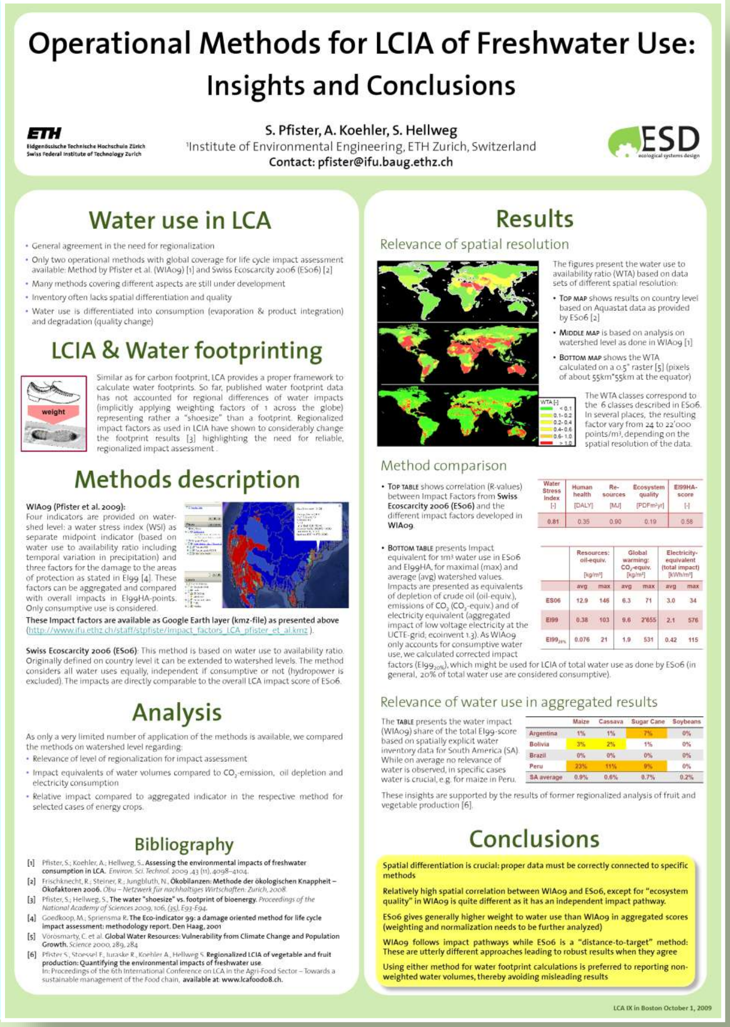
Operational Methods for LCIA of Freshwater Use:

Insights and Conclusions



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2 operational methods available

