Environmental impact of dairy farming systems in Denmark, Germany and Italy

Matteo Guerci\textsuperscript{1}, Troels Kristensen\textsuperscript{2} and Marie Trydeman Knudsen\textsuperscript{2}

\textsuperscript{1} Dipartimento di Scienze Agrarie ed Ambientali - Università degli studi di Milano
\textsuperscript{2} Departement of Agroecology - Aarhus University
• Dairy producers will meet increasing environmental demands in the future (limits on GHG emissions etc.)

• Removal of milk quota might accelerate the process of intensification and specialization

• Best strategy for efficient and environmentally friendly dairy systems?
AIM OF THE STUDY

• To analyze the environmental impact of different dairy farming systems in Denmark, Germany and Italy performing an LCA

• To identify the most important parameters influencing the environmental sustainability
LCA – FROM CRADLE TO FARM GATE

OFF-FARM

ON-FARM

Energy

Crop production

Enteric emissions

Storages

Stables

FU: 1 kg ECM
LCA: TOOL AND IMPACT CATEGORIES

OFF-FARM

- Global Warming Potential: kg CO$_2$ eq.
- Eutrophication potential: g PO$_{3-4}$ eq.
- Land use: m$^2$

ON-FARM

- Acidification potential: g SO$_2$ eq.
- Non renewable energy use: MJ eq.
- Biodiversity: Damage Score (DS)
<table>
<thead>
<tr>
<th>HERD</th>
<th>DK-1</th>
<th>DK-2</th>
<th>DK-3</th>
<th>DK-4</th>
<th>DK-5</th>
<th>GER-1</th>
<th>GER-2</th>
<th>IT-1</th>
<th>IT-2</th>
<th>IT-3</th>
<th>IT-4</th>
<th>IT-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows</td>
<td>no</td>
<td>168</td>
<td>122</td>
<td>116</td>
<td>127</td>
<td>123</td>
<td>92</td>
<td>36</td>
<td>77</td>
<td>35</td>
<td>98</td>
<td>350</td>
</tr>
<tr>
<td>Milk production</td>
<td>ton ECM cow⁻¹</td>
<td>6.27</td>
<td>7.72</td>
<td>8.53</td>
<td>10.43</td>
<td>7.98</td>
<td>10.96</td>
<td>6.28</td>
<td>10.22</td>
<td>6.33</td>
<td>10.48</td>
<td>7.89</td>
</tr>
<tr>
<td>Concentrate</td>
<td>% of herd DMI</td>
<td>26.9</td>
<td>26.6</td>
<td>44.9</td>
<td>39.6</td>
<td>61.5</td>
<td>36.9</td>
<td>3.3</td>
<td>44.1</td>
<td>13.1</td>
<td>45.2</td>
<td>42.5</td>
</tr>
<tr>
<td>Pasture</td>
<td>% of herd DMI</td>
<td>21.9</td>
<td>24.8</td>
<td>6.2</td>
<td>6.5</td>
<td>0.0</td>
<td>0.0</td>
<td>71.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Efficiency</td>
<td>kg ECM kg⁻¹ DMI cow</td>
<td>0.91</td>
<td>1.18</td>
<td>1.22</td>
<td>1.34</td>
<td>1.19</td>
<td>1.40</td>
<td>1.31</td>
<td>0.82</td>
<td>1.16</td>
<td>1.40</td>
<td>1.19</td>
</tr>
<tr>
<td>N efficiency ex animal</td>
<td>%</td>
<td>18.2</td>
<td>19.7</td>
<td>20.3</td>
<td>22.6</td>
<td>21.9</td>
<td>23.7</td>
<td>18.7</td>
<td>23.3</td>
<td>16.3</td>
<td>21.7</td>
<td>25.6</td>
</tr>
<tr>
<td>LAND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop area</td>
<td>ha</td>
<td>225.5</td>
<td>162.5</td>
<td>135.7</td>
<td>142.5</td>
<td>74.4</td>
<td>64.0</td>
<td>43.0</td>
<td>58.0</td>
<td>21.4</td>
<td>30.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Maize</td>
<td>% farm land</td>
<td>2.3</td>
<td>0.0</td>
<td>16.3</td>
<td>31.8</td>
<td>32.5</td>
<td>50.7</td>
<td>0.0</td>
<td>36.2</td>
<td>38.0</td>
<td>53.3</td>
<td>25.0</td>
</tr>
<tr>
<td>Ryegrass+Maize II</td>
<td>% farm land</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>22.8</td>
<td>75.0</td>
<td>26.1</td>
</tr>
<tr>
<td>Grassland in rotation</td>
<td>% farm land</td>
<td>47.1</td>
<td>40.9</td>
<td>14.2</td>
<td>44.2</td>
<td>0.0</td>
<td>8.6</td>
<td>90.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Permanent grassland</td>
<td>% farm land</td>
<td>11.1</td>
<td>21.2</td>
<td>11.9</td>
<td>5.9</td>
<td>0.9</td>
<td>40.7</td>
<td>10.0</td>
<td>63.8</td>
<td>33.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lucerne</td>
<td>% farm land</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>8.4</td>
<td>23.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total grassland</td>
<td>% farm land</td>
<td>58.2</td>
<td>62.0</td>
<td>26.1</td>
<td>50.1</td>
<td>0.9</td>
<td>49.3</td>
<td>100.0</td>
<td>63.8</td>
<td>42.2</td>
<td>23.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Crop yield</td>
<td>ton DM ha⁻¹</td>
<td>6.37</td>
<td>5.18</td>
<td>6.06</td>
<td>7.17</td>
<td>6.83</td>
<td>8.56</td>
<td>5.26</td>
<td>8.84</td>
<td>13.29</td>
<td>19.48</td>
<td>29.07</td>
</tr>
<tr>
<td>FARM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stocking rate</td>
<td>LU ha⁻¹</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
<td>2.1</td>
<td>2.1</td>
<td>1.1</td>
<td>2.2</td>
<td>2.5</td>
<td>5.6</td>
<td>9.8</td>
</tr>
<tr>
<td>Milk intensity</td>
<td>ton ECM ha⁻¹</td>
<td>4.66</td>
<td>5.52</td>
<td>6.72</td>
<td>8.69</td>
<td>11.86</td>
<td>15.69</td>
<td>5.25</td>
<td>12.69</td>
<td>10.34</td>
<td>30.69</td>
<td>61.14</td>
</tr>
<tr>
<td>Total N</td>
<td>kg N ha⁻¹</td>
<td>134</td>
<td>141</td>
<td>264</td>
<td>274</td>
<td>290</td>
<td>435</td>
<td>134</td>
<td>337</td>
<td>496</td>
<td>787</td>
<td>1273</td>
</tr>
<tr>
<td>N surplus</td>
<td>kg N ha⁻¹</td>
<td>86</td>
<td>89</td>
<td>194</td>
<td>217</td>
<td>224</td>
<td>324</td>
<td>125</td>
<td>177</td>
<td>197</td>
<td>792</td>
<td>1001</td>
</tr>
<tr>
<td>feed self sufficiency (base on DM )</td>
<td>%</td>
<td>92.9</td>
<td>82.9</td>
<td>84.6</td>
<td>85.3</td>
<td>50.5</td>
<td>63.1</td>
<td>96.7</td>
<td>65.1</td>
<td>76.0</td>
<td>54.3</td>
<td>47.5</td>
</tr>
</tbody>
</table>
ENVIRONMENTAL IMPACT RESULTS

