Water Pollution-1

-Water Resources and Usage

Changha Lee

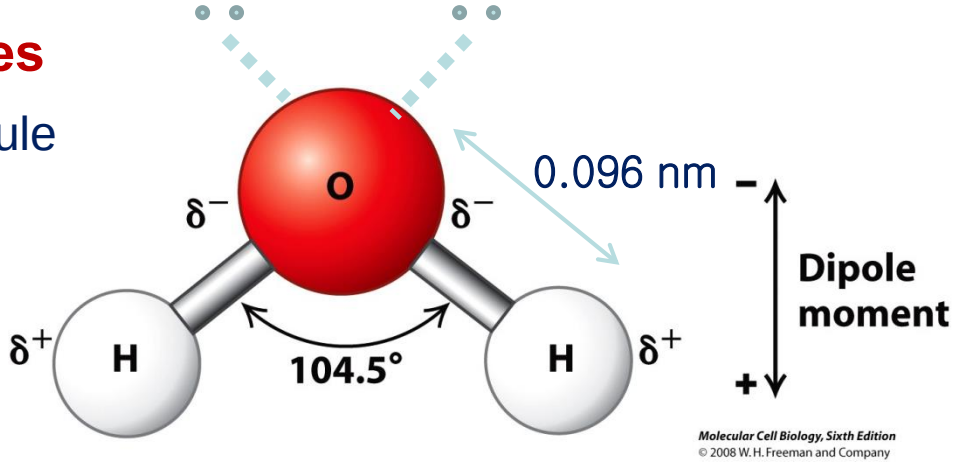
School of Chemical and Biological Engineering

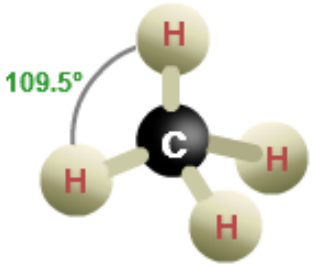
Seoul National University

Water Properties

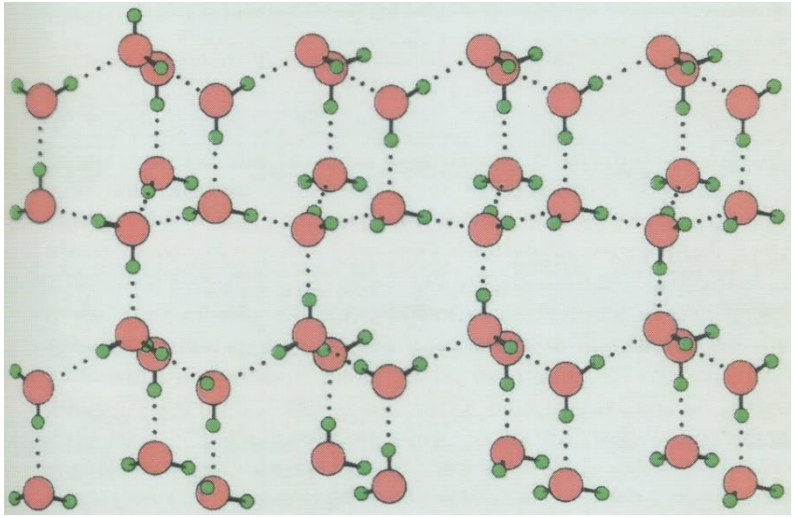
√ Water Properties

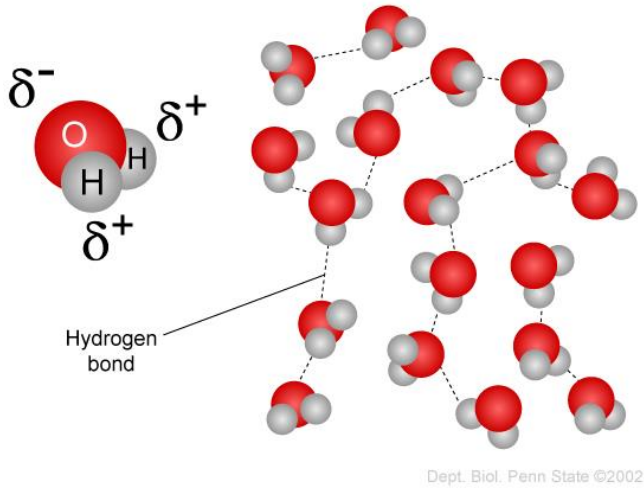
- Polar molecule





- High affinity for itself (thus ice crystals)





- The only common substance that expands as it freezes

Water Properties

- Density
  - Density of liquid water is around 1 g/cm^3
  - Density is maximum at 4℃
  - Frozen water is less dense than liquid water therefore ice floats and lakes stratify in winter

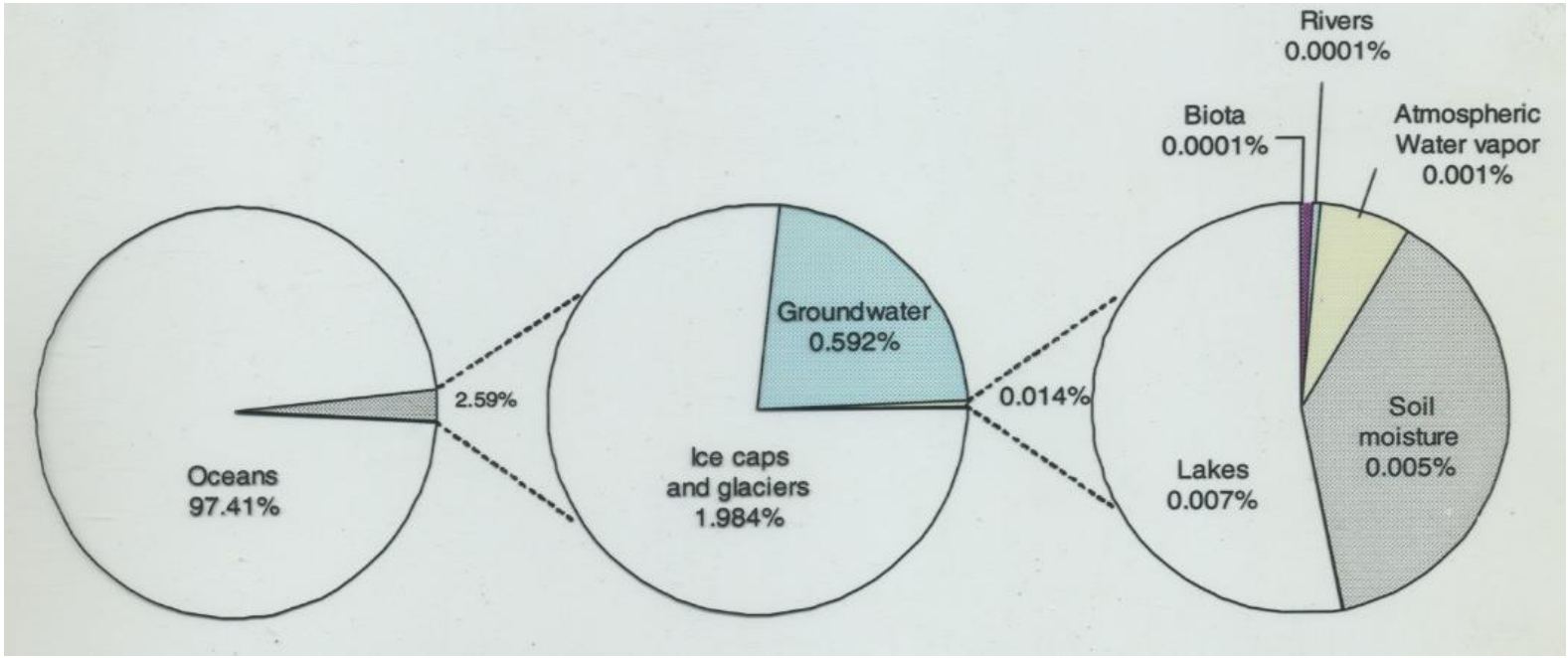
- Melting and boiling points
  - High boiling points compared to similar compounds (H_2S, H_2Se, H_2Te)
  - Stays liquid over wide temperature range between m.p. and b.p.