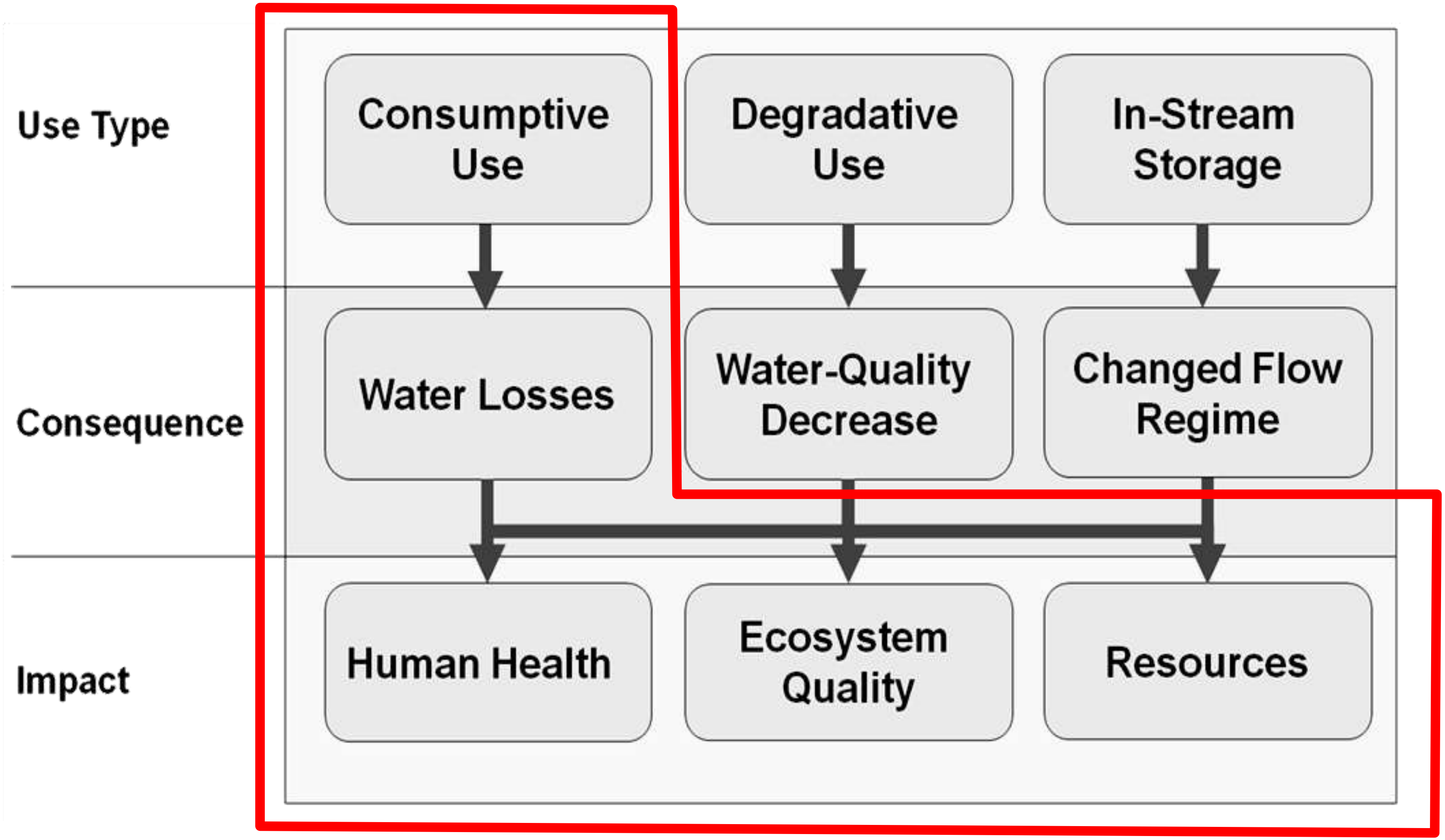
- Ecological scarcity (presented by Rolf)
  - Water use, Distance-to-target

- Our method (Pfister et al. 2009)
  - Water consumption
  - Damage oriented
  - Compatible with Eco-indicator 99:
