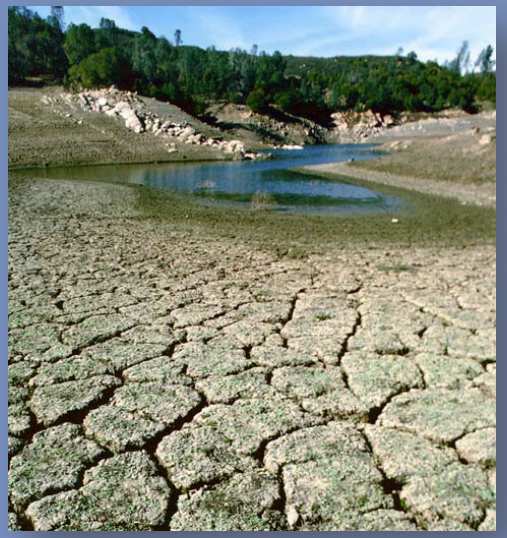
OUTLINE

- Introduction
  - Population
  - Water use
  - Water availability
  - Conflicts
- Droughts in the past

  Examples and Impacts
- Climate change and droughts
  - IPCC report on 21st century droughts
- Conclusions



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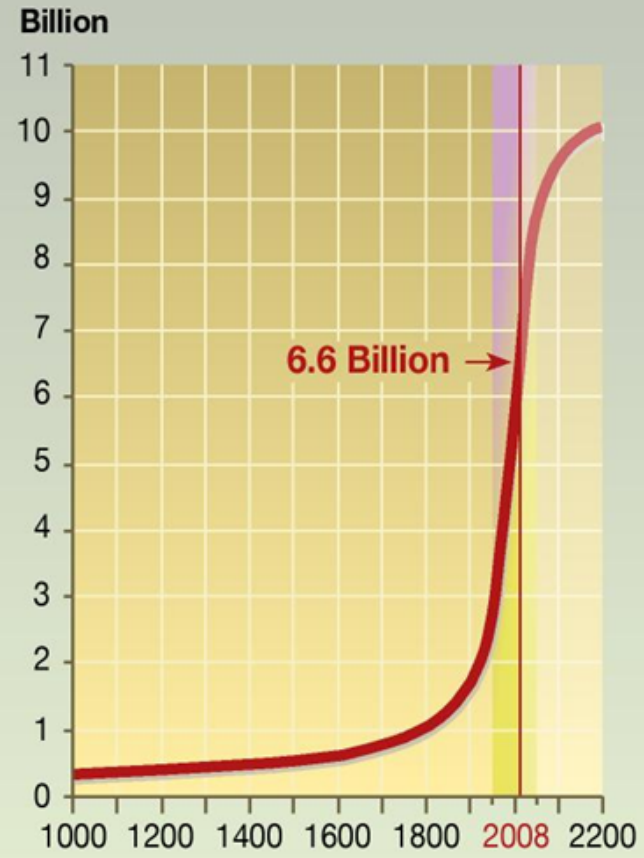
World Population Evolution

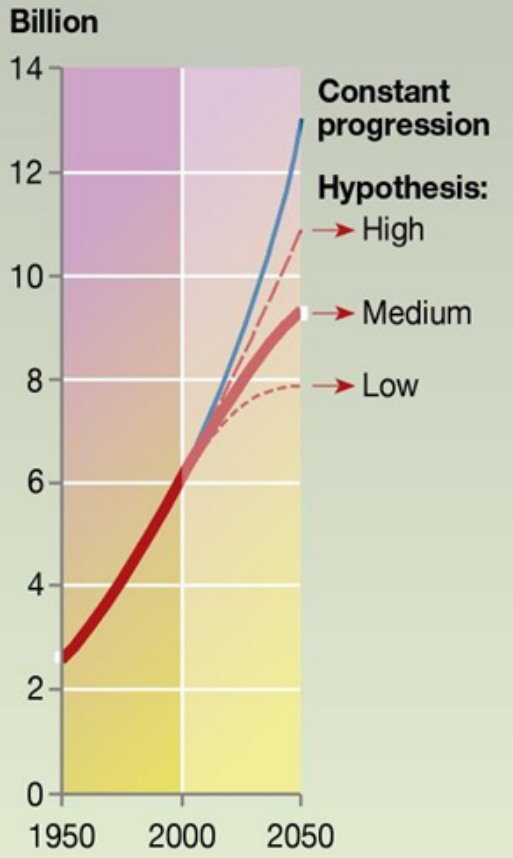


Three hypothesis for the world population evolution:

According to the population bureau of the United Nations, the medium hypothesis is the most likely one: for 1995-2000 and 2045-2050, it takes into consideration the decrease of number of children per woman (2.82 to 2.15) as well as an improvment of life expectancy (65 to 76 years). The natural growth would fall from 1.35% in 1995-2000 to 0.47% in 2045-2050.

Constant progression:

The blue line represents what would be the demographic evolution if the current birth rate (2.82 children per woman).



Sources : *The World at Six Billion* (October 1999) and *World Population Prospects: The 2006 Revision* (February 2007), United Nations, department of social and economics affairs, population division, New York.

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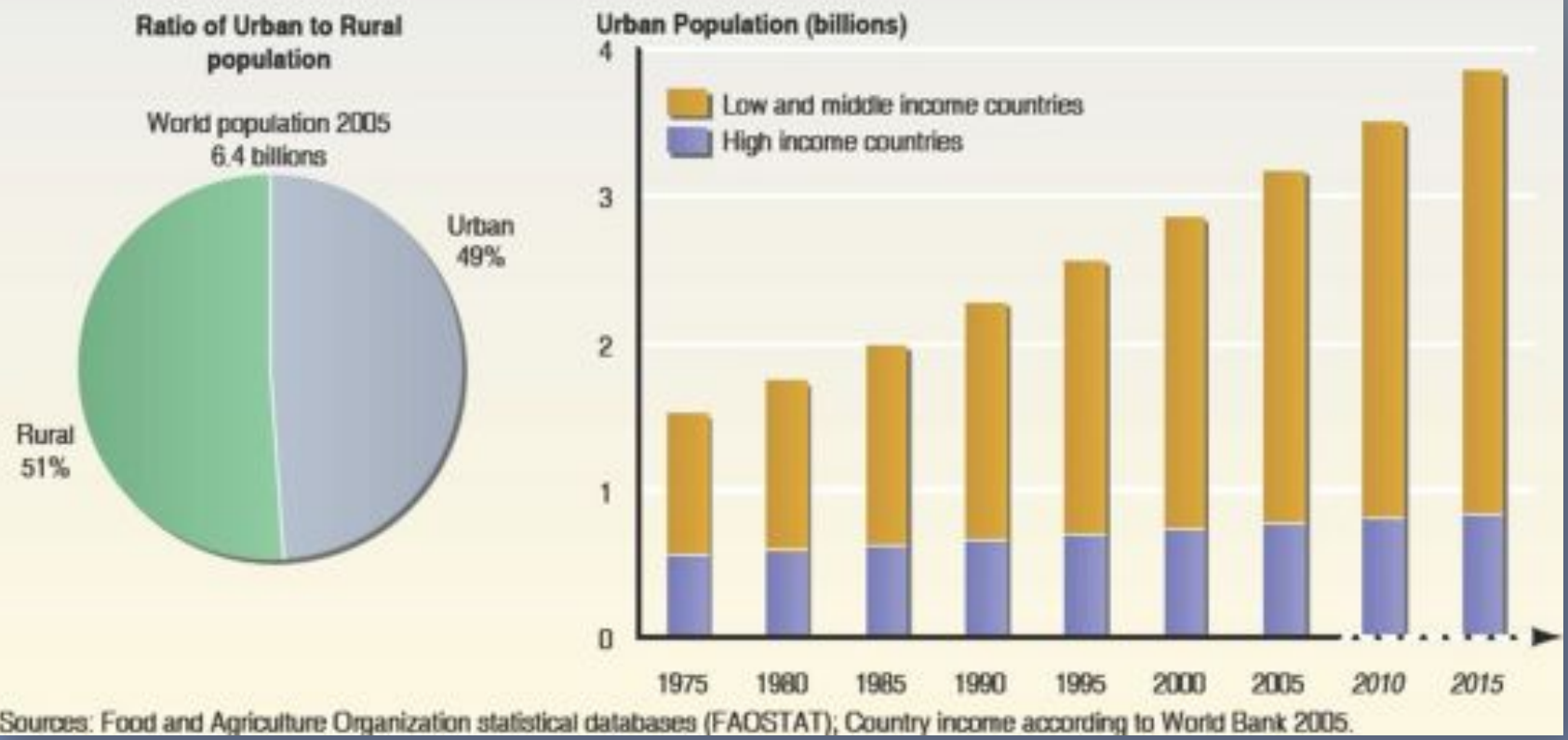
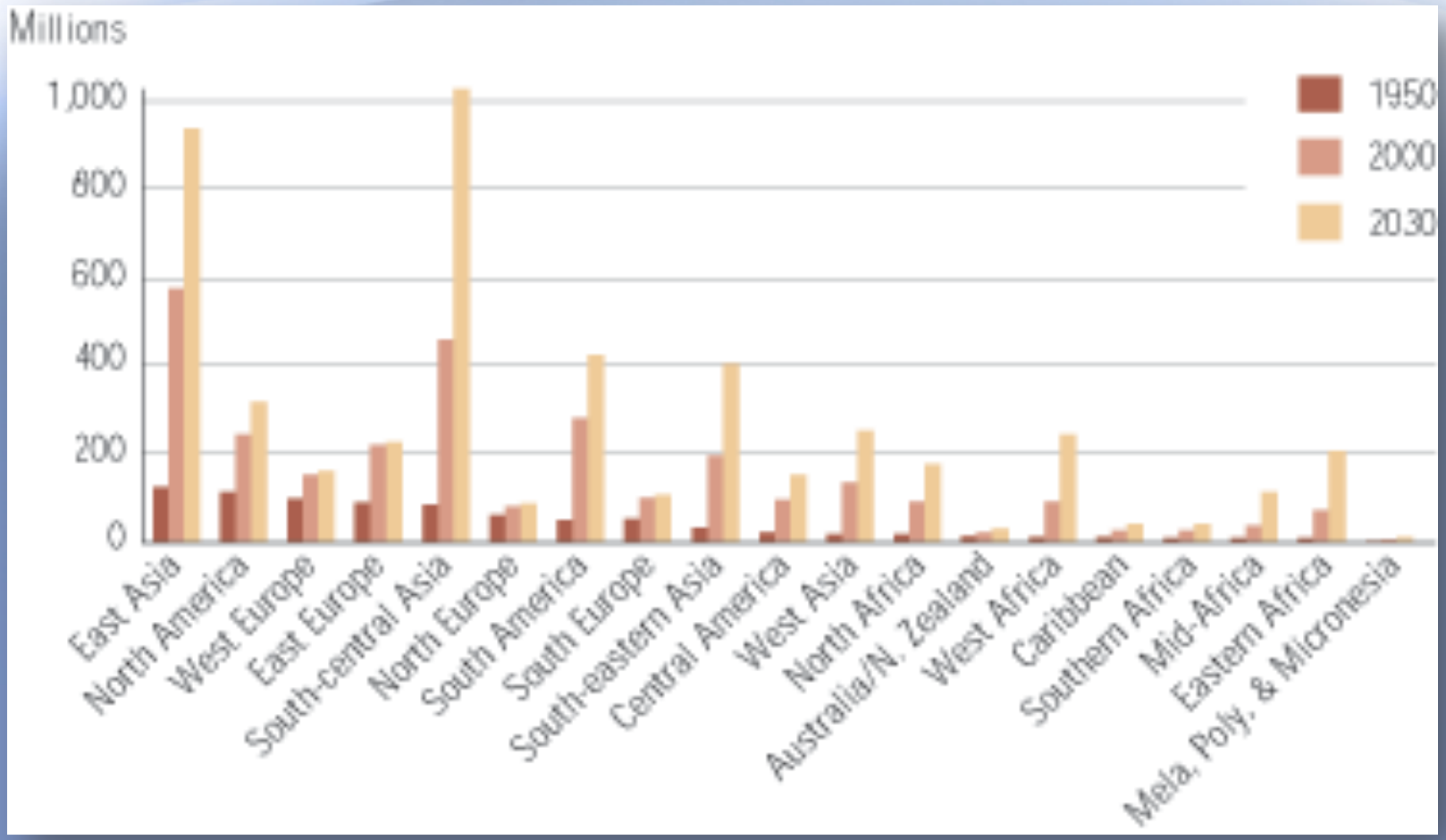
GLOBAL URBAN POPULATION: TREND

