Water Footprint of Volkswagen Passenger Cars – Results and Challenges

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Introduction

- Need for water grows twice as fast as the world population
  → Sustainable water management is urgently needed!
- Several water footprint methods are available, but hardly tested

Stand-alone methods

- Virtual Water
- Water Footprint according to WFN
- Global Water Tool
- Corporate Water Gauge

ISO 14046 (working draft)

LCA methods

Water inventories:
- Bayart et al. (2010)
- Boulay et al. (2011a)
- Ecoinvent (2011)
- PE International (2011)
- Quantis (2012)

Impact assessment methods for Human health, Ecosystems, Resources:

Midpoint:
- Hauschild and Wenzel (1998)
- Brent (2004)
- Bösch et al. (2007)
- Mila i Canals et al. (2008)
- Frischknecht et al. (2009)
- Bayart et al. (2009)
- Pfister et al. (2009)
- Boulay et al. (2011b)
- Veolia (2011)

Endpoint:
- Motoshita et al. (2008)
- Pfister et al. (2009)
- Maendly & Humbert (2011)
- Motoshita et al. (2011)
- van Zelm et al. (2011)
- Boulay et al. (2011b)

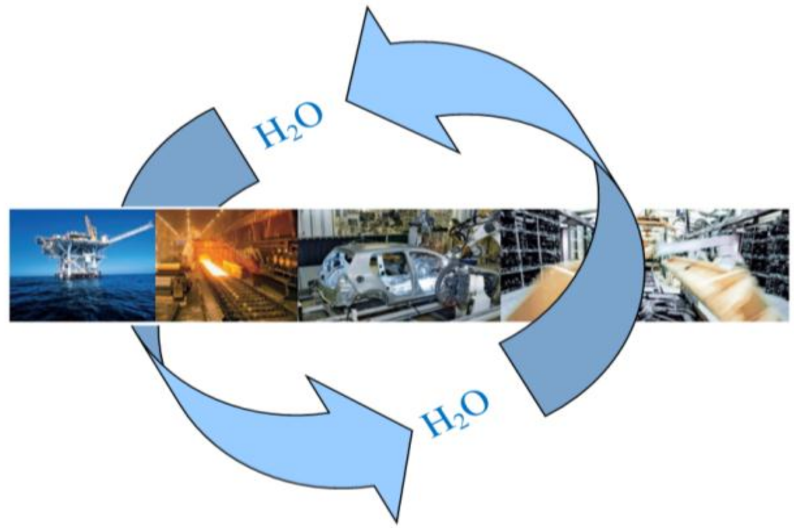
Berger, M. & Finkbeiner, M.
Water Footprinting: How to address water use in LCA? *Sustainability* **2010**, 2(4)
http://www.mdpi.com/2071-1050/2/4/919/

- Daimler: Water footprint of production site Sindelfingen
- EuroCopper: Water footprint of copper sheet and tube
- Siemens: Water footprint of seawater desalination plants
- Volkswagen: Water footprint of passenger cars
- Neoperl: Water footprint of flow regulator
- German EPA: Water footprint of milk production

M. Berger, J. Warsen, S. Krinke, V. Bach, M. Finkbeiner (2012): **Water footprint of European cars: potential impacts of water consumption along automobile life cycles.** *Environmental Science and Technology, 46 (7), 4091-4099*

Aim

- How much water is consumed in a car's life cycle?
  - Polo 1.2 TDI
  - Golf 1.6 TDI
  - Passat 2.0 TDI



- What is the impact of this water consumption?

Procedure

- Determine water consumption by means of LCA software and Volkswagen’s certified full car LCI models
- Geographical differentiation of water consumption
  - Dividing total water consumption to shares of material groups
  - Assigning material specific water consumption to geographical regions based on import mixes, location of production sites and industrial sectors (top down)
  - Example polymers:
    1. Water consumption of crude oil production, refinery, polymerisation, component fabrication
    2. Regionalisation based on European import mixes of crude oil, location of refineries, polymerization plants, and of plastic component producers
- Application of selected impact assessment methods

