# Water supply today and in the future

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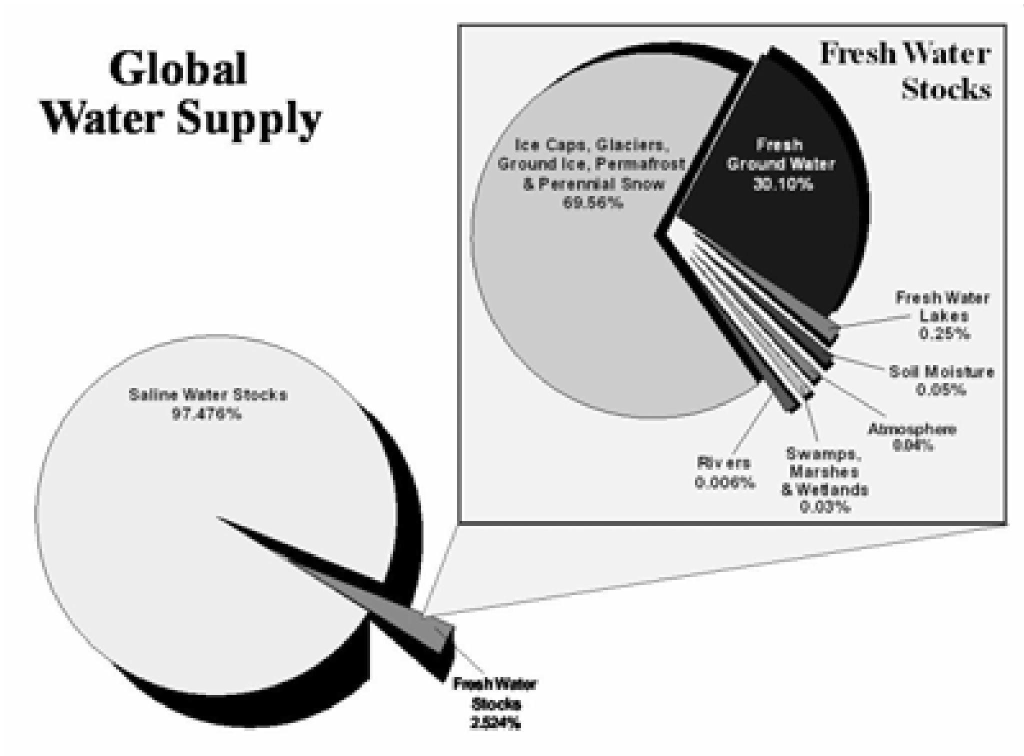
# Overview

1. Water reservoirs on Earth & the Hydrological Cycle
2. Global freshwater supply vs. demand
3. Uneven distribution: Large regional and seasonal differences
4. Water usage: conflicts and problems (quantitative vs. qualitative aspects)
5. Water crisis? Water supply in the future

# Volume of water stored in the water cycle's reservoirs:

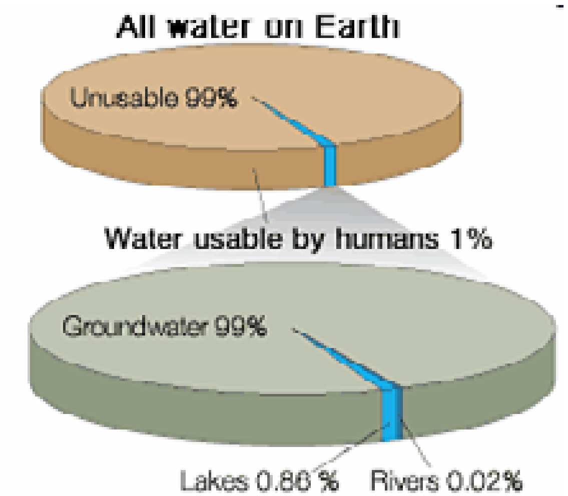
| | Vol ($10^6$ $km^3$) | % of total |
|---|---|---|
| Seas and oceans | 1370 | 97.25 |
| Ice caps, glaciers and snow covers | 29 | 2 |
| Groundwater | 9.5 | 0.7 |
| Lakes | 0.125 | 0.01 |
| Soil moisture | 0.065 | 0.005 |
| Atmosphere | 0.013 | 0.001 |
| Streams and rivers | 0.0017 | 0.0001 |
| Living beings | 0.0006 | 0.00004 |

# Global Water Supply




http://www.buzzfeed.com/jonah/global-water-supply-chart

# The water supply on Earth is immense, but only ~1% is directly usable

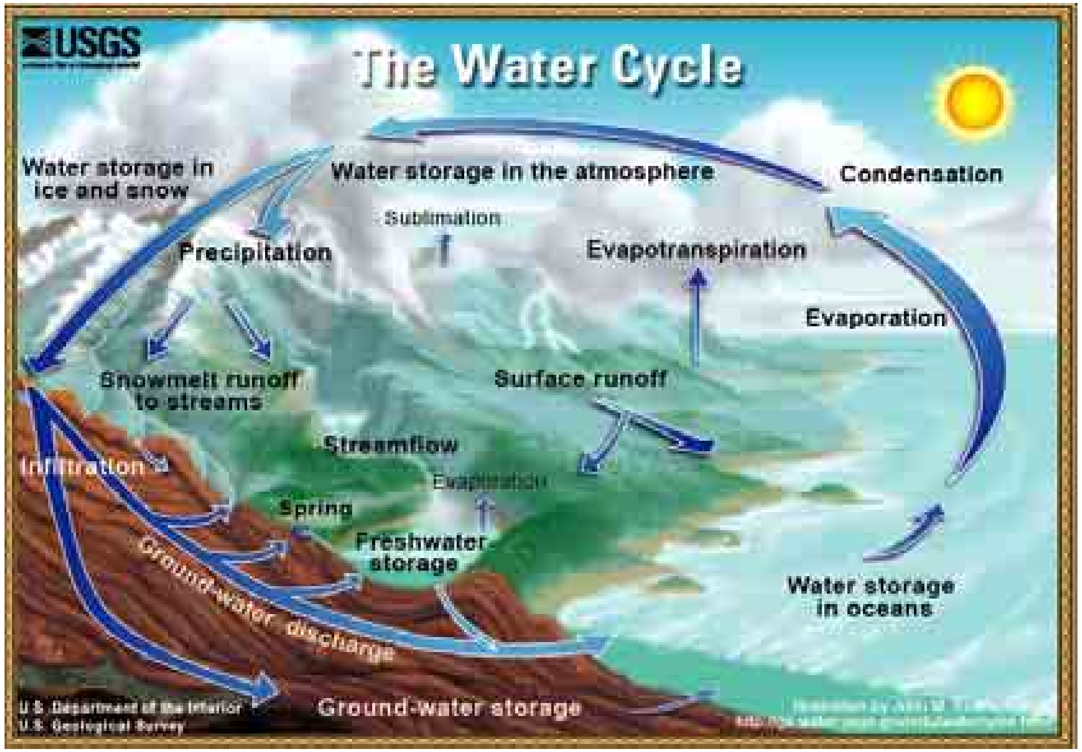


# The good news: Water renewal is much faster in freshwater than in the oceans

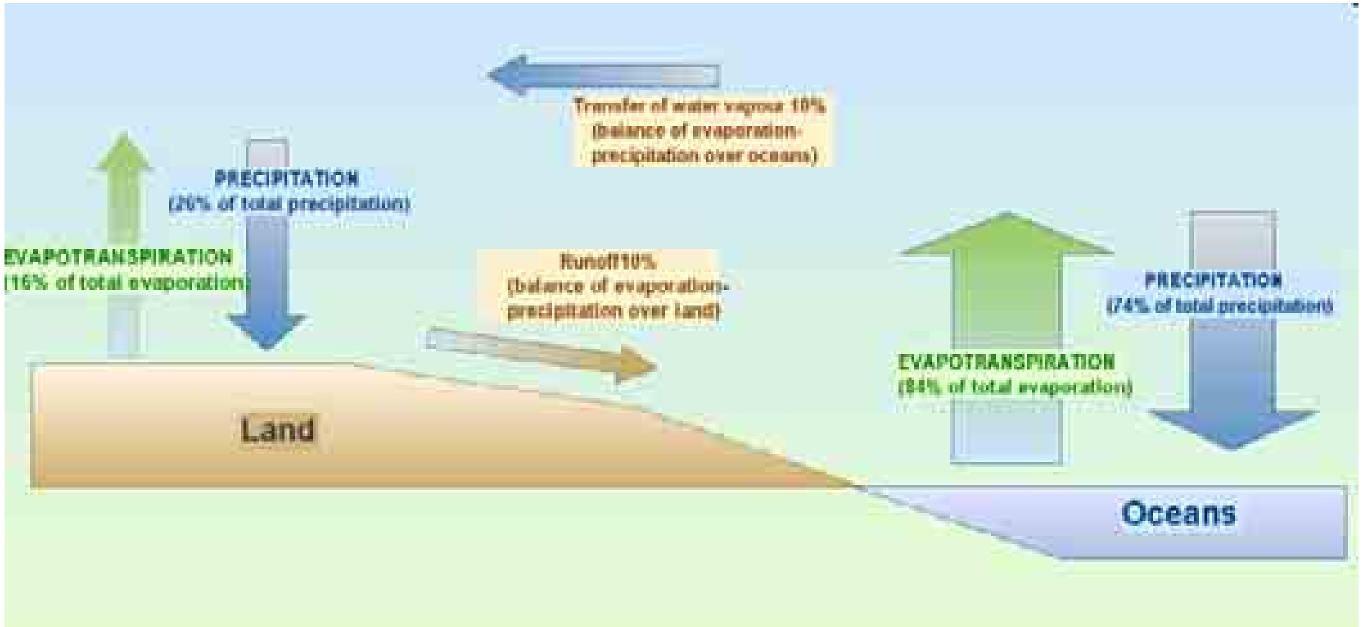
## Average residence times:

| | |
| --- | --- |
| Groundwater: deep | 10,000 years |
| Seas and oceans | 3,200 years |
| Groundwater: shallow | 100 to 200 years |
| Lakes | 50 to 100 years |
| Ice caps and glaciers | 20 to 100 years |
| Streams and rivers | d to 6 months |
| Seasonal snow covers | 2 to 6 months |
| Soil moisture | 1 to 2 months |
| Atmosphere | 9 days |

# The Water Cycle (Hydrological Cycle)



# The Global Water Balance

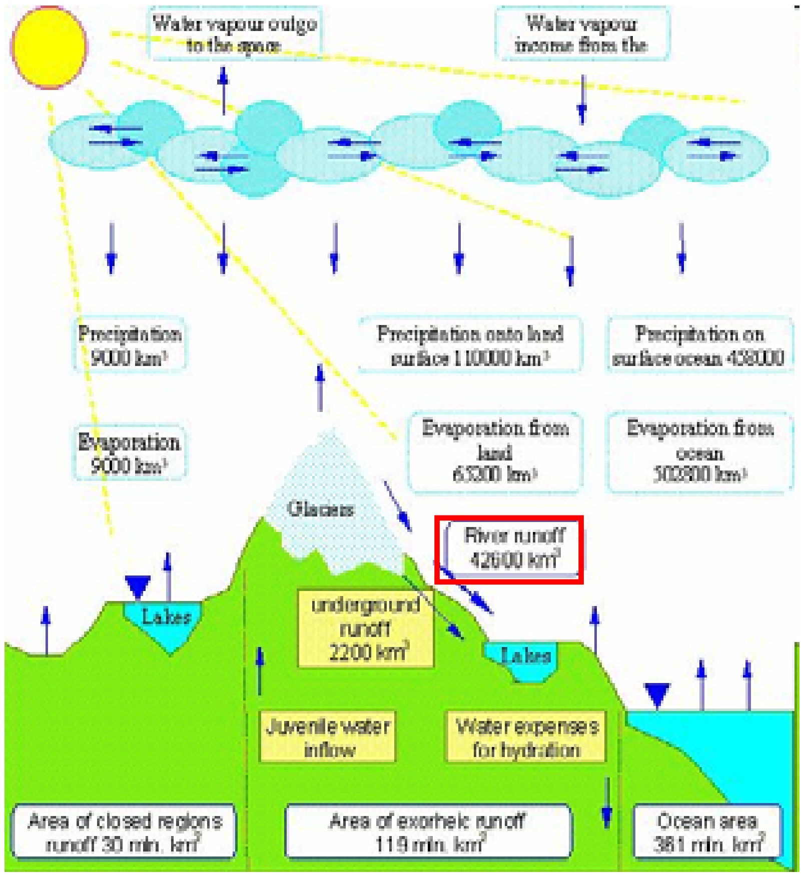



For continents, the balance of water is:

$$P = E + r$$

(P = precipitation, E = evapotranspiration, r = runoff)

Global river discharge ≈ potential freshwater supply

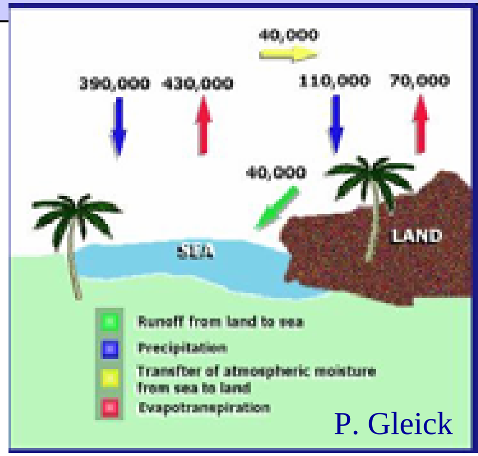



Source: St Petersburg State Hydrological Institute (I. Shiklomanov)

# Major problems (from a hydrological and economic point of view)

- Regional and seasonal differences in the water supply and water balance (uneven distribution of precipitation)
- Water transportation over long distances is not economic
- Seawater desalination is energy consuming and expensive

# Is there enough freshwater?



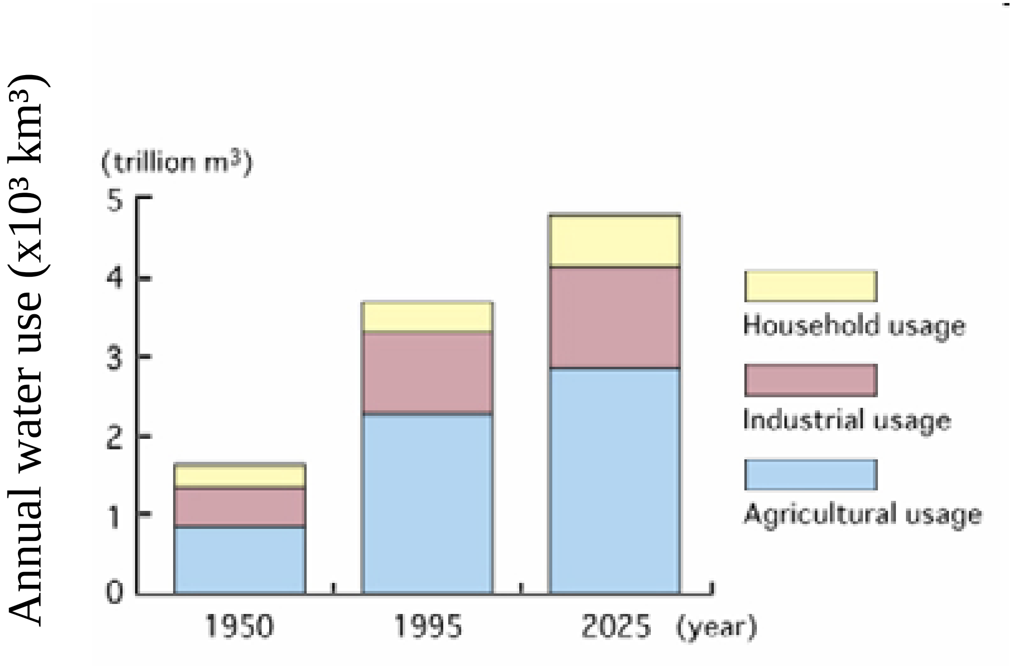

- Potential freshwater supply ~40,000 $km^3\ y^{-1}$
- Global human population ~6.8 x $10^9$
- Potentially per person and y ~5,880 $m^3$ available
- Each person would have 16,100 L $d^{-1}$
- Domestic consumption <20- >1000 L $pers.^{-1}\ d^{-1}$
- Industrial consumption ~ 1,500 L $pers.^{-1}\ d^{-1}$
- Agricultural use can exceed 5,000 L $pers.^{-1}\ d^{-1}$