Urban population: status and trends

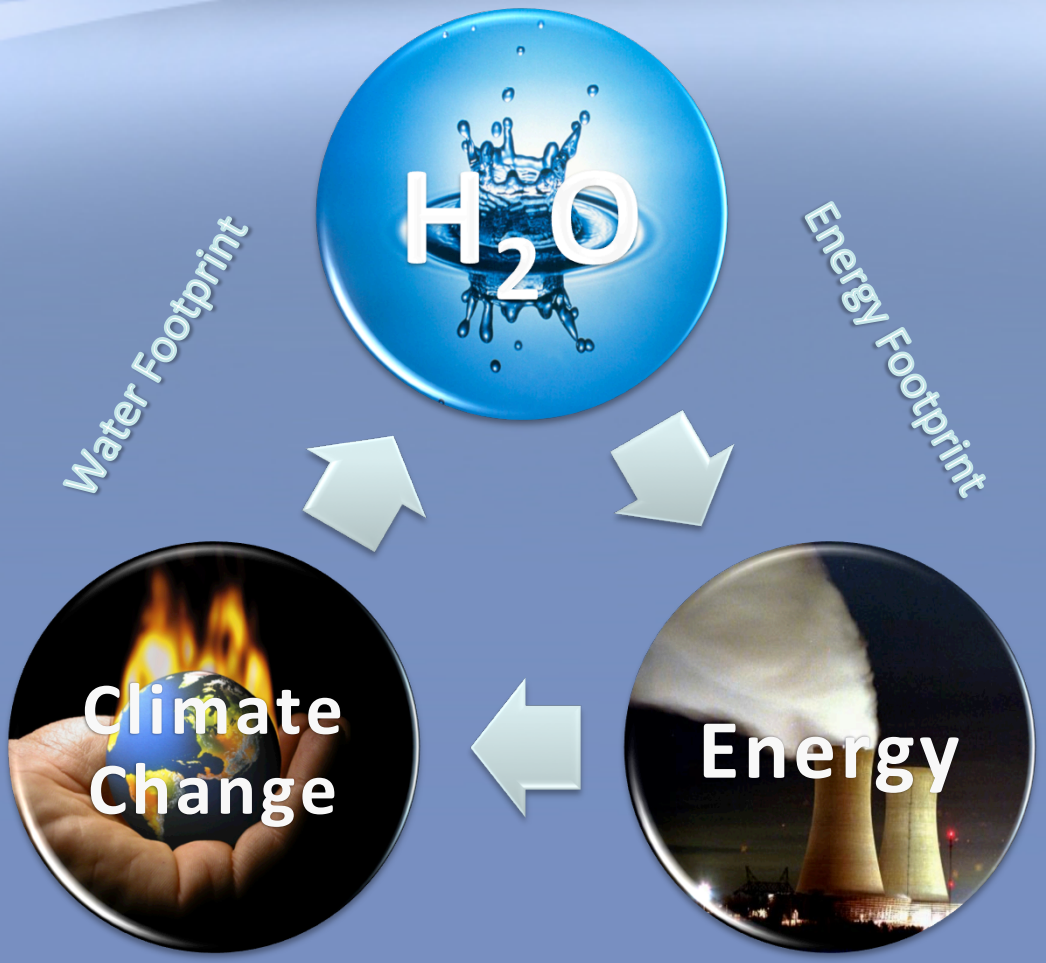


Sources: Food and Agriculture Organization statistical databases (FAOSTAT); Country income according to World Bank 2005.

REGIONAL URBAN POPULATION: TREND
(1950, 2000, AND 2030)



Water-Energy-Climate Nexus



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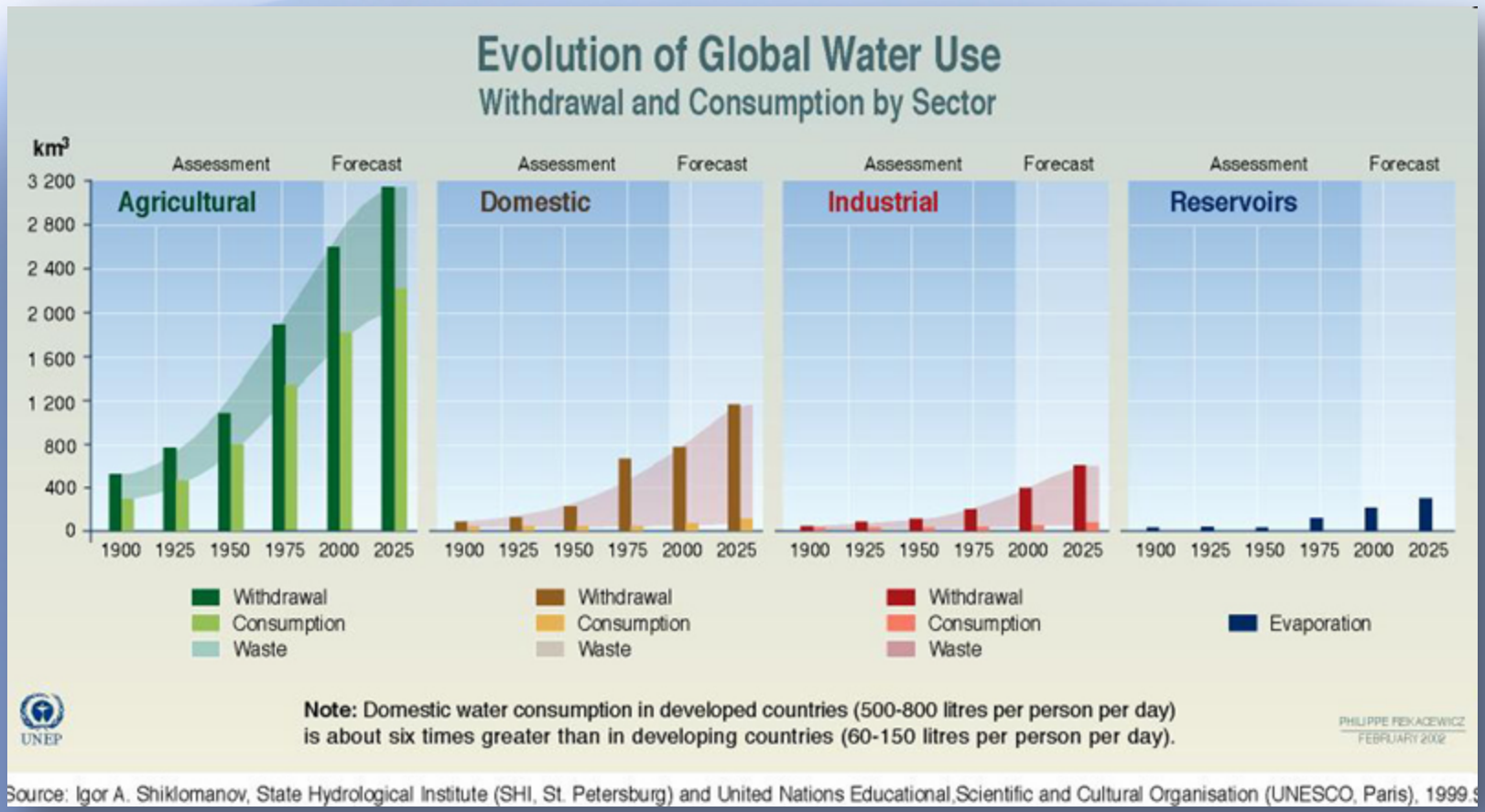
GLOBAL WATER USE



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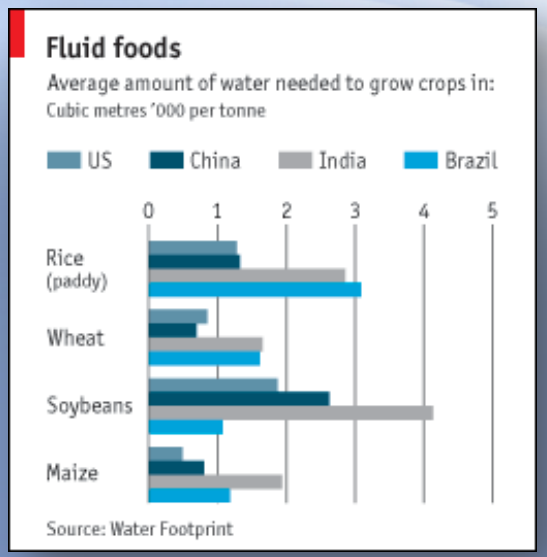
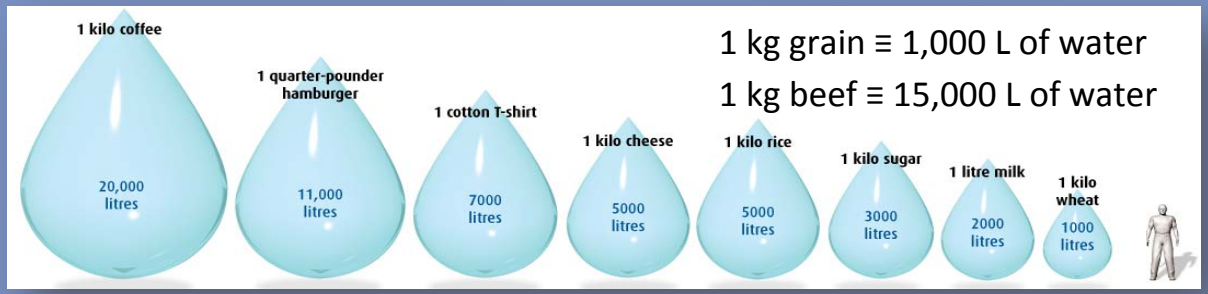
Virtual Water Use

- Meaty American and European diets
  - 5,000 L of water/day
- Vegetarian African and Asian diets
  - 2,000 L of water/day
- Meat consumption in China
  - 20 kg (1995) ⇨ 50 kg (2009)
- Dietary habits difficult to be reversed!!