Water Properties

- Specific heat
  - 4.18 kJ/kg ℃ : higher than every liquid except ammonia
  - 5 times that of rocks and concrete
  - Provides dampening of heating and cooling
- Heat of vaporization
  - Very high latent heat : condensed water
  - Distributes heat around the globe
- Polar solvent
  - Dissolves and transports many substances

Water Resources

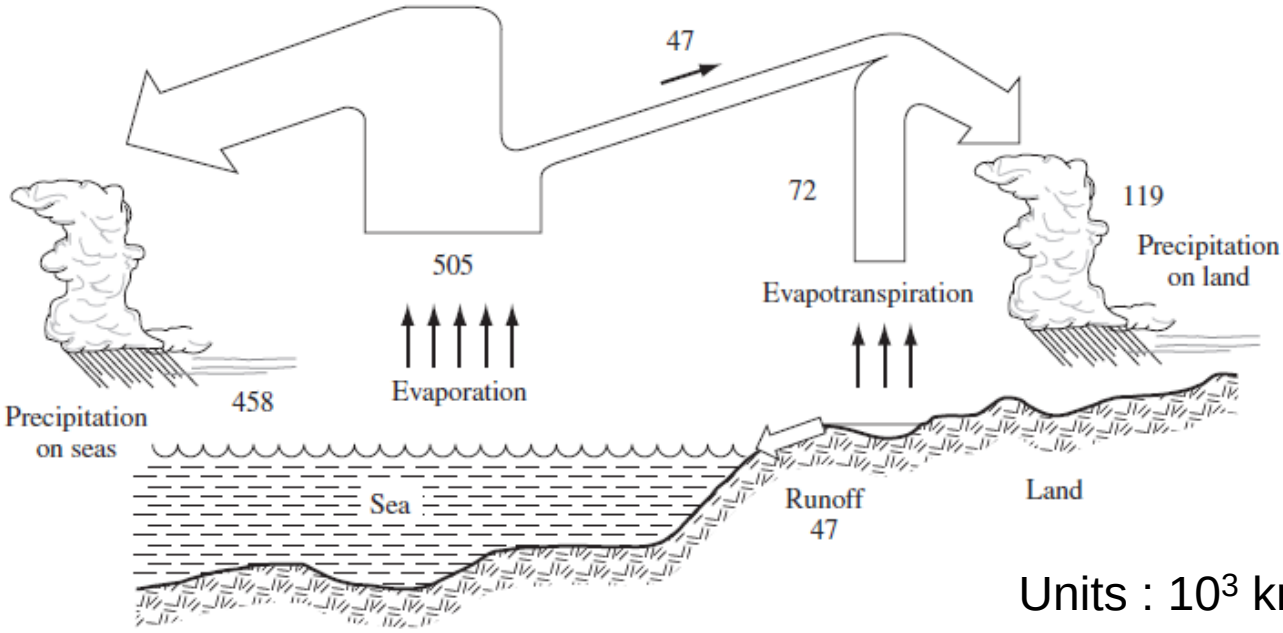
- 70% of the Earth is covered by water
- Freshwater is < 3% of total water resources (including ice caps)
- 98% of available freshwater is groundwater
- < 1% of the fresh water (0.014% of all water) is usable in a renewable fashion.



Water Resources

- Precipitation = primary source of freshwater
- 65% of precipitation returns to the atmosphere
- Distribution of water across the globe is very uneven:
  - Water rich countries have about 100 x 10^3 m^3/person in runoff/yr
  - Water poor countries have about 0.02 to 2 x 10^3 m^3/person in runoff/yr
- For drinking water, need <1m^3/person/year
  - 2 L per day recommended for fluid replenishment
- Developed countries use 30 m^3/person/year for domestic use
- Of freshwater used in the world:
  - 6% is domestic and recreation
  - 73% irrigated agriculture
  - 21% industry (43% in the USA)

