Dynamical resource nexus assessments: from accounting to sustainability approaches

Gloria Salmoral, Xiaoyu Yan
University of Exeter, United Kingdom (g.salmoral@exeter.ac.uk)
Overview

- Potential merits and limitations that life cycle assessment (LCA) has for assessing critical water-energy-food links.
- A case study with key water-energy consumption linkages for food purchase in a catchment in South West England.

✓ The relevance of geographical and temporal contextualization of processes
✓ The dependence on embedded water and energy
✓ The weight that transport has on sustainability energy assessments
The Tamar catchment covers a total land area of 1,820 km² in the South West of England. The farmed land (including pastures), totals 136,000 ha (75% of the catchment area).
The Tamar catchment

Agricultural production and losses

Crops distribution and weight per main land use category: EDINA Agricultural Census (2011)
Land use map: 2012 Corine Land Cover
Crop yields: UK Farm Business Survey
Allocation factors for human consumption: FAO (2011) Global food waste and food losses
Multi-step evaluation of food purchase

Click on each box for more details

Food purchase at home

Consumption of water and energy at different food process steps

Resources within and outside the catchment

Consumption of water and energy for overseas transport
Multi-step evaluation of food purchase

Click on each box for more details

- Inside red squares selected food categories in the study are shown
- 12 food products are selected from Agri-Footprint and Ecoinvent 3 databases (click on the graph for more info)
- Selected products comprise 60% of food purchase at home in terms of kcal

Food purchase in South West England

Calculations based on Living Costs and Food Survey - Office for National Statistics
Multi-step evaluation of food purchase

Click on each box for more details

• Selected products comprise 60% of food purchase kcal at home

<table>
<thead>
<tr>
<th>Food category</th>
<th>Food product selected</th>
<th>Food product selected in Simapro</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Milk and milk products excluding cheese</td>
<td>Skimmed milk</td>
<td>Standardized milk, skinned, from processing, at plant/NL Economic</td>
</tr>
<tr>
<td>2 Cheese</td>
<td>Cheese</td>
<td>Cheese, from cheese production, at plant/NL Economic</td>
</tr>
<tr>
<td>3 Carcase meat</td>
<td>Beef meat</td>
<td>Beef meat, fresh, from beef cattle, at slaughterhouse, PEF compliant/IE Economic/Economic</td>
</tr>
<tr>
<td>4 Non-carcase meat and meat products</td>
<td>Chicken meat</td>
<td>Chicken meat, fresh, at slaughterhouse/NL Economic</td>
</tr>
<tr>
<td>5 Eggs</td>
<td>Eggs</td>
<td>Consumption eggs, laying hens &gt;17 weeks, at farm/NL Economic</td>
</tr>
<tr>
<td>6 Fats</td>
<td>Butter</td>
<td>Butter, from cow milk [GLO]</td>
</tr>
<tr>
<td>7 Sugar and preserves</td>
<td>Sugar</td>
<td>Sugar, from sugar cane, from sugar production, at plant/BR Economic</td>
</tr>
<tr>
<td>8 Fresh and processed potatoes</td>
<td>Potatoes</td>
<td>Starch potato, at farm/DK Economic</td>
</tr>
<tr>
<td>9 Fresh and processed vegetables</td>
<td>Carrots</td>
<td>Carrot, at farm/NL Economic</td>
</tr>
<tr>
<td>10 Fresh and processed fruit</td>
<td>Apple</td>
<td>Apple [GLO]</td>
</tr>
<tr>
<td>11 Flour</td>
<td>Wheat flour</td>
<td>Wheat germ, from dry milling, at plant/NL Economic</td>
</tr>
<tr>
<td>12 Other cereals and cereal products</td>
<td>Rice</td>
<td>Rice, late, continuous flooding, at farm/CN Economic</td>
</tr>
</tbody>
</table>
Multi-step evaluation of food purchase

Click on each box for more details

- Agri-Footprint and Ecoinvent 3 databases are used
- Raw materials during the life cycle inventory, including freshwater and energy, are summarized and extracted at different process steps
- See an example of processes involved in a life cycle inventory for two different types of resources

Consumption of water and energy for overseas transport

Overview
The Tamar catchment
Results
Conclusions
Example of a life cycle inventory for beef meat