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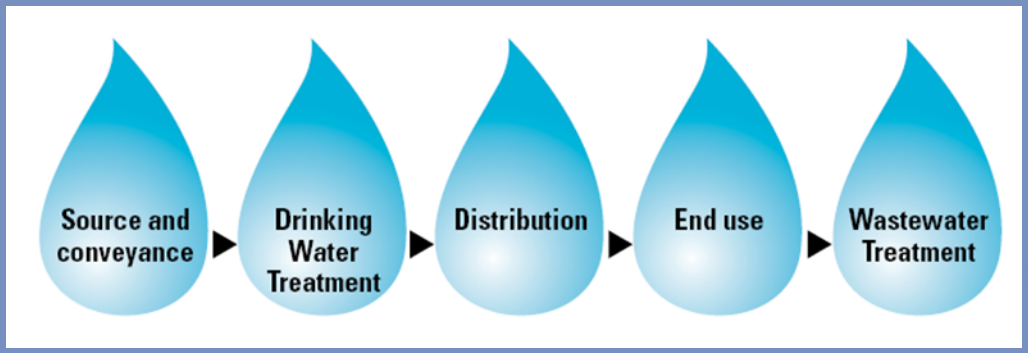
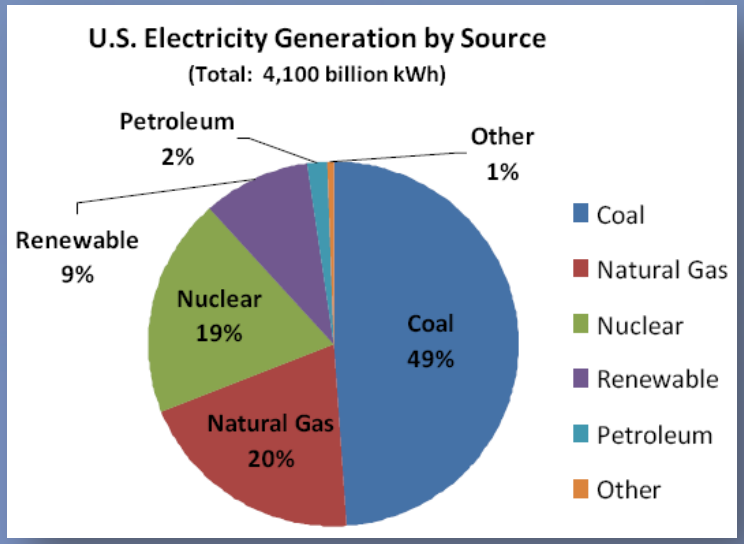
WATER & ENERGY

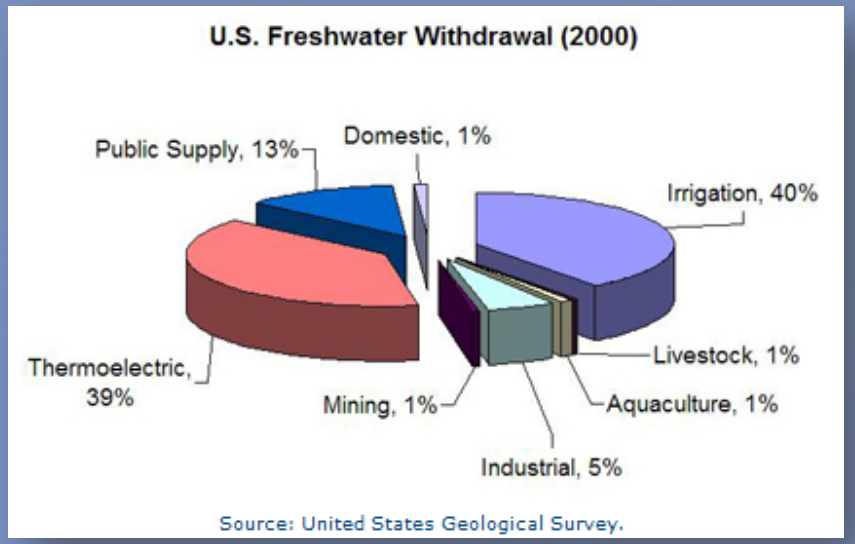
- Huge amounts of energy are needed for making water available to various users:
  - Withdrawal, conveyance, treatment, and supply
  - In USA: 116 billion pounds of CO_2 while producing such energy
  - Equal to pollution from 10 million cars



WATER & ENERGY

- Energy production needs a lot of water:
  - ~ 25 gallons per kWh
  - ~ 39% of freshwater withdrawals in USA (excluding hydropower demand) are for thermoelectric plants (136 bgd).





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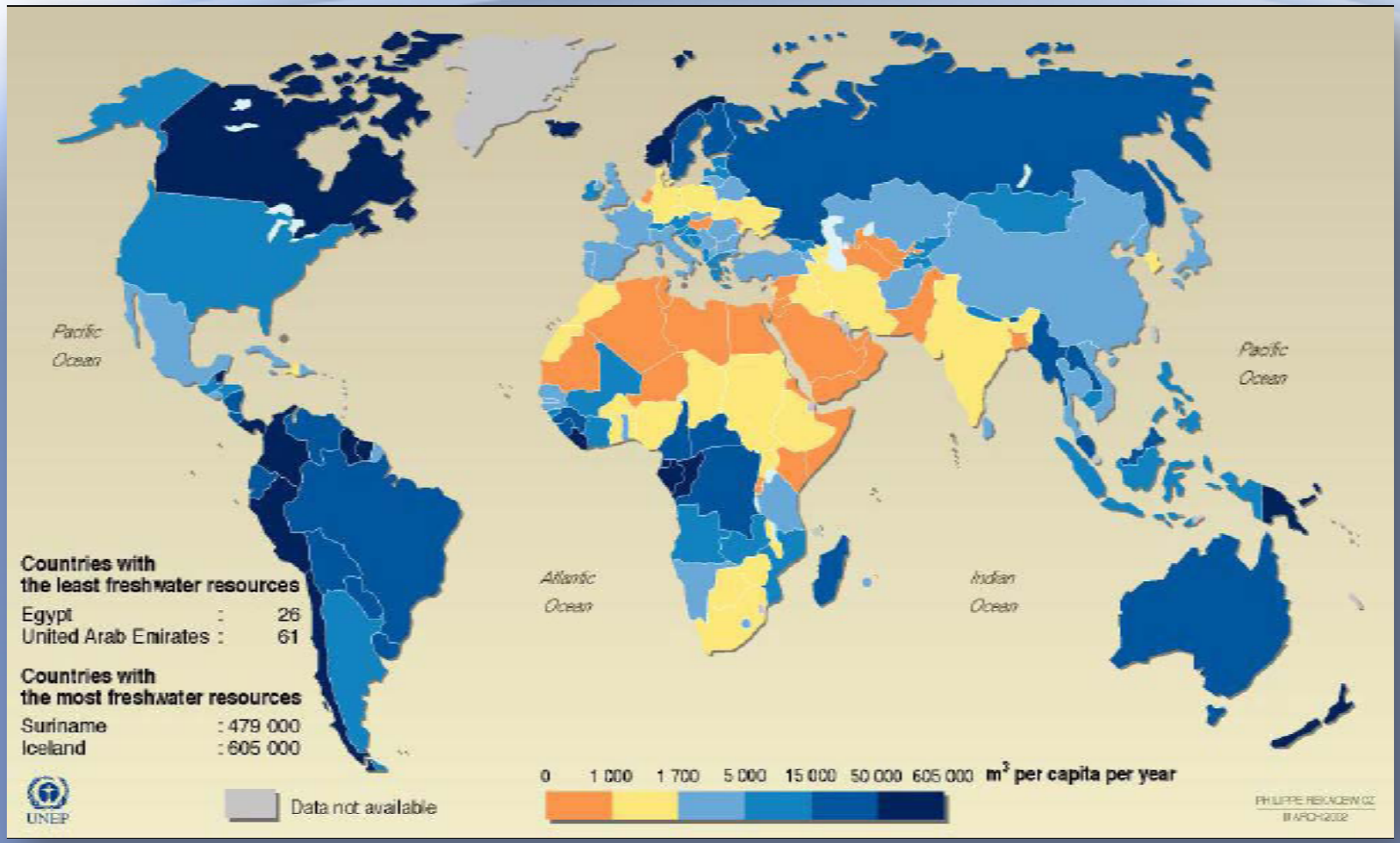
WATER & ENERGY

- Electricity production is one of the largest users of water. *[Example: For a 60-watt incandescent light bulb burning for 12 hours a day for a year in 111 million houses, a power plant would consume about 655 billion gallons of water.]*
- Water use efficiency *(Virginia Tech Study, 2008)*
  - Natural gas — 3 gallons/million BTU
  - Hydroelectric — 20 gallons/million BTU
  - Coal — 41 to 464 gallons/million BTU
  - Liquid natural gas — 145 gallons/million BTU
  - Nuclear — 2,400 to 5,600 gallons/million BTU
  - Fossil fuel thermoelectric — 230 to 270 gallon/million BTU
  - Ethanol — *2,500 to 29,100 gallons/million BTU*
  - Biodiesel — *14,000 to 75,000 gallons/million BTU*
- Biofuels – an irony when it comes to water
  - Currently 2% irrigated water used for energy crops
  - If all plans were implemented, 180 km^3 of water will be needed.

