Aligning FAO Global Livestock Environmental Assessment Model (GLEAM) and FAOSTAT balance sheets for animal feed

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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!
Feed coefficients in GAPS

- In base-year, feed demand is determined by herd size and demand per animal and year

\[ feed_{a,l,i} = \chi_{a,l,i}^{FD} \cdot herd_{a,l} \]

With \( a \) : species, \( l \) : herd x system, \( \chi \) : Intake per animal and year, fresh matter

- Total feed demand:

\[ tfeed_i = \sum_{a,l} feed_{a,l,i} = \sum_{a,l} \chi_{a,l,i}^{FD} \cdot herd_{a,l,i} \]

(1)

- Consistency with FAOSTAT food balance sheets (FBS):

\[ tfeed_i = tfeed_i^{FBS} \]
Linking traded feed coefficients to GLEAM

• Feed intake per animal and day, dry matter base:

\[ \gamma_{a,l,ig,n}^{FD} = \sum_{i \in ig} \chi_{a,l,i}^{FD} \cdot \kappa_{i,n}^{FD} / 365 \]  

(2)

With \(ig\): feed group, \(n\): nutrient, \(\gamma\): Intake per animal and day, dry matter base, \(\kappa\): Intake nutrient content per unit of fresh matter

• Relevant nutrients: \(n = \{DM, RP, GE\}\)

• Note: regional indexes have been omitted to avoid index clutter! \(\kappa\) has a regional index like \(\gamma\)!
Roughages coefficients

• Roughages feed intake per animal and day, dry matter base:

\[ \gamma_{a,l,ig,n}^{RG} = \sum_{r \in ig} \chi_{a,l,r}^{RG} \cdot \kappa_{r,n}^{RG} / 365 \]  

(3)

With \( r \): roughages

• Elements of \( r \):  \( r = \{ STRAW, SILAG, GRASS \} \)

• Each element treated differently:
  • Straw/residues are by-products of other farming activities
  • Silage is deliberately farmed
  • Grass may originate from managed (pastures) or unmanaged (rangeland) suitable (?) lands
Elements of r: Straw/residues

- Straw balance:

\[
\sum_i xS_i \cdot \left( \frac{1}{HI_i} - 1 \right) \cdot \eta_i^{"STRAW"} = \sum_{a,l} \chi_{a,l,\"STRAW\"} \cdot herd_{a,l} \tag{4}
\]

With \(xs\): domestic crop production, \(HI\): harvest index, \(\eta\): share of straw production used for feed

- Note: No distinction of straw types in feed coefficients, only aggregates!

- Fraction of produced straw used for feed very much dependent on country context, but certainly: \(0 \leq \eta \leq 1\)
Elements of r: (Maize) Silage

- Silage balance:

\[
\sum_{sila} \chi_{sila}^{RG} = \sum_{a,l} \chi_{a,l,"SILAG"} \cdot \text{herd}_{a,l}
\]  \hspace{1cm} (5)

With \(\chi_{sila}^{RG}\): domestic silage production, \(\text{sila}\): types of silage crops

- Note: Silage production taken from discontinued FAOSTAT

- Assumption: All silage production used for animal feed
Elements of r: Grass

• Grass balance:

\[ \sum_w area_w \cdot npp_w \cdot \eta^{Grass}_w = \sum_{a,l} \chi^{RG}_{a,l,'GRASS'} \cdot herd_{a,l} \quad (6) \]

With \( w \)=type of grassland, \( area \): available area, \( npp \): net primary productivity, \( \eta \): share of net primary production exploited for feed

• Note: No distinction of straw types in feed coefficients, only aggregates!

\[ w = \{ PASTR, RANGE \} \]

• Fraction of npp used for feed very much dependent on country context, but certainly: \( 0 \leq \eta \leq 1 \)
Variables and supports

- Variables to be estimated:

\[
VAR = \begin{bmatrix}
\gamma^{(\cdot)} \\
\eta^{(\cdot)} \\
HI \\
\kappa^{(\cdot)}
\end{bmatrix}
\]

- Intake per animal and day, dry matter
- Use shares
- Harvest indexes
- Nutrient contents per unit of fresh matter

- Entropy requires variables to be expressed by weights and supports:

\[
VAR = \sum_{s} WGT_{s} \cdot SPT_{s}, \ s = \{LOW, EXP, UPR\}
\]
Constructing supports

- Intakes ($\gamma$):
  - LOW: GLEAM global minimum value or 0
  - EXP: GLEAM coefficients
  - UPR: GLEAM global maximum*1.25

- Use shares ($\eta$):
  - LOW: FAOSTAT/GLEAM global minimum value or 0
  - EXP: FAOSTAT/GLEAM median country observation
  - UPR: FAOSTAT/GLEAM global maximum

- Harvest indexes (H$I$):
  - LOW: Various sources ...
  - EXP: ...
  - UPR: ...

- Nutrient contents ($\kappa$):
  - LOW: FEEDIPEDIA global minimum value or 0
  - EXP: FEEDIPEDIA average
  - UPR: FEEDIPEDIA global maximum (1 for DM)
Objective function

- Cross-entropy objective, subject to constraints:

\[
\min_{GCE} = \sum_{WGT} \sum_{s} WGT_{s} \cdot \ln \left( \frac{WGT_{s}}{pwgt_{s}} \right)
\]

\[
s.t. (1) - (6)
\]

- \(pwgt\) are prior weights, set to mimic assumed distributions
- Procedure solves each country in parallel, implemented as NLP in GAMS using CONOPT
Feed intakes before and after entropy

Herd x System
- MILK_GRASS
- MEAT_GRASS
- TOTL_BACKY
- TOTL_MONO2
- MILK_MIXED
- MEAT_MIXED
- TOTL_MONO1
Monogastrics
• Tendency to underestimate total intake
• Include swill? How?

Ruminants:
• Generally good fit: roughages permit sufficient degrees of freedom
And now?

- Scrutinize fitted rations, improve GCE procedure
- Include roughages demand and supply in GAPS
- Straw / crop residues
  - Straw market, but what are other uses?
  - Express use shares as function of prices?
- Maize silage
  - Possible to treat as any other crop
- Grass
  - Conversion from rangeland to pasture
  - Make use shares price dependent
Thank you

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