International Institute for Applied Systems Analysis
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Conference on Agricultural Productivity and the Environment
11-12 March 2015, USDA, Washington DC

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

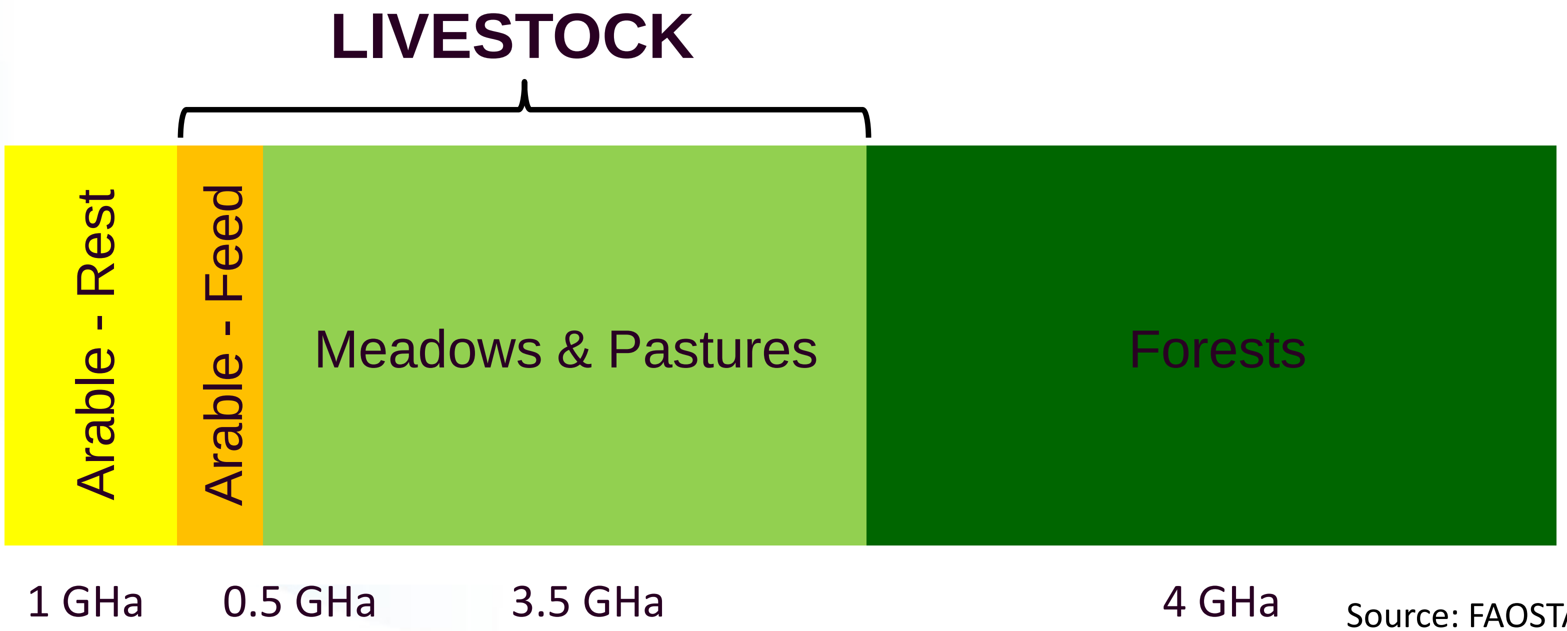
science for global insight

The context

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

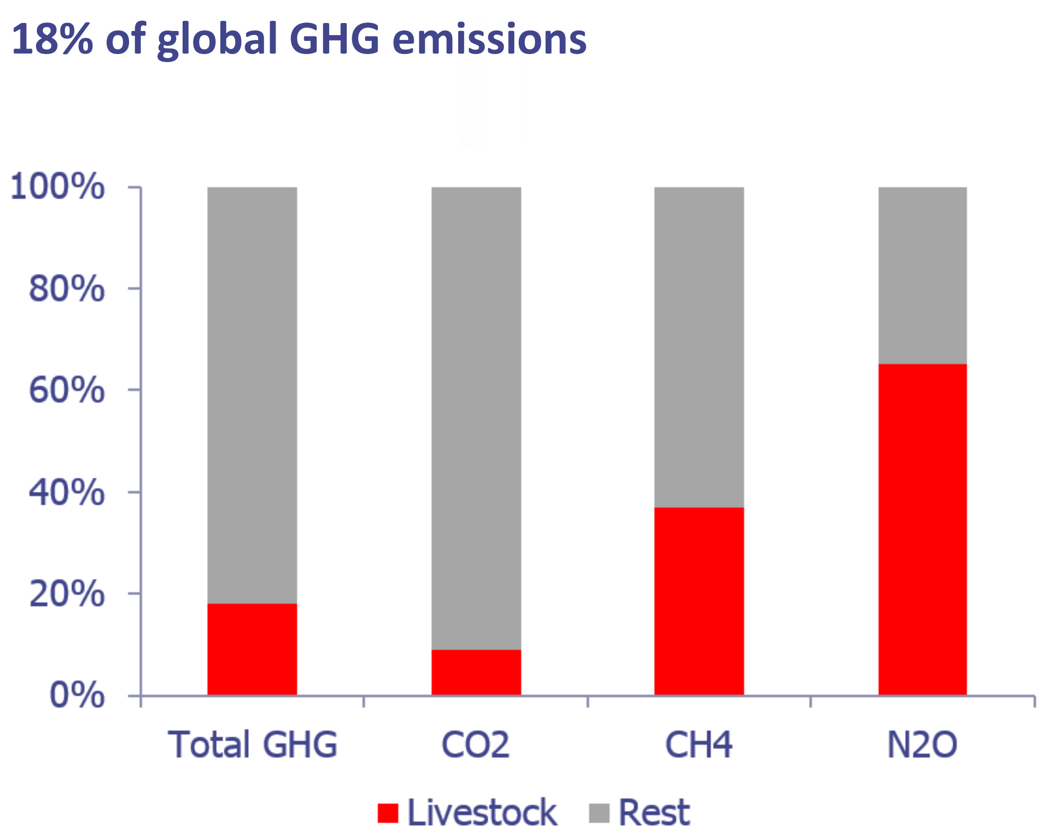
Source: Steinfeld et al. (2006)

- **30% of global land area**



Source: FAOSTAT

Livestock sector



Source: Steinfeld et al. (2006)

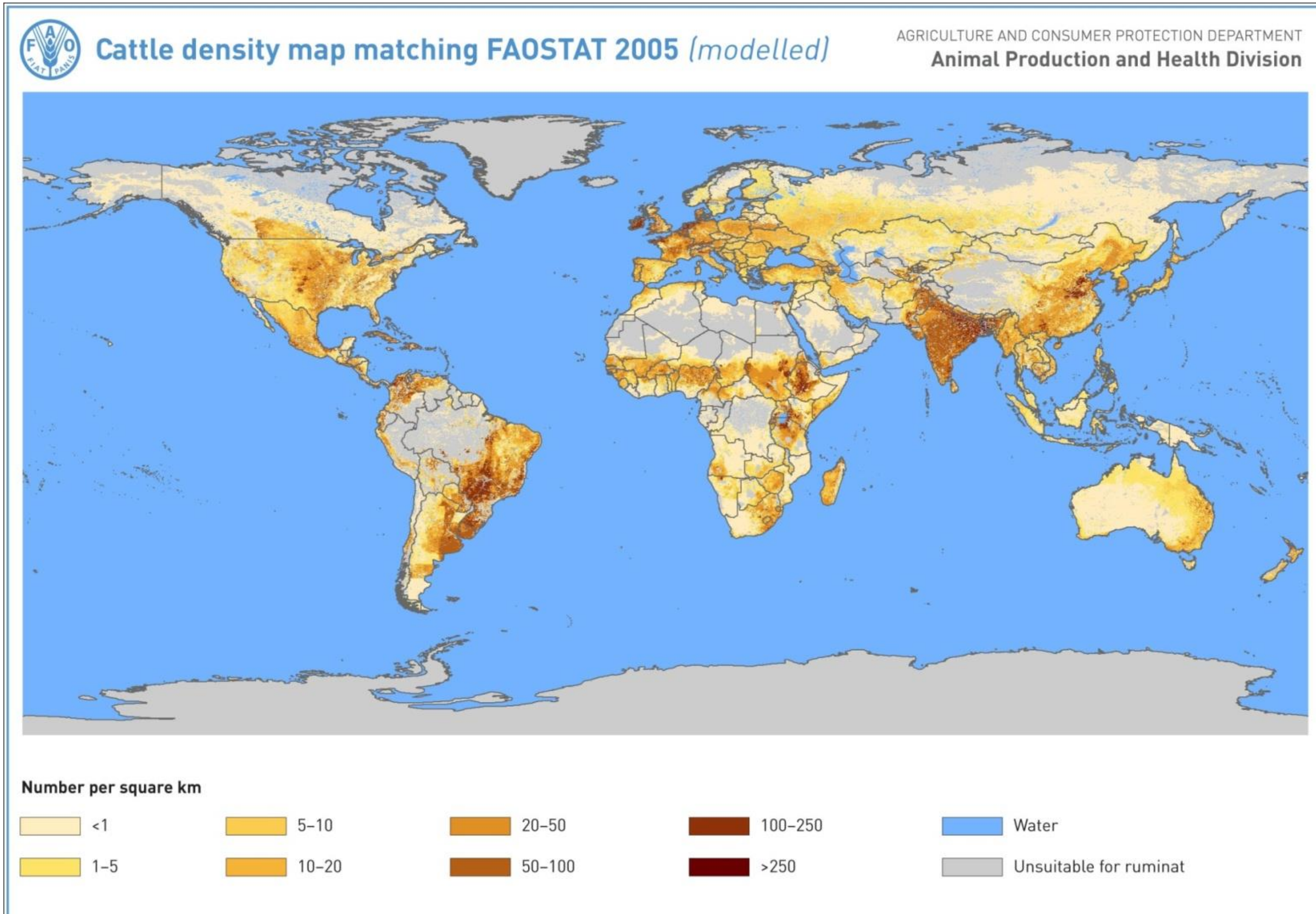
Outline

- 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

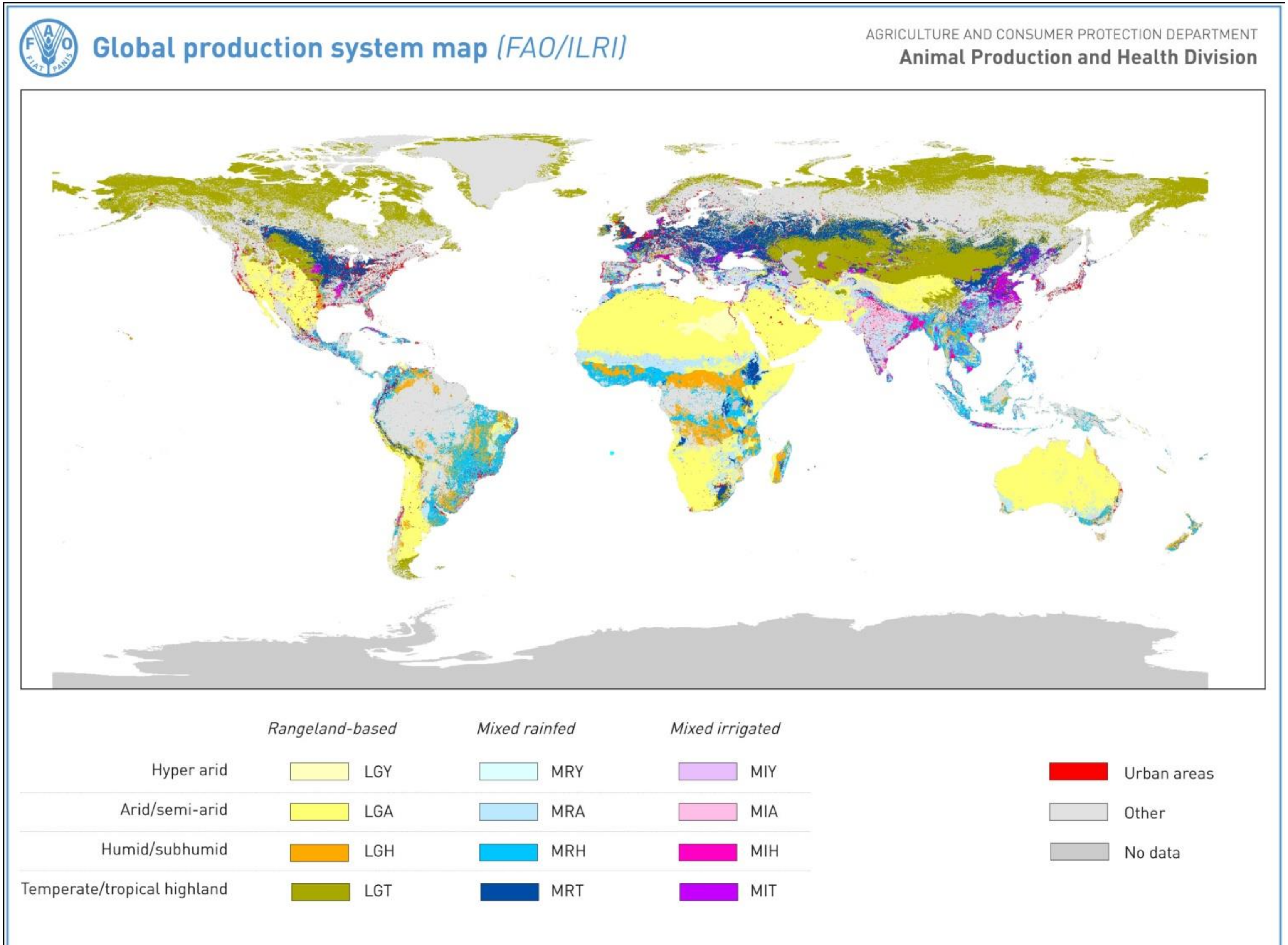
Gridded Livestock of the World – Robinson et al. (2011)



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

PNAS

SPECIAL FEATURE

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

Mario Herrero[a,b,1], Petr Havlík[b,c], Hugo Valin[c], An Notenbaert[b], Mariana C. Rufino[b], Philip K. Thornton[d], Michael Blümmel[b], Franz Weiss[c], Delia Grace[b], and Michael Obersteiner[c]

