Water, water everywhere – Reflections on system boundaries from an LCA perspective

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Joint Graduate School of Energy and Environment

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- Center of Excellence in Energy Technology and Environment established in 1998
- Research-based and Professional-oriented graduate programs in Energy and Environmental Technology & Management
- Strategic Environmental Assessment (SEA) Group's research areas:
  - ❖ LCA of biofuels
  - ❖ LCA of power production
  - ❖ Ecolabelling and Certification
  - ❖ Sustainable development indicators




LIFE CYCLE ASSESSMENT: CURRENT STATUS ON WATER

How has LCA dealt with water?

- Abiotic resource depletion
  - global impact
- Life cycle inventory
  - volume of freshwater used for a product
  - limited information on origin
  - no information on fate
- Life cycle impact assessment
  - currently well-established methods hardly provide assessment schemes and characterisation factors

How is LCA dealing with water?

- Recommendations from the UNEP-SETAC Life Cycle Initiative
  - the assessment method should be *regionalized in reference to the hydrological context*
  - freshwater consumption is a phenomenon that creates impacts because it lowers freshwater levels and also deprives other users in the technosphere and ecosphere
  - a set of *water resource types* with the constraints and limits for its use and supply
  - resource depletion can be considered as a midpoint, while human health and reduction in biodiversity seem to be appropriate endpoints
  - natural resource damage categories may not be considered if the cause–effect chain is modeled up to the human health and ecosystem quality categories
  - impact pathways should be considered that highlight human health damages through the use of lower quality water for domestic purposes and reductions in food production
  - impacts of food-compensation production and those on biodiversity through desiccation and loss of habitat should also be addressed

Freshwater use

- In-stream freshwater use
  - the use of water *in situ* (e.g., navigational transport on a river)
- Off-stream freshwater use
  - the use of water that requires human removal from a natural body of water or groundwater aquifer (e.g., pumping or diversion for municipal, agricultural, or industrial uses)
- Freshwater degradative use
  - The withdrawal and discharge into the same watershed after the quality of the water has been altered
- Freshwater consumptive use
  - the use of freshwater when release into the same watershed does not occur because of evaporation, product integration, or discharge into different watersheds or the sea

Elements of environmental concern

1. Sufficiency of freshwater resources for contemporary human users
   - *Deficiency scenario*: limited capabilities to provide a product or supply a service
     - Midpoint Indicator: cubic meters of freshwater equivalent unavailable for downstream users
       - freshwater scarcity in the area (spatially explicit modeling)
       - quality assessment (distance-to-target or functionality)
     - Endpoint Indicator: Disability Adjusted Life Years (DALY)
       - denial of access to safe drinking water implies increases in sanitation- and water-quality related diseases
       - reduced freshwater availability for irrigation can cause diminished crop yields in agricultural production, and ultimately malnutrition
   - *Compensation scenario*: compensation for the loss of yield of human activities through backup technologies
     - product system boundaries extended to include the environmental burdens generated by the backup technologies chosen
     - Marginal approach could be adopted if the technologies affected by the decrease in freshwater availability were exactly known

Elements of environmental concern

2. Sufficiency of freshwater resources for existing ecosystems
   - decrease in freshwater availability reduces aquatic ecosystem habitats, leads to the desiccation of the land, and thus modifies the occurrence of terrestrial species
   - Midpoint Indicator: cubic meters of freshwater unavailable for ecosystems and the functions they provide
   - appropriate characterization factors which quantify potential losses in biodiversity and ecosystem functions considering *regional ecosystem characteristics*
3. Sustainable freshwater resource base for future generations and the future use of present-day generations
   - further consumptive use higher than freshwater renewability rate in a *specific area* creates freshwater depletion
   - Midpoint Indicator: cubic meters of freshwater equivalent depleted
   - water depletion, the volume of water that 'disappears' from a given watershed for a period of time
   - *time-dependent* distinction of freshwater depletion
   - *watershed level* or *level of individual water bodies* (e.g., fossil aquifers and lakes)

System boundaries

- Geographically specific modeling—regionalization
  - impact assessment scheme depends on local and regional conditions (including water quality, water availability, socio-economic parameters, and allocation between off-stream users)
  - spatially explicit modeling: regionalization
    - Integrated water resource management: *watershed level*
    - Socio-economic: *national level*
    - *Cross the watershed and national levels* by applying geographic information systems
    - Grouping areas among *different water resource profiles* reduces the number of characterization factors to specific archetypes, (e.g. Swiss Ecological Scarcity Method)
- Temporal modeling
  - characterization factors for dry season and wet season