Water from groundwater source

- 1.9 kg Beef cattle, fresh, from beef cattle at
  0.00276 m
- 3.93 kg Drinking water, water purification treatment
  0.00461 m
- 100 kg Grass, grazed in pasture/IE Economic
  0.00123 m
- 5.32 kg Compound feed beef cattle/IE Economic
  0.00891 m
- 0.858 kg Calcium ammonium nitrate (CAN), NP
  0.00023 m
- 0.49 kg Lime fertilizer, all regional storehouse/GER
  0.0015 m
- 1.74 kg Coal, 18/32, open pit mining
  0.00024 m

Energy from coal

- 1.9 kg Beef cattle for slaughter, at beef farm, PEF
  3.67 MJ
- 19.8 kg Grass silage, at beef farm/IE Economic
  0.32 MJ
- 5.32 kg Compound feed beef cattle/IE Economic
  1.5 MJ
- 0.8728 kg Polyethylene low density granulate (PE-LD)
  0.26 MJ
- 1.54 kg Barley grain, consumption mix at feed
  0.122 MJ
- 0.741 MJ Electricity mix, AC, consumption mix, at consumer
  0.567 MJ

Source: SimaPro, Agrifootprint database

2.5 % node cut-off
Multi-step evaluation of food purchase at home

Consumption of water and energy at different food process steps

Resources within and outside the catchment

Click on each box for more details

The Tamar catchment

Results

Conclusions

Overview

Application of ratios to each food product $i$:

- Ratio for each $i$ between imports-exports (ton) and food purchase for human consumption (ton):

$$ratio_{import_{i}} = \frac{import_{i}}{domestic\ supply} \times \frac{(food\ supply + processing)}{domestic\ supply}$$

$$ratio_{export_{i}} = \frac{import_{i}}{domestic\ supply} \times \frac{(food\ supply + processing)}{domestic\ supply}$$

FAO trade balance sheets are used. Classification such as feed and seed are not considered for human consumption.

- Ratio for each $i$ of imports-exports ($) by trade partner country $j$:

$$ratio\ country\ import_{ij} = \frac{import_{ij}}{import_{i}}$$

$$ratio\ country\ export_{ij} = \frac{export_{ij}}{export_{i}}$$

Consumption of water and energy for overseas transport
Multi-step evaluation of food purchase

Assumptions made for the calculation of overseas food miles

- Perishable foods (e.g., milk, eggs, vegetables) are transported by plane, the non-perishable (e.g., butter, rice, sugar) by ship.


- Ship transport: distances between Plymouth and other ports [https://seadistances.org/](https://seadistances.org/)

- 1 tkm Plane, technology mix, cargo, 68 t payload and 1 tkm Container ship ocean, technology mix, 27,500 dwt pay load capacity are obtained from the European Life Cycle Database (ELCD) v3.1 database
Results

Resource consumption by food product

Resource consumption distribution by processes

National and overseas energy consumption

National and overseas freshwater consumption

Resources consumption considering food miles

Global distribution of energy embedded in food imports

Overview | The Tamar catchment | Multi-step evaluation of food purchase | Conclusions
Animal products are more energy intensive because of production of compound feed and fertilizers.

Freshwater consumption of food products greatly depends on irrigation.

Overseas transport is not included.
Overseas transport is not included

Country of production: BR (Brazil), CN (China), DK (Denmark), IE (Ireland), GLO (Global) NL (The Netherlands)
The production of primary crops (e.g., carrots) and livestock (e.g., beef) accounts for the largest proportion of energy and freshwater use.

A detailed assessment within each primary product is essential.
Tamar catchment imports similar amount of embedded energy (51%) as uses locally (49%).

National and overseas energy consumption

Overseas transport is not included.
Tamar catchment imports more embedded freshwater (70%) than uses locally (30%).

National and overseas freshwater consumption

Overseas transport is not included

only processes > 1 hm³ are shown
- 92% energy consumption at origin of production from EU countries
- 46% energy consumption of overseas transport from non-EU countries
- With the inclusion of overseas transport total energy consumption (including production in UK) increases by 144% (from 1,133,000 GJ to 2,767,000 GJ)
Imports from EU are quite energy intensive due to the type of food product (i.e., beef meat) and transport.
Products transported by place require more energy input.
Largest volume and intensity of freshwater from EU too
Fruit, vegetables, meat and rice as the most demanding products from overseas.
Conclusions

• The Tamar imports about 51% and 70% of energy and water for food purchase at home, without including overseas transport.

• The weight of the overseas transport is very relevant, comprising about 60% of the total energy consumption.

• Improved differentiation of processes (e.g., water consumed in primary crop products) is required to identify hotspots and origins of resource use.

• Freshwater values for food production need to be adapted for the country of production.

• Renewable and non-renewable sources will depend greatly on the electricity mix from the country of production.