Livestock in FAO Global Agriculture Perspectives System (GAPS): brief history, current work and next steps

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Livestock Modelling Workshop:
GLW-GLEAM-GAPS/IMPACT Integration
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Global Perspectives Studies at FAO: Publications

Corporate reports on key issues
- E.g. report on “The future of food and agriculture – Trends and challenges” (2017)

World Agriculture towards 20XX
- Long-term projections of agriculture, food security and natural resource use. Last baseline projection until 2050 (AT2050, Alexandratos and Bruinsma, 2012)

Upcoming report:
The future of food and agriculture – Alternative pathways to 2050
Global Agriculture Perspectives System (GAPS)

- **GAPS v1**
  - Partial equilibrium model for agricultural commodities
  - Replicates the AT2050 projections for 110 countries and 34 commodities
  - Strongly influenced by IMPACT regarding equations and deep parameters
  - Base year 2005/07
  - Implemented in GAMS

- **For upcoming report: Extension and Upgrade to GAPS v2**
  - Build around 2011-2013 FAOSTAT Food Balance Sheets (FBS) and Productions Statistics
  - GAEZ v4 for climate change impacts on land and water resources and crop yields
  - GLEAM for feed requirements, herd dynamics, and proportions of animal production systems (4 ruminant species in 4 herds and production systems; 2 monogastric species in 3 systems)
  - UN DESA World Population Prospects 2015
  - OECD Shared Socioeconomic Pathways for income projections
  - 154 countries and 68 commodities
GAPS – Basic structure

ACTIVITIES | CROP | LEVELS | YIELDS | PRIMARY PRODUCTION

AGRICULTURAL MAKE MATRIX

PRIMARY COMMODITIES | PROCESSED COMMODITIES | OTHER COMMODITIES

DOMESTIC SUPPLY

- USE FOR PROCESSING
- USE FOR AGRICULTURAL INPUTS
- USE FOR FOOD
- OTHER INDUSTRIAL USES, LOSSES, ...

= NET TRADE (+/-)
GAPS – Livestock module

Livestock activities

Aggregate feed bundle

Feed bundle = f(bundle price, herd size | parameters)

Herd size

Animal make Matrix (share of producing animals, yields)

Livestock activities

Feed use commodity 1

Feed use commodity 2

Feed use commodity ...

Animal product 1

Animal product 2

Animal product ...

Primary supply animal products

Total feed

Commodities
GAPS – Herd size

• Equations:

  Number of animals:

  \[ \text{herd}_{a,l,t} = \lambda_{a,l,t} \cdot PP_{a,l,t}^{\omega_{a,l,t}^{PP}} \cdot PFEED_{a,l,t}^{\omega_{a,l,t}^{PFEED}} \]

  With \( a \): species, \( l \): herd x system, \( \lambda \): shift parameter, PP: Producer price, PFEED: Aggregate feed price

• GAPS solves for prices to clear markets in time \( t \)
• Shift parameters refer to price-independent growth of herds
Derivation of shifters - example large ruminants in SSA – only population and income shifts
Including Expert Opinions: E.g Herd size

Stylized expert statements:
“That’s not possible”, “[...] too high [...]”, “[...] too low [...]”
“Until 2030, countries will push towards achieving SDGs, get funding, too,...”
“Climate change will cause losses of pasture land, will become visible after 2030,...”
“Beyond 2050, population growth slows down and pressure on herd sizes declines a bit”
GAPS - Feed demand

Equations:

• CES-Aggregation:

\[ \text{bundle}_{a,l} = \left( \sum_i \beta_{a,l,i} \text{feed}_{a,l,i} \right)^{\frac{\sigma_{a,l}}{\sigma_{a,l} - 1}} \]

With \( a \): species, \( l \): herd x system, \( \beta \): share parameter, \( \sigma \): substitution elasticity

• First-order condition for cost-minimization:

\[ \text{feed}_{a,l,i} = \text{bundle}_{a,l} \beta_{a,l,i}^{\sigma_{a,l} - 1} \left( \frac{PFEED_{a,l}}{PC_i} \right)^{\sigma_{a,l}} \]

With \( p_{bundle} \): bundle price, \( p_{feed} \): feed market price

• Feed demand levels by herds and systems, and share parameters (\( \beta \)) obtained from GLEAM feed coefficients

• Precondition: align feed uses from FBS, herd sizes from production statistics, and GLEAM coefficients
**GLEAM2GAPS: Database challenges**

**Comparability of databases**

- **GLEAM**
  - follows its own classification of animal feeds
  - feed coefficients expressed in maximum intake, dry matter base
  - Includes traded (e.g. maize) and non-traded (e.g. grass) feeds

- **GAPS**
  - is built on FAOSTAT food balance sheets and production statistics
  - market balances expressed in primary equivalents (except oilseeds)
  - no distinction of feed destinations (herds or systems), only one column per country and year
  - Does not include roughages or other non-traded feeds

- Without additional information, feed balances cannot be completed
- Pasture/rangeland requirements calculated post-solve as plausibility check
# GLEAM feeds (e.g. grains and products)

