Protein Production: Planet, Profit plus People?

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Overview

- Food sustainability and food security
- Prioritizing environmental impacts
- Why nitrogen and protein are pivotal
- Food, feed, fibre, feedstock, fuel options
- Citizens, consumers, cultural aspects
- European diets and policy aspects
- Health aspects
Food sustainability

- Sustainability: huge range of definitions!
- Ecology, Economy, Society (People Planet Profit)
- Sustainable food production (and consumption?)
- Human health, equity, animal welfare included?
- Context and time dependent

- Sustainability is a moving target!
- And the *rate of change* is staggering ...
Sustainability: dynamic equilibrium?

![Graph showing world population growth over time.](image)

- Year range: 0 to 2000
- World population range: 0 to 8 billion
- The population has been increasing significantly, particularly from the mid-20th century.
Impacts of food supply

Food production and consumption have tremendous impacts:

- *Pollution* (pesticides, eutrophication, climate change)
- *Resource depletion* (biodiversity, water, phosphate, fuel)

Production appropriates: **land** 30%, **water** 70%, **energy** 20%
The challenge ...

By 2050 – within 40 years! – we will need 60% more food to feed 2 billion more mouths ... (FAO, 2012):

- for food security we need to double yield / ha, so
- for sustainability we need to quarter impacts / ton
A safe operating space for humanity

Prioritizing impacts (boundary = 1)

1. Biodiversity loss >10
2. Nitrogen cycle 3.45
3. Climate change 1.1-1.5
4. Phosphate cycle 0.77-0.86
5. Ocean acidification 0.81
6. Land-use change 0.78
7. Freshwater use 0.65
8. Ozone depletion 0.50
Natural carbon cycle (basic)

0.04% atmospheric carbon dioxide

plant → animal → human
Current carbon cycle

0.04% atmospheric carbon dioxide

plant \rightarrow animal \rightarrow human

combustion of coal and oil + 1-2%
Natural nitrogen cycle (basic)

78% atmospheric nitrogen ($N_2$)

- ammonia synthesis ($NH_3$) by lightning and bacteria
- bacterial degradation
- ammonia emissions
- protein synthesis by plants
- animal
- human
Current nitrogen cycle

78% atmospheric nitrogen ($N_2$)

- ammonia synthesis ($NH_3$) by Haber-Bosch process
- ammonia synthesis ($NH_3$) by lightning and bacteria

+ 100-200%

- protein synthesis by plants
- bacterial degradation
- ammonia emissions
- animal
- human

vrije Universiteit Amsterdam Institute for Environmental Studies (IVM)
Nitrogen and protein are pivotal

- Human contribution to C cycle 1-2%; N 100-200%
- C-cycle < N-cycle > biodiversity
- Energy content of nitrogen fertiliser = 37% of all energy input in US agriculture
- Crops take up 50% of fertiliser → impacts on:
  - terrestrial ecosystems (via ammonia emissions)
  - aquatic ecosystems (via eutrophication)
Algal bloom in the Gulf of Mexico
Dead zone in the Gulf of Mexico
Impacts on any coastal shelf ...
<table>
<thead>
<tr>
<th>Year</th>
<th>Population (billion)</th>
<th>Meat Production (billion kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>2.7</td>
<td>45</td>
</tr>
<tr>
<td>2000</td>
<td>6.0</td>
<td>233</td>
</tr>
<tr>
<td>2050</td>
<td>9.1</td>
<td>465</td>
</tr>
</tbody>
</table>

Note: 3 billion people maximum without N-fertilisers
Protein inefficiency of factory farming

- 40% of global grain harvest and 70% of soy to livestock
- food and feed crops are competing for land + water
- alternative: direct human plant protein consumption

- 1 kg animal protein requires 6 kg plant protein (resources)
- moreover, biodiversity loss via ammonia emissions (pollution)
- animal / plant protein = 50-fold water requirement (resources)
Options to reduce impacts