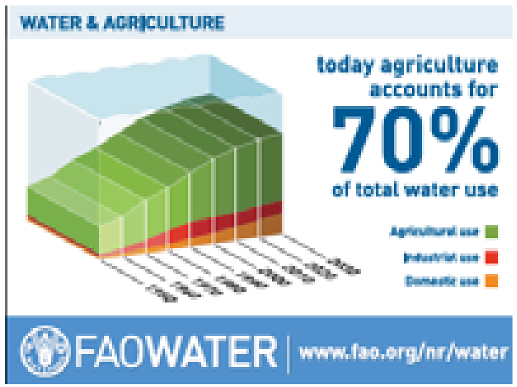

(Food) quality matters for water consumption

## ~10% of the potential water supply is currently being used

(588 $m^3$ per person and year)

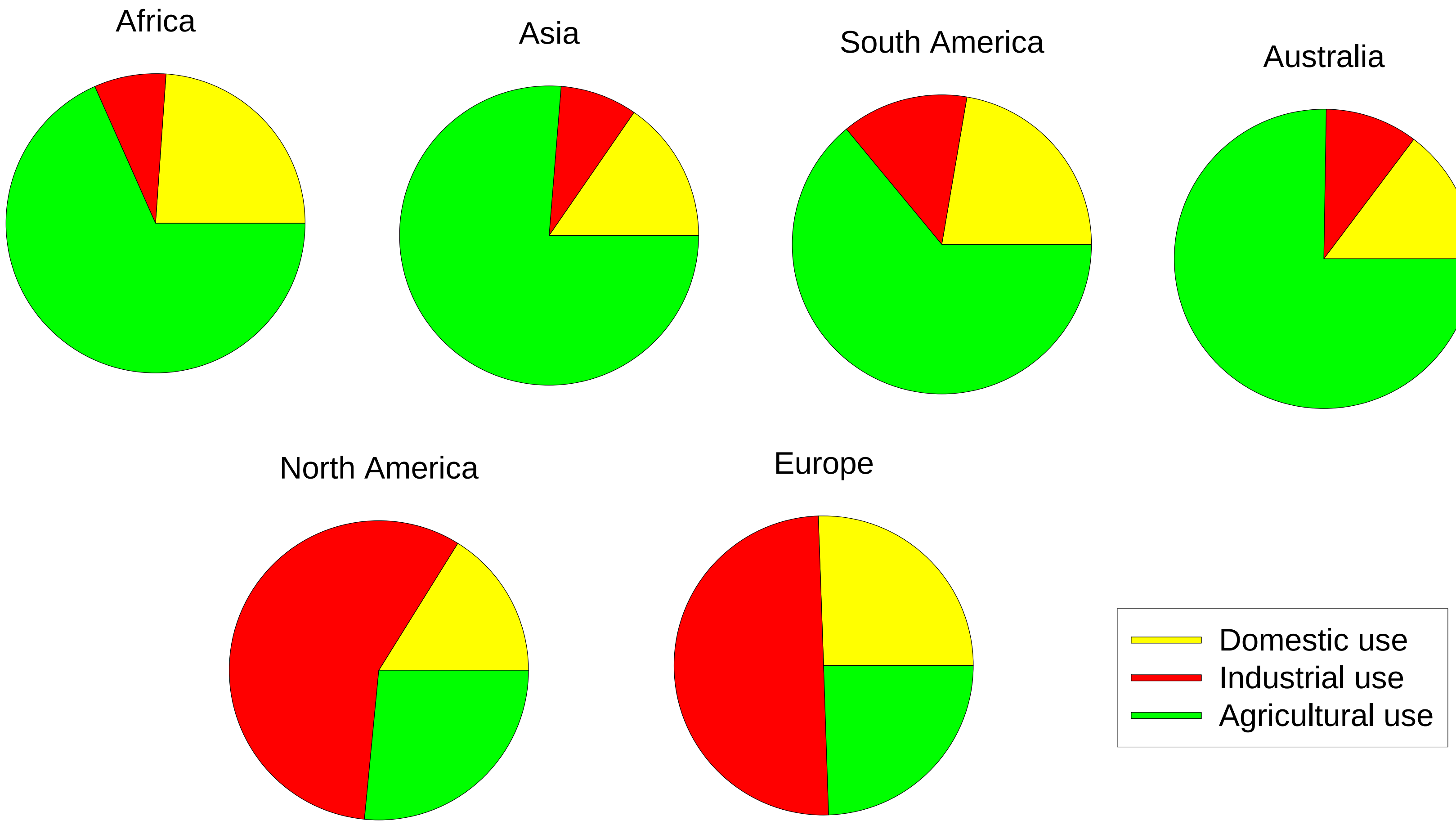
## This is expected to increase to 12.2% by 2025




Rapid and overproportional increase of (agricultural) water usage

# Relative water use (%)

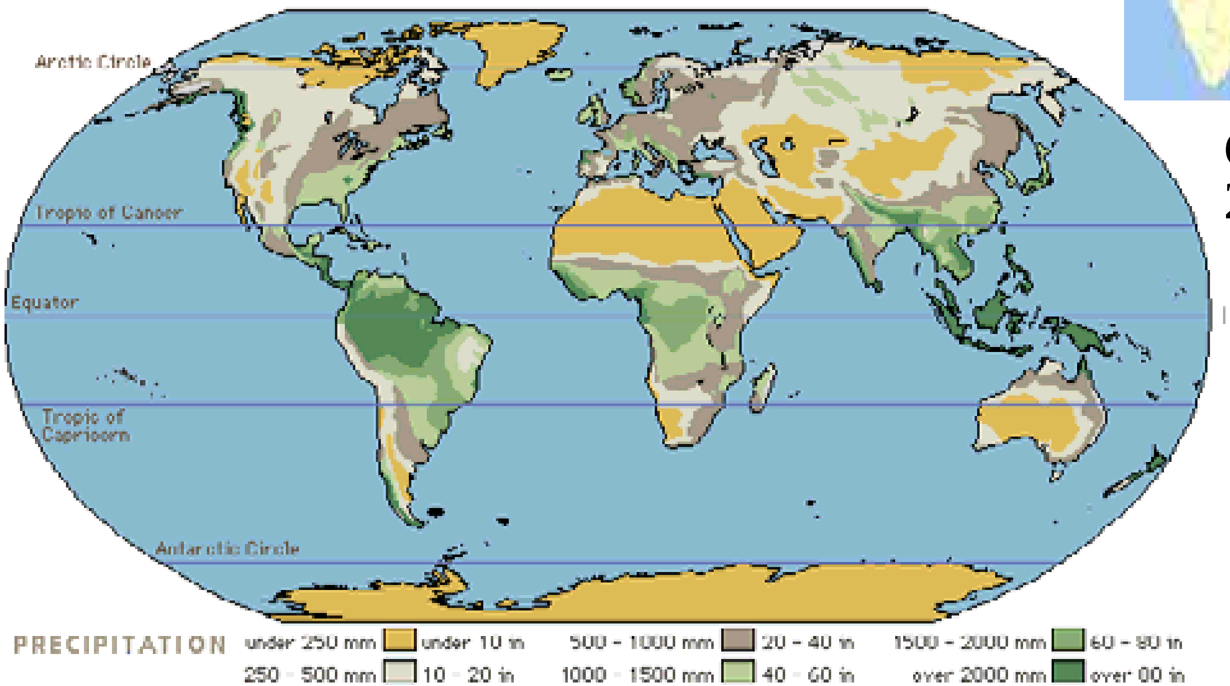


# Water as a resource

- On a global and long-term scale, water is renewable and is not consumed
- Locally (regionally) and temporarily, water can be consumed and is not renewable

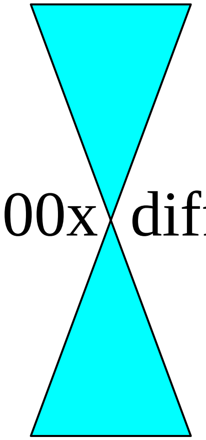
The appropriate scale for understanding water scarcity is at the local or regional level (UN Water 2007)

# uneven distribution of precipitation





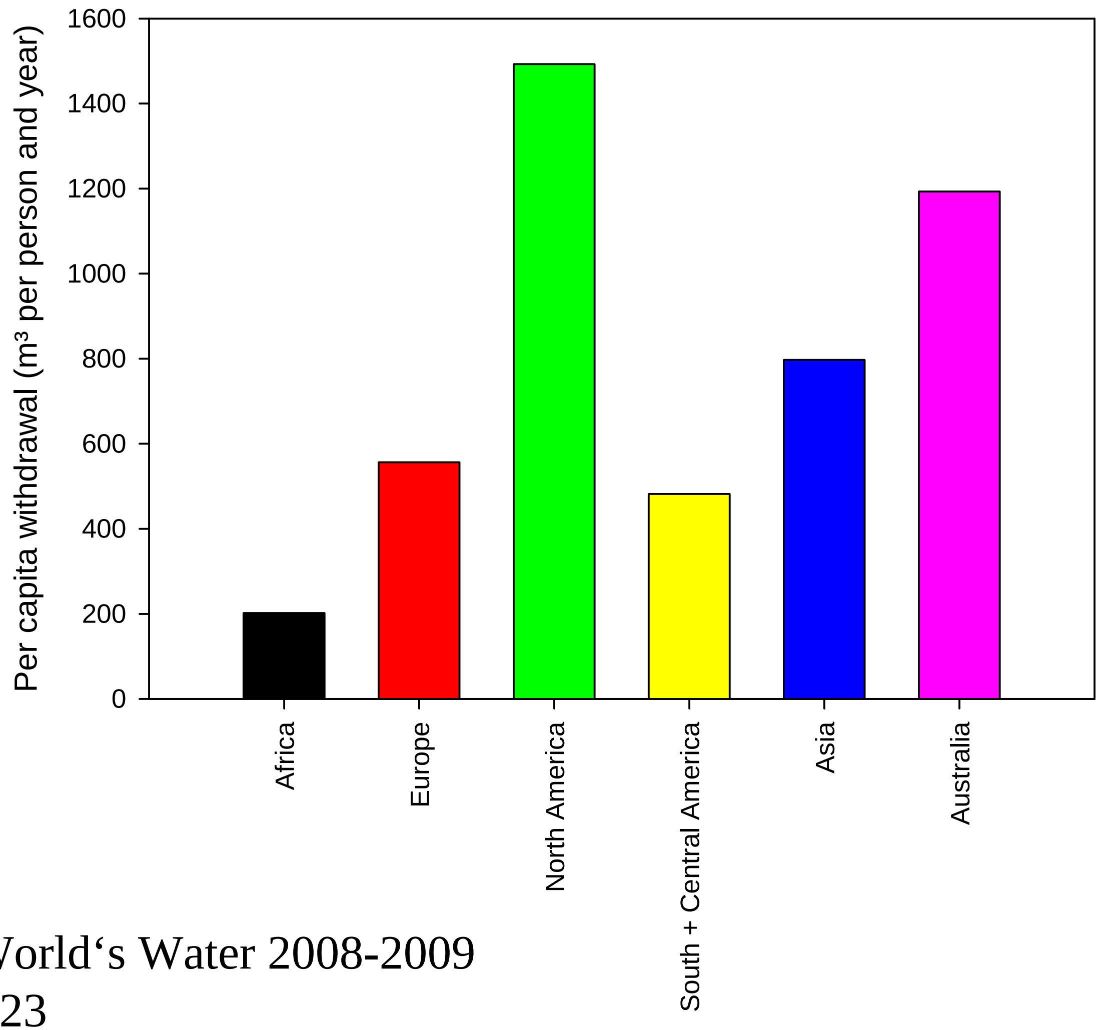
Cherrapunjee region,
26,461 mm per year



1000x difference

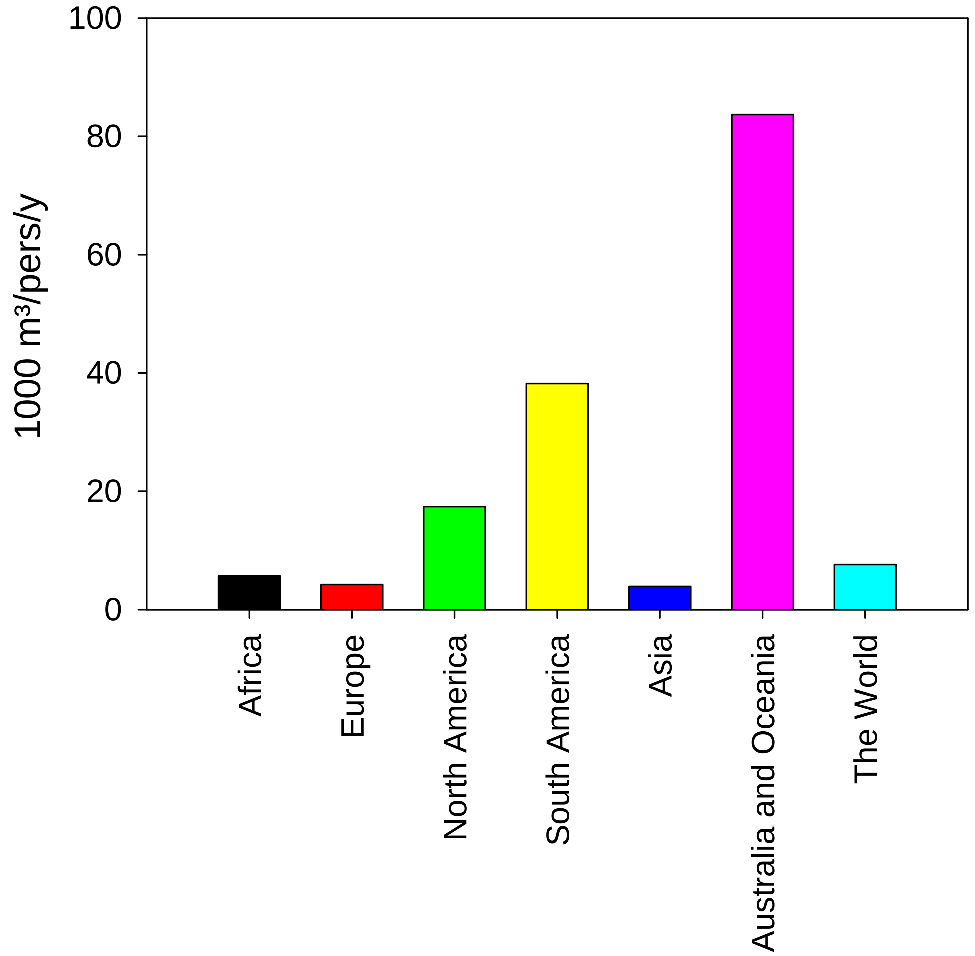
Atacama Desert,
Northern Chile
Wadi Halfa, Sudan
with <25 mm

