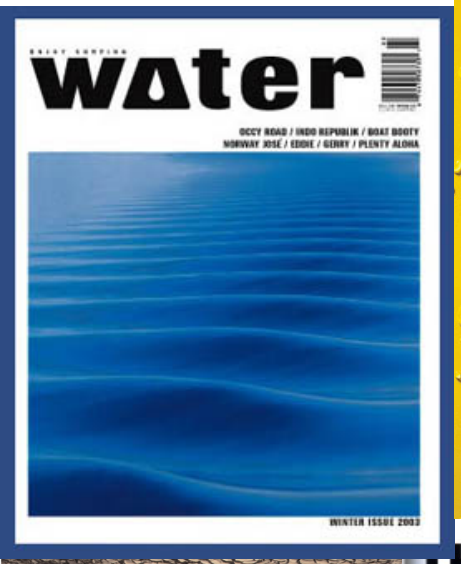
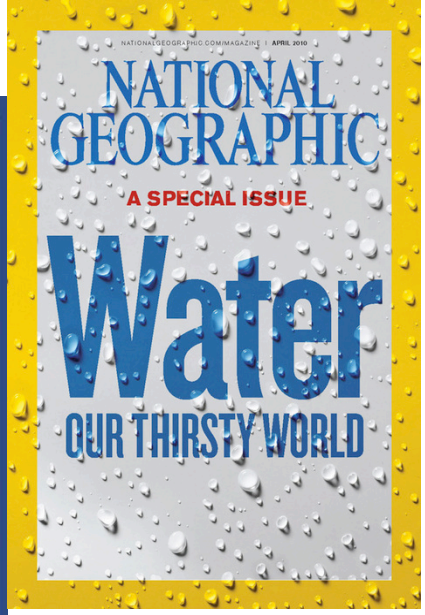




Water: Enough?

Ronald Turco

Professor, Environmental Microbiology & Agronomy

Director, Indiana Water Resources Research Center & The Purdue Water Community

Keith Cherkauer

Professor, Agriculture and Biological Engineering

Food security is affected by water availability.

Water becomes food

You consume food

You consume water

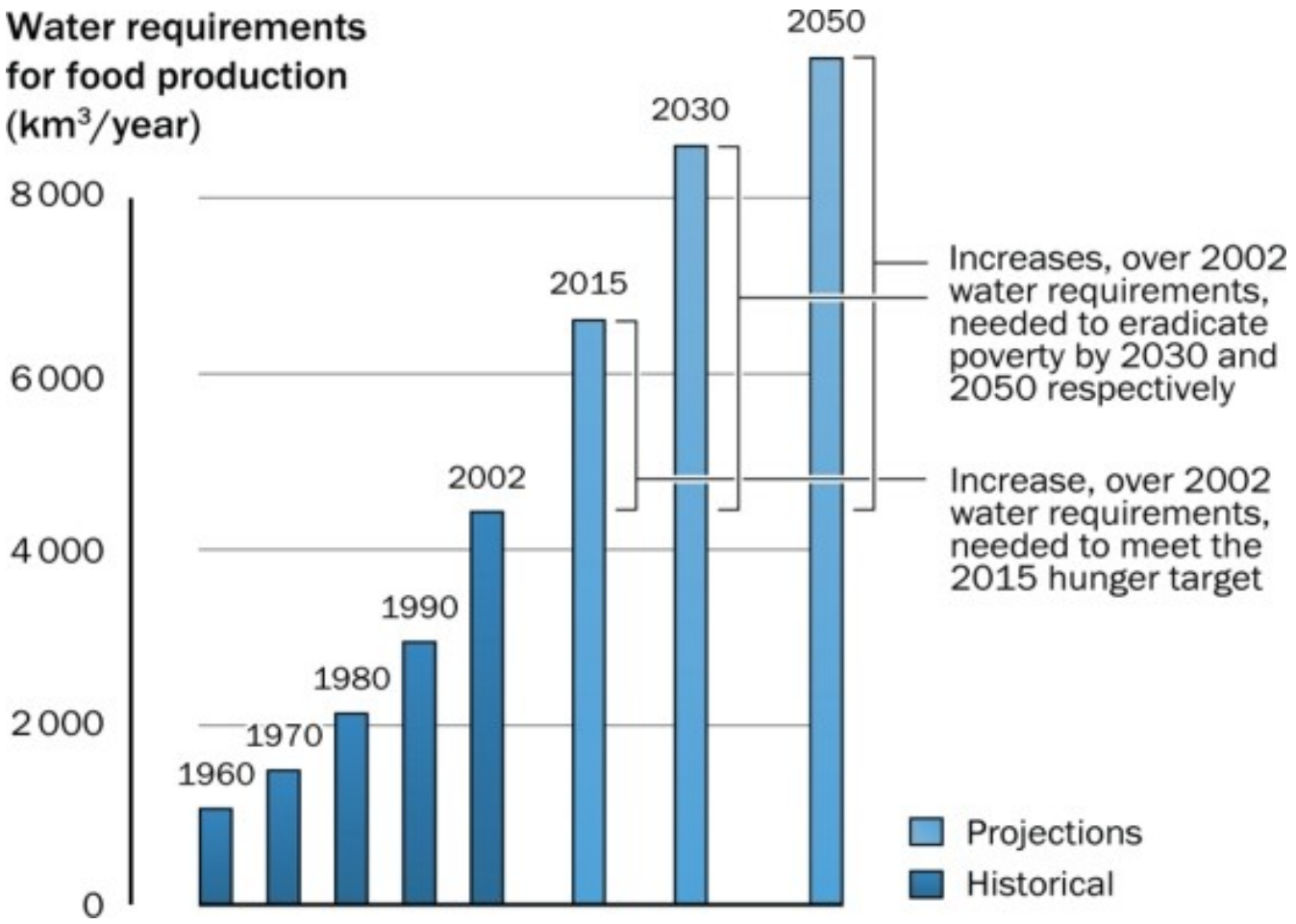
You are water

Wonderful water
divine chameleon forming
itself and our life

Nizamettin Esen Haymanali

http://www.waterencyclopedia.com/Da-En/Developing-Countries-Issues-in.html
http://blogs.ei.columbia.edu/2011/05/16/giving-the-earth-a-cool-shower-is-massive-irrigation-hiding-the-greenhouse-effect-around-the-world/

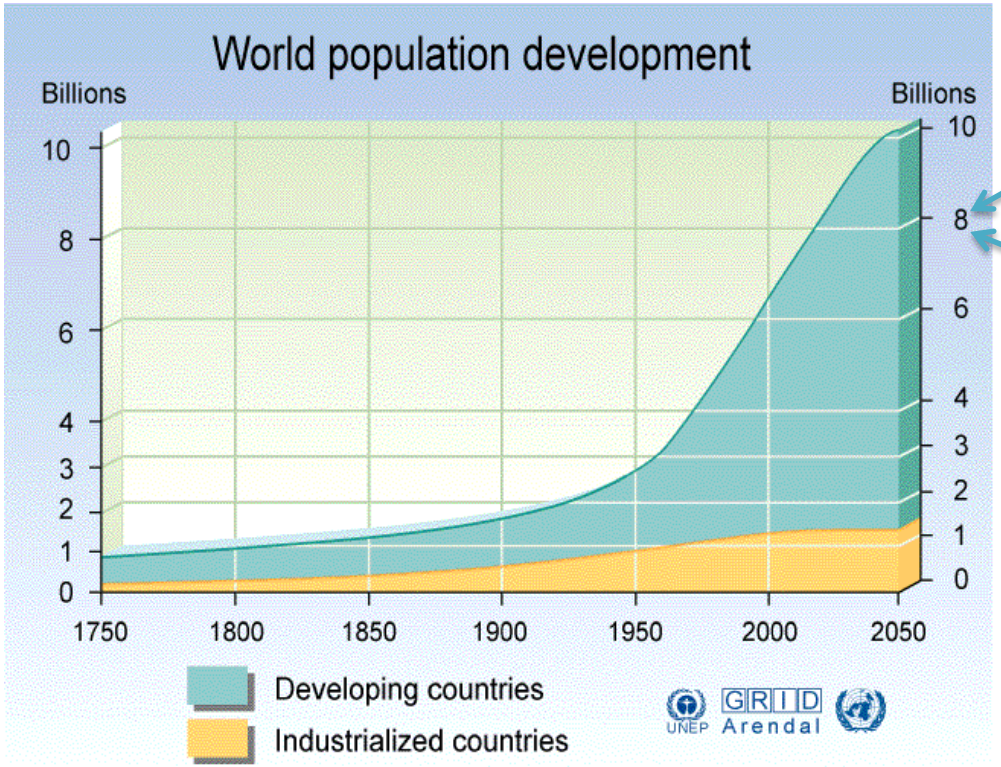
Over the next 50 years we will double the demand for water in agriculture -- assuming consumption patterns stays the same.



1 km³ = 1,000,000,000,000 L

http://www.grida.no/graphicslib/collection/vital-water-graphics-2

The increasing population on earth is putting a demand on water resources via both direct consumption and to a far larger degree, indirect consumption in food and other products.



8.76×10^{15} L / year drink demand

2.08×10^{18} L / year food demand

Direct Consumption is less than 1% of the world's total yearly need for fresh water.

3L per day drink
5000L per day food

http://www.grida.no/graphicslib/collection/vital-water-graphics-2

So how much fluid does the average, healthy adult living in a temperate climate need?

Adequate intake (AI) for men is roughly 3 liters (about 13 cups) of total beverages a day.

The AI for women is 2.2 liters (about 9 cups) of total beverages a day.

Access to water is critical factor in a free and well educated society.

Millions of women spending several hours a day collecting water limits their time in school.

http://www.mayoclinic.com/health/water/NU00283/

You are 55 to 78% water and it is a major part of everything you do!

Water per day per person

Drinking	**2-4 L**
Domestic	**40-400 L**
Food (the hidden water)	**1000-5000 L (and more)**

The average American uses about 378 L water per day **not accounting for water embedded in food and other products**.

How much useable water (directly useable) is on earth?

Is there new water?

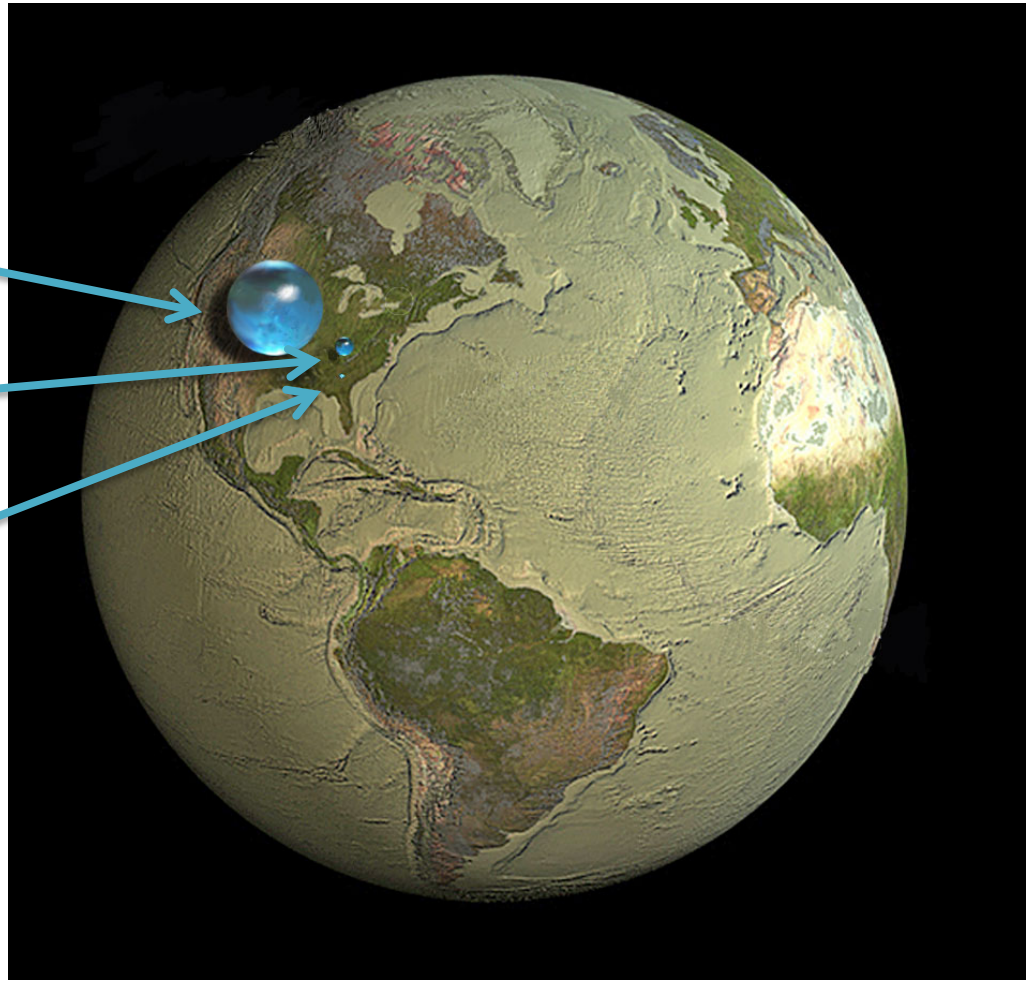
Where does water go?