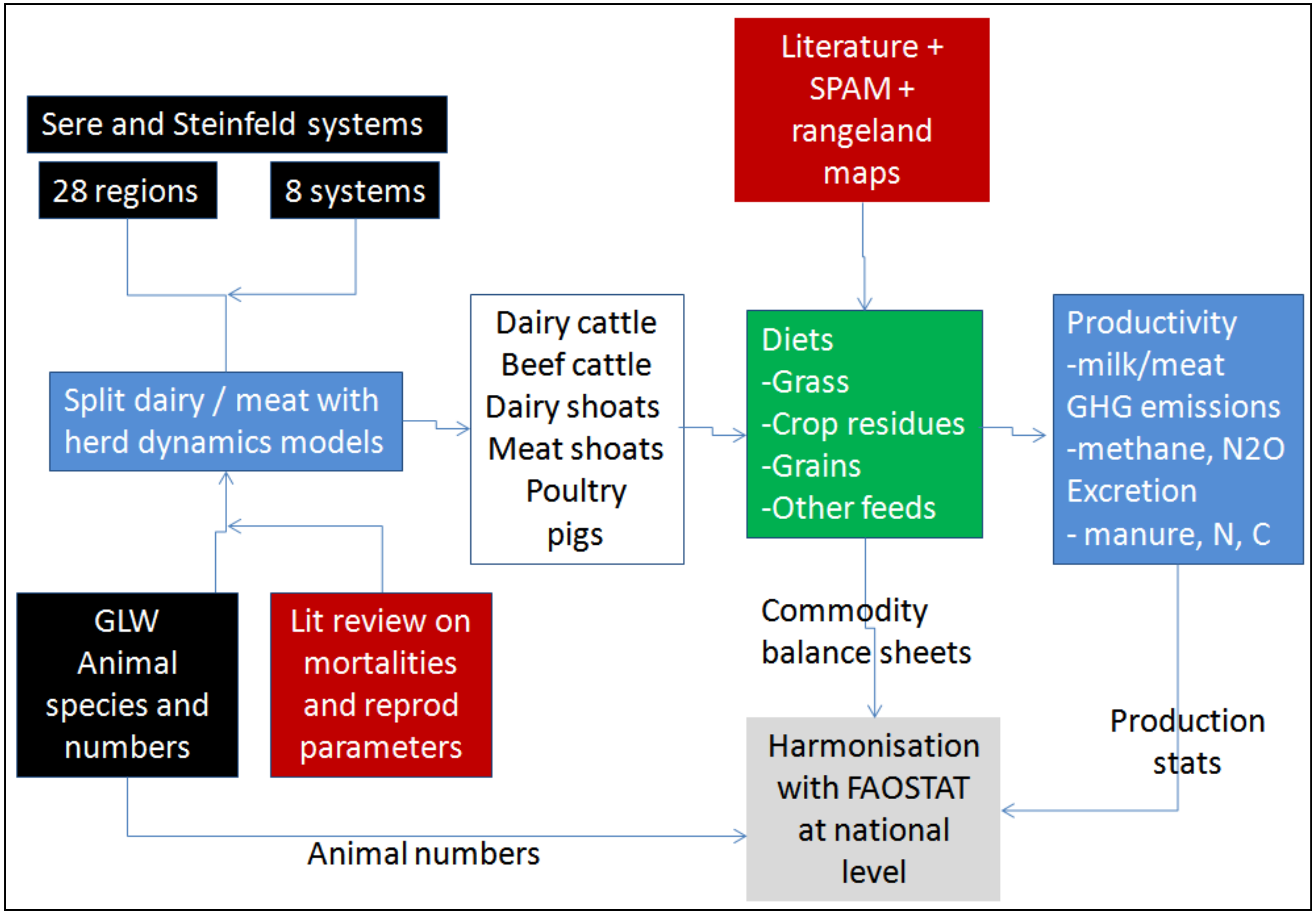
[a]Commonwealth Scientific and Industrial Research Organization, St Lucia, QLD 4067, Australia; [b]International Livestock Research Institute, 00100 Nairobi, Kenya; [c]International Institute for Applied Systems Analysis, Laxenburg, Austria; and [d]CGIAR Research Programme on Climate Change, Agriculture and Food Security, International Livestock Research Institute, 00100 Nairobi, Kenya

Edited by William C. Clark, Harvard University, Cambridge, MA, and approved October 15, 2013 (received for review April 30, 2013)

Livestock sector coverage

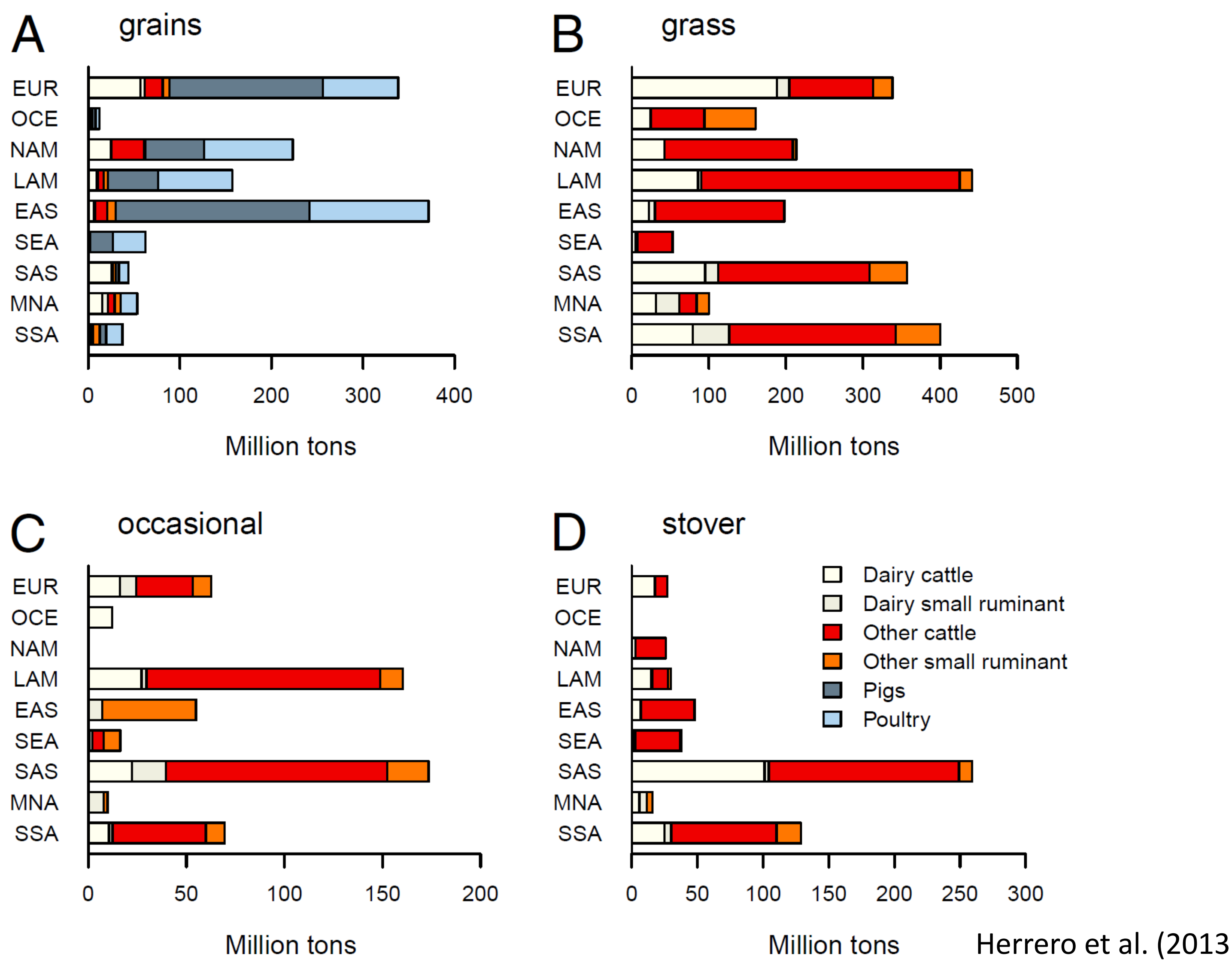
- **Livestock categories:**
  - Bovines: Dairy & Other
  - Sheep & Goats: Dairy & Other
  - Poultry: Laying hens, Broilers, Mixed
  - Pigs
- **Production systems:**
  - **Ruminants**
    - Grass based: Arid, Humid, Temperate/Highlands
    - Mixed crop-livestock: Arid, Humid, Temperate/Highlands
    - Urban, Other
  - **Monogastrics**
    - Smallholders
    - Industrial

Production systems parameterization



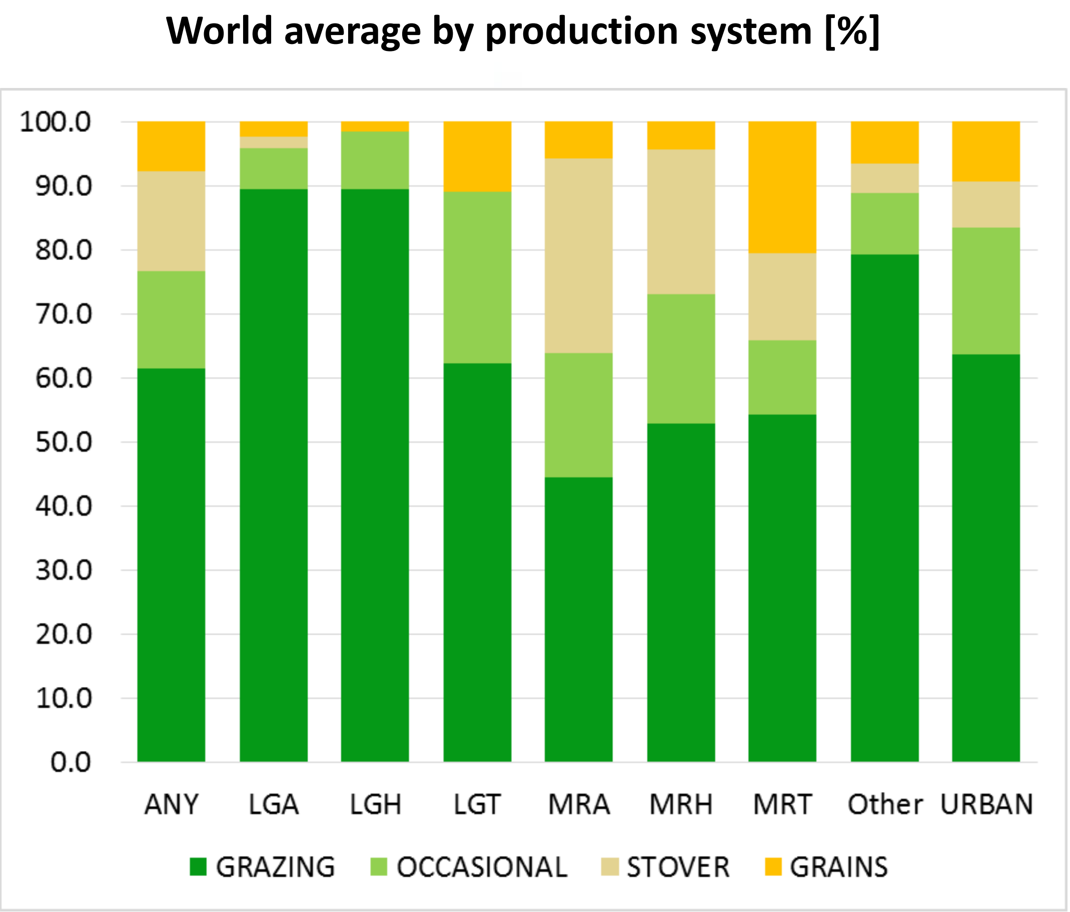
Herrero et al. (2013)

Biomass use for livestock



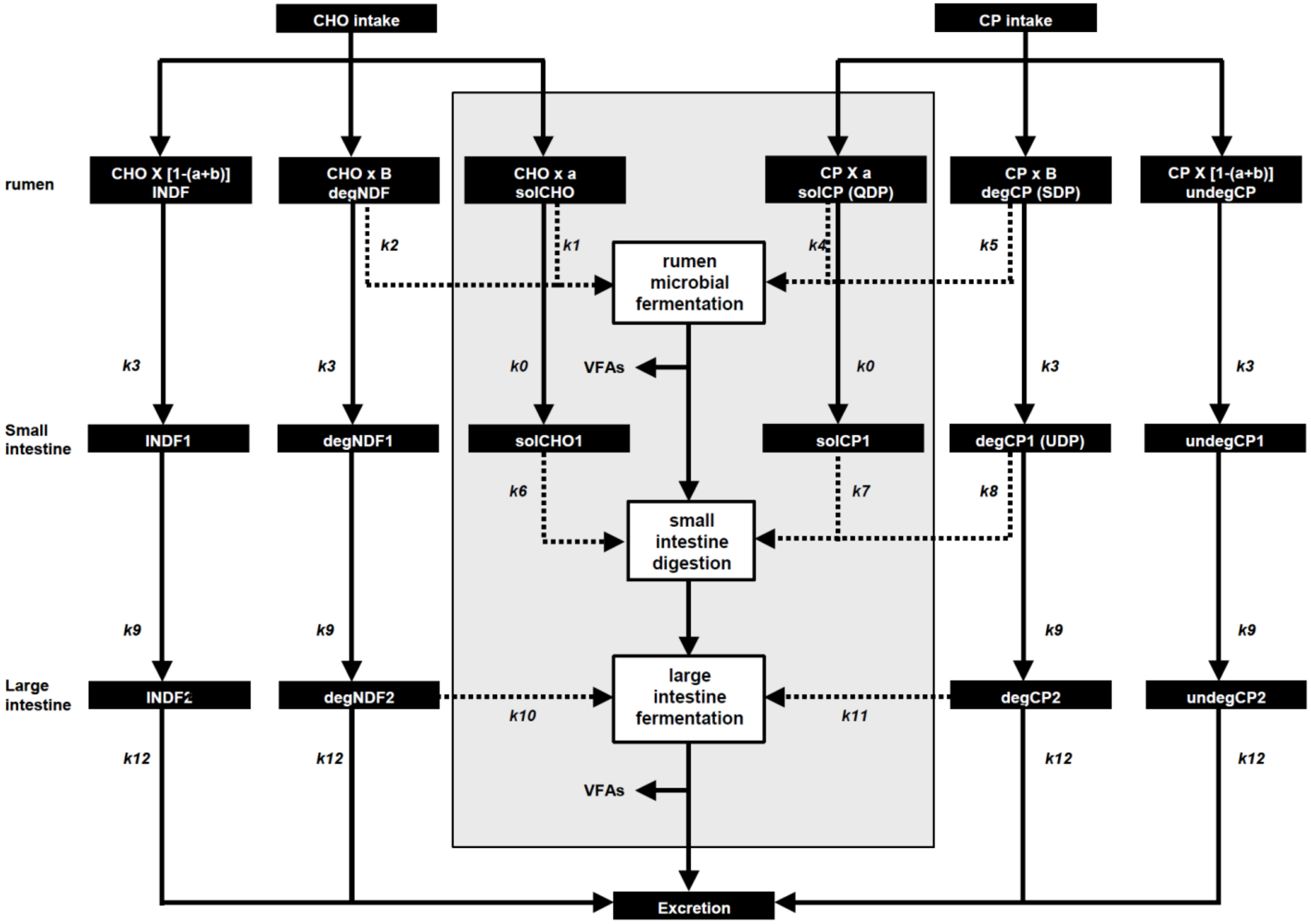
Herrero et al. (2013)

