E-TEST Einstein Telescope EMR Site & Technology

Sustainability of groundwater resources versus Life Cycle Assessment (LCA) of water: challenges and lessons

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Einstein Telescope EMR Site & Technology

WP3 and WP4: Cross-border hydrogeological model

Val Dieu 15/02/2023

Hydrogeology Environmental Geology

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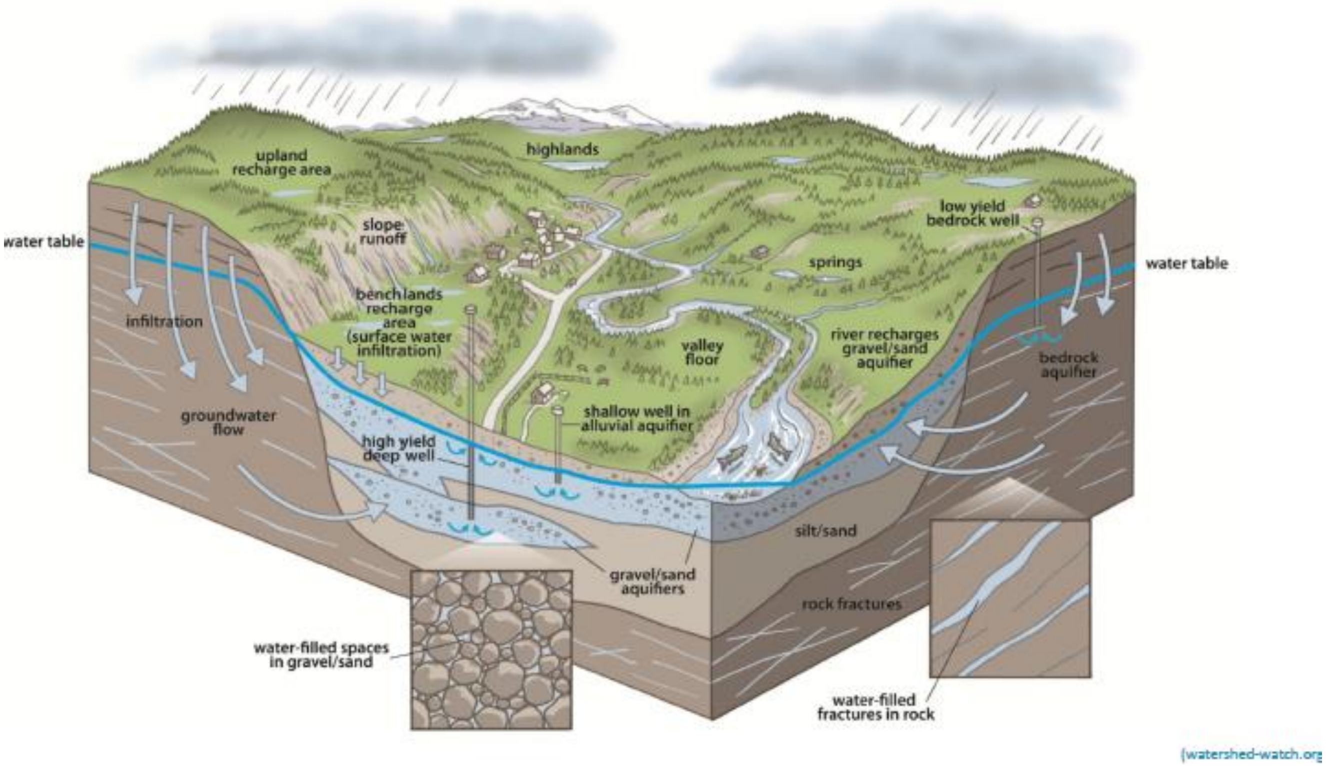
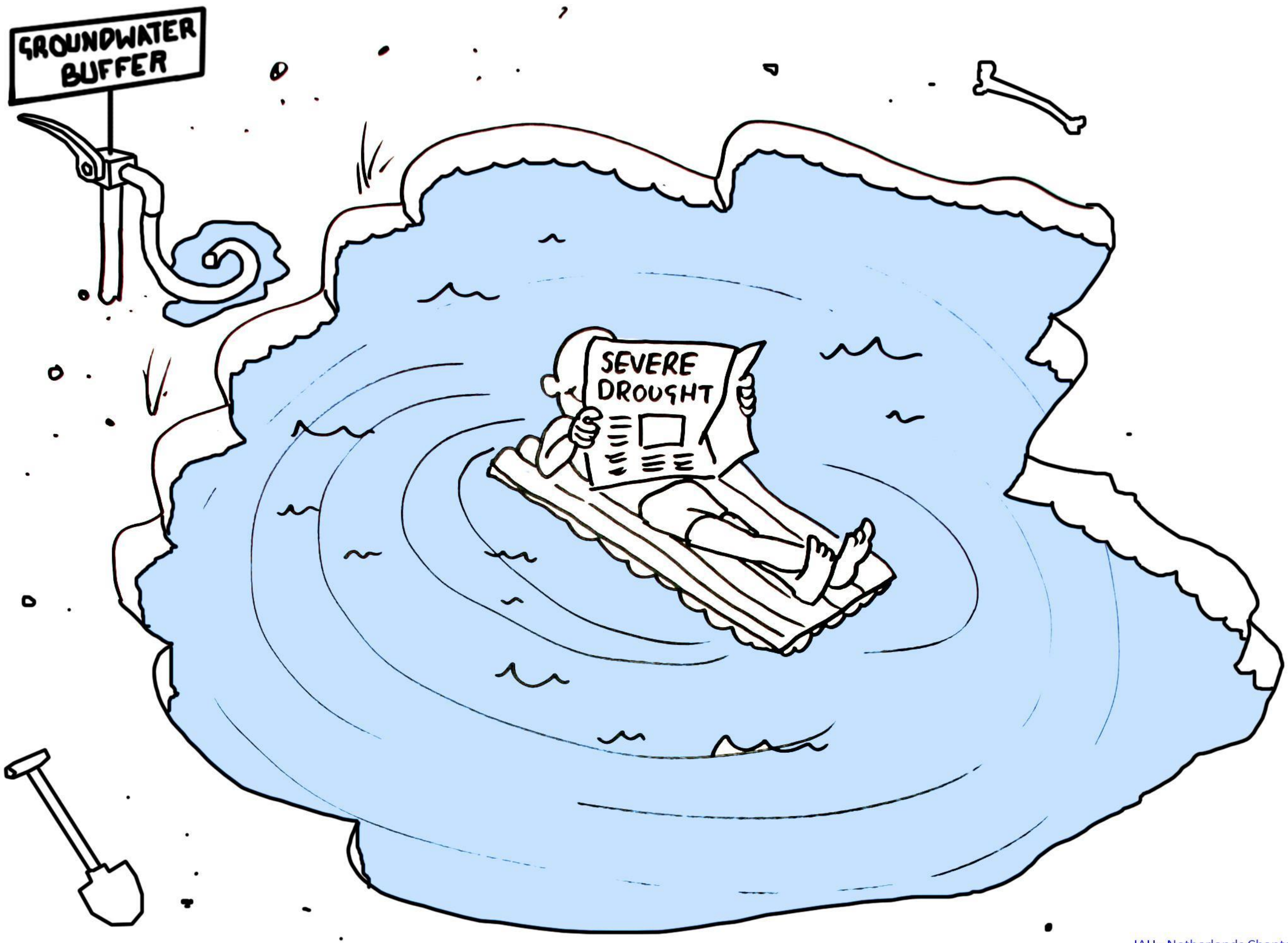
Groundwater resources

