Animal production and Nitrogen: Global trends in growth and efficiency

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Animals have key functions in societies

**Animals provide**
- Nutritious food (milk, meat, egg)
- Draught, wool and hides
- Manure

**Animals serve/contribute**
- Employment & income to farmers, industry
- Savings banks, social status
- Leisure animals
- "Livestock ladder" - smallholders
Animal production is debated

- Animal production contributes to environmental burden:
  - Resources use (land, water, biodiversity)
  - Greenhouse gas emissions (CH4, N2O)
  - Ammonia emissions
  - Eutrophication of water bodies

- Animal production contributes to health risks
  - Zoonosis
  - Antibiotics, hormones
  - Diet-related diseases

- Animal welfare is sometimes at stake
Large diversity in animal production systems

A simple & functional categorization:

- Grazing systems
- Mixed crop-animal systems
- Specialized (animal feeding) systems ('foot-loose')
Only 14 domesticated animal species

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Domestication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>10000 BC</td>
</tr>
<tr>
<td>Pig</td>
<td>9000 BC</td>
</tr>
<tr>
<td>Cattle</td>
<td>8000 BC</td>
</tr>
<tr>
<td>Goat</td>
<td>8000 BC</td>
</tr>
<tr>
<td>Chicken</td>
<td>6000 BC</td>
</tr>
<tr>
<td>Donkey</td>
<td>5000 BC</td>
</tr>
<tr>
<td>Water buffalo</td>
<td>4000 BC</td>
</tr>
<tr>
<td>Horse</td>
<td>4000 BC</td>
</tr>
<tr>
<td>Reindeer</td>
<td>3000 BC</td>
</tr>
<tr>
<td>Fox</td>
<td>1800 AD</td>
</tr>
<tr>
<td>European Mink</td>
<td>1800 AD</td>
</tr>
<tr>
<td>Hamster</td>
<td>1930 AD</td>
</tr>
</tbody>
</table>

Diamond, 2002
Growing demands for animal products

- **Driving factors:**
  - Population growth
  - Urbanization and changing food patterns
  - Growing middle classes in emerging economies

- **At the same time:**
  - Increasing support of suppliers & processing industry
  - An increase in animal and labour productivity
  - A decrease in real prices
Changes in number of animals 1961-2011
Mean livestock units per capita did not increase
Kernel density distributions of LSU density of 151 countries

Ruminants

Monogastric animals
Spatial variations within countries
Trends in animal production systems

- Increases poultry > pork > dairy > beef ≥ sheep & goat
- Further intensification and concentration of production, i.e. more products per unit of animal, labour, land and feed
- Centralisation of market chains
- New farms in emerging economies are often footloose and industrial, near cities
- Governmental regulations popp-up, in more countries

- Smallholder farms (2 ha) are under pressure;
  “if smallholder farms loose, all may loose”
Animal production and nitrogen

- Meat (muscles) is protein and water
- Animal protein contains ~16% N

- Conversion of plant protein in animal protein depends on
  - Animal species & breed
  - Animal age
  - Quality of the feed
  - Management & environmental conditions
Global animal production is increasing exponentially; ~0.3 Tg N/yr in last 10 yrs
Global animal excretion is increasing linearly:

\(~1.0\ Tg\ N/yr\)
Relationship between LSU density and N surplus of 151 countries in 2000-2010

Liu et al., 2016
Nutrient Use Efficiency in animal production

• **FCR** = Feed conversion ratio, kg feed per kg product
• **NUE** = N use efficiency, kg N in product per kg feed N

➢ FCR and NUE are defined at:
  ➢ Animal level
  ➢ Herd level
  ➢ System level
Global changes of NUE-herd, 1900-2050

Nitrogen recovery in livestock production

AFR, Africa; EUR, Europe; NA, North America (Canada, United States); NAS, North Asia (Russian Federation, Belarus, Ukraine, Republic of Moldova); OCE, Oceania (Australia and New Zealand); SAS, South Asia (rest of Asia); SCA, South and Central America.
Increases of NUE- & PUE-herd in NL
Changes of NUE in pig production in China at animal, herd and system levels