Composition of ruminant diets



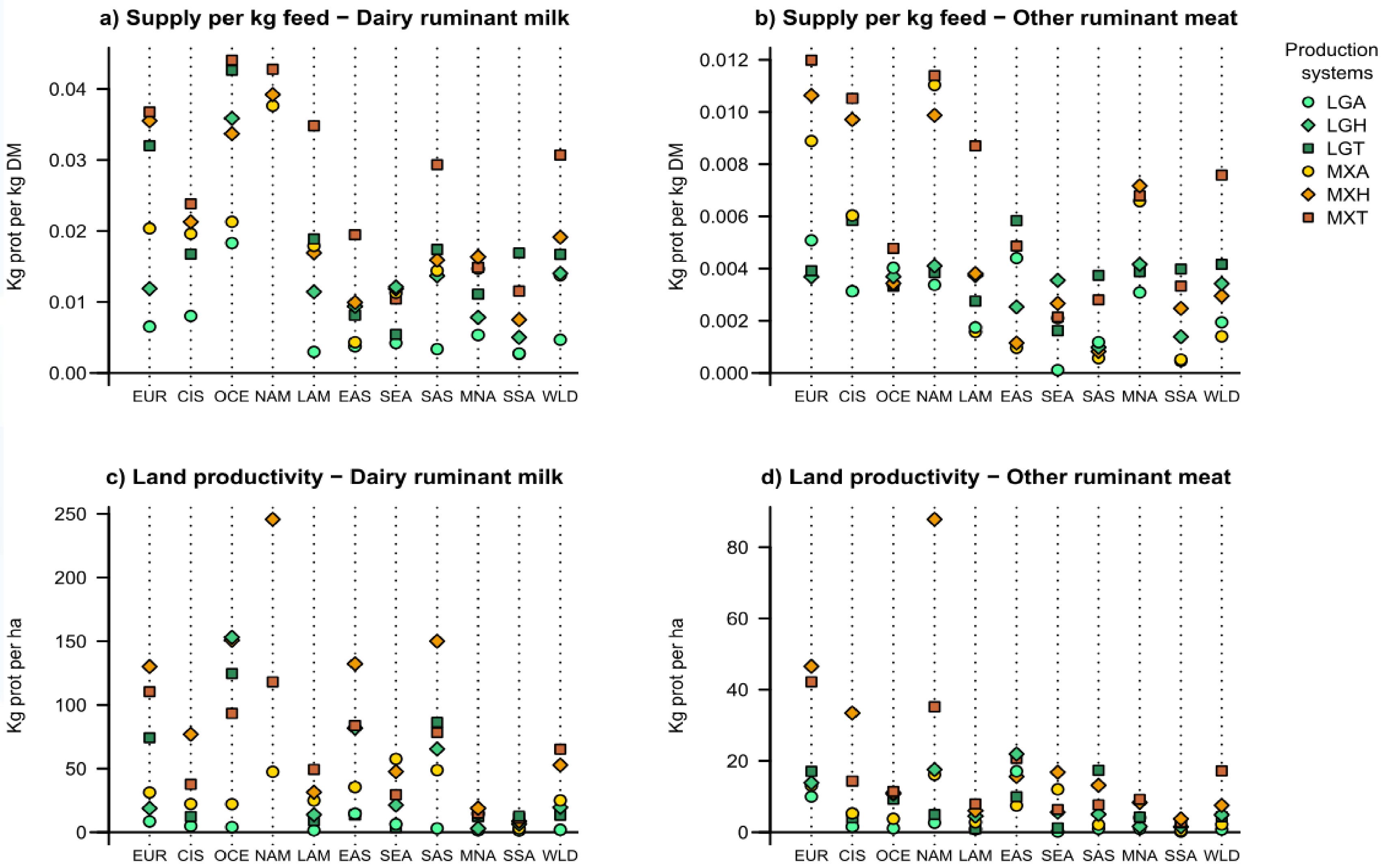
Herrero et al. (2013)

Digestibility model calculations

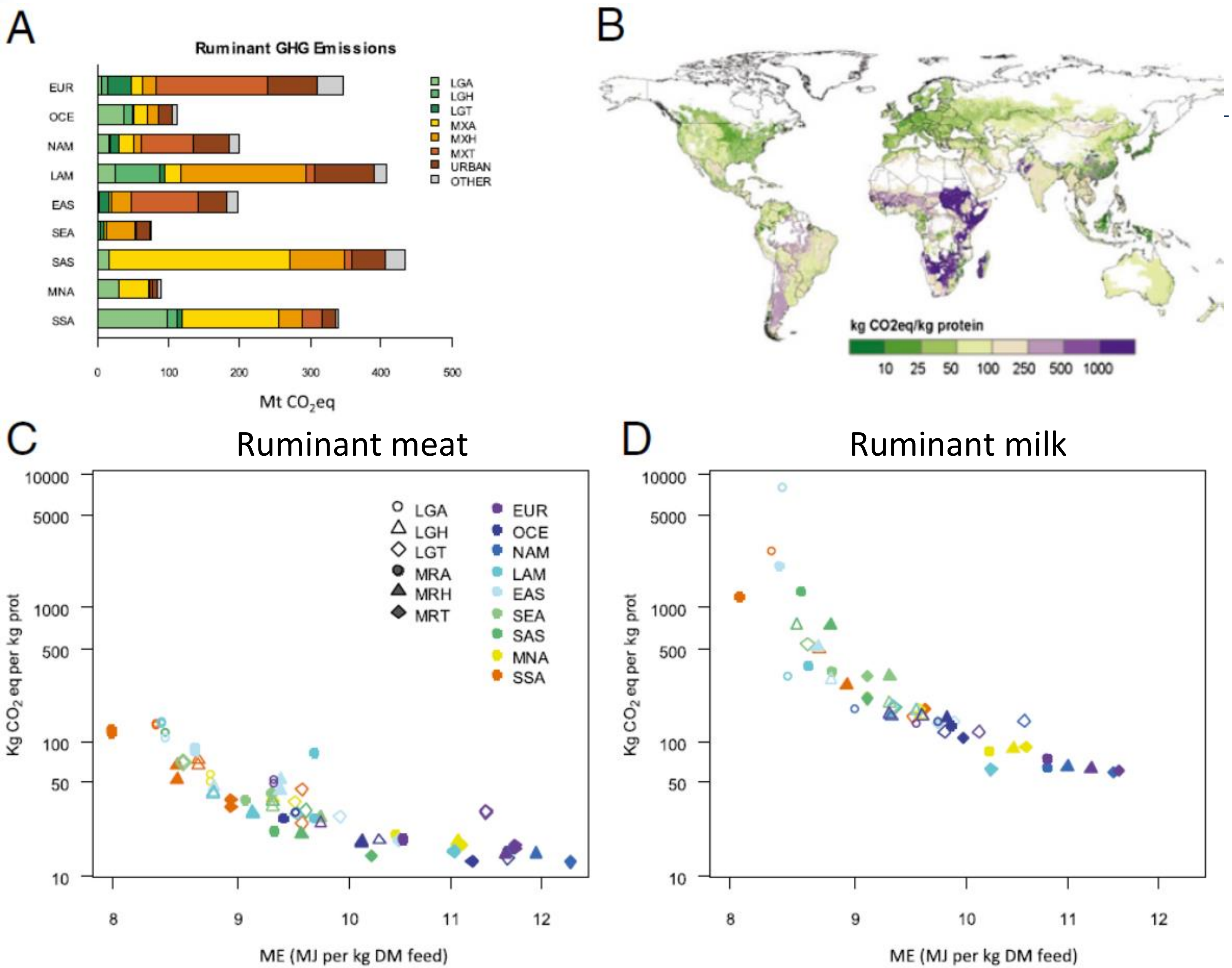


Herrero et al. (2013)

Ruminant production efficiency



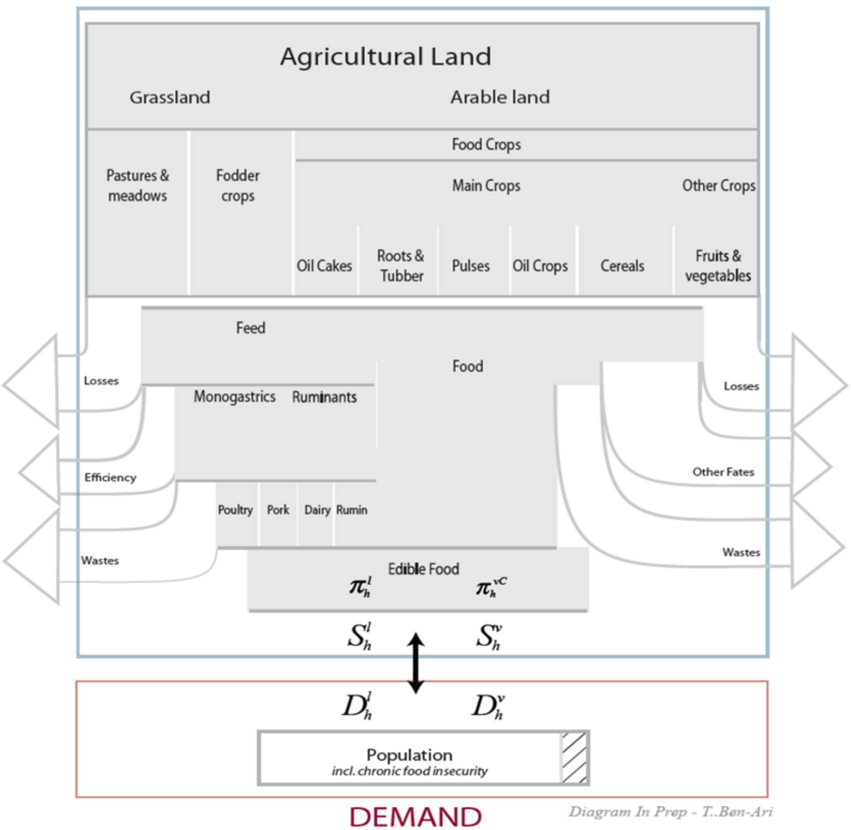
Adapted from Herrero et al. (2013)



Herrero et al. (2013)

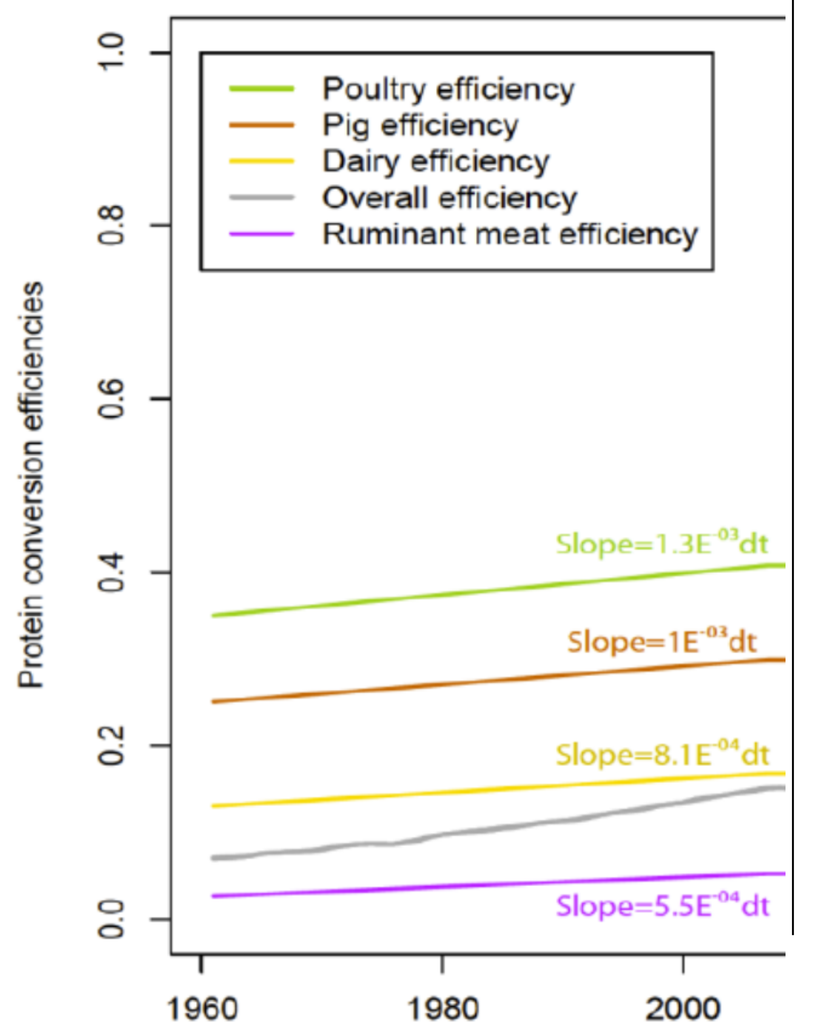
Feed conversion efficiencies

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



Historical feed conversion efficiencies

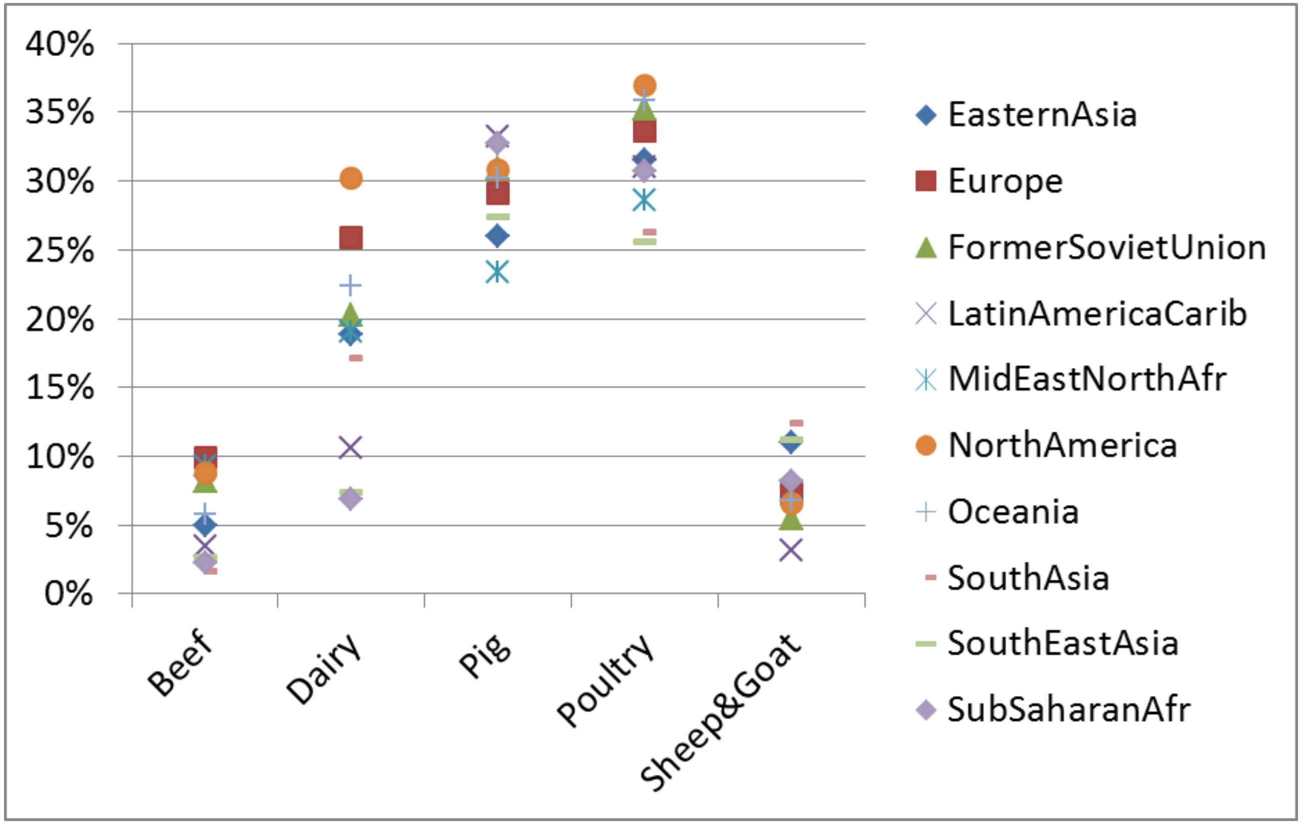
[kg protein in product / kg protein in feed]