9.30 x 10^{16} L of available water or 1.33 x 10^{7} L per person on earth, if it was evenly distributed!

All Water
Dia= 860 miles
Volume = 332,500,000 mi^3

All Fresh Water
Dia= 169 miles
Volume = 2,551,100 mi^3

Available Water
Dia= 35 miles
Volume = 22,339 mi^3
Lakes and Rivers



1 $mile^3$ of water = 4.16 Trillion L
7 billion people / earth (today)

http://ga.water.usgs.gov/edu/2010/gallery/global-water-volume.html

The 71% of the earth's surface is covered in water however, of this volume only 1 % is useable !

Antarctic and Greenland ice sheets, contains 99% of all fresh water on earth

Five Oceans 97.5%

Glaciers, Snow & Ice 1.75%

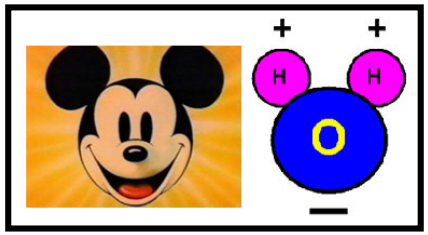
Groundwater 0.075%

Lakes, swamps & rivers 0.025%

The world's water resources are finite !

The world's water demands are expanding and unmet !

The total amount of water on earth is fixed at about 1.36×10^{20} liters (3.6×10^{19} gal) – it is constantly moving between three phases.



Dihydrogen monoxide

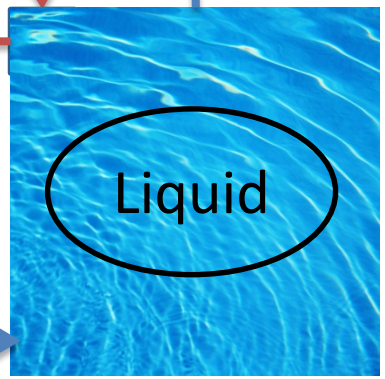
Sublimation

Evaporation

Deposition

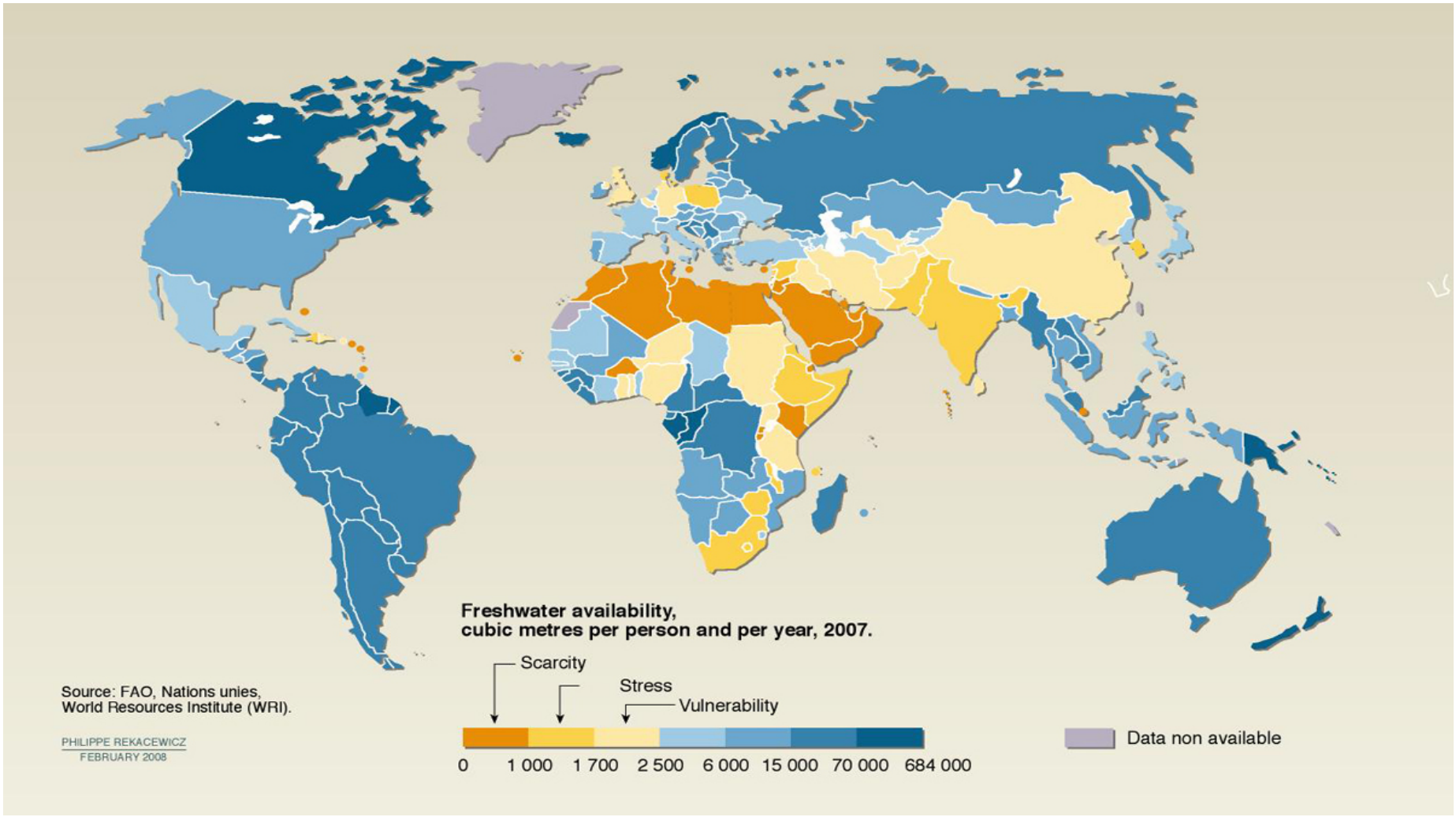
Condensation

Freezing



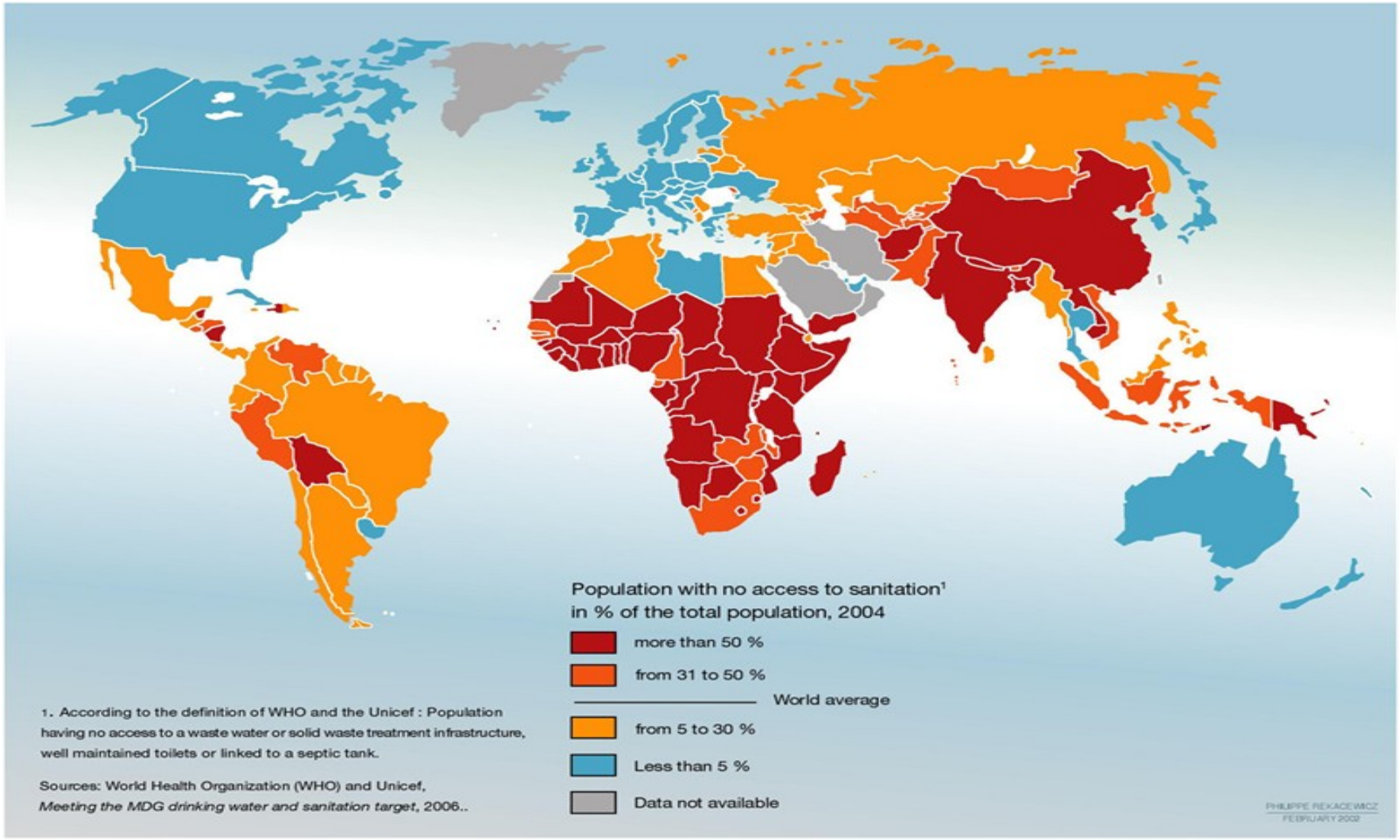
Melting

The availability of fresh water per person is uneven reflecting the unevenness in the distribution of the supply (physical and geopolitical issues.)

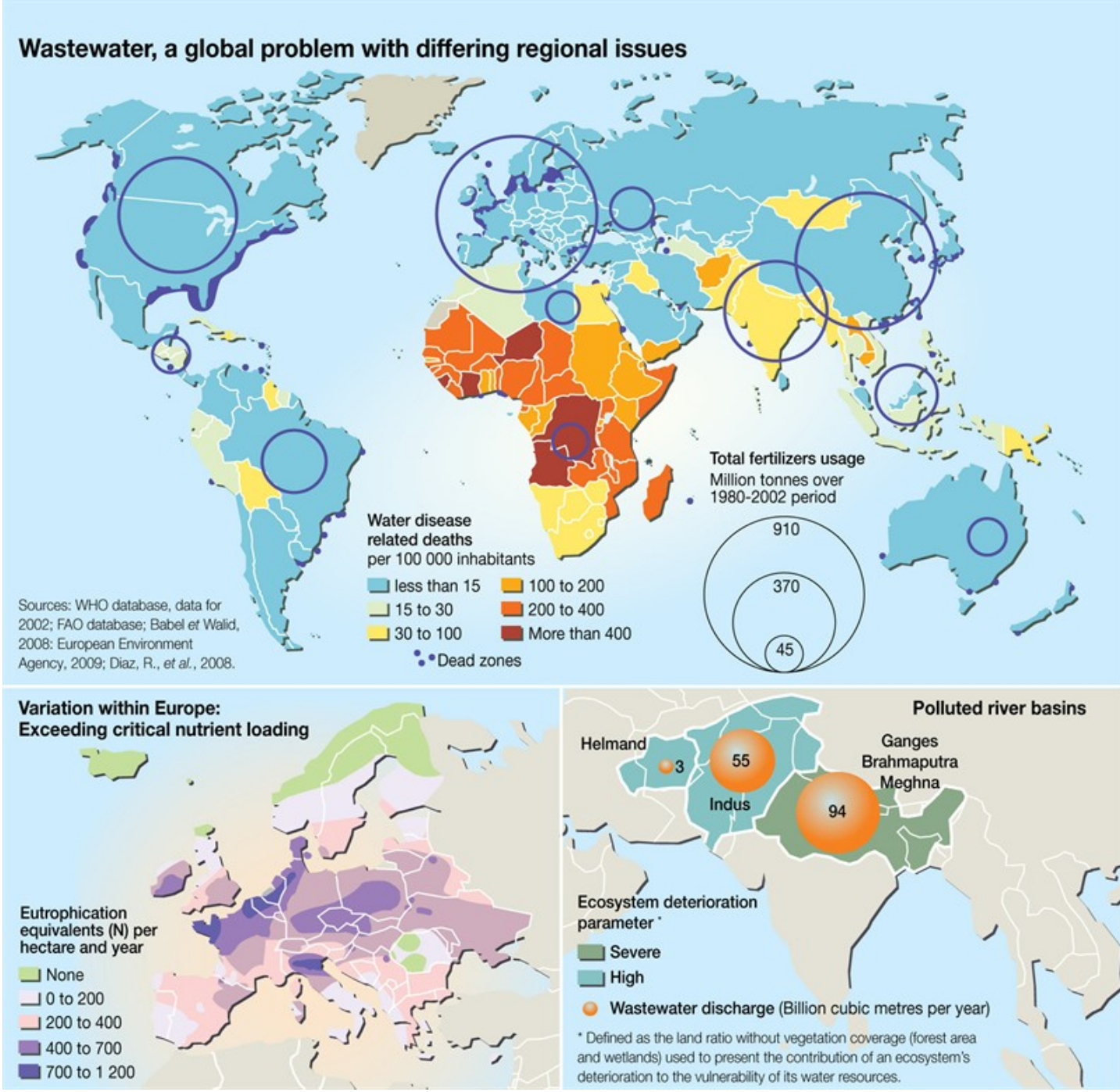


http://www.grida.no/graphicslib/collection/vital-water-graphics-2

Conversely, waste water treatment is also uneven across the globe – leading to pollution of local supplies.