- *not well understood*
- *out of sight, out of mind*



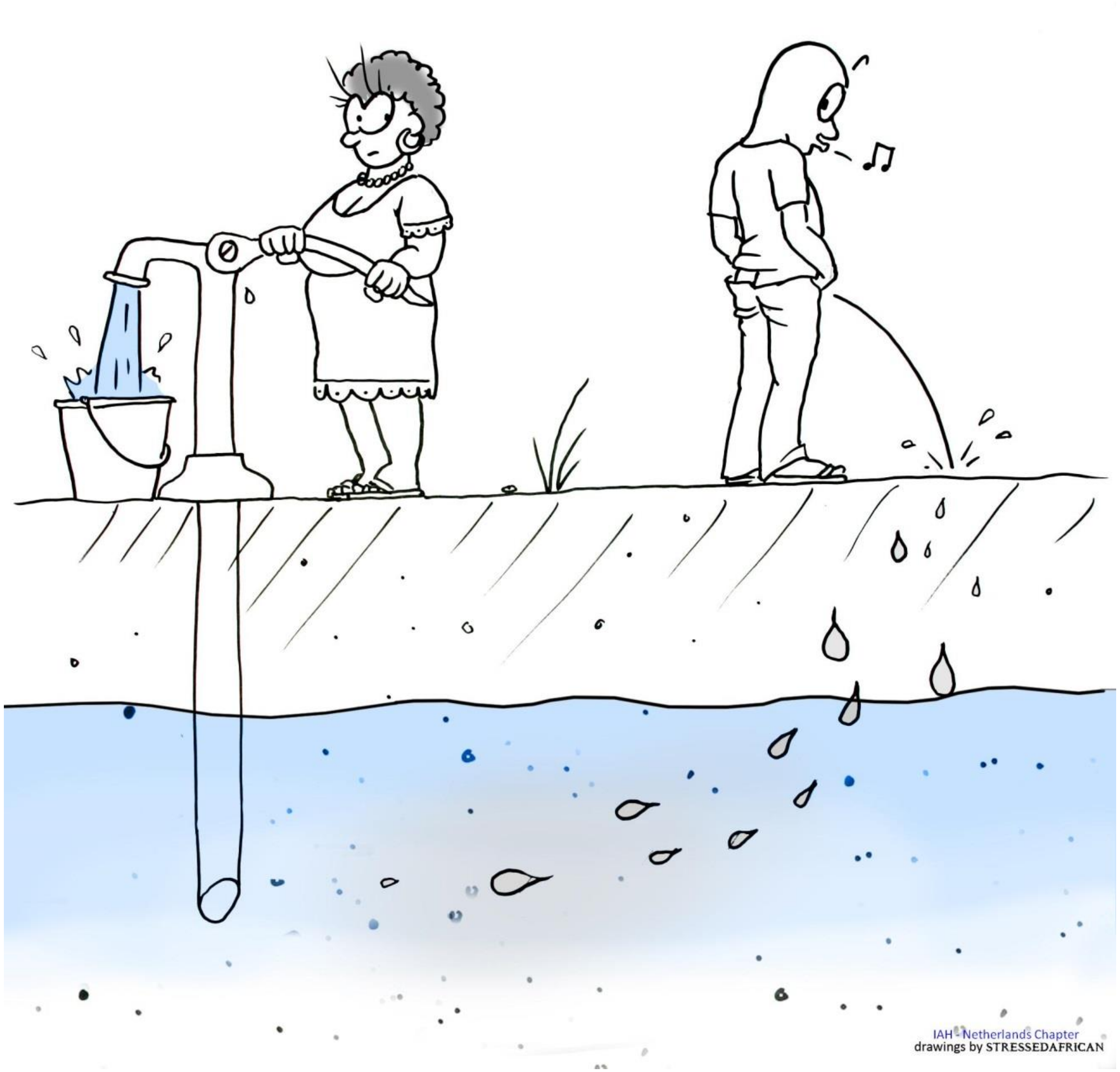
aquifers = saturated geological formations with a 'useful' permeability

out of sight, out of mind



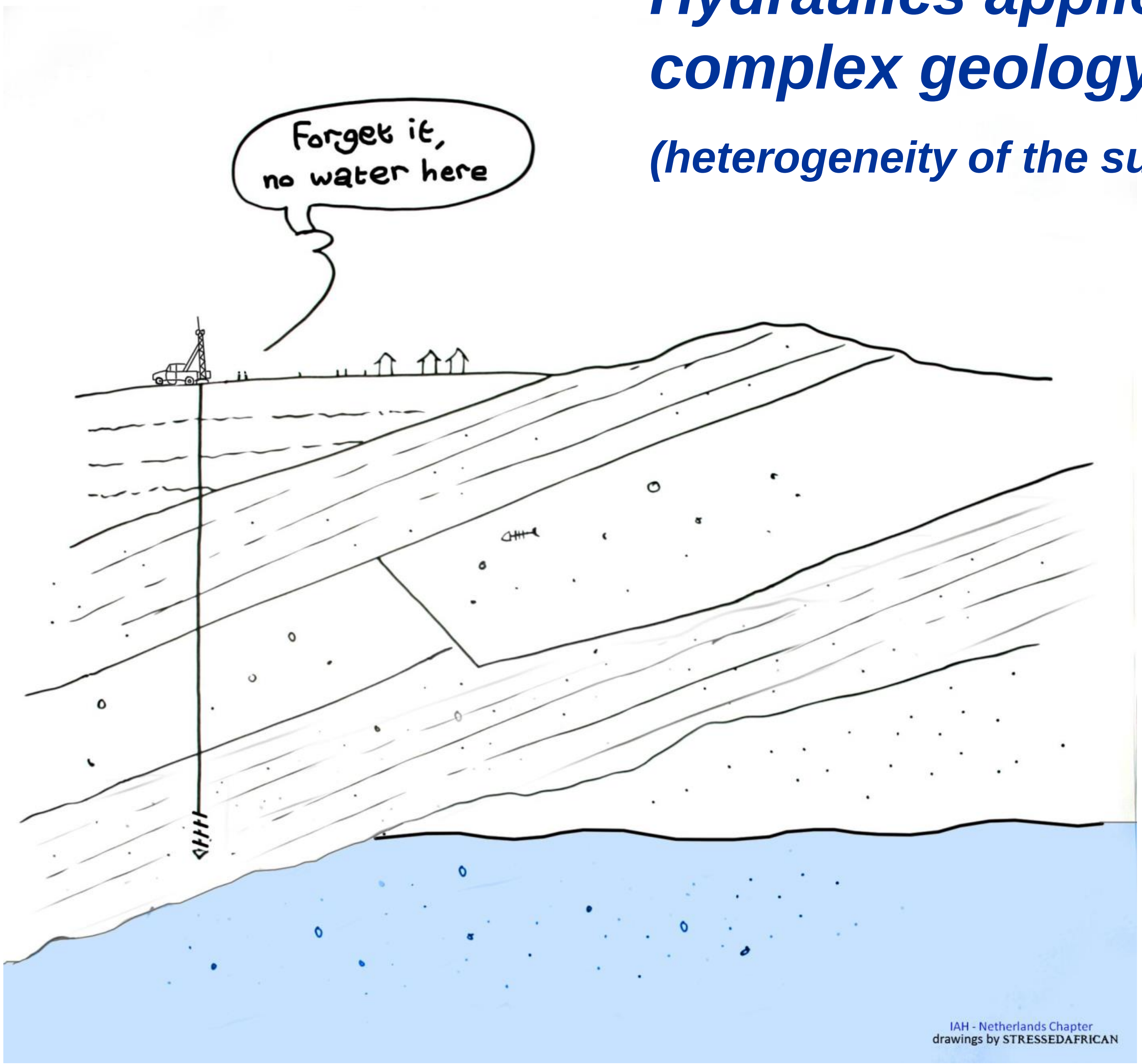
IAH - Netherlands Chapter
drawings by STRESSEDAFRICAN

