The future of global livestock systems and the environment

Petr Havlík, Hugo Valin, Mario Herrero, Aline Mosnier, Avery Cohn and many collaborators...

Ecosystems Services and Management Program
The context

- 987 Mio poor engaged in livestock activities
- 17% of average daily energy intake
- 33% of average daily protein intake
- 30% of global land area

Source: Steinfeld et al. (2006)

LIVESTOCK

- 1 GHa Arable - Rest
- 0.5 GHa Arable - Feed
- 3.5 GHa Meadows & Pastures
- 4 GHa Forests

Source: FAOSTAT
Livestock sector

18% of global GHG emissions

Source: Steinfeld et al. (2006)
Outline

- Production systems heterogeneity and scope for productivity improvement?
  - State of heterogeneity
  - Historical developments on productivity
  - Role of climate change
- Livestock production systems transition and the environment
- Livestock versus crop-based climate change mitigation
  - Synergies and trade-offs
  - Relation to food security
- Application to Brazil
Livestock production systems
Livestock

Gridded Livestock of the World – Robinson et al. (2011)

Cattle density map matching FAOSTAT 2005 (modelled)

AGRICULTURE AND CONSUMER PROTECTION DEPARTMENT
Animal Production and Health Division

Number per square km
- <1
- 1-5
- 5-10
- 10-20
- 20-50
- 50-100
- 100-250
- >250

Source: Gridded Livestock of the World
Livestock production systems distribution

Sere and Steinfeld (1996) classification updated by Robinson et al. (2011)
Livestock production systems database

Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems

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Livestock sector coverage

Livestock categories:
- Bovines: Dairy & Other
- Sheep & Goats: Dairy & Other
- Poultry: Laying hens, Broilers, Mixed
- Pigs

Production systems:
- Ruminants
  - Grass based: Arid, Humid, Temperate/Highlands
  - Mixed crop-livestock: Arid, Humid, Temperate/Highlands
  - Urban, Other
- Monogastrics
  - Smallholders
  - Industrial
Production systems parameterization

Herrero et al. (2013)
Biomass use for livestock

Herrero et al. (2013)
Composition of ruminant diets

Herrero et al. (2013)
Digestibility model calculations

Herrero et al. (2013)
Ruminant production efficiency

Adapted from Herrero et al. (2013)
Ruminant meat

Ruminant milk

Herrero et al. (2013)
Feed conversion efficiencies

- Historical FCE not available in FAOSTAT
- Decomposed by using an identity
- model AgRIPE (Soussana et al., 2013)

Historical feed conversion efficiencies

[kg protein in product / kg protein in feed]

Soussana et al. (2013)
Biophysical consistency: Livestock

Feed conversion efficiencies in 2000
[kg protein in product / kg protein in feed]

Adapted from Herrero et al. (2013)
Feed conversion efficiencies

Future global FEC change for the central scenario SSP2 calculated based on historical slopes

\[ E(t) = E_c + (E_0 - E_c) e^{-a \cdot t / E_c} \]

- \( E(t) \) – projected feed conversion efficiency in year \( t \)
- \( E_0 \) – 2000 feed conversion efficiency
- \( E_c \) – ceiling feed conversion efficiency (increasing 0.5% p.a.)
- \( a \) – historically derived slope of feed conversion efficiency growth

Future regional FEC change for alternative scenarios based on yield growth differentials calculated for crops
Feed conversion efficiencies

Herrero et al. (2014)
FCE versus TFP in the poultry sector

Productivity growth in poultry [% p.a.]