    - Can be used as add-on to standard LCA

Reference:

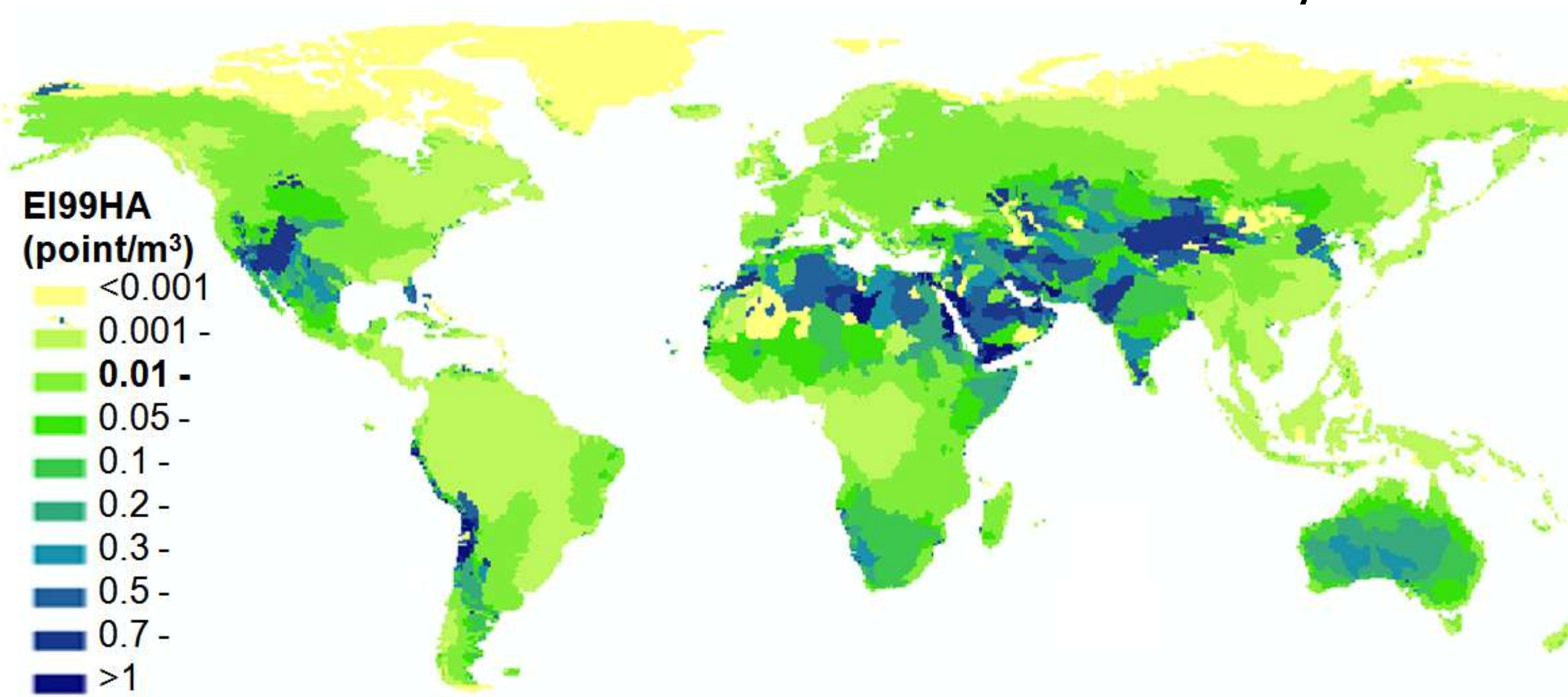
Pfister, S.; Koehler, A.; Hellweg, S. **Assessing the environmental impacts of freshwater consumption in LCA.** *Environ. Sci. Technol.* 2009, 43 (11), 4098–4104.