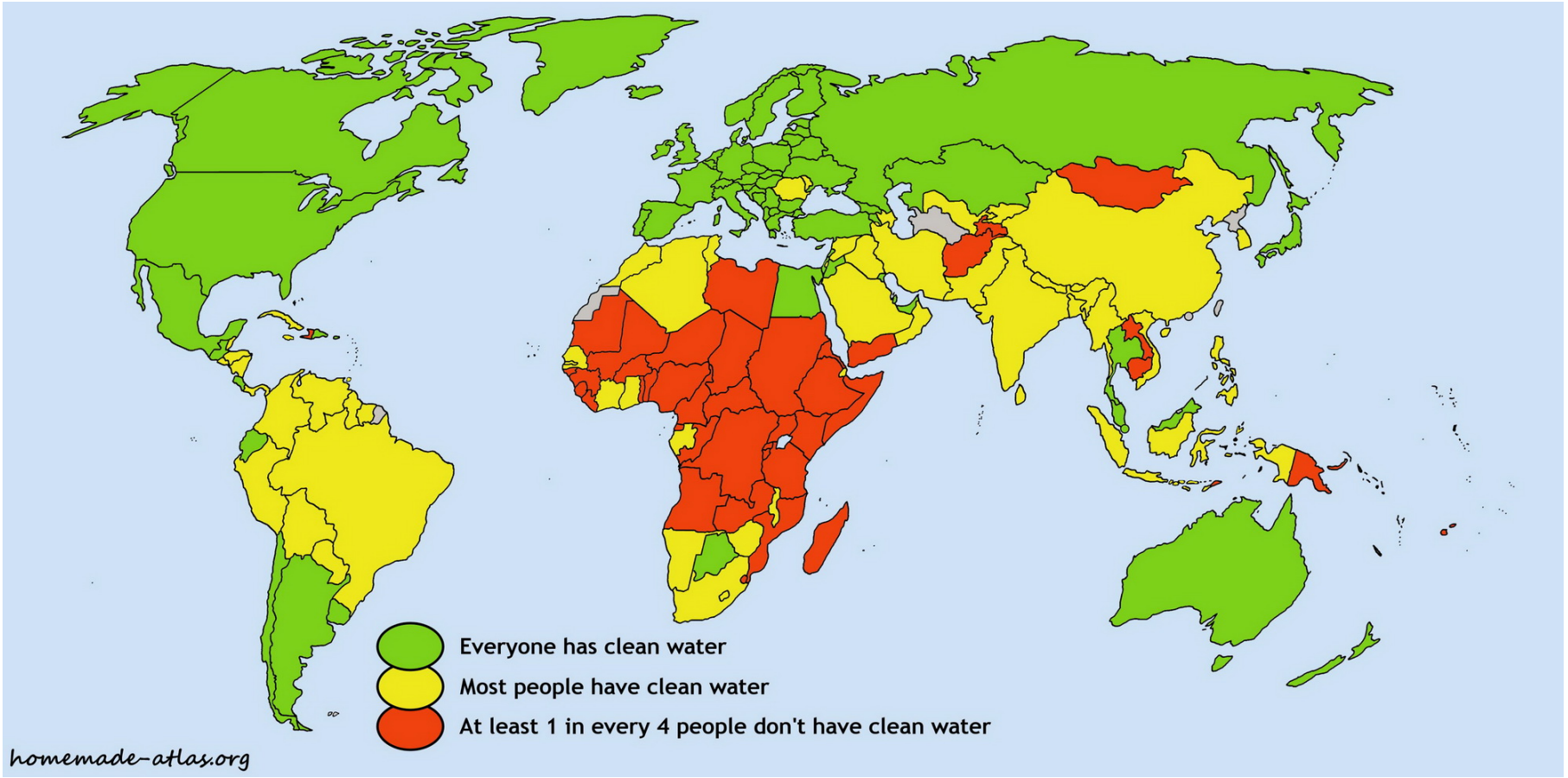


The <u>fresh water to waste water</u> connection is critical and not always talked about.

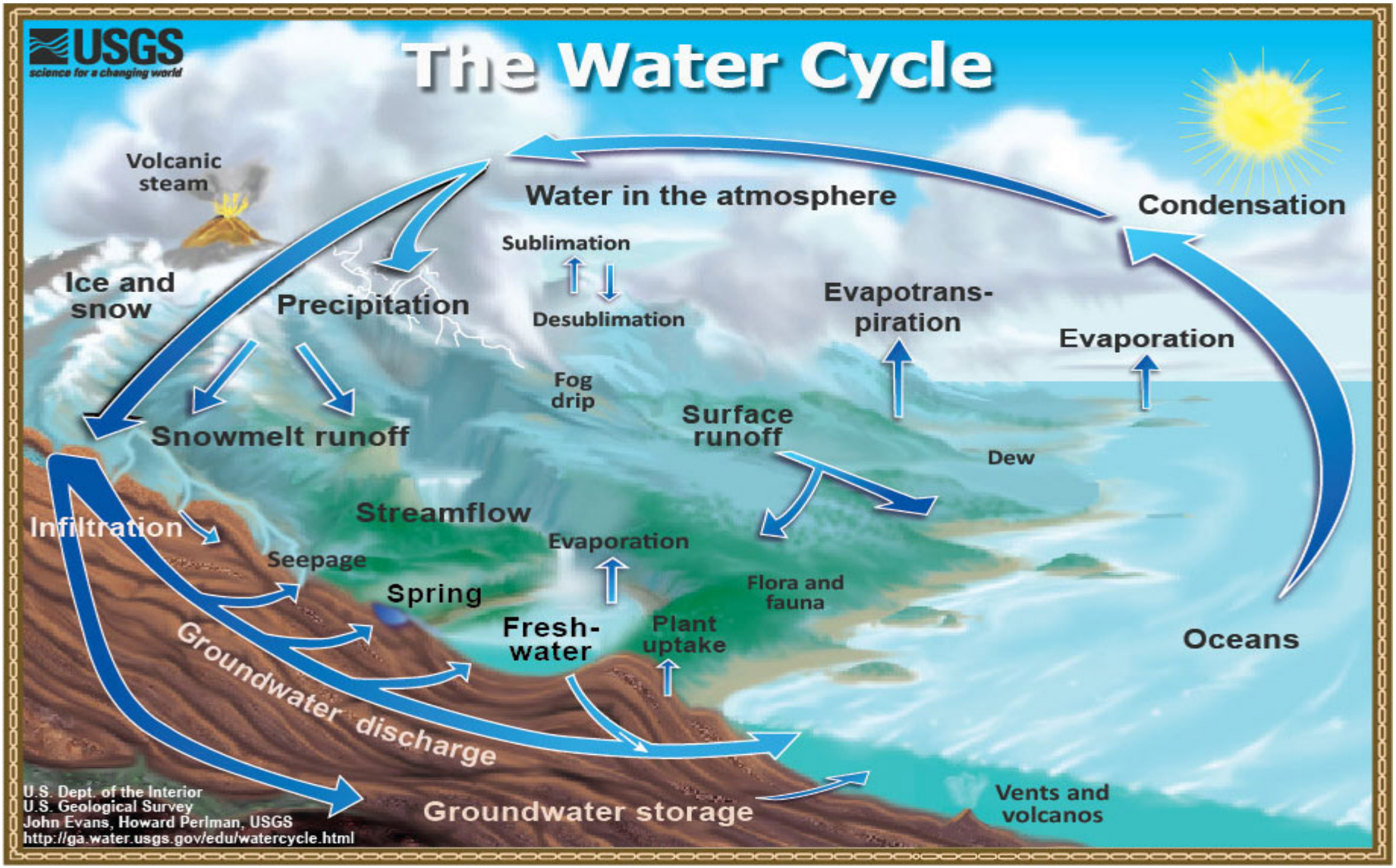


http://www.grida.no/graphicslib/collection/vital-water-graphics-2

Combination of weak supplies and poor sanitation results in ~ 3 million water related deaths per year.

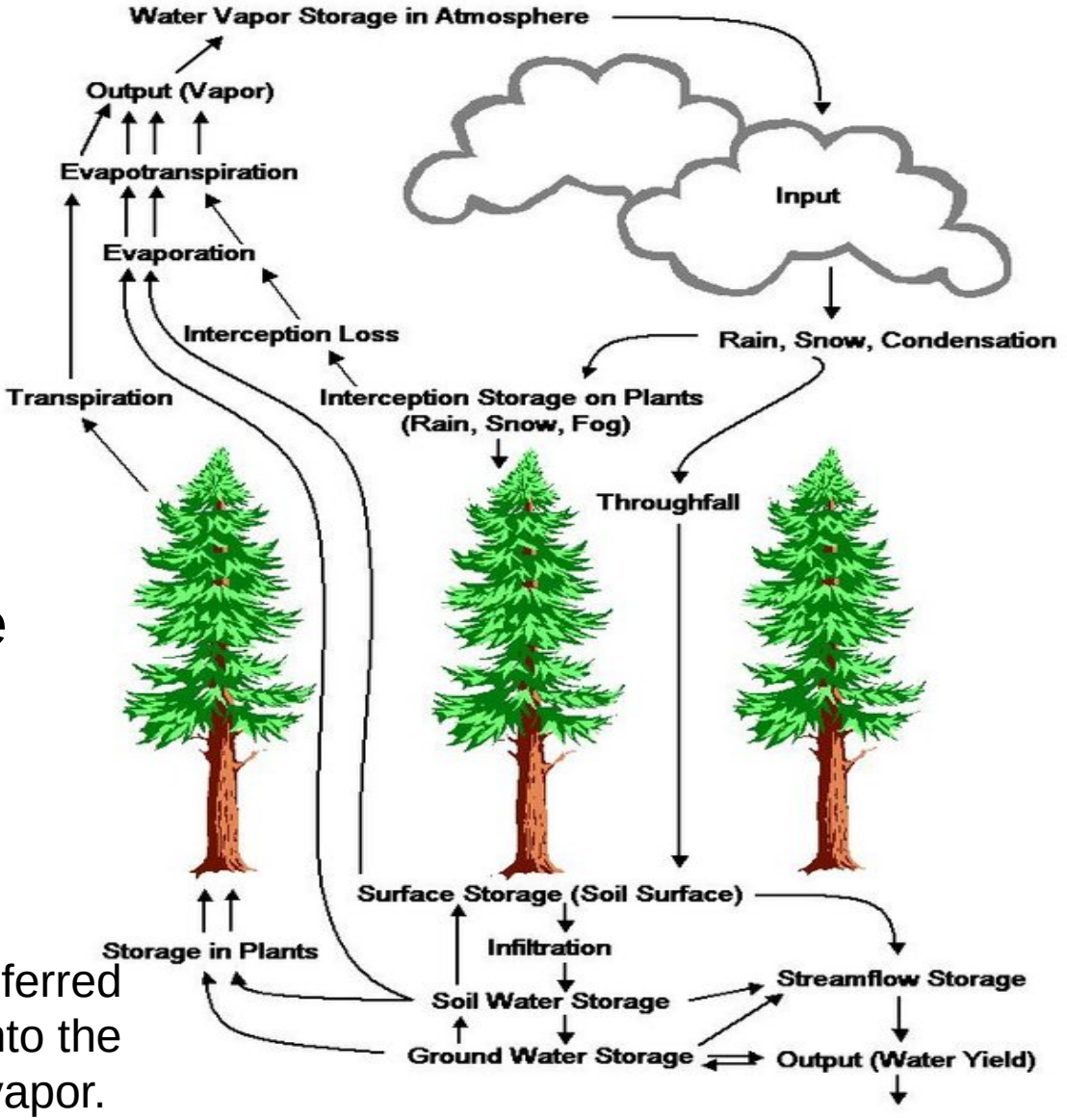


The three phases control the world's available water supply as part of a global Water Cycle.



Water flows along a “high to low” concentration (energy) gradient.