Global warming
from 0.55 to 1.91 kg CO₂ eq. kg ECM⁻¹

Biodiversity
from 0.45 to 2.73 DS kg ECM⁻¹

Acidification
from 7.44 to 25.64 g SO₂ eq. kg ECM⁻¹

Land occupation
from 1.21 to 3.77 m² kg ECM⁻¹

Eutrophication
from 4.61 to 11.12 g PO₄³⁻ eq. kg ECM⁻¹

Non renewable energy
from 0.92 to 5.29 MJ eq. kg ECM⁻¹

Best
- GER-2
- DK-2
- IT-5
- DK-3
- DK-5
- IT-2

Worst
CONTRIBUTION TO GLOBAL WARMING

- DK-1: 95%
- DK-2: 44%
- DK-3: 73%
- DK-4: 66%
- DK-5: 95%
- GER-1: 73%
- GER-2: 66%
- IT-1: 73%
- IT-2: 66%
- IT-3: 73%
- IT-4: 66%
- IT-5: 73%

Acidification

On-farm: from 75 to 95 %

Eutrophication

On-farm: from 82 to 95 %
Energy use: On-farm: from 18 to 77%
RELATION BETWEEN MILK PRODUCTION LEVEL AND GLOBAL WARMING

kg ECM < 6400
7700 < kg ECM < 8600
9300 < kg ECM < 11000
RELATION BETWEEN STOCKING RATE AND GLOBAL WARMING

LU ha\(^{-1}\) < 1.2
1.2 ≤ LU ha\(^{-1}\) ≤ 2.5
LU ha\(^{-1}\) ≥ 5.6
RELATION BETWEEN SHARE OF GRASSLAND, GLOBAL WARMING AND BIODIVERSITY
CONCLUSIONS

- Huge variability among the systems: but generally high contribution of on-farm activities on global impact

- Relation among the impact indicators: improving one impact category means to improve the global environmental sustainability of the farm

- No relation in a product perspective between the environmental impact and the milk production (kg ECM cow⁻¹) and the stocking rate

- High proportion of grassland improves the environmental sustainability and reduces biodiversity losses
• LCA: a useful tool to quantify the global product orientated environmental impact - but uncertainty and some different basic assumptions make it difficult to compare with other works

• Farm specific conditions should be considered - and also local impacts should be analyzed (i.e.: eutrophication ha⁻¹) to better identify sustainable systems

• First “attempt” to estimate the biodiversity losses to produce 1 kg of milk - but it needs further improvements
THANKS