FRESH WATER AVAILABILITY IN 2000



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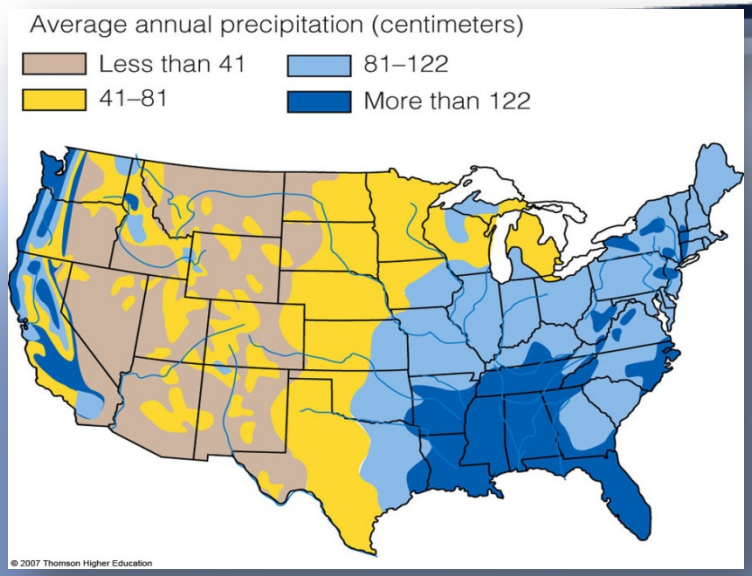
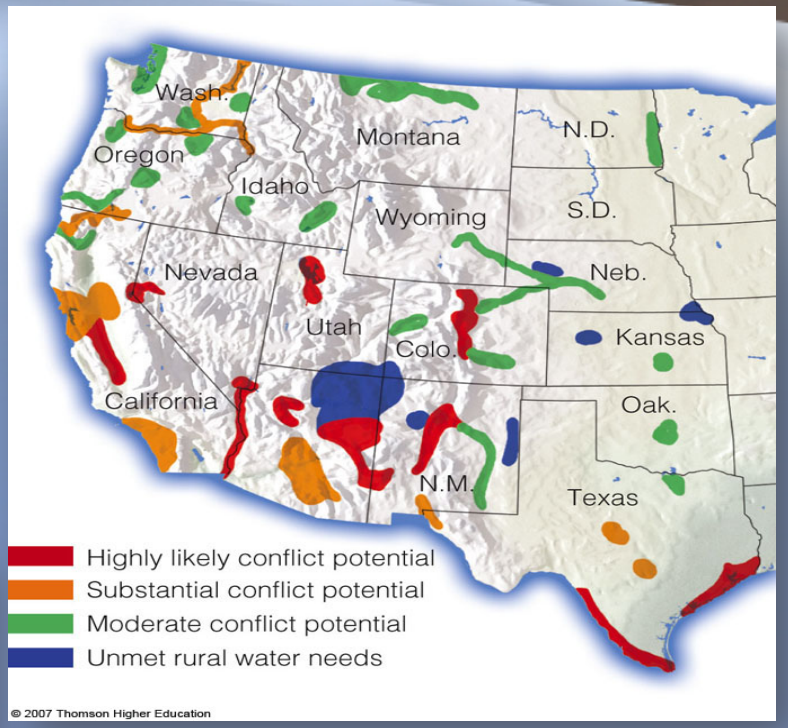
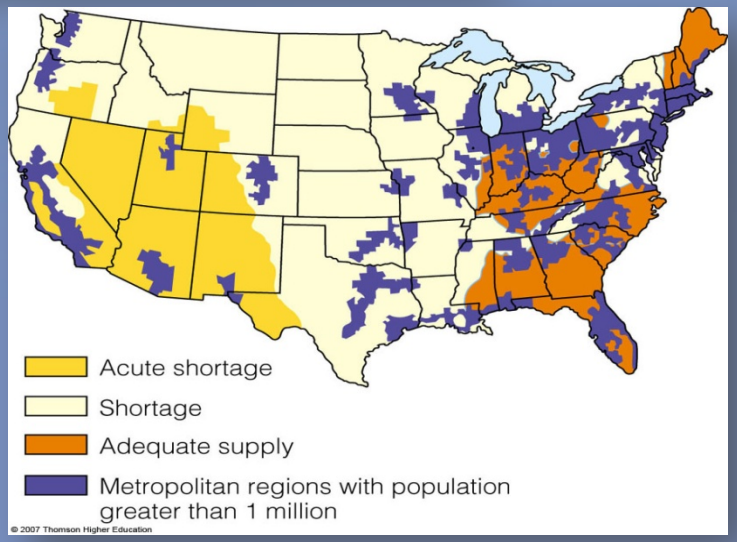
Freshwater Resources and Conflicts (USA)







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MAJOR DROUGHTS IN THE PAST

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TYPES OF DROUGHTS

- Meteorological drought
- Hydrological drought
- Agricultural drought
- Groundwater drought
- Water supply drought
- Socio-economic drought
- Commonly used drought variables:
  - Precipitation, streamflow, soil moisture, etc.
- Commonly used drought indices
  - SPI, PDSI

(Source: NDMC & AMS)

Recent Drought News

- Mega-drought threat to Southwest US ***(Nature, 2011)***
  - Arid regions might face quasi-permanent drought conditions as climate continues to warm.
  - Southwestern climate may in fact switch to an extended dry mode such as the ones that occurred during particularly warm Pleistocene periods
- Regional drought has a global impact on "Economy & Government" ***(Nature, 2011)***
  - Last years droughts in Russia and Ukraine reduced the wheat harvest by 32.7% and 19.3%, respectively.
  - The fall in wheat production has contributed to a sharp rise in global prices, more than doubled in 8 months

Continental Droughts (1950-2000)

Top five drought events based on their spatial extent larger than 500, 000 (Sq. Km)

Continent	1950's	1960's	1970's	1980's	1990's
Africa				1982-1984 1984-1985 1985-1986	1990-1991 1991-1992
Asia		1964-1965	1972-1973	1982	1997-1998 1999-2000
Europe	1950 1951-1952 1953-1954 1959		1975-1976	1989	1991
North America	1952-1954 1954-1957		1976-1977	1988-1989	
South America	1951	1961 1963-1964 1968			1997-1998

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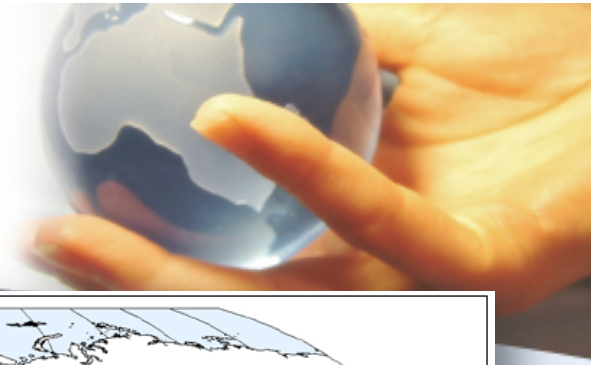
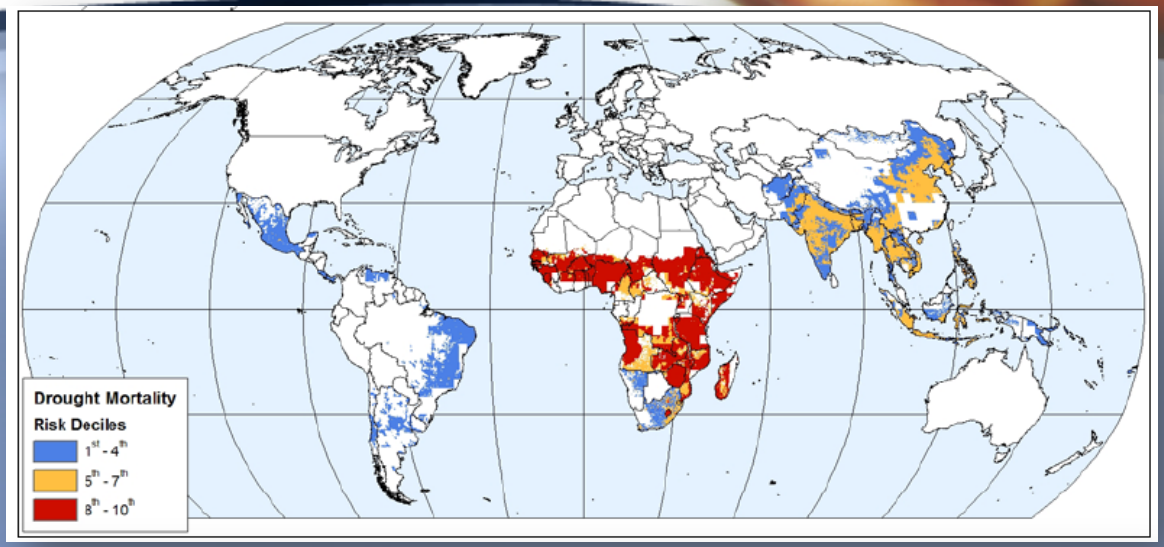
Source: Sheffield et al., 2009 and other sources

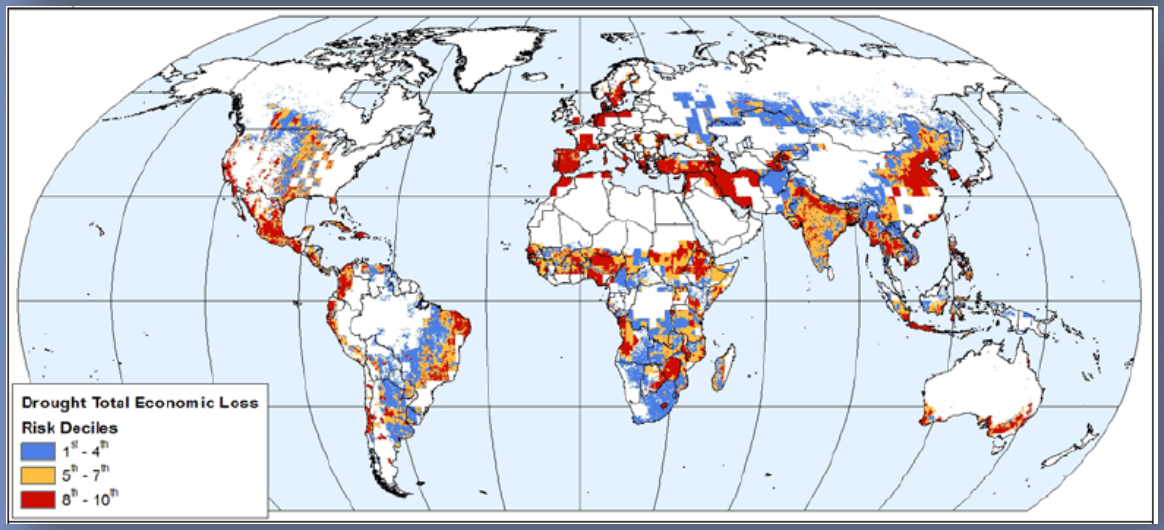
DISTRIBUTION OF DROUGHT EFFECTS (1980-2000)