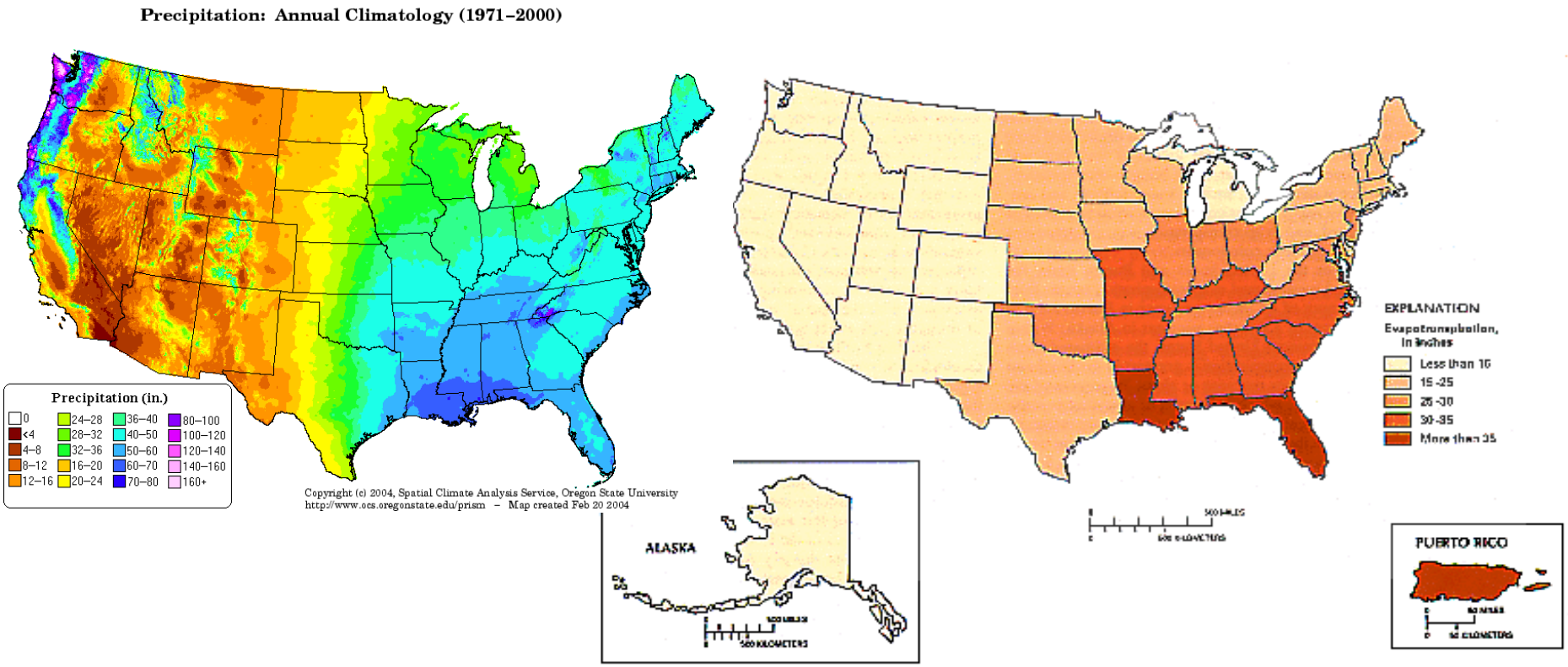
Wet soil to dry soil
Uphill to downhill
Low salt to high salt
Earth to the atmosphere



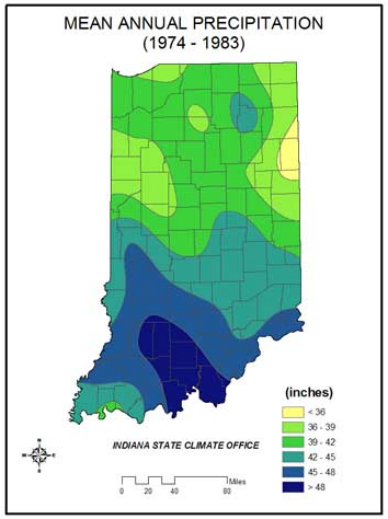
Evapotranspiration: water is transferred from the soil and plant surfaces into the atmosphere in the form of water vapor.

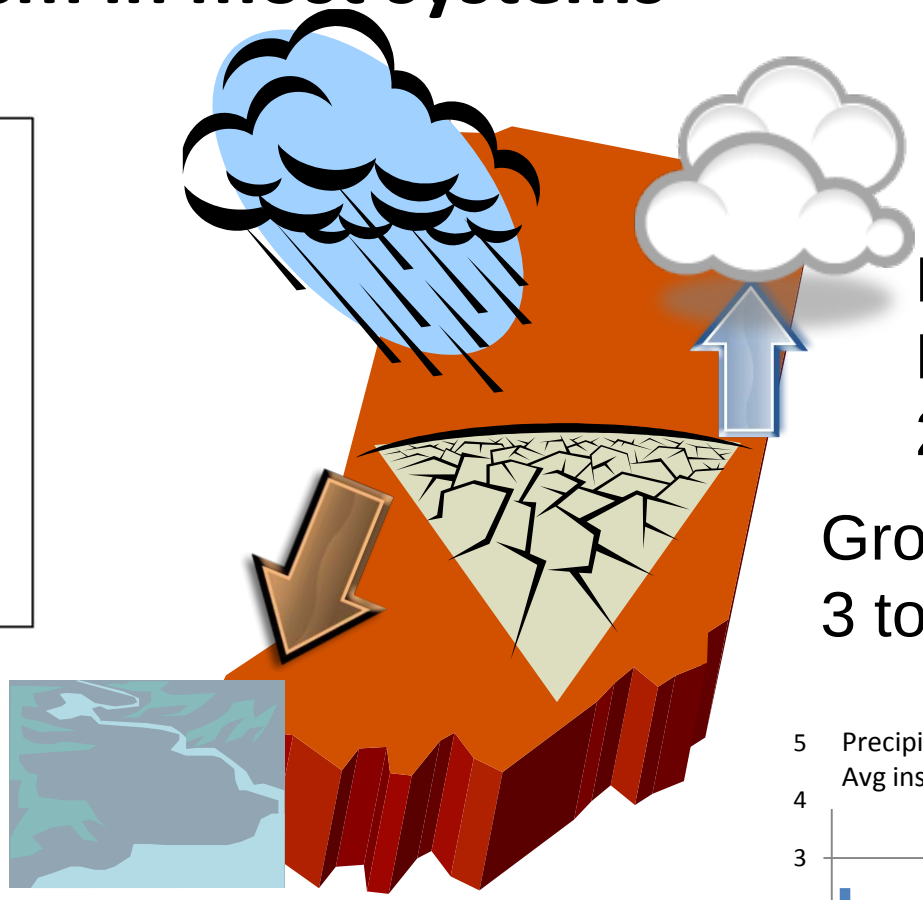
http://www.eoearth.org/article/Hydrologic_cycle?topic=49483

The input of precipitation starts the reaction: net evapotranspiration is a function of soil and plant type, we can drink the rest.



Evapotranspiration is the dominate water loss mechanism in most systems

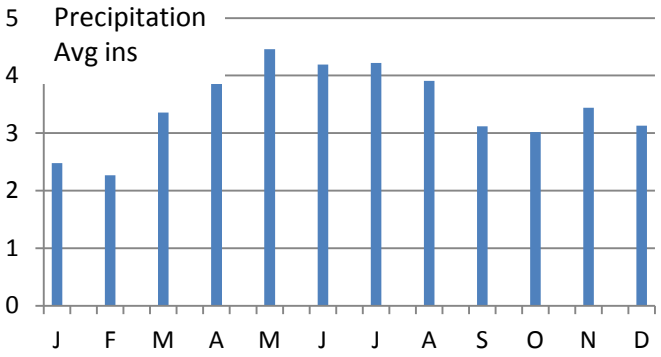




Precipitation
38 to **40** inyr^{-1}

Evapotranspiration
Evaporation
26 inyr^{-1}

Groundwater recharge
3 to 4 inyr^{-1}



Potential Surface Runoff
8 to 9 in yr^{-1}

Surface Runoff
5.62 x 10^{12} gals yr^{-1}

From Clark, 1980

https://climate.agry.purdue.edu/climate/facts.asp

Rainfall is the best source of water for agriculture as it provides vast amounts of green water!

Area	Rainfall Amount (in)	Gallons
1 Ac	1	27,154 (113 tons)
"	3	81,462
"	5	135,770
1 sq mile	1	17×10^6

http://ga.water.usgs.gov/edu/earthrain.html

Rainfall over Indiana generates vast amounts of water

Area	Rainfall Amount (in)	Gallons
23,307,520 ac Indiana	1	6.3×10^{11} (2.6×10^{9} tons)
"	3	1.89×10^{12}
"	5	3.16×10^{12}
372 sq mile Indianapolis	1	6.46×10^{9}

http://ga.water.usgs.gov/edu/earthrain.html

The majority of agriculture is rain fed. Irrigated agriculture provides 40% of the world's food and consumes 75% of world's freshwater resources; up to 95% in some developing countries.

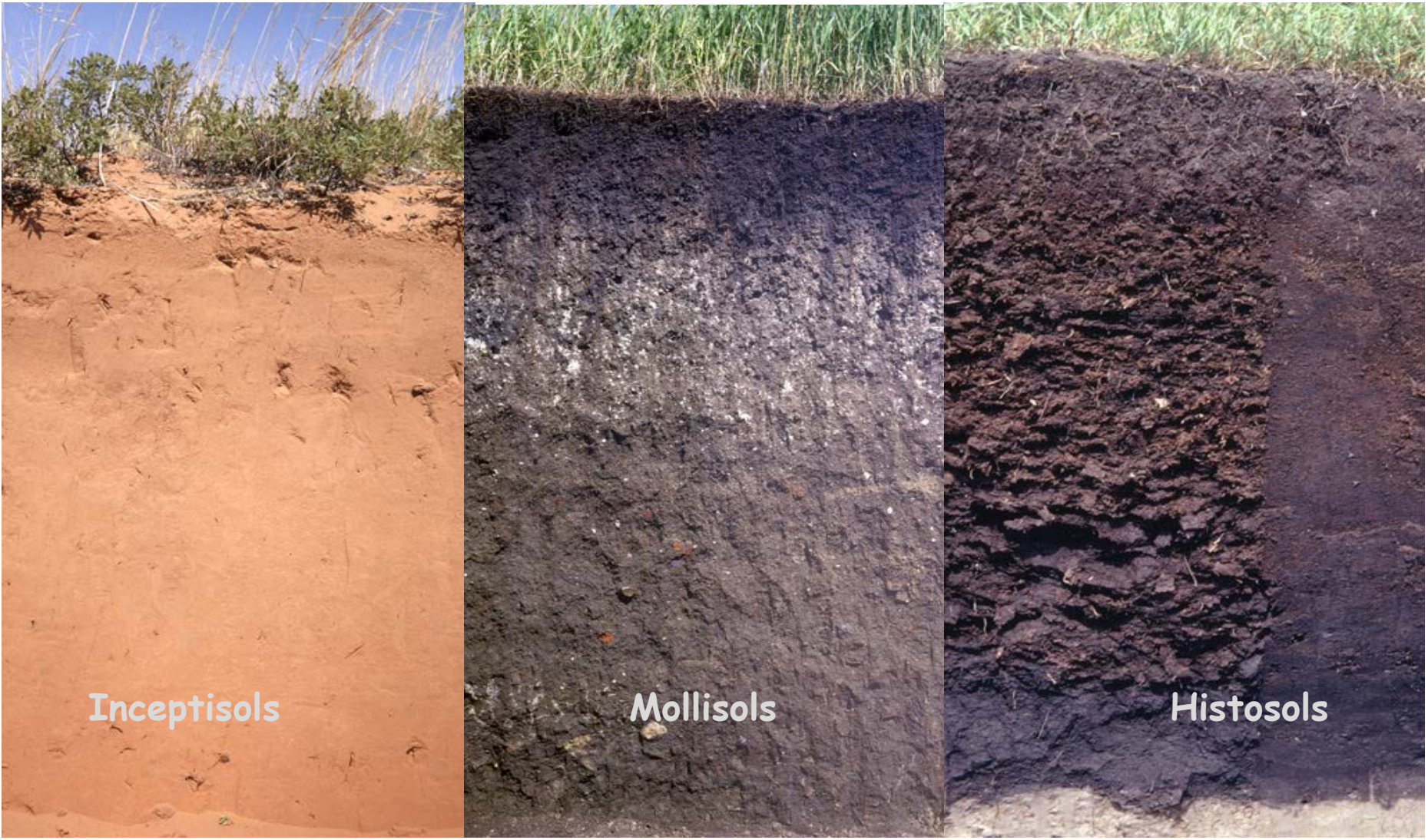
Today

14 plants and 8 terrestrial animals provide 90% of the worlds calories from some 30,000 eatable plant species

