A life cycle assessment of seasonal grass-based and confinement dairy farms

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Background

- Irish dairy producers mainly grass-based
- Post milk quota abolition production expected to grow
  - Government target to increase milk output by 50% by 2020
- Land availability will be new constraint
- Expansion in confinement dairy systems expected
- How will this impact the environment?
Aim of study

• Primary objective to develop a life cycle assessment model (LCA) to analyse the environmental impact of a seasonal calving-grass based dairy system and a confinement dairy system

• Study confined to two research farms
  • Data intensive
  • On-farm emission measurements
## Farm data

<table>
<thead>
<tr>
<th>Item</th>
<th>Grass</th>
<th>Confinement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm size</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td># Friesian cows</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>kg FPCM/cow</td>
<td>6,639</td>
<td>8,040</td>
</tr>
<tr>
<td>Replacement rate</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Grass, kg/cow</td>
<td>4,093</td>
<td>-</td>
</tr>
<tr>
<td>Silage, kg/cow</td>
<td>1,063</td>
<td>3,742</td>
</tr>
<tr>
<td>Concentrate, kg/cow</td>
<td>370</td>
<td>2,865</td>
</tr>
<tr>
<td>N fertiliser, kg ha</td>
<td>260</td>
<td>85</td>
</tr>
</tbody>
</table>
System Boundaries

Upstream
- N Fertilizer
- Energy
- Concentrate

Dairy Farm
- Silage
- Crop
- Pasteure
- Manure
- Soil

Housing
- Ruminant
- Milk
- Meat

Emissions
- N₂O
- CO₂
- CH₄
- NH₃
- PO₄
- NO₃
- N₂O
Environmental Impacts

- Global Warming
- Land use
- Acidification
- Finite Energy
- Eutrophication
Functional unit

• Environmental impacts assessed per unit of product and per unit area

  • per kg of fat and protein corrected milk (FPCM; 4% fat and 3.3% protein)
  • per ha of land occupied
Allocation

• Dairy systems produce and consume co-products
  • Milk, culls and surplus calves
  • Feed by-products e.g. corn gluten
• Impacts were allocated between co-products
  • Biological basis – Milk and meat
  • Economic basis – concentrate co-products
Inventory analysis

• Resource use recorded on-farm e.g. finite energy use

• Average yields applied to estimate area required for purchased feed

• On-farm emissions quantified using published algorithms and on-farm measurements

• Off-farm emissions Ecoinvent database/literature
Impact assessment

• Emissions converted into environmental impacts

• Greenhouse gas emissions → CO₂ equivalent
  • CO₂ = 1; CH₄ = 21; N₂O = 310

• Acidifying emissions → SO₂ equivalents
  • SO₂ = 1.2; NH₃ = 1.6; NOₓ = 0.5

• Eutrophic emissions → PO₄ equivalents
  • PO₄ = 1; NO₃ = 0.1; NH₃ = 0.35; NOₓ = 0.13
LCA model results

Greenhouse gas

<table>
<thead>
<tr>
<th>System</th>
<th>Methane</th>
<th>Nitrous oxide</th>
<th>Carbon dioxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>0.6</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>TMR</td>
<td>1.2</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

kg CO$_2$e per kg FPCM
LCA model results

Acidification

- Sulphur dioxide
- Nitrogen oxides
- Ammonia

<table>
<thead>
<tr>
<th>System</th>
<th>Grass</th>
<th>TMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>g SO$_2$e per kg FPCM</td>
<td>6</td>
<td>16</td>
</tr>
</tbody>
</table>

The Irish Agriculture and Food Development Authority
LCA model results

Eutrophication

![Bar chart showing the comparison of g PO₄e per kg FPCM for Grass, System, and TMR.](chart)

- Grass: 3 g PO₄e per kg FPCM
- System: 5 g PO₄e per kg FPCM (Nitrate 3 g, Nitrogen oxides 1 g, Phosphate 0.5 g, Ammonia 0.5 g)
- TMR: 4 g PO₄e per kg FPCM (Nitrate 2 g, Nitrogen oxides 2 g, Phosphate 0.5 g, Ammonia 0.5 g)

The Irish Agriculture and Food Development Authority
LCA model results

Finite energy use

MJ per kg FPCM

Grass

System

TMR

Electricity

Concentrate

Grass

Grass silage

Maize silage

The Irish Agriculture and Food Development Authority
LCA model results

Land use

System

Grass

TMR

m² per kg FPCM

0

0.2

0.4

0.6

0.8

1

Concentrate

Grass

Grass silage

Maize silage
## LCA model results

<table>
<thead>
<tr>
<th>Impact per total ha</th>
<th>Grass</th>
<th>Confinement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finite energy use, GJ</td>
<td>31</td>
<td>42</td>
</tr>
<tr>
<td>Global warming, t CO$_2$e</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Acidification, kg SO$_2$e</td>
<td>98</td>
<td>157</td>
</tr>
<tr>
<td>Eutrophication, kg PO$_4$</td>
<td>46</td>
<td>52</td>
</tr>
</tbody>
</table>
Scenario analysis

• Allocation decisions
  • Economic allocation – milk and meat
  • Mass allocation – concentrate co-products

• Mitigation options
  • Concentrate feed type and origin
  • Manure treatment
  • Reduce N surplus
Conclusions

• Grass-based system require less resources and emitted less emissions per kg of FPCM

• Potential to improve both systems
  • Concentrate composition and use
  • N efficiency
  • Manure management

• Further LCA harmonisation required
Thank you