<table>
<thead>
<tr>
<th>FeedItemCode</th>
<th>FeedItemName</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAINS</td>
<td>Grains from wheat (Triticum spp.), barley (Hordeum vulgare), sorghum (Sorghum spp.), rye (Secale cereale) or oat (Avena sativa) plants.</td>
</tr>
<tr>
<td>GRNBYDRY</td>
<td>‘Dry’ by-products of grain industries such as brans, middlings, etc.</td>
</tr>
<tr>
<td>GRNBYWET</td>
<td>‘Wet’ by-products of grain industries such as biofuels, distilleries, breweries, etc.</td>
</tr>
<tr>
<td>WHEATS</td>
<td>Grains from wheat (Triticum aestivum).</td>
</tr>
<tr>
<td>WHEATN</td>
<td>Grains from wheat (Triticum aestivum).</td>
</tr>
<tr>
<td>BARLEY</td>
<td>Grains from barley (Hordeum vulgare).</td>
</tr>
<tr>
<td>MILLET</td>
<td>Grains from millet (P. glaucum, E. coracana, P. miliaceum...).</td>
</tr>
<tr>
<td>RICE</td>
<td>Grains from rice (Oryza sp.).</td>
</tr>
<tr>
<td>SORGHUM</td>
<td>Grains from sorghum (Sorghum sp.).</td>
</tr>
<tr>
<td>CWHEAT</td>
<td>Grains from wheat (Triticum aestivum).</td>
</tr>
<tr>
<td>CBARLEY</td>
<td>Grains from barley (Hordeum vulgare).</td>
</tr>
<tr>
<td>CMILLET</td>
<td>Grains from millet (P. glaucum, E. coracana, P. miliaceum...).</td>
</tr>
<tr>
<td>CRICE</td>
<td>Grains from rice (Oryza sp.).</td>
</tr>
<tr>
<td>CSORGHUM</td>
<td>Grains from sorghum (Sorghum sp.).</td>
</tr>
<tr>
<td>CGRNBYDRY</td>
<td>‘Dry’ by-products of grain industries such as brans, middlings, etc.</td>
</tr>
<tr>
<td>CORN</td>
<td>Grains from maize (Zea mays) plant.</td>
</tr>
<tr>
<td>MZGLTM</td>
<td>By-product from maize processing. It is a protein-rich feed, with about 65% crude protein content.</td>
</tr>
<tr>
<td>MZGLTF</td>
<td>By-product from maize processing. Unlike the gluten meal, its protein content is lower, of about 25% crude protein content.</td>
</tr>
<tr>
<td>MAIZES</td>
<td>Grains from maize (Zea mays).</td>
</tr>
<tr>
<td>MAIZEN</td>
<td>Grains from maize (Zea mays).</td>
</tr>
<tr>
<td>CMAIZE</td>
<td>Grains from maize (Zea mays).</td>
</tr>
</tbody>
</table>
GAPS and FBS commodities (e.g. grains and products)

<table>
<thead>
<tr>
<th>FBSName</th>
<th>FBSCode</th>
<th>GAPSCode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat and products</td>
<td>2511</td>
<td>C_WHEA</td>
</tr>
<tr>
<td>Barley and products</td>
<td>2513</td>
<td>C_BARL</td>
</tr>
<tr>
<td>Maize and products</td>
<td>2514</td>
<td>C_MAIZ</td>
</tr>
<tr>
<td>Rye and products</td>
<td>2515</td>
<td>C_XCER</td>
</tr>
<tr>
<td>Oats</td>
<td>2516</td>
<td>C_XCER</td>
</tr>
<tr>
<td>Millet and products</td>
<td>2517</td>
<td>C_MILL</td>
</tr>
<tr>
<td>Sorghum and products</td>
<td>2518</td>
<td>C_SORG</td>
</tr>
<tr>
<td>Cereals, Other</td>
<td>2520</td>
<td>C_XCER</td>
</tr>
</tbody>
</table>

Comparability of GLEAM and GAPS databases

- Categories for feed commodities do not allow direct (1-to-1) mapping
- Comparability is a bit better for oilseed cakes, worse for other tradables and processed feeds
- Need to create an intermediate grouping...
... some trial comparisons ...
... to obtain a procedure for data integration:

Steps:

• Determine feed groups \( ig \) with many-to-1 correspondence to GAPS commodities \( (i) \) as well as GLEAM feeds \( (g) \).

• General criterion for \( ig \): Low substitutability between groups, high substitutability within groups.

• Compute shares of herds by productions systems within each group \( ig \):

\[
share_{h,s,ig} = \frac{\sum_{g \in ig} \gamma_{h,s,g} \text{herd}_{h,s}}{\sum_{h,s,g \in ig} \gamma_{h,s,g} \text{herd}_{h,s}}
\]

With \( \gamma \) : GLEAM maxinitake.

• Distribute FBS feed uses by shares:

\[
feed_{h,s,i \in ig} = tfeed_i^{FBS} \cdot share_{h,s,ig}
\]

With \( tfeed \): Total feed uses.
Combined feed uses, GLEAM vs GAPS, high aggregation, average DM content
GLEAM2GAPS: Next steps

Adjust DM contents of tradable feeds

Close feed balances by including non-tradables

• Straw / crop residues
  ▪ By-product of crop production
  ▪ Very important e.g. in SSA countries

• Maize silage
  ▪ Not included in FBS, ProductionStatistics discontinued
  ▪ Important farming activity in HIC and ECA countries

• Grass
  ▪ Availability determined by exploitable NPP and location of pastures and rangeland
  ▪ Some conceptual challenges regarding transition from rangeland to pasture
  ▪ Including pasture/rangeland supply in equilibrium equations would permit pricing

More on feed balances and pasture/rangeland demand now!
Thank you

www.fao.org/global-perspectives-studies