# Absolute per-capita water use



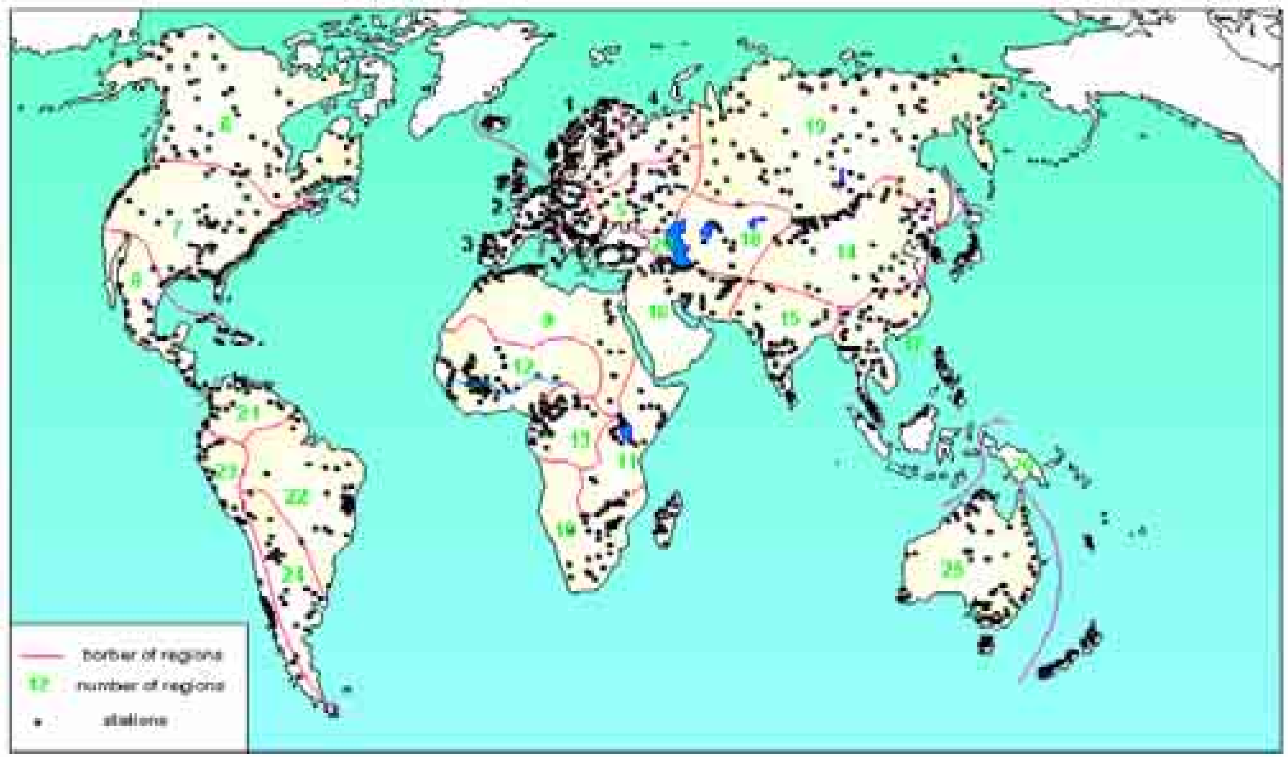

Sources:
Gleick, P.H.: The World‘s Water 2008-2009
FAO Water Report 23
FAO Aquastat database

# Potential water availability

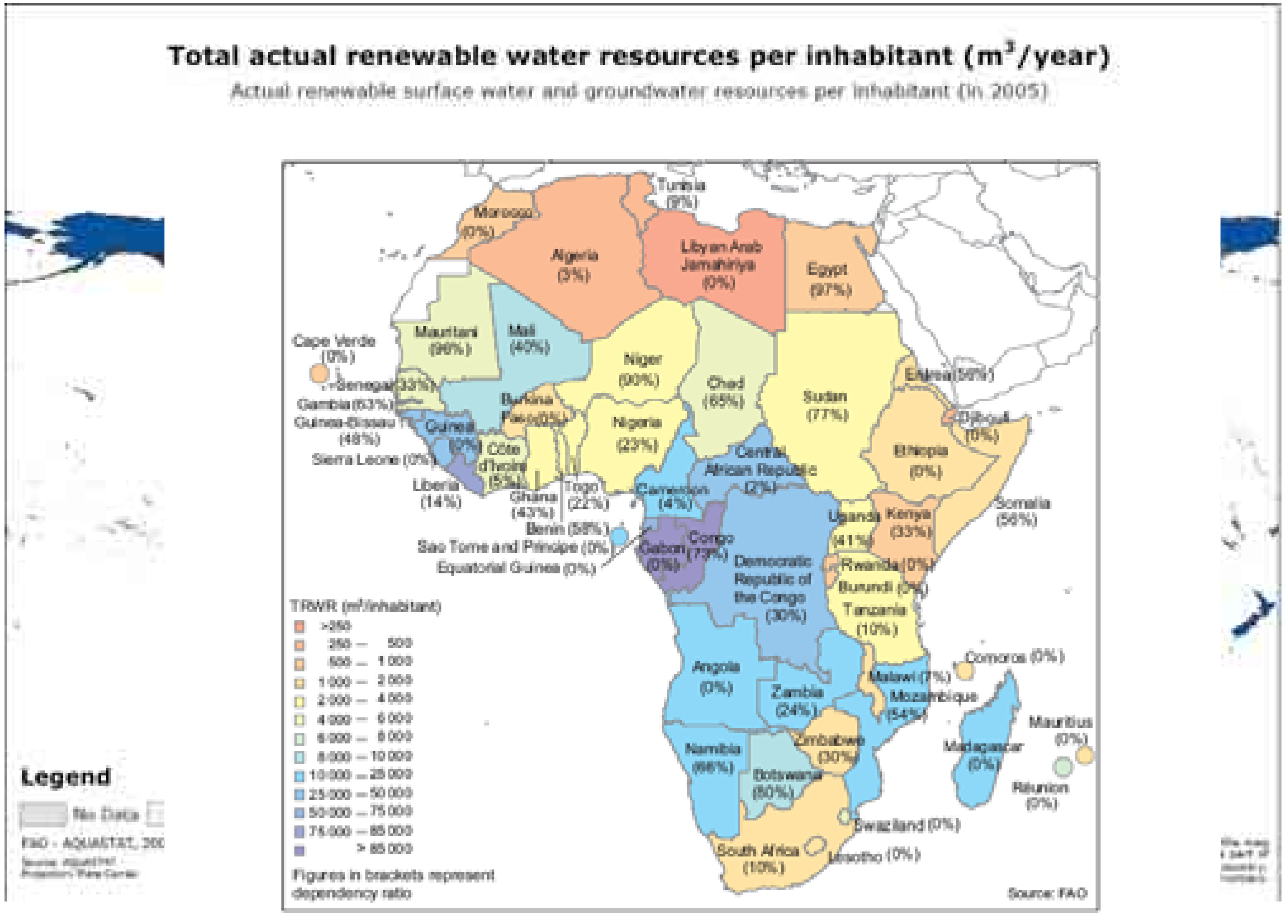



Sources:
FAO Water Report 23
FAO Aquastat database

# The natural-economical regions of the World and gauge stations




For estimation of renewable water resources on the global scale, the observation data (monthly and annual) from about 2500 hydrological sites have been used (Source: SHI, I. Shiklomanov)

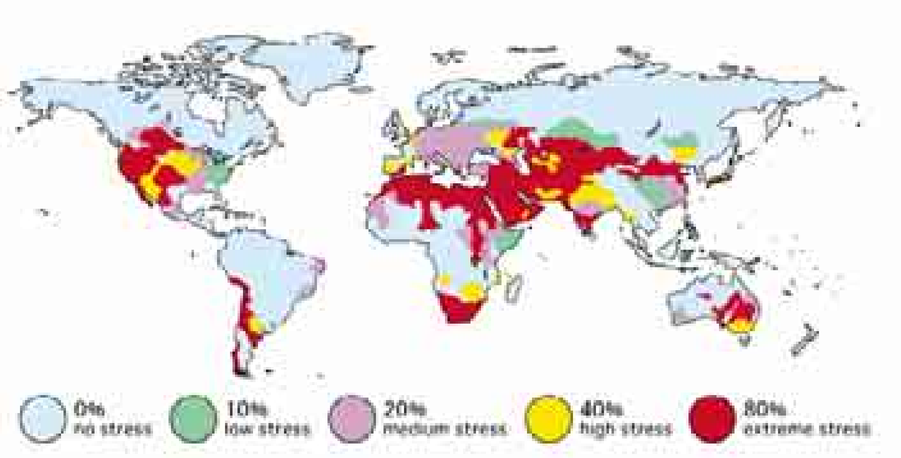



Water scarcity below 1,000 m³/person/y,

severe water scarcity below 500 m³/person/y

# Key concept: Water Stress

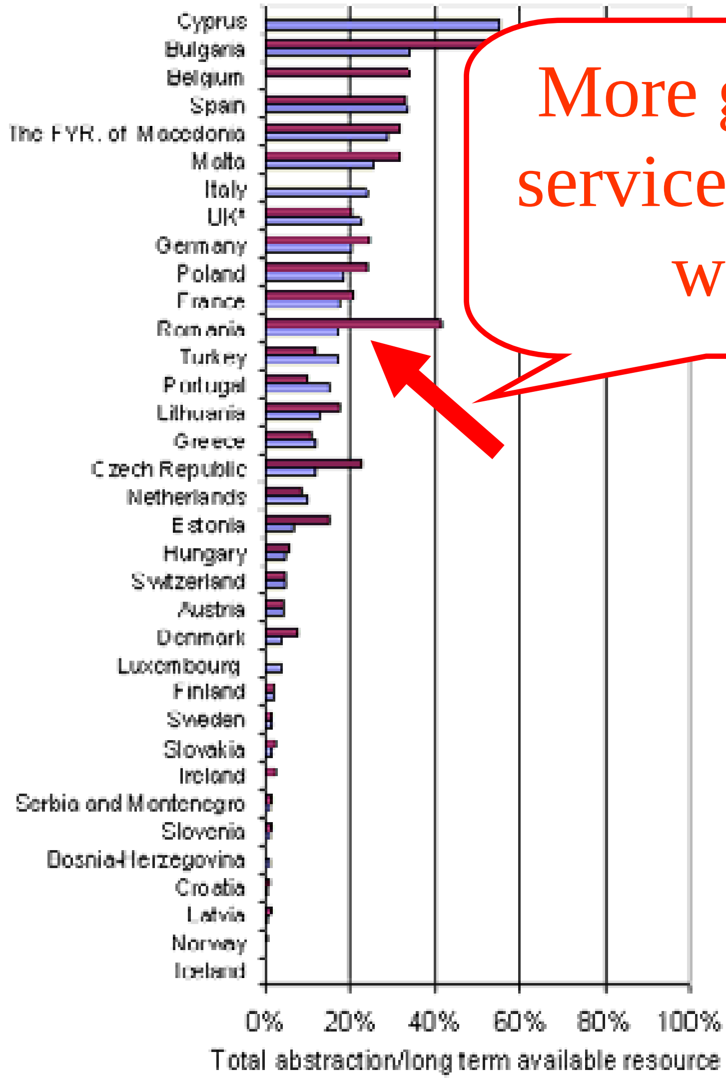
2025 –Status-quo Scenario




Source: World Water Council & Sience on Sustainability Summary Report 2006

Water stress (according the UNEP definition) occurs if the withdrawal-to total-availability ratio (=water exploitation index,WEI) exceeds 10%. Severe water stress can occur where the WEI exceeds 40 %, indicating unsustainable water use

# Water stress is not restricted ... )arid areas

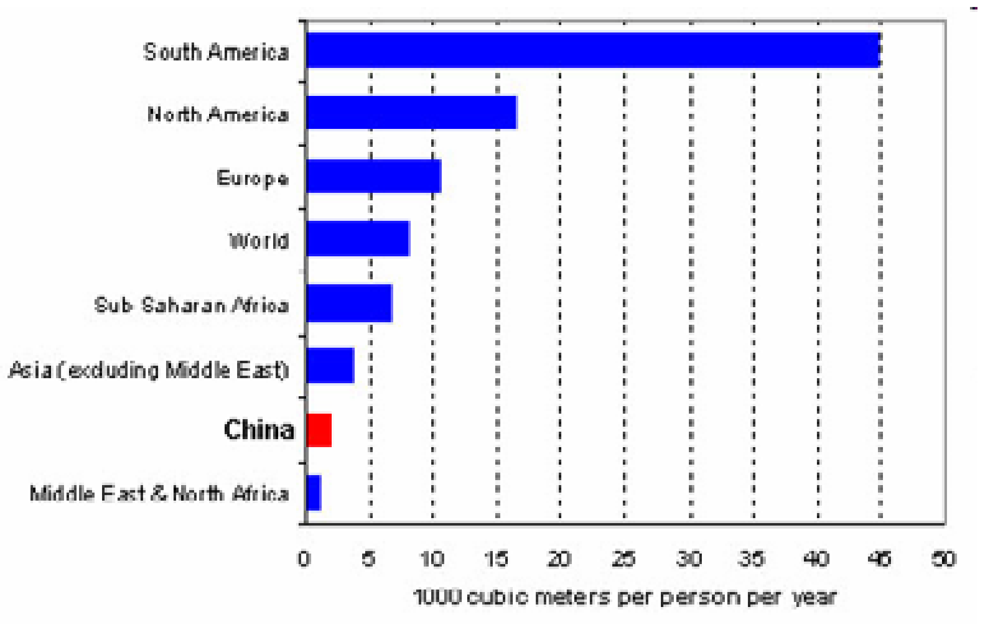



More goods & services for less water

...e eight countries can be ... water-stressed (Germany, ...d Wales, Italy, Malta, Belgium, Spain, Bulgaria and Cyprus), representing 46% of Europe's population. High water abstraction for non-consumptive uses (cooling water) occurs in Germany, England and Wales, Bulgaria and Belgium. Most of the water abstracted in the other four countries (Italy, Spain, Cyprus and Malta) is for consumptive uses (especially irrigation) and there is therefore higher pressure on water resources in these four countries.

(WEI =water exploitation index; Source: EEA CSI18 & Eurostat, 1992-2003)

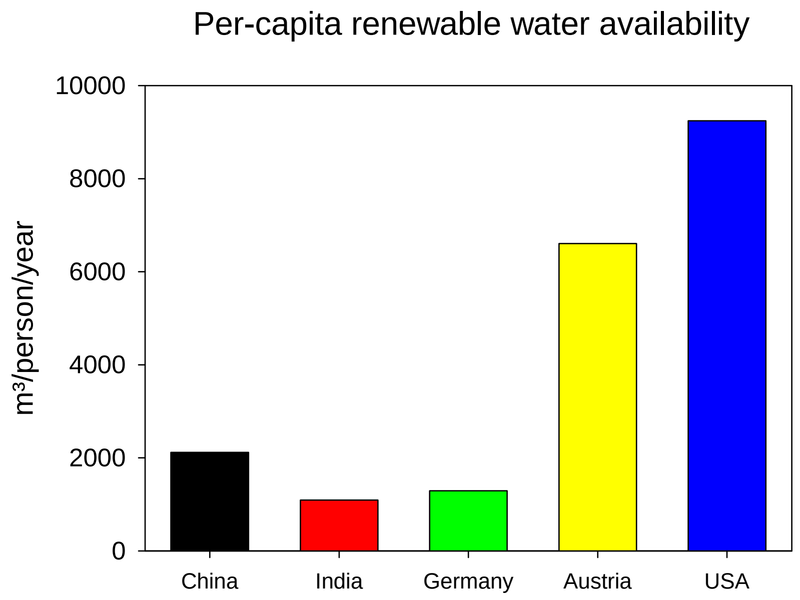
## Water Availability Per Capita, 2007




Source: EarthTrends 2007, The World Resources Institute

# China

- ~ One fifth of the world's population
- Only 7 percent of global water resources
- Per-capita water availability is low




Source: www.fao.org/nr/water/aquastat/data

# China

- The majority of available water is concentrated in the south, leaving the north and west to experience regular droughts, which cause severe sandstorms and increasing desertification


Map of major rivers and watersheds in China. The increasing darkness indicates a decreasing annual per capita water availability (Jiang 2009).

