



Geosciences Information  
for Teacher Workshop  
*Vienna, Austria –23-25 April, 2012*



*GIFT - 2012*  
*Water!*



# Water Cycle, Freshwater Availability and Distribution: the Major Challenges for Water in the Next 100 Years

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## **Premise: water is with us, but it is not easy to understand**

Flood occurred at  
Barcellona di Pozzo di  
Gotto (Sicily) on Nov 26,  
2011





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Water!



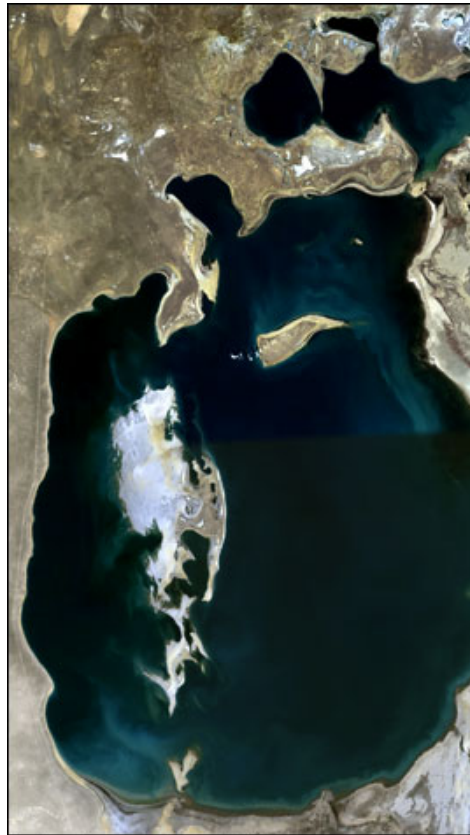
## The Lake Aral Disaster







## **The Lake Aral Disaster**



July - September, 1989



August 12, 2003





## The Lake Aral Disaster



**The Aral Sea**

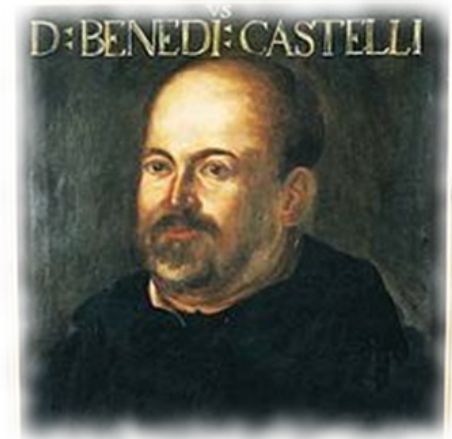
Image sources: [www.alexandre.leroux.net/water/pictures/boat\\_over\\_aral\\_sea.jpg](http://www.alexandre.leroux.net/water/pictures/boat_over_aral_sea.jpg)  
and [maguires.com/patupe/photos.htm](http://maguires.com/patupe/photos.htm)



# Humans only recently started to study water

Until the Middle Age (around 1600 AD) flow in rivers was assumed to mainly come from groundwater and only marginally from rainfall. This was an ancient theory that is attributed to Aristotelis.

Only some 400 years ago an Italian abbé, Benedetto Castelli, postulated that water balance on the Earth is mainly driven by rainfall input. He proved his theory by measuring rainfall with a glass and using the collected data to reconstruct the inflow to the Lake Trasimeno, located in Central Italy.



Curiously, no one had the idea of observing rainfall and river flows before. Humans started observing stars more than 5000 years ago, but waited until 400 years ago to observe water (with the exception of ancient civilizations, like Egyptians, that collected a few observations of water levels).



## **We wish we started before....**

The results is that humans do not have long records of water observations (meteorology, water resources....).

The longest rainfall series today available is the one collected in Padua (Italy), which was observed every day from 1725 (with only a few missing values up to today).

If we had longer observation records, we would not spend much time discussing about climate change, water resources variability and so forth.







# What is hydrology? It is the science of the water cycle

From Wikipedia:  
Hydrology is the study of the movement, distribution, and quality of water on Earth and other planets, including the hydrologic cycle, water resources and environmental watershed sustainability (<http://en.wikipedia.org/wiki/Hydrology>)