Impact from water consumption in LCA



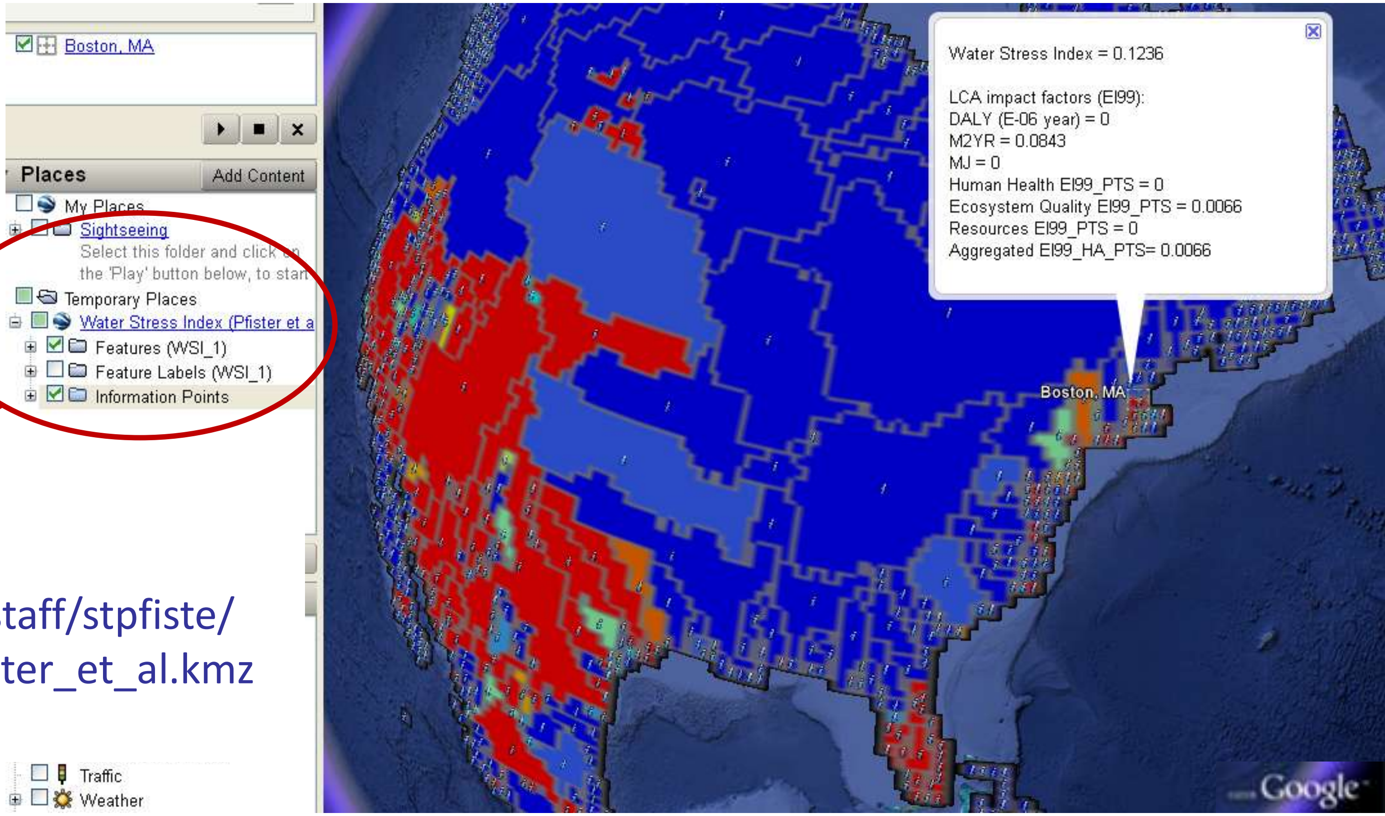
Regionalized damage factors

Published as GIS-file → not so user-friendly



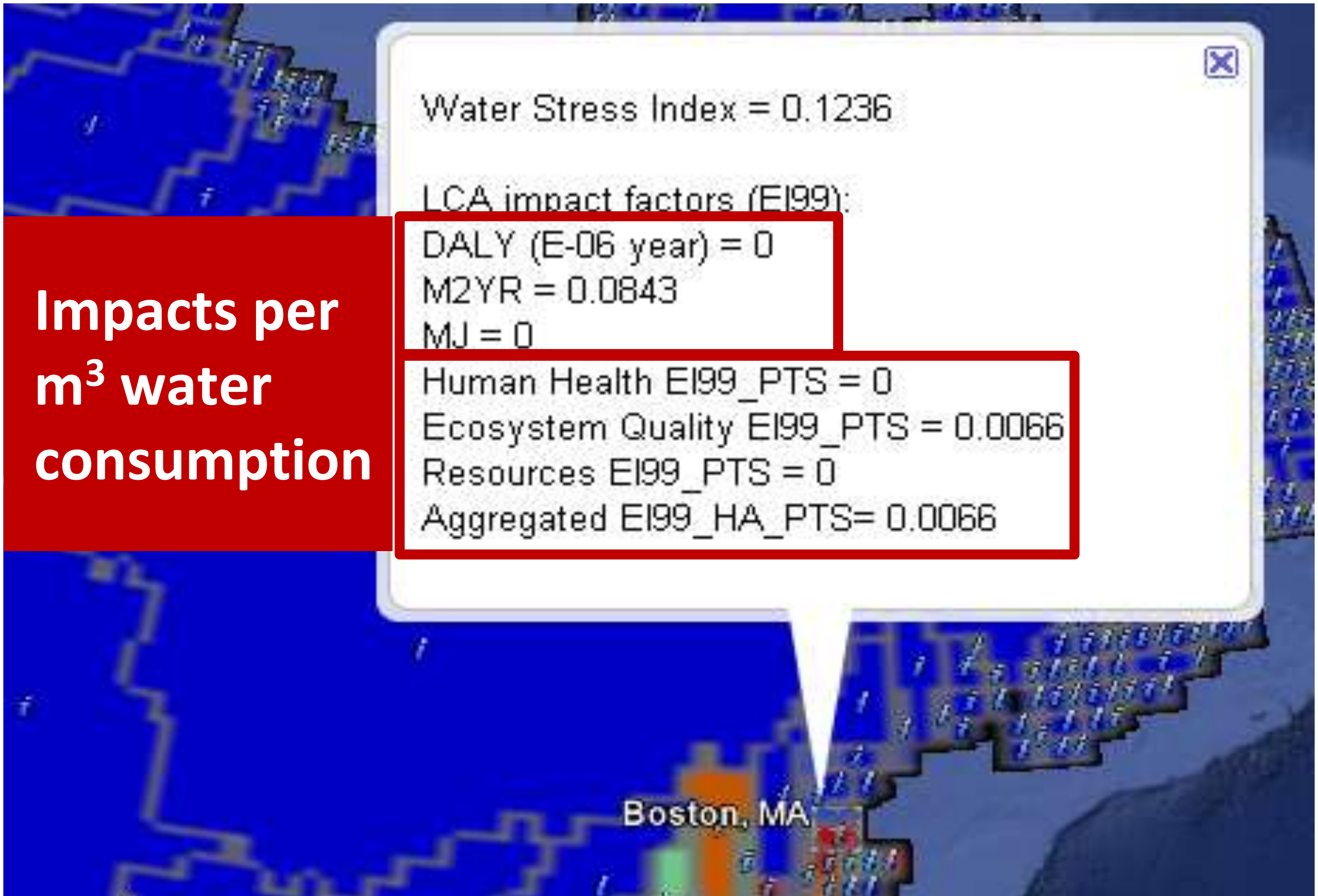
How to use our “add-on”