Results - inventory

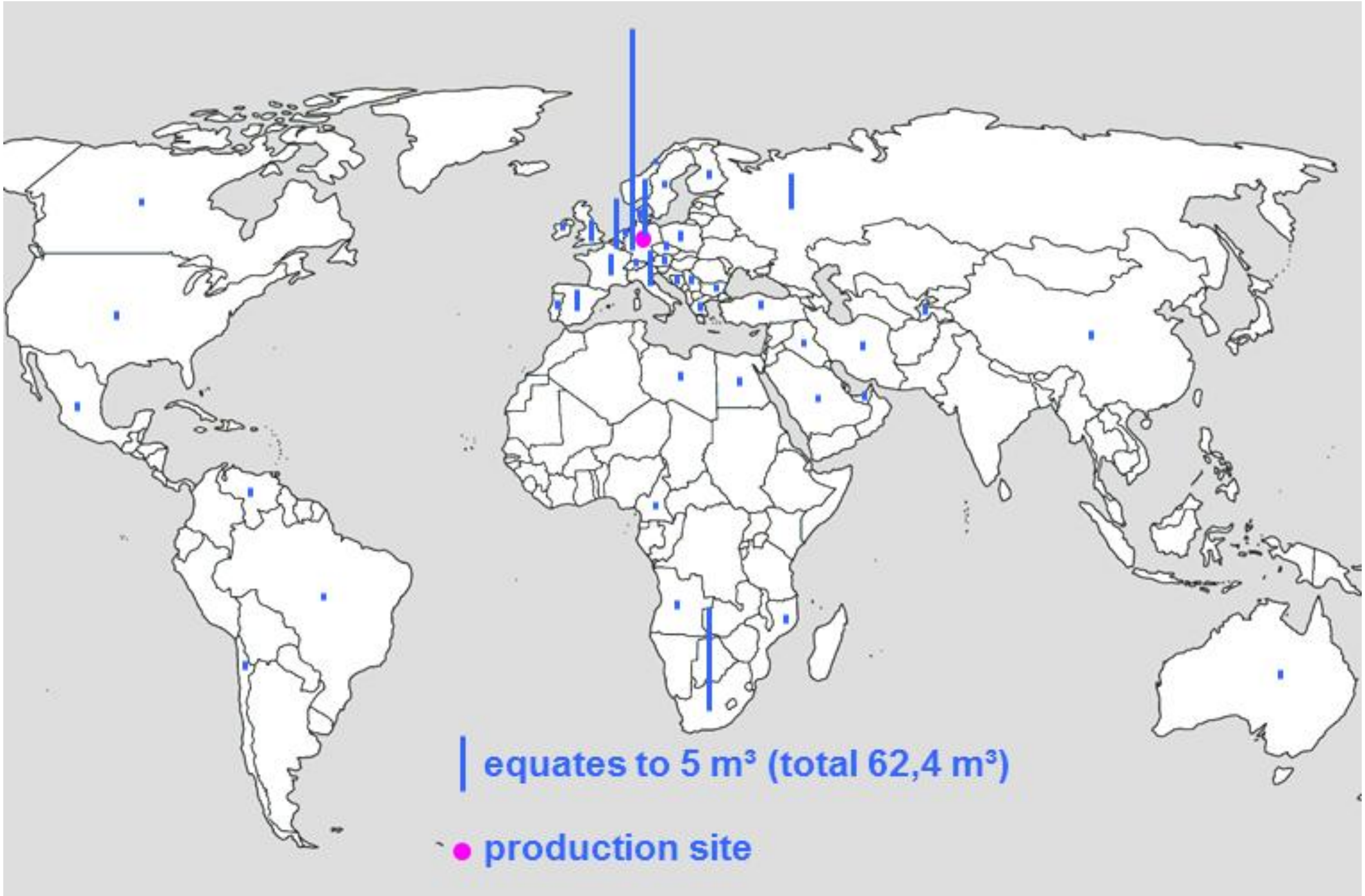
- > 90% of water consumption in production phase (fossil fuels)
- Steel & polymeres are the dominant material groups (> 60%)
- High specific contribution of special metals (> 20%), particularly precious metals in catalysts (PGM)

