An Extended Environmental-Input-Output Lifecycle Assessment Model to Study the Food-Energy-Water Nexus

**Introduction**

The goal of this study is to:

- Develop a physically based environmental accounting of U.S. food production systems and to integrate these data into the Environmental-Input-Output Lifecycle Assessment (EIO-LCA) model [1].
- Characterize and compare the food, energy, and water intensities of every U.S. economic sector.

The extended EIO-LCA model can determine the food resource use in units of mass (kg) or energy content (kcal), water use (kGal), and energy use (TJ) of any economic activity within the United States.

**I O-LCA Methodology**

The major components of the model are two matrices (A and B) and three vectors (f, s, and g) [2].

The A matrix represents required monetary inputs of products (rows) for one dollar of output by an industry or process (columns). Typically, A is used with a functional unit vector, or final demand, f to find the scaling vector, s.

The B matrix represents physical environmental flows (rows) for each industry (columns). B is multiplied by the scaling vector s to determine the total environmental impact, g. These flows include energy, food, and water use, and other flows of interest.

**Data Sources**

Sources include the Bureau of Economic Analysis (BEA), the EIO-LCA model, and the United Nations Food and Agriculture Organization (UNFAO) [3].

**Data Analysis**

UNFAO data was aggregated into eight BEA farming sectors. These are the only sectors that directly produce food from the environment.

<table>
<thead>
<tr>
<th>Mass Intensity [Kg/USD]</th>
<th>Calorie Intensity [kcal/USD]</th>
<th>BEA Industrial Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.03</td>
<td>585</td>
<td>Vegetable and melon farming</td>
</tr>
<tr>
<td>1.56</td>
<td>8,626</td>
<td>Tree nut farming</td>
</tr>
<tr>
<td>3.75</td>
<td>11,945</td>
<td>Greenhouse, nursery, and floriculture production</td>
</tr>
<tr>
<td>5.20</td>
<td>24,373</td>
<td>Oilseed farming</td>
</tr>
<tr>
<td>10.39</td>
<td>37,300</td>
<td>Grain farming</td>
</tr>
<tr>
<td>5.45</td>
<td>1,660</td>
<td>Fruit farming</td>
</tr>
<tr>
<td>28.08</td>
<td>102,800</td>
<td>Sugarcane, sugar beet farming</td>
</tr>
<tr>
<td>6.42</td>
<td>4,300</td>
<td>All other crop farming</td>
</tr>
</tbody>
</table>

With the B matrix extended, $1M of final demand was queried for each BEA industry.

**Interpretation**

The results indicate that:

- The primary sector has the largest water and food intensity.
- The secondary and tertiary sectors usually have minimal food intensity, and have a strong correlation between water and energy intensity.
- Electricity Generation has the highest energy intensity, and second highest water intensity.
- Transportation is energy intensive, but not food or water intensive.

Note that this data excludes resources already embedded within an industry, such as in old machinery. However, new capital purchases are included. All model data is from 2002, the most recent EIO-LCA model available.

**Conclusion**

The results of this study enable a more complete understanding of food, energy, and water as key ingredients to a functioning economy. With the food data added to the EIO-LCA framework, researchers will be able to better study the Food-Energy-Water Nexus and gain insight into how these three vital resources are interconnected. Any EIO-LCA study can now track embedded food as part of its impact assessment.

**Acknowledgements & References**

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