out of sight, out of mind

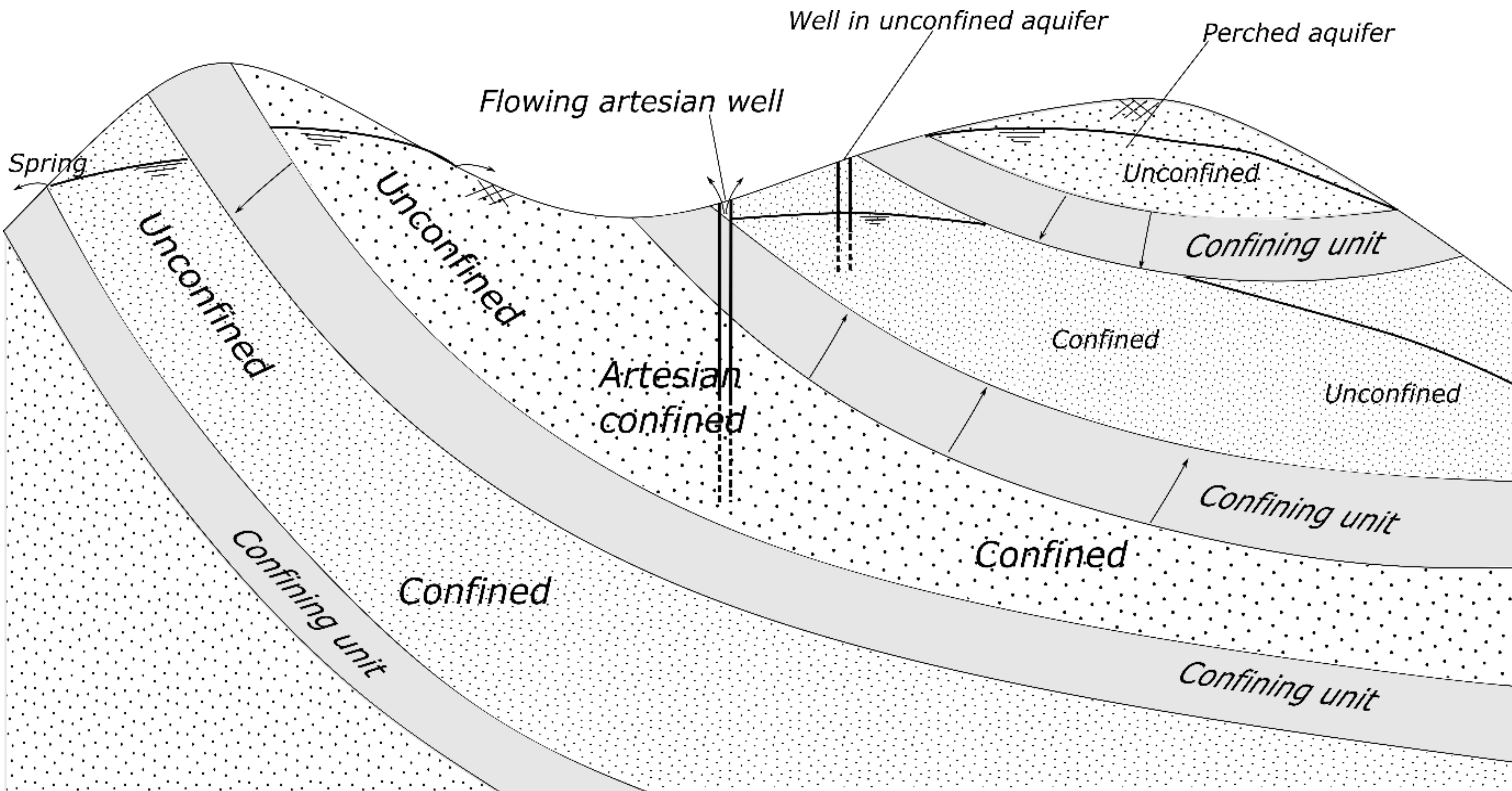


Hydraulics applied in a complex geology

(heterogeneity of the subsoil properties)



explaining… different situations



(from Dassargues 2018, 2020)

Groundwater advantages and drawbacks

➡ ***two aspects:***

- ***quantity***
- ***quality***

Advantages :

- *a better protection against contaminations*
- *a quasi-constant temperature*
- *a short distance between production and consumption places*
- *a very constant answer to the demand in function of time and delayed maxima/minima with regards to rainfall*
- *natural remediation and degradation of contaminants by bio-physico-chemical processes*

Drawbacks :

- *pumping costs*
- *uncertainties linked to the heterogeneity of the geology*
- *sometimes high (unwanted) solute concentrations*
- *expensive and uncertain protection and risk assessment*
- *groundwater quality and quantity remediation is long, complex and expensive*

Key issues :

- *overexploitation and decrease of groundwater levels*
- *management and permission of groundwater accesses and uses*
- *salinization problems*
- *other various contaminations*

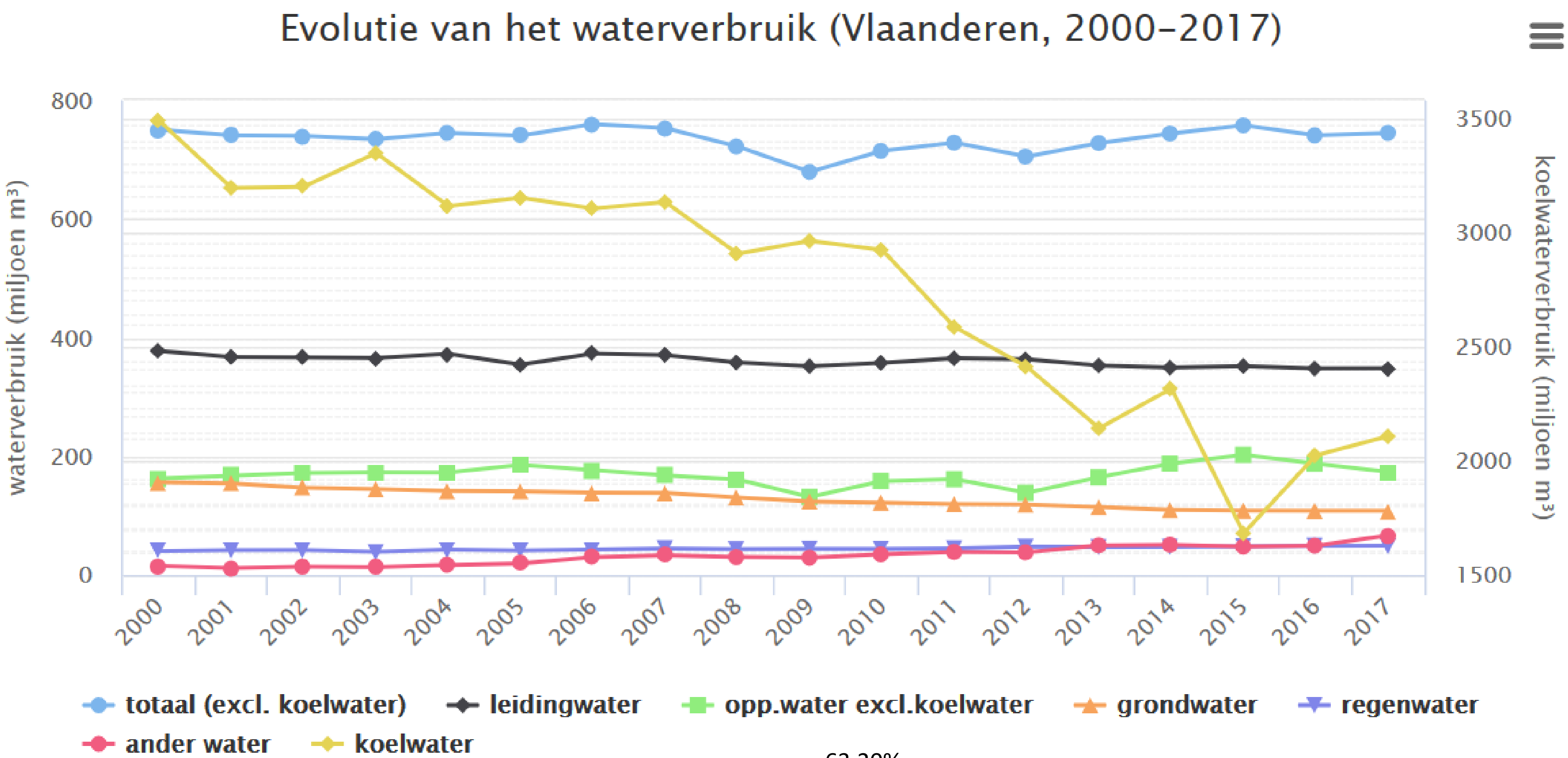
Water use in Belgium is stable or even decreasing (-10% from 1990)