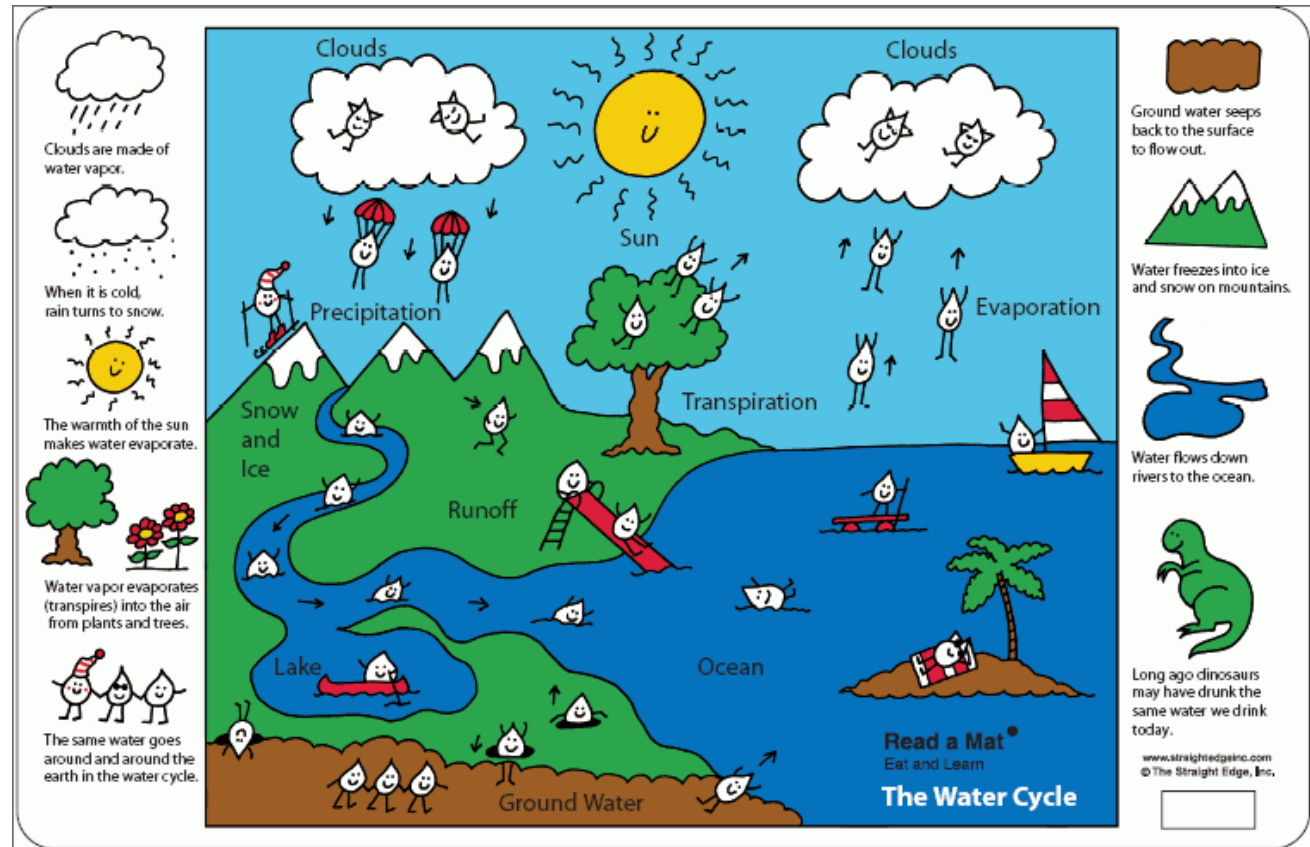


Image from: <http://ga.water.usgs.gov/edu/watercycle.html>



## Hydrological cycle

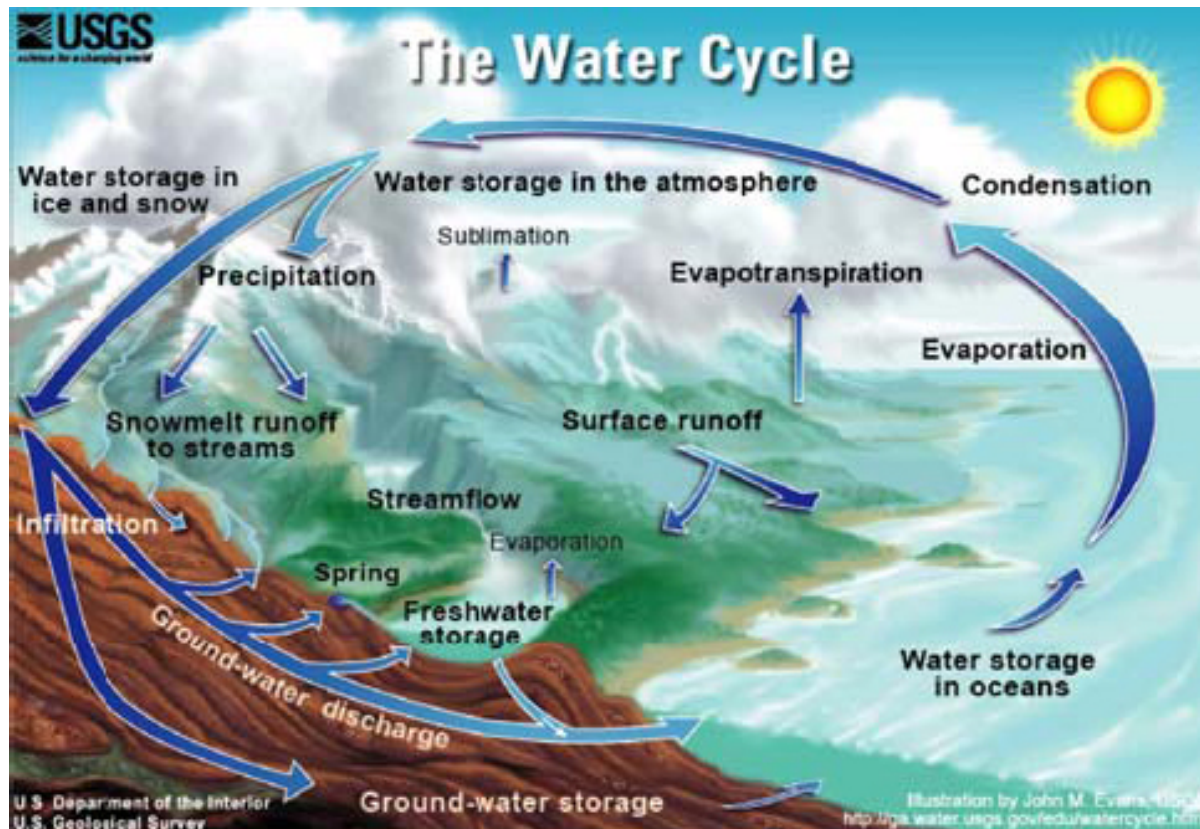


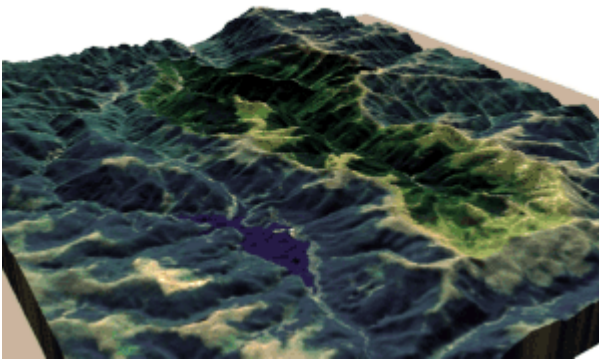
Image from: <http://ga.water.usgs.gov/edu/watercycle.html>



## **Hydrological cycle**

There are many details of the water cycle that are not fully known.  
For instance:

- How rainfall partitions into infiltration and overland flow?
- How does groundwater flow take place?
- What is the amount of direct fluxes of spring water into the oceans?



The watershed is still a partial  
mystery!  
(Picture produced by NASA)