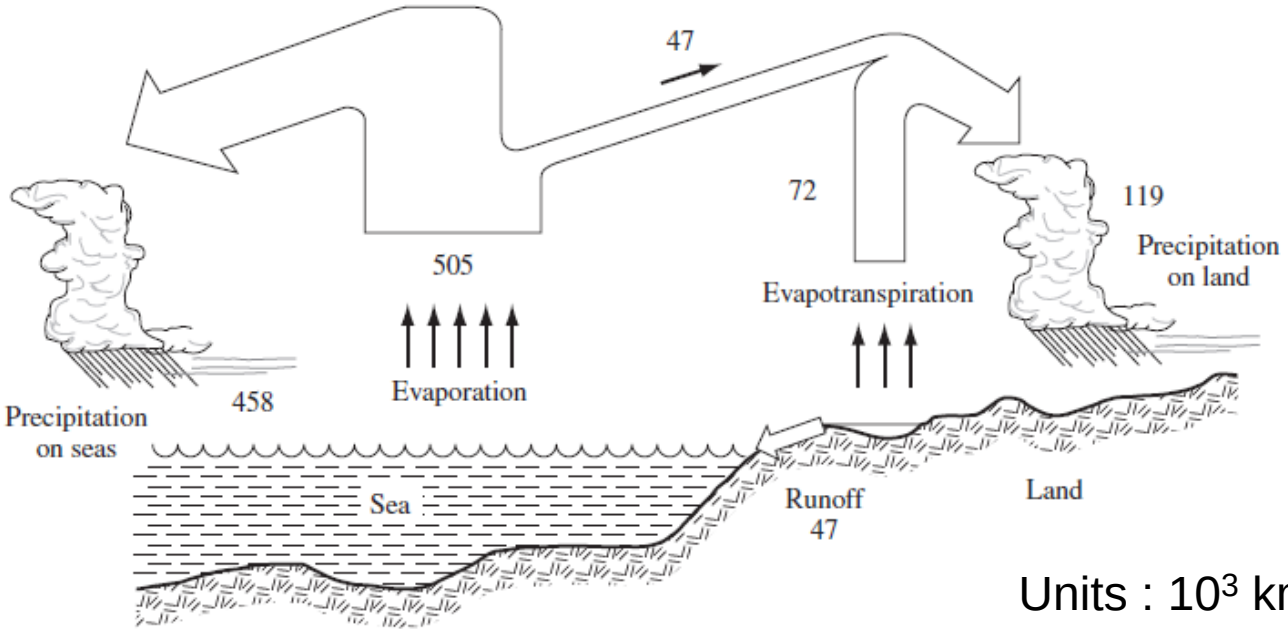
Simplified Hydrologic Cycle



Units : 10^3 km^3/yr

- Evaporation of ocean water (88%): desalination process
- Evapotranspiration (12%): evaporation of water and transpiration of water from leaves
- These processes use ½ of the sun's energy that strikes the earth