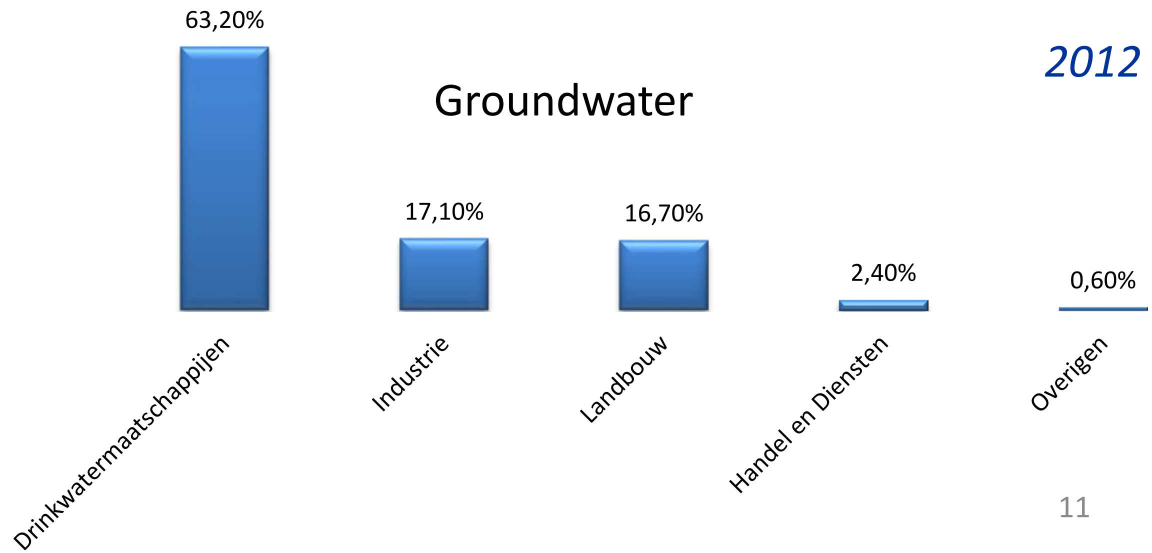
but misleading infos in the medias:

'Les chiffres affolants de la consommation en eau en Belgique' (Télémoustique)
'La Belgique parmi les régions les plus menacées par une pénurie en eau' (LLB et Le Soir))
'Watertekort in Belgïe…' (De Morgen, De Standaard, …)
…

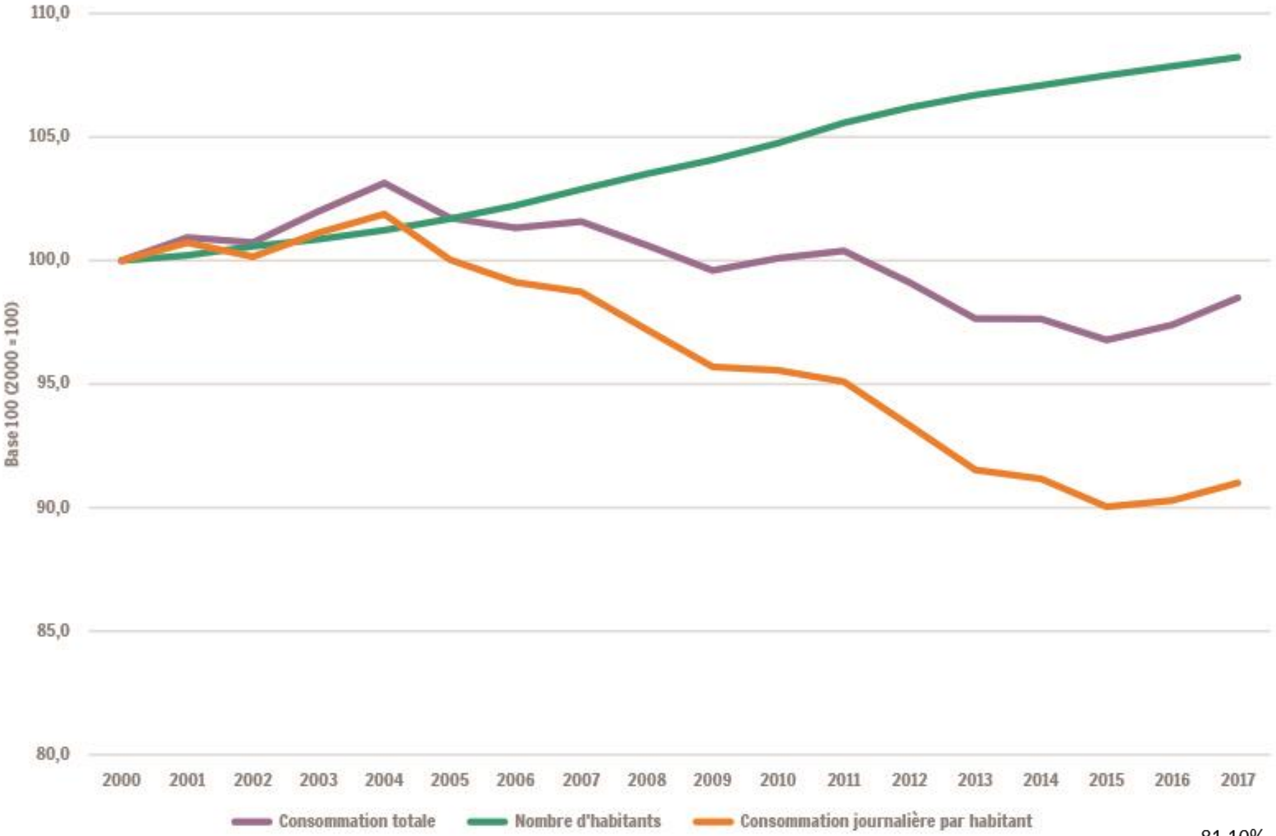
*The problem is the **spatial** and **temporal** distribution of water availability*
→ *that is more and more sensitive due to increasing population and climate changes*

