Integrative Sustainability Analysis of Industrial Sugar Production
Swiss Beet Sugar compared to Brazilian Cane Sugar

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   » Background
   » Goal and scope

2 Methods
   » Concept for integrative sustainability assessment
   » Assessment modules

3 Results & Interpretation
   » Module results

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   » Sustainability assessments & decision-making
Sugar production in Switzerland
Conflicting priorities

» Multi-functional goals of Swiss agricultural production
  » Sustainability/Ecology/Animal wellbeing vs. Decentralized settlement/Landscape conservation vs. Supply security vs. Market orientation/Profitability

» Since 1990 priority shift from supply security to market orientation and profitability due to market liberalization and trade globalization

» Disadvantageous results for Swiss sugar in study about energy-related product declarations
  » Reaction of national media
    » “Switzerland supports environmentally disadvantageous, more expensive domestic sugar production through significant ‘subsidies’ and at the same time prevents essential incomes for farmers in developing countries (counteracts development aid)”

→ Huge public/political pressure on Swiss sugar production
Goal & scope of the study

» Goals
  » Comparison of industrial production of 1kg of white
    » Beet sugar in Switzerland with
    » Cane sugar in Brazil
  from a sustainability perspective (going beyond the assessment of greenhouse gas emissions)
  » Ecological, economic and social (triple bottom line approach)
  accounting for sensitivities to methodological assumptions
  » Allocation and life cycle impact assessment methods

» Time reference
  » Focus on current production conditions in both countries
  » Indications on foreseeable changes

» System boundaries (cradle-to-gate)
  » From resources to delivery to gate of central storehouse
Case description

» The Swiss case

The Brazilian case
Case description
Industrial sugar production

» The Swiss case

» The Brazilian case

Brazil, Center South
» ± 89% sugar cane
» ± 86% sugar
» ± 91% bioethanol

Harvest
» 50% mechanic
» 69% pre-harvest field burning

(Macedo et al., 2008; UNICA, 2010)
Concept of sustainability assessment
The triple bottom line approach

Module 1: Environmental performance → Attributional Life Cycle Assessment (A-LCA)

Module 2: Economic performance → Life Cycle Costing (LCC)

Module 3: Social performance → UNEP-Guidelines on Social LCA of Products
Environmental life cycle assessment
Goal and scope definition

» Attributional Life Cycle Assessment (A-LCA)

» Functional unit:
  » 1kg loose, industrial white sugar at the gate of Swiss storehouse

» By-products:
  » CH: sand/stones, beet pulp, potash fertilizer, district heat, molasses
  » BR: Green electricity, bioethanol

» Cradle-to-gate perspective
  » From raw material extraction to gate of central storehouse (i.e. including distribution)

» Allocation and impact assessment methods

<table>
<thead>
<tr>
<th>Allocation &amp; LCIA</th>
<th>Ecological scarcity 2006</th>
<th>GWP 100</th>
<th>CED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substitution</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Economic</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Environmental life cycle assessment
Swiss agricultural production in LCA

System boundary

Resources
- Infrastructure:
  - Buildings
  - Machinery

Field production
- Field work:
  - Soil cultivation
  - Fertilization
  - Sowing/Planting
  - Mechanical treatment
  - Harvest
  - Transport to farm

Direct and indirect emissions

Infrastructure
- Production goods:
  - Seed
  - Mineral fertilizers
  - Farmyard manure
  - Pesticides
  - Energy carriers
  - Irrigation water

Production goods:
- Storing farmyard manure

Product treatment:
- Grain drying
- Potato grading

Products
- Sugar beet
  - Fodder beet
  - Silage maize
  - Carrots
  - Beet root
  - Cabbage
- Wheat
- Barley
- Rye
- Grain maize
- Oat
- Fava bean
- Protein peas
- Sunflower
- Rape seed
- Potatoes
- Co-product:
  - Straw

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Economic performance assessment
Full cost accounting

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross value added</td>
<td>= Production value – acquisition value + subsidies (share of goods production)</td>
</tr>
<tr>
<td>Net profit ratio</td>
<td>= Pre-tax operational result / sales (profitability)</td>
</tr>
<tr>
<td>Production costs</td>
<td>= Material- + manufacturing costs incl. wages (factor input in production)</td>
</tr>
<tr>
<td>Revenue from taxes</td>
<td>= Tax rate * pre-tax operational results (Contribution to public activities)</td>
</tr>
<tr>
<td>GDP ratio</td>
<td>= % of branch to GDP (Branch contribution to nation production of goods)</td>
</tr>
<tr>
<td>Workplaces</td>
<td>= # employees (Contribution to national employment)</td>
</tr>
</tbody>
</table>
### Assessment of societal impacts
Guidelines for social LCA of products (UNEP, 2010)