- Biorefinery “cascade” required: food → feed → fibre → feedstock → fuel
- One crop, one purpose → multi-purpose crops
- Water conservation systems
- Better meat analogues, low in energy & egg white
- War on food waste
- Resource efficiency is key!
Cultural aspects: hunter-gatherers
Globalisation? (RDI = 50 to 60 g/day)

<table>
<thead>
<tr>
<th>Protein source (g/day)</th>
<th>low country</th>
<th>high country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef &amp; veal</td>
<td>4,6 DE</td>
<td>10,4 IT</td>
</tr>
<tr>
<td>Mutton &amp; goat</td>
<td>0,1 FI</td>
<td>5,4 EL</td>
</tr>
<tr>
<td>Pork</td>
<td>6,7 UK</td>
<td>22,7 AT</td>
</tr>
<tr>
<td>Poultry</td>
<td>4,6 SE</td>
<td>11,7 IE</td>
</tr>
<tr>
<td>Offal</td>
<td>0,5 DK</td>
<td>9,6 IE</td>
</tr>
<tr>
<td>Fish &amp; shellfish</td>
<td>2,9 AT</td>
<td>15,7 PT</td>
</tr>
<tr>
<td>Dairy (including cheese)</td>
<td>13,9 ES</td>
<td>28,2 NL</td>
</tr>
<tr>
<td>Eggs</td>
<td>2,1 IE</td>
<td>5,0 FR</td>
</tr>
<tr>
<td>Cereals</td>
<td>17,6 NL</td>
<td>35,5 IT</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,6 IT</td>
<td>5,5 PT</td>
</tr>
<tr>
<td>Pulses</td>
<td>&lt;0,1 4</td>
<td>3,7 ES</td>
</tr>
<tr>
<td>Vegetables</td>
<td>2,1 FI</td>
<td>7,7 EL</td>
</tr>
<tr>
<td>Stimulants (coffee)</td>
<td>&lt;0,1 EL</td>
<td>2,6 DK</td>
</tr>
<tr>
<td>Plant protein</td>
<td>32,6 NL</td>
<td>53,3 EL</td>
</tr>
<tr>
<td>Animal protein</td>
<td>55,3 UK</td>
<td>76,2 FR</td>
</tr>
<tr>
<td>Total protein</td>
<td>95,8 DE</td>
<td>118,9 PT</td>
</tr>
</tbody>
</table>
Policy and communication

- For consumers food safety and food security are stronger stimuli than sustainability.
- Governments are developing food strategies addressing all three plus obesity (health).
- When trying to “nudge” consumer choice, they should be aware of consumer “framing”, and stress health, rather than sustainability.
Animal production & human health 1

➔ Antibiotics resistant bacteria
  – MRSA (Methicillin resistant *Staphylococcus aureus*)
  – ESBL (Extended spectrum beta lactamase), including
    • KPC (*Klebsiella pneumoniae* carbapenemase)

➔ Over 90% of antibiotics go to livestock, currently 550 tons annually in NL (prophylactic use in feed banned in 2006)

➔ Therefore, resistant bacteria originate in intensive farming (including fish farms), rather than in hospitals

➔ Few new antibiotics are in the pipeline: end of an era?
Animal production & human health 2

- Zoonotic and emerging animal diseases
  - Avian influenza, Q fever
  - SARS (Severe Acute Respiratory Syndrome)
  - BSE (Bovine Spongiform Encephalopathy)

- On the rise as a result of sheer animal numbers
- Epidemics frequency increases by concentrations of poultry, pigs and humans in South East Asia
- Amplification by climate change will occur
Conclusions

- Meat & dairy prices may impact food security
- Diet change is crucial, but consumer acceptance is slow and “nudging” is insufficient: carrot *plus* stick?
- Multiple gains: biodiversity, climate, health, equity, animal welfare, more protein, biofuel from residues
- Double production & quarter impacts by 2050? The urgency is severely underestimated!
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Thank you for your attention!