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

$$E(t) = E_c + (E_0 - E_c)e^{(-a.t/Ec)}$$

E(t) – projected feed conversion efficiency in year *t*

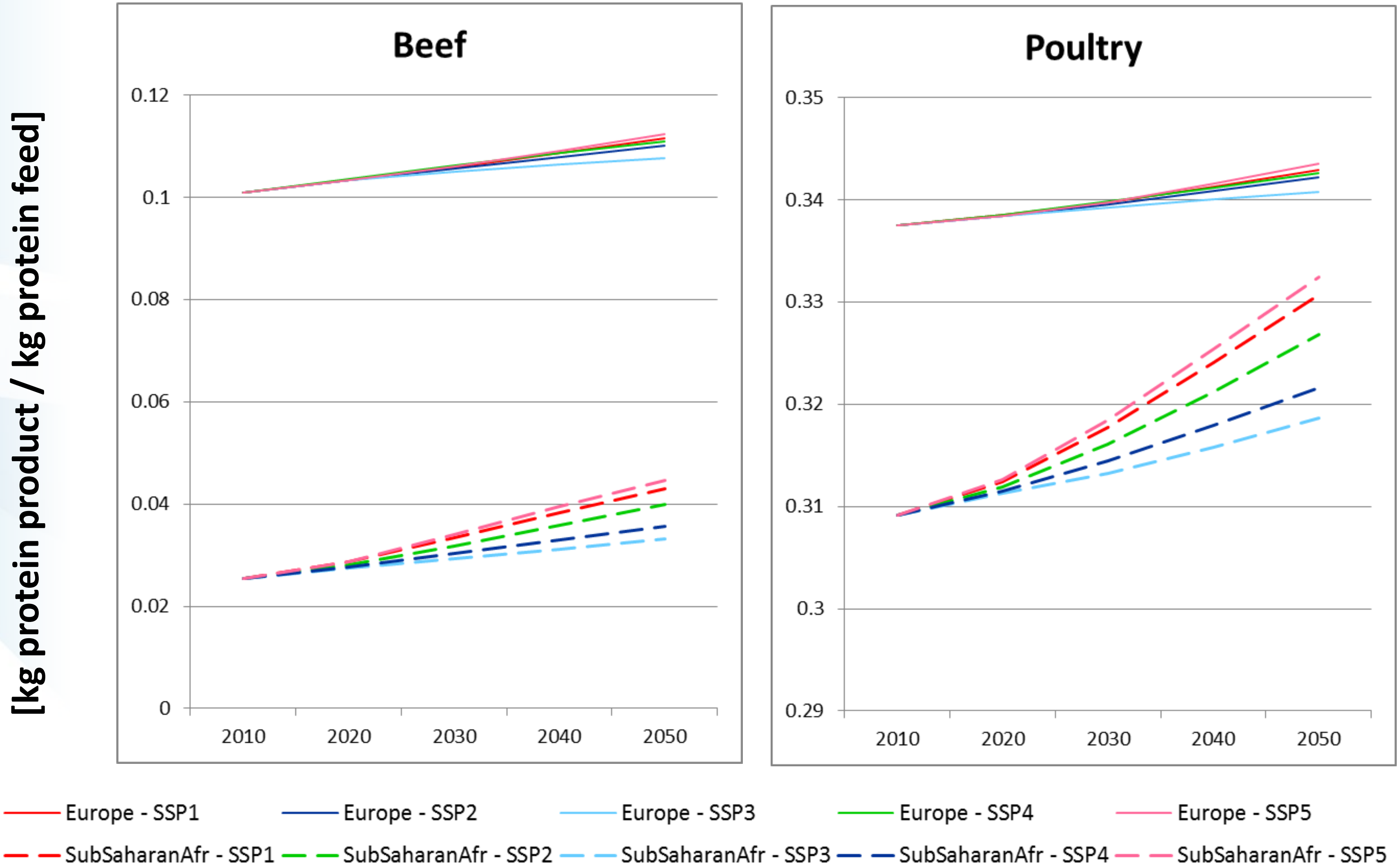
E_0 – 2000 feed conversion efficiency

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

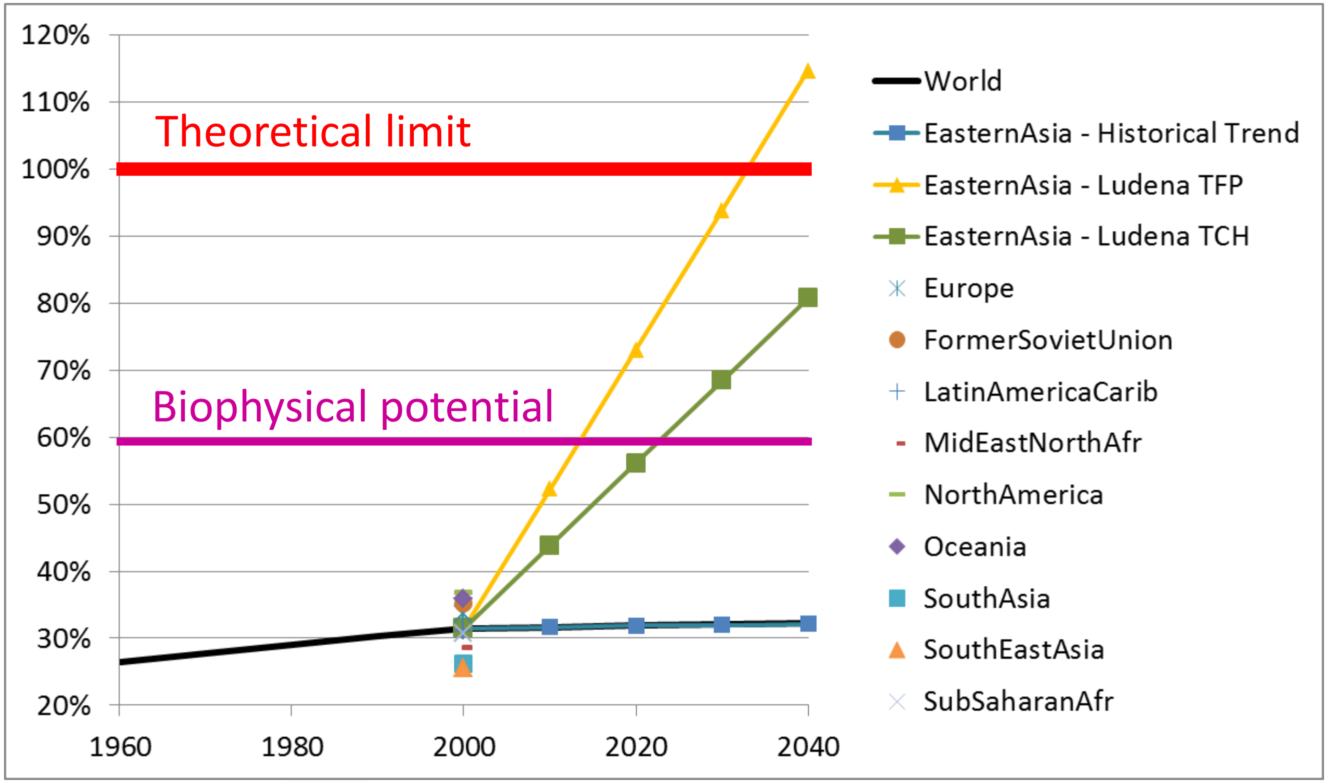


Herrero et al. (2014)

FCE versus TFP in the poultry sector

Productivity growth in poultry [% p.a.]

Historical FCE World (1961-2010)	Trend FCE China (2001-2040)	Ludena07: TFP World (2001-2040)	Ludena07: TFP China (2001-2040)	Ludena07: TCH World (2001-2040)	Ludena07: TCH China (2001-2040)
0.47	0.08	3.60	6.60	2.64	3.91



Effect of climate change on livestock

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

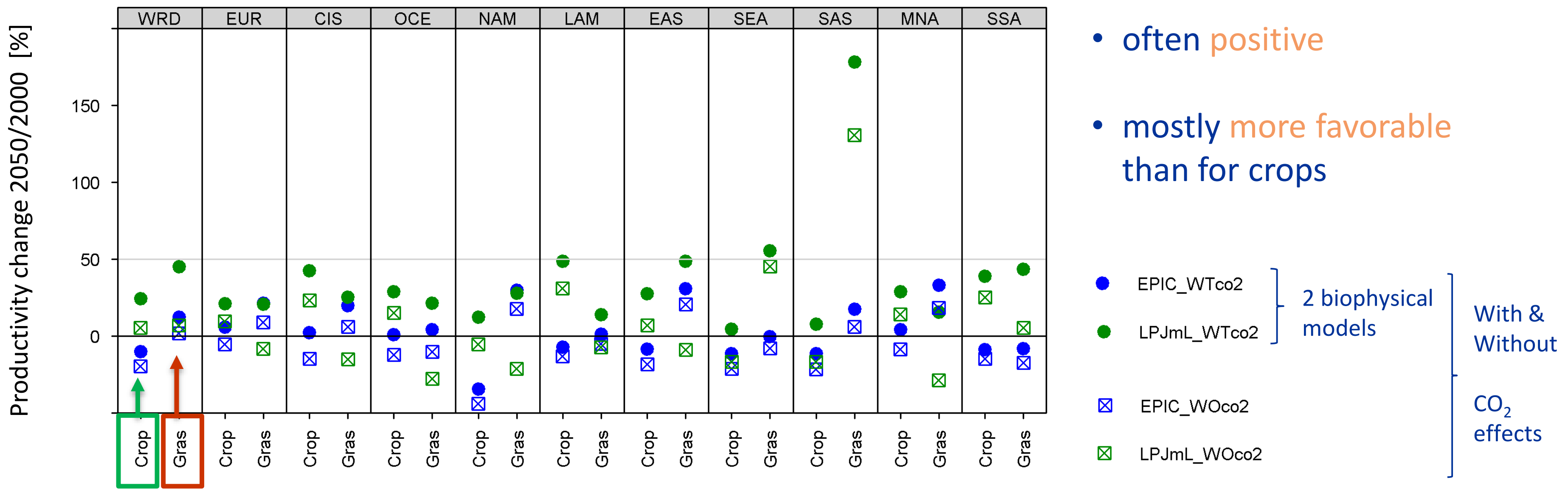
- Radiative forcing: RCP8p5 (with and without CO2 fertilization)
  - 5 Climate models
  - 2 Crop models:
    - EPIC
    - LPJmL

    (Müller and Robertson, 2014)

ISI-MIP

Climate change impact on livestock

- Quality and **quantity of feed**



CC effect on **grassland:**

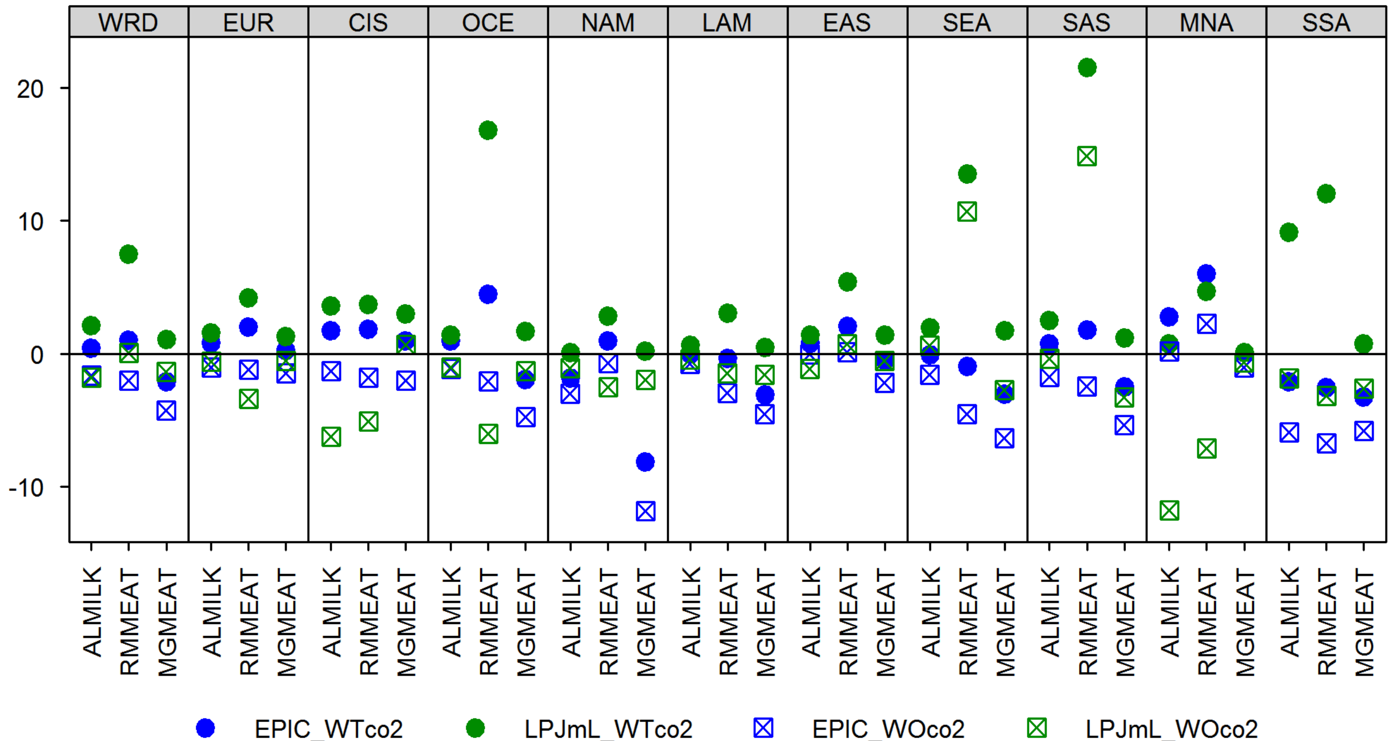
- often positive
- mostly more favorable than for crops

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

Havlík et al. (FAO, in press)

Climate change impact on livestock

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

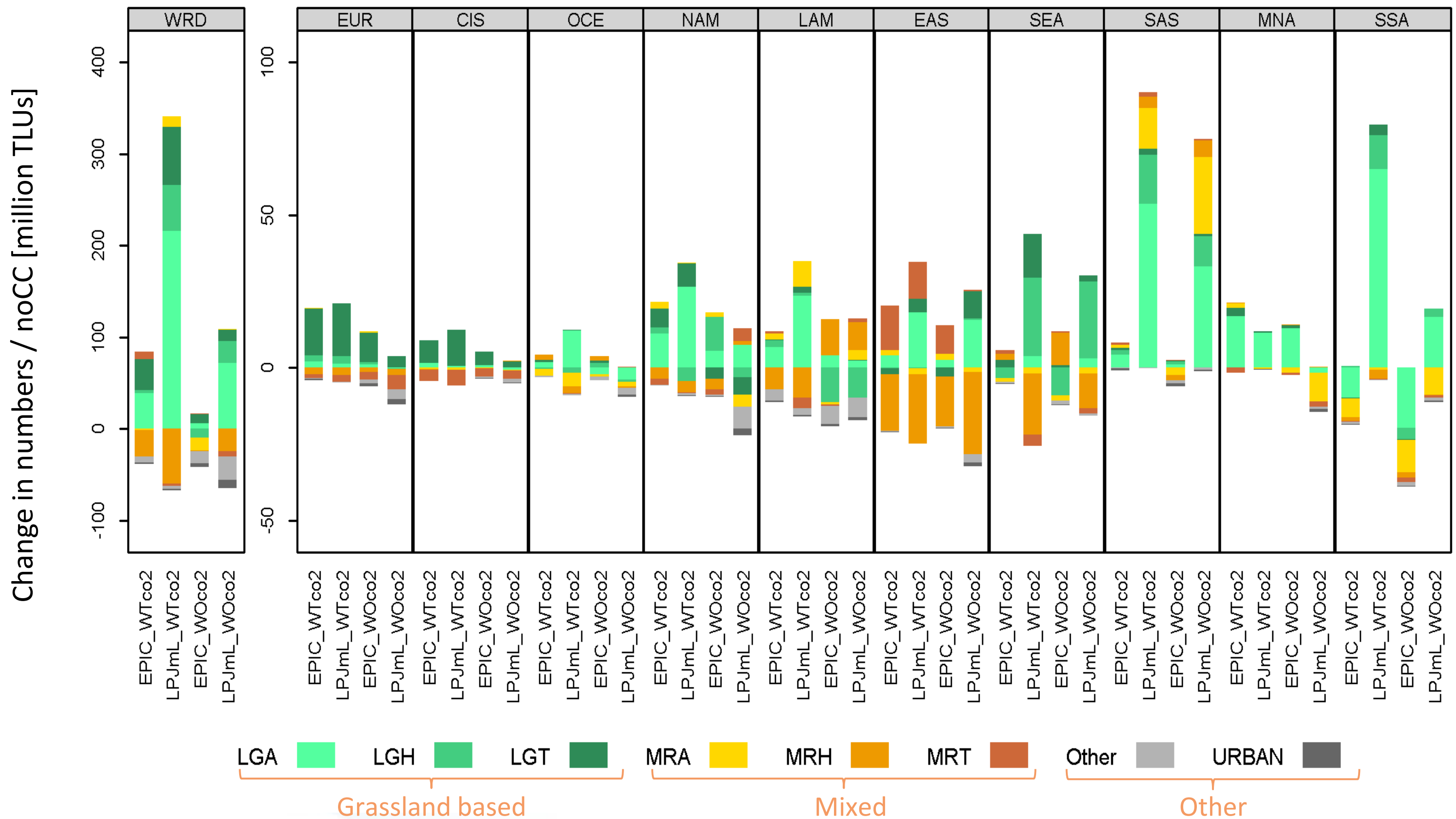


Havlík et al. (FAO, in press)