Mortality



Total economic loss



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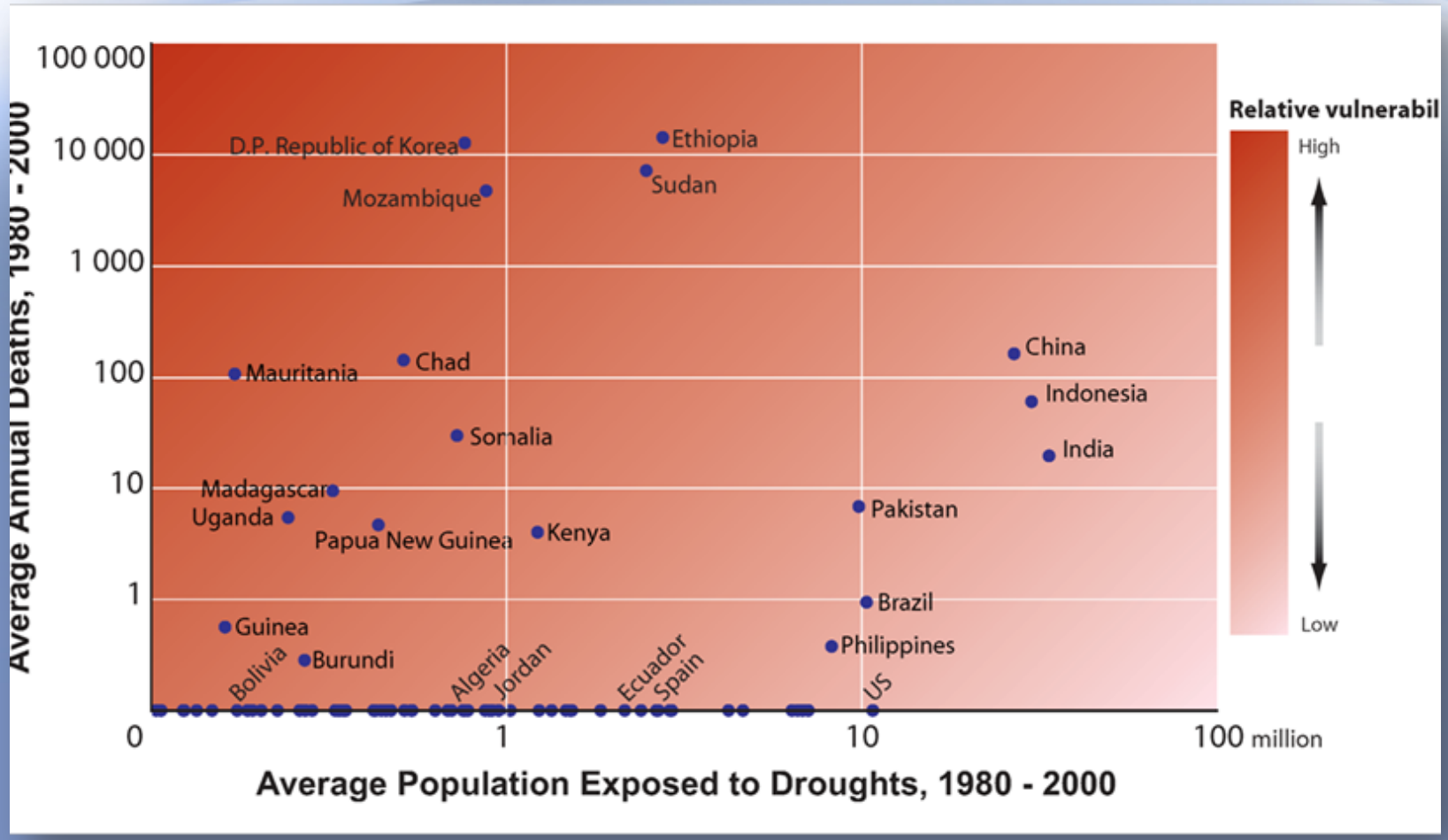
Source: Natural disasters hotspots: A Global risk analysis

Loss of Life due to Droughts



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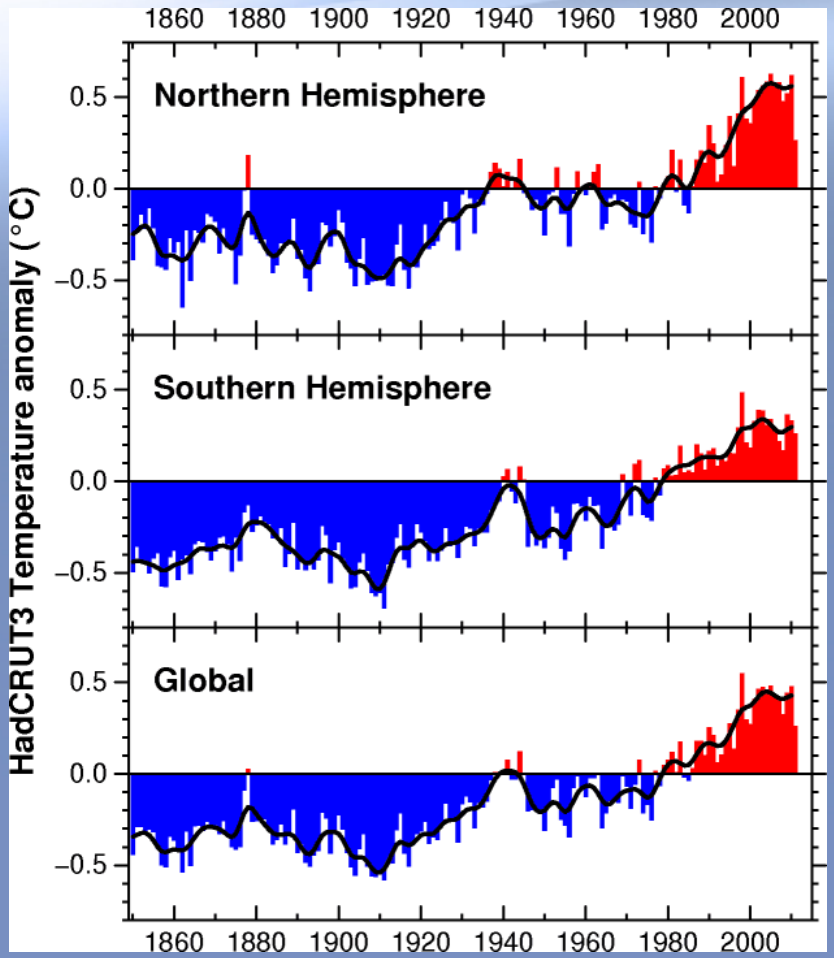
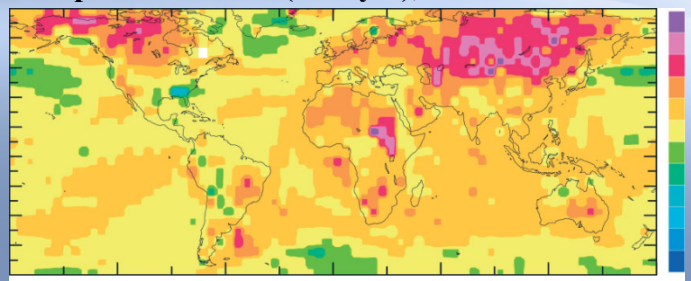
HYDROMETEOROLOGAL FACTORS AND DROUGHTS

(HISTORICAL TRENDS)

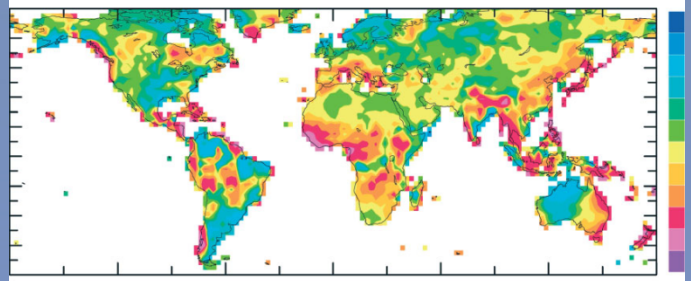


Source: http://www.cru.uea.ac.uk/cru/data/temperature/

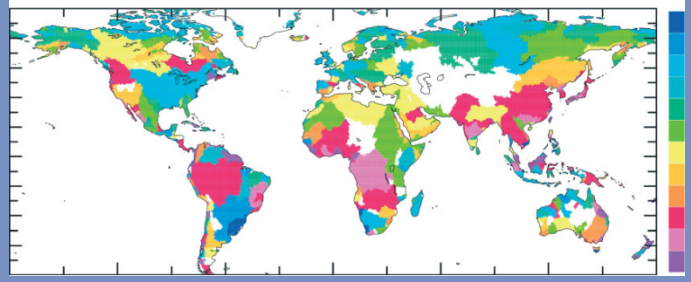
Temperature trend (K/50yrs), 1950-2008



Precipitation trend (mm/day/50yrs), 1950-2008



Runoff trend (0.1mm/day/50yr), 1948-2004



Source: Dai , Wiley Interdisciplinary Reviews: Climate Change, 2011

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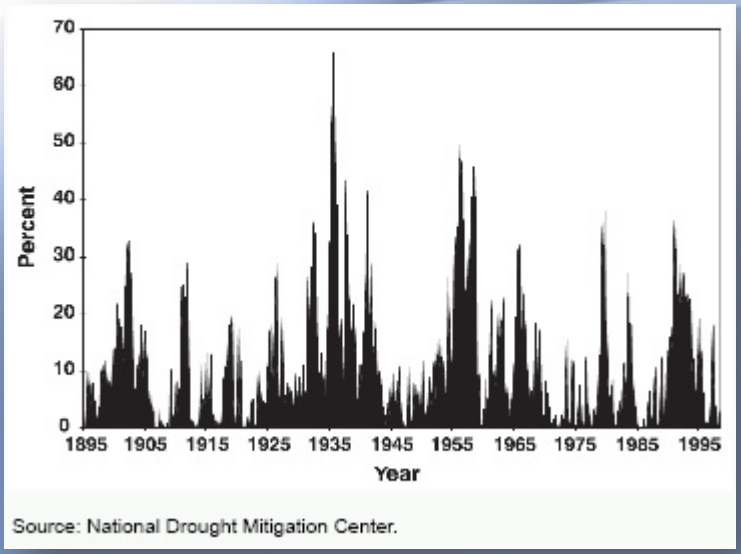
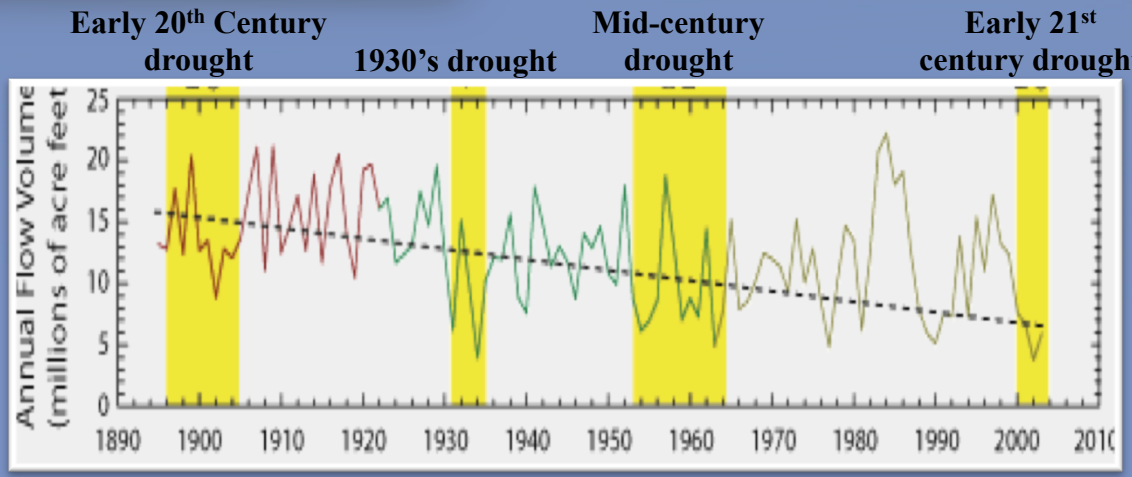
DROUGHTS IN USA



Source: National Drought Mitigation Center.

- Nearly 10% of the total land area experienced either severe or extreme droughts at any given time.
  - Cost $144 billion between 1980 -2003 (Ross and Lott, 2003)
- Dust bowl drought of 1930's is one of the severe droughts during 20th century.