Wheat, rice, and corn provide ½ world's calories

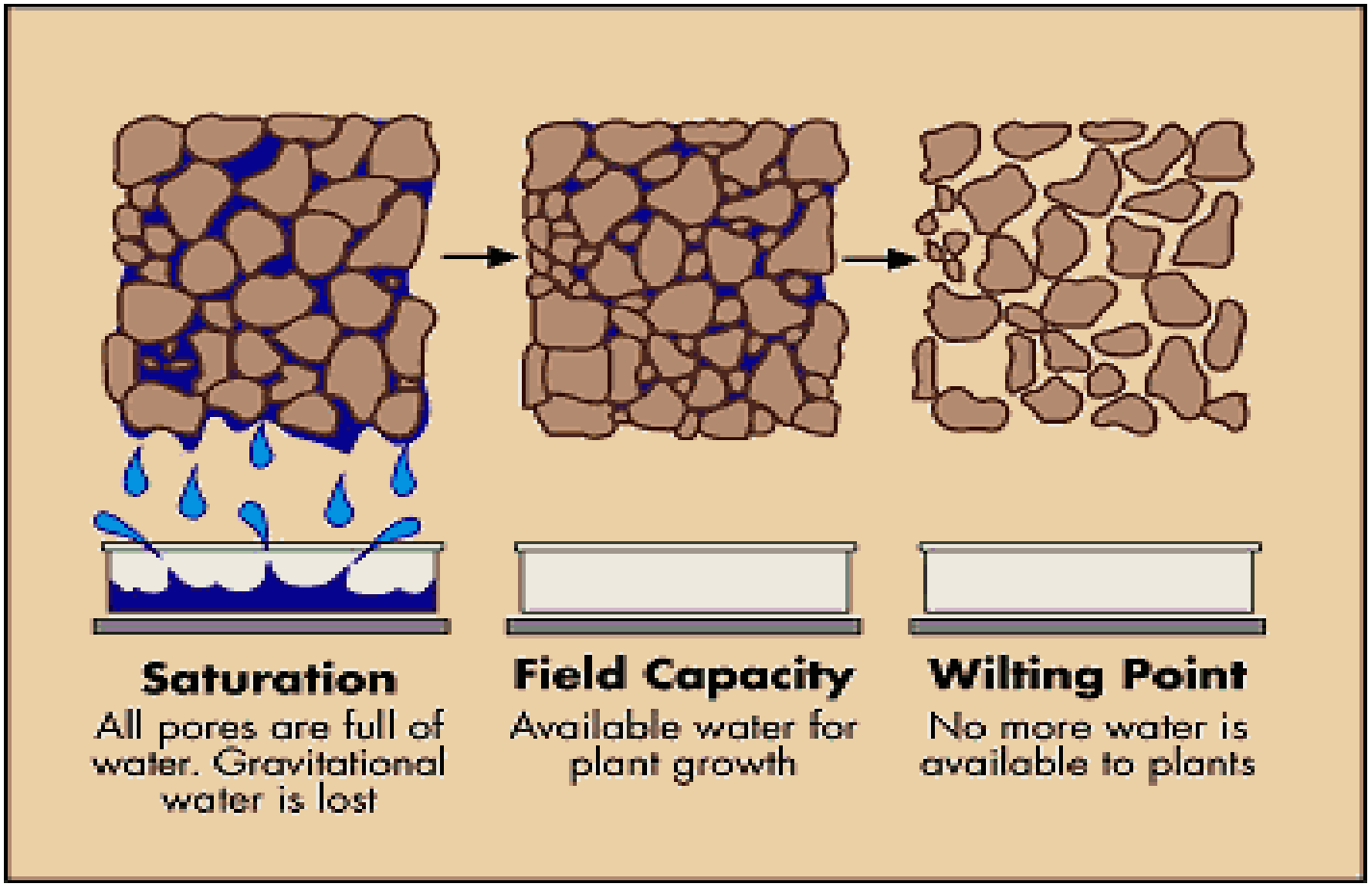
Four primary forms of animals: fish, beef, pork, and chicken

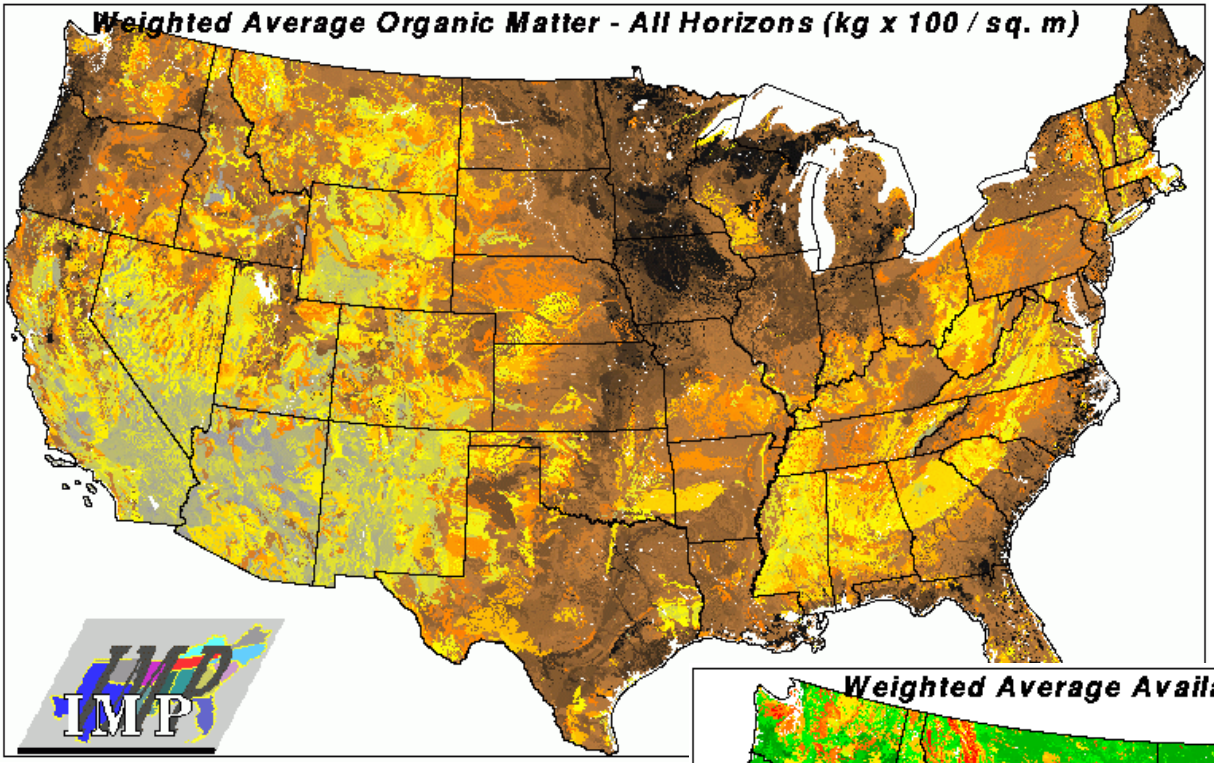
Water for agriculture (food) is controlled by the soils ability to hold and then deliver a supply.



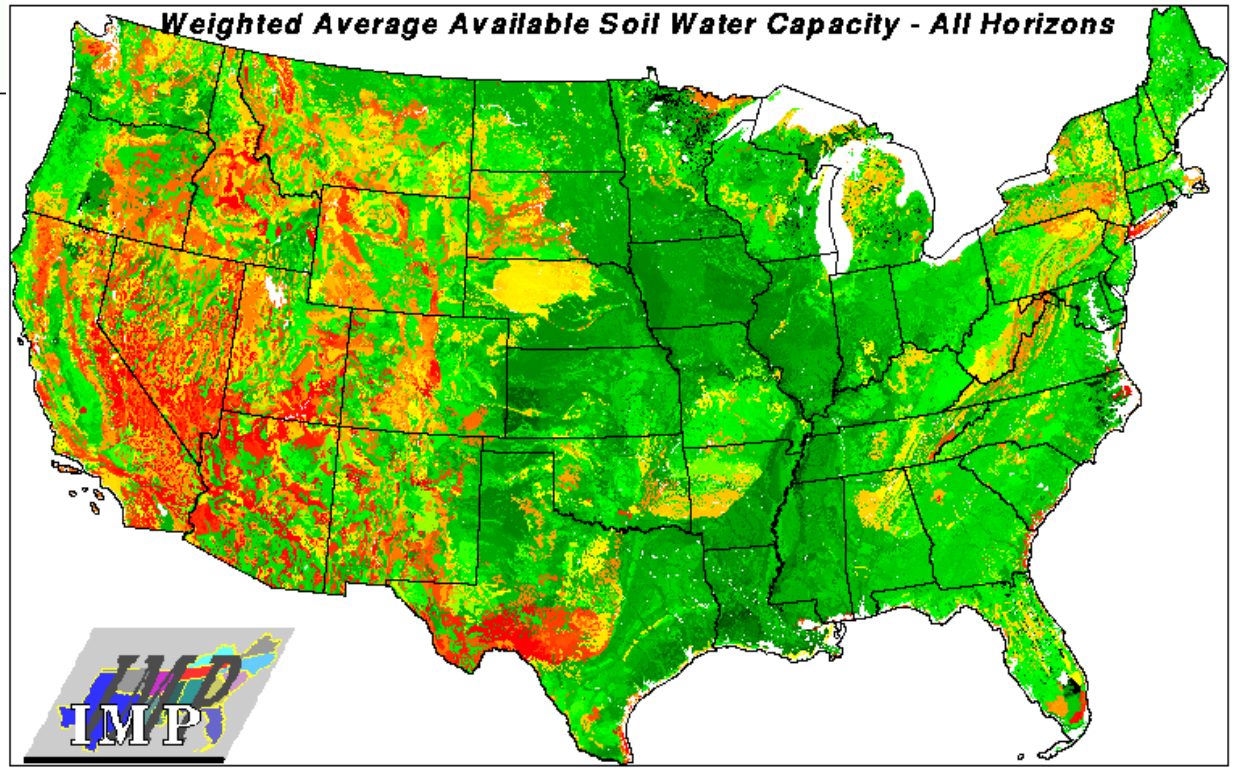
http://soils.usda.gov/technical/classification/orders/

The difference between field capacity and wilting point is water used for plant growth .. Soil Organic Matter





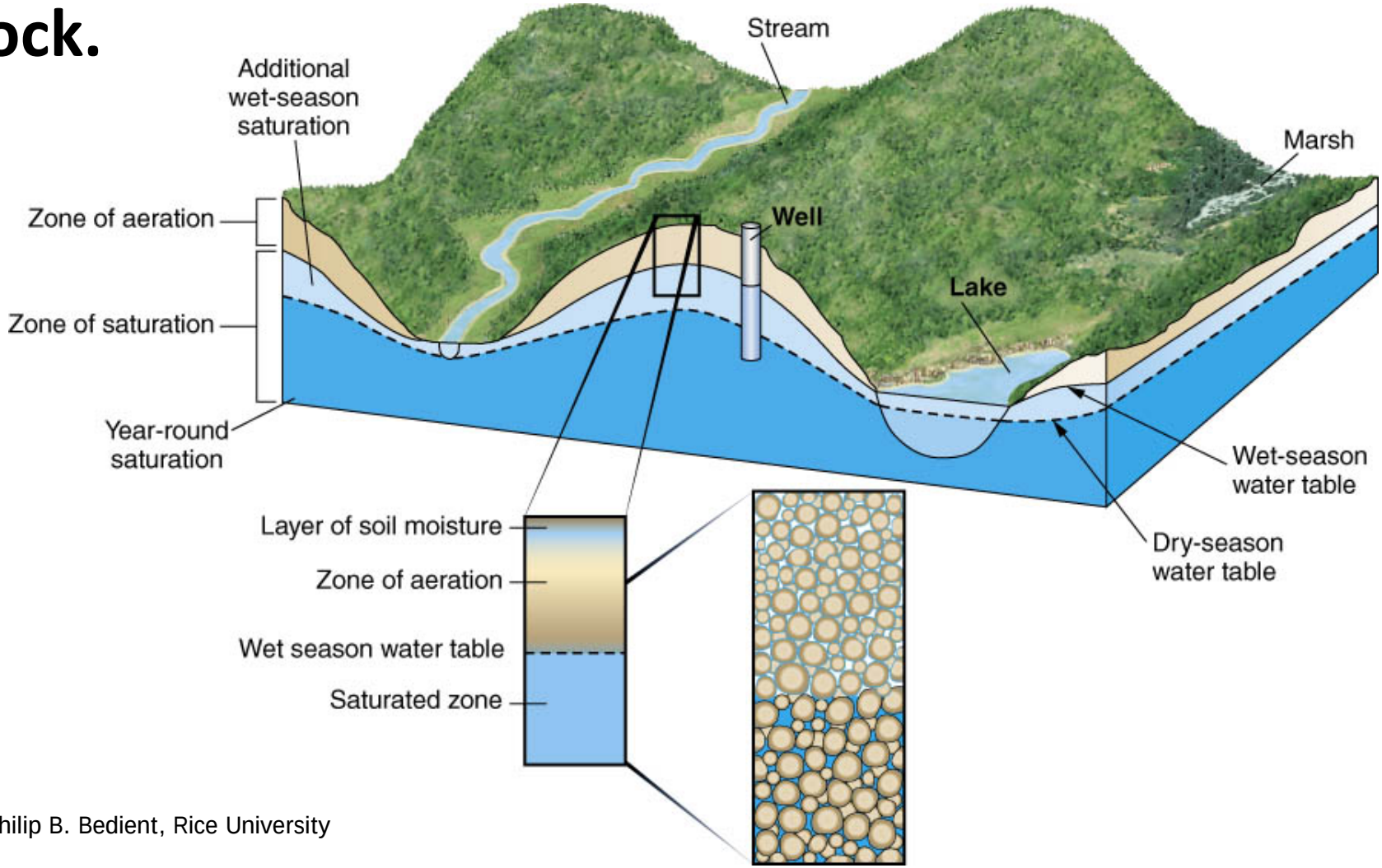
Soil Organic Matter Holds water !!