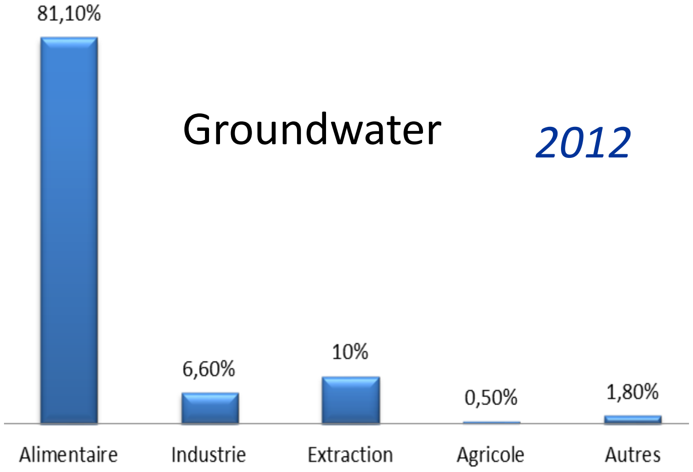
Water use in Flanders





Water use in Wallonia





Groundwater

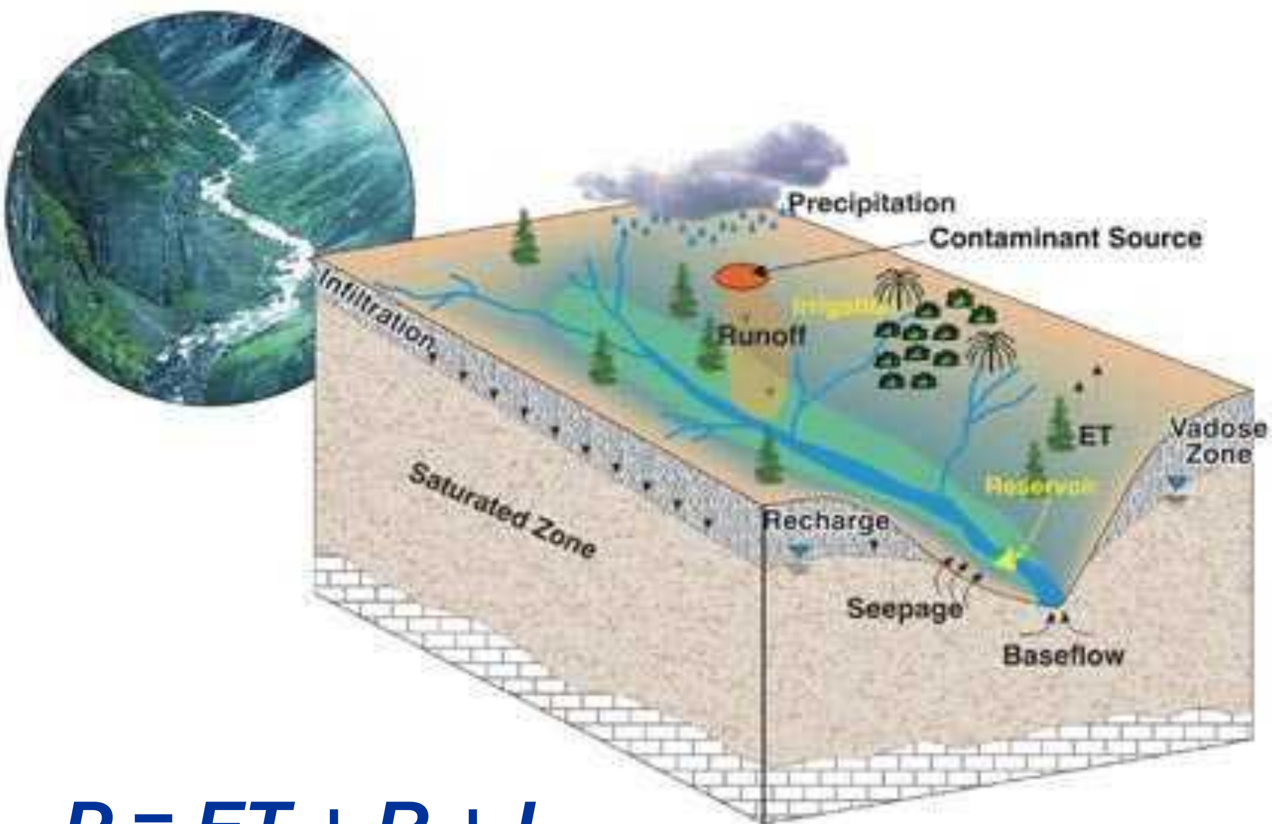
2012

Quality issues: main contamination sources for groundwater

(after 'Sustainable use of groundwater: Problems and Threats in the European Communities', Ministerseminar, nov.1991, Den Haag)

abandoned wells – septic tanks – underground tanks – landfill & waste disposal centres – fertilizers – pesticides – herbicides – irrigation – decantation basins – tailings - …

Hydrological cycle



balance on a basin

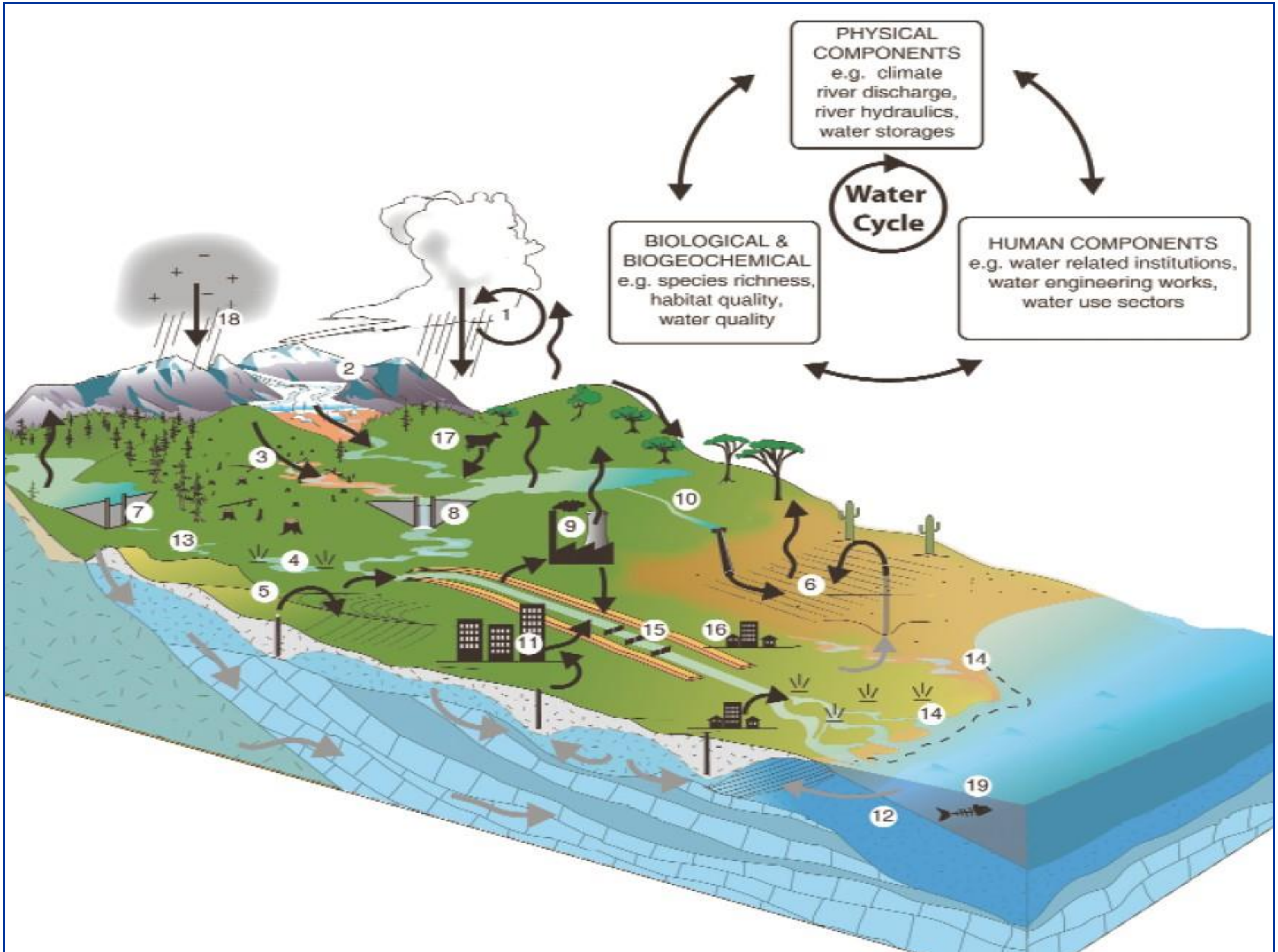
- *precipitations*
- *storages*
- *runoff*
- *evaporation*

$$P = ET + R + I$$

$$P = ET + R + Q_{gw} + \Delta Storage + Q_{pumped}$$

Q measured at the basin outlet

Hydrological cycle : complex network of fluxes and storage … more an more influenced by human activities !



Scale issue when dealing with exchanges between basins !