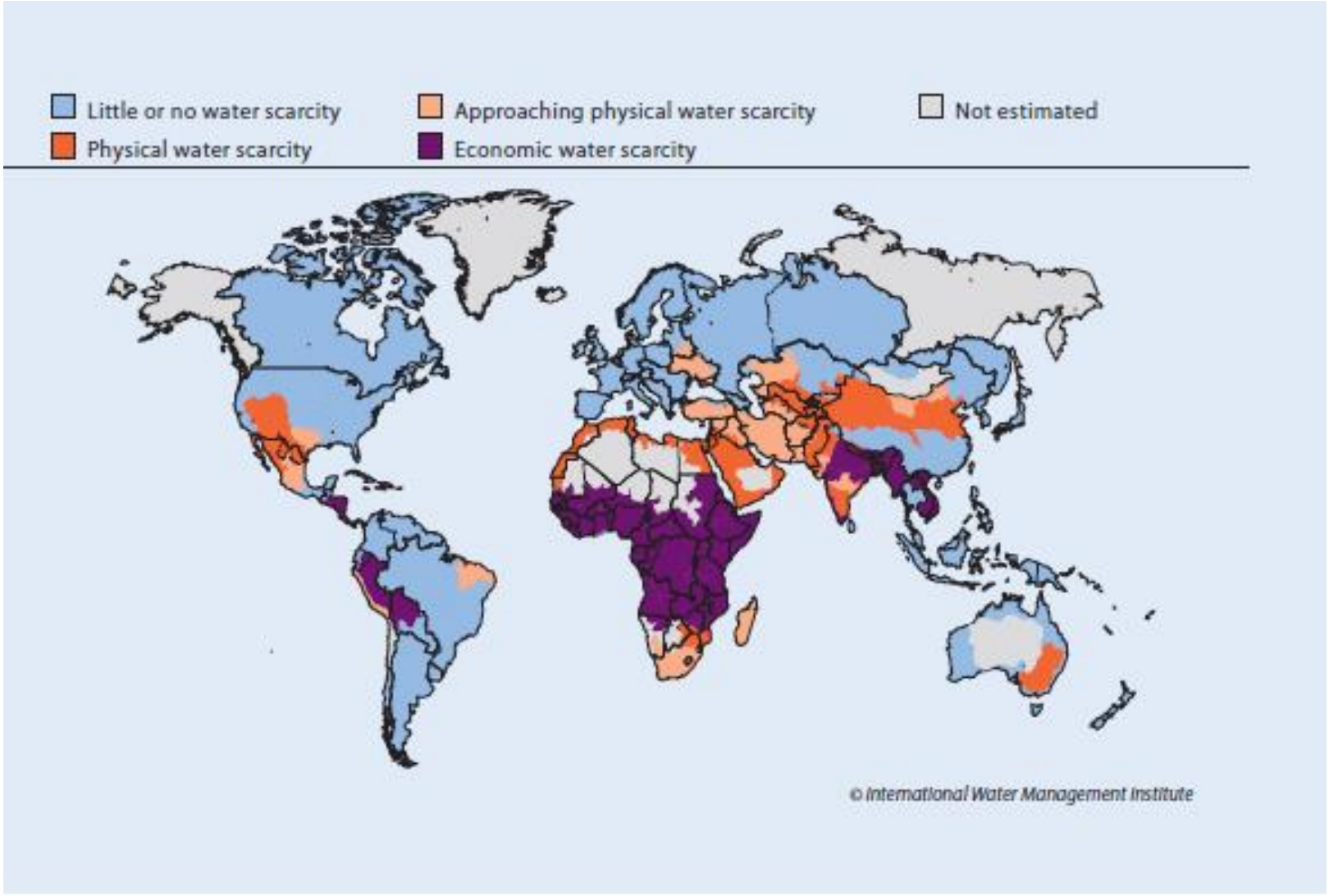
Simplified Hydrologic Cycle



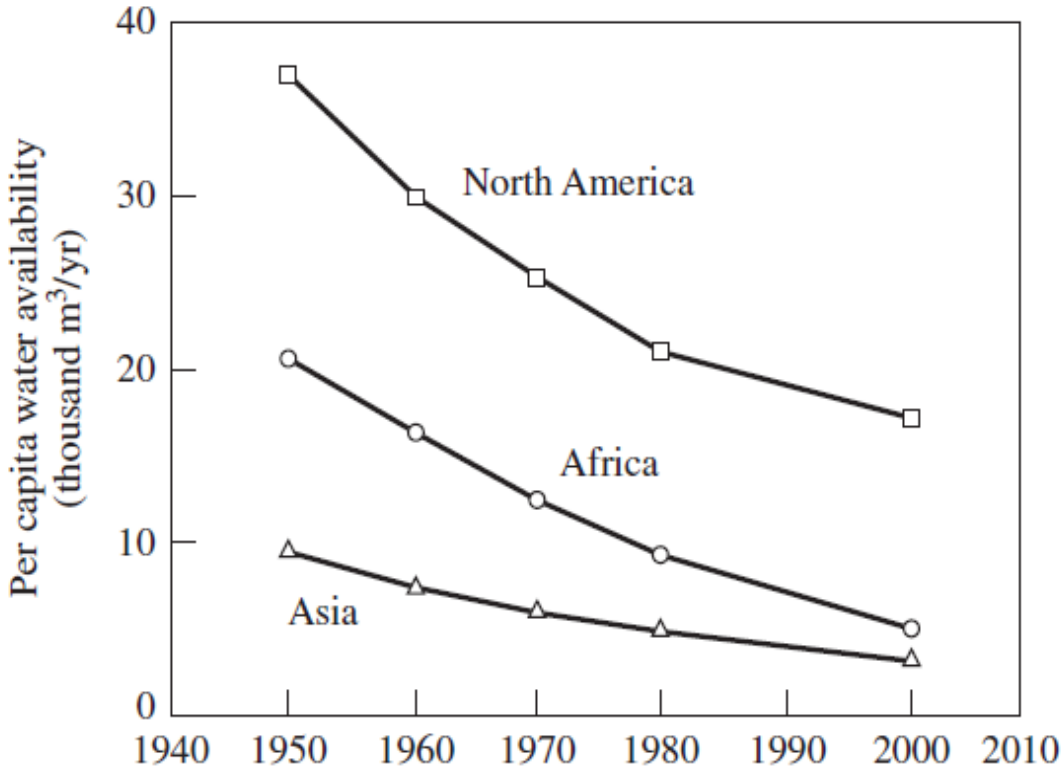
Units : 10^3 km^3/yr

- Over oceans – less precipitation than evaporation
- Over land - more precipitation than evaporation
- To maintain balance there must be runoff water returned to oceans by stream and groundwater flow
- 10% of worlds annual runoff is withdrawn for human use.
  It may seem like a lot should be available, but not in so many places.

Water Surplus vs. Scarcity



Water Usage



Country	Percent of Total Flow Originating Outside of Border
Egypt	97
Hungary	95
Mauritania	95
Gambia	86
Syria	79
Sudan	77
Iraq	66
Bangladesh	42

Emerging Threats to World Water Problems

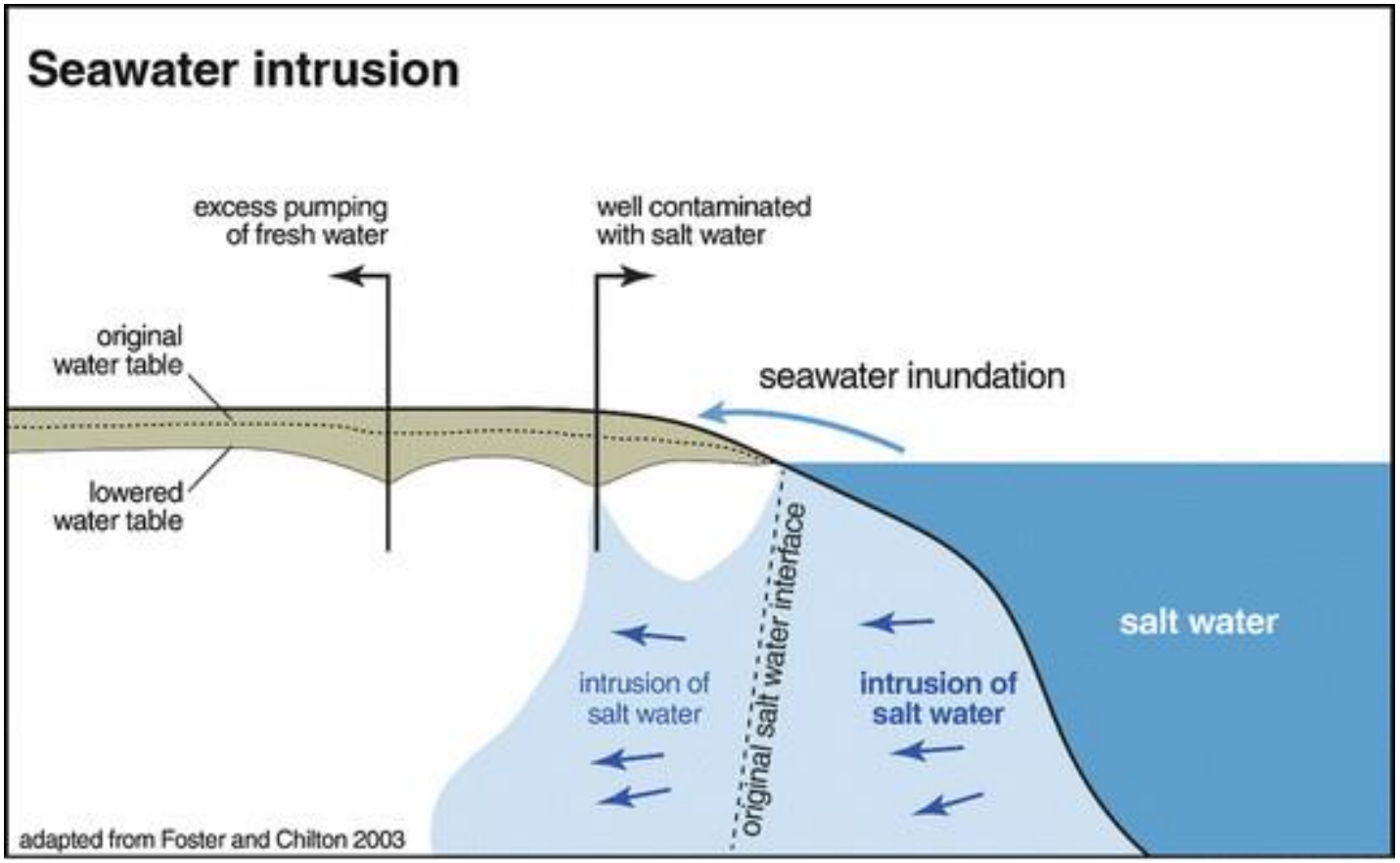
- In the past century over half of all **wetlands** on the planet were lost to development and conversion. Wetlands are important because they act as water “filters” and flood buffers

- Water **pollution** is a serious threat to the world’s water. Microbes, salts, and pollution from agriculture and industry contribute to the problem.
  - Emerging contaminants, super-bacteria

- **Climate change** will likely have major impacts on the world’s freshwater resources. Some areas will suffer more frequent and severe droughts; other places will face more frequent and severe floods.