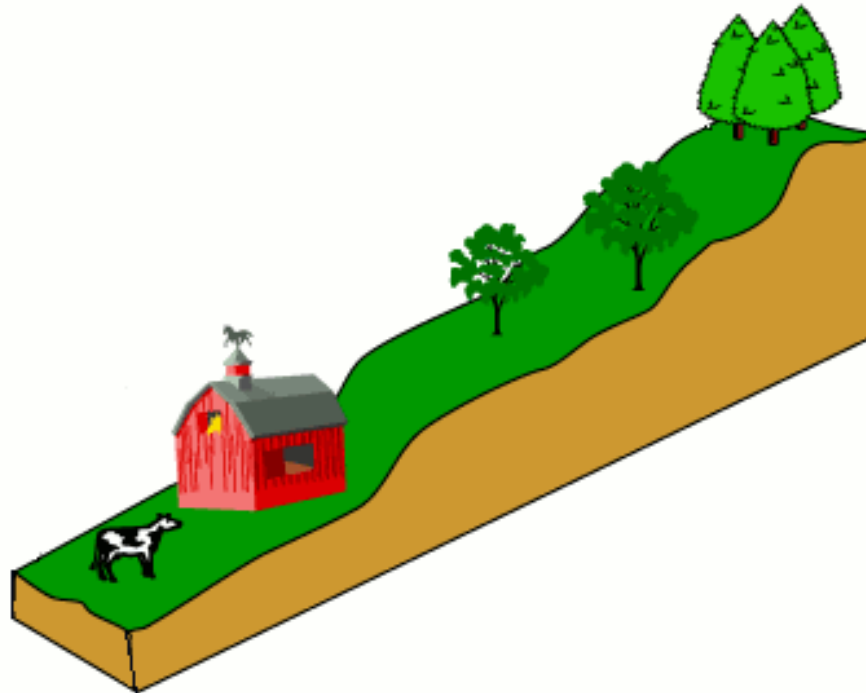






# How rainfall partitions into infiltration and overland flow?

“Hortonian” mechanism of surface runoff formation  
Infiltration excess

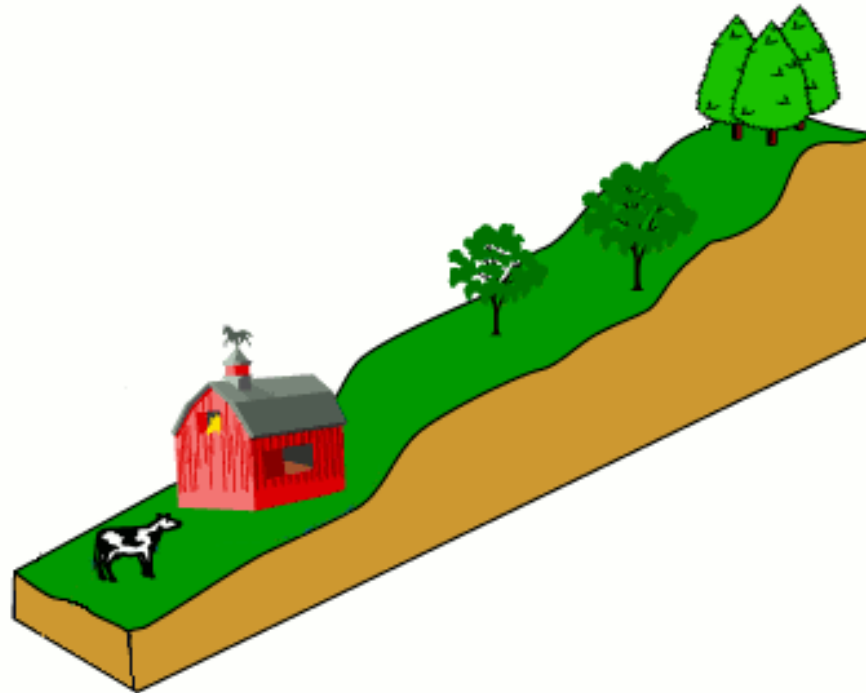




# How rainfall partitions into infiltration and overland flow?

“Dunnian” mechanism of surface runoff formation  
Saturation excess

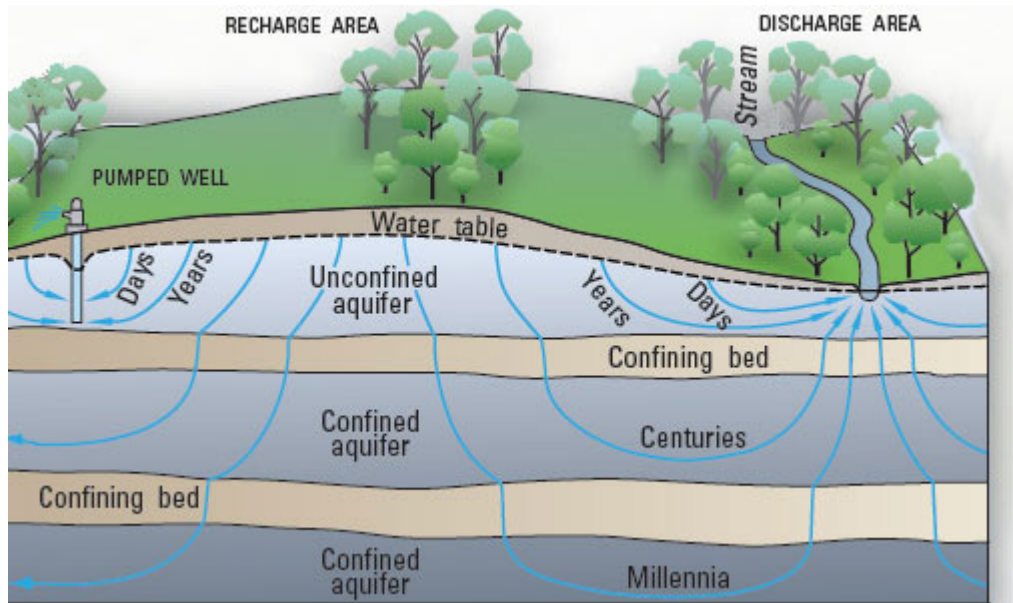
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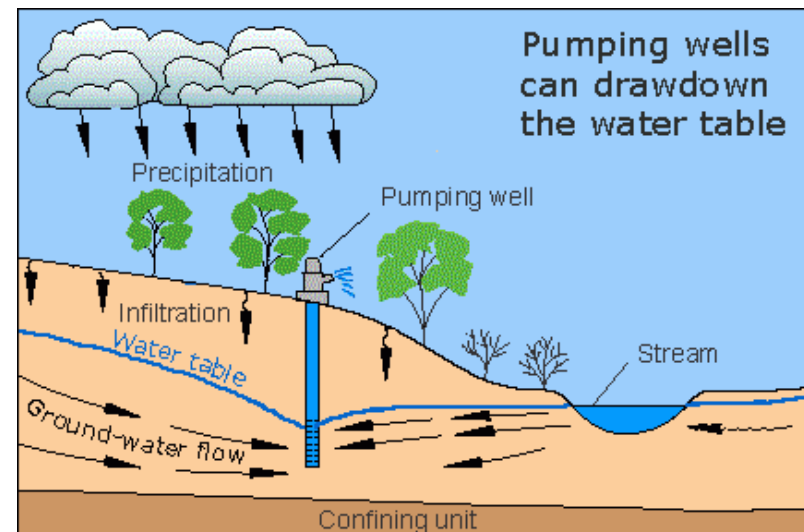
## How groundwater flows?

Groundwater flow can take millennia to develop!



Images from: <http://ga.water.usgs.gov/>

Humans have an impact!

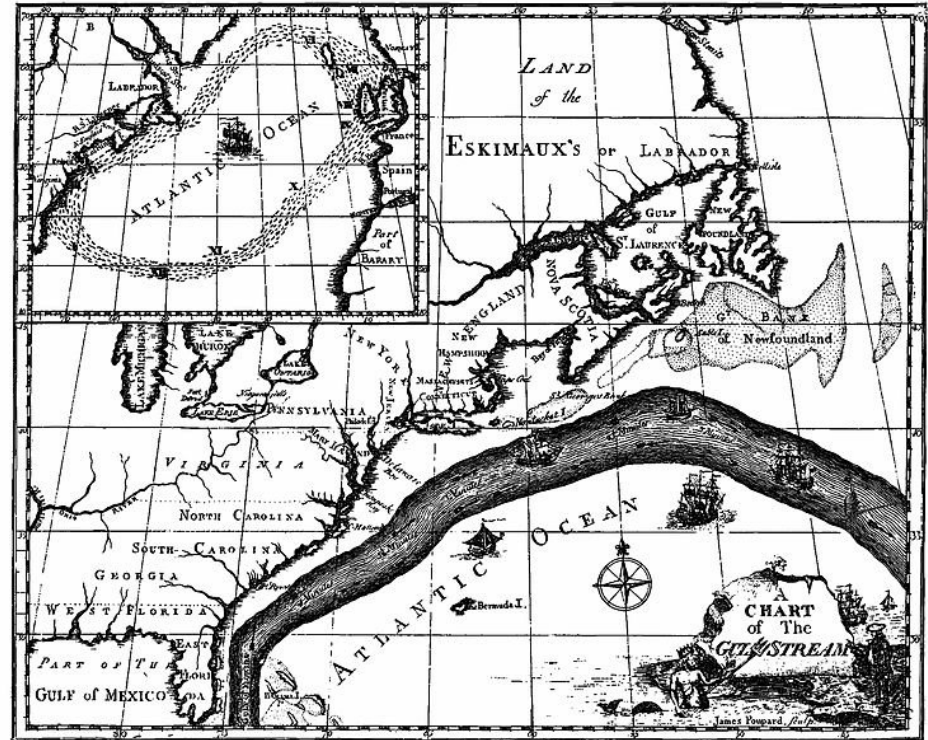






## Some groundwater flows directly into the ocean...

- There is a considerable direct flux of groundwater into the oceans.
- Although hydrologists are trying to setting up global models, at the current state of the art we can get a very rough estimate only of such fluxes.
- Yet, mathematical model of ocean circulation show that these fluxes are impacting the major stream like the Gulf stream.
- Therefore these fluxes are impacting future climate.

