Life Cycle Assessment of Dietary Patterns

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What is Life Cycle Assessment?

an environmental accounting tool...

the “compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO 14040)

“cradle to grave” of a product or service
Inputs and Outputs in LCA
Things to know about LCA

- Relative assessment method, based on “functional unit”
  - “allows a fair comparison of different systems providing the same function”
- ISO standards offer guidelines to establish consistency, but no single method for conducting LCA: methodological choices can effect results
- Tends to be data intensive
- Aims to assess the environmental significance (impacts) of inputs & outputs
  - **Typical impact categories:** Energy use, global warming potential, eutrophication, acidification, tropospheric ozone, human toxicity
  - **Others important to food/ag:** land use, water use, biodiversity, eco-toxicity
Uses of LCA

- Identify hot spots
- Identify and evaluate unintended consequences
- Identify and avoid burden shifting: to other life cycle stages, other environmental impacts or other geographic regions
- Compare products and scenarios
- Benchmarking, product footprints, Eco-labels, Environmental Product Declarations (EPDs)
- Inform public policy
- Decision-making tool, *not* decision maker!
Example LCA results: carbon footprint of fluid milk – average of US production

- Carbon dioxide, fossil
- Nitrous oxide
- Methane, biogenic
- Methane, fossil
- Other

kg CO₂e / kg milk consumed

feed production, milk production, processing, packaging, transport/distribution, retail, consumer
Example LCA results: carbon footprint of fluid milk – average of US production

Food losses are often significant. Perspective matters...
Strong growth in food related LCA

Journal articles with topic = food and “life cycle assessment”

(web of Science search, January, 2013)
Example: comparison of LC carbon footprint of different foods

<table>
<thead>
<tr>
<th></th>
<th>Per as-sold weight</th>
<th>Per g protein</th>
<th>Per kcal food energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg CO₂e / kg</td>
<td>kg CO₂e / g protein</td>
<td>kg CO₂e / kcal food energy</td>
</tr>
<tr>
<td>ground beef</td>
<td>29.29</td>
<td>0.120</td>
<td>0.0127</td>
</tr>
<tr>
<td>ground lamb</td>
<td>25.67</td>
<td>0.105</td>
<td>0.0091</td>
</tr>
<tr>
<td>cheese</td>
<td>8.60</td>
<td>0.035</td>
<td>0.0021</td>
</tr>
<tr>
<td>ground pork</td>
<td>8.20</td>
<td>0.032</td>
<td>0.0028</td>
</tr>
<tr>
<td>ground chicken</td>
<td>4.75</td>
<td>0.018</td>
<td>0.0020</td>
</tr>
<tr>
<td>salmon</td>
<td>3.27</td>
<td>0.015</td>
<td>0.0022</td>
</tr>
<tr>
<td>egg</td>
<td>3.00</td>
<td>0.024</td>
<td>0.0021</td>
</tr>
<tr>
<td>tuna</td>
<td>2.60</td>
<td>0.010</td>
<td>0.0022</td>
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<tr>
<td>brown rice</td>
<td>1.20</td>
<td>0.014</td>
<td>0.0003</td>
</tr>
<tr>
<td>skim milk</td>
<td>1.10</td>
<td>0.032</td>
<td>0.0032</td>
</tr>
<tr>
<td>whole milk</td>
<td>1.10</td>
<td>0.035</td>
<td>0.0018</td>
</tr>
<tr>
<td>dry beans</td>
<td>1.00</td>
<td>0.004</td>
<td>0.0003</td>
</tr>
<tr>
<td>strawberries</td>
<td>0.38</td>
<td>0.057</td>
<td>0.0012</td>
</tr>
<tr>
<td>broccoli</td>
<td>0.37</td>
<td>0.013</td>
<td>0.0011</td>
</tr>
<tr>
<td>orange</td>
<td>0.33</td>
<td>0.035</td>
<td>0.0007</td>
</tr>
<tr>
<td>tomatoes, field production</td>
<td>0.33</td>
<td>0.037</td>
<td>0.0018</td>
</tr>
<tr>
<td>tomatoes, <em>hothouse production</em></td>
<td>5.30</td>
<td>0.604</td>
<td>0.0296</td>
</tr>
<tr>
<td>apple</td>
<td>0.28</td>
<td>0.109</td>
<td>0.0005</td>
</tr>
<tr>
<td>potato</td>
<td>0.20</td>
<td>0.008</td>
<td>0.0002</td>
</tr>
<tr>
<td>lettuce</td>
<td>0.20</td>
<td>0.022</td>
<td>0.0014</td>
</tr>
<tr>
<td>winter squash</td>
<td>0.09</td>
<td>0.010</td>
<td>0.0002</td>
</tr>
<tr>
<td>cucumbers, field production</td>
<td>0.08</td>
<td>0.014</td>
<td>0.0007</td>
</tr>
<tr>
<td>cucumber, <em>hothouse production</em></td>
<td>1.68</td>
<td>0.909</td>
<td>0.0454</td>
</tr>
</tbody>
</table>

Footnote: Life cycle impact data originally compiled by Gonzalez et al, *Food Policy* 2011, 36, 562-570. Nutritional data from USDA.
Food consumption perspective

- Because of differences in environmental impact between foods, diet choices matter.
- Comparing dietary patterns gives a more complete understanding of dietary choices.