Thinking about water availability

de Marsily 2009: *'This is not so much a global problem as it is a regional problem of availability to satisfy our needs for improving human health, food security, biodiverse natural ecosystems and effective energy production.'*

Scanlon *et al.* 2017, Cai *et al.* 2018 :

multiple feedback effects, interconnections and couplings among these four main domains dependent on water resources

➡ *the 'water – energy – food nexus'*

… natural resources may limit the development of our well-being and of our growing human communities

The global picture

Water on Earth (currently estimated) at
1,387 million km^3
100 % *-96.5 % seawaters*
-0.96 % other saline waters
➡ *2.54 % freshwaters*
-1.75 % ice caps and glaciers
-0.02 % vapor in the atmosphere, soil moisture and permafrost
➡ *0.77 % 'available' freshwaters*
0.01 % lakes and rivers
0.76 % groundwaters

➡ ***ratio (lakes + rivers) / groundwater = 1/76 !!!***

Freshwater is quite unevenly distributed or easily accessible
➡ *groundwater takes a critical importance (especially in arid zones)*

Renewability of groundwater ?
… in arid zones, water production from very old groundwater reserves
(i.e., 'fossil groundwater' not renewed for thousands of years),
automatically brings up the question of sustainable development

… hides huge regional differences

Terminology

Simmons 2015 : *'confusion exists between used water, consumed water and produced water or withdrawn water'*

Used water:

➡ *water can be used many times, ensuring different successive functions or services:*
- *recycled water (with water treatment)*
- *reused water (without treatment)*

Consumed water:

➡ *water that is not (at least locally) recycled or reused (i.e., evaporated, transpired or transformed into food)*

Produced water:

➡ *withdrawn water, extracted from a source: a part can actually be reinjected (recycled) or reused, while the other part is consumed*

Main problem:

➡ ***irrigation: the water is mostly evapotranspirated and leaves the local scale basin***

➡ ***quantity + quality problem***

Terminology (2)

Water 'footprint' *(i.e., from a NGO called Water Footprint Network WFN)*

➡ *the total volume of freshwater used to produce the goods and services consumed by the individual or community or produced by the business*

LCA of water *(i.e. Life Cycle assessment from the general LCA community)*

➡ *metric(s) that quantifies the potential environmental impacts related to water (not the volume of water used or consumed but the caused potential impacts)*

(Pfister et al. 2017)

➡ ***LCA based water footprint ≠ Water footprint (WFN)***

but

both assessment methods can be seen as complementary

Main issues:

- ***global vs. local perspective***
- ***'green' water vs 'blue' water and 'gray' water***

➡ ***+ various physical interpretations of 'water stress index' or other similar empirical factors***

Terminology (3)

Global vs. local perspective

(Pfister et al. 2017)

- *the shortage of water is always a local problem (‘use’ ≠ ‘consumption’)*
- *e.g., groundwater pumped for domestic use will be in a big part recycled (or reused) in the same catchment*
- *this is taken into account in LCA assessment but not in Water Footprint assessments (main goal of WFN approach is to account for global water use)*

- *in WFN assessments, water is treated as any other goods and traded virtually via products between water abundant and water scarce regions,*

  the robustness of the argumentation for worrying about global water quantity is questionable

Example

- ***evapotranspiration in Belgium of 500 mm/y of soil moisture over a 1km² region (= 500,000 m³) would be worse than groundwater pumping of 250,000 m³ in Mauritania for irrigation !***
  indeed, this is not consistent in terms of environmental impact

The reasoning should be clearly different than for the other products !

Terminology (4)

(based on Pfister et al. 2017)

Green water vs Blue water and Gray water

Green water = water used for plant growth from naturally available precipitation

Blue water = water withdrawn from aquifers and rivers

Gray water = locally recycled water but with a quality impairment

Example

➡ *agriculture in Belgium (until recently) is mainly rain-fed agriculture using the natural soil moisture and reducing use of blue water: green water*

water footprint assessments consider the total green water as consumed

but without agriculture in Belgium natural vegetation would have consumed also green water (even more)

➡ ***pure volumic water footprint assessments are often misleading indicators***

Terminology (5)

Examples

- ‘1kg of beef needs 15,000 L of water’ (WF assessment)

(but if the beef is raised on rain-fed non-irrigated grasslands, the impact can be even positive on the local water balance)

➡ *in our regions, most of this amount is green water*

- ‘1kg of tomatoes needs 214 L of water’ (WF assessment)

(here most often it needs irrigation with blue surface water and groundwater in greenhouses or in semi-arid regions)

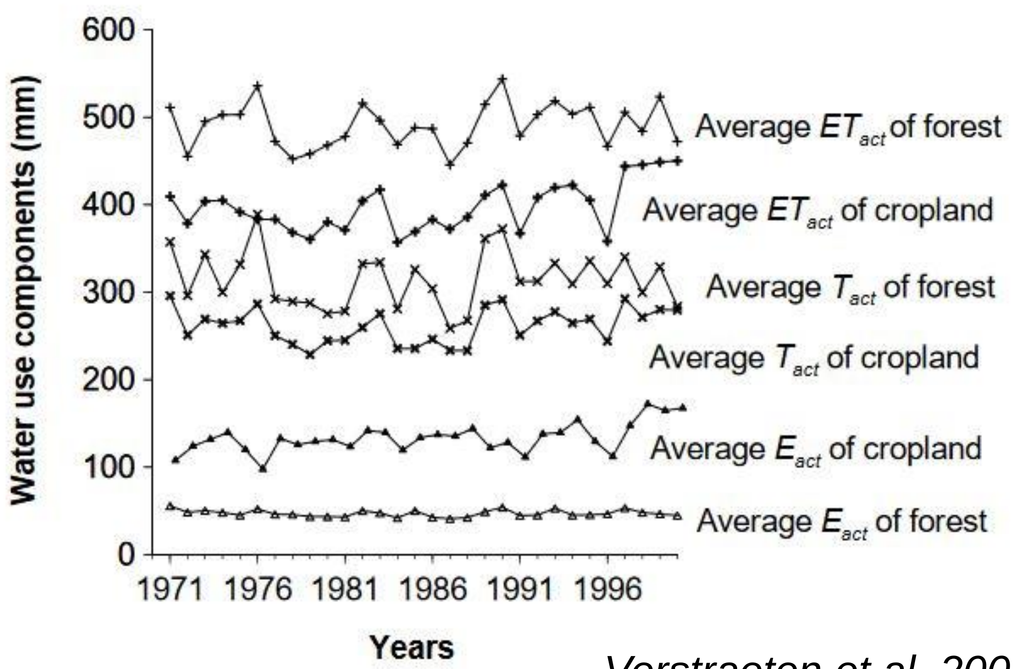
➡ *in our regions, most of this amount is blue water*

Irrigation is the most negative process as it increases evapotranspiration !

The impact of any agricultural production could be assessed depending on many factors

➡ *fundamental to distinguish between* - *rain-fed agriculture*
- *irrigated agriculture*

In our regions, agriculture consumes less water than the natural land use (i.e. forest)



Verstraeten et al. 2005

➡ ***… be careful with too simplistic impact or water footprint assessments !***

Terminology (6)

(based on Pfister et al. 2017)

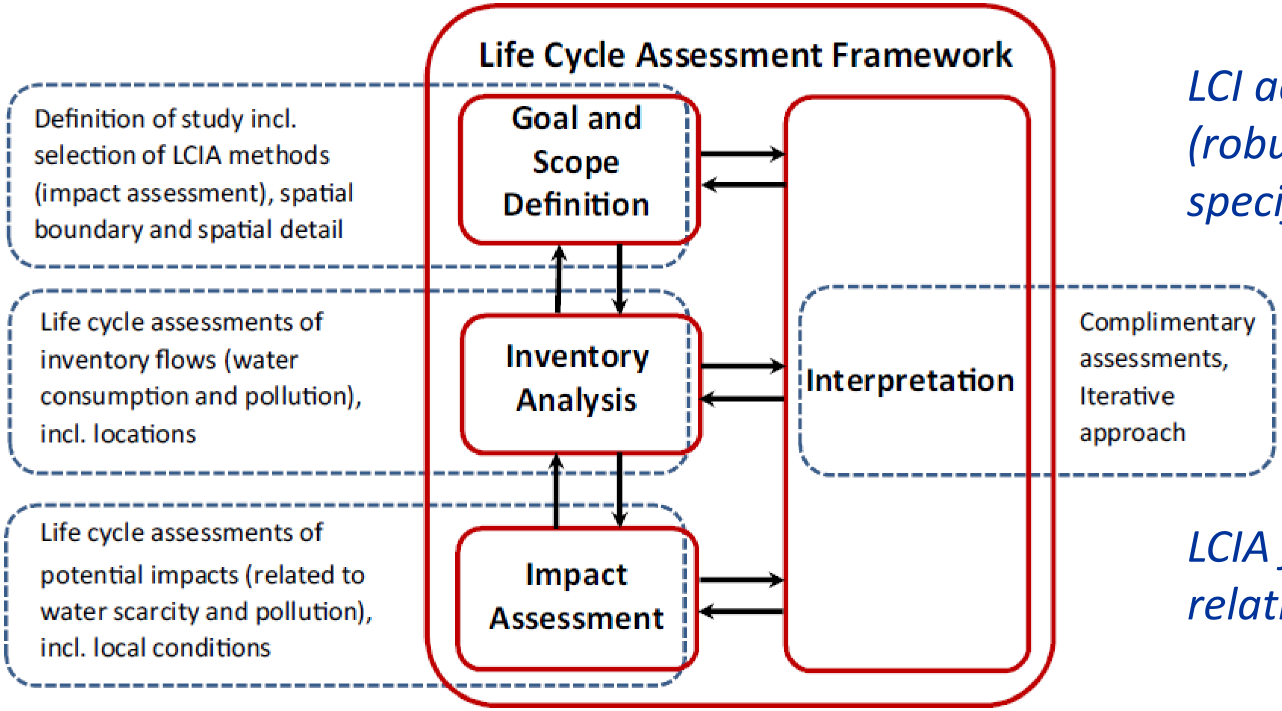
… and gray water ? *(locally recycled water but with a quality impairment)*

not taken into account in WFN Water Footprint assessments

indeed we are dependent on the local development and organization of each region

LCA water assessments

include LCI (LC Inventory) and LCIA (LC Impact Assessment)