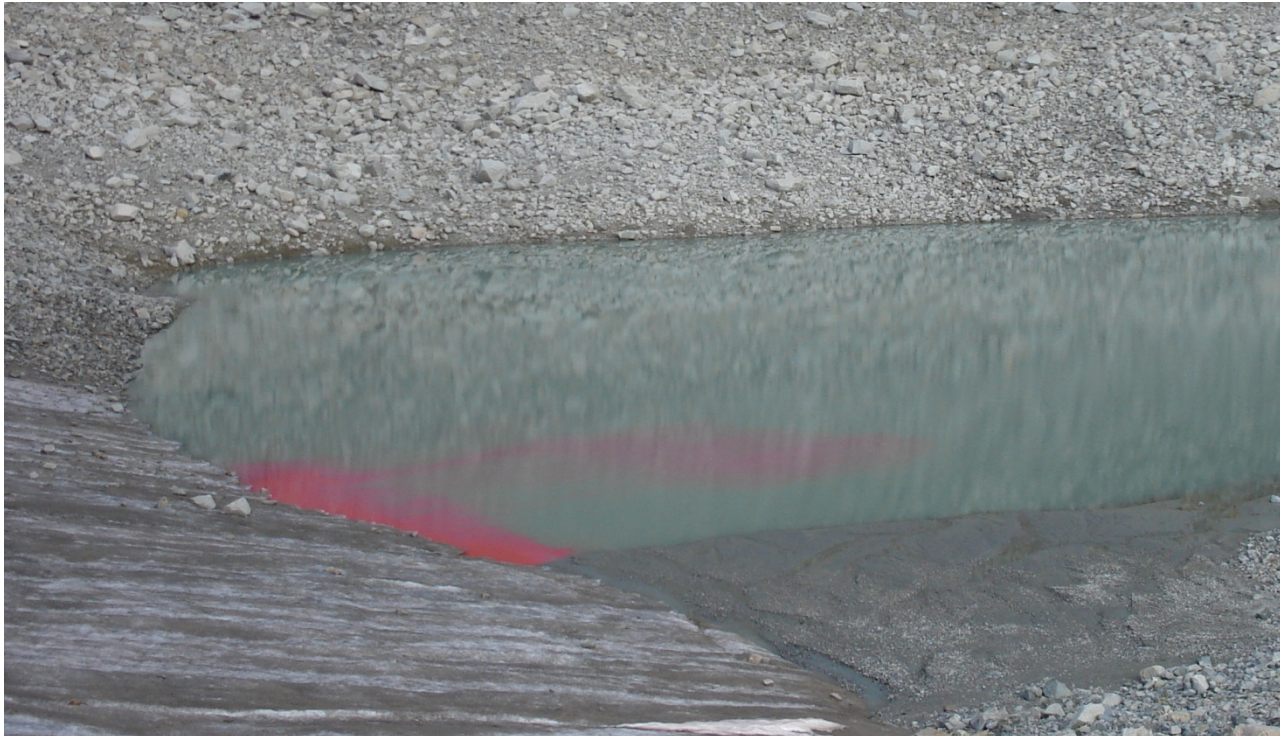


Benjamin Franklin's map of the Gulf Stream. Source: Wikipedia



## **Topical research fields: looking for drop paths....**

- Tracer studies



Source: [http://serc.carleton.edu/microbelife/research\\_methods/envIRON\\_sampling/hydrotrace.html](http://serc.carleton.edu/microbelife/research_methods/envIRON_sampling/hydrotrace.html)





## **Topical research fields: looking for vegetation functioning**







## **Topical research fields: analysis of human impact**

- Sociohydrology



Kabaty, Warsaw, 2008

[ursynow.org.pl](http://ursynow.org.pl)

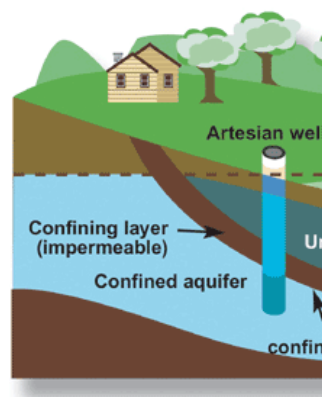
Source: courtesy by A. Sikorska - Warsaw University of Life Sciences