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<td>0.47</td>
<td>0.08</td>
<td>3.60</td>
<td>6.60</td>
<td>2.64</td>
<td>3.91</td>
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Theoretical limit

Biophysical potential

World
EasternAsia - Historical Trend
EasternAsia - Ludena TFP
EasternAsia - Ludena TCH
Europe
FormerSovietUnion
LatinAmericaCarib
MidEastNorthAfr
NorthAmerica
Ocearia
SouthAsia
SouthEastAsia
SubSaharanAfr
Effect of climate change on livestock

- Several channels:
  - Feed availability
  - Feed quality
  - Water availability
  - Heat stress
  - Diseases

- Radiative forcing: RCP8p5 (with and without CO2 fertilization)
  - 5 Climate models
  - 2 Crop models:
    - EPIC
    - LPJmL
      (Müller and Robertson, 2014)
Climate change impact on livestock

- Quality and **quantity of feed**

  - Not accounted for: heat stress, diseases and disease vectors, water, ...

  - **CC effect on grassland:**
    - often positive
    - mostly more favorable than for crops

  - **Productivity change 2050/2000 [%]**

    | WRD | EUR | CIS | OCE | NAM | LAM | EAS | SEA | SAS | MNA | SSA |
    |-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
    |     |     |     |     |     |     |     |     |     |     |     |

  - **2 biophysical models**
    - EPIC_WTco2
    - LPJml_WTco2
    - EPIC_WOco2
    - LPJml_WOco2

  - **With & Without CO₂ effects**

Havlík et al. (FAO, in press)
Climate change impact on livestock

- Livestock product consumption compared to NoCC in 2050 [%]

Havlík et al. (FAO, in press)
Climate change adaptation

- Livestock system transitions triggered by climate change

Absolute ruminant number change due to climate change, by system [2050]

Havlík et al. (FAO, in press)
Livestock production efficiency and land use
Productivity and livestock systems transitions
What is livestock systems transition?

W. Africa 1966 – pastoral system  ➔  2004 – crop-livestock system

Courtesy of B. Gerard
Population, GDP, consumer preferences

MARKET & TRADE: EU + WORLD \(\rightarrow\) PRICES

**Demand**
- Food
- Fibers
- Energy
- Industry

**Markets**

**Production**
- **EPIC**
  - Crop model
  - Worldwide: 18 crops (FAO + SPAM)
  - Management systems: low/high input & irrigated
- **RUMINANT**
  - Digestibility model
  - 7 animals (FAO + Gridded livestock)
  - Management options: fertilizer, irrigation & tillage
- **BIOENERGY**
  - Processing
  - Perennial crops
  - Short rotation coppice
  - Conversion technologies
  - First generation biofuels
  - Second generation biofuels
  - Biomass power plants
- **G4M**
  - Global Forest model
  - Harvestable wood
  - Harvesting costs

**Land use**
- **EU28:** 9 additional crops, crop rotations.
- Management options: fertilizer, irrigation & tillage

**Land cover**
- Cropland
- Grassland
- Short rotation plantations
- Managed forest
- Natural forest
- Other natural land

Gridded representation of world land use

Source: www.globiom.org
Grasslands

- Demand = Supply for each SimU (pixel)
- Demand = livestock numbers * grazing requirements
- Supply = utilized grassland area * forage productivity

- Demand considered as given
- Alternative productivity layers by CENTURY and EPIC
- Utilized grassland area and forage productivity “revealed” by simultaneously minimizing the differences between
  a. livestock demand for forage and forage supply
  b. utilized grassland area and FAOSTAT statistics on permanent meadows and pastures
Grassland productivity – EPIC & CENTURY

Source: Havlík et al. 2014, SI

CENTURY_NAT – CENTURY model for native grasslands; CENTURY_MGT – CENTURY model for productive grasslands; EPIC_EXT – EPIC model for grasslands under extensive management; EPIC_MID – EPIC model for grasslands under semi-intensive management; EPIC_INT – EPIC model for grasslands under intensive management
Forage available for livestock

Source: Havlík et al. 2014, SI

Total area = 1 835 Mha
Livestock production systems transitions

- **Two reference scenarios**

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<tr>
<th>Systems</th>
<th>Herds</th>
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<tr>
<td>FIX</td>
<td>Fixed</td>
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<tr>
<td>DYN</td>
<td>Flexible*</td>
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* in regions with specialized herds
Livestock production systems and GHG emissions in 2030