51.700 l

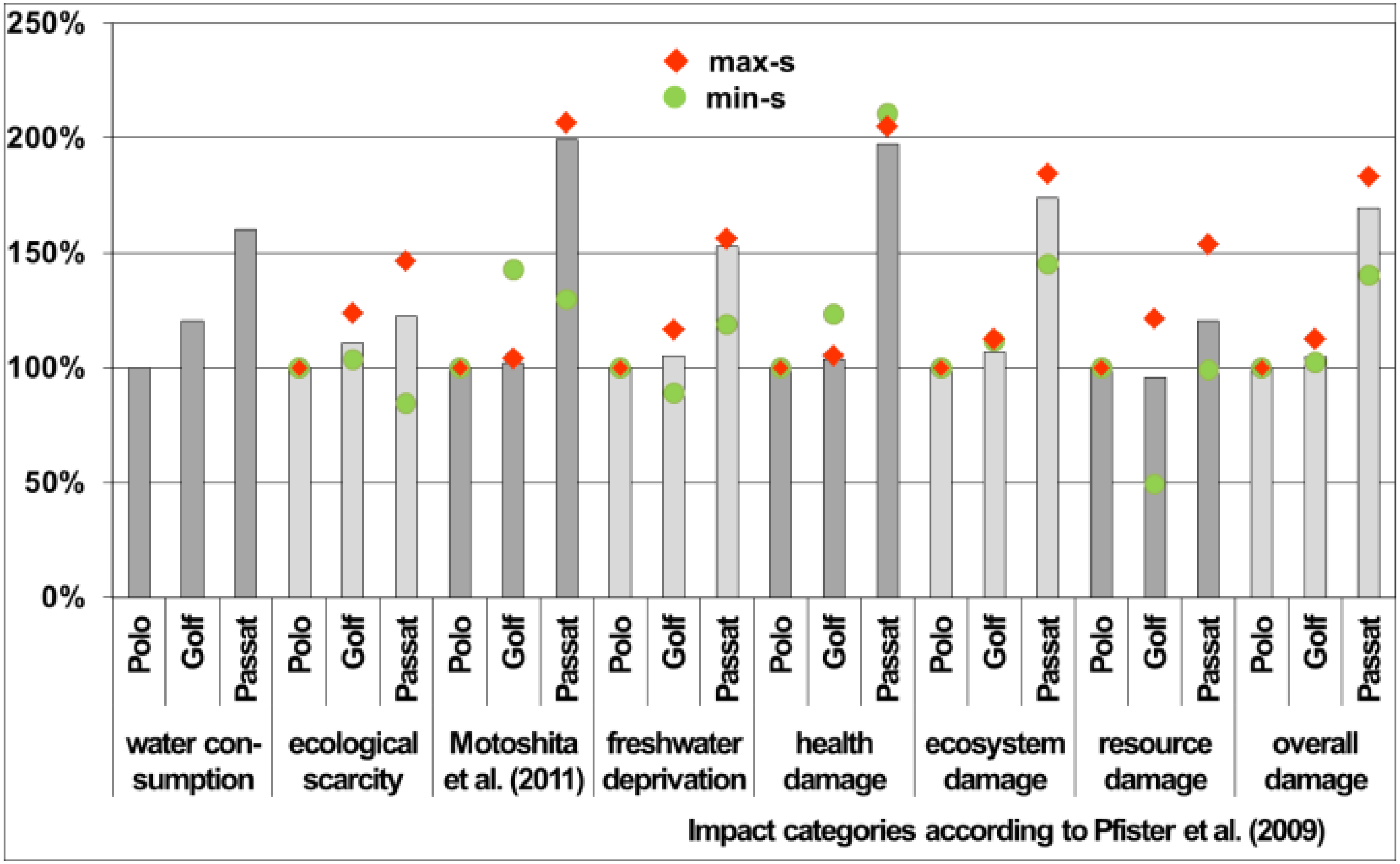
62.400 l

82.900 l

- Water consumption in more than 40 countries, only 10% at production site

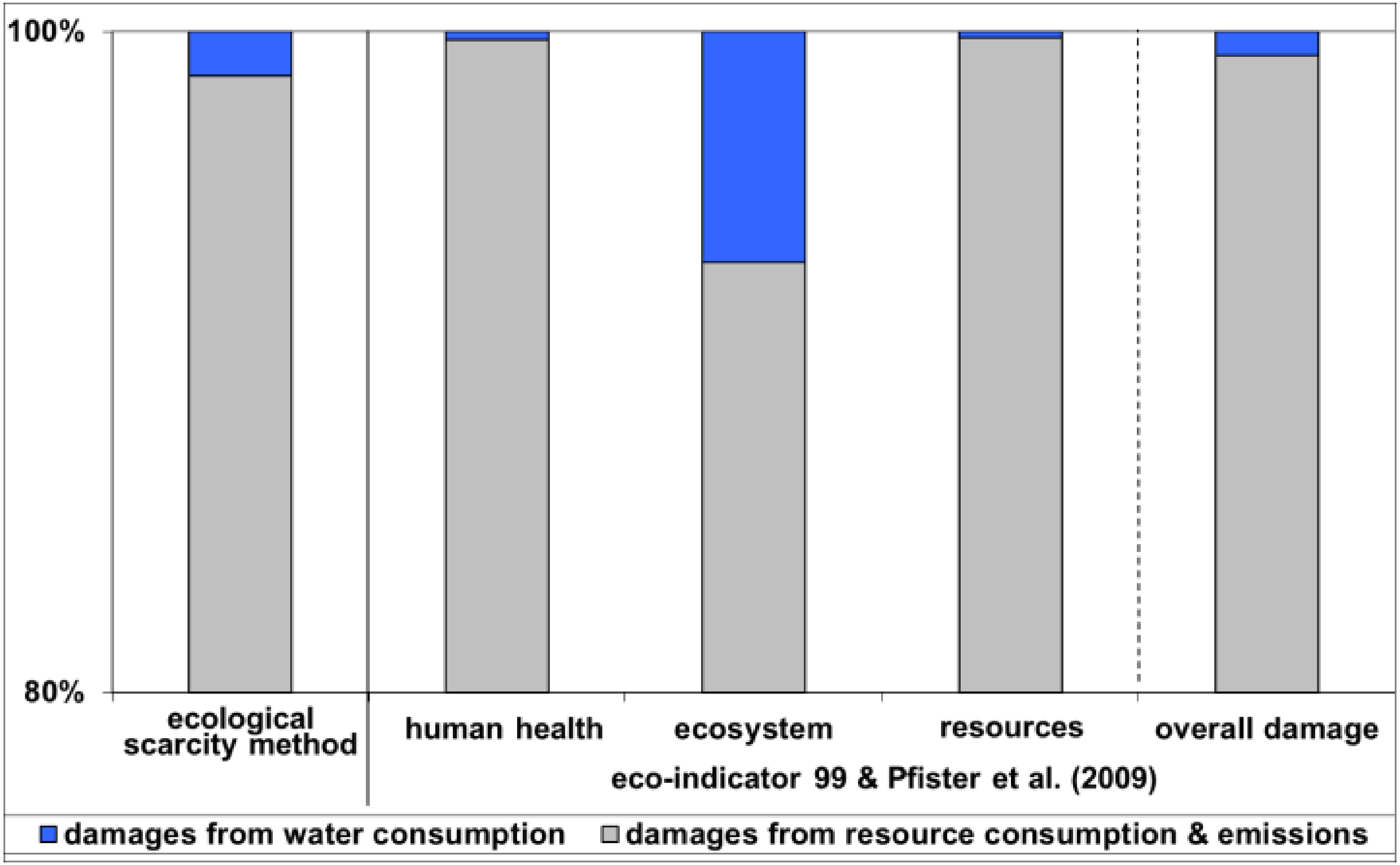


Results - impact assessment



- Ranking of cars changes in impact assessment as water consumptions in different countries is assessed differently; especially relevant is PGM production in South Africa

Results – impact assessment



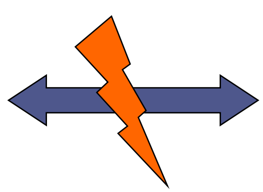
- Damages resulting from water consumption relatively low compared to resource consumption, emissions, etc. (1-7% of total production damage)

Challenges

- High uncertainties in the reported water data in inventory data bases
