Will the world have enough to eat?

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Before 1875 hunger was a problem of poverty and scarcity.

After 1875 hunger became a problem of poverty amidst plenty.

Will it remain so, or will the hunger of the poor once more be exacerbated by rising food prices?

Future developments are hard to predict, but we do know a few things.
Between now and 2050, global demand for phytomass for food will drastically increase

- World population may rise from 6.8 billion to 9 billion

- Demand for animal products relates to economic growth

- Biobased economy: global energy consumption in 2050 (Schiffer, 2008):
  - 980 EJ = 55 GT of grain equivalents
  - 8 x current farm production

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### Global demand in 2050

<table>
<thead>
<tr>
<th>Countries</th>
<th>Type of growth</th>
<th>‘Scenarios’</th>
<th>Phytomass (GT GE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Population growth</td>
<td>More food</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td>Current</td>
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<td></td>
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<td>7</td>
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<td>2050: plus all citizens a European diet</td>
<td>&gt; 23</td>
</tr>
<tr>
<td>Middle-income</td>
<td>Economic growth</td>
<td>More feed and feedstock</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rich</td>
<td>Biobased economy</td>
<td>More feedstock</td>
<td></td>
</tr>
</tbody>
</table>

*Will the supply as easily respond as in the 20th century?*

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Required growth for *food and feed* is nothing new

After: Evans, 1998

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Required growth for *food and feed* is nothing new

After: Evans, 1998

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Required growth for food and feed is nothing new

But conditions in 2010 very different than in 1950

After: Evans, 1998
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Outline

1. Concepts for assessing agro-production options
2. What is the globe’s production potential
3. Economic constraints
4. Implications
Production ecological principles

Potential

Defining factors
- CO₂
- Radiation
- Temperature
- Crop features

limiting factors
- Water
- Nutrients

Reducing factors
- Weeds
- Pests
- Diseases
- Pollutants

Production level (t/ha)

Van Ittersum and Rabbinge, 1997
Agro-production systems

At lower input levels, less complex systems are more energy efficient (less energy needed for maintenance)

But raising yields requires more complex systems.
Evolution of agro-production systems

- Green Revolution systems
- Novel systems
- Short fallow on heavy soils
- Short fallow on light soils
- Long fallow systems
- Zero fallow systems

Potential production

Usable phytomass

Level of complexity

Energy input

Koning and Van Ittersum, 2009; Van Ittersum and Koning - Agro2010
2. What is the globe’s agro-production potential
Global potential food production

- Potential agricultural area and water availability
- 90% of potential or water-limited yields
  - based on simple crop growth model (LUE)
- Multiple cropping

- 72 GT grain equivalents
  (roughly 10 times what is currently produced)

Penning de Vries et al., 1995
Van Ittersum and Koning - Agro2010
However: Agricultural area

- Current cropland
  - 3.39
  - 1.55
  - 2.95

- Current grassland
  - 3.39

- Potential cropland
  - 1.95

- Potential grassland
  - 1

- Human Settlement
- Biodiversity
- Forestry

Penning de Vries et al., 1995
Young, 1999
Koning et al., 2008
**However: Yield gaps**

**Lobell, Cassman and Field (2009):**

- Average: Potential: 16 – 95%
- Mean: 57%
- Mainly Asia

<table>
<thead>
<tr>
<th>Region</th>
<th>Yield (% of potential or water limited)</th>
<th>Crop(s)</th>
<th>Reference</th>
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<tr>
<td>Nebraska (USA)</td>
<td>89</td>
<td>Maize</td>
<td>Grassini and Cassman</td>
</tr>
<tr>
<td>Flevoland (NL)</td>
<td>80</td>
<td>Various</td>
<td>Wolf et al.</td>
</tr>
<tr>
<td>Ansai (China)</td>
<td>25-39</td>
<td>Various</td>
<td>Lu Changhe and Wang Tao</td>
</tr>
<tr>
<td>Finland</td>
<td>68 (WL)</td>
<td>Barley</td>
<td>Rötter et al.</td>
</tr>
<tr>
<td>Australia</td>
<td>79 (WL)</td>
<td>Wheat</td>
<td>Hochman et al.</td>
</tr>
<tr>
<td>Kenya</td>
<td>52 (FE)</td>
<td>Maize</td>
<td>Tittonell et al.</td>
</tr>
<tr>
<td>SE Asia</td>
<td>44-71</td>
<td>Rice (paddy)</td>
<td>Laborte et al.</td>
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*Reidsma and Ewert, 2005*
However: Production methods

- Assumption: best technical means
- But e.g. organic production ca. 30% lower yields on average
However: Climate change?

- Current insight: small overall effect on global cereal production if T +1-3°C
  - potential compensating effects CO$_2$ to be confirmed
  - differences mid- to high-latitude vs low-latitude regions
  - extreme climate events may have significant negative effects (also on livestock production)!