Source: Havlík et al. 2014
Feed and land productivity in 2030

Source: Havlík et al. 2014
Contribution of LPSTs to GHG mitigation

Source: Havlík et al. 2014
Total abatement calorie cost (TACC) curves

Source: Havlík et al. 2014
Livestock versus crop productivity gains
Impact of increased productivity

Scenarios of future yield development towards 2050
- Baseline = linear historical trend continue
- Low growth (SLOW) = half historical linear trend
- Convergence (CONV) = closing part of yield gap (50% for crops, 25% for ruminant).
  - Distinguish crop case (CONV-C) and livestock case (CONV-L)

Three different pathways of yield increase from baseline to scenario
- Conventional intensification = based on more input. Production price and fertilizer use increase (elasticity 0.75)
- Sustainable intensification = idem but no fertilizer increase (elasticity 0)
- Free tech = based on productivity gains. Production price stable, cost of innovation supported by public expenditure.
Findings

Source: Valin et al., ERL, 2013
Findings

Source: Valin et al., ERL, 2013
What if livestock system transitions are considered?

- Projections 2000-2030
  - S0: No crop yield increase
  - S: -50% yield improvement
- Fixed demand on B reference:
  - no rebound effect

- B: Baseline = historical trend
- C: + 100% in developing regions

Source: Havlík et al., AJAE, 2013
Results: Market and production impacts

Prices index across scenarios

Distribution of ruminant systems

Source: Havlík et al., AJAE, 2013
Impact on land use change in 2030

Source: Havlík et al., AJAE, 2013
Stimulating systems transitions through grassland management

Cattle ranching intensification in Brazil can reduce global greenhouse gas emissions by sparing land from deforestation

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Grassland intensification

- Brazil only
- Conventional and SEMI-INTENSIVE systems
- SEMI-INTENSIVE system
  - Grassland productivity double of the conventional productivity
  - Annual cost differential between the conventional pasture and the semi-intensive pasture averages 80 USD per hectare depending on the remoteness from the markets (includes fertilizer, lime, pasture seed, and labor)
Leakage or rebound?

Two policies tested

1) **Subsidy** per hectare of semi-intensive grassland

2) **Tax** per hectare of conventional grassland

Source: Cohn et al., 2014
Brazil: REDD potential of pasture intensification policies

Beef transport cost as percentage of final selling price

Cohn et al., 2014
Brazil: REDD potential of pasture intensification policies

Beef herd in 2000 [1000 TLUs]

Cohn et al., 2014
Brazil: REDD potential of pasture intensification policies

Beef herd in 2030 [1000 TLUs]

Cohn et al., 2014
Brazil: REDD potential of pasture intensification policies

Deforestation due to pasture expansion: 2030 baseline [1000ha]

Cohn et al., 2014
Brazil: REDD potential of pasture intensification policies

Deforestation due to pasture expansion: 2030 with subsidy for intensification [1000ha]

Cohn et al., 2014
Summary
Summary and conclusions

- (Partial factor) productivity in the livestock sector – if measured as feed conversion efficiency, is ambivalent:
  - Large heterogeneity and gaps in the ruminant sector
    - But physical and institutional barriers may hinder closing them
  - More limited improvement possible in pig and poultry
- Productivity improvement for cattle could decrease considerably pressure on the natural system
  - Demand side mitigation can be effective but large gains can be achieved on production side
- Livestock and crop sectors cannot be considered separately in the environmental impact debate:
  - Both sector interacts
  - Livestock pressure on the system is preponderant and cannot be forgotten
Thank you!

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References


Soussana, J.-F. et al. (2013). Storylines for the livestock sector scenarios in EU, studied SICA regions and global level, ANIMALCHANGE.