- Impact factors: view in Google Earth



KMZ-file:
download at:
http://www.ifu.ethz.ch/staff/stpfiste/Impact_factors_LCA_pfister_et_al.kmz

How to use our "add-on"

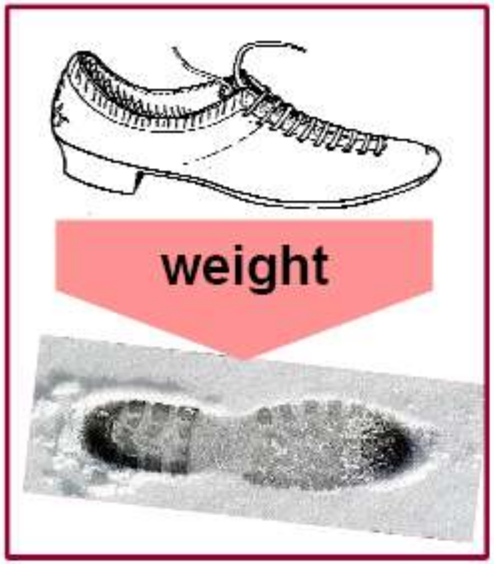


Impacts per m^3 water consumption

Water footprint

- Impact factors should be used for proper water footprinting (as for carbon footprints)

➡ Reporting of water volumes (inventory) is only a "shoesize"



- Agreement on "good practice" required → avoid misleading results

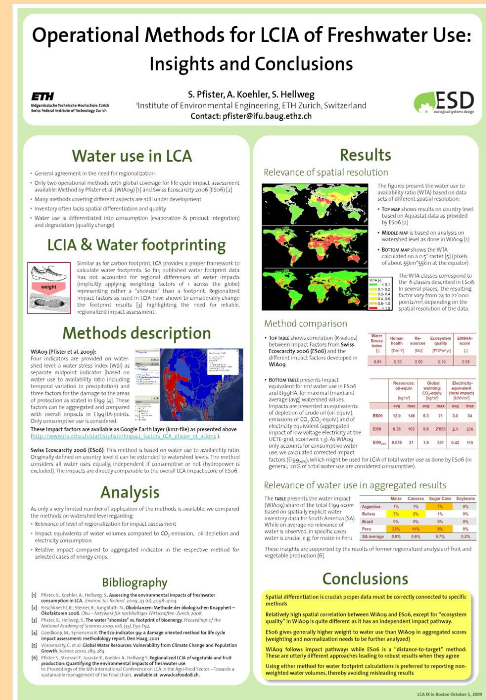
Further results

- Comparison of the methods:
  - Correlation analysis on watershed levels
  - Relevance of water in aggregated impact scores
- Case study of energy crops production
  - Relevance varies a lot in space
- Conclusions
  - Existing methods allow proper inclusion of water use in LCA

Special Invitation

Come to my poster during the lunch break

Provide comments & ask questions for mutual benefit



THANKS FOR YOUR ATTENTION!

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REFERENCE:

Pfister, S.; Koehler, A.; Hellweg, S. **Assessing the environmental impacts of freshwater consumption in LCA.** *Environ. Sci. Technol.* 2009, 43 (11), 4098–4104.