- Additional uncertainties due to geographical differentiation in the applied top-down approach
- The results of impact assessment are strongly sensitive to the location of water consumption, i.e. the quality of geographical differentiation is crucial.

  → Spatially explicit water flows are needed in LCA databases (bottom-up)
- Some methods require additional data (source, quality, time). However, high resolution inventory data hardly available, especially if complex background systems are involved
- Trade-off:

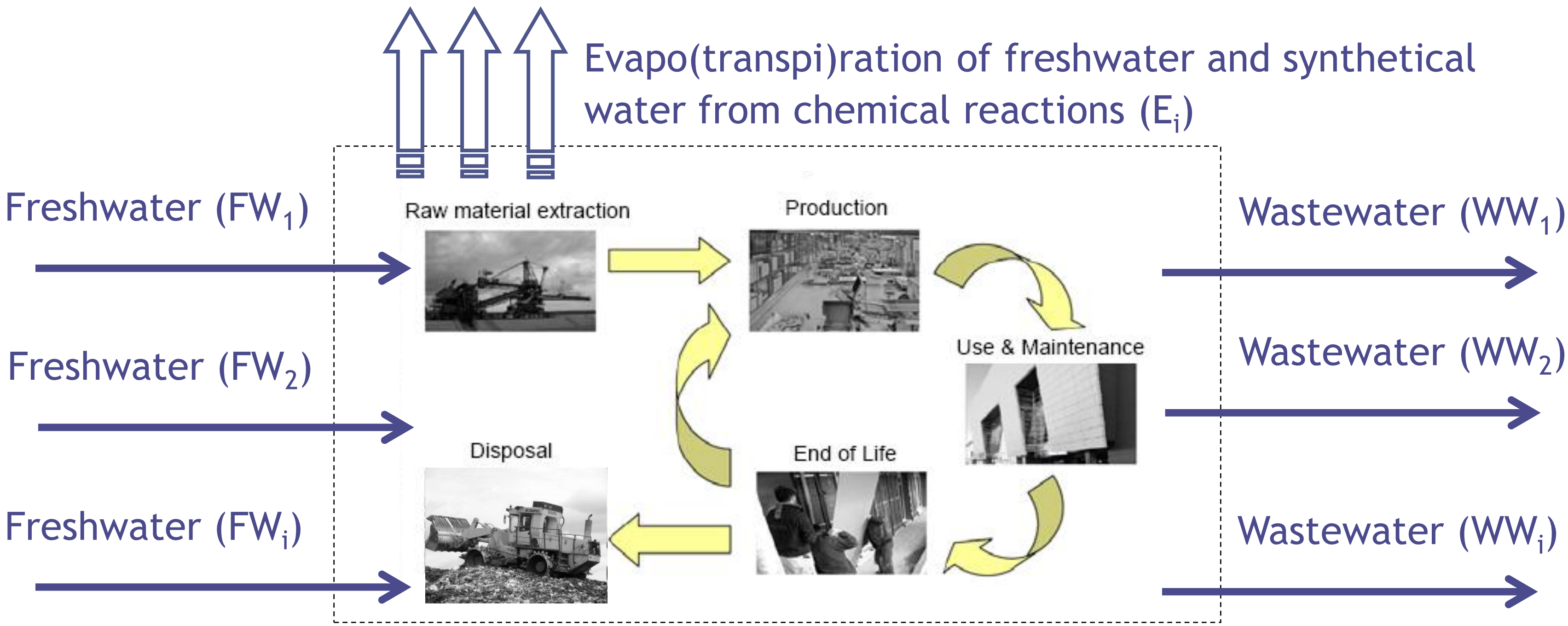
Precission



Applicability

M. Berger, M. Finkbeiner (2012): **Methodological challenges in volumetric and impact oriented water footprints.** *Journal of Industrial Ecology (in press), DOI: 10.1111/j.1530-9290.2012.00495.x*