Defined diet

Food 1
Food 2
Food 3
...
Food n

Environmental impact DB

Environmental indicators

USDA National Nutrient DB

Nutritional indicators
Literature review of diet-level LCA

- We have identified 32 studies in the English-language literature that use an LCA approach to evaluate food consumption patterns (meals or diets)
  - 80% are based on process LCAs of individual food items, aggregated into consumption patterns (“bottom up” approach)
  - Others use Economic Input-Output LCA (or hybrid): “top down” approach linking EIO tables with sector-level resource use and environmental emissions
  - Nearly half consider only GHGE impacts
  - Only 40% include use (consumption) phase: refrigeration, cooking, transport from retail to home
  - Vast majority from EU countries; only one US study
  - Only ~ half attempt to equalize compared diets on a nutritional basis
- Broad trends
  - Environmental impacts of food LC typically dominated by agricultural production
  - Animal-based foods have greater impact than plant-based foods across all categories (exceptions: hothouse produced or air shipped fruits/veggies)
  - Shifts from current average European diets to dietary recommendations can decrease GHGE up to 10%
A few examples...

- GHGE of self-selected diets of French adults
  (Vieux et al., *Am J Clin Nutr* 2013; 97: 569-583)
  - Evaluated individual diets from cross-sectional dietary survey (n=1918 adults)
  - Assigned GHGE values to 391 widely consumed foods to represent the 1314 foods identified in survey
  - Defined nutritional quality indicators:
    - Mean adequacy ratio ....above population median
    - Mean excess ratio ....below population median
    - Energy density ....below population median
  - Concluded that high nutritional quality diets were associated with slightly higher GHGEs

- Linear programming to minimize GHGE while meeting UK dietary requirements
  (Macdiarmid et al., *Am J Clin Nutr* 2012; 96: 632-9)
  - Linked nutrient composition and GHGE for 82 food groups.
  - Used linear programming to meet dietary requirements while minimizing GHGE.
  - 90% reduction from 1990 UK baseline with a diet containing only 7 foods in unrealistic quantities.
  - Adding “acceptability constraints” gave more realistic diet with 52 foods; 36% reduction in GHGE
A few examples...

  - Hybrid LCA: EIO complemented with classical LCA
  - diets normalized to 2000 kcal person\(^{-1}\) day\(^{-1}\)
    - mean 2006 intake
    - D-A-CH (official recommendations of German Nutrition Society)
    - UGB (alt. recommendations by Federation for Independent Health consultation)
    - Ovo-lacto vegetarian (USDA)
    - Vegan (USDA)

<table>
<thead>
<tr>
<th></th>
<th>change from 2006 mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D-A-CH</td>
</tr>
<tr>
<td>GHGE</td>
<td>-11%</td>
</tr>
<tr>
<td>NH(_3) emissions</td>
<td>-22%</td>
</tr>
<tr>
<td>land use</td>
<td>-15%</td>
</tr>
<tr>
<td>blue water use</td>
<td>-26%</td>
</tr>
<tr>
<td>phosphorus use</td>
<td>-12%</td>
</tr>
<tr>
<td>primary energy use</td>
<td>-7%</td>
</tr>
</tbody>
</table>
Challenges and Future Work

• Balancing environmental impact and nutritional health: comprehensive nutritional basis for functional unit
  – Diet quality indices? e.g., Healthy Eating Index
  – Nutrient profiling schemes? e.g., Nutrient Rich Foods index, Overall Nutritional Quality Index (NuVal)
  – Other approaches?

• Data availability & quality
  – Ag production, but also food processing
    • USDA LCA Digital Commons: www.lcacommons.gov
  – Region specific
  – Expanded environmental impact categories
  – Build consistent dataset of food LCA results

• Geo-spatial specificity
  – Water use impact, land use impact, eutrophication

• Valuation and weighting of environmental impact categories
Closing Remarks

• Environmental sustainability adds further dimensions to dietary guidelines: not just what we eat but where and how it was produced, supply chain impacts, wastage, etc.
• “Environmental folklore” about what’s good and bad complicates consumer decisions
• Life Cycle Assessment provides a strong analytical framework for making sound recommendations
• Ongoing data and method developments are necessary
• A quantitative link to comprehensive nutritional quality is needed.

http://www.thelocalist.net/
Thank You

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