Correlation of the regionalized impact factors

Water Stress Index [-]	Human health [DALY]	Re-sources [MJ]	Ecosystem quality [PDFm^2yr]	EI99HA-score [-]
0.81	0.35	0.90	0.19	0.58

- Relatively high correlation for
  - Water stress index and resources (same basis)
- Low correlation for ecosystem quality

Relevance of water in aggregated impact scores

- Comparison: our method with the ecoscarcity method
  - Significant differences observed
- Case study of energy crops production
  - For “add-on” in EI99
  - Relevance varies a lot in space
- The details will be presented on the poster only

Conclusions

- Many methods under development
- Existing methods allow already inclusion of water use in LCA
- Proper inventory is often lacking
- Regionalization mainly applicable for foreground processes

Operational Methods for LCIA of Freshwater Use: Insights and Conclusions

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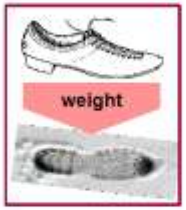
ESD
ecological systems design

Water use in LCA

- General agreement in the need for regionalization
- Only two operational methods with global coverage for life cycle impact assessment available: Method by Pfister et al. (WIA09) [1] and Swiss Ecoscarcity 2006 (ES06) [2]
- Many methods covering different aspects are still under development
- Inventory often lacks spatial differentiation and quality
- Water use is differentiated into consumption (evaporation & product integration) and degradation (quality change)

LCIA & Water footprinting



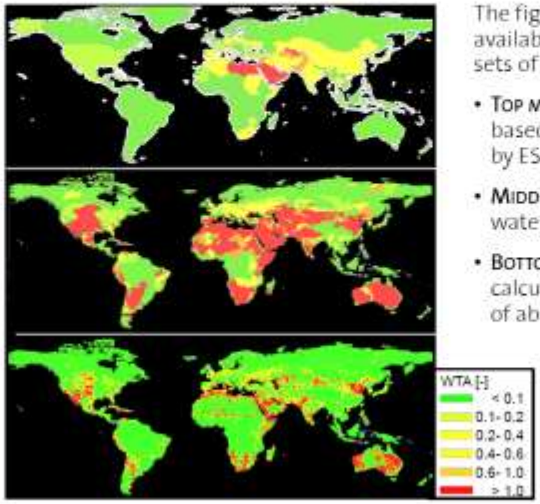
Similar as for carbon footprint, LCA provides a proper framework to calculate water footprints. So far, published water footprint data has not accounted for regional differences of water impacts (implicitly applying weighting factors of 1 across the globe) representing rather a "shoesize" than a footprint. Regionalized impact factors as used in LCIA have shown to considerably change the footprint results [3] highlighting the need for reliable, regionalized impact assessment .

Methods description

WIA09 (Pfister et al. 2009):
Four indicators are provided on watershed level: a water stress index (WSI) as separate midpoint indicator (based on

Results

Relevance of spatial resolution



The figures present the water use to availability ratio (WTA) based on data sets of different spatial resolution:

- **Top map** shows results on country level based on Aquastat data as provided by ES06 [2]
- **Middle map** is based on analysis on watershed level as done in WIA09 [1]
- **Bottom map** shows the WTA calculated on a 0.5° raster [5] (pixels of about 55km*55km at the equator)

The WTA classes correspond to the 6 classes described in ES06. In several places, the resulting factor vary from 24 to 22'000 points/m³, depending on the spatial resolution of the data.

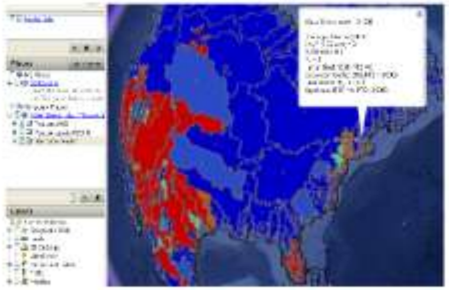
Method comparison

- **Top table** shows correlation (R-values) between Impact Factors from **Swiss Ecoscarcity 2006 (ES06)** and the different impact factors developed in **WIA09**.

Water Stress Index [-]	Human health [DALY]	Re-sources [MJ]	Ecosystem quality [PDFm²yr]	EI99HA-score [-]
0.81	0.35	0.90	0.19	0.58

Methods description

WIA09 (Pfister et al. 2009):
Four indicators are provided on watershed level: a water stress index (WSI) as separate midpoint indicator (based on water use to availability ratio including temporal variation in precipitation) and three factors for the damage to the areas of protection as stated in EI99 [4]. These factors can be aggregated and compared with overall impacts in EI99HA-points. Only consumptive use is considered.