New water footprint method: inventory

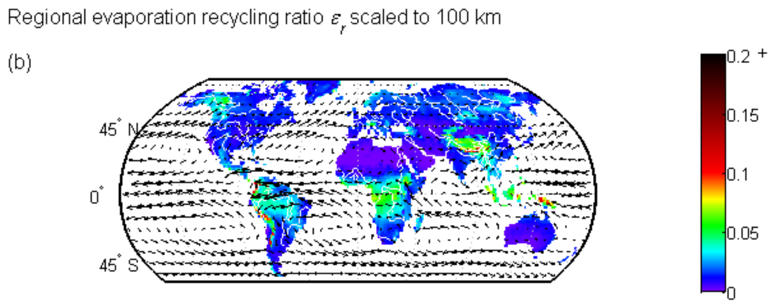


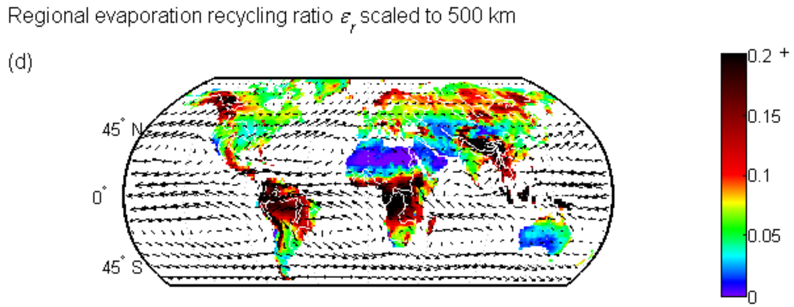
- Water consumption: $$WC = \sum_i FW_i - WW_i - ER_i$$
- Evaporation recycling (ER) is determined by basin internal evaporation recycling (BIER)

→ denotes fraction of evapo(transpi)ration and synthetically created water that is returned to the originating watershed via precipitation

$$ER_i = E_i \cdot BIERi$$

- Basin Internal Evaporation Recycling (BIER):
  - Continental evaporation recycling within radii of 25, 50, 75, 100, 200, and 500 km is calculated for each raster point based on van der Ent et al. (2011)





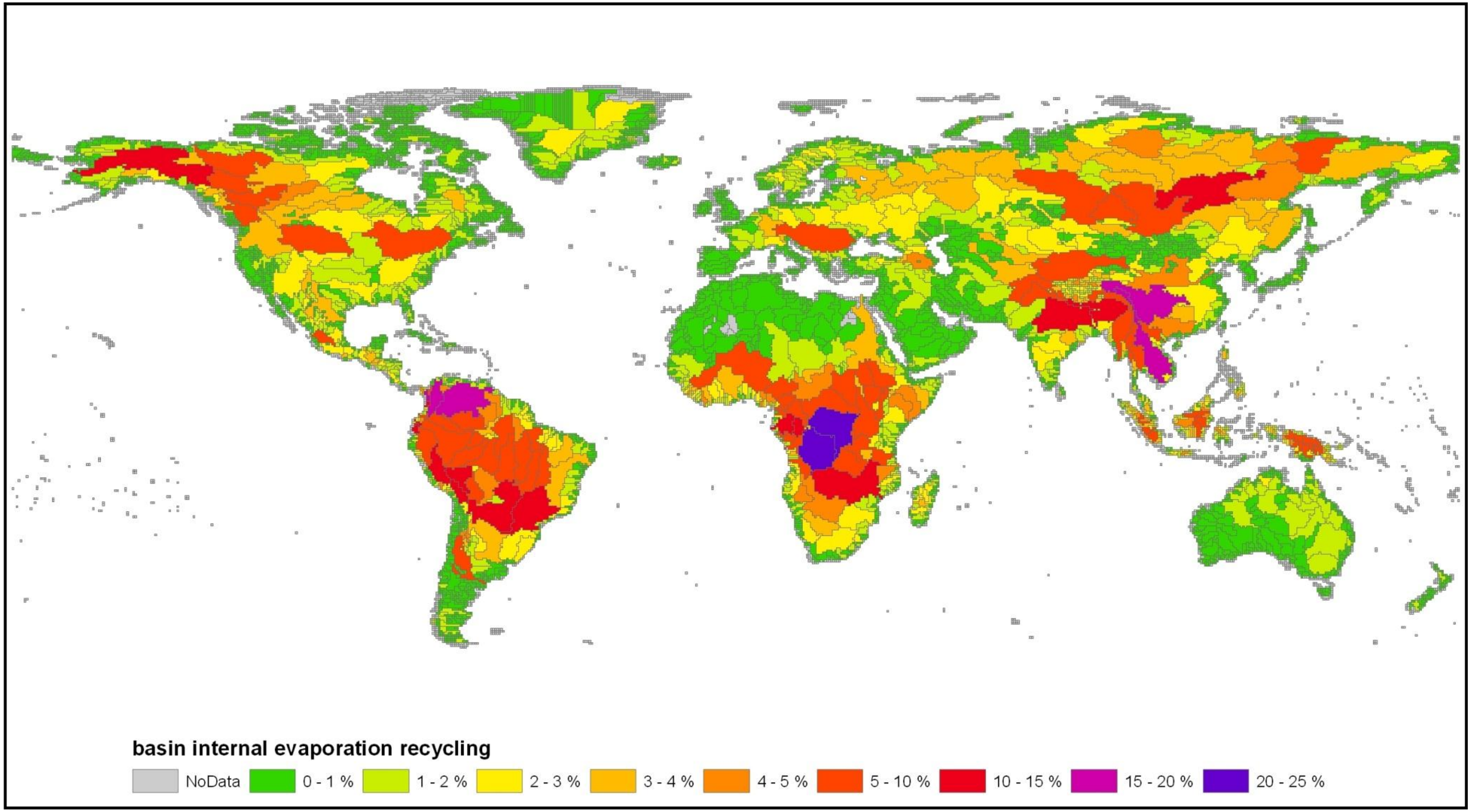
  - Depending on the size of the watershed, evaporation recycling ratios are assigned to the watershed (by averaging values of the raster within the watershed):
    - $A_{watershed} < 1964\ km^2$ → evaporation recycling value of r = 25 km ($A = 1964\ km^2$)
    - $1964\ km^2 < A_{watershed} < 7854\ km^2$ → value of r = 50 km ($A = 7854\ km^2$)