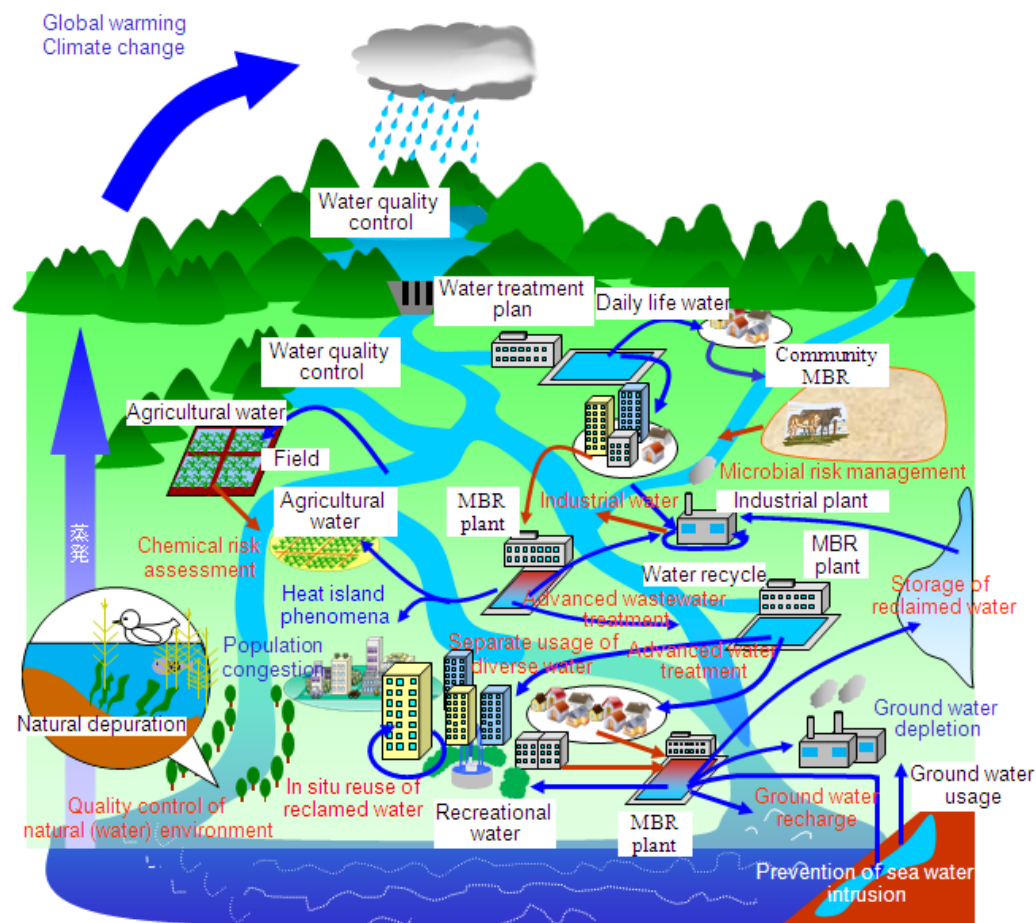
## Socio-hydrology

### Aquifers and wells



Ground

Civil water use



Water diversion



# How much water do we have?

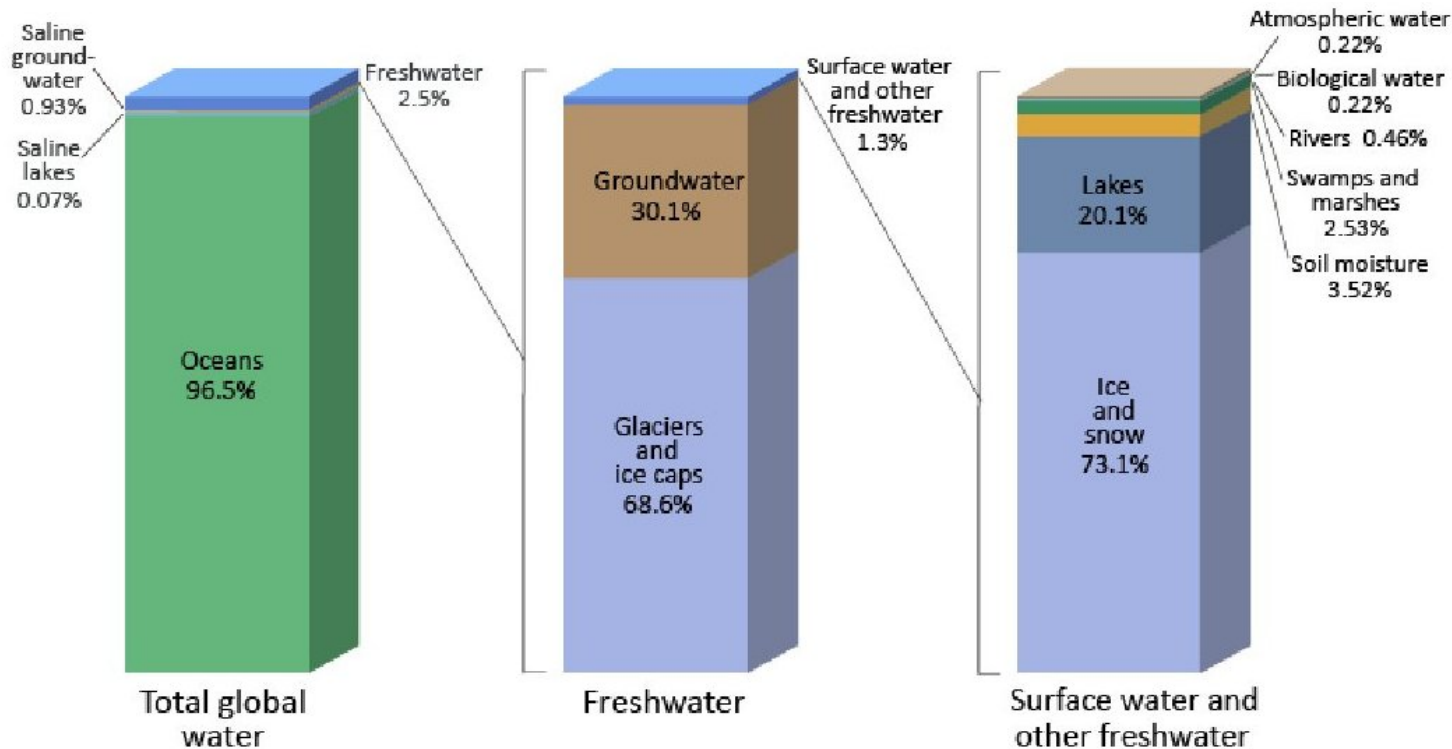
From <http://ga.water.usgs.gov/edu/earthhowmuch.html>

Water source	Water volume, in cubic kilometers	Percent of freshwater	Percent of total water
Oceans, Seas, & Bays	1,338,000,000	--	96.54
Ice caps, Glaciers, & Permanent Snow	24,064,000	68.6	1.74
Ground water	23,400,000	--	1.69
Fresh	10,530,000	30.1	0.76
Saline	12,870,000	--	0.93
Soil Moisture	16,500	0.05	0.001
Ground Ice & Permafrost	300,000	0.86	0.022
Lakes	176,400	--	0.013
Fresh	91,000	0.26	0.007
Saline	85,400	--	0.007
Atmosphere	12,900	0.04	0.001
Swamp Water	11,470	0.03	0.0008
Rivers	2,120	0.006	0.0002
Biological Water	1,120	0.003	0.0001

Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources* (Oxford University Press, New York).