These Impact factors are available as Google Earth layer (kmz-file) as presented above (http://www.ifu.ethz.ch/staff/stpfiste/Impact_factors_LCA_pfister_et_al.kmz).

Swiss Ecoscarcity 2006 (ES06): This method is based on water use to availability ratio. Originally defined on country level it can be extended to watershed levels. The method considers all water uses equally, independent if consumptive or not (hydropower is excluded). The impacts are directly comparable to the overall LCA impact score of ES06.

Analysis

As only a very limited number of application of the methods is available, we compared the methods on watershed level regarding:

- Relevance of level of regionalization for impact assessment
- Impact equivalents of water volumes compared to CO_2-emission, oil depletion and electricity consumption
- Relative impact compared to aggregated indicator in the respective method for selected cases of energy crops.

Bibliography

[1] Pfister, S.; Koehler, A.; Hellweg, S.. **Assessing the environmental impacts of freshwater consumption in LCA.** *Environ. Sci. Technol.* 2009 ,43 (11), 4098–4104.

[2] Frischknecht, R.; Steiner, R.; Jungbluth, N., **Ökobilanzen: Methode der ökologischen Knappheit – Ökofaktoren 2006.** *Öbu – Netzwerk für nachhaltiges Wirtschaften: Zurich, 2008.*

[3] Pfister, S.; Hellweg, S., **The water "shoesize" vs. footprint of bioenergy.** *Proceedings of the National Academy of Sciences 2009, 106, (35), E93-E94.*

[4] Goedkoop, M.; Spriensma R. **The Eco-indicator 99: a damage oriented method for life cycle impact assessment: methodology report. Den Haag, 2001**

[5] Vörösmarty, C. et al. **Global Water Resources: Vulnerability from Climate Change and Population Growth.** *Science* 2000, 289, 284

[6] Pfister S., Stoessel F., Juraske R., Koehler A., Hellweg S. **Regionalized LCIA of vegetable and fruit production: Quantifying the environmental impacts of freshwater use.**
In: Proceedings of the 6th International Conference on LCA in the Agri-Food Sector – Towards a sustainable management of the Food chain, **available at: www.lcafood08.ch.**

Method comparison

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- **Bottom table** presents Impact equivalent for 1m³ water use in ES06 and EI99HA, for maximal (max) and average (avg) watershed values. Impacts are presented as equivalents of depletion of crude oil (oil-equiv.), emissions of CO_2 (CO_2-equiv.) and of electricity equivalent (aggregated impact of low voltage electricity at the UCTE-grid; ecoinvent 1.3). As WIA09 only accounts for consumptive water use, we calculated corrected impact factors ($EI99_{20\%}$), which might be used for LCIA of total water use as done by ES06 (in general, 20% of total water use are considered consumptive).

	Resources: oil-equiv. [kg/m³]		Global warming: CO_2-equiv. [kg/m³]		Electricity-equivalent (total impact) [kWh/m³]	
	avg	max	avg	max	avg	max
ES06	12.9	146	6.3	71	3.0	34
EI99	0.38	103	9.6	2'655	2.1	576
$EI99_{20\%}$	0.076	21	1.9	531	0.42	115

Relevance of water use in aggregated results

The **table** presents the water impact (WIA09) share of the total EI99-score based on spatially explicit water inventory data for South America (SA). While on average no relevance of water is observed, in specific cases water is crucial, e.g. for maize in Peru.

	Maize	Cassava	Sugar Cane	Soybeans
Argentina	1%	1%	7%	0%
Bolivia	3%	2%	1%	0%
Brazil	0%	0%	0%	0%
Peru	23%	11%	9%	0%
SA average	0.9%	0.6%	0.7%	0.2%

These insights are supported by the results of former regionalized analysis of fruit and vegetable production [6].

Conclusions

Spatial differentiation is crucial: proper data must be correctly connected to specific methods

Relatively high spatial correlation between WIA09 and ES06, except for "ecosystem quality" in WIA09 is quite different as it has an independent impact pathway.

ES06 gives generally higher weight to water use than WIA09 in aggregated scores (weighting and normalization needs to be further analyzed)

WIA09 follows impact pathways while ES06 is a "distance-to-target" method: These are utterly different approaches leading to robust results when they agree

Using either method for water footprint calculations is preferred to reporting non-weighted water volumes, thereby avoiding misleading results