# China

- Rivers, lakes and underground aquifers in northern China are literally drying up due to overuse
- Widespread pollution: According to China's State Environmental Protection Agency (SEPA), 70 percent of lakes and five of China's seven largest rivers are so polluted that they are no longer suitable for human contact.

Journal of Environmental Management 11, 3185-3196 (2009)

# China's water scarcity

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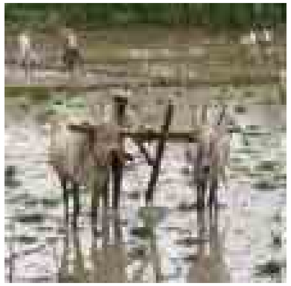
China has been facing increasingly severe water scarcity, especially in the northern part of the country. China's water scarcity is characterized by insufficient local water resources as well as reduced water quality due to increasing pollution, both of which have caused serious impacts on society and the environment. Three factors contribute to China's water scarcity: uneven spatial distribution of water resources; rapid economic development and urbanization with a large and growing population; and poor water resource management.

While it is nearly impossible to adjust the first two factors, improving water resource management represents a cost-effective option that can alleviate China's vulnerability to the issue. Improving water resource management is a long-term task requiring a holistic approach with constant effort. Water right institutions, market-based approaches, and capacity building should be the government's top priority to address the water scarcity issue.

# Seasonal variation

is extreme in Monsoon regions





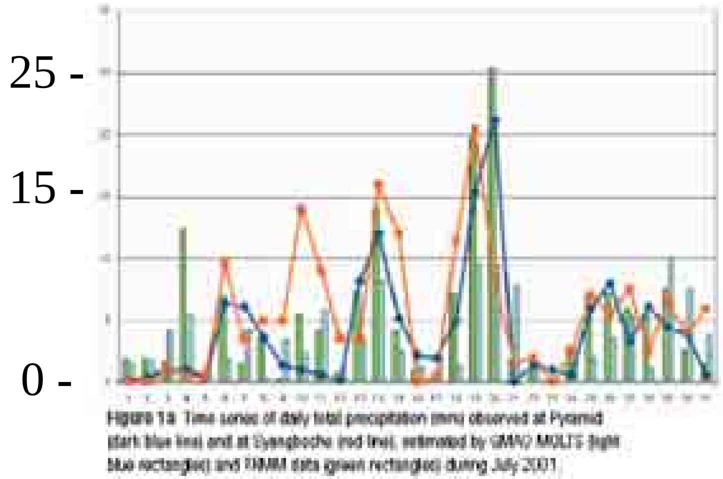
World precipiatation record:
Cherrapunjee region,
26,461 mm per year


# Extreme diel variation

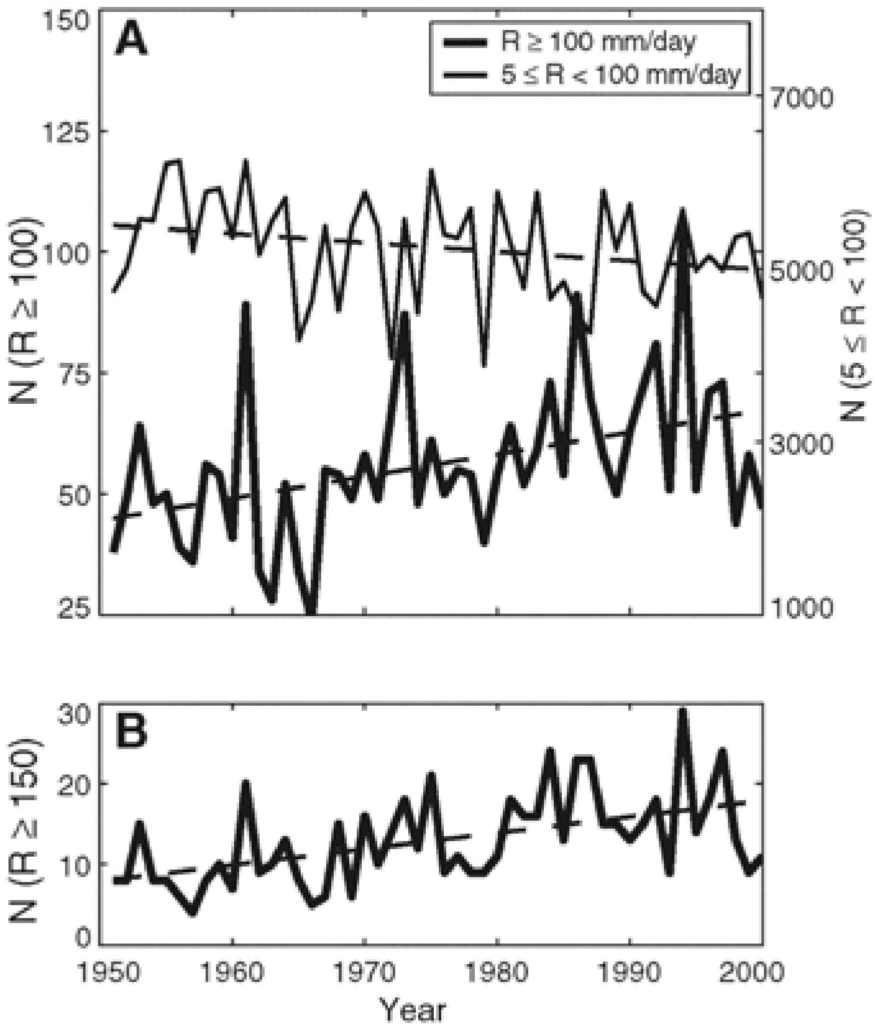
An example from the

Himalayas region

Daily precipitation (mm)




Lau et al. (2005) CEOP NEWS05



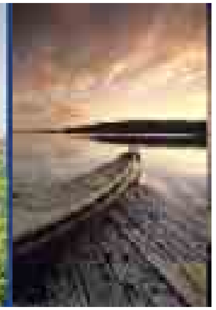

Heavy rainfall increased since 1950

**Fig. 3. Temporal variation (1951 to 2000) in the number (N) of (A) heavy (R >= 100 mm/day, bold line) and moderate rainfalls (5 <= R, B. N. Goswami et al., Science 314, 1442 -1445 (2006)**

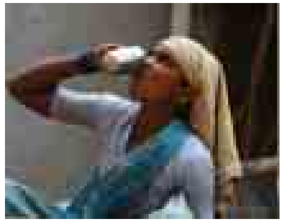
| Uneven distribution | Water usage | Water crisis |
| --- | --- | --- |



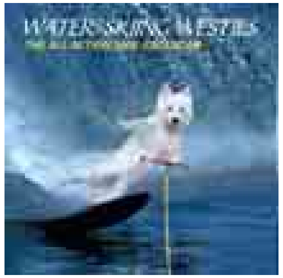


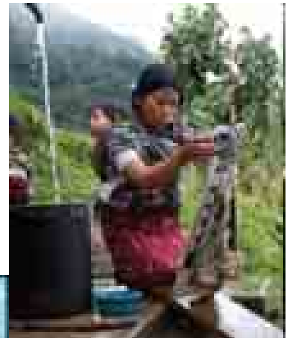
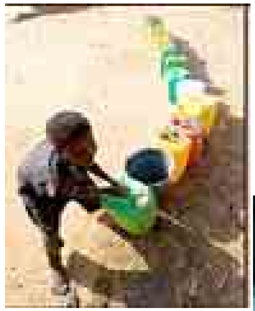




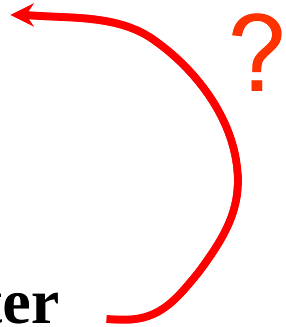



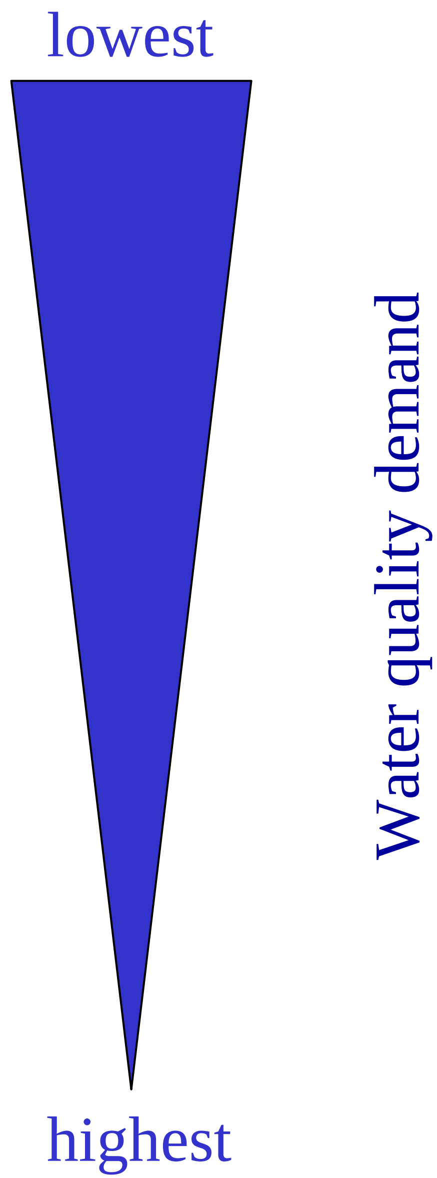




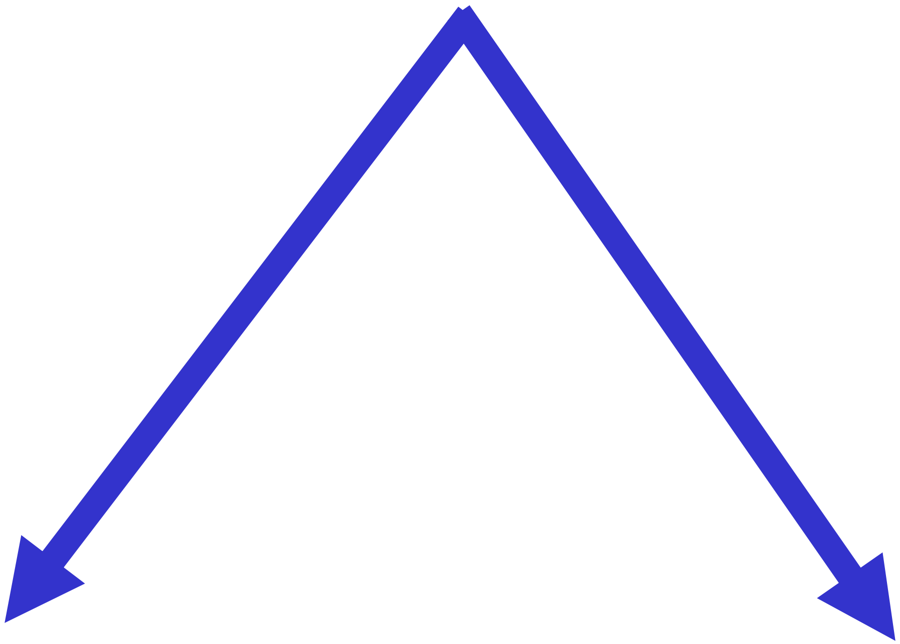




- **Cooling & Industrial use**
- **Hydroelectricity**
- **Shipping routes**
- **Irrigation**
- **Recreational activities**
- **Sanitation**
- **Aquaculture**
- **Drinking water**



## Multiple water use creates conflicts of interests

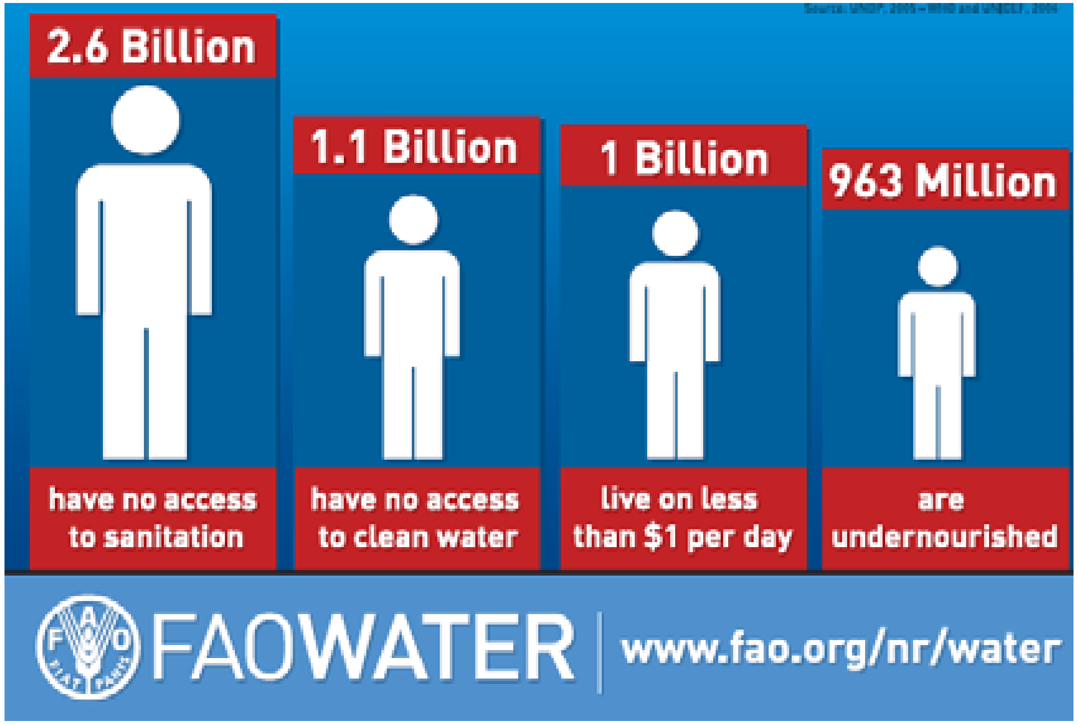


Irrigation +
Industrial use

Drinking water
for humans and cattle

Promoting economic growth vs.
providing clean water for the inhabitants

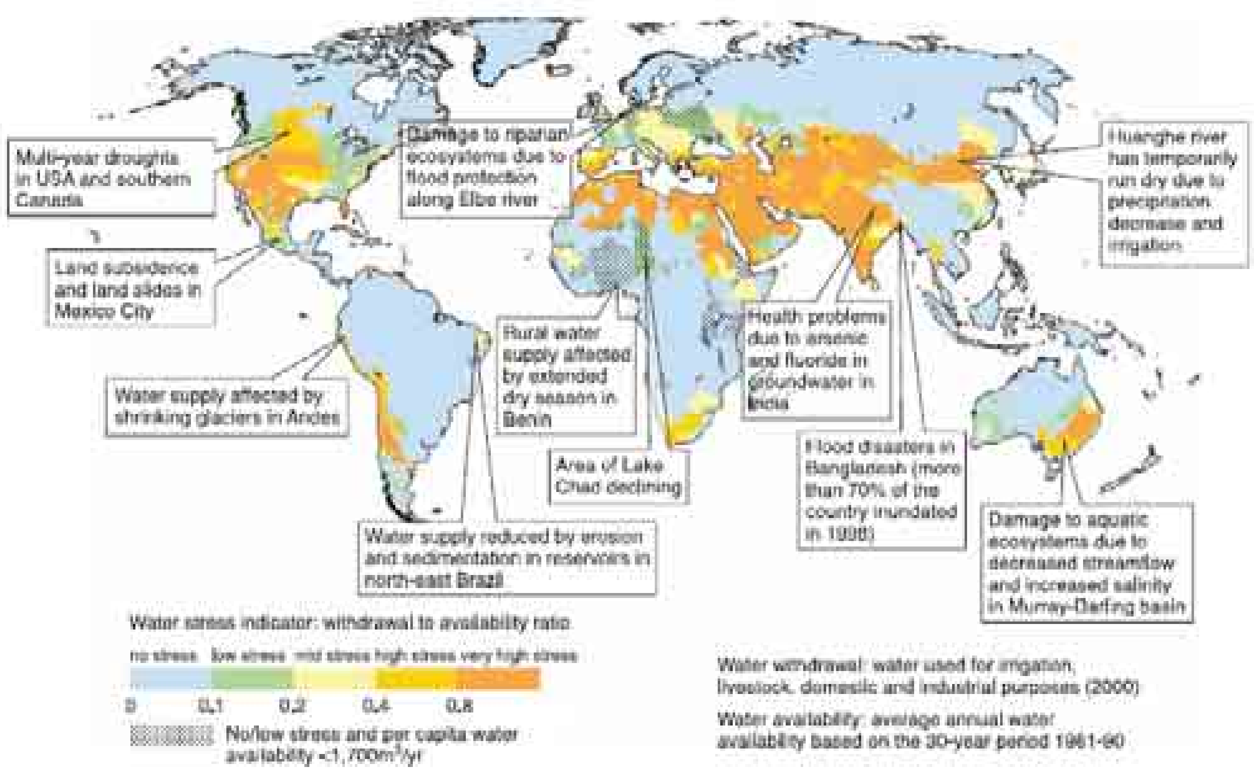
# Water crisis? Water supply in the future

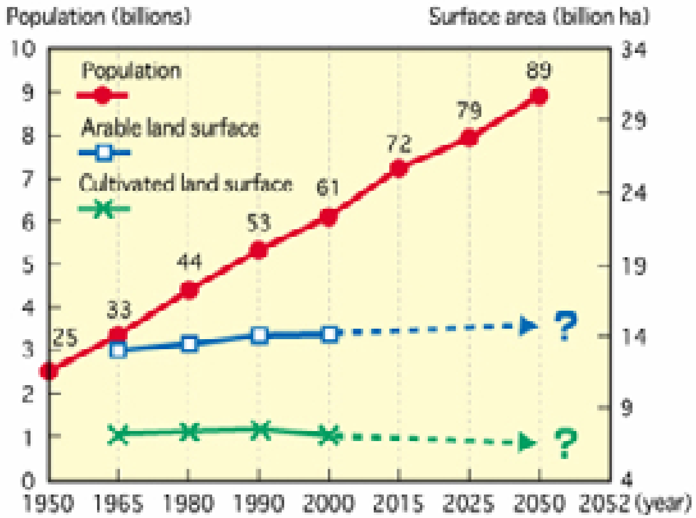
# Waterborne diseases

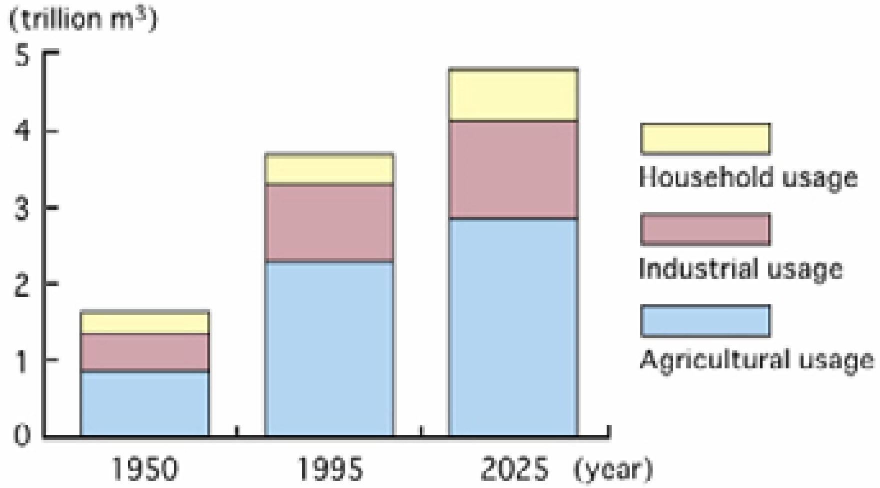
- 4 billion cases of diarrhoea each year, causing
- 2.2 million deaths (5000 every day)
- 1 million deaths caused by malaria
- cholera, filariasis, schistosomiasis, intestinal worms are further water-related diseases

(Source: UN Water 2007)




Examples of current vulnerabilities of freshwater resources and their management; in the background, a water stress map based on Alcamo et al. (2003a; IPCC Fourth Assessment Report 2007).



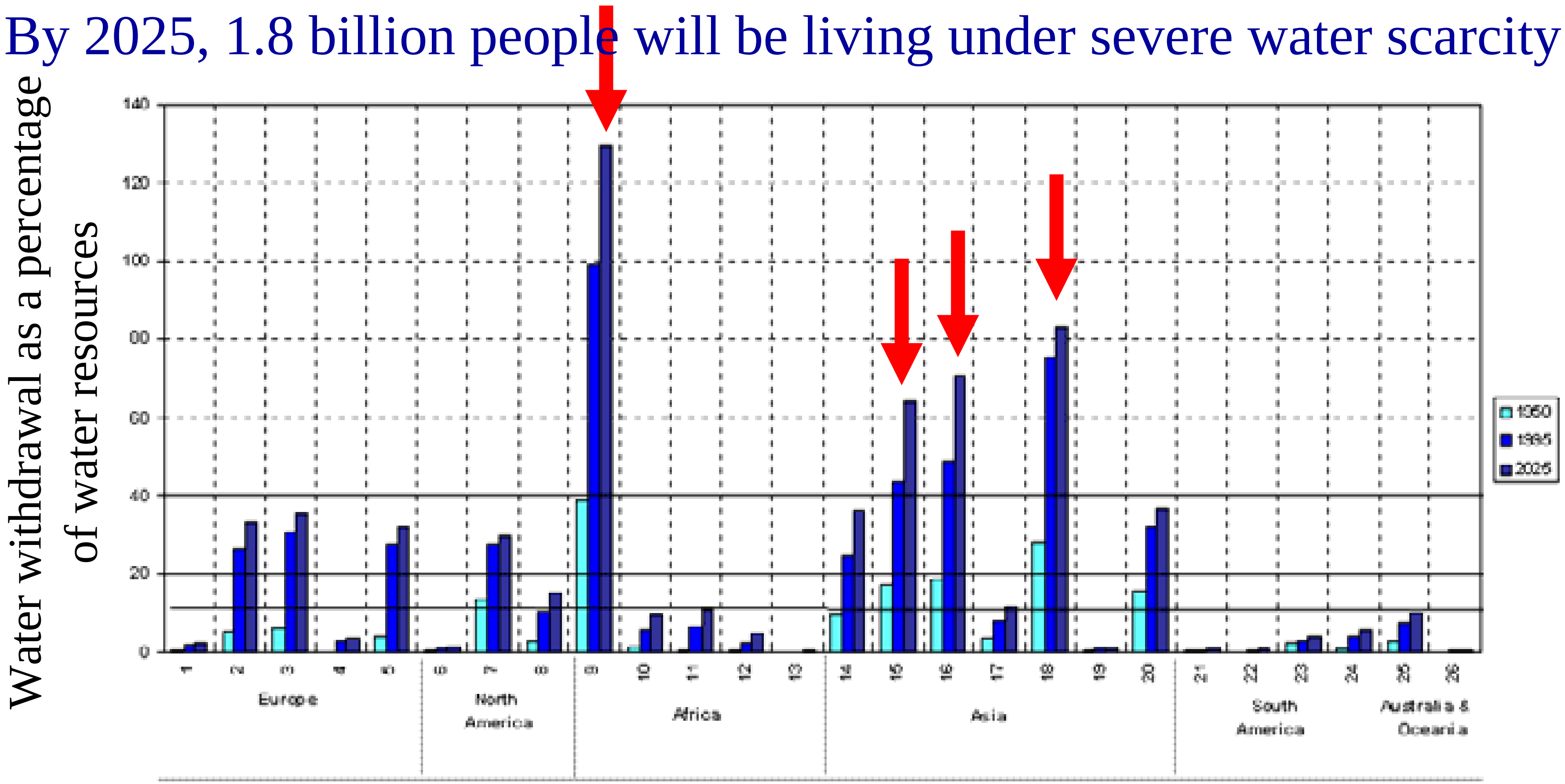




Global population tripled in the 20th century, but water usage increased by a factor of six. Assuming that the world population increases from six to eight billion by 2025, there is growing concern that four billion people, i.e ~50% of world population in 2025, globally may face water stress.

Source' Endangered Global Water Supply and Food Production

http://www.sos2006.jp/english/rsbs_summary

## By 2025, 1.8 billion people will be living under severe water scarcity

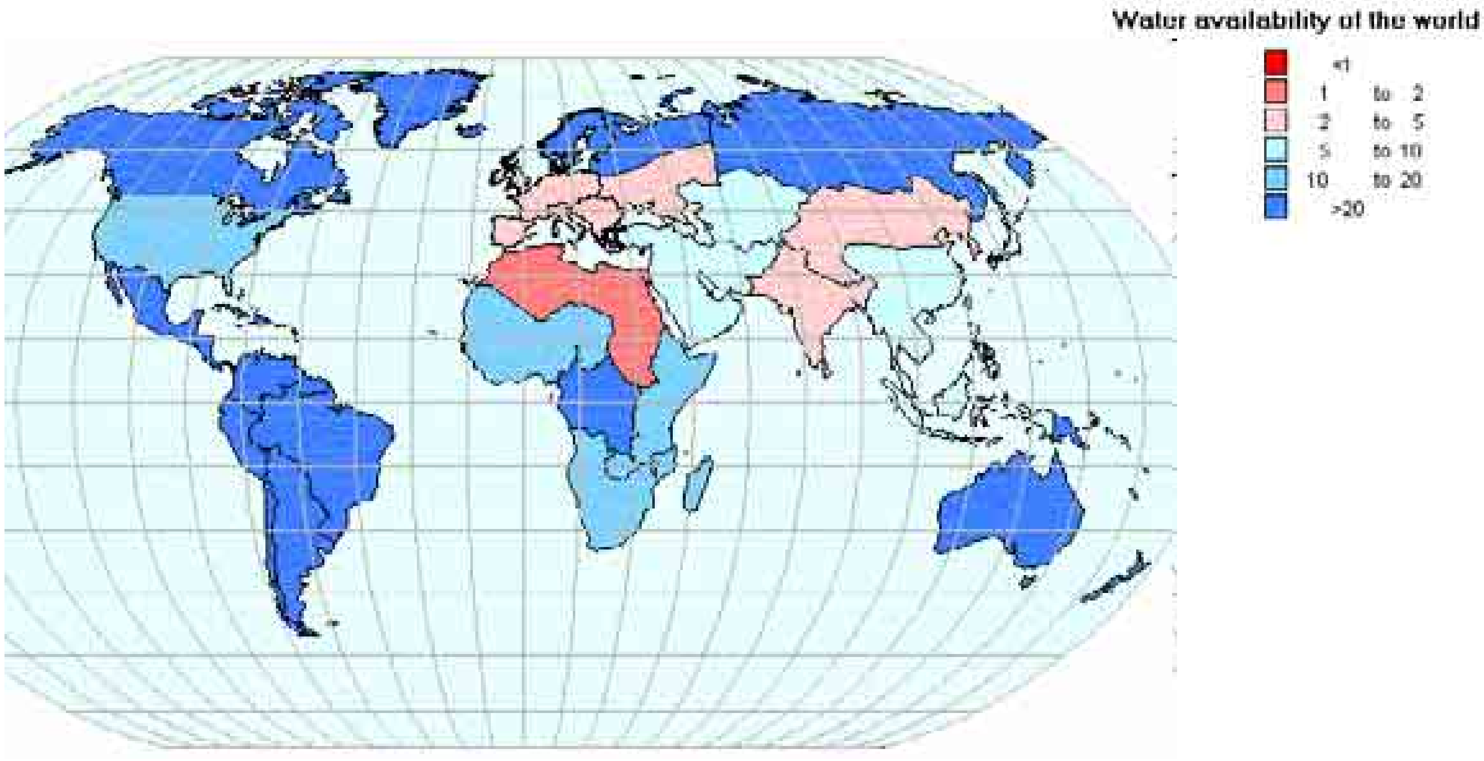



Water withdrawal by the natural - economic regions in percentage of water resources for 1950, 1995, 2025 years:

1 - North; 2 - Central; 3 - South; 4 - North part of ETS SU; 5 - South part of ETS SU;6 - North; 7 - Central; 8 - South; **9 - North**; 10 - South; 11 - East; 12 - West; 13 - Central; 14 - North China, Mongolia; **15 - South Asia; 16 - West Asia**; 17 - South-East Asia; **18 - Middle Asia**; 19 - Siberia, Far East of Russia; 20 - Caucasus; 21 - North; 22 - East; 23 - West; 24 - Central; 25 - Australia; 26 - Oceania.

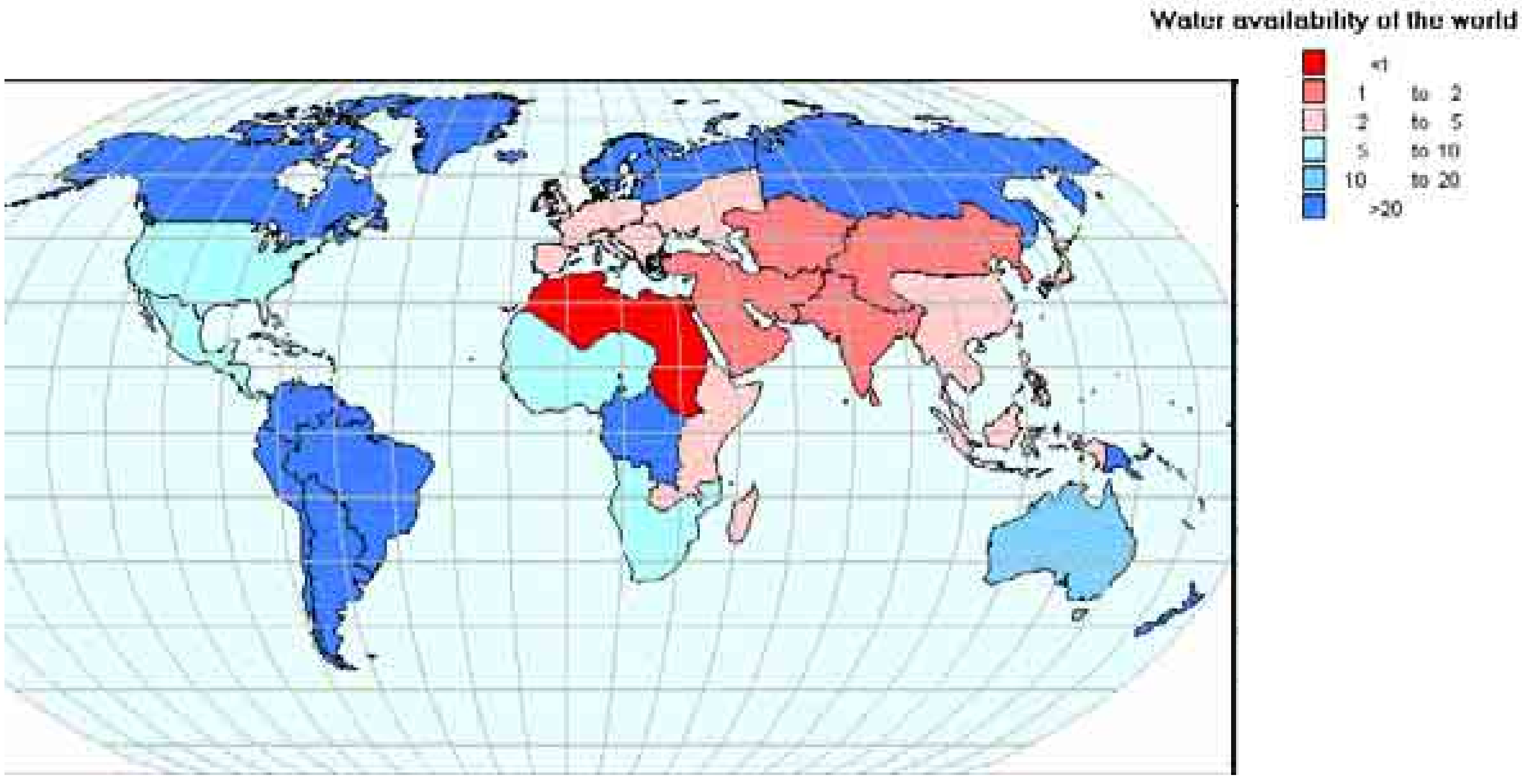
(Source: SHI, I. Shiklomanov)

| Uneven distribution | Water usage | Water crisis |
|---|---|---|

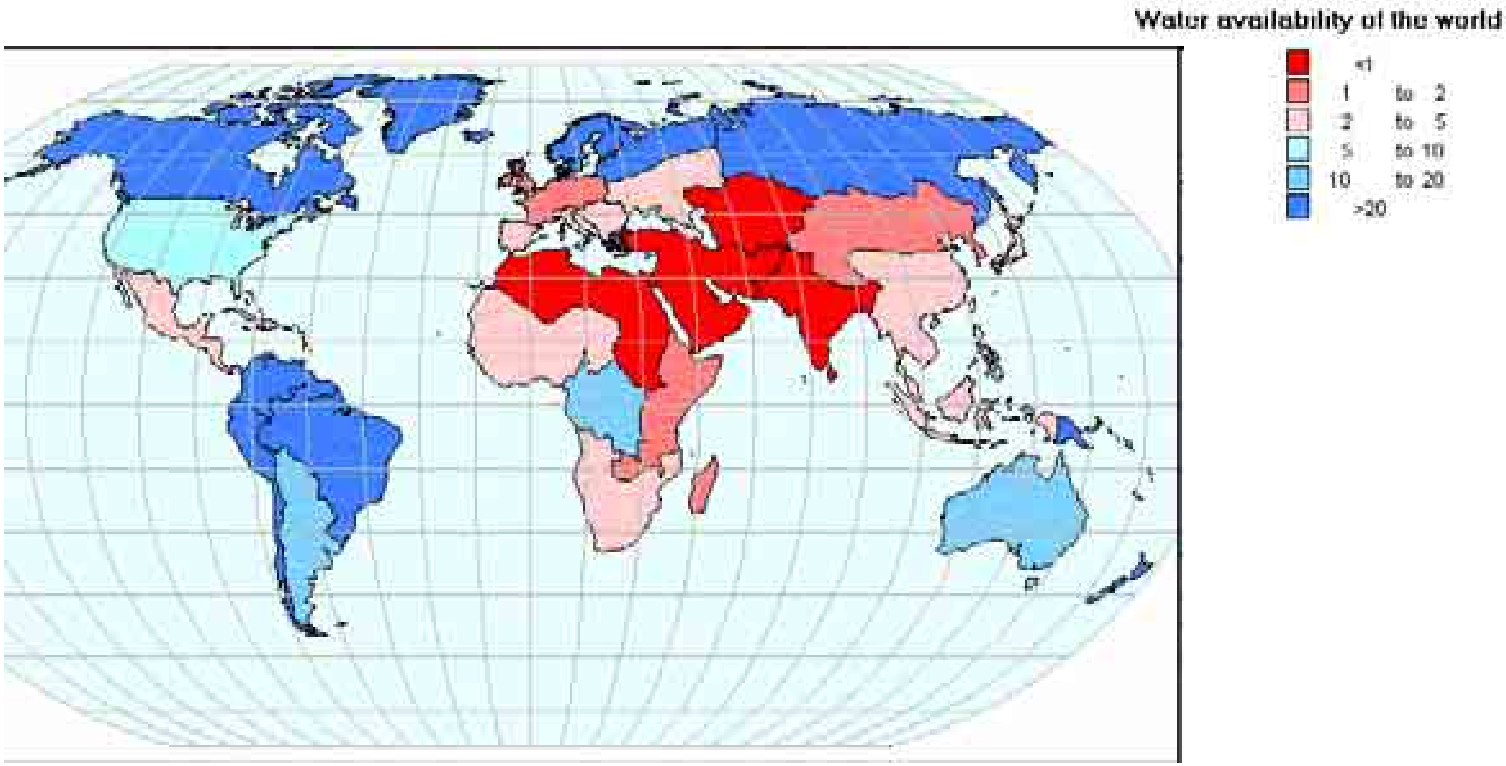



Per-capita water availability (in thousand m³ per year) in 1950

(Source: SHI, I. Shiklomanov)



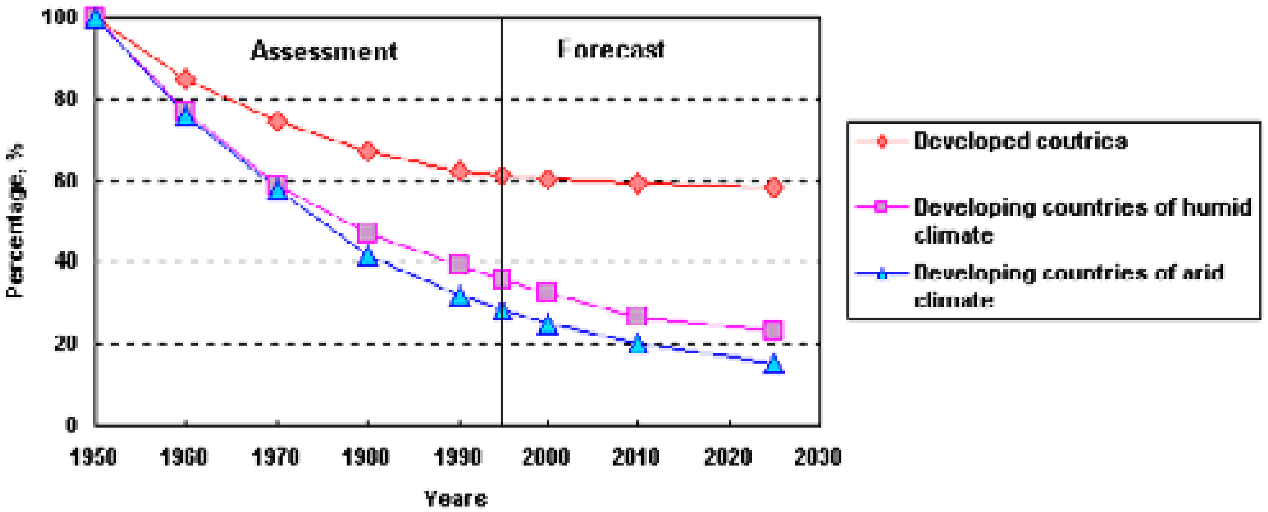

Per-capita water availability (in thousand $m^3$ per year) in 1995



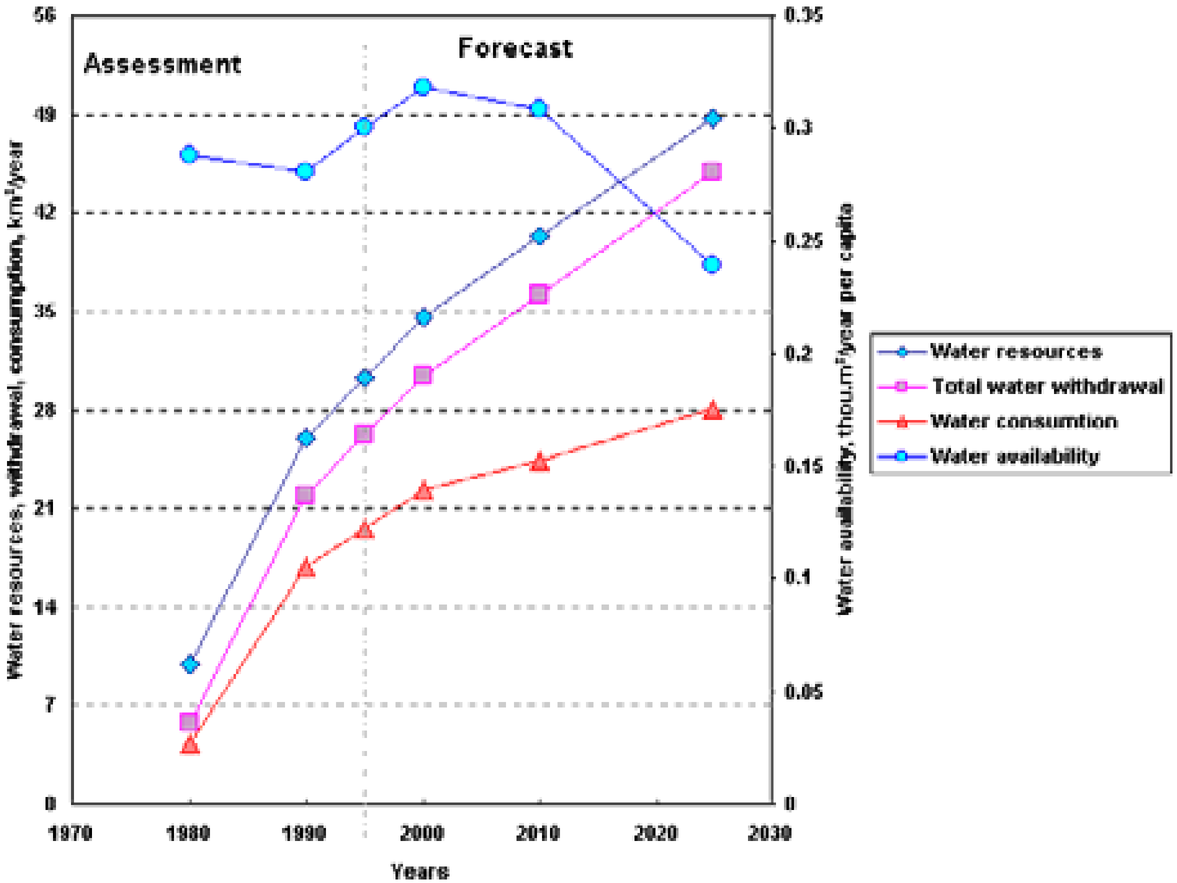

Per-capita water availability (in thousand m³ per year) in 2025

| Uneven distribution | Water usage | Water crisis |
|---|---|---|

*... it is very important to analyse the tendencies and rates of changing specific water availability depending on social-economic and physiographic conditions.* (SHI, I. Shiklomanov)




Dynamics of specific water availability by natural-economical regions of the world in percent, 1950-2025




Water resources and water use (km$^3$/year) and water availability (thousand m$^3$/year per capita) for the countries of the Arabian Peninsula.

# (Un)known threat for water supply: climate change

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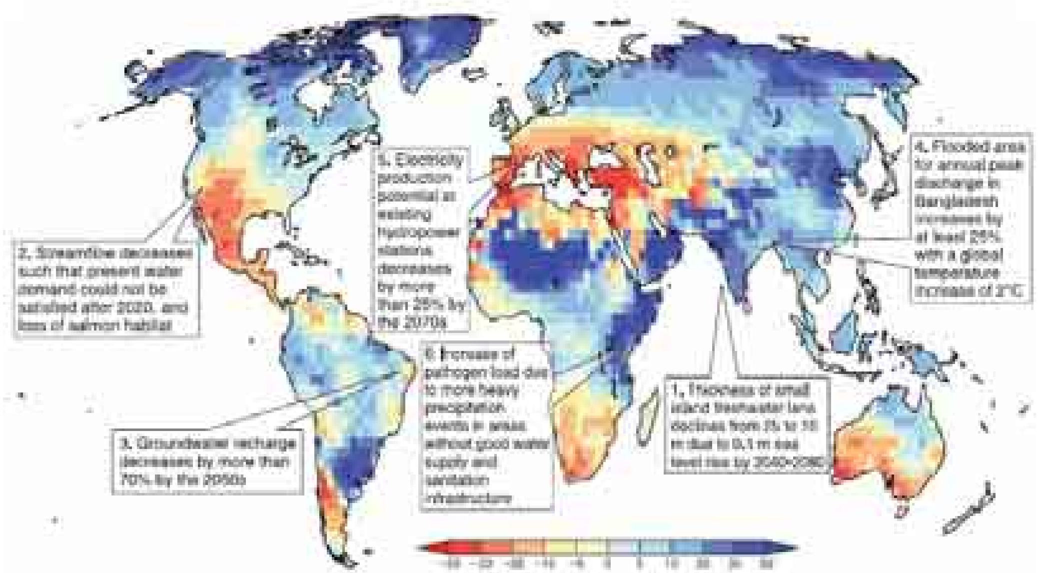
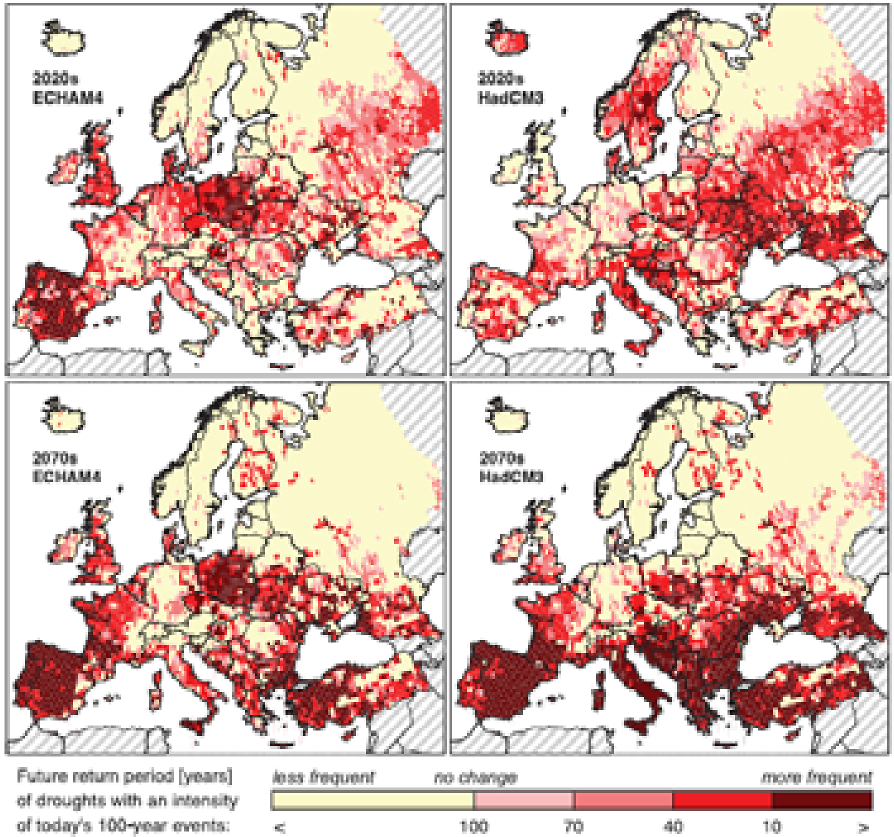


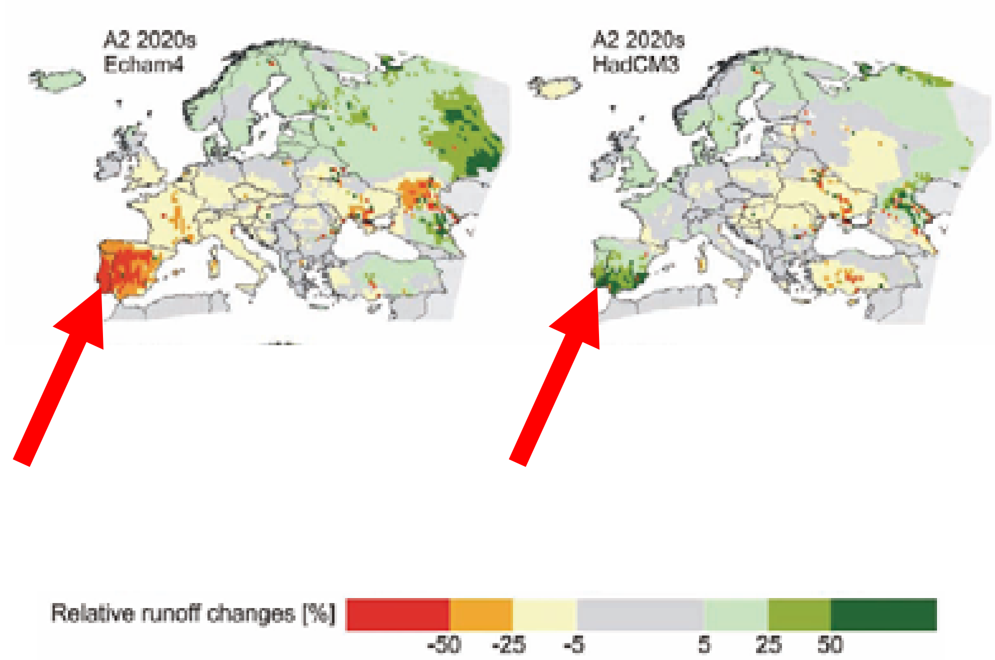

**Figure 3.8.** *Illustrative map of future climate change impacts on freshwater which are a threat to the sustainable development of the affected regions.*

Source: IPCC Fourth Assessment Report (2007)




Change in the recurrence of 100-year droughts, based on comparisons between climate and water use in 1961 to 1990 and simulations for the 2020s and 2070s (Lehner et al., 2005b, IPCC 2007).

Uncertainty in predictions: different models may arrive at opposite conclusions



# (Un)known threat for water supply: climate change

- Precipitation
- Snow cover, glaciers, permafrost
- Streamflow
- Evapotranspiration
- Floods and droughts
- Water quality?
- Irrigation water demand?

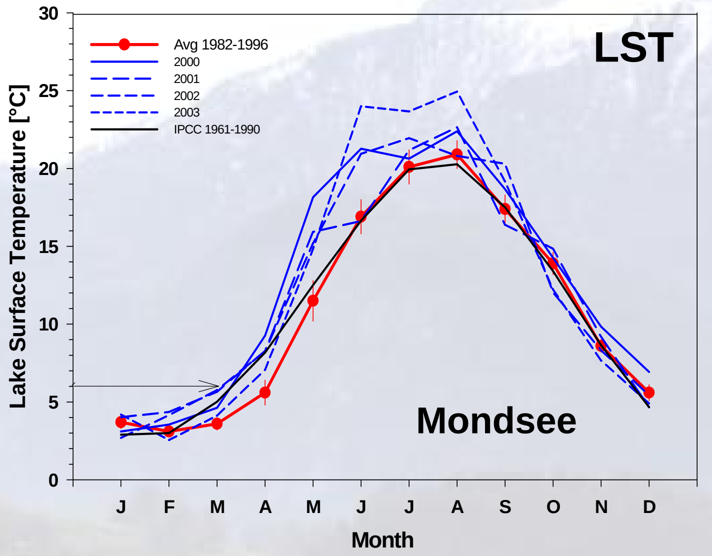
| | Observed climate-related trends |
|---|---|
| Precipitation | Increasing over land north of 30°N over the period 1901–2005.<br>Decreasing over land between 10°S and 30°N after the 1970s (WGI AR4, Chapter 3, Executive summary).<br>Increasing intensity of precipitation (WGI AR4, Chapter 3, Executive summary). |
| Cryosphere | |
| Snow cover | Decreasing in most regions, especially in spring (WGI AR4, Chapter 4, Executive summary). |
| Glaciers | Decreasing almost everywhere (WGI AR4, Chapter 4, Section 4.5). |
| Permafrost | Thawing between 0.02 m/yr (Alaska) and 0.4 m/yr (Tibetan Plateau) (WGI AR4 Chapter 4 Executive summary; this report, Chapter 15, Section 15.2). |
| Surface waters | |
| Streamflow | Increasing in Eurasian Arctic, significant increases or decreases in some river basins (this report, Chapter 1, Section 1.3.2).<br>Earlier spring peak flows and increased winter base flows in Northern America and Eurasia (this report, Chapter 1, Section 1.3.2). |
| Evapotranspiration | Increased actual evapotranspiration in some areas (WGI AR4, Chapter 3, Section 3.3.3). |
| Lakes | Warming, significant increases or decreases of some lake levels, and reduction in ice cover (this report, Chapter 1, Section 1.3.2). |
| Groundwater | No evidence for ubiquitous climate-related trend (this report, Chapter 1, Section 1.3.2). |
| Floods and droughts | |
| Floods | No evidence for climate-related trend (this report, Chapter 1, Section 1.3.2), but flood damages are increasing (this section). |
| Droughts | Intensified droughts in some drier regions since the 1970s (this report, Chapter 1, Section 1.3.2; WGI AR4, Chapter 3, Executive summary). |
| Water quality | No evidence for climate-related trend (this report, Chapter 1, Section 1.3.2). |
| Erosion and sediment transport | No evidence for climate-related trend (this section). |
| Irrigation water demand | No evidence for climate-related trend (this section). |

Source: IPCC Fourth Assessment Report (2007)

# EU projects REFLECT & CLIME

ÖAW

## Surface and deep water temperatures increase in central European lakes at 0.1-0.2°C per decade



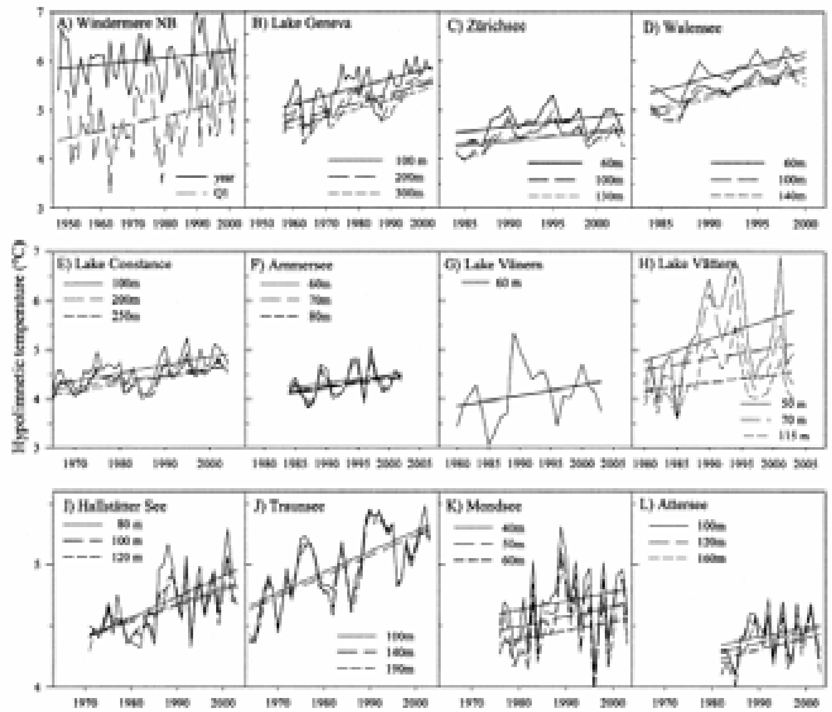
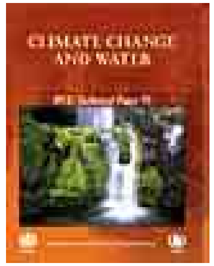



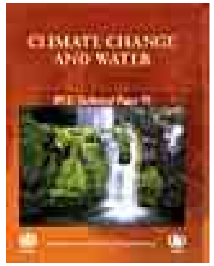

Fig. 2. Time series and regression lines for annual average deepwater temperatures. (A) Windermere North Basin 60 m and the first 10-week period (Q1), (B) Lake Geneva, (C) Zürichsee, (D) Walensee, (E) Lake Constance, (F) Ammersee, (G) Lake Vänern, (H) Lake Vättern, (I) Hallstättersee, (J) Traunsee, (K) Mondsee, and (L) Attersee for the depths indicated.

**Livingstone & Dokulil (2001):** ***L & O 46, 1220-1227,*** **Dokulil et al. (2006):** ***L & O 51, 2787-2793***




## Climate change - conclusions from the IPCC Report Climate Change and Water 2008

- Increases in temperature, sea level and precipitation variability are key parameters.
- Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater.
- Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, water system reliability and operating costs




- Climate change affects the function and operation of existing water infrastructure as well as water management practices

- The negative impacts of climate change on freshwater systems outweigh its benefits

# Solutions? “More for less“ – increasing water productivity

- There is no one single solution to the water crisis - to solve our water problems takes “a comprehensive, integrated and soft approach“ (P. Gleick)

# NGO‘s and interstate commissions in the water sector

- 1947 International Water Supply Association
- 1955 The Great Lakes Commission
- 1959 International Commission for the Protection of Lake Constance (IGKB)
- 1962 Australian Water Association
- 1964 American Water Resources Association

- 1981 European Water Pollution Control Association
- 1999 European Water Association
- 1988 Malaysian Water Association
- 1999 International Water Association (IWA)

- 1961 – Tanzania (Tanganyika) achieves independence
- 1963 Kenya achieves independence

The **East African Water Association** (EAWA) was launched in December 2003 with support of the Austrian Development Cooperation. EAWA is presently interlinking more than 130 East African experts in aquatic ecology, aquatic ecosystems and resource management, biodiversity and conservation ecology, and water and sanitation.

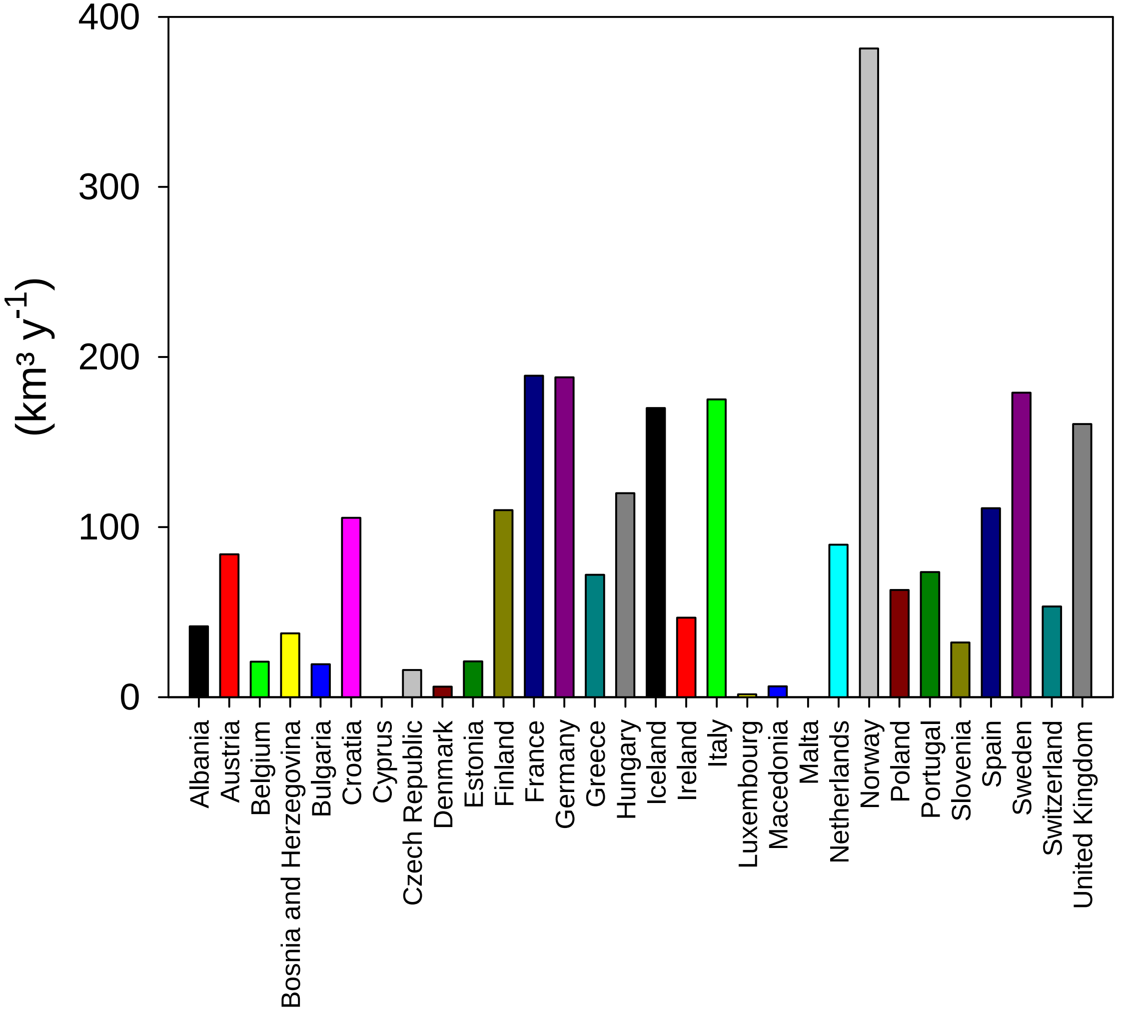
KISUMU WORKSHOP & EXHIBITION, June 2008. Bridging research, technology & development: sustainable water management in Eastern Africa – phase II: initiating interactive stakeholder partnerships for sustainable water resource development.

# Integrating BOMOSA cage fish farming system in reservoirs, ponds and temporary water bodies in Eastern Africa

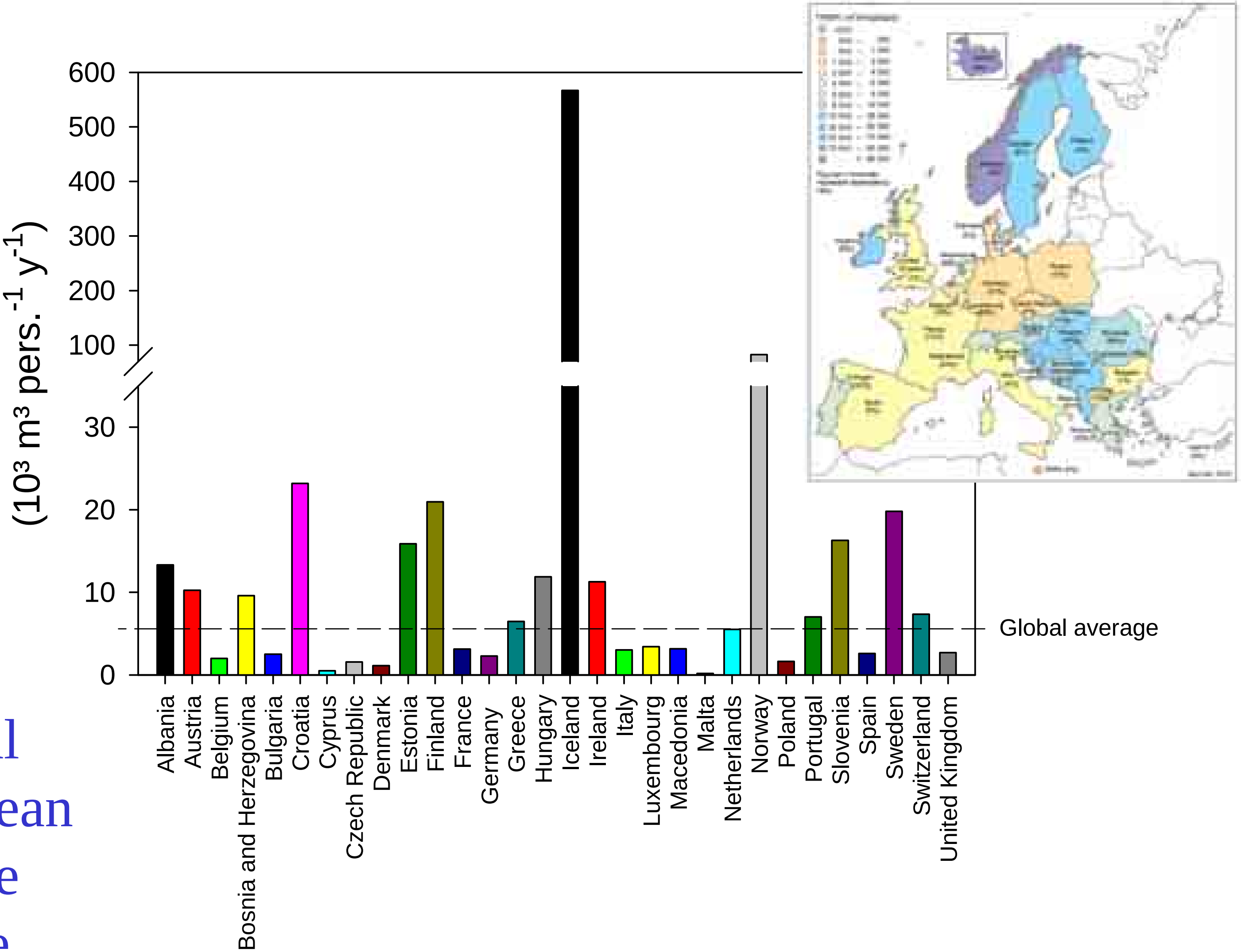
SIXTH FRAMEWORK PROGRAMME

**INNOVATION TOWARDS SUSTAINABILITY, pioneering small-scale fish farming in Eastern Africa by establishing rural aquaculture networks**

Annual renewable water resources in Europe

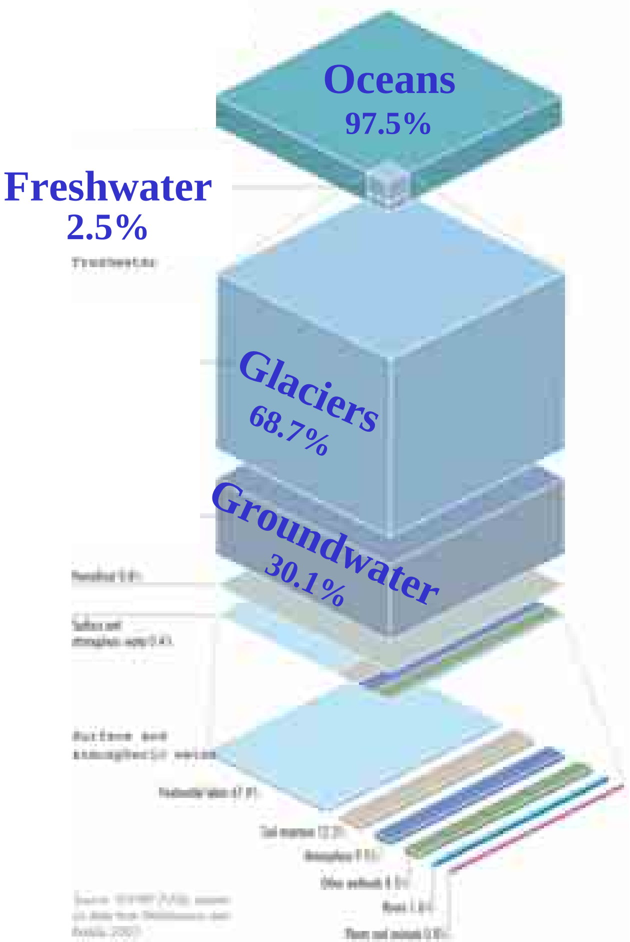


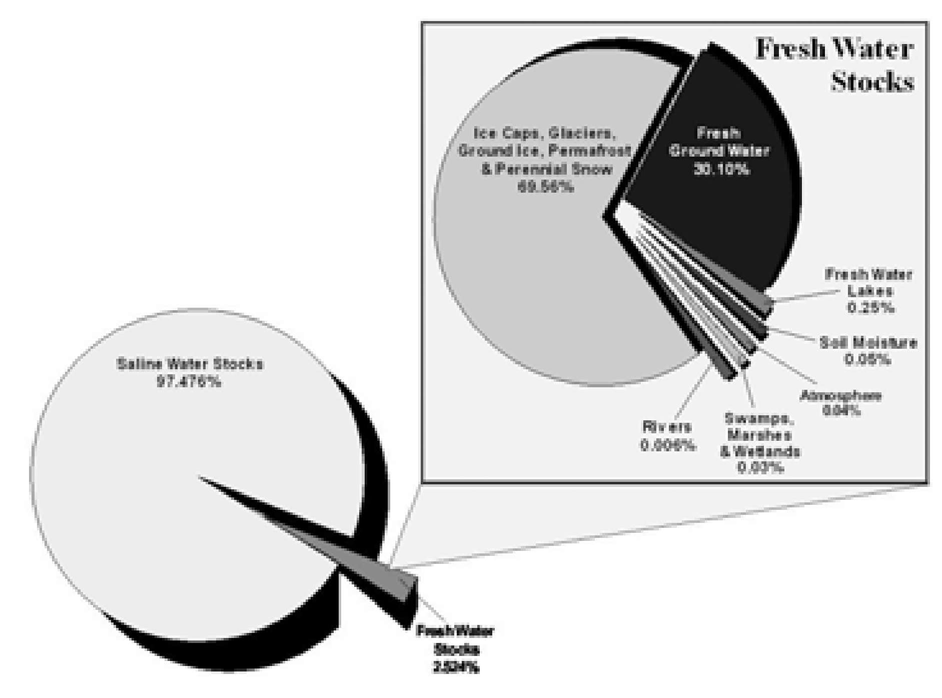
Per-capita renewable water resources in Europe




Even several large European countries are water scarce

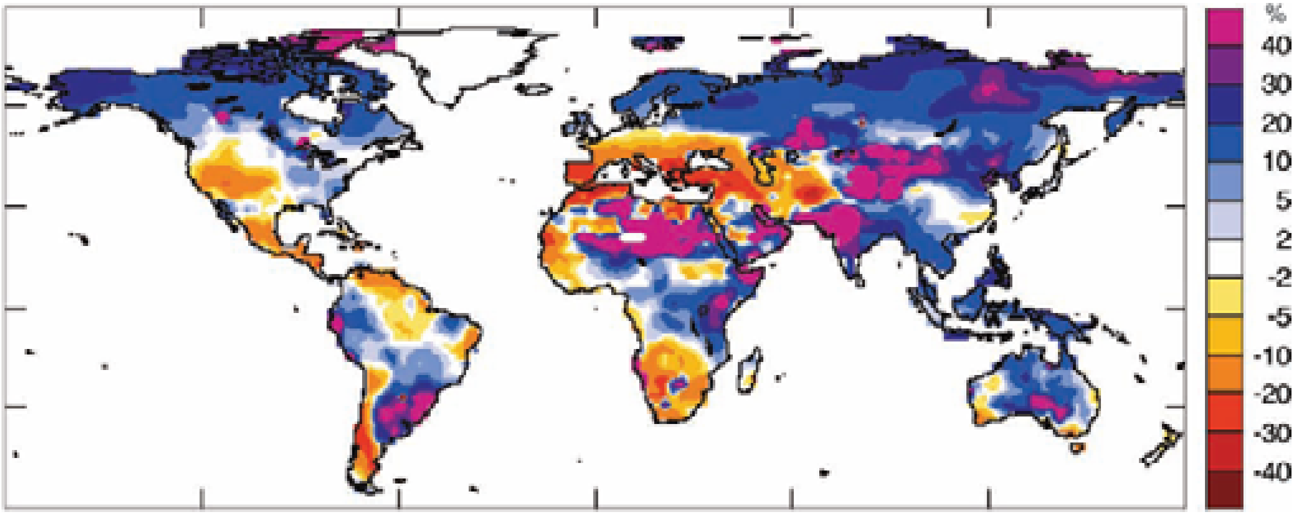
# Global Water Supply




http://www.buzzfeed.com/jonah/global-water-supply-chart

| Uneven distribution | Water usage | Water crisis |
|---|---|---|

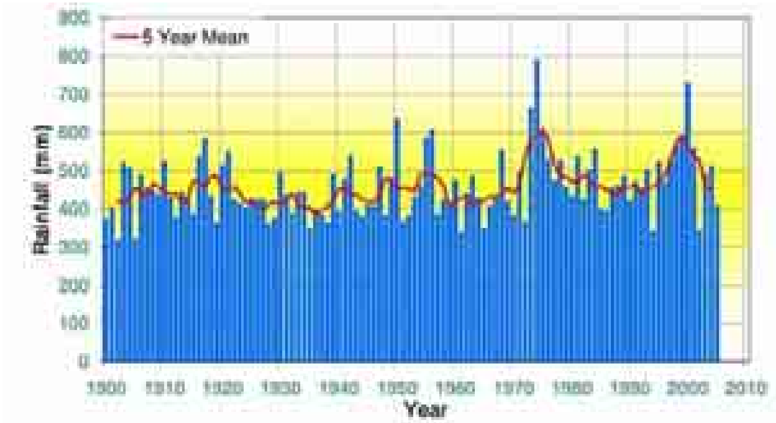


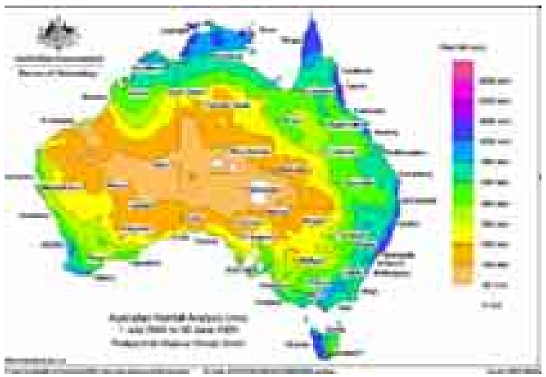

Change in annual runoff by 2041-60 relative to 1900-70, in percent, under the SRES A1B emissions scenario and based on an ensemble of 12 climate models (after Milly et al., Nature 2005).

- **Self-extracted** water is defined as water extracted directly from the environment for use, and includes water from rivers, lakes, farm dams, groundwater and other water bodies.
- **Distributed** water is water supplied to a user, often through a non-natural network (piped or open channel), and where an economic transaction has occurred for the exchange of this water.
- **Reused** water refers to wastewater that may have been treated to some extent, and then used again without first being discharged to the environment. It excludes water that is reused onsite, for example on-farm water reuse or water being constantly recycled within a manufacturing plant.

## Annual rainfall for Australia and the states and territories from 2003 to 2005 and the longer term average from 1961-1990

| Annual Rainfall | Australia | NT | QLD | SA | TAS | VIC | WA |
|---|---|---|---|---|---|---|---|
| 2005 (mm) | 399 | 477 | 478 | 206 | 1,250 | 616 | 306 |
| 2004-05 (mm) | 364 | 376 | 502 | 151 | 1,121 | 648 | 254 |
| 2004 (mm) | 507 | 637 | 610 | 214 | 1,223 | 578 | 463 |
| 2003 (mm) | 476 | 686 | 518 | 260 | 1,227 | 611 | 388 |
| Average (mm) | 472 | 548 | 630 | 236 | 1,168 | 654 | 352 |



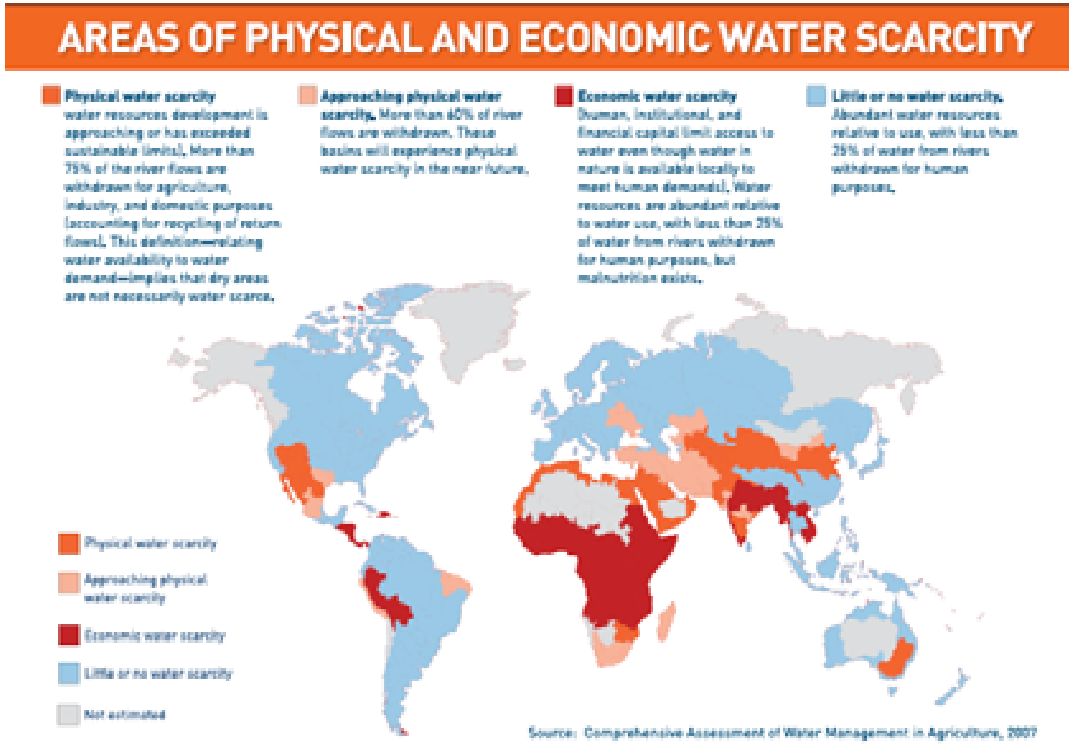



Source: Bureau of Meteorology

Australia is the driest inhabited continent in the world; rainfall is extremely variable and droughts are a common occurrence

## Eckdaten der Österreichischen Wasserwirtschaft

- Flüsse mit einem Einzugsgebiet größer als 10 km² bilden ein Gewässernetz von 31.000 km Länge.
- 62 Seen besitzen eine Fläche größer als 50 ha.
- Es wurden 136 Grundwasserkörper identifiziert.
- Jährliche Niederschlagssumme: 1.170 mm
- Jährliches Wasserdargebot: 84 Mrd. m3, 1/3 davon ist Grundwasser, 3 % davon werden jährlich von Haushalten, Gewerbe, Industrie und Landwirtschaft benötigt.
- Trinkwasser stammt zu 100 % aus Grund- und Quellwasser.
- Rund 90 % der Bevölkerung werden mit Trinkwasser aus zentralen Wasserversorgungen versorgt.
- Durchschnittlicher Wasserverbrauch in Haushalten: 135 l/Person/d
- Abwasser von bereits 92 % der Bevölkerung wird der öffentlichen Abwasserreinigung zugeleitet.
- Mehr als 60 % der heimischen Stromproduktion stammt aus Wasserkraftwerken



AREAS OF PHYSICAL AND ECONOMIC WATER SCARCITY
Physical water scarcity (water resources development is approaching or has exceeded sustainable limits). More than 75% of the river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flows). This definition—relating water availability to water demand—implies that dry areas are not necessarily water scarce.
Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
Economic water scarcity (human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.
Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.
Physical water scarcity
Approaching physical water scarcity
Economic water scarcity
Little or no water scarcity
Not estimated
Source: Comprehensive Assessment of Water Management in Agriculture, 2007