Emerging Threats to World Water Problems

- **Rising sea levels and increased pumping will decrease fresh groundwater availability in coastal areas**



Emerging Threats to World Water Problems

- We need technologies that can help us ***save or recycle*** enough water to hedge against climate change and reduce stress on threatened natural resources while still allowing us to meet our needs for agricultural, industrial, and residential use.

- As of 2013, 780 Million people had no access to clean drinking water (UN, 2013).

- *Those who solve the worlds water problems deserve two Nobel Prices: One for science and one for peace.* – John F. Kennedy

Resource Management

- **Overall there is plenty of water, but the water isn't always where it is needed.**
  - Too much, too little, too dirty…
- **Possible strategies:**
  - Build dams (capture and store runoff)
  - Well drilling
  - Transfer water (reallocation)
  - Improve resource management
  - Other (desalination, icebergs, relocate people)

Examples of Resource Management

- NAWAPA (plan to divert water from Alaska and Canada to the Colorado River Basin - 1960's)
- China – charges more for water in semiarid north, also change use from low-value to high-value
- US Southwest – Land ownership comes with water rights – cities are buying and leasing farms for water rights
- Recycle or reuse waste water
  - Tokyo: wastewater used to flush toilets after sand filtration and chlorination
  - Hong Kong: use seawater for toilets
- Middle East – Israel reuses > 35% of wastewater – mostly for irrigation

Dams

- Worldwide, 93% of the 100 largest dams were built prior to WWII

- Before 1970 large dams were built in developing countries – now there are few due to monetary and environmental concerns.

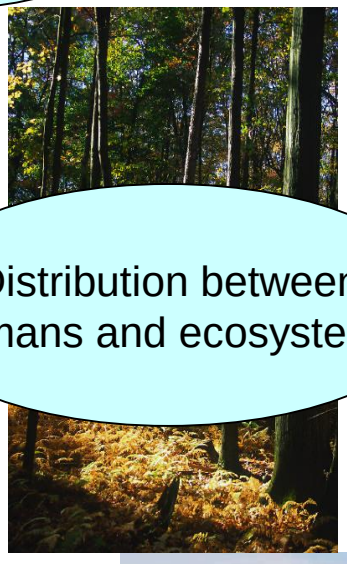
- Small dams (ponds) are now more popular
  - In China there are over 6 million small ponds and 90,000 small hydroelectric projects.
  - In India there are about 4 million small dams.

- The Four Rivers Restoration Project (4대강 사업) in Korea
  - Resource management vs. environmental impacts (water pollution)

7 Great Challenges in the Water Area

Safe water quality for a growing population

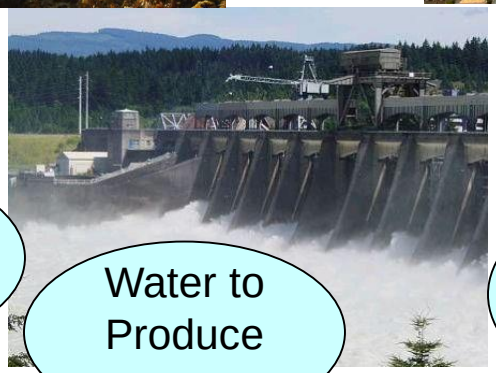
Water infrastructure (distribution & collection)



Distribution between humans and ecosystems

Water induced disasters & Disaster protection

Enough food for all



Water to Produce energy

Solution for water conflicts and fair water share for all

How much water do we need?

Sufficient	> 1700 m^3
Water stress	1000 - 1700 m^3
Scarcity	500 - 1000 m^3
Extreme scarcity	< 500 m^3

From Falkenmark & Widstrand, 1992

Water Requirements for People, Services, and Industry

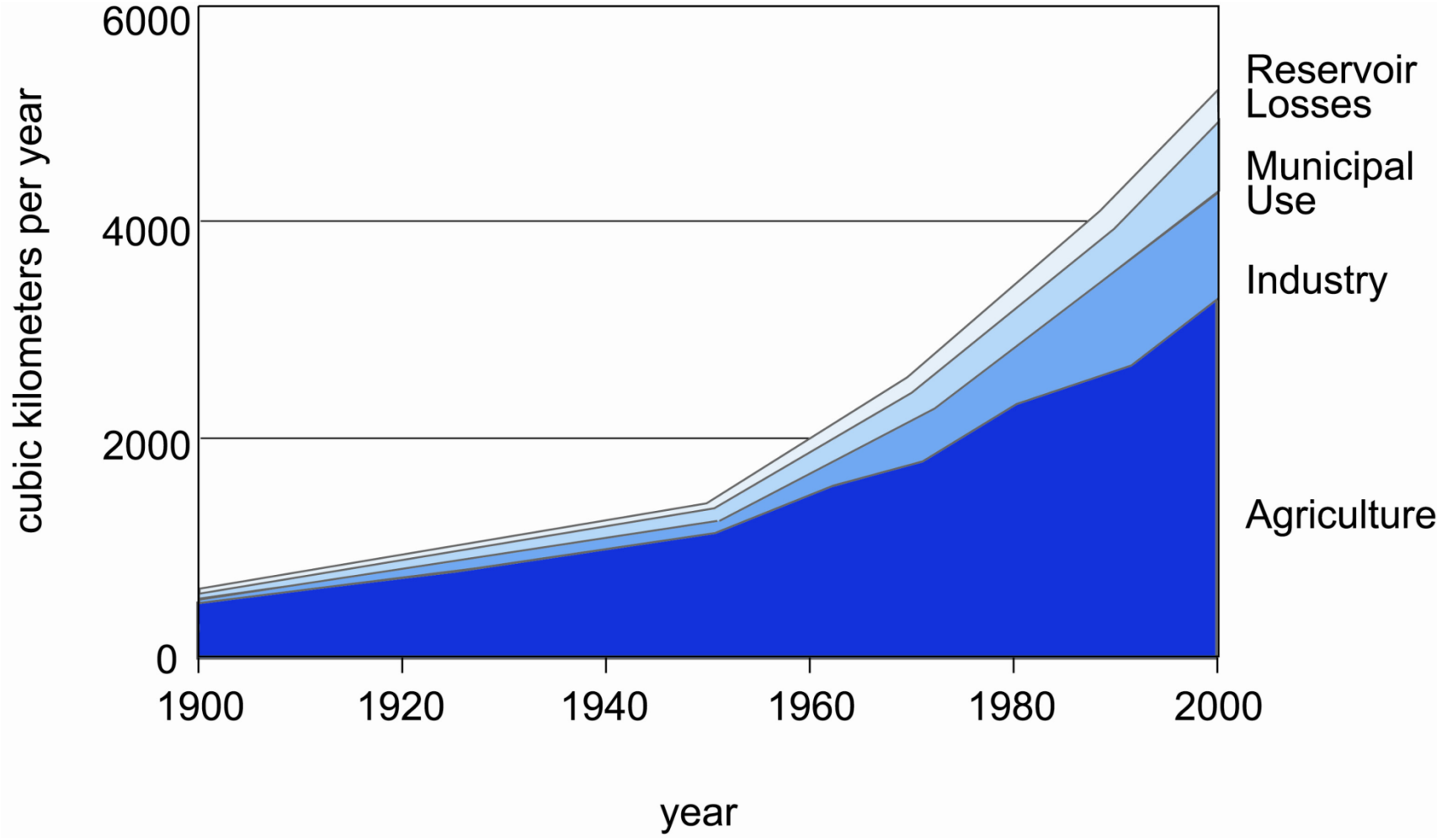
Purpose	Daily requirements liter/person	Annual requirements m^3/person
Drinking water	3 - 9	1 - 3
Personal hygiene, sanitation, and cooking	30 - 50	11 - 18
Other household needs	80 - 250	30 - 90
Services	20 - 400	8 - 140
Industries	20 - 400	8 - 140