LCI accounts for local scale state (robust analysis of region specific databases)

LCIA focuses on the local relative 'water scarcity'

LCA water assessments

include LCI (LC Inventory) and LCIA (LC Impact Assessment)

➡ *often considered as less 'robust' because more subjective than water footprint assessments*

Example

definition of the local 'water scarcity index'
most often expressed as
total annual freshwater withdrawal / annually available renewable water

➡ *leading to the use of empirical index value*
Example: same index value for Mauritania and Belgium
(as withdrawals are strongly reduced when availability is very limited)

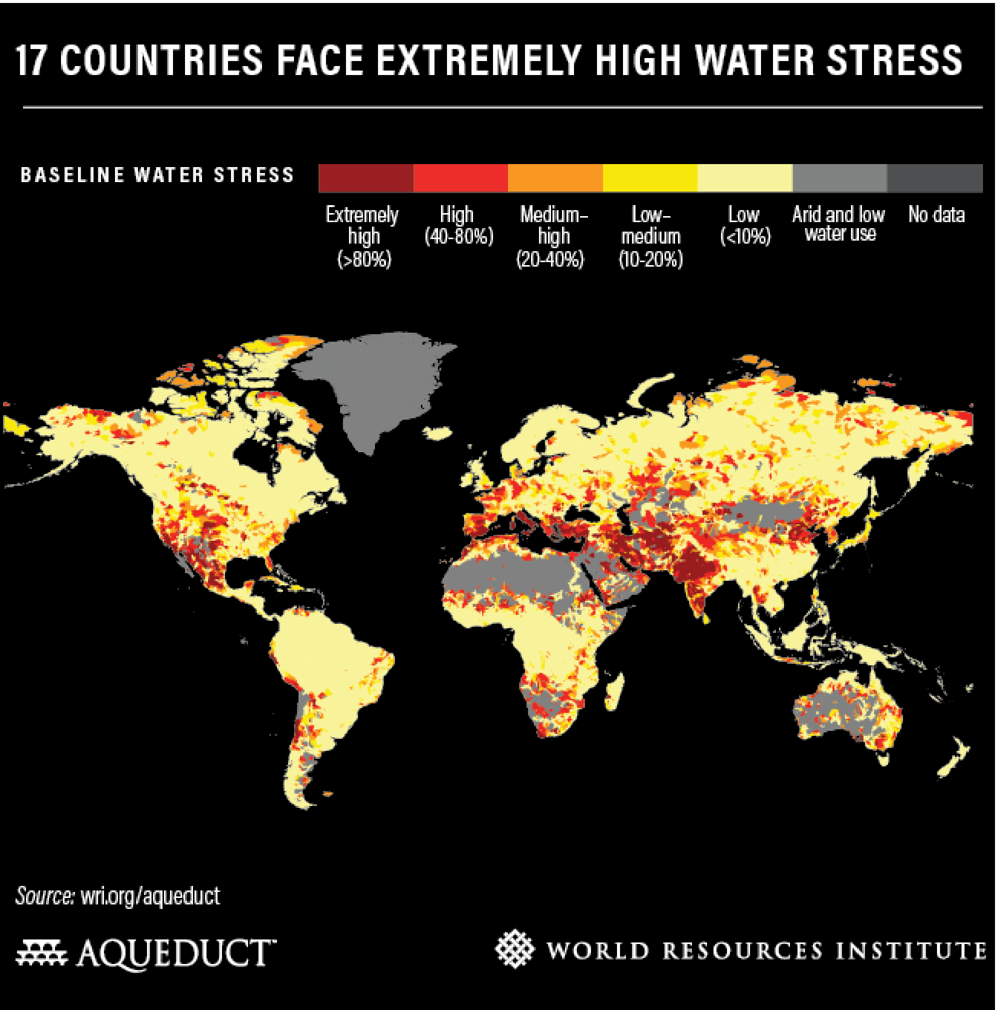
An example: World Resource Institute

…made the headlines in the media (a few years ago)

with an example of misleading/biased information:

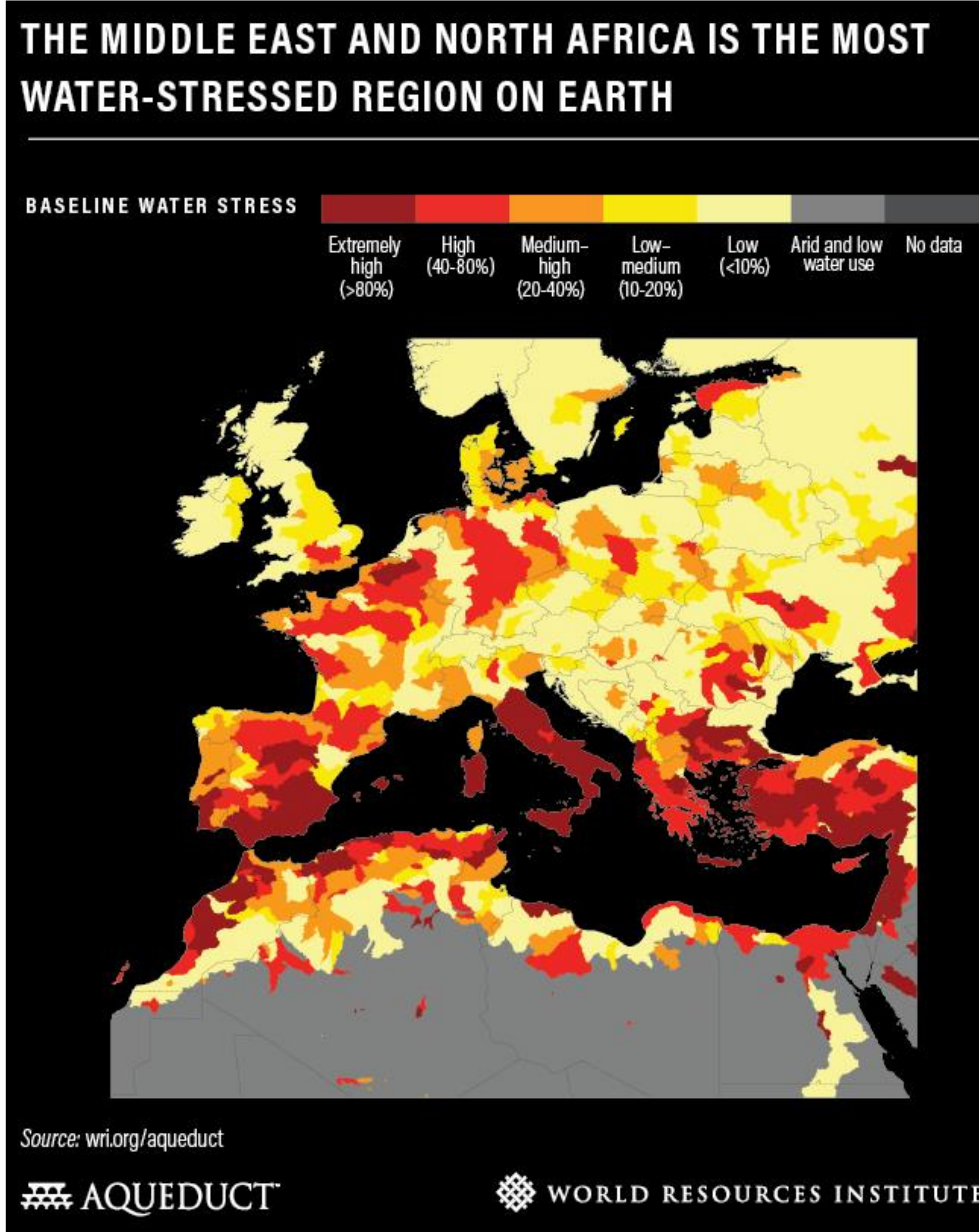
about the 'water stress country rankings'

with regards to 'water-quantity related risks' (2013, 2015, 2019)