*Parry et al., 2004; Easterling et al., 2007*
However: Resource degradation and depletion

- Irreversible land loss: 0.1-0.2% of all suitable land per year (*Scherr & Yadav, 2001*)

- Reversible productivity losses: 38% of cropland.
  - Substantial, but compensated by innovations (*Scherr & Yadav, 2001; Oldeman et al., 1990*)

- Phosphorus depletion
Global production potential

Simulation study: 72 GT GE

However:
- Claims on land for other purposes: up to 43%
- Yields > 80% of potential are difficult to achieve
- Climate change and Resource degradation: 0% effect

Realistic potential: ca. 36 GT GE

Irrigated land: max +50%: ca. 27 GT GE

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Can we lift the potential?

- **Within agricultural domain**
  - Stretching potential yield
  - Improve conversion efficiencies

- **Outside agricultural domain**
  - Non-farm biomass
Stretching the potential yield

- Actual yield increases: often little tendency to decrease

EU average crop yields

Ewert et al., 2005

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Stretching the potential yield

- Actual yield increases: often little tendency to decrease
- Increase in potential yields of major crops: diminishing returns
- Improvements through crop architecture and crop duration: diminishing returns
- Potential yield improvements now seem source-driven

After: Fischer and Edmeades, 2010

UK wheat yields

After: Fischer and Edmeades, 2010

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Stretching the yield potential

- Actual yield increases: often little tendency to decrease
- Increase in potential yields of major crops: diminishing returns
- Improvements through crop architecture and crop duration: diminishing returns
- Potential yield improvements now seem source-driven
- Is it possible to breed for higher LUE?
- Untapped genetic diversity and genetic engineering hold promise but large investments needed!
Improving Conversion

- Conversion of phytomass into animal products
- Meat substitutes
- Biorefinement

Marine Production

Photo by M. Troell
The agro-production potential

- Max. 36 GT rather than 72 GT GE
- Increasing this potential food production through
  - lifting yield potential,
  - improved conversion and
  - marine production
- Many of these options are remote possibilities
3. Economic constraints
Why supply becomes tight long before technical potentials have been exhausted

Profit is maximal when iso-profit line (input-output price ratio as slope) gives highest intercept with the y-axis

With favourable input-output price ratios, developing novel systems may be profitable

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Why supply becomes tight long before technical potentials have been exhausted

Output (primary biomass) vs. Input (human controlled energy)

Technical potential

Novel systems (Innovation possibility set)

Green Revolution systems

Low input systems

Higher input-output price ratios reduce production and may make innovations unprofitable

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Why supply becomes tight long before technical potentials have been exhausted

Higher input-output price ratios reduce production and may make innovations unprofitable. They can even make producers opt for low-input techniques.

NB:
- Less favoured areas have higher input-output price ratios (higher transport costs, risk etc.)
- Depletion of fossil fuels and phosphate rock will raise input prices

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Trend change is possible

- Depletion of fossil fuels, rock phosphate & water → input prices increase → steeper slope of iso-profit lines
- This may be compensated by higher output prices, but that means a trend change
- Any trend change might be reinforced by decreasing returns to agricultural research
  - Past high returns were due to possibilities for raising potential yield by increasing the sink rather than source capacity of crops

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A cyclic downturn at the time of the trend change may discourage timely investment causing a period of especially high food prices.

Price fluctuations around trend are partly endogenous (leapfrogging of prices and investment).

Real wheat prices England & US (1901-1905 = 100)

Koning and Van Ittersum, 2009
Risk increasing factors

- Depletion of fossil fuel → increased interaction between food and energy markets
  - No multilateral regulation of energy markets
  - Little strategic investment in renewable energy sources
- No multilateral co-ordination of the markets for food and biobased non-foods

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Risk increasing factors

• Farm policy liberalization
  • Abandoning public food stocks
  • Reduction in price support and price stabilization

• Research investment
  • Cuts on public research investment
  • Private research investment does not compensate this
Beintema & Elliott, 2009

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Ca. 40 billion USD (2000)
So, technical potential for feeding the world may be small rather than abundant.

Also because of environmental implications and needed (policy) measures.

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4. Implications and recommendations
Policy:
- stop promoting bioenergy competing with food/feed
- discourage feed-inefficient livestock systems

Research:
- sustainable yield gap closure (GxExM)
- resource use efficiency
- multi-scale assessment (global vs local)

Research policy:
- increase investment in public R&D
- use international funding to facilitate coherence and synthesis of bottom-up approaches
References


• Koning, N. and M. van Ittersum, 2009. Will the world have enough to eat? Current Opinion in Environmental Sustainability 1: 77-82.
Thank you