THANK YOU

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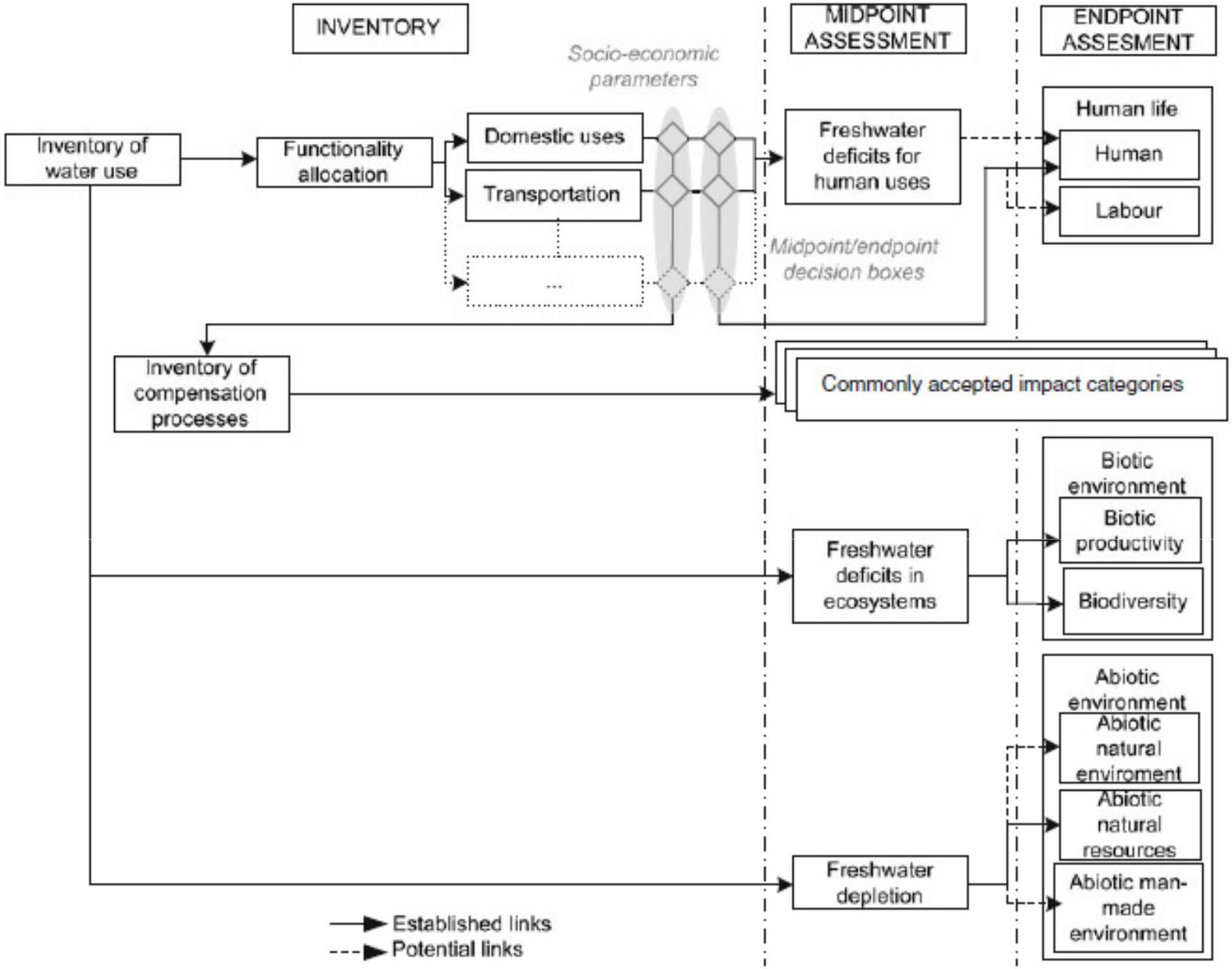

Description of relevant cause–effect chains

Bayart et al. (2009): Int J Life Cycle Assess (2010) 15:439–453

TABLE 1. Inventory Data and Environmental Impacts Per kg Cotton Textile

	global production share	consumptive use (blue water reported in ref *38*) (m^3/kg)	Water deprivation (m^3/kg)	ecosystem quality (PDF·m^2·yr/kg)	human health (10^{-6} DALY/kg)	resources (MJ/kg)	fraction of total damage (Eco-indicator-99) caused by water consumption[a]
Argentina	0.7%	6.11	2.01	2.71	0.206	5.45	12%
Australia	1.4%	3.92	1.42	5.10	0	1.07	14%
Brazil	5.6%	0.61	0.01	0.0188	0.004	0.00946	0%
China	27.2%	2.35	0.93	0.449	0.61	3.97	5%
Egypt	0.8%	10.79	10.15	87.1	18.36	53.9	77%
Greece	1.8%	4.89	3.20	0.806	0.126	7.41	9%
India	19.9%	5.73	5.16	2.12	11.93	15.0	24%
Mali	0.6%	4.07	0.99	3.29	5.681	0	14%
Mexico	0.6%	4.52	3.12	2.62	0.695	7.07	13%
Pakistan	8.5%	9.88	9.17	15.7	20.68	41.6	52%
Syria	0.9%	8.41	8.00	8.23	7.752	39.1	41%
Turkey	3.3%	7.34	5.40	3.65	3.741	13.6	21%
Turkmenistan	1.1%	14.12	13.66	13.6	12.27	65.3	53%
United States	16.4%	1.90	0.75	0.465	0.003	2.80	4%
Uzbekistan	4.4%	11.14	10.58	10.8	11.71	39.6	45%
average	**93.4%**	**8.54**	**3.48**	**3.88**	**5.71**	**12.8**	**17%**
$US_{CROPWAT}$[b]	*16.4%*	*8.91*	*3.72*	*4.91*	*0.0274*	*16.7*	*23%*
$US_{estimate}$[b]	*16.4%*	*3.27*	*2.48*	*3.61*	*0.0237*	*13.6*	*19%*

[a] Total damage includes state-of-the-art LCA results for final cotton textile at plant: 2.58 points/kg, without the damages of water consumption (*3, 18*). [b] For the United States, we derived national average impacts of water consumption from data on watershed-level, applying two approaches ($US_{CROPWAT}$ and $US_{estimate}$).

Pfister et al. (2009): Environ. Sci. Technol. 2009, 43, 4098–4104

Swiss Ecological Scarcity Method: The New Version 2006

	Water pressure range
Low	<0.1
Moderate	0.1 to <0.2
Medium	0.2 to <0.4
High	0.4 to <0.6
Very high	0.6 to <1.0
Extreme	≥1

Frischknecht et al. (2008): http://www.esu-ervices.ch/cms/fileadmin/download/Frischknecht-2006-EcologicalScarcity-Paper.pdf