Yield gap analysis of feed crop-livestock systems: the case of grass-based beef production in France

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Introduction

Feed-crop livestock system
Introduction

Concepts of production ecology

- Potential
- Limited
- Actual

**Production level**

- **Defining factors**
  - Crops: Breed, Climate
  - Livestock: Breed, Climate

- **Limiting factors**
  - Crops: Water, Nutrients
  - Livestock: Water, Feed quantity, Feed quality

- **Reducing factors**
  - Crops: Pests, Diseases, Weeds
  - Livestock: Diseases, Stress

Van Ittersum and Rabbinge, 1997; Van de Ven et al., 2003
Introduction

kg beef t\(^{-1}\) DM \times t DM ha\(^{-1}\) year\(^{-1}\) = kg beef ha\(^{-1}\) year\(^{-1}\)

Potential or limited production
Objectives

- Quantify yield gaps in feed-crop livestock systems
- Analyse yield gaps in feed-crop livestock systems
- Identify improvement options to mitigate yield gaps for beef production systems in the Charolais area of France
Materials and methods

Beef production systems in the Charolais area of France

Two main types

- Cow-calf systems (calves sold at 300-420 kg)
- Cow-calf-fattener systems (calves sold at 690-720 kg)
Materials and methods

12 farm types with Charolais cattle

Diets
- Fresh grass: 44-66%
- Hay: 28-37%
- Cereals: 4-19%

Area feed production: 76-295 ha
Stocking density: 1.21-1.81 livestock units per ha

Economic data

Réseaux d’Élevage Charolais (2014)
Materials and methods

Potential and resource-limited live weight production

Feed crop-livestock production system

Daily weather data
Feeding strategy
Herd management

Charolais cattle
(LiGAPS-Beef)

Livestock production system

hay
grass silage

grass intake

trampling

Grass
(LINGRA)

Wheat
(LINTUL-2)

Maize
(literature)

Feed crop production system

Daily weather data
Irrigation
Crop management
Materials and methods

Daily weather data
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Charolais cattle
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Potential and resource-limited live weight production

Feed crop-livestock production system

Livestock production system

Feed crop production system

Daily weather data
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Charolais cattle (LiGAPS-Beef) Grass (LINGRA) hay grass silage Daily weather data Irrigation Crop management Daily weather data Feeding strategy Herd management

Potential and resource-limited live weight production

Feed crop-livestock production system

Livestock production system

Feed crop production system

Grass (LINGRA) Wheat (LINTUL-2) Maize (literature)
Simulated production levels (kg live weight ha\(^{-1}\) year\(^{-1}\))

- Potential production \(\rightarrow\) maximum production per hectare, 100% grass silage, potential grass yields
- Resource-limited production \(\rightarrow\) water-limited crop production and feed-limited cattle production

Measured: actual production realized on farms

Additional production levels simulated

- Feed-limited cattle production and potential crop production
- Resource-limited production with sub-optimal cattle management
- Resource-limited production with sub-optimal cattle management, calf mortality, and prolonged calving intervals
## Results & discussion

### Yield gaps in feed crops

<table>
<thead>
<tr>
<th>Production level or relative yield gap</th>
<th>Unit</th>
<th>Grass (kg DM ha(^{-1}) year(^{-1}))</th>
<th>Hay</th>
<th>Grass silage</th>
<th>Maize silage</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential production ((Y_P))</td>
<td>kg DM ha(^{-1}) year(^{-1})</td>
<td>14.4</td>
<td>16.6</td>
<td>18.7</td>
<td>25.2</td>
<td>8.3</td>
</tr>
<tr>
<td>Water-limited production ((Y_L))</td>
<td>kg DM ha(^{-1}) year(^{-1})</td>
<td>7.2</td>
<td>7.5</td>
<td>-</td>
<td>19.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Actual production ((Y_A))</td>
<td>kg DM ha(^{-1}) year(^{-1})</td>
<td>4.8</td>
<td>3.2-5.7</td>
<td>-</td>
<td>10.0-10.5</td>
<td>5.0-5.6</td>
</tr>
</tbody>
</table>

- **Relative yield gap, \((Y_P - Y_A) / Y_P\)**
  - Grass: 67% 66-81%
  - Hay: -
  - Grass silage: -
  - Maize silage: 58-60%
  - Wheat: 33-40%