Bai et al., 2016
NUE of dairy production in China in 2010 at herd and system levels

Bai et al., 2013
N flows in the manure chain of China in 2010

N flows in Tg N
NUE (herd) = 11%
Manure N applied to land = 18%
Total loss = 17.8 Tg N

Bai et al., 2016
Exploring the boundaries of NUE

- Open circles: manure N loss 50%; manure N recovery 30%; ‘new’ N input recovery 50%
- Filled circles: manure N loss 10%; manure N recovery 70%; ‘new’ N input recovery 50%
- Squares: manure N loss 50%; manure N recovery 30%; ‘new’ N input recovery 100%
- Diamonds: manure N loss 50%; manure N recovery 70%; ‘new’ N input recovery 100%
- Triangles: manure N loss 10%; manure N recovery 70%; ‘new’ N input recovery 100%
Apparent NUE of agricultural sectors in NL

Note: externalization of feed import not considered
Agriculture: manure export is output
Agriculture*: manure export is neglected
Agriculture**: manure export is negative import

CBS, 2016
Solutions to improve NUE in animal production

- Continue to improve NUE at herd level through
  - Improved animal feeding
  - Improved breeds
  - Improved health and herd management

- Improve manure management of housed animals:
  - Collect 100% of excrements in leak-tight storages
  - Reduce gaseous N losses to <15% during storage
  - Increase fertilizer N effectiveness to >70%
  - Replace fertilizer by manure nutrients

- Re-connect animal production to crop production
  - Mixed systems or virtual (via feed & manure transport)
Integrating crop and livestock systems in NL: cost of manure distribution is critical

(a) Mixed crop–animal farms
Cost of low-emissions manure application ~3 € per m$^3$

(b) Specialized crop farms
5-10 € per m$^3$
Specialized animal farms
~20 km

(c) Specialized crop farms
10-20 € per m$^3$
Specialized animal farms
~100 km

(d) Specialized crop farms abroad
20-25 € per m$^3$
Specialized animal farms
~500 km
Cooperation and incentives needed

- Cooperation between:
  - Farmers
  - Private sectors: suppliers & processing industries
  - Governments: regulating and facilitating policies
  - Knowledge institutes

- Incentives/regulations related to
  - Implementation of BMPs, BATs
  - Targets/limits of N & P inputs and outputs
Summary & conclusions

- Animal production is diverse and rapidly developing
- NUE at herd level is increasing, but not at system level.
- Manure management is critical to improving NUE at system level
- The amount of N in animal excrements is large, but a significant fraction is lost.
- Solutions to improve NUE involve
  - Cooperation
  - Implementation of BMPs, BATs.
  - NUE/Noutput/Nsurplus
Thank you!

Questions?
Concentrations of animals
Pig farm size vs farm income & N losses

Survey of 92 pig farms in Beijing

Wei et al., 2016
Nomadic pastoral systems

Grassland-based beef production

Grassland-based dairy production

Feed lots

Subsistence livestock production systems

Nomadic pastoral systems

Increasing intensity

Animal protein, kg per ha

1

10

100

1,000

10,000

Dairy and beef production systems
Framework for cooperation in animal production

- Food quality and safety first
- Technology tailored to regional market demands
- Getting the basics right
- Include smallholders
- Act together
- Learn from the past
- Develop capacity

Van der Lee et al., 2013
Global market, but producer prices differ

FAOSTAT, retrieved 2013
CIA World Factbook
Mean feed and protein conversion rates

<table>
<thead>
<tr>
<th>Product</th>
<th>Protein conversion, kg protein/kg human edible protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>2.5</td>
</tr>
<tr>
<td>Egg</td>
<td>3.3</td>
</tr>
<tr>
<td>Chicken</td>
<td>5</td>
</tr>
<tr>
<td>Pork</td>
<td>10</td>
</tr>
<tr>
<td>Beef</td>
<td>25</td>
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</table>
Changes in mean N content of feed in NL

N content of concentrates (g/kg)

N-content of roughage (g/kg dm)