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Criteria</th>
<th>Indicators</th>
<th>Data</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
<td>No. of Criteria: 9 (e.g. child labor)</td>
<td>...</td>
<td>mostly quantitative (e.g. ILO&lt;sup&gt;1&lt;/sup&gt;)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local community</td>
<td>No. of Criteria: 5 (e.g. respect of indigenous rights)</td>
<td>...</td>
<td>qualitative (e.g. AI&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td></td>
<td>Society</td>
<td>No. of Criteria: 3 (e.g. corruption)</td>
<td>...</td>
<td>mostly qualitative (e.g. TI)</td>
</tr>
<tr>
<td></td>
<td>Consumer</td>
<td>No. of Criteria: 2 (e.g. transparency)</td>
<td>...</td>
<td>qualitative (e.g. webpages)</td>
</tr>
<tr>
<td></td>
<td>Supplier</td>
<td>No. of Criteria: 2 (e.g. fair competition)</td>
<td>...</td>
<td>qualitative (e.g. Häberli, 2008)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>21 Criteria</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

1 ILO = International Labor Organisation; 2 AI = Amnesty International; 3 TI = Transparency International

**Assessment Concept**

0 SIP: positive, exemplary conditions
1 SIP: average, problematic conditions
2 SIP: negative, unacceptable conditions

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Assessment & decision-making
### LCA results (total supply chain)

Ecological scarcity 2006 and allocation by substitution

#### Switzerland

- **Gross total (no co-products):**
  - Farmyard manure, Mineral fertilizers, Pesticides: ~85%
  - Field emissions to air, soil, water
- **Credits (co-products):**
  - Beet pulp
  - Melasse
  - Others (Stone/Sand, potash fertilizer, district heat)
- **Net total (incl. co-products):**

#### Brazil

- **Gross total (no co-products):**
  - Mineral fertilizers, Pesticides: ~55%
  - Field burning
- **Credits (co-products):**
  - Bioethanol
  - Green electricity
- **Net total (incl. co-products):**

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**95% confidence interval**

**Environmental impact points (EIP)**

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**References**

- ETH
- Swiss Federal Institute of Technology Zurich

**NSSI**

Natural and Social Sciences Interface
LCA results (total supply chain)
Ecological scarcity 2006 and allocation sensitivity

Significant differences in co-product profiles of sugar factories:
→ CH: environmentally intensive, cheap
→ BR: environmentally extensive, expensive
LCA results (agricultural cultivation)
Different assessment perspectives

CED (non-renewables)

CH beet cultivat.

BR cane cultivat.

Global Warming Potential 100a

CH beet cultivat.

BR cane cultivat.

Ecological scarcity 2006

CH beet cultivat.

BR cane cultivat.

- Green manure (on farm)
- Mineral fertilizers (cradle-to-farm)
- Pesticides (cradle-to-farm)
- Field work etc. (on farm)
- Field emissions (on farm)
- Others

Degree of mechanization

N2O, NH3, CO2 (i.a. fy. manure)

N2O, NH3, CO2, CH4 (i.a. field burning)

Assessment concept

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%
## Life cycle costing (LCC)

### Overview of all results

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Reference</th>
<th>Agricultural prod.</th>
<th>Sugar production</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CH</td>
<td>BR</td>
<td>CH</td>
</tr>
<tr>
<td>Gross value added</td>
<td>Total (MCHF)</td>
<td>163.8</td>
<td>1'782.3</td>
<td>82.5</td>
</tr>
<tr>
<td>1kg (CHF)</td>
<td>–</td>
<td>0.66</td>
<td>0.06</td>
<td>0.30</td>
</tr>
<tr>
<td>Net profit ratio</td>
<td>–</td>
<td>0.38</td>
<td>0.14</td>
<td>0.03</td>
</tr>
<tr>
<td>Without DP¹</td>
<td>–</td>
<td>0.02</td>
<td>–</td>
<td>0.03</td>
</tr>
<tr>
<td>Without DP + CC²</td>
<td>–</td>
<td>0.25</td>
<td>–</td>
<td>0.03</td>
</tr>
<tr>
<td>Production costs</td>
<td>1kg (CHF)</td>
<td>0.44</td>
<td>0.12</td>
<td>0.85³</td>
</tr>
<tr>
<td>Revenue form taxes</td>
<td>Total (MCHF)</td>
<td>0.35</td>
<td>723.0</td>
<td>0.67</td>
</tr>
<tr>
<td>GDP ratio</td>
<td>Total (%)</td>
<td>0.03</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Workplaces</td>
<td>Total (in 10³)</td>
<td>2.72</td>
<td>231.2</td>
<td>0.27</td>
</tr>
<tr>
<td>Total (%)</td>
<td>–</td>
<td>0.06</td>
<td>0.23</td>
<td>0.01</td>
</tr>
</tbody>
</table>