## How much water do we have?

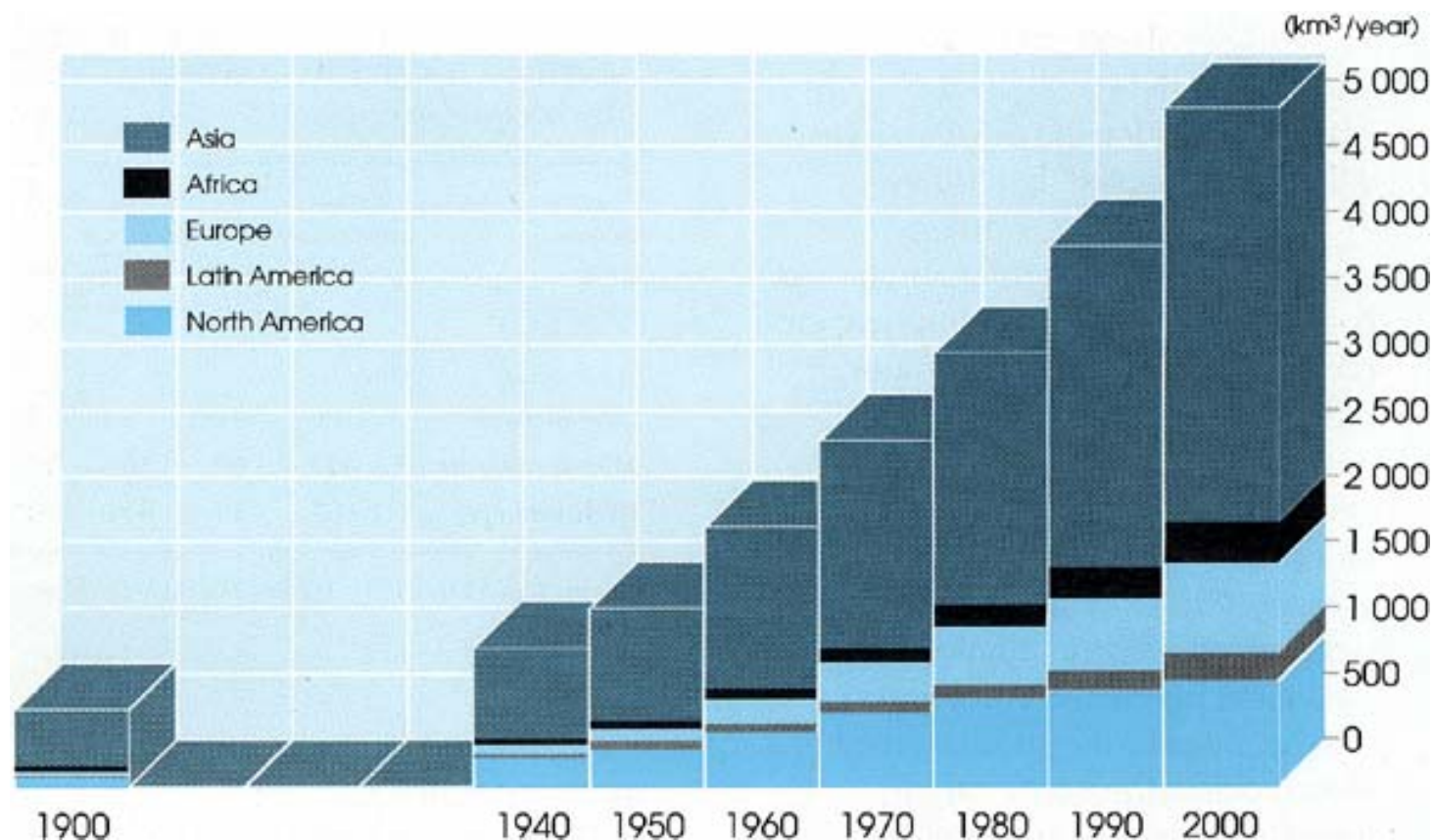


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

From <http://ga.water.usgs.gov/edu/earthwherewater.html>



## Global water uses

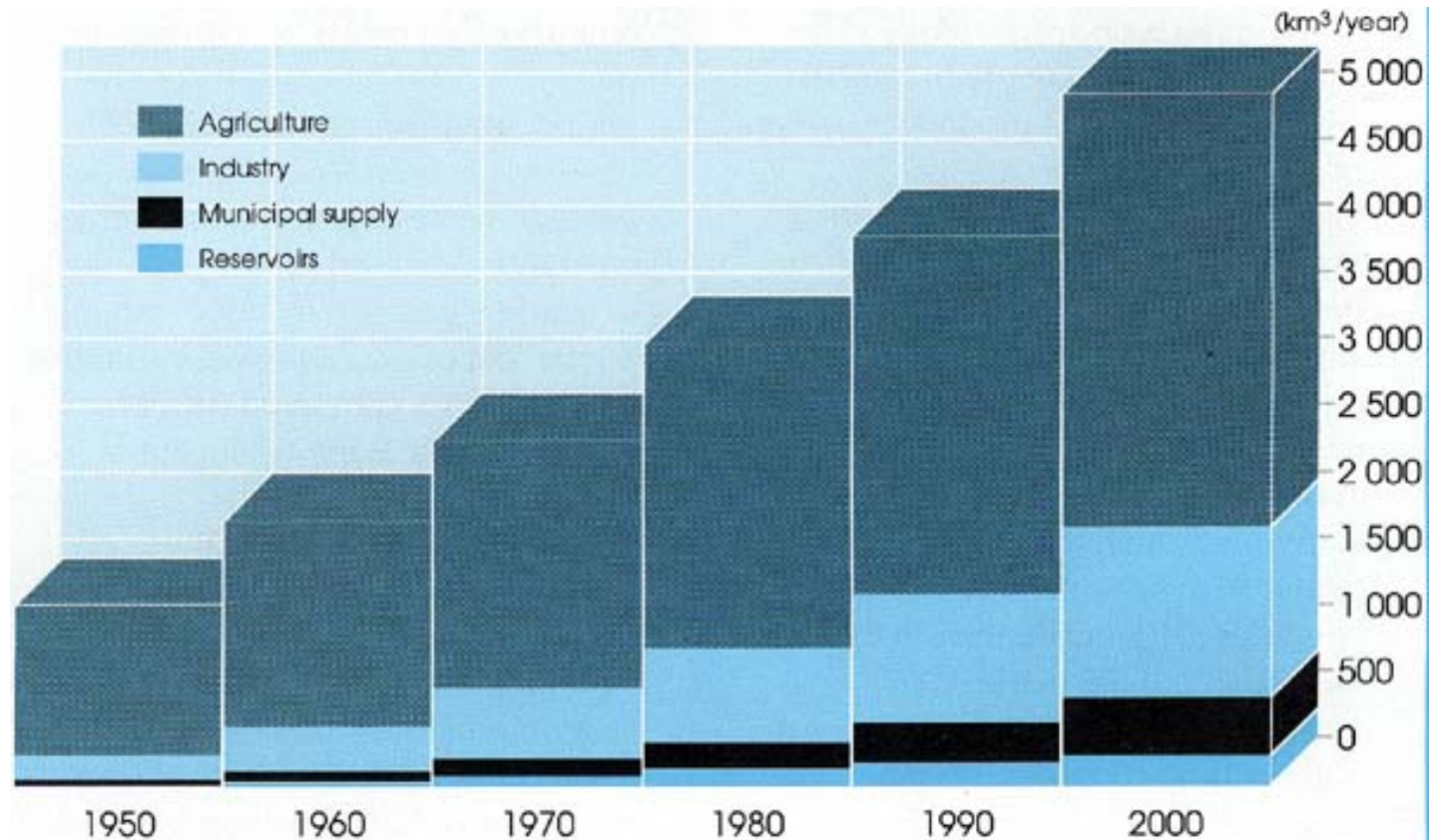


Source: I.A. Shiklomanov. 1990. Global water resources. Nat. Resour., 26: 34-43





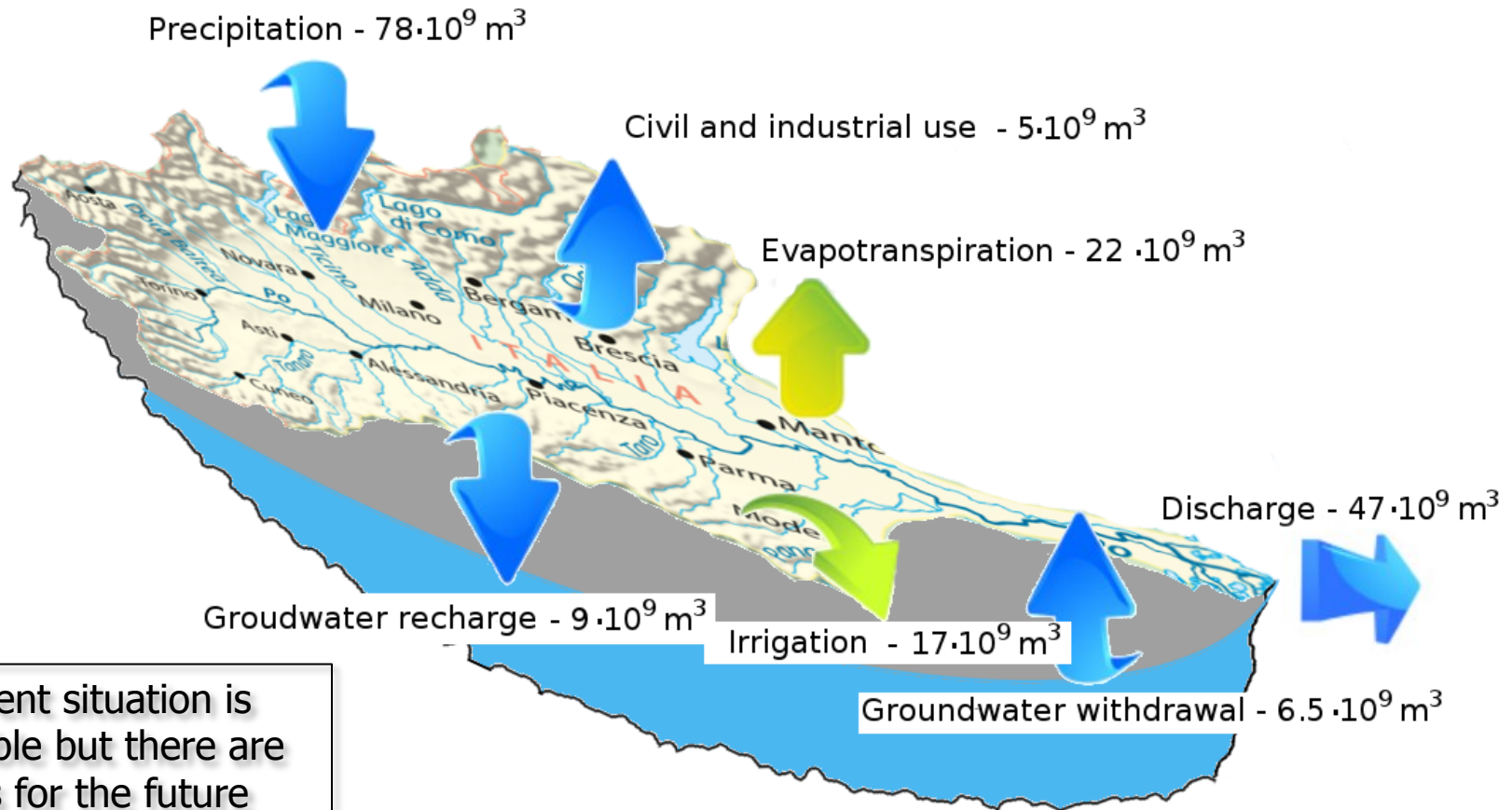
## Global water uses



Source: I.A. Shiklomanov. 1990. Global water resources. Nat. Resour., 26: 34-43