Social good and human right

Economic good

From Zehnder *et al.* 2003

Estimated Annual World Water Use
(Total and by Sector 1900–2000)



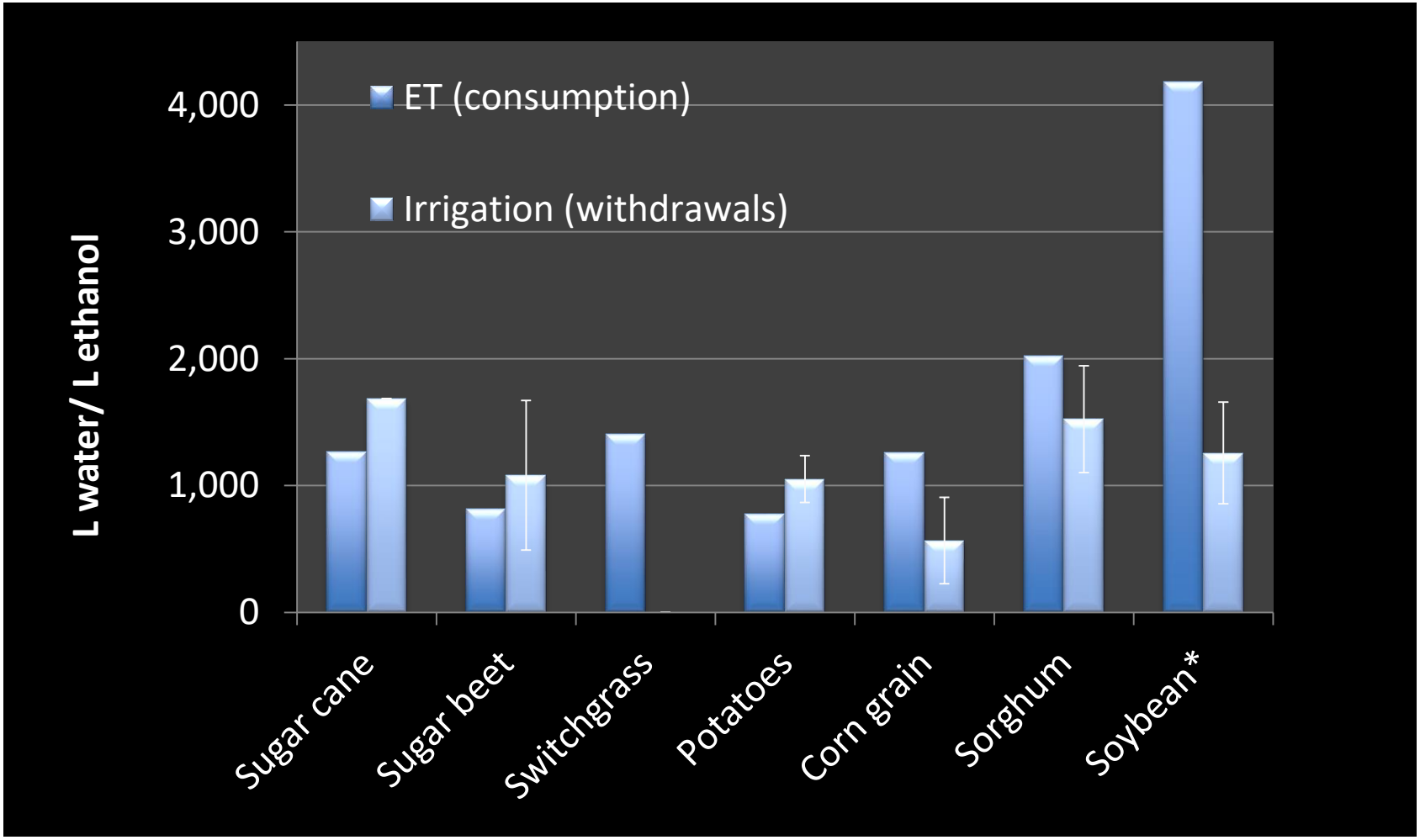
Water Needed to Produce 1 kg of Plant Material (Dry Weight)

Sorghum	250	Liter
Corn	350	Liter
Clover	460	Liter
Wheat	500	Liter
Potatoes	636	Liter
Cucumber	713	Liter
Alfalfa	900	Liter

Rule of thumb:
For 1 kg of bread 1 m^3 water is needed
For 1 kg of beef 15 m^3 water is needed

Partially from Muller, 1974

Water Footprint of Biofuels



Are we ready for 50 gallons of water per mile driven on ethanol?