Annual flow volume at Colorado River at Lee's Ferry (Source: USGS)

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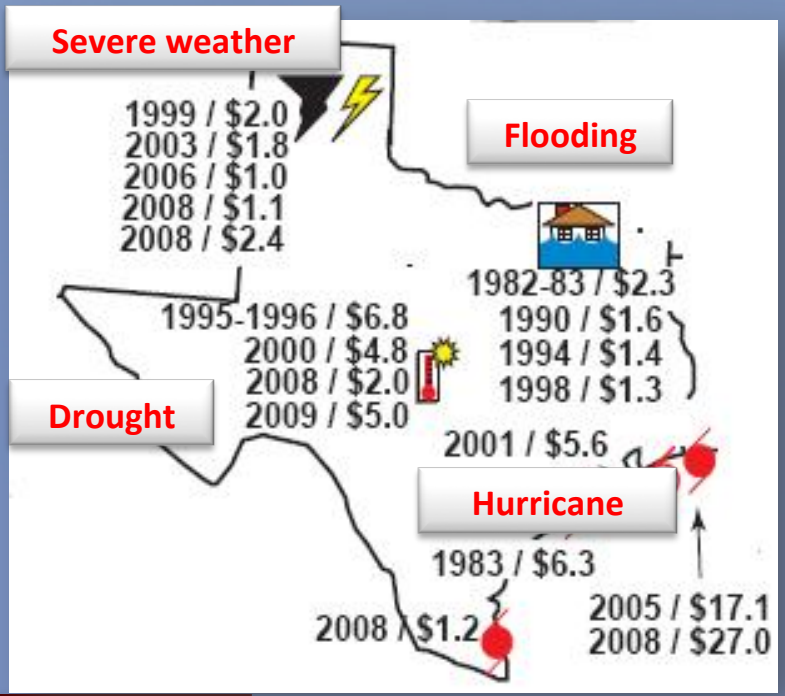
TEXAS DROUGHTS *(RECENT DECADES)* 1980-2009

- Drought
  - began in late 2007
  - worsened in 2008
  - continued through 2009



Source: NOAA

Source: AP Photo/Texas Farm Bureau, Matt Felder

Loss: $3.6 billion dollars!!!!

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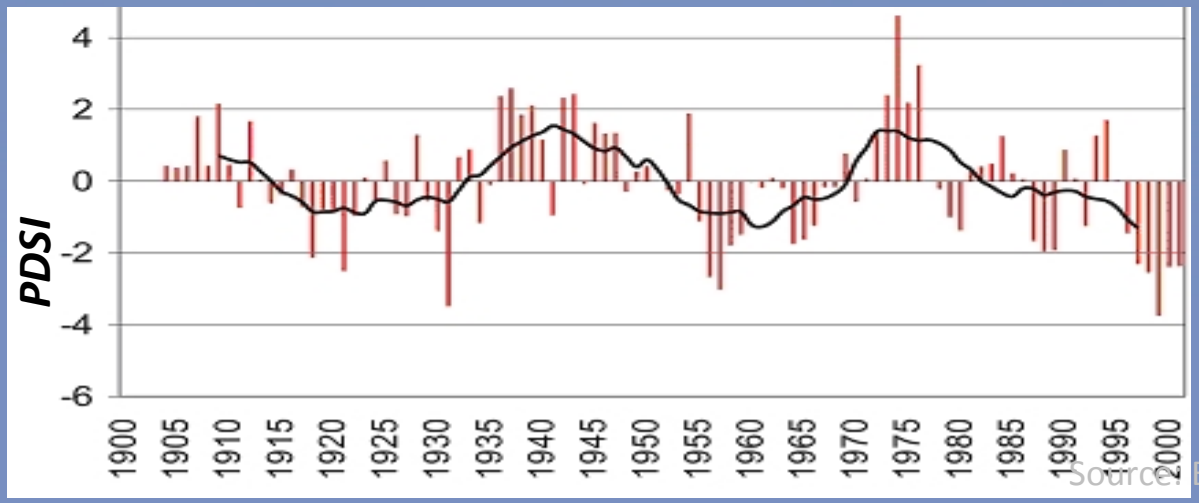
CANADA

- The Prairies are more susceptible to drought (Environment Canada, 2004).
- The 1999-2004 drought event produced the worst drought in over a hundred years in parts of Canada and in particular, the Canadian Prairies.
- In 2001, Saskatoon was 30% drier than in any year since 1891 (DRI, Canada).
- Drought occurred during 2002 cost $3.6 billion.

Time series: Annual PDSI – Location: Sherbrooke, QC



Source: Environment Canada

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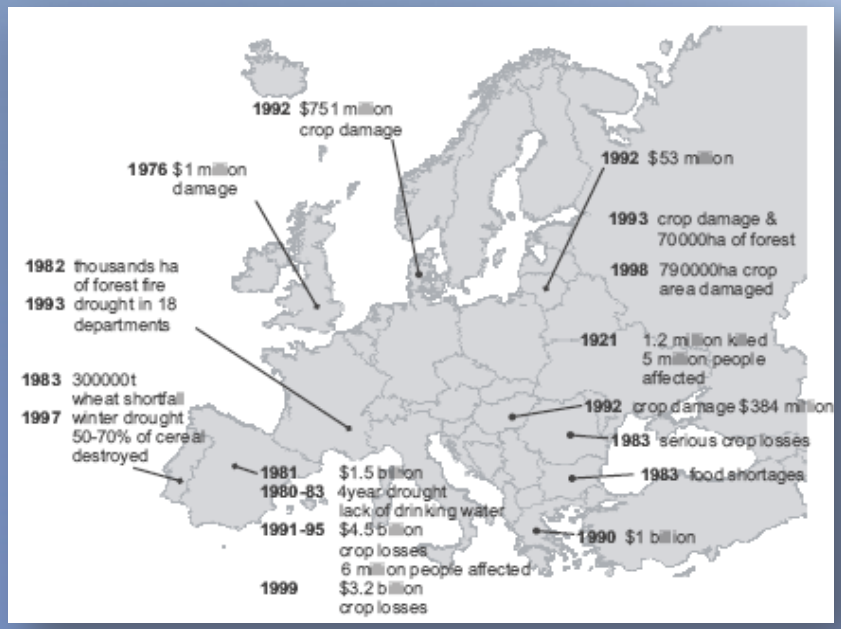
EUROPE

- During the past 30 years, several major droughts affected Europe (Mishra and Singh, 2010), most notably:
  - 1976 (Northern and Western Europe)
  - 1989 (most of Europe)
  - 1991 (most of Europe)
  - 2003 (large parts of Europe associated with the summer heat wave)
- Economic impact:
  - Since 1991, the yearly average economic impact been **€5.3 billion** Drought in 2003 amounting to at least **€8.7 billion**



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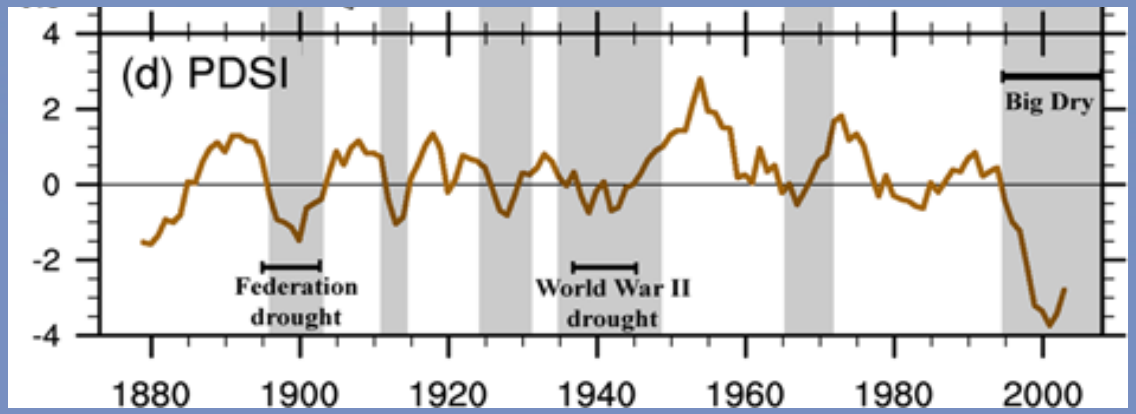
AUSTRALIA

- Major droughts
  - Federation Drought (1895–1902)
  - World War II drought (1937–1945): Occurred during the Dust Bowl episodes (1930's) in USA.
  - Big Dry (Since 1995's) is exceptional drought
- ENSO in general related to Australian drought cannot explain the ''Big Dry'', Instead, it is predominantly driven by the Indian Ocean Dipole (IOD).

Location: Southeastern Australia – ***Time series:*** 5-yr running mean of PDSI

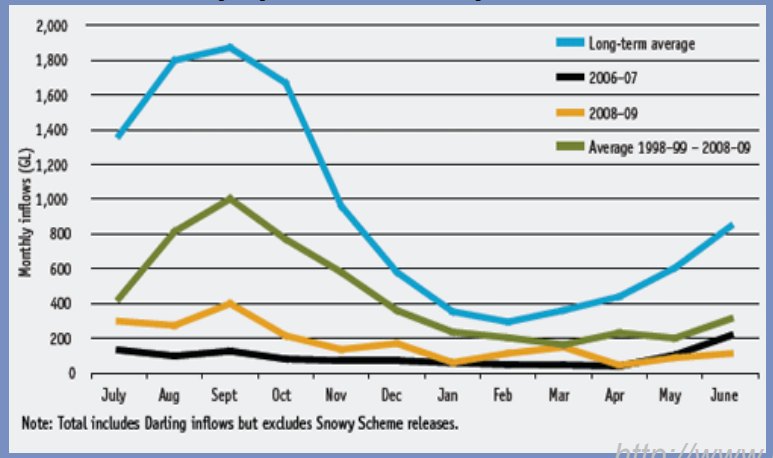


Source: Ummenhofer et al. (2009)

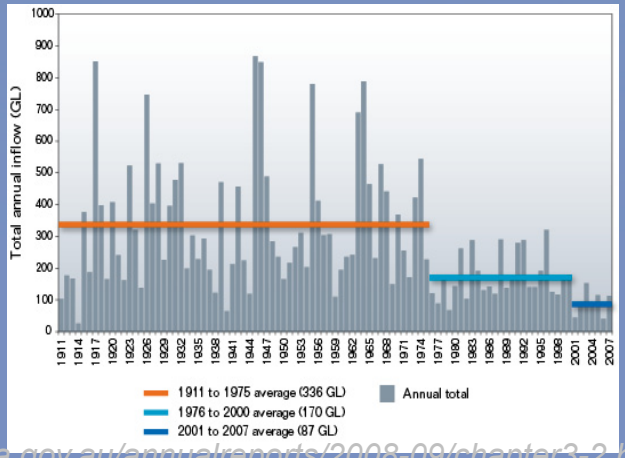
AUSTRALIA

- **Major Australian drought years (www.bom.gov.au)**
  - **1895-1903:** Sheep numbers halved & more than 40% loss of cattle.
  - **1911-16:** Loss of 19 million sheep and 2 million cattle.
  - **1939-45:** Loss of nearly 30 million sheep between 1942 and 1945.
  - **1982-83:** Loss estimated in excess of $3000 million. Most intense drought in terms of vast areas affected.
  - **1991-95:** Resulting in possible $5 billion cost to the economy.