William W. Hargrove
and Robert J. Luxmoore

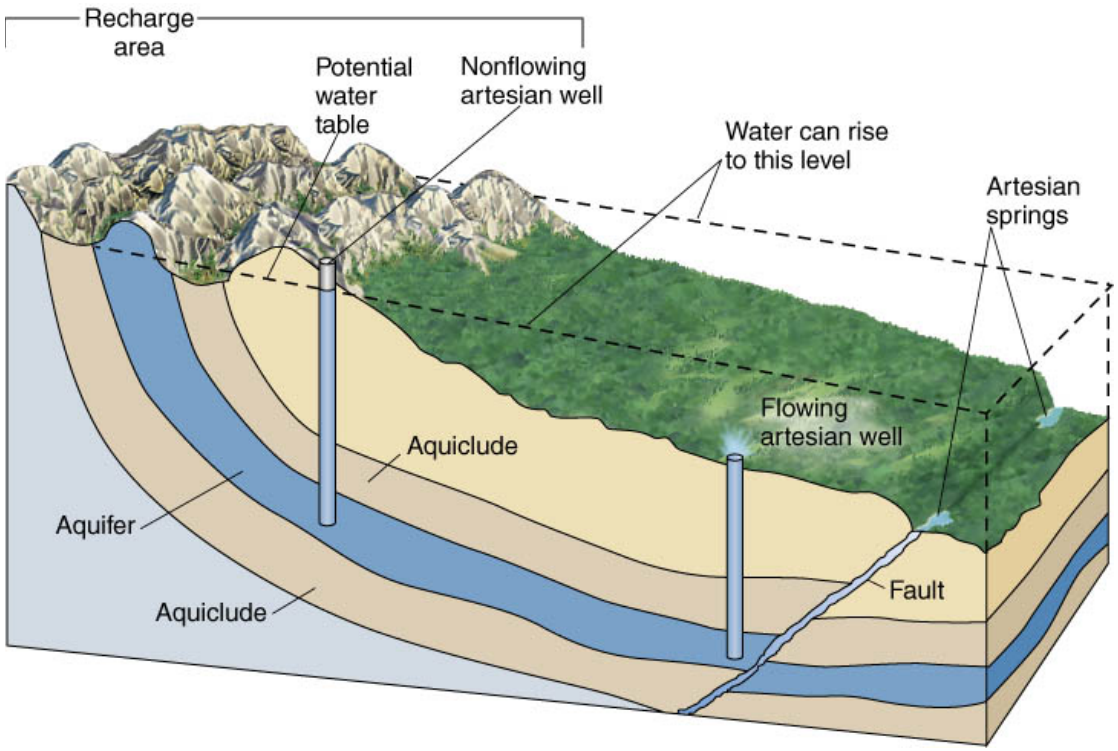
http://proceedings.esri.com/library/userconf/proc98/proceed/to350/pap333/p333.htm

Groundwater and surface water are connected. Ground water occurs when water recharges the subsurface through cracks and pores in soil and rock.



Philip B. Bedient, Rice University

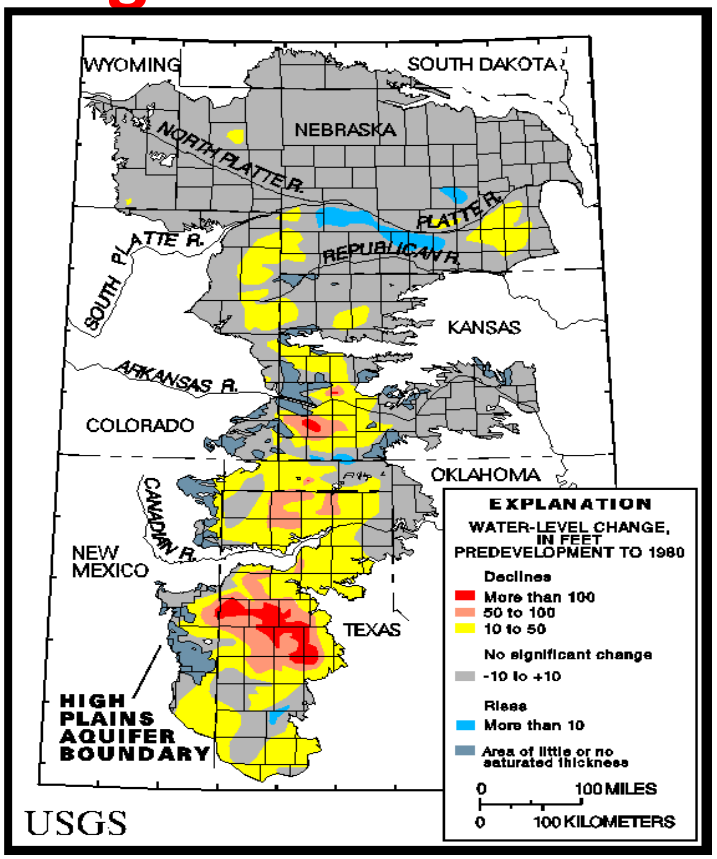
Groundwater for well water is a tricky trade as nature can't keep up with removal rates.



Philip B. Bedient, Rice University

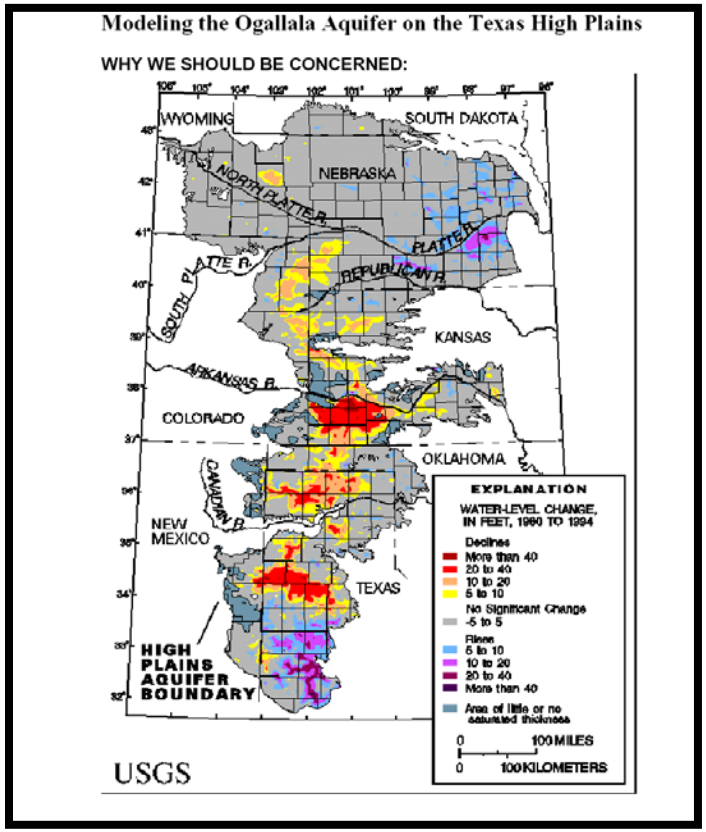
Groundwater recharge is critical for long-term stability of a regions water supplies. Not all areas allow for recharge that is equal to the use.

Irrigation for food is a resource trade.



Ogallala Aquifer

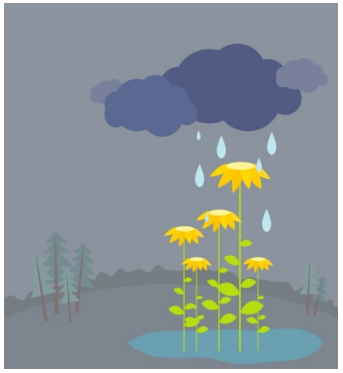
170,000 wells
3.3 B AcFt



Draw down 2-3 feet per year – recharge is 10% by rainfall

(1 acre foot = 326,000 gallons)

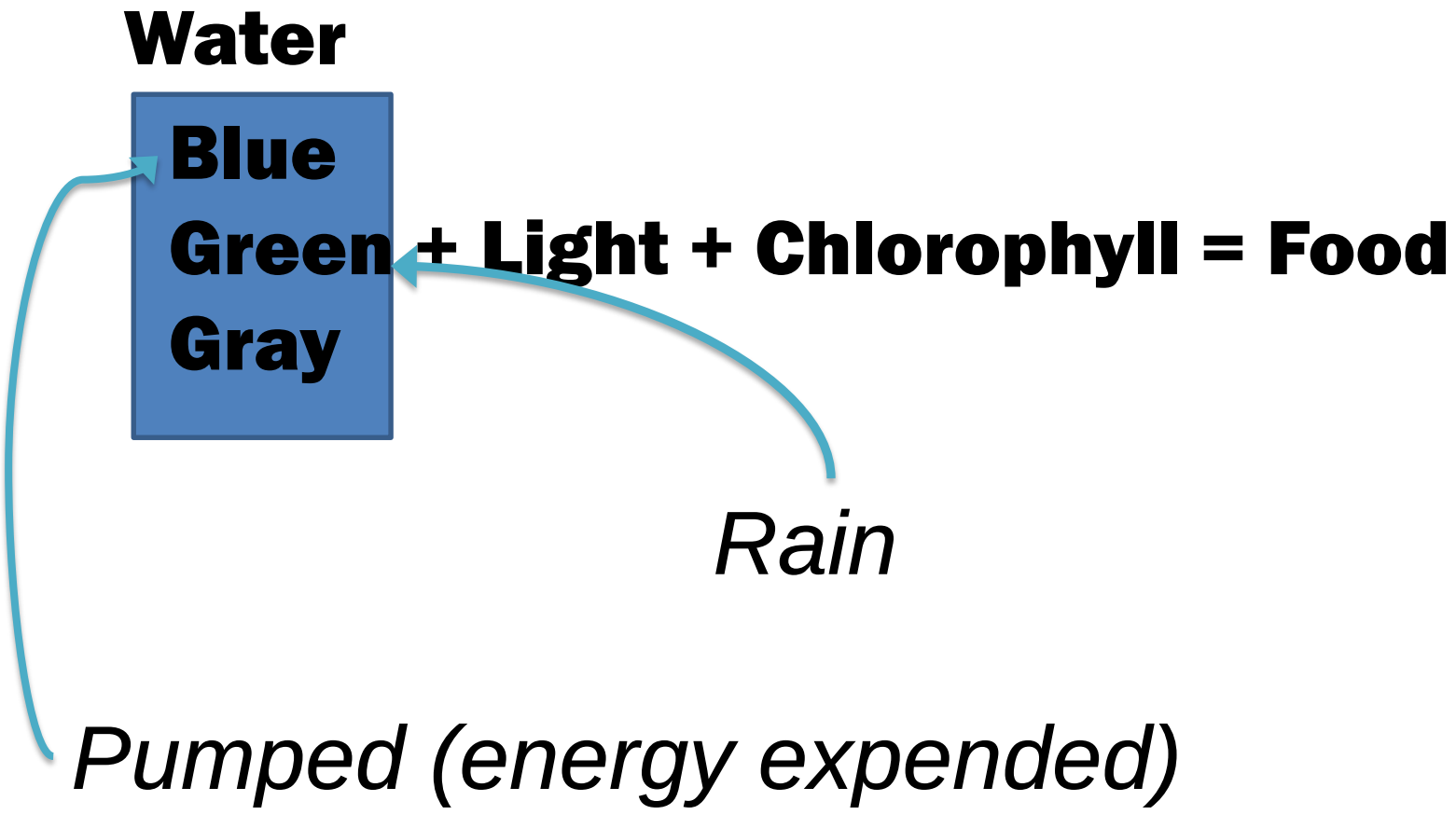
Agriculture uses three types of water: green, blue and gray water – two are free and one is not.