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

PNAS

Climate change mitigation through livestock system transitions

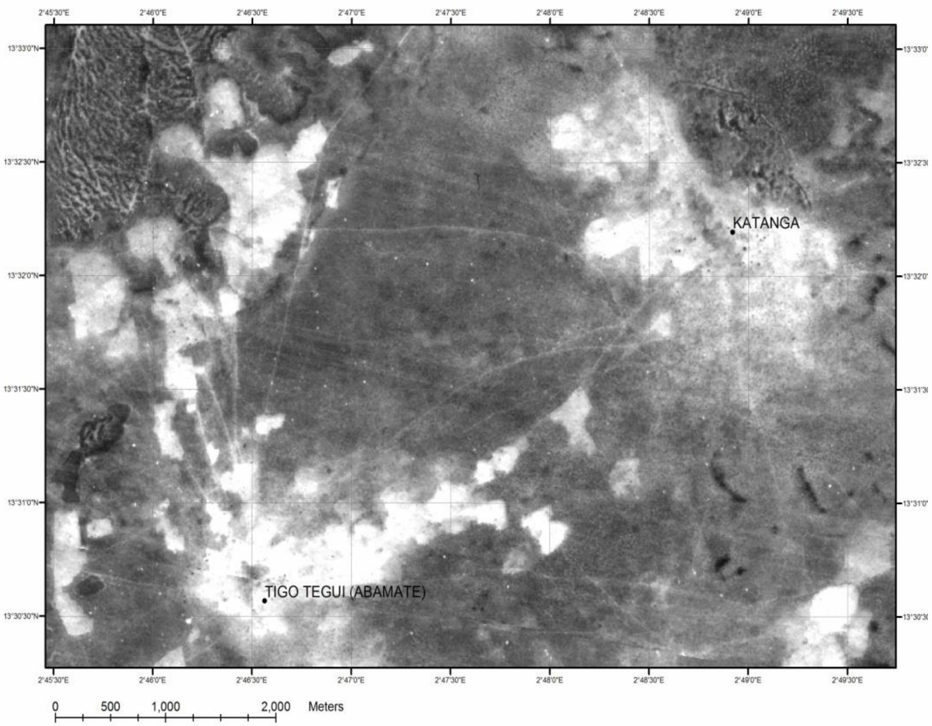
Petr Havlík[a,b,1], Hugo Valin[a], Mario Herrero[b,c], Michael Obersteiner[a], Erwin Schmid[d], Mariana C. Rufino[b,e], Aline Mosnier[a], Philip K. Thornton[f], Hannes Böttcher[a], Richard T. Conant[b,g], Stefan Frank[a], Steffen Fritz[a], Sabine Fuss[a,h], Florian Kraxner[a], and An Notenbaert[b,i]

[a]Ecosystems Services and Management Program, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria; [b]Sustainable Livestock Futures Programme, International Livestock Research Institute, Nairobi, 00100, Kenya; [c]Sustainable Agriculture Flagship, Commonwealth Scientific and Industrial Research Organisation, St. Lucia, QLD 4067, Australia; [d]Institute for Sustainable Economic Development, University of Natural Resources and Life Sciences, A-1180 Vienna, Austria; [e]Forest and Environment Program, Center for International Forestry Research, Nairobi, 00100, Kenya; [f]Consultative Group on International Agricultural Research Program on Climate Change, Agriculture and Food Security, International Livestock Research Institute, Nairobi, 00100, Kenya; [g]Natural Resource Ecology Laboratory and Department of Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO 80523-1499; [h]Resources and International Trade, Mercator Research Institute on Global Commons and Climate Change, 10829 Berlin, Germany; and [i]Tropical Forages Program, International Center for Tropical Agriculture, Nairobi, 00621, Kenya

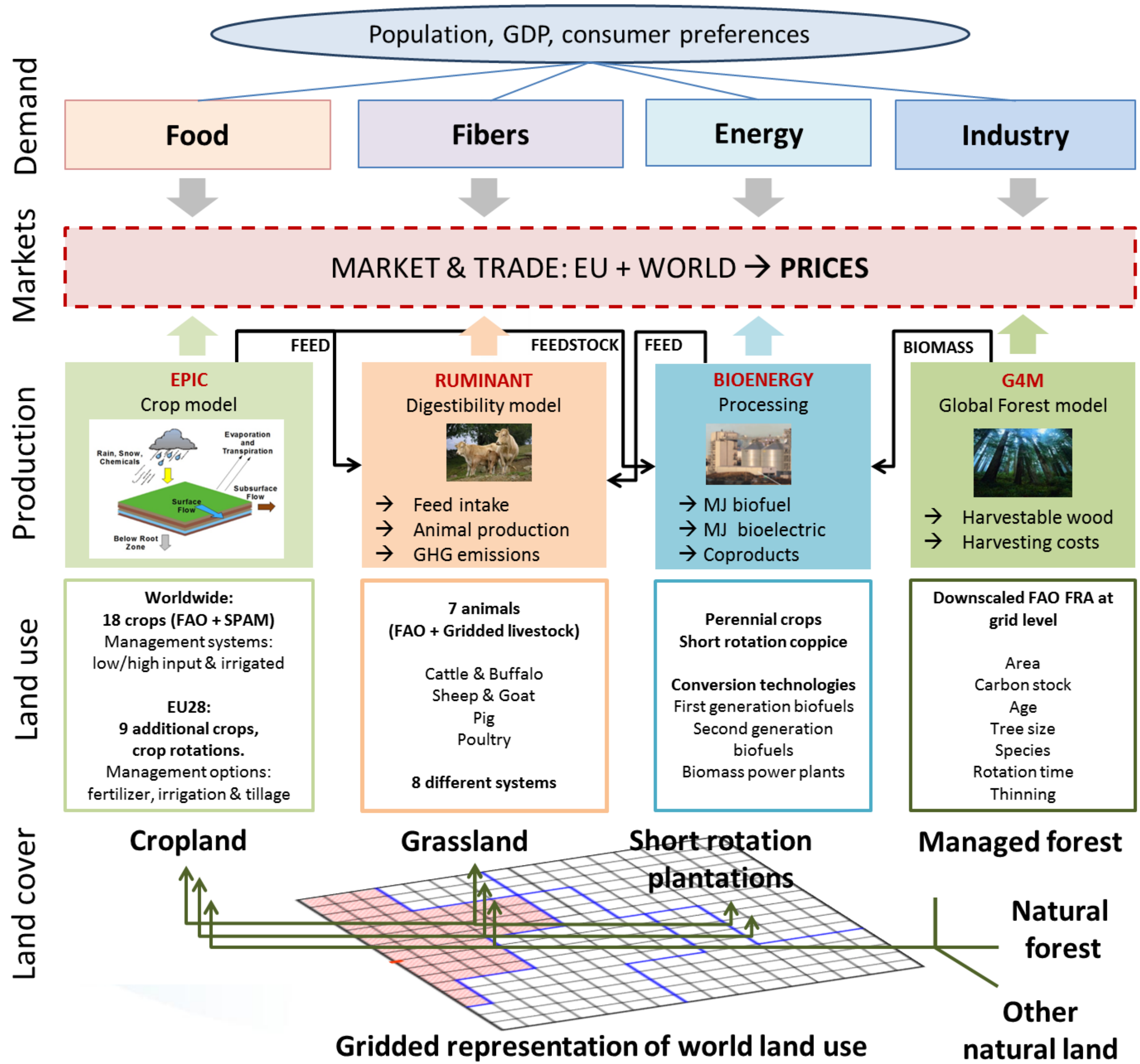
Edited by William C. Clark, Harvard University, Cambridge, MA, and approved January 29, 2014 (received for review April 30, 2013)

What is livestock systems transition?

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



Courtesy of B. Gerard



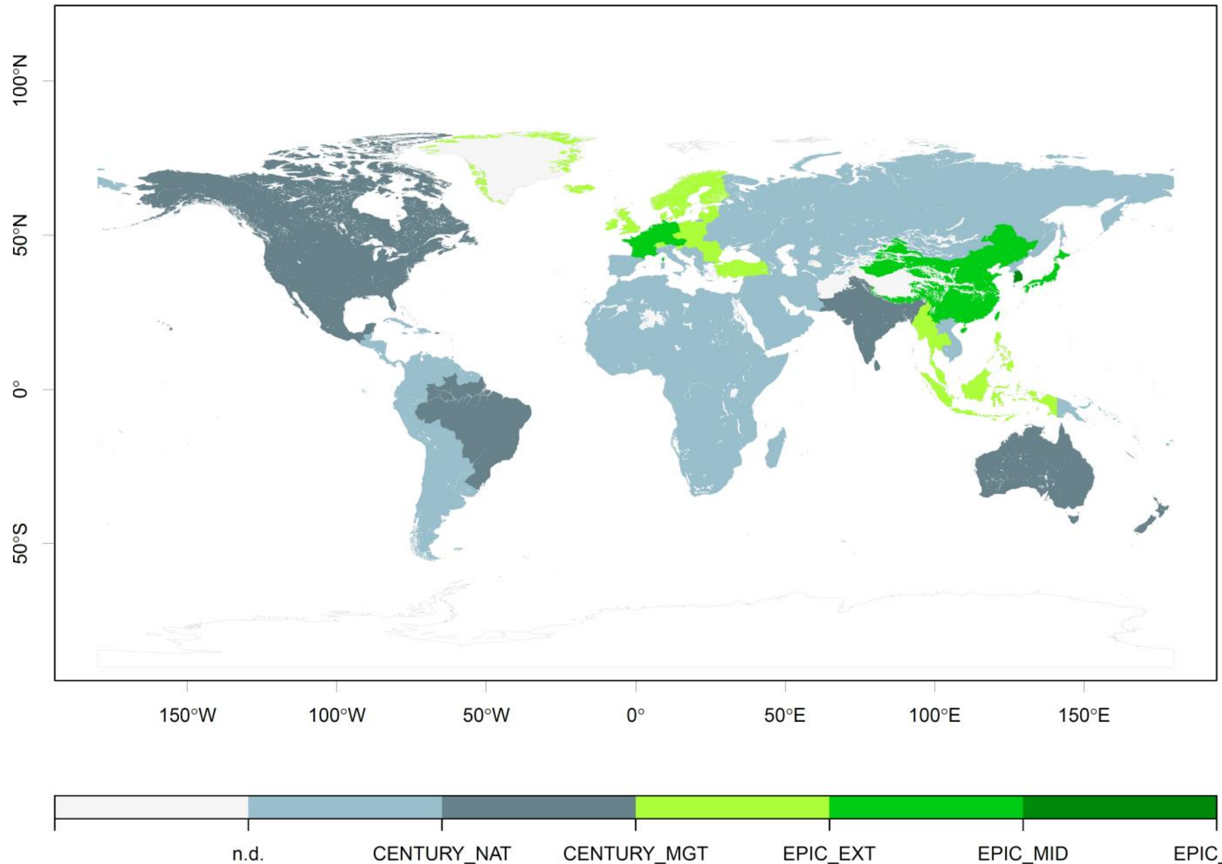
Source: www.globiom.org

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

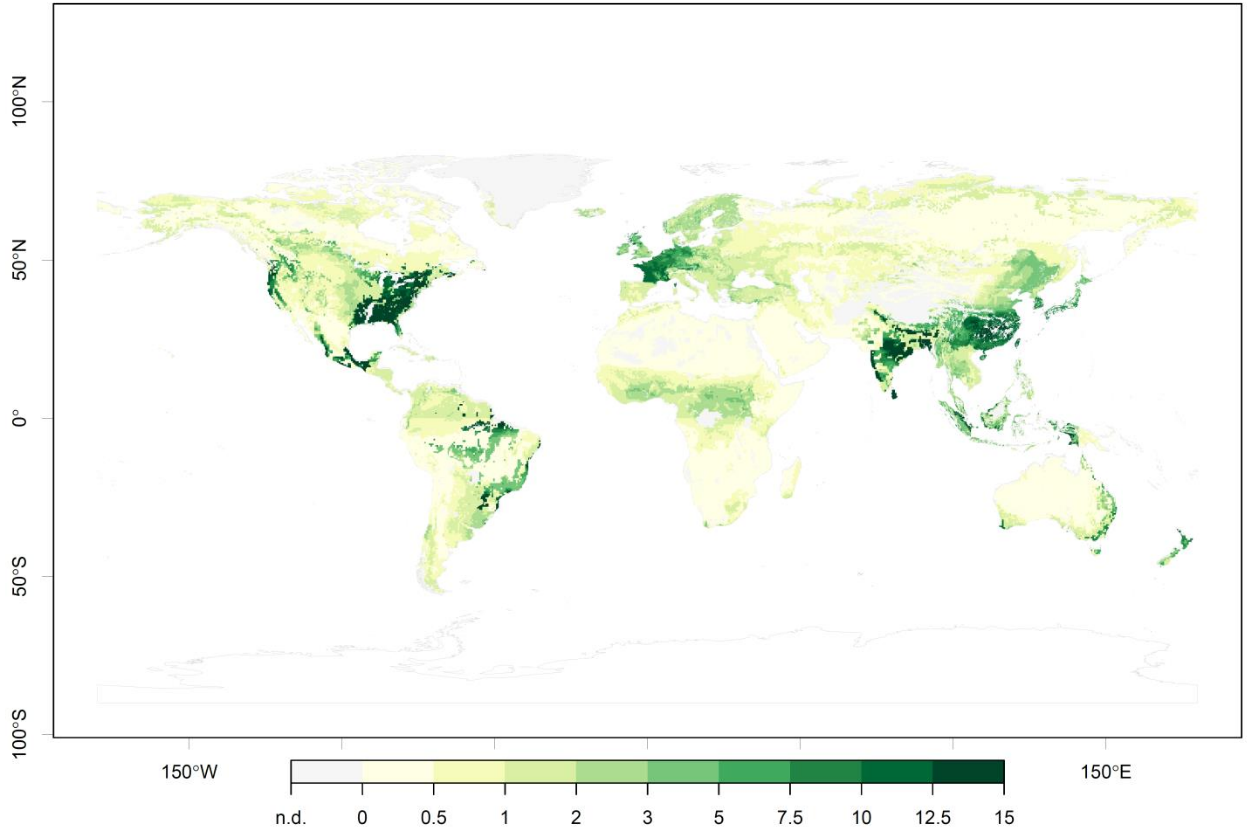


Source:

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

tDM/ha

Total area = 1 835 Mha

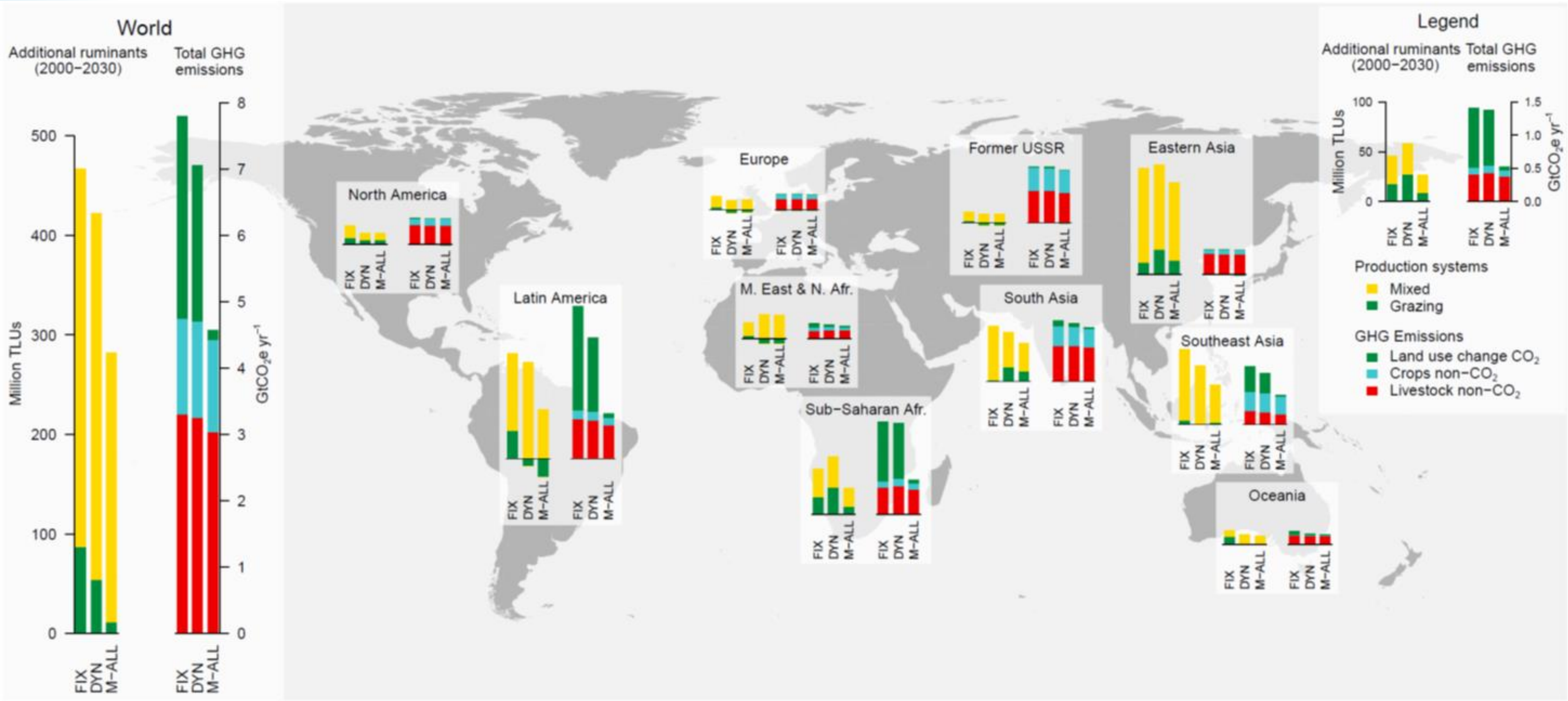
Livestock production systems transitions

- **Two reference scenarios**

	Systems	Herds
FIX	Fixed	Fixed
DYN	Flexible	Flexible*

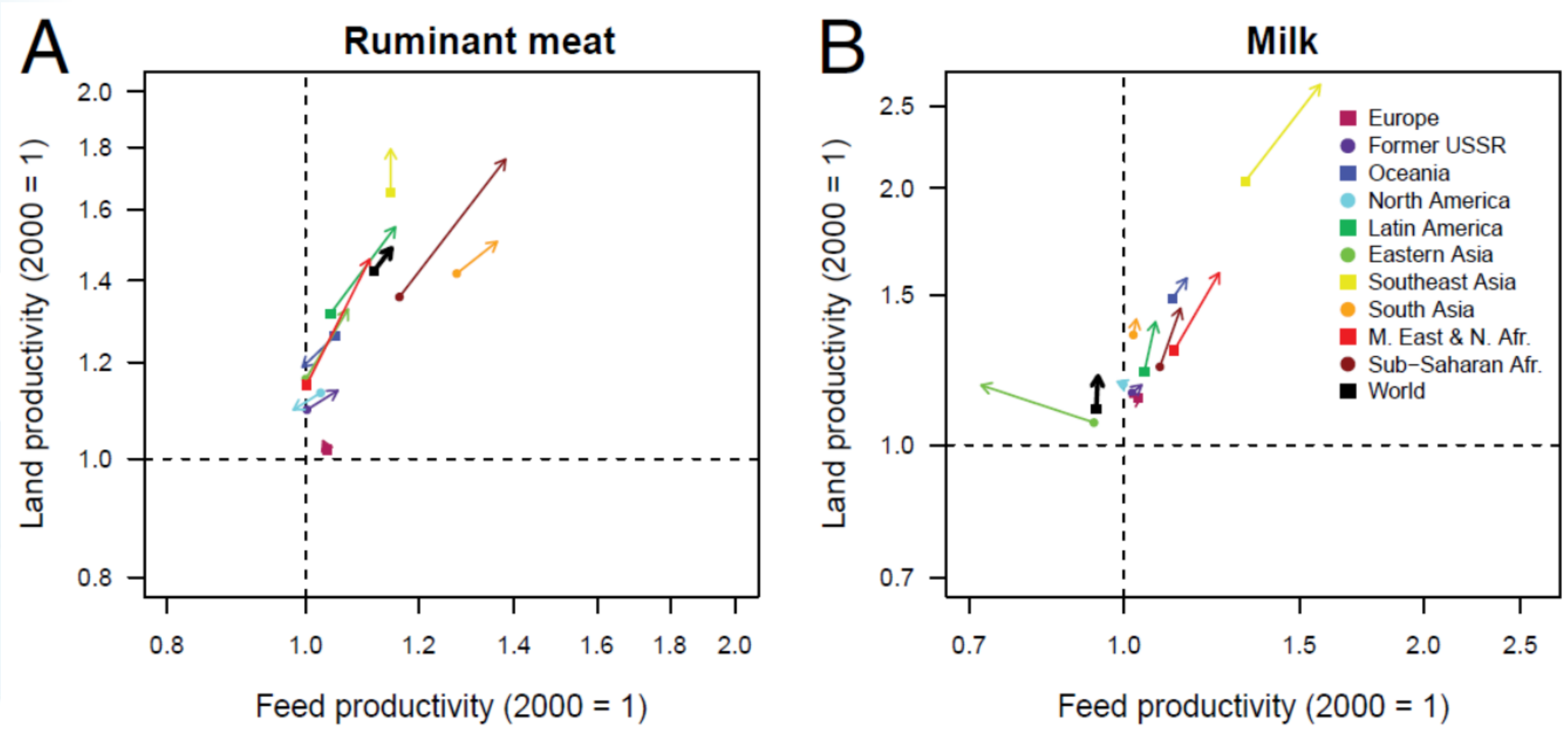
* in regions with specialized herds

Livestock production systems and GHG emissions in 2030



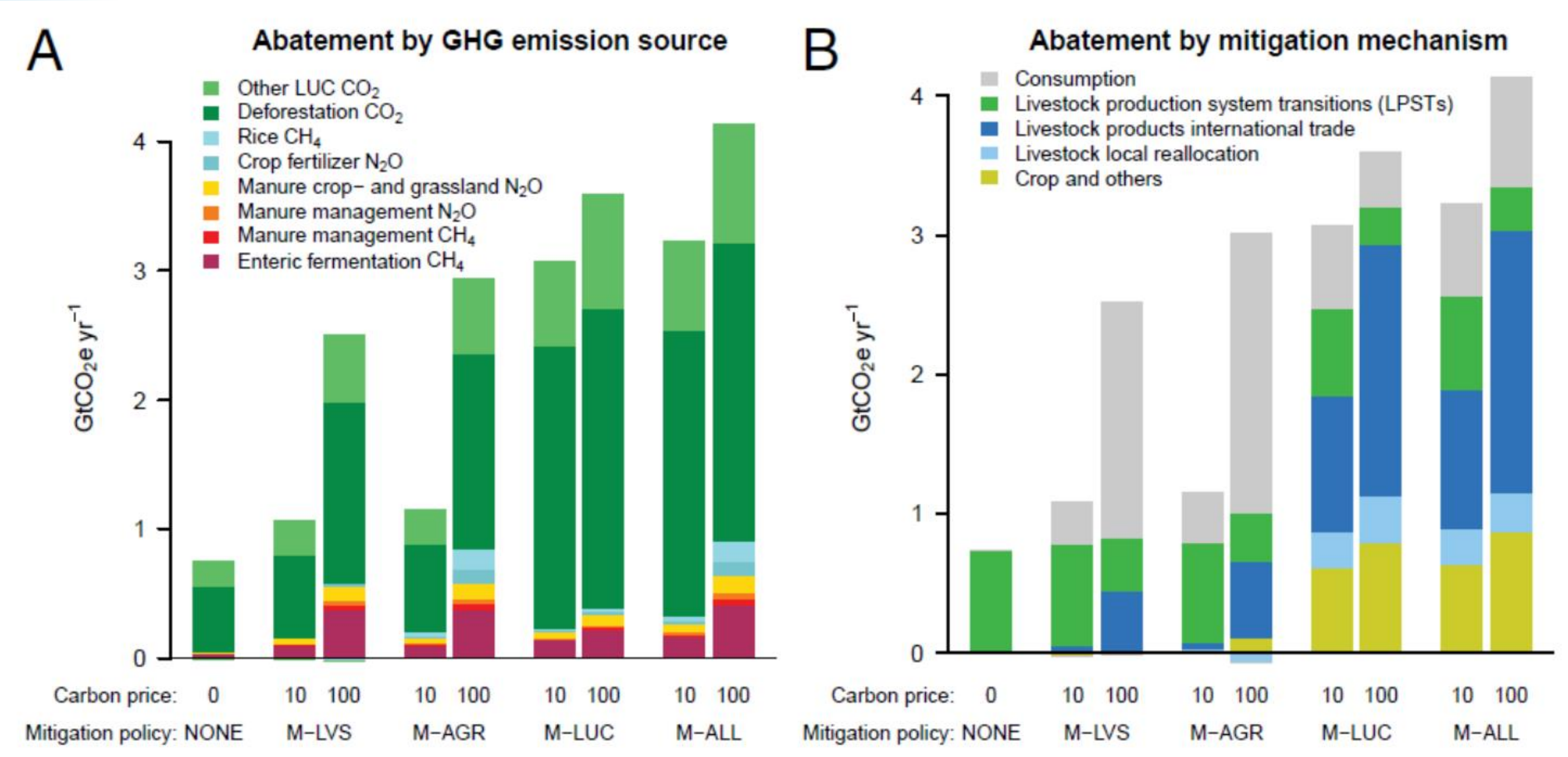
Source: Havlík et al. 2014

Feed and land productivity in 2030



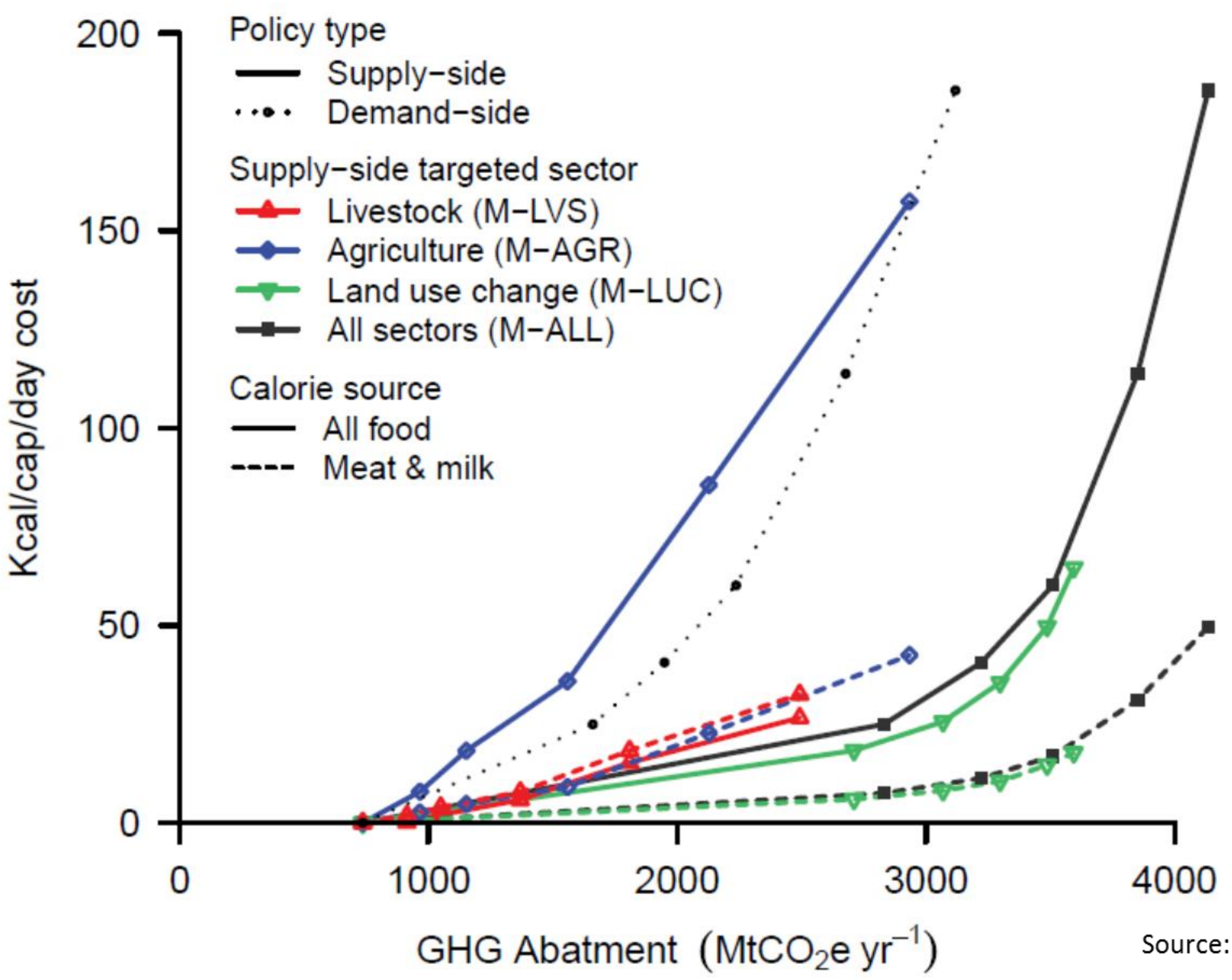
Source: Havlík et al. 2014

Contribution of LPSTs to GHG mitigation



Source: Havlík et al. 2014

Total abatement calorie cost (TACC) curves



Source: Havlík et al. 2014

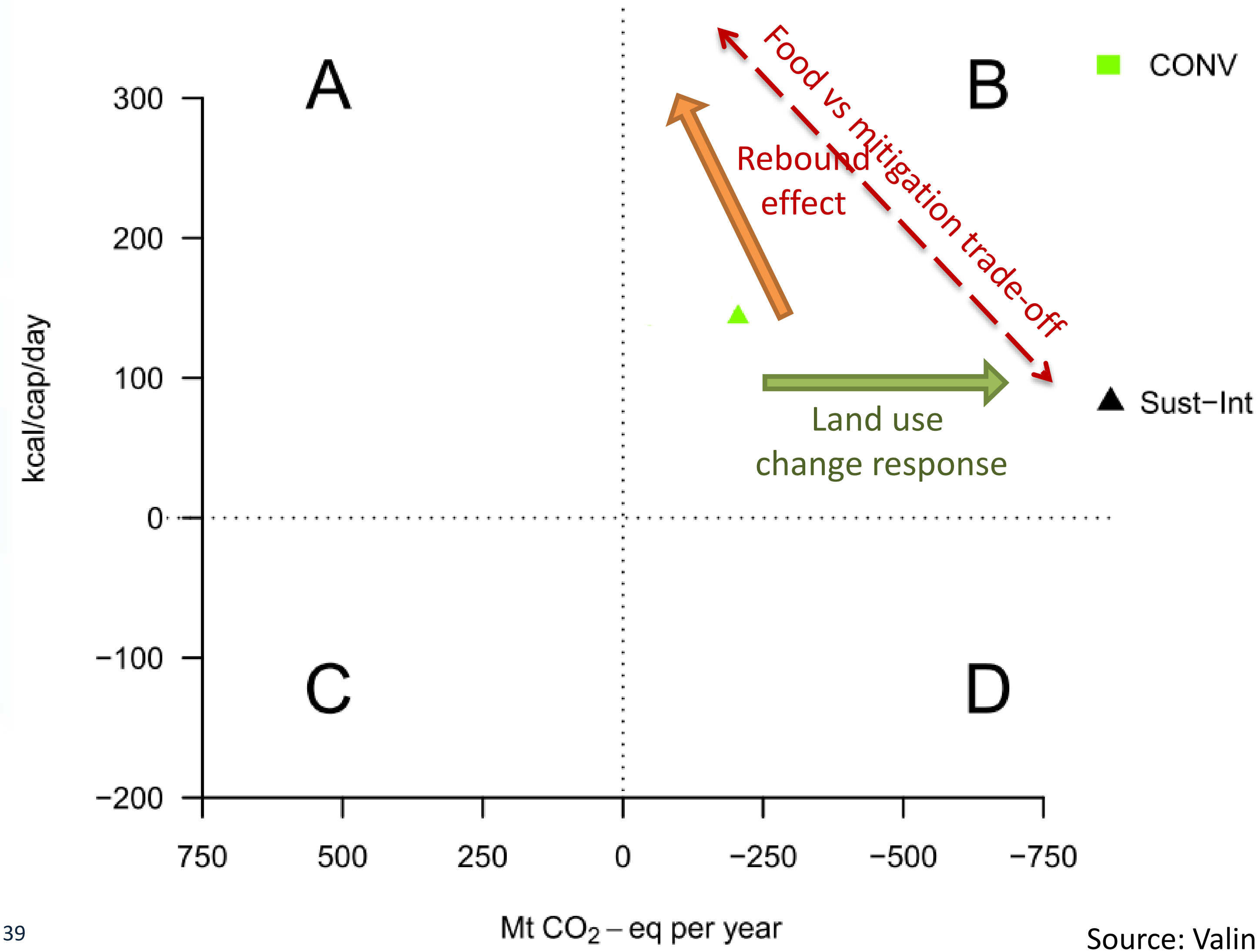
Livestock versus crop productivity gains

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)

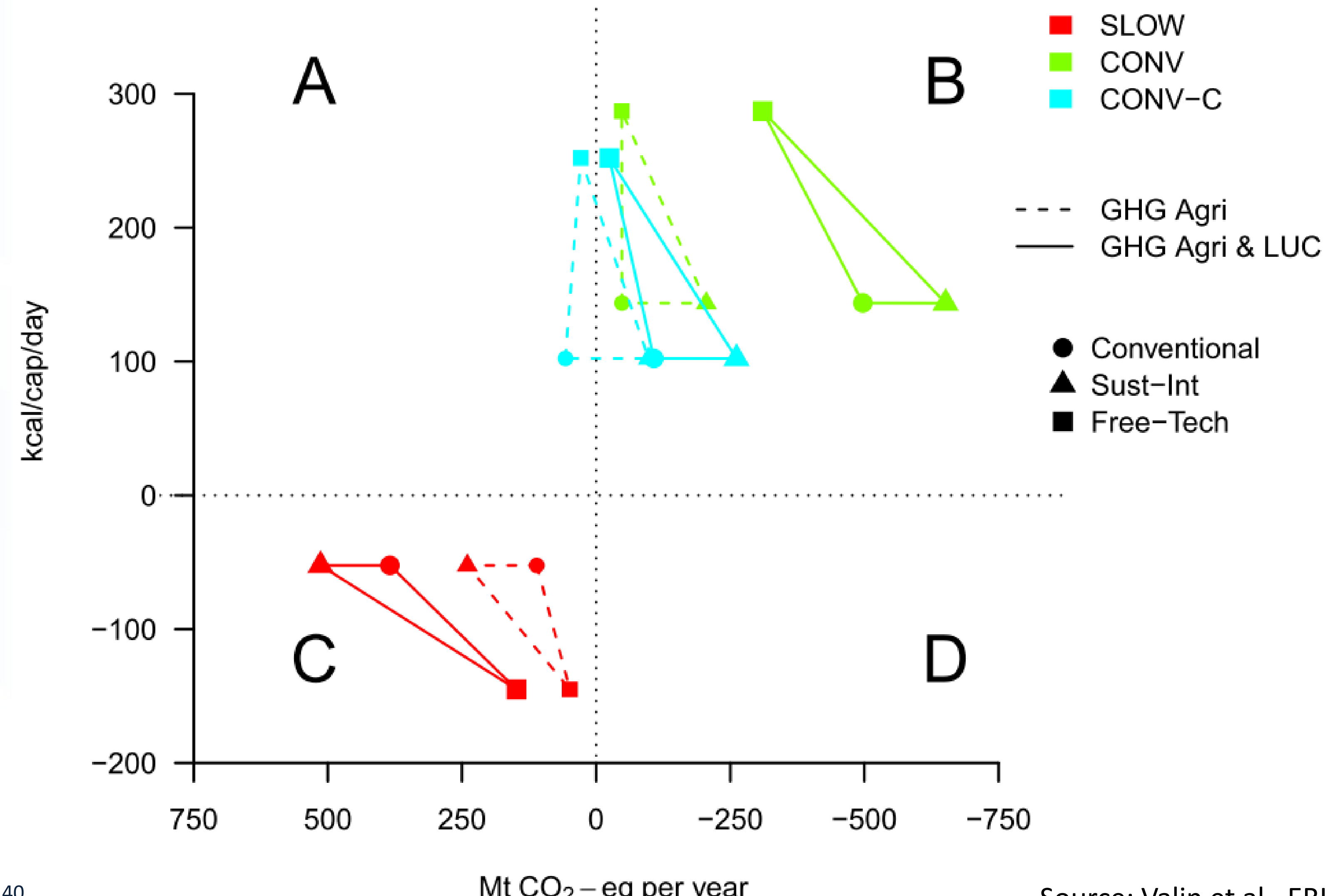
- Three different pathways of yield increase from baseline to scenario
  - Conventional intensification = based on more input. Production price and fertilizer use increase (elasticity 0.75)
  - Sustainable intensification = idem but no fertilizer increase (elasticity 0)
  - Free tech = based on productivity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

Findings



Source: Valin et al., ERL, 2013

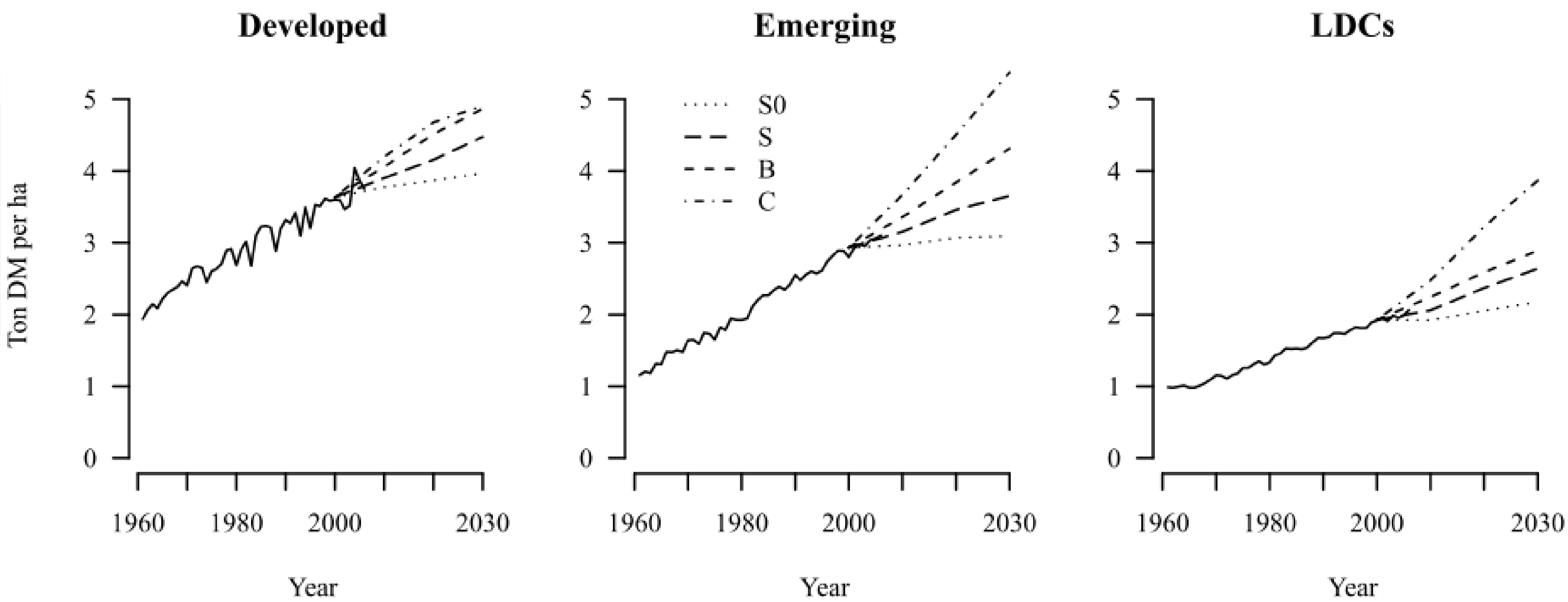
Findings



Source: Valin et al., ERL, 2013

What if livestock system transitions are considered?

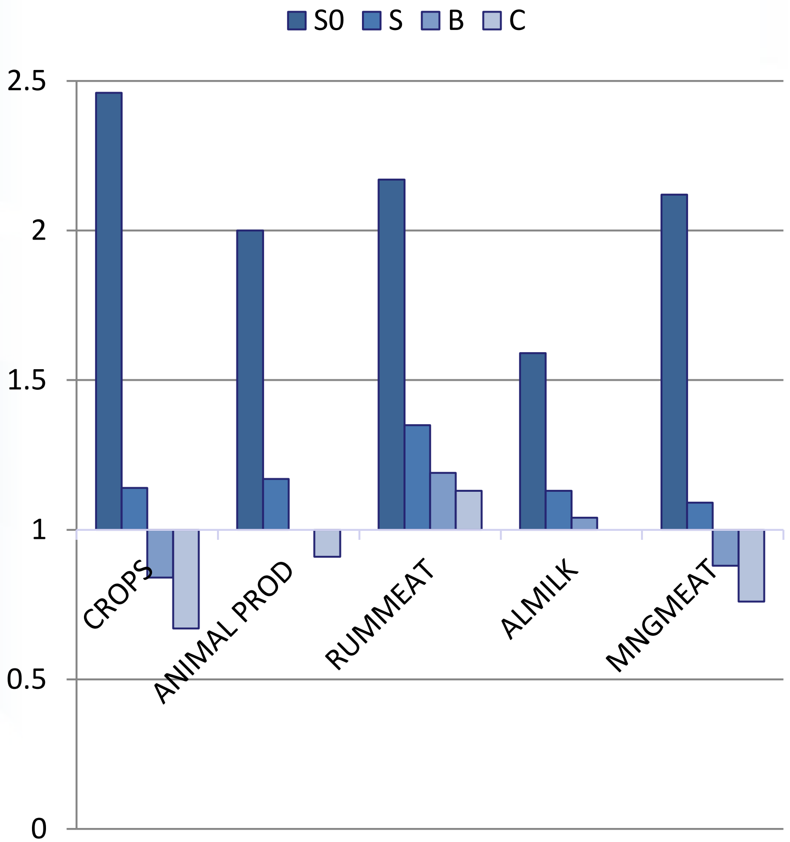
- Projections 2000-2030
  - S0: No crop yield increase
  - S: -50% yield improvement
  - B: Baseline = historical trend
  - C: + 100% in developing regions
- Fixed demand on B reference:
  - no rebound effect



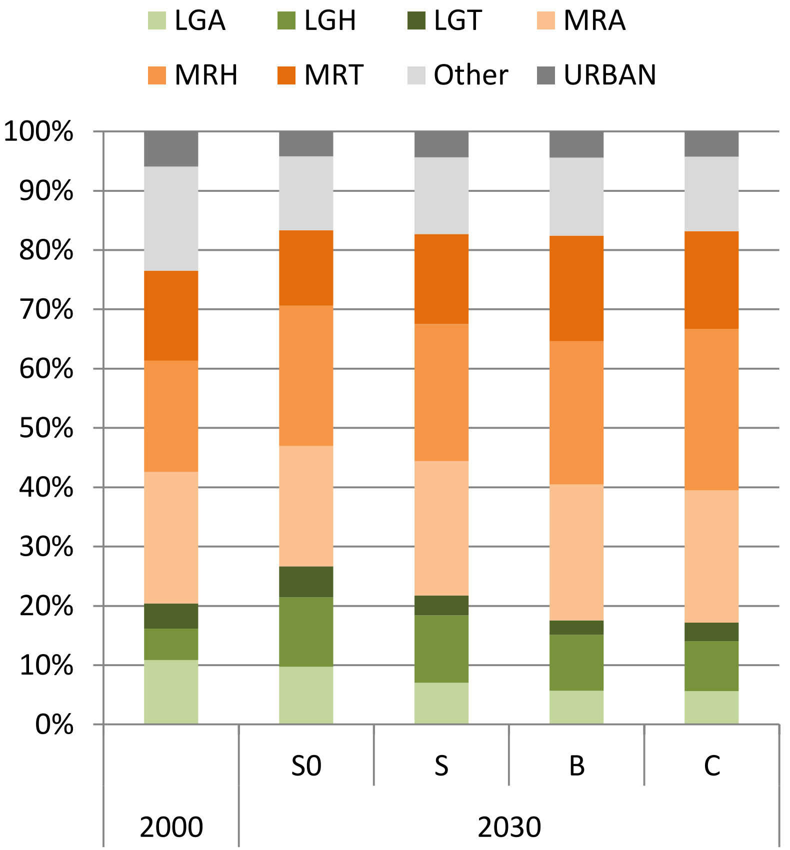
Source: Havlík et al., AJAE, 2013

Results: Market and production impacts

Prices index across scenarios

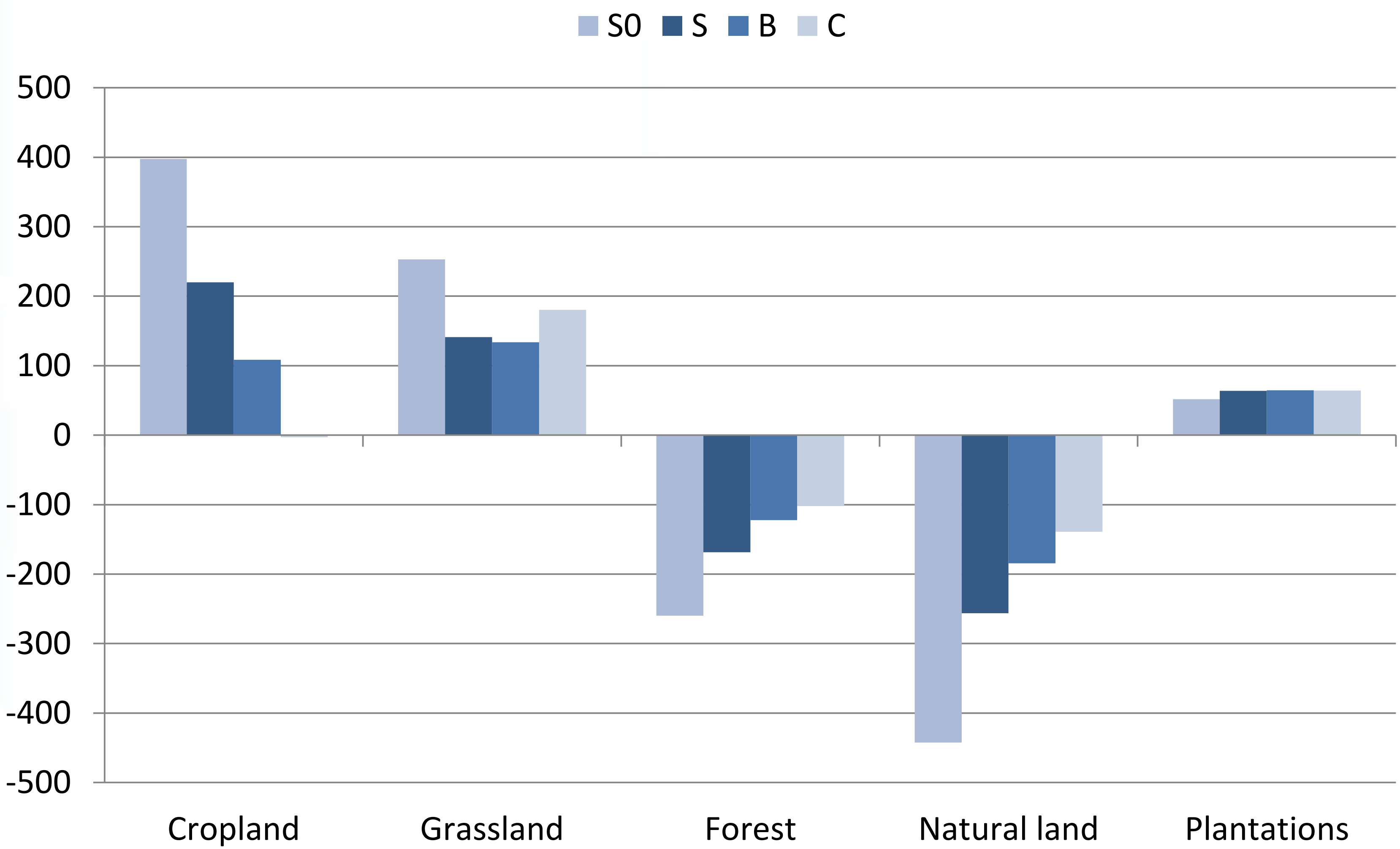


Distribution of ruminant systems



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

Avery S. Cohn[a,b,1], Aline Mosnier[c], Petr Havlík[c], Hugo Valin[c], Mario Herrero[d], Erwin Schmid[e], Michael O'Hare[f], and Michael Obersteiner[c]

[a]The Fletcher School, Tufts University, Medford, MA 02155; [b]Energy Biosciences Institute, University of California, Berkeley, CA 94704; [c]International Institute for Applied Systems Analysis, 2361 Laxenburg, Austria; [d]Commonwealth Scientific and Industrial Research Organization, St. Lucia, QLD 4067, Australia; [e]Institute for Sustainable Economic Development, University of Natural Resources and Life Sciences Vienna, 1180 Vienna, Austria; and [f]Goldman School of Public Policy, University of California, Berkeley, CA 94720

Edited by William C. Clark, Harvard University, Cambridge, MA, and approved March 25, 2014 (received for review April 16, 2013)

Grassland intensification

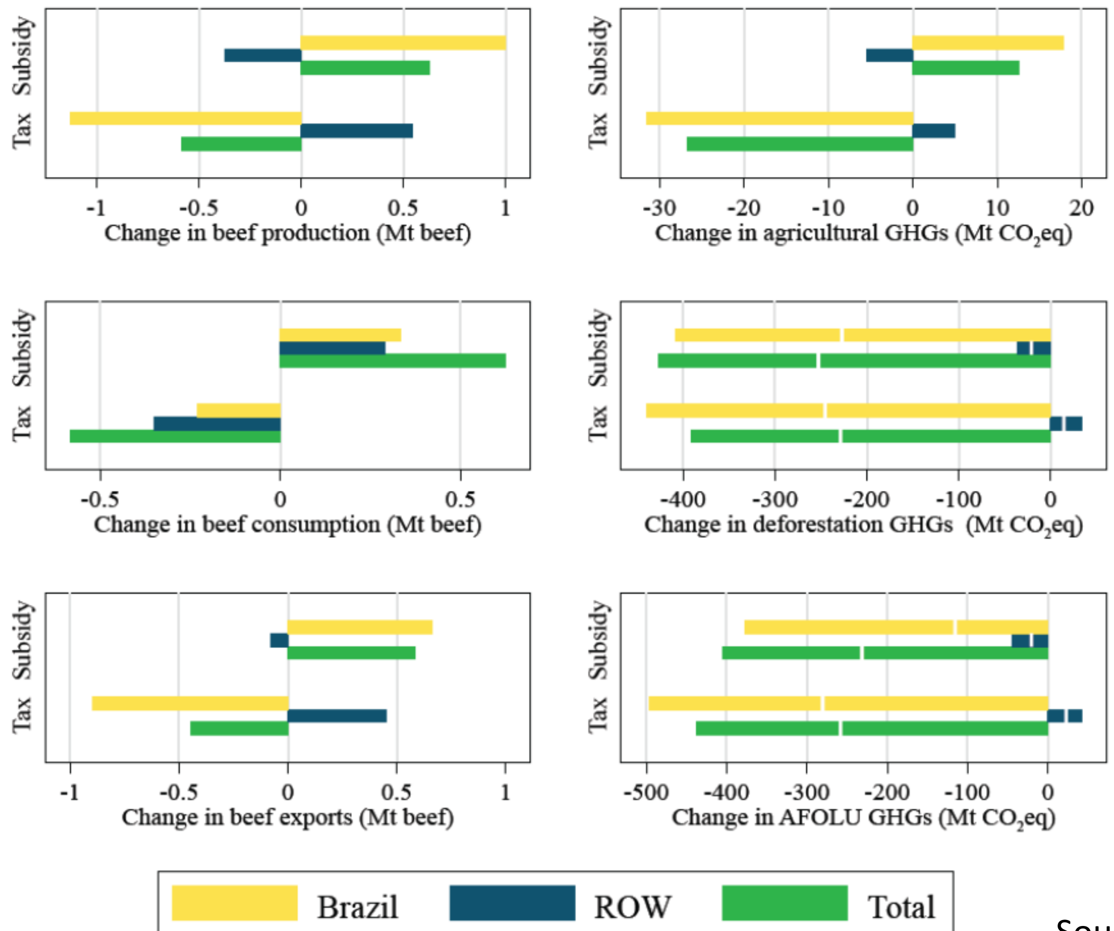
- Brazil only
- Conventional and SEMI-INTENSIVE systems
- SEMI-INTENSIVE system
    - **Grassland productivity** double of the conventional productivity
    - **Annual cost differential** between the conventional pasture and the semi-intensive pasture averages 80 USD per hectare depending on the remoteness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

Leakage or rebound?

Two policies tested

1) Subsidy per hectare of semi-intensive grassland

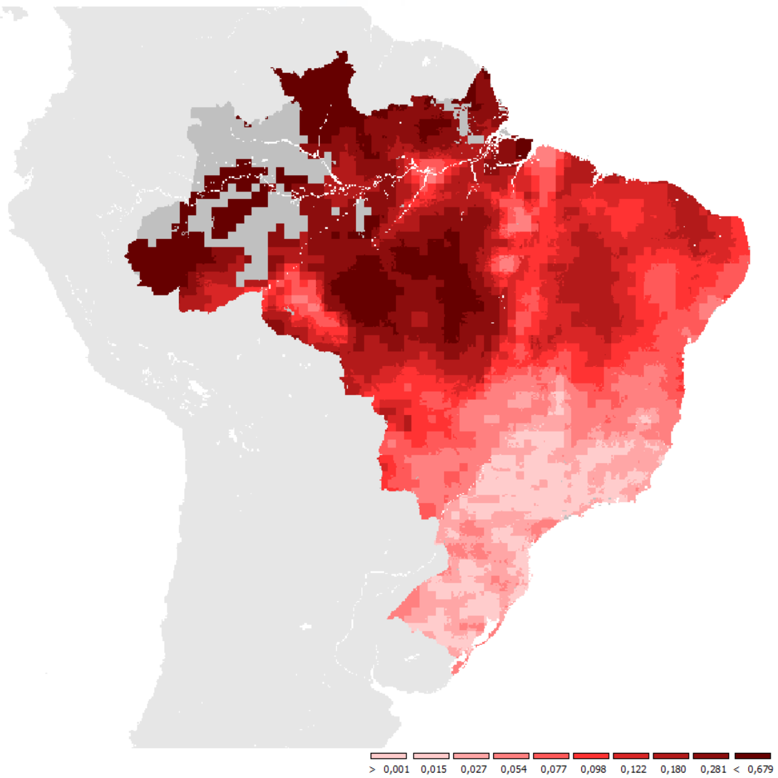
2) Tax per hectare of conventional grassland



Source: Cohn et al., 2014

Brazil: REDD potential of pasture intensification policies

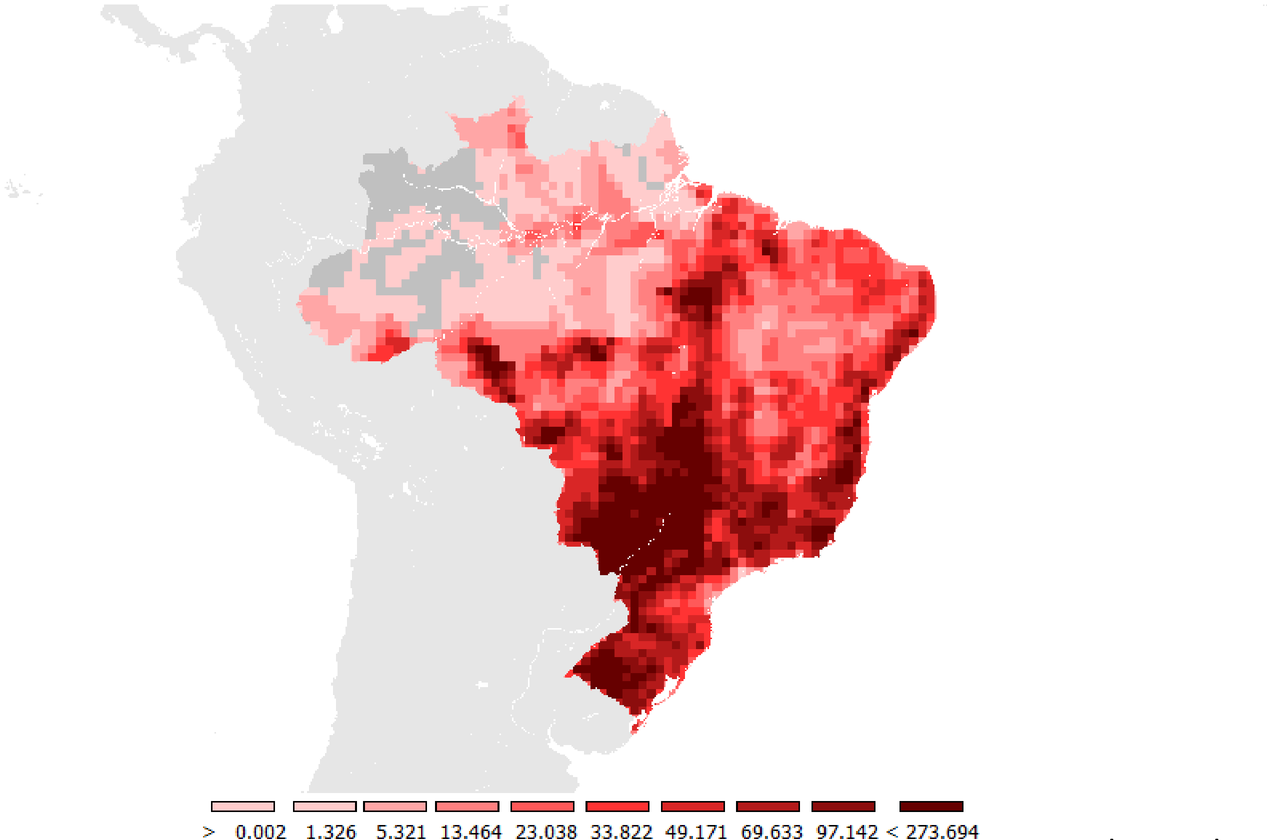
Beef transport cost as percentage of final selling price



Cohn et al., 2014

Brazil: REDD potential of pasture intensification policies

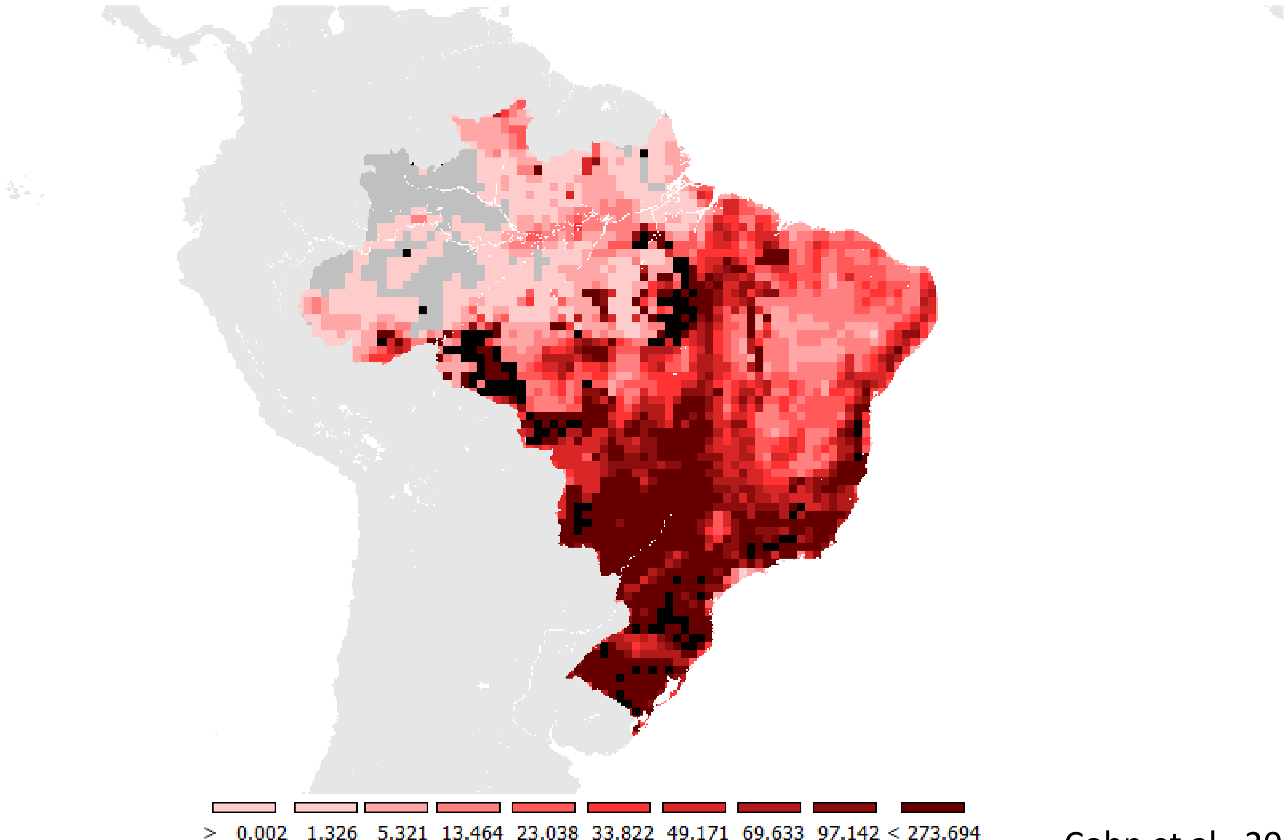
Beef herd in 2000 [1000 TLUs]



Cohn et al., 2014

Brazil: REDD potential of pasture intensification policies