River Murray system monthly inflows, 2008–09



Annual streamflows into Perth's dams



http://www.mdba.gov.au/annualreports/2008-09/chapter3-2.html

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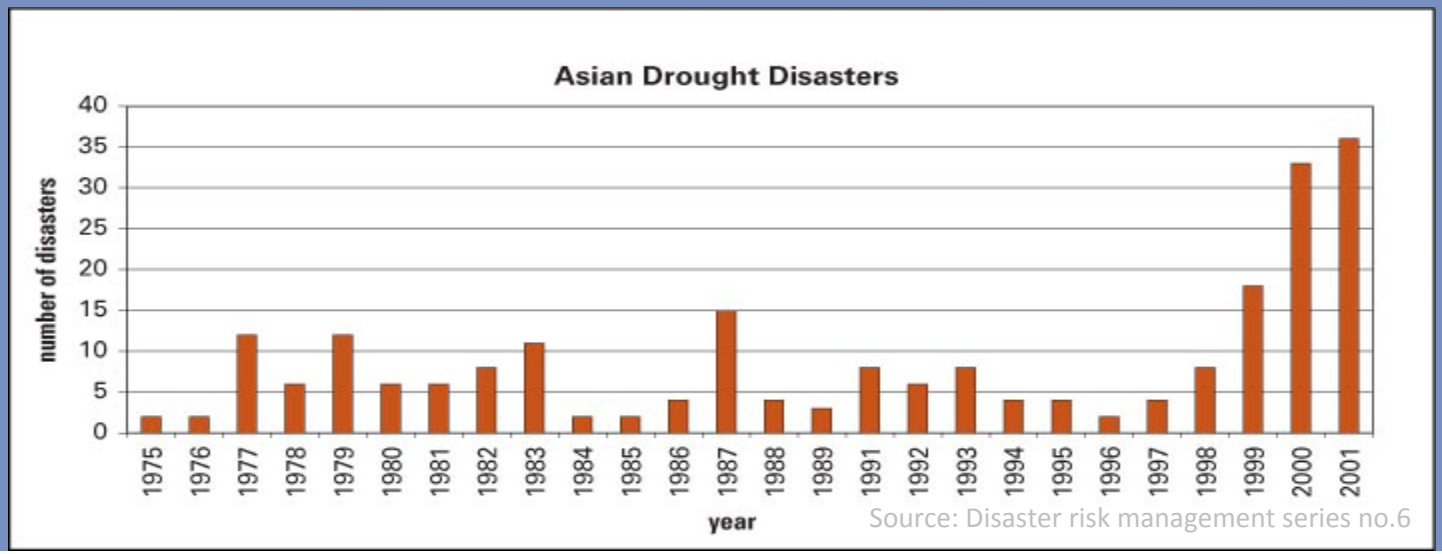
Asia

- Major causes: increasing water stress, temperature and frequency of El Niño events and reduction in the number of rainy days.
- China example:
  - During 1972–1997, there were 20 years during which the Yellow River experienced drying-up (zero streamflow) episodes. Example: during 1997 period, 226 days with no streamflow in the Yellow River in Northern China.



Source: Disaster risk management series no.6

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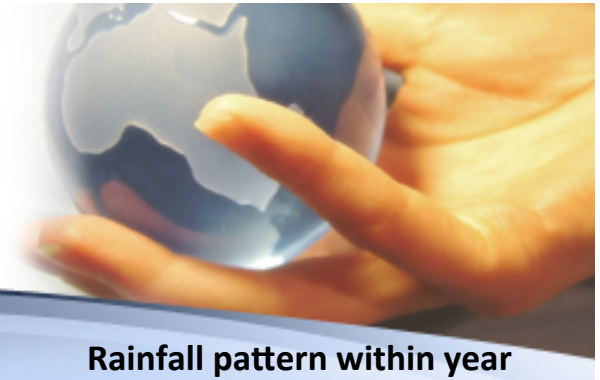
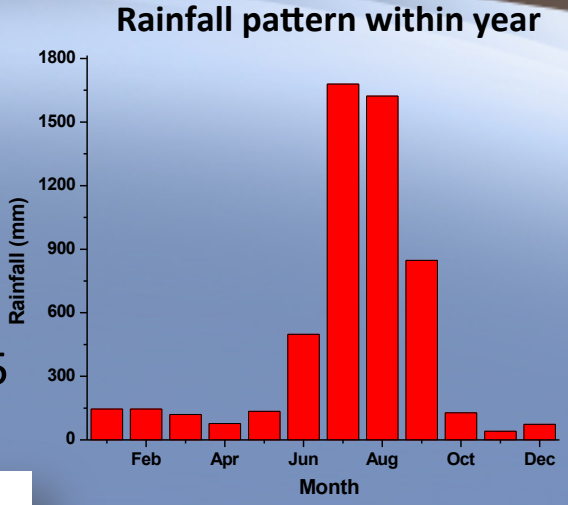
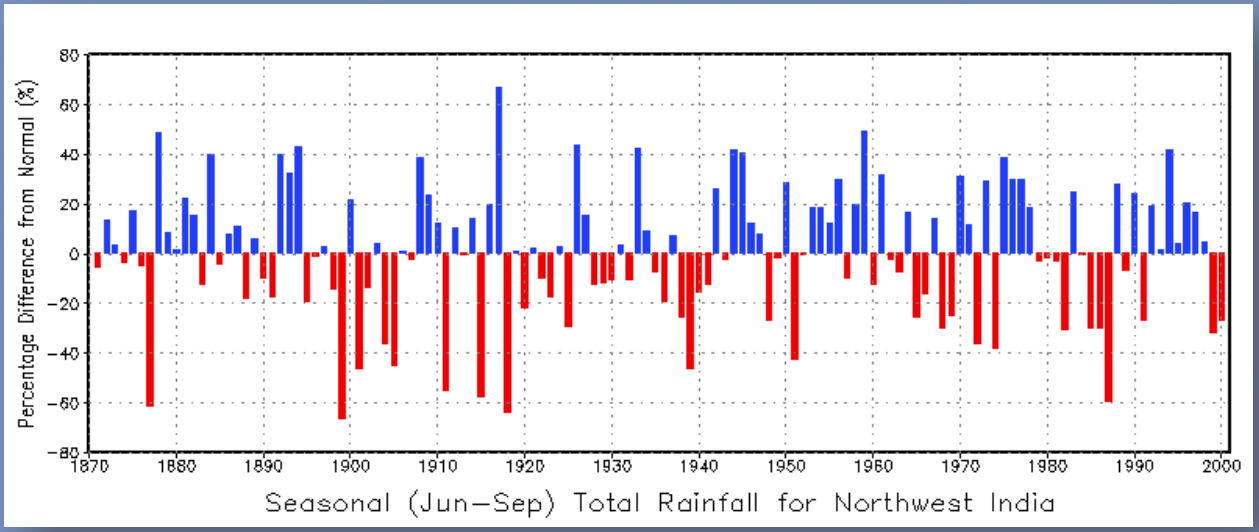
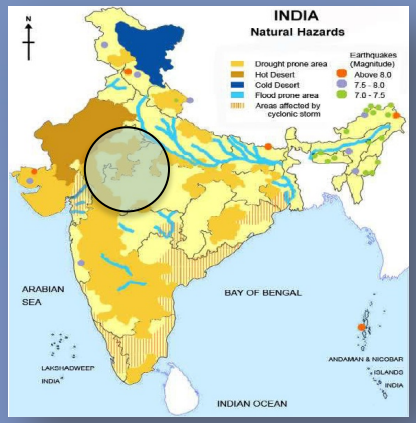
INDIA



- Indian agriculture is highly dependent on monsoon season.
  - Two-third of the land area vulnerable to drought.
  - Example of major drought: occurred in 1987
  - Due to deficiency in rainfall
  - Affected 60% of crop area & a population of 285 million







(Source: http://www.monsoondata.org/hist/)

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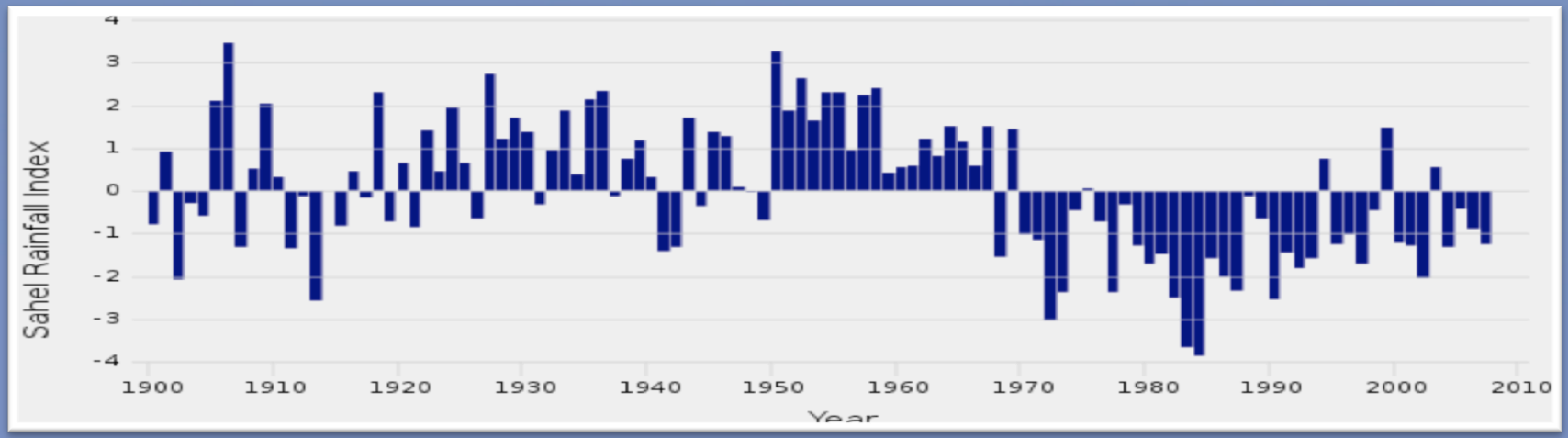
AFRICA (EXAMPLE: SAHEL DROUGHTS)

- Famine followed severe droughts in the 1910s, the 1940s, the 1960s, the 1970s, and the 1980s.
- From the late 1960s to early 1980s: 100,000 people were killed and 750,000 left dependent on food aid.
- ***Other countries suffered:*** Burkina Faso, northern Nigeria, southern Niger, northern Cameroon, Sudan, Ethiopia, Eritrea and Somalia.