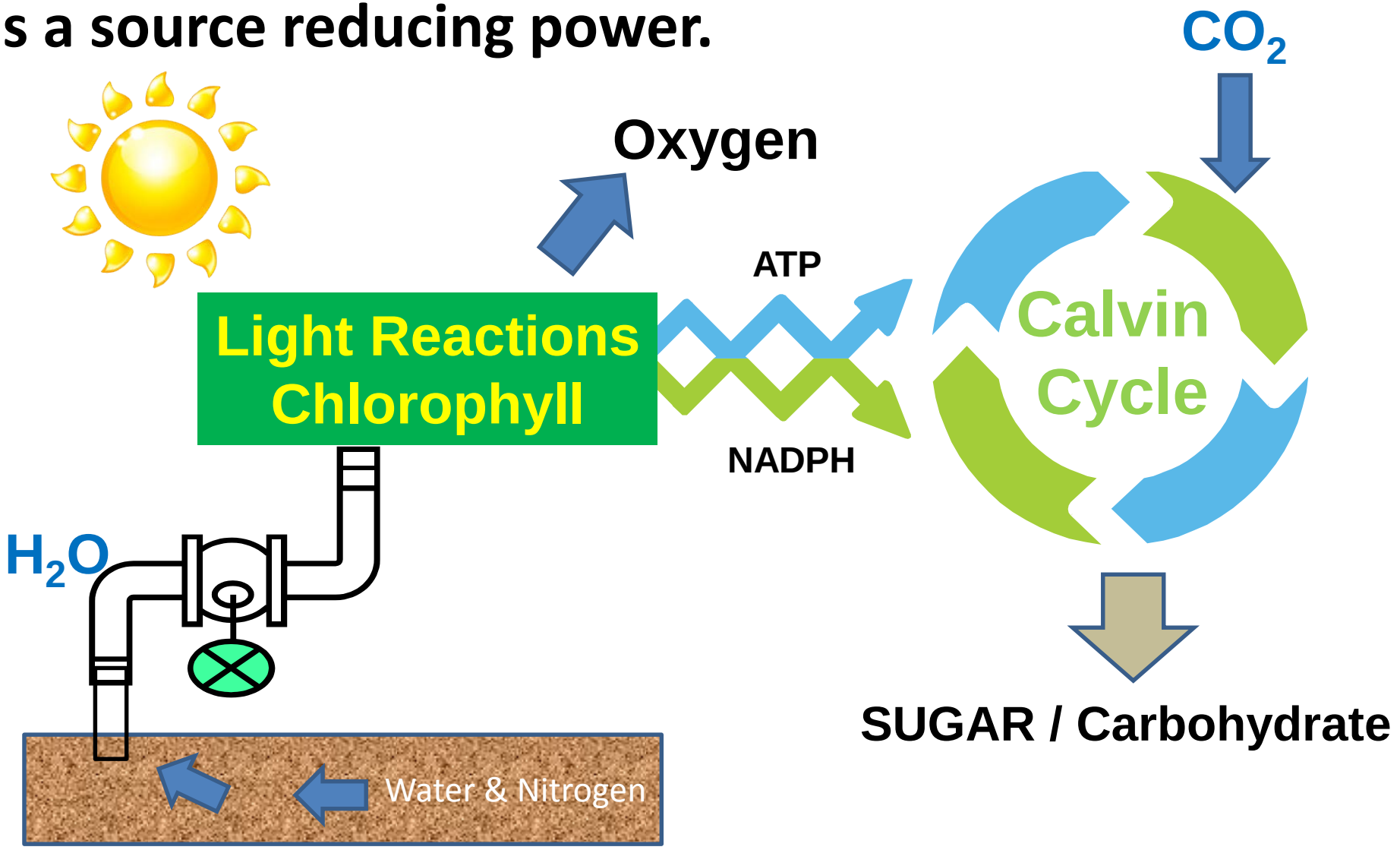
Green water = precipitation

Blue water = irrigation removed from other fresh water sources

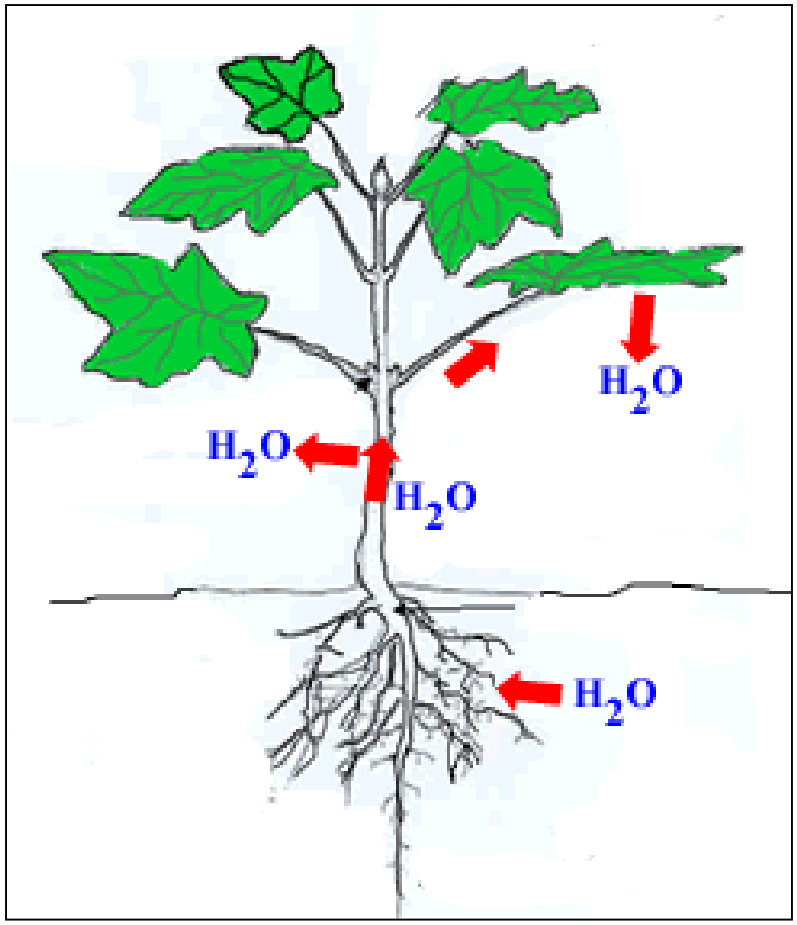
Gray water = irrigation from high grade waste water


Water
Blue
Green
Gray
+ Light + Chlorophyll = Food
Rain
Pumped (energy expended)

Water's role in plant growth is critical as it holds up the plant, moves nutrients and waste materials and is a source reducing power.



To be clear, about 95% of the plant's biomass is from photosynthesis reaction (5% from soil minerals)- photosynthesis is linked to water



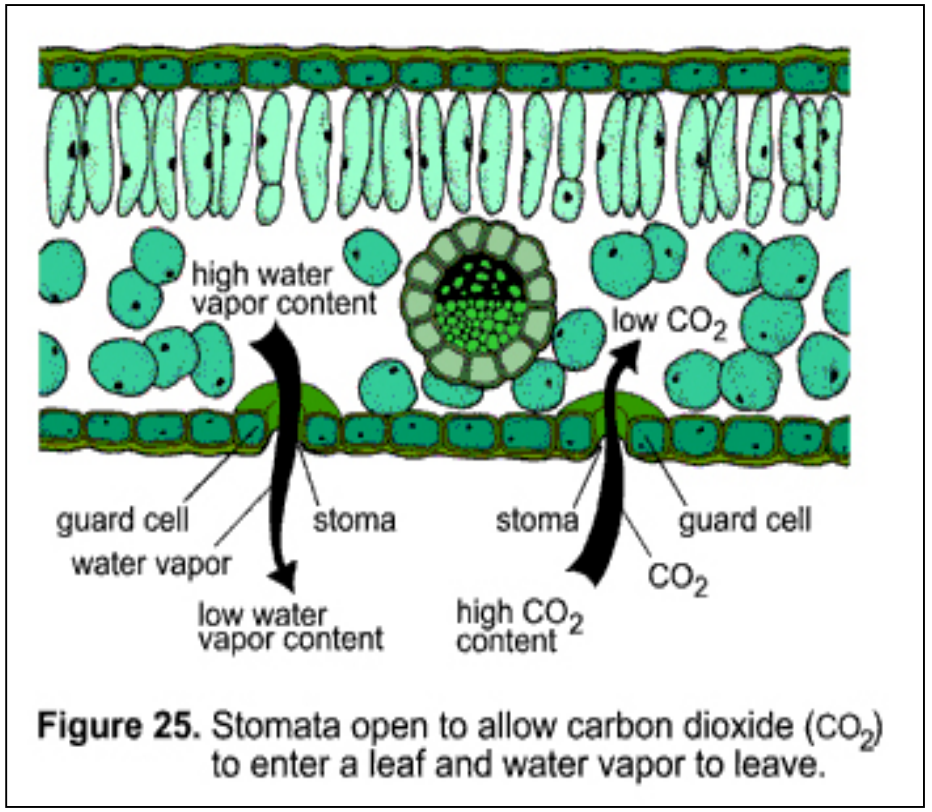


Figure 25. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.

From J. Volenec

The ability to supply water to a plant is significant for production.

How much water does it take to produce a 1.5 lb. bag of alfalfa?

- A) 10 lbs. (1.2 gallons)
- B) 50 lbs. (6 gallons)
- C) 100 lbs. (12 gallons)
- D) 1000 lbs. (121 gallons)
- E) 2000 lbs. (241 gallons)

A 1.5 lb. Bag of Alfalfa requires a lot of water – its water use efficiency (WUE) is not great.

E) 2000 lbs. (241 gallons)

WUE is expressed as kg H_2O/kg DM

WUE=350 means that 350 kg H_2O is needed to produce 1 kg of plant biomass a low number is preferred

Ranges from 250 >1000

Factors that improve yield also tend to improve WUE

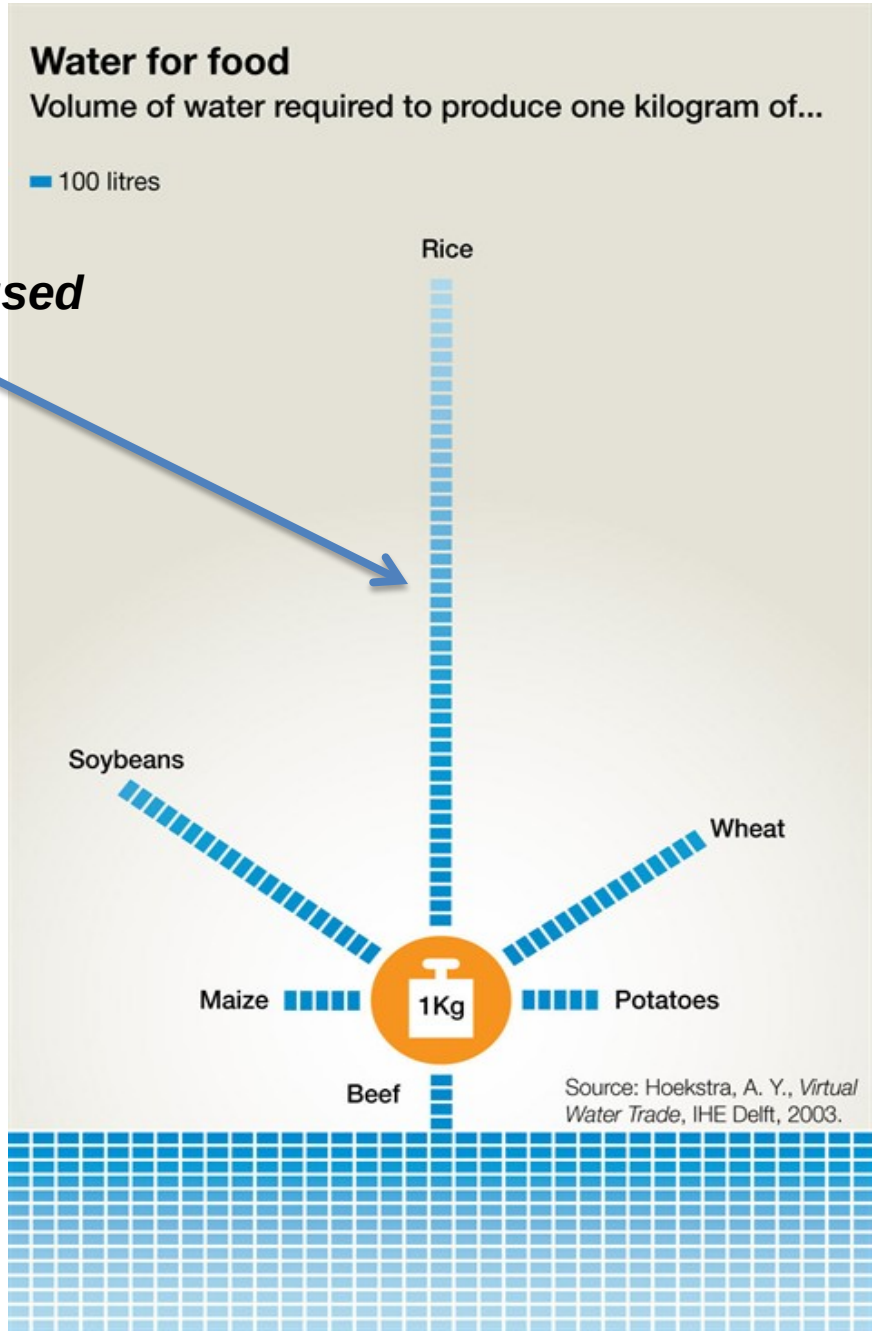
Food is water!

Total water used

Water Footprint consists of three components:

BLUE + GREEN + GREY water usage!