¹ DP = Direct payment, ² CC = Cultivation contribution; ³ incl. acquisition costs for sugar beets and cane

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### Social LCA results

Illustrative extraction from “Workers” and “Local community”

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Indicator</th>
<th>Switzerland</th>
<th>Brazil</th>
<th>SIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child labor</td>
<td>% employees &lt; 15 years</td>
<td>0%</td>
<td>~10%</td>
<td>0/2</td>
</tr>
<tr>
<td>Fair salary</td>
<td>ø wages (AP², FI³)</td>
<td>4’413</td>
<td>5’828</td>
<td>0.5/0.5</td>
</tr>
<tr>
<td>Work hours</td>
<td># Work hours</td>
<td>38</td>
<td>42.2</td>
<td>0/1</td>
</tr>
<tr>
<td>Forced labor</td>
<td>Share of employment</td>
<td>0%</td>
<td>~3%</td>
<td>0/1</td>
</tr>
<tr>
<td>Migration and delocalization</td>
<td>Qualitative</td>
<td>inexistent</td>
<td>prevalent (land expansion)</td>
<td>0/2</td>
</tr>
<tr>
<td>Respect of indigenous rights</td>
<td>Qualitative</td>
<td>Traditions preserved</td>
<td>Land acquisition</td>
<td>0/2</td>
</tr>
<tr>
<td>Safe and healthy living conditions</td>
<td>Qualitative</td>
<td>Very high standards</td>
<td>Toxic emissions (field burning, pesticide spreading)</td>
<td>0/2</td>
</tr>
</tbody>
</table>

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1 AP = Agricultural production; ² FI = Food industry; ³ SIGI = Social Institution & Gender Index OECD

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From an integrative sustainability perspective, the Swiss beet sugar performs rather better than imported cane sugar from Brazil, Center South.

Counting away the considerable governmental financial support in sugar beet cultivation, Swiss beet sugar economically performs clearly worse.

Identified trade-offs between sustainability dimensions discloses that the final prioritization of one product over another strongly depends on the weightings of agricultural goal dimensions (→ societal preference discourse).

The selected three-pillar based assessment approach delivers an integrative perspective on sugar supply chains and is much more insightful than an isolated greenhouse gas balance (→ prevention of problem shifting).
Conclusions made before are restricted to the current situation in the respective countries

In contrast to Switzerland (and Europe?) in Brazil substantial optimization potentials are unexhausted in all three sustainability dimensions

<table>
<thead>
<tr>
<th>What</th>
<th>Sustainability effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ban of field burning until 2018</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>Improvement of conditions of field workers</td>
<td>✓✗✗ ✓✓✓</td>
</tr>
<tr>
<td>Improved regulation of area expansion</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>Farming efficiency (varieties, precision farming)</td>
<td>✓✓✓ ✓✓✓ ✓✓✓</td>
</tr>
<tr>
<td>Factory improvements:</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>Optimization of energy recovery from bagasse</td>
<td>✓✓✓ ✓✓✓ ✓✓✓</td>
</tr>
<tr>
<td>Reduction of air emissions</td>
<td>✓✓✓</td>
</tr>
</tbody>
</table>
Assessments & decision-making
It’s all about the adequate perspective

A-LCA under the “ceteris paribus” assumption is adequate for product declarations & marketing, product development & improvement (Frischknecht & Stucki, 2010)

- However, be aware of data uncertainties and methodological sensitivities, but also methodological shortcomings, e.g.
  - Long-term cultivation impacts on soil quality, fertility and biodiversity accurately accounting for sophisticated Swiss crop rotation and Brazilian monoculture

To inform strategic decisions on the future of e.g. Swiss sugar production, the insights should be enhanced by a C-LCA that considers structural effects related to the decision (“mutatis mutandis”), e.g. indirect land-use changes in Brazil due to area expansion

- e.g. “What are the net environmental or sustainability effects of abandoning Swiss domestic sugar production and instead importing the sugar from exporting countries?”
Selected references...