## Are these uses sustainable? The case of Po River (Italy)





## Are these uses sustainable?

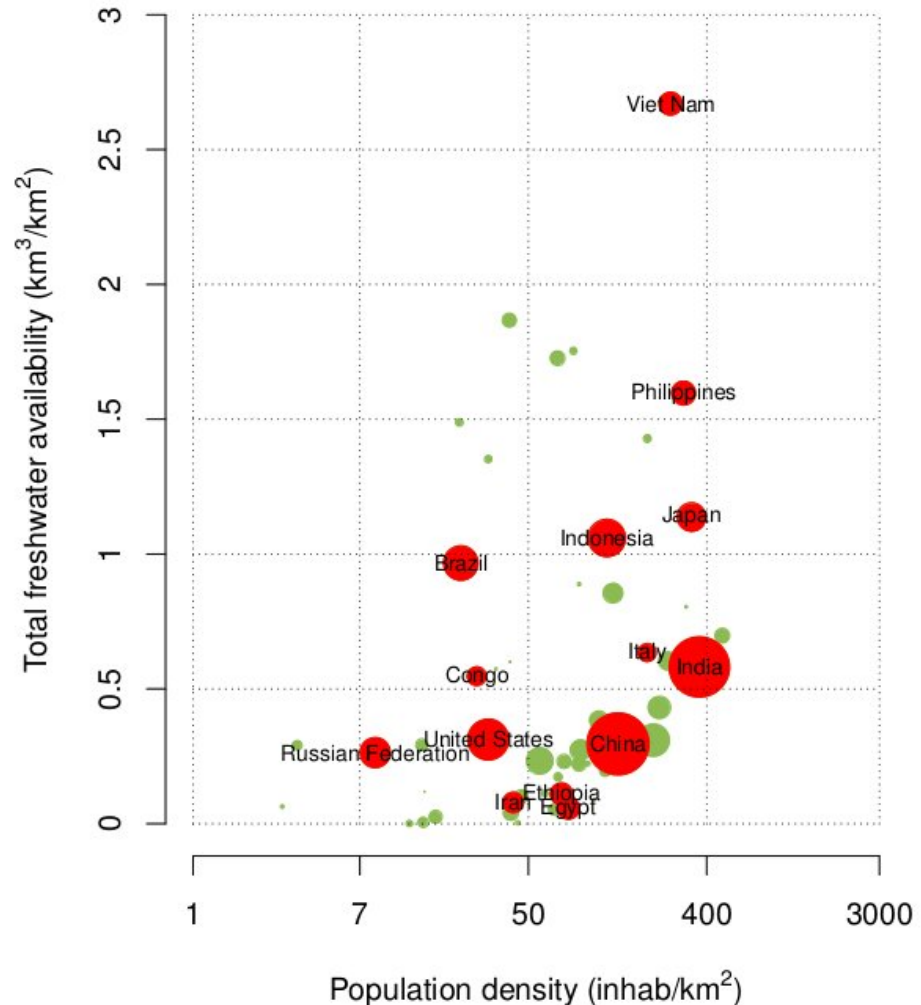
The size of the symbols is proportional to total population of the country.

Question: is freshwater availability enough to satisfy these countries?

The answer depends on A and B:

A: Percentage of freshwater availability that can be effectively withdrawn

B: Water needs for human use.



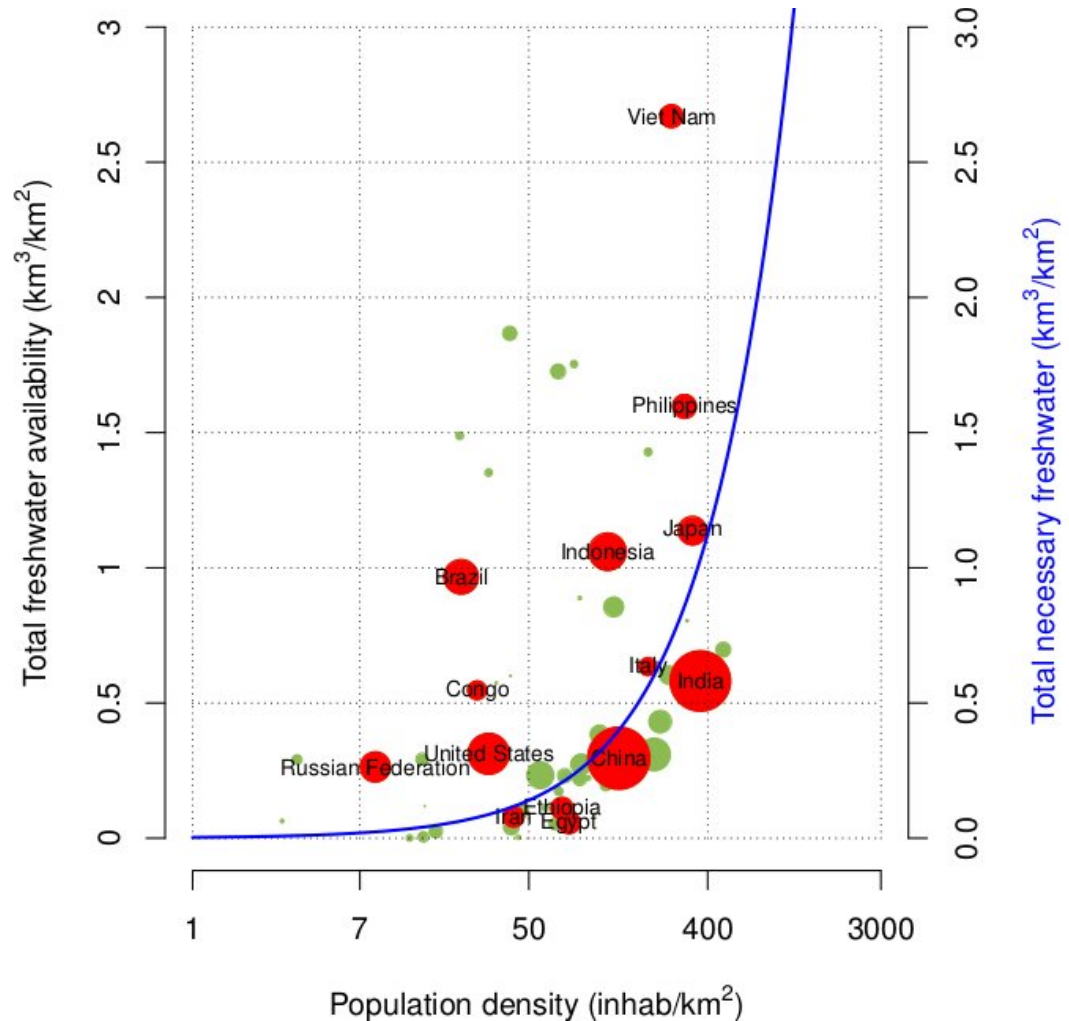


## Are these uses sustainable?

The Italian picture:

Italy is efficient in exploiting water and has moderate water needs

The situation of Italy is matched and reflects reduced margins to ensure sustainability in the future



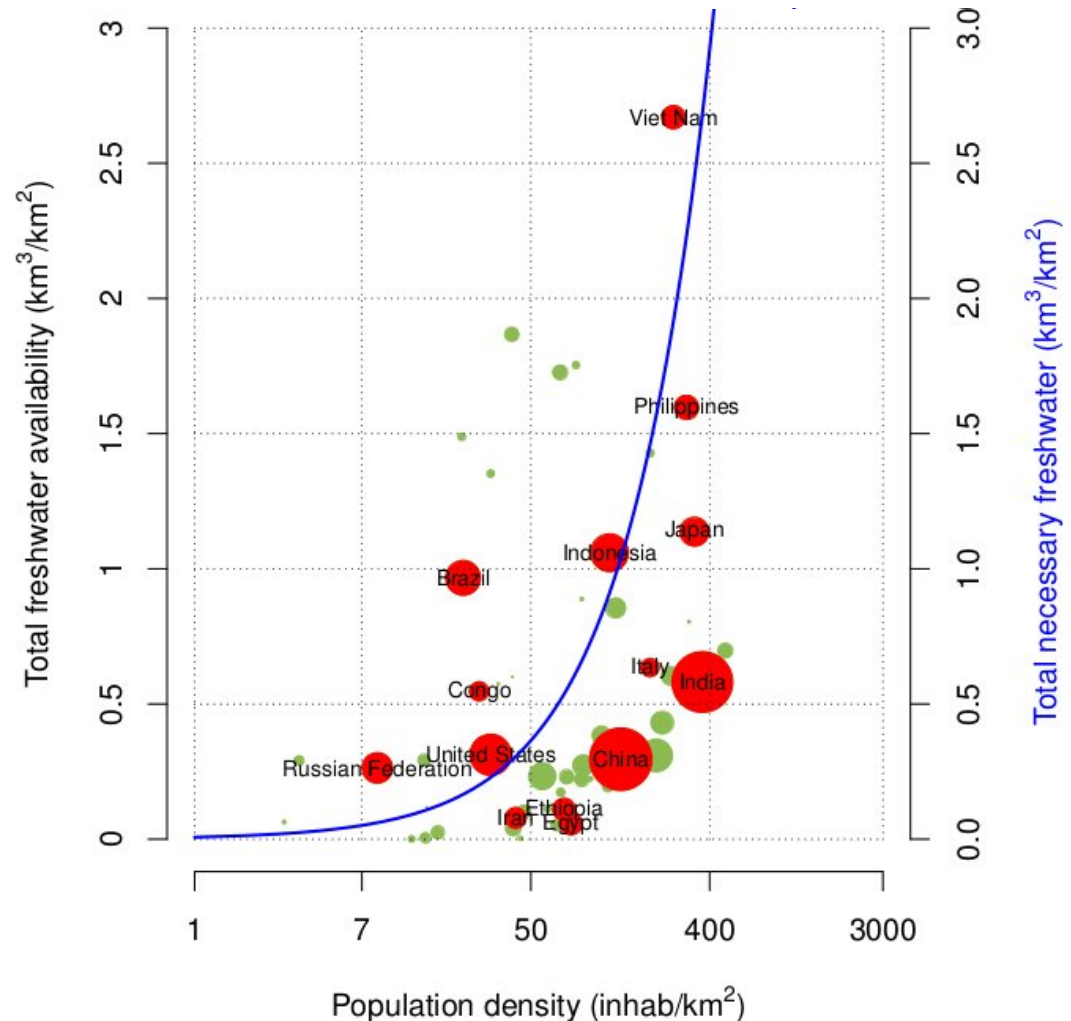




## Are these uses sustainable?

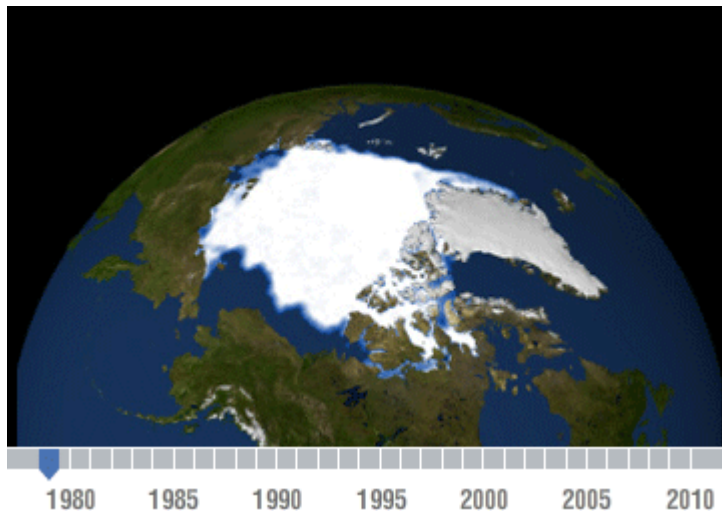
What happens if the water use is less efficient?

Countries located below the blue line need to be very efficient in water use.

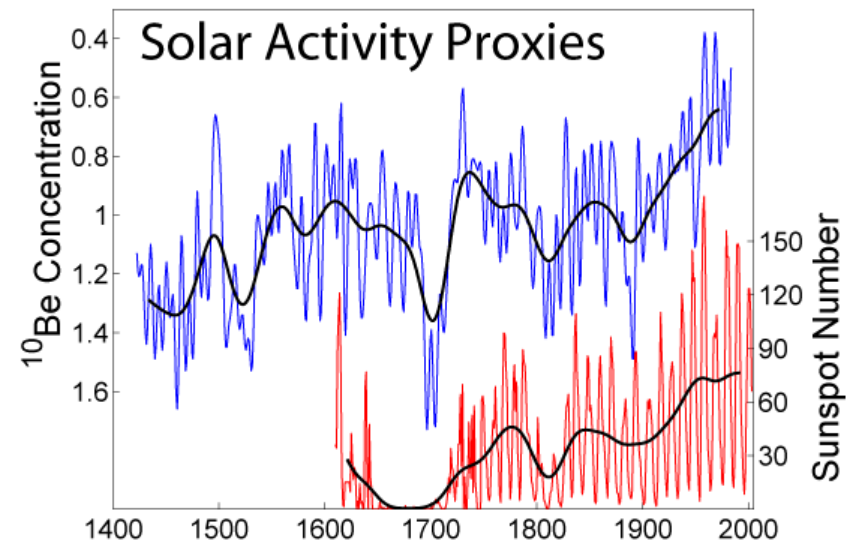




## Are these uses sustainable in the face of climate change and increasing population?



Climate change is potentially much influential





## **Conclusions**

- Hydrology is a young science; many of the processes taking place in the water cycle are still not known.
- Hydrology is a very fertile science, and hydrologists feel a profound sense of community.
- Focused research is needed to address the world water problem. Water is a priority!
- Climate change is related to water, and conditions water availability in the future. Water will be a priority, no matter of climate change.
- Everyone of us needs to better learn about water. Only with an increasing and public awareness of water dynamics we can improve our efficiency in planning water uses. Please help us to spread water knowledge among the public.



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**Thank you!**