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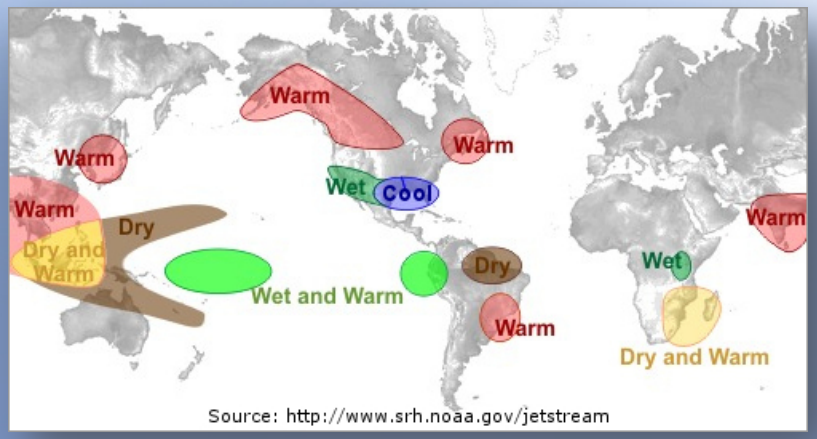
Source: JISAO

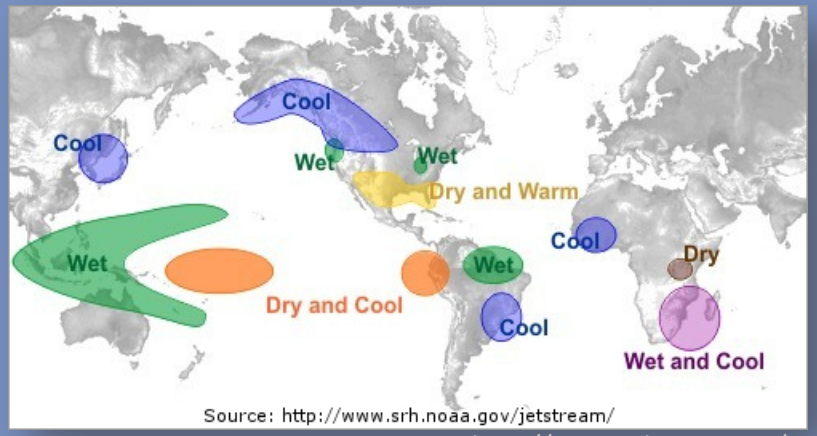
Climate Teleconnection (ENSO)

- El Niño-Southern Oscillation
  - Naturally occurring phenomenon that involves fluctuating ocean temperatures in the equatorial Pacific
  - Effect varies across the globe
- e.g., United States
  - El Niño (Warm Phase)
    - Enhanced precipitation across the southern US
  - La Niña (Cool Phase)
    - Less precipitation in the southern US

Typical El Niño Effects
December Through February



Typical La Niña Effects
December Through February



Source: http://www.srh.noaa.gov/jetstream

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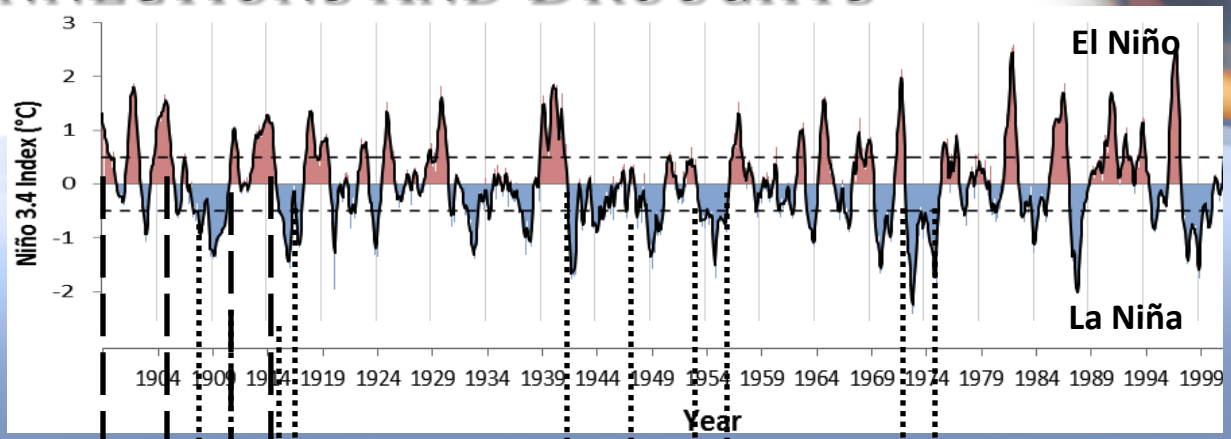
TELECONNECTIONS AND DROUGHTS



Monthly rainfall pattern in a year

Texas (USA) La Niña

North west India (El Niño)

Southeast Australia (El Niño)

England

Inter-arrival time: El Niño : 2 to 7 years
North west India: 1 to 5 years (mean: 1.8 years)
Texas: 1 to 5 years (mean: 2 years)
Southeast Australia: 1 to 4 years (mean: 1.85 years)
England: 1 to 4 years (mean: 2 years)

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CLIMATE CHANGE AND DROUGHTS

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Overall Impacts of Climate Change

- Fresh water availability
- Extremes (Flood/droughts)
- Ecosystem and bio-diversity
- Agriculture
- Energy
- Human health
- Water supply and sanitation
- Infrastructure
- Economy

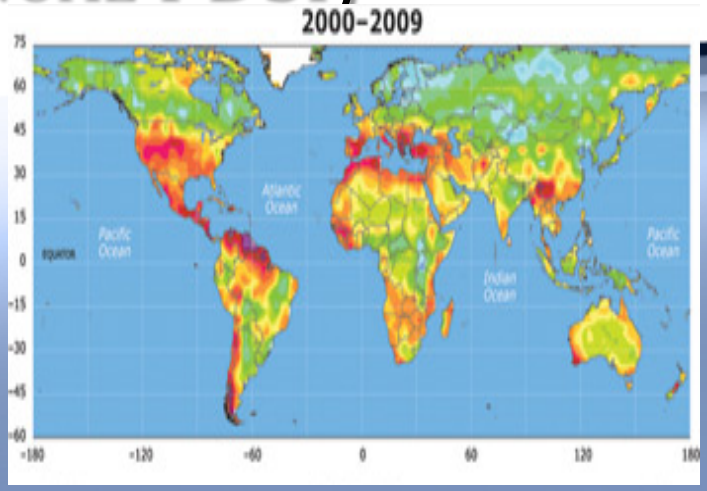
WHAT IPCC REPORT SAYS FOR 21ST CENTURY?

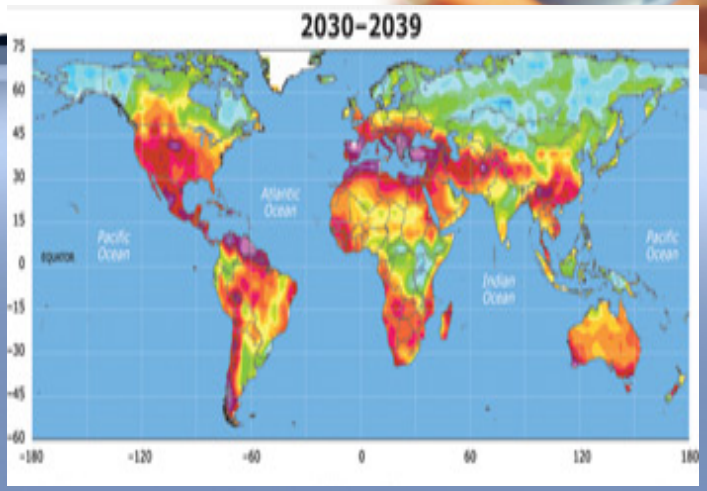
- Many semi-arid and arid areas are particularly projected to suffer a decrease in water resources (e.g., the Mediterranean Basin, western USA, southern Africa and northeastern Brazil).
- The proportion of land surface in extreme drought at any one time is projected to increase, in addition to a tendency for drying in continental interior during summer, especially in the sub-tropics, low and mid-latitudes.
- Water supplies stored in glaciers and snow cover are projected to decline in the course of the century, thus reducing water availability during warm and dry periods.

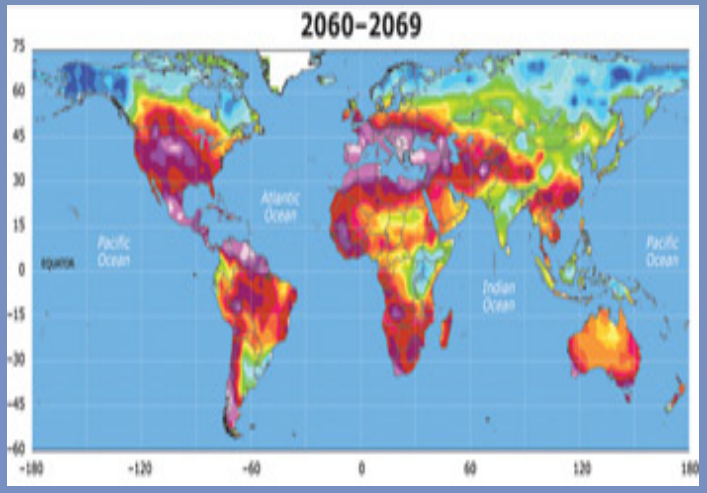
AGRICULTURE AND FOOD SECURITY

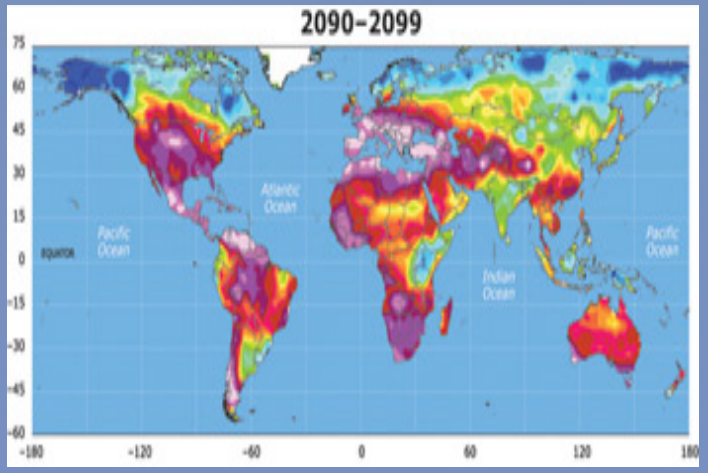
- The climate change will affect agricultural productivity (World Bank, 2007)due to:
  - Changes in precipitation, temperature, carbon dioxide (CO2) fertilization, climate variability, and surface water runoff.
  - Example: Temperature increases of ~1◦C to 3◦C would reduce yields of three temperate-zone California perennials (almond, walnut, and table grapes) by 2050 (Lobell et al., 2006) (based on 22 climate models and three IPCC scenarios).

Future Droughts (based on mean annual PDSI)









-20 +20

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Dai (2010)

CONCLUSIONS

- Drought adversely affects water resources and other allied sectors. For example, severe societal impacts from Sahelian drought (in Africa) and Dust Bowl drought (USA) can be considered as eye openers.
- In the 20th century, from the middle of the century, drought areas have increased substantially in many parts of the world
- Using coupled climate models from the IPCC AR4 project increased aridity in the 21st century, with continued drying over most of Africa, southern Europe and the Middle East, most of Americas, Australia, and Southeast Asia.
- The inter-arrival time of droughts for different parts of the world can be related to climate indices for better drought prediction.