    …

    - $A_{watershed} > 785398\ km^2$ → value of r = 500 km ($A = 785398\ km^2$)

New water footprint method: results

- Inventory: Basin Internal Evaporation Recycling (BIER)



New water footprint method: impact assessment

- Impacts are determined, by multiplying local WC with corresponding water deprivation index (WDI):

$$WF_{impact} = \sum_i WC_i \cdot WDI_i$$

1. Based on consumption-to-availability ratio, relating annual water consumption (AWC) to renewability rate (RR)

$$WDI''''' = \frac{AWC}{RR}$$

2. Add annually usable surface water stocks (SWS_{au}) to RR

$$WDI'''' = \frac{AWC}{RR + SWS_{au}}$$

3. Square RR to consider sensitivity to additional AWC (1/10=10/100=0.1 but $1/10^2$=0.01; $10/100^2$=0.001)

$$WDI''' = \frac{AWC}{(RR + SWS_{au})^2}$$

4. Implement adjustment factor to account for ground water stocks

$$WDI'' = \frac{AWC}{(RR + SWS_{au})^2} \cdot AF_{GWS}$$

5. Implement sensitivity index (SI) to consider vulnerability of population and ecosystems

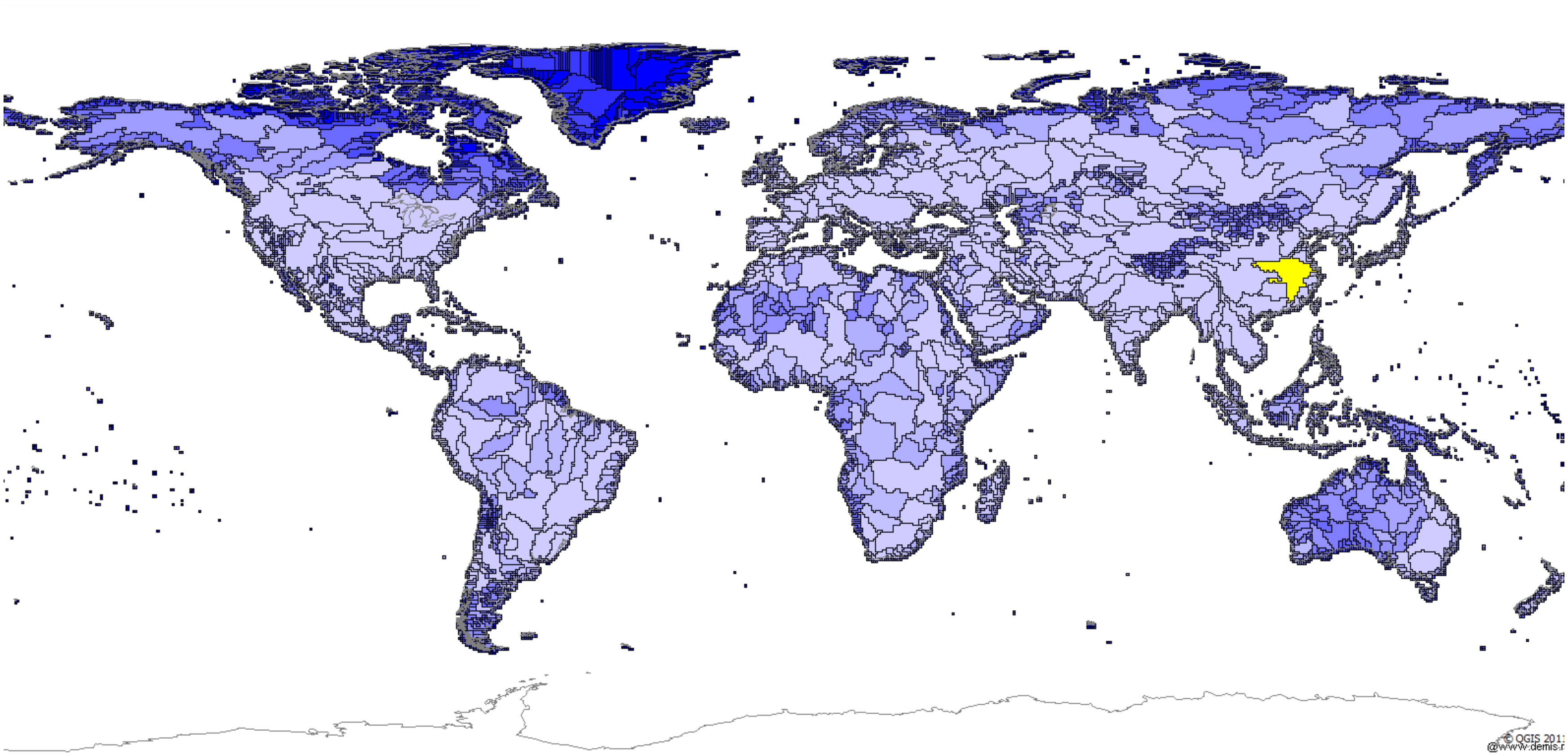
$$WDI' = \frac{AWC}{(RR + SWS_{au})^2} \cdot AF_{GWS} \cdot SI$$