- **Relative yield gap, \((Y_L - Y_A) / Y_L\)**
  - Grass: 33% 24-57%
  - Hay: -
  - Grass silage: -
  - Maize silage: 46-49%
  - Wheat: 23-32%

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Grazing (average farm types)
Results and discussion

![Graph showing feed production (t DM ha\(^{-1}\) year\(^{-1}\)) vs. feed efficiency (kg live weight t\(^{-1}\) DM). The graph includes different categories such as 'Feed-limited cattle / potential feed crops,' 'Resource-limited,' 'Resource-limited - cattle management,' 'Resource-limited - cattle management - calf mort. and int.,' and 'Actual.' The potential production is marked as a single point.](image)
Results and discussion

- Feed-limited cattle; potential crop growth
- Resource-limited production
- Actual production

Live weight production (kg ha\(^{-1}\) year\(^{-1}\))

Feed production (t DM ha\(^{-1}\) year\(^{-1}\))

Feed efficiency (kg LW t\(^{-1}\) DM)

Potential production

Potential production
Results

<table>
<thead>
<tr>
<th>Potential</th>
<th>Resource-limited</th>
</tr>
</thead>
<tbody>
<tr>
<td>RYG = 85%</td>
<td>RYG = 47%</td>
</tr>
<tr>
<td>41%</td>
<td></td>
</tr>
<tr>
<td>31%</td>
<td></td>
</tr>
<tr>
<td>9%</td>
<td></td>
</tr>
</tbody>
</table>

- Sub-optimal diet
- Water-limitation in feed crops
- Sub-optimal selling/slaughter weights, culling rates, calving date, age at first calving, stocking density
- Calf mortality and calving interval
- Cow mortality, diseases, and stress, and nutrients, pests, diseases, and weeds in crops
- Actual production

\[
\text{RYG} = \frac{\text{Actual production}}{\text{Potential}} \times 100\%
\]
Results

- Sub-optimal diet
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Results & discussion

Explanations for yield gaps

- Socio-economic and environmental constraints → exploitable yield gaps

Exploitable yield gap under resource-limited production:

$$47\% - 36\% = 11\%$$ of the resource-limited production
Results & discussion

Explanations for yield gaps

- Socio-economic and environmental constraints → exploitable yield gaps

- Farmers are eligible for grassland premiums if:
  - stocking densities < 1.4 livestock units per ha
  - more than 75% of the farmland is grassland
  - low N fertilization rates (max. 125 kg N ha\(^{-1}\))

- Cattle premiums are paid per cow

- Prices of farmland are € 2,800-4,000 per ha
Results and discussion

Yield gap mitigation → not attractive from an economic perspective

Relative difference:

Cattle
- Diseases
- Stress
- Mortality
- Prolonged calving intervals

Feed crops
- Nutrient limitations
- Pests, diseases, and weeds

\[
\frac{(\text{Resource-limited / manag.} - \text{Actual})}{\text{Resource-limited / manag.}} \times 100\% 
\]
Results and discussion

How to mitigate yield gaps after the change in common agricultural policy (CAP) of the EU in 2015?

- **Replace hay by grass silage**: ✓
- **Irrigate feed crops**: x
- **Increasing slaughter weights**: x
- **Later calving date**: ?
- **Increasing culling rates of cows**: ?
- **Earlier start grazing season**: ✓
- **Rotational grazing**: ✓/?
Conclusions

A generic framework and modelling method is now available to assess yield gaps in feed-crop livestock systems.

Its application to beef production systems in France shows that:

- Yield gaps were 85% of potential live weight production and 47% of resource-limited live weight production
- The main factors attributing to yield gaps were identified (feed quality and quantity limitations, water-limitation in feed crops, cattle management)
- The approach allows to identify improvement options for yield gap mitigation (grazing management, feeding silage)
Thank you for your attention!
Results

![Bar chart showing resource-limited production percentages for different farm types.

- Selling/slaughter weights, culling rates, calving date, stocking density
- Calf mortality and calving interval
- Cow mortality, diseases, and stress, and nutrients, pests, diseases, and weeds in crops
- Actual production]
Results

[Graphs showing relationships between revenue cattle and operational profit with regression lines and equations]

- Revenue cattle: $y = 0.007x + 2.08$
- Operational profit + Bovine premiums + PHAE: $y = 0.036x + 0.90^*$
- Operational profit: $y = 0.016x + 0.95^*$

[Regression lines plotted with data points indicating relationship between relative difference and operational profit.]
Results