The World Resource Institute = American Private Foundation supported by Democrats Party, Coca Cola and other donators in US

***WRI** (2013, 2015, 2019)*



***WRI** (2013, 2015, 2019)*

WORLD RESOURCES INSTITUTE

National Water Stress Rankings

EXTREMELY HIGH BASELINE WATER STRESS

1. Qatar
2. Israel
3. Lebanon
4. Iran
5. Jordan
6. Libya
7. Kuwait
8. Saudi Arabia
9. Eritrea
10. United Arab Emirates
11. San Marino
12. Bahrain
13. India
14. Pakistan
15. Turkmenistan
16. Oman
17. Botswana

HIGH BASELINE WATER STRESS

18. Chile
19. Cyprus
20. Yemen
21. Andorra
22. Morocco
23. Belgium
24. Mexico
25. Uzbekistan
26. Greece
27. Afghanistan
28. Spain
29. Algeria
30. Tunisia
31. Syria
32. Turkey
33. Albania
34. Armenia
35. Burkina Faso
36. Djibouti
37. Namibia
38. Kyrgyzstan
39. Niger
40. Nepal
41. Portugal
42. Iraq
43. Egypt
44. Italy

‘Les chiffres affolants de la consommation en eau en Belgique’ (Télémoustique)
‘La Belgique parmi les régions les plus menacées par une pénurie en eau’ (LLB et Le Soir))
‘Watertekort in Belgïe…’ (De Morgen, De Standaard, …)

47. Sudan 53. South Korea 59. France 65. Indonesia

***WRI** (2013, 2015, 2019)*

how their indicator is built:

total annual freshwater withdrawal / annually available renewable water

but

- large approximation in withdrawal assessments

example: water consumption estimated during the night in function of the light measured on satellites images

- large approximation in available water

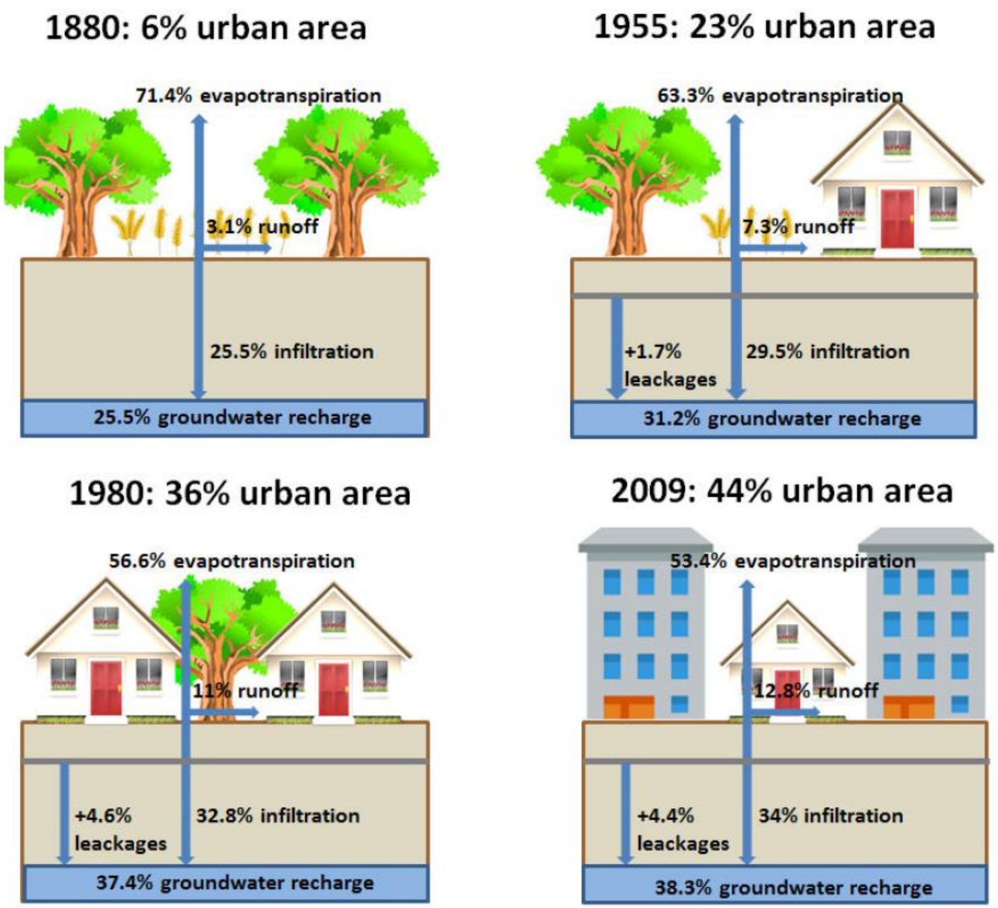
example: gray water not accounted (all is assumed as consumed, not used)

- but the most biasing factor: the indicator itself

that's why Niger seems a less water stressed region than Belgium !

➡ *other indicators could be developed (i.e., involving a sensitivity analysis of available renewable water if the withdrawal are changed, …)*

Thinking 'green' : the impact on groundwater resources is more complex than usually thought



(from Minnig et al. 2018)

In Switzerland, transformation of natural landscapes into impervious areas leads to a considerable increase in groundwater recharge due to the reduction of evapotranspiration that more than compensates for the increase in runoff and due to the contribution of water main leakages (Minnig et al. 2018, JoH)

➡ ***… be careful with too simplistic impact assessments !***

The rising threat:

wild and not optimized irrigation

- *increase of EvT (thus consumed water)*
- *partial remediation: drip irrigation (but expensive)*
- *rising groundwater levels ➡ increased evaporation, reduced agricultural efficiency*
- *waterlogging and drainage problems*

- *needed 'leaching out' of the salt increases groundwater salinity*
- *…*

What about drainage of groundwater in the Einstein Telescope infrastructures ?

During ET exploitation

- *if about 100 L/s to be drained and/or pumped to the surface*
- *100 L/s = 360 m^3/h = 8,640 m^3/day = 3.2 Millions of m^3/year*

- *compared to recharge: 250 mm/year over an area of 10 x 10 km^2*
- *0.25 x 100 x 1x10^6 = 25 Millions of m^3/year*

- *not a so large impact*
- *but check the local piezometric levels with respect to river water levels for preserving current biological functions*
- *re-use of this drained/pumped groundwater*
    - *for drinking water (gw quality should be OK)*
    - *for reinjection in some rivers*
    - *for reinjection in aquifers*
    - *for irrigation purposes (in summer)*

Messages to take home…

- *renewability of freshwater can only be assessed at a local (regional) scale*
- *water 'consumption' = evapotranspiration* ***not to be confused with***

  'use', 'production', 'withdrawals', …

  (e.g. high withdrawals do not automatically imply high consumption and even less induced water scarcity)

- *in terms of 'water footprint' and LCA ?*

  … very important to distinguish rain-fed from irrigation products !
- *in terms of water balance, rain-fed agriculture should be encouraged*

  as irrigation is the main driver increasing evapotranspiration
- *water issues are not only a quantity problem, but also a quality problem*
- *water shortages are due to the uneven spatial and temporal distributions of freshwaters*

  and inadequate management !
- *groundwater is not easy to manage (including the fight against undeclared*

  illegal wells and hidden withdrawals)

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