6. Determine values between 0.01 and 1 by means of a logistic function

$$WDI = \frac{1}{1 + e^{-k \cdot WDI'}\left(\frac{1}{0.01} - 1\right)}$$

New water footprint method: impact assessment

- Step 1: AWC and RR $$WDI''''' = \frac{AWC}{RR}$$
  - Data for AWC and RR are derived from WaterGap2.2 for more than 10.000 watersheds



New water footprint method: impact assessment

- Step 2: $WDI'''' = \frac{AWC}{RR + SWS_{au}}$
  - Based on the WaterGAP 2.2 model, effective surface water stocks (SWS_{eff}) are determined for each watershed by:
    - multiplying the area of surface water bodies (A_{SWB}), i.e. lakes and wetlands, with their effective depth (d_{eff})
    - and by adding the volumes of reservoirs ($V_{reservoir}$)

$$SWS_{eff} = \sum_i \left(A_{SWB,i} \cdot d_{eff,i}\right) + V_{reservoir,i}$$

  - The annually usable surface water stocks SWS_{au} are determined as 1% of SWS_{eff}

$$SWS_{au} = \frac{SWS_{eff}}{100}$$

New water footprint method: impact assessment

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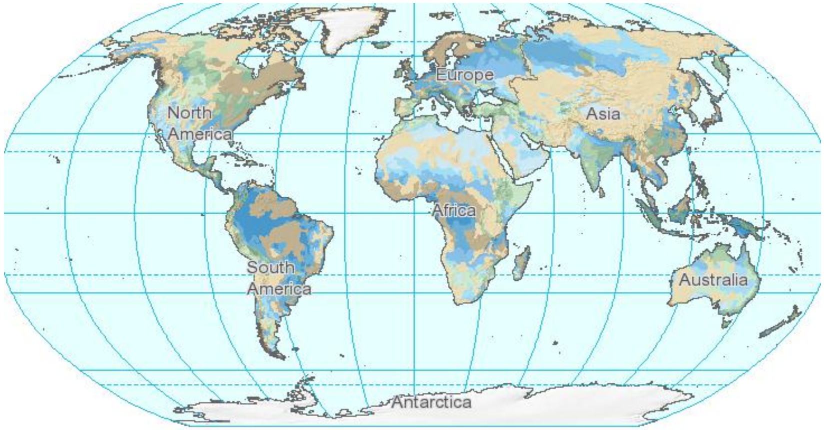
- Step 4: $$WDI'' = \frac{AWC}{(RR + SWS_{au})^2} \cdot AF_{GWS}$$
  - In contrast to surface water stocks, groundwater stocks cannot be quantified - only geological structures and annual recharge are known (WHYMAP)
  - Correction of scarcity by means of groundwater stock adjustment factors (AF_{GWS}):
    - Major groundwater basin, very high recharge (> 300 mm): 0.900
    - Major groundwater basin, high recharge (100 - 300 mm): 0.925
    - Complex hydrogeological structure, very high recharge (> 300 mm): 0.950
    - Complex hydrogeological structure, high recharge (100 - 300 mm): 0.975