The “water use impact” reflects removal of blue water

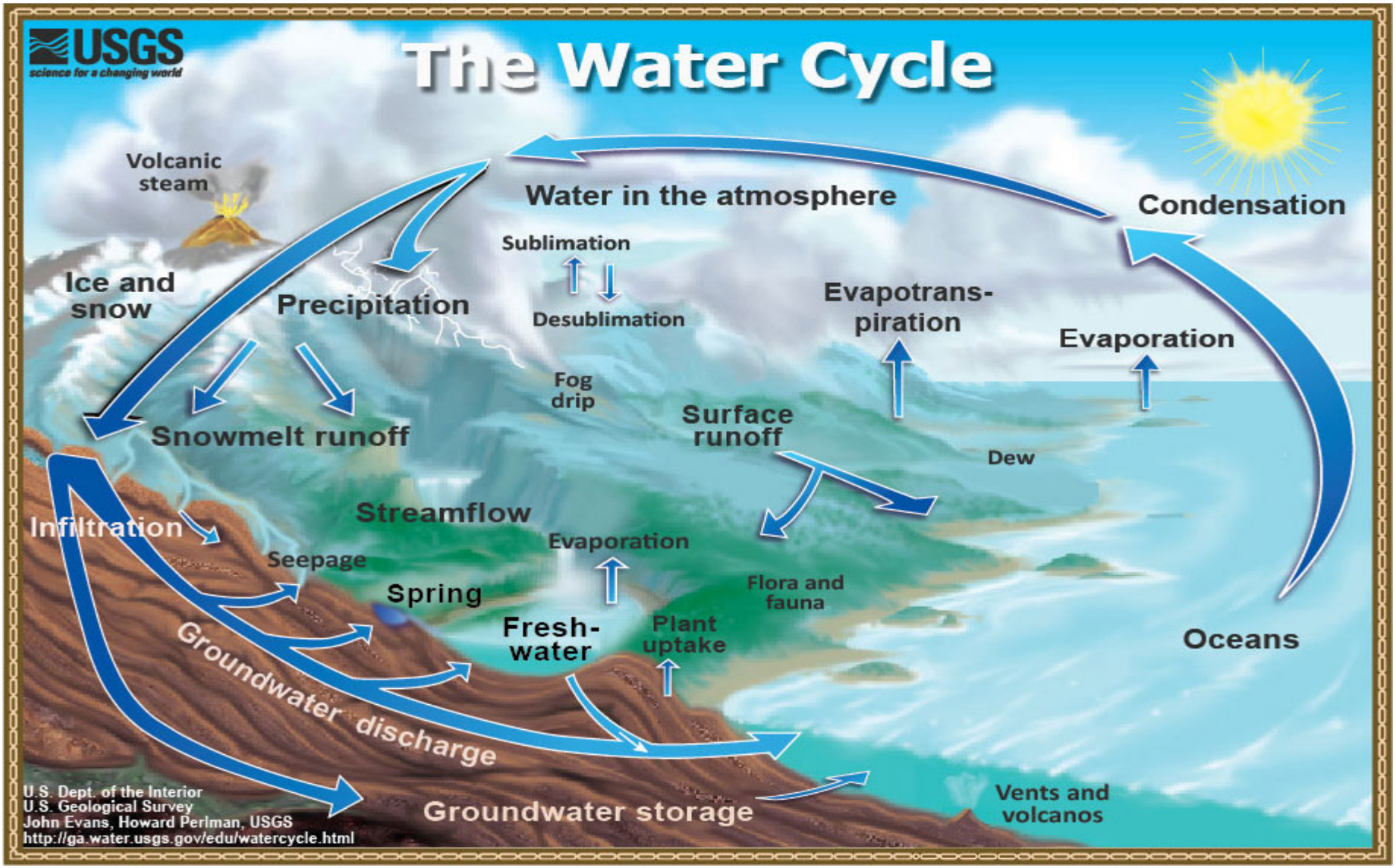


The water foot print of a number of important food products reveal huge amounts of water are needed for the items.

Item	Water	Item	Water
1 kg wheat	1 m^3	1 egg	135 L
1 kg rice	3 m^3	1 beer (L)	25 L
1 kg milk	1 m^3	1 hamburger	2400 L
1 kg cheese	5 m^3	1 coffee (8oz)	140 L
1 kg pork	5 m^3	1 sheet paper	10 L
1 kg beef	15 m^3		

Hoekstra & Chapagain, 2008

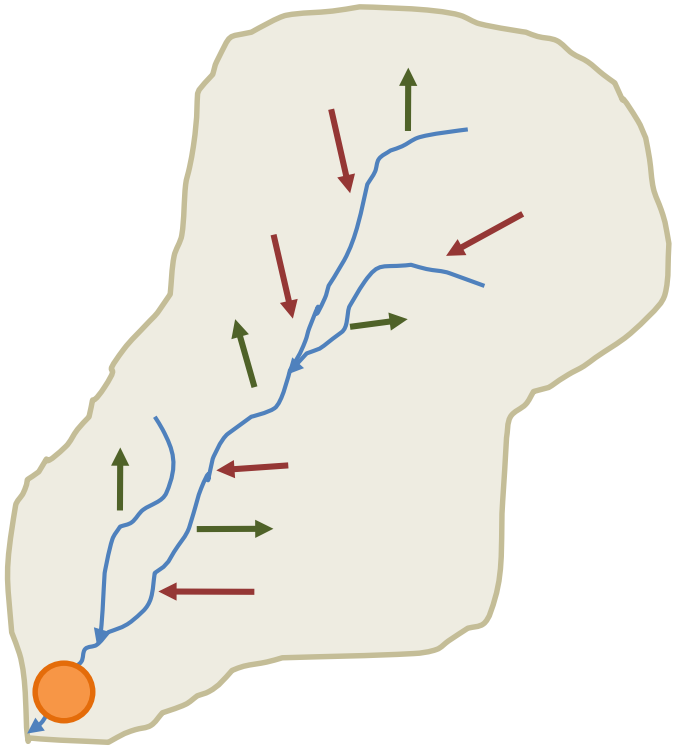
The three phases control the world's available water supply as part of a global Water Cycle.



Theoretical Assessment – Wabash River

Assess water reuse by:

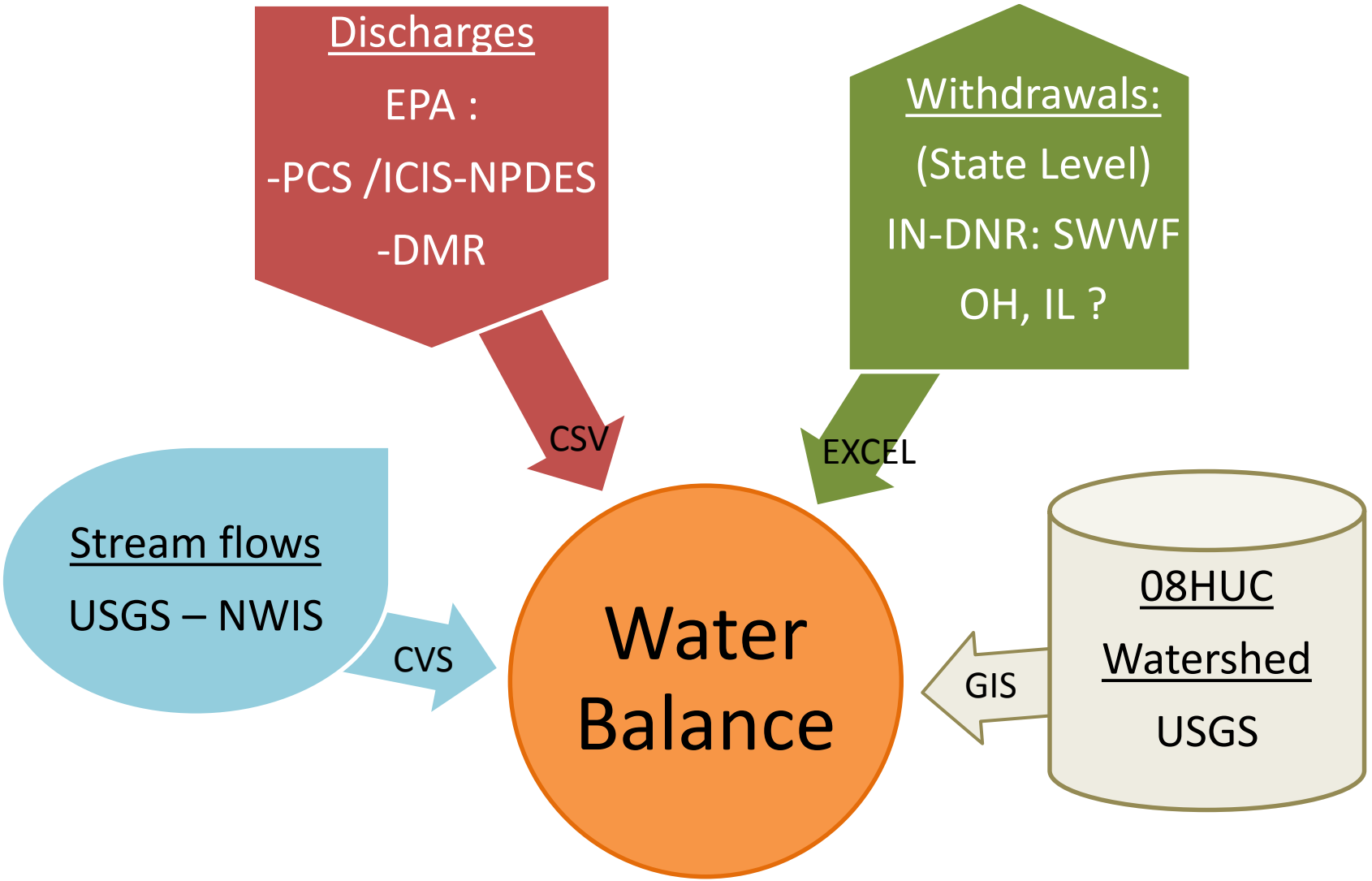
- Determining volume of water DISCHARGED into streams
- Take US Geological Survey (USGS) gauging station STREAM FLOW measures as reference
- Evaluate the relationship between discharges and surface waters stream flow



- Compare with volume of surface water WITHDRAWN
- Analysis at different Hydrologic Unit Code (HUC) Levels

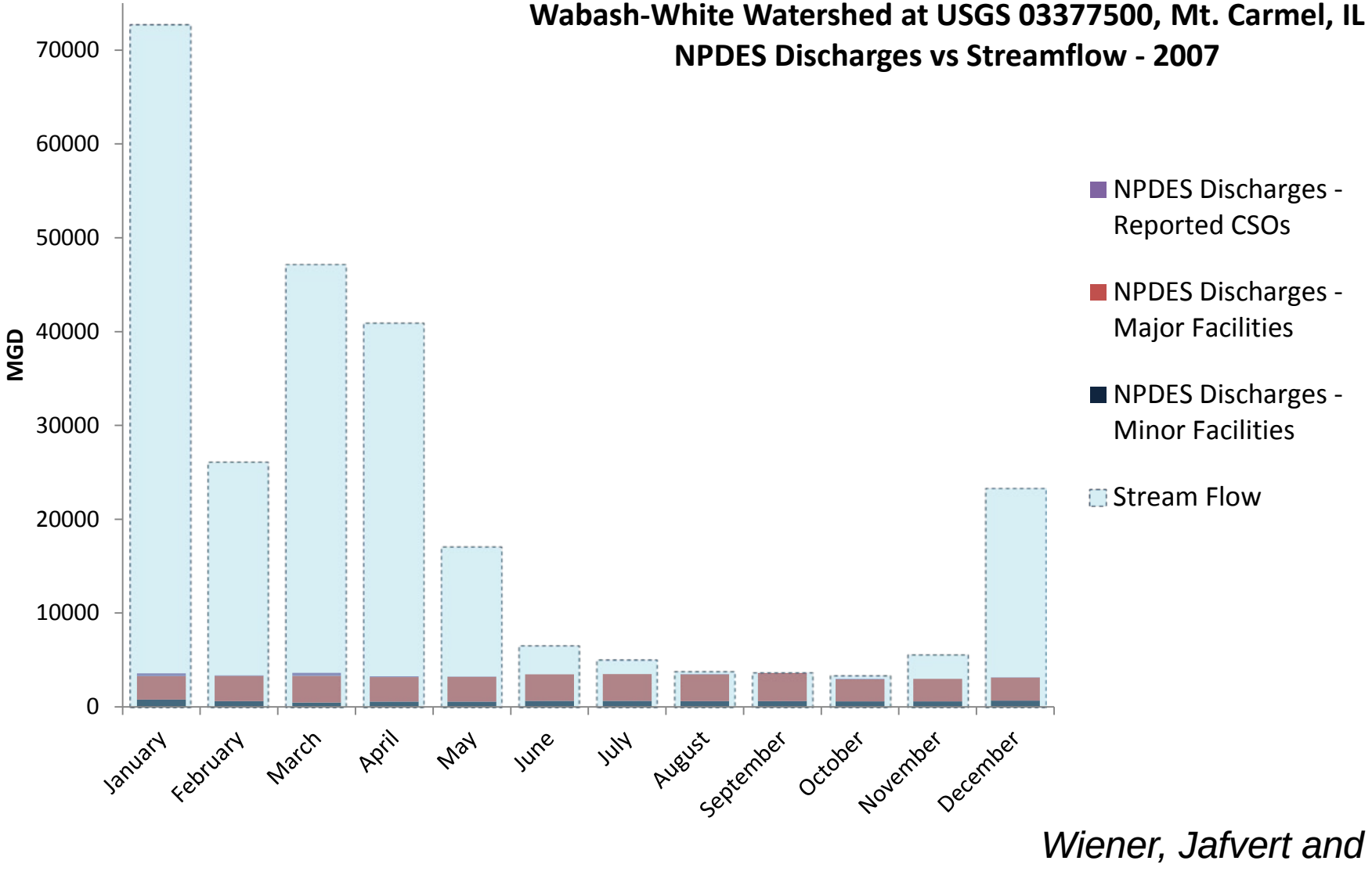
Wiener, Jafvert and Nies

Preliminary datasets



Wiener, Jafvert and Nies

Results



Wiener, Jafvert and Nies

Significance

During low flow months:

- "Used" water ranges between 5 – 98%
- We are essentially withdrawing, using, treating and discharging the entire volume of the river

Relevance of holistic approach – Extent of unplanned water reuse + withdrawals situation => discussion about managing our water resources

Wiener, Jafvert and Nies