Dominguez R., S.E. Powers, J.G. Burken and P.J.J. Alvarez (2009). Environ. Sci. Technol. 43 (9), 3005-3010

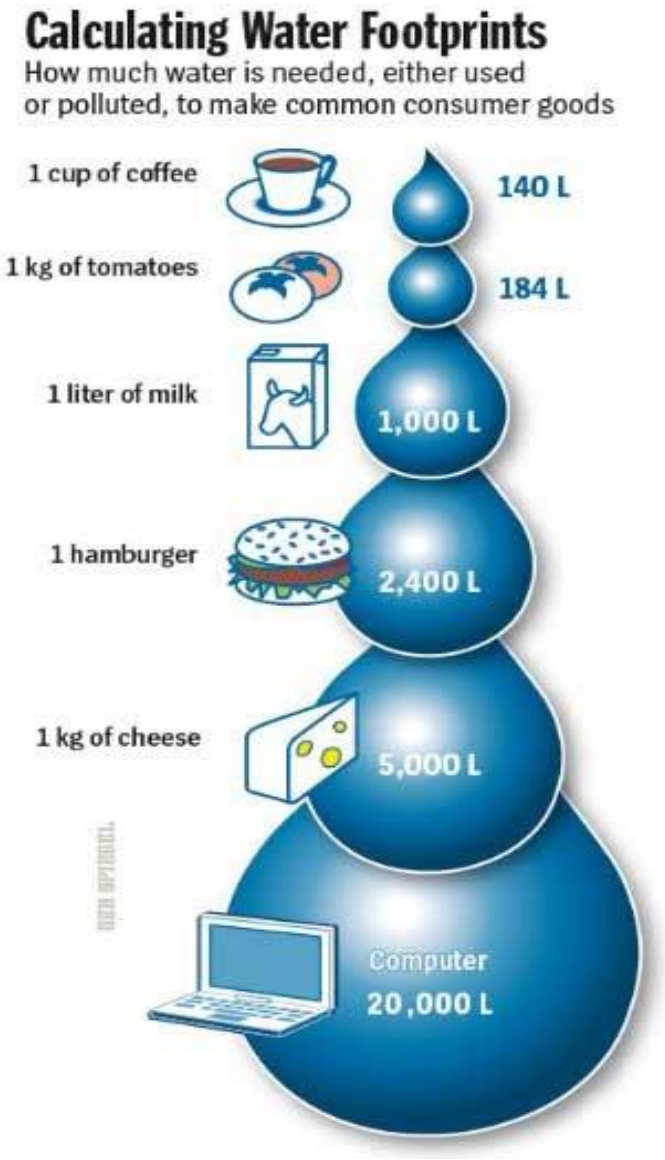
Virtual Water and Water Footprint

- **Virtual water:**
the total volume of water needed to produce and process a commodity or service.

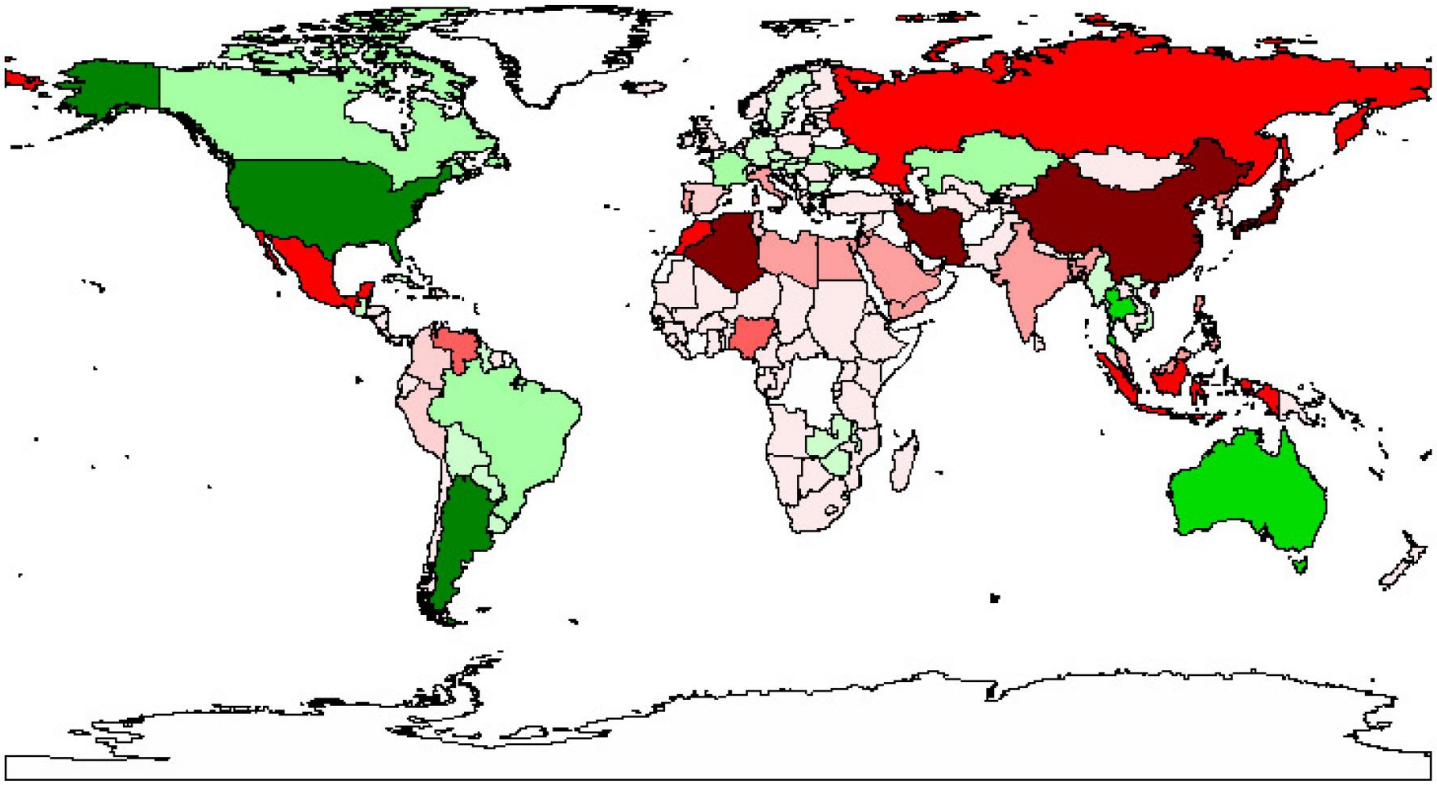
- **Blue water FP:** Amount of freshwater required to make a product

- **Green water FP:** The amount of rainwater required to make a product

- **Grey water FP**: Water needed to dilute pollutants (salt, metals, biocides, bacteria) to meet water quality standards as a result of making a product



Net Virtual Water Trade by Country
(Average over the Period 1997–2001)

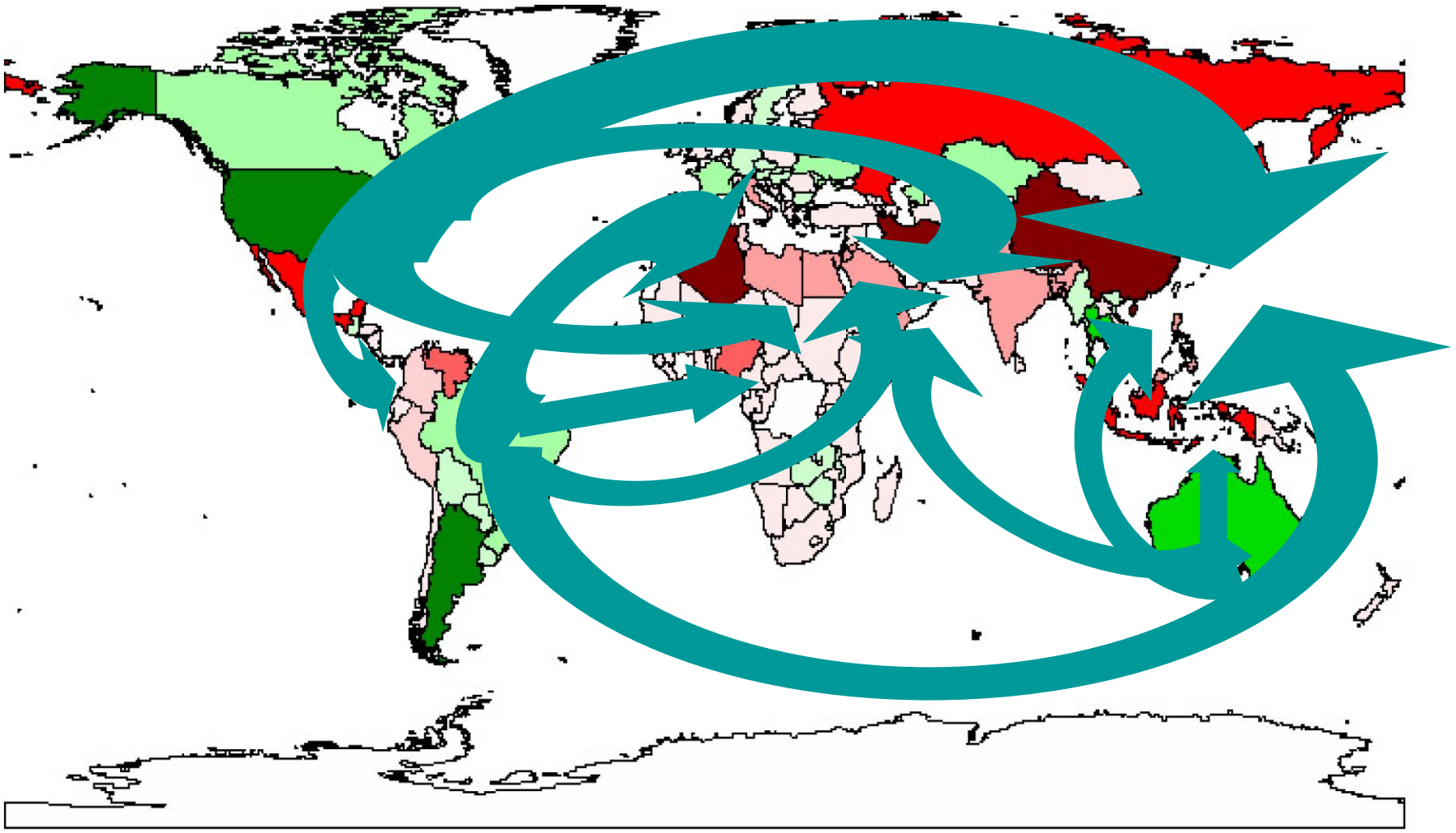


Unit: cubic km

no data	-15 - 0	15 - 20
-100 - -50	0 - 5	20 - 30
-50 - -25	5 - 10	30 - 60
-25 - -15	10 - 15	

From Yang *et al.* 2007

Virtual Water Flows by Regions
(Average over the Period 1997–2001)



From Yang *et al.* 2006

Challenges & Implications

- Food security and virtual water trade are key elements for a sound regional and local water management.
- Economic power of less developed countries and regions must be strengthened to allow virtual water import for optimizing local water management.
- For integrated water management, the principle of national food self-sufficiency has to be abandoned or at least questioned.

Examples of Unsustainability of Water

- **Agriculture is the single largest consumer of water & the most inefficient.**

- **The Aral Sea is disappearing.**
  The sustaining rivers coming into the Aral Sea are used to irrigate cotton.

1998 **2008**

Unequal & Inequitable Distribution of Water – Results in CONFLICT!

- Political
- National
- Violent
- Economic

- Economic Conflict:

  250 million gallons will sustain 100,000 high tech jobs in California, and only 10 agricultural jobs.

  Will water be the oil of next century?

Challenges to Sustainable Water Management

- Over-exploitation
- Disposal mentality
- Emerging pollutants (xenobiotics, EDCs, genes, nanomaterials, …)
- Lack of holisitic perspective with long-term vision

Sustainable Water Reuse Options

- **Treated wastewater can be used for**
  - Groundwater or small stream recharge
  - Irrigation (agriculture, golf courses and forestry, drip irrigation to minimize evaporation losses)
  - Landscaping (decorative ponds)
  - Dust control
  - Toilet flushing (low flush toilets)
  - Power plant cooling
  - Industrial use

- **Treated wastewater can be used in combination with harvested storm water runoff and rainwater**

Implications

- Sustainable water management requires equal attention to the triple bottom line (society + economy + environment), tailored solutions consistent with local/regional idiosyncrasies, and readiness to accept unconventional solutions

- It is not the technology what is sustainable, but how you put the system together

Pollution source control	*over*	*Treatment*
Recovery	*over*	*Wasting*
Reuse	*over*	*Discharge*