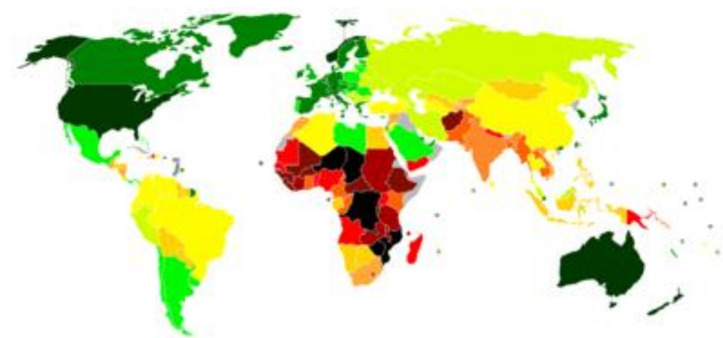
New water footprint method: impact assessment

- Step 5: $$WDI' = \frac{AWC}{(RR + SWS_{au})^2} \cdot AF_{GWS} \cdot SI$$
  - Development of a sensitivity index (SI) to account for vulnerability of human health (SI_{hh}) and ecosystems (SI_{es}) to water stress

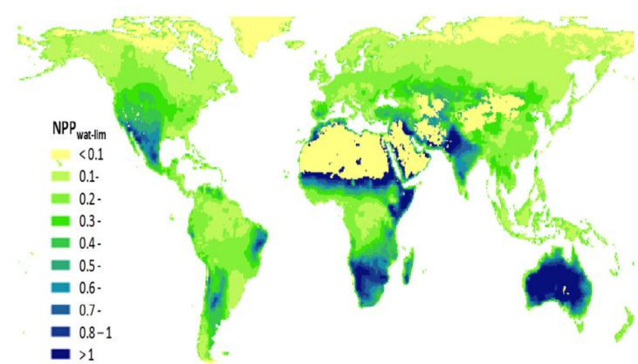
$$SI = SI_{hh} + SIes$$

  - Sensitivity of human health measured by human development index (HDI)

$$SI_{hh} = 1 - HDI$$



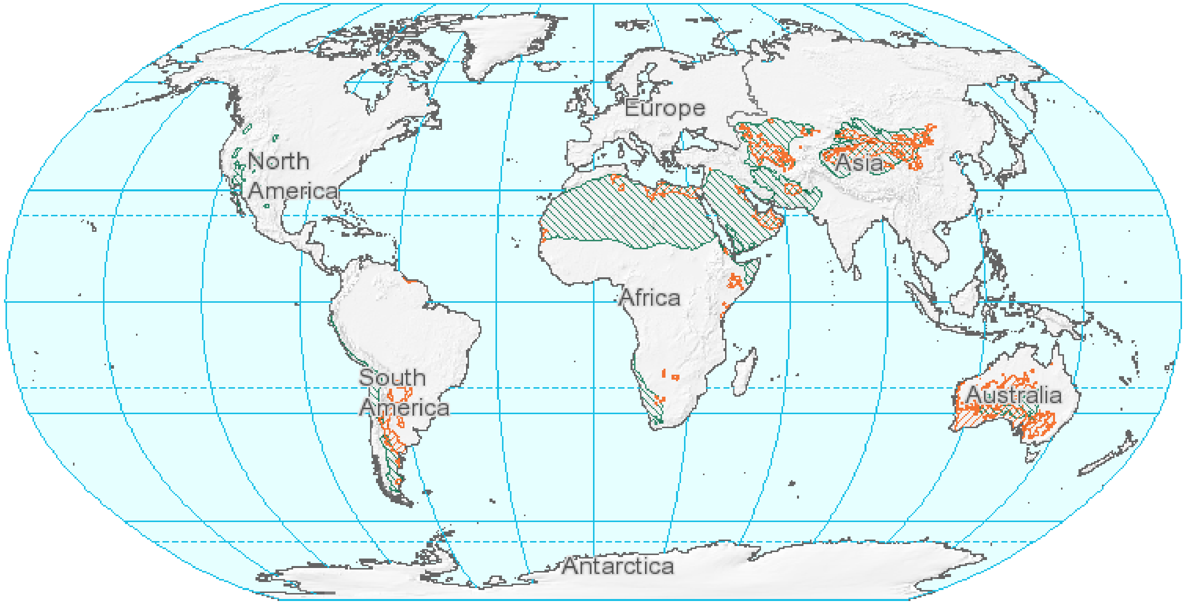
  - Sensitivity of ecosystems is measured by share of net primary production which is limited by water availability ($NPP_{wat\text{-}lim}$) (Pfister et al. 2009)



→ correlation between net primary production and vascular plant species biodiversity was revealed

New water footprint method: impact assessment

- WDI is set to 1 automatically, in:
  - Areas with low rainfall (< 200 mm/a)
  - Areas with saline groundwater (> 5 g/l TDS) and rainfall < 400 mm/a
  - This avoids artifacts that regions are considered not water scarce, simply as there is no consumption due to low population density and absence of agriculture/industry



New water footprint method: results

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- Impact assessment: Characterization factors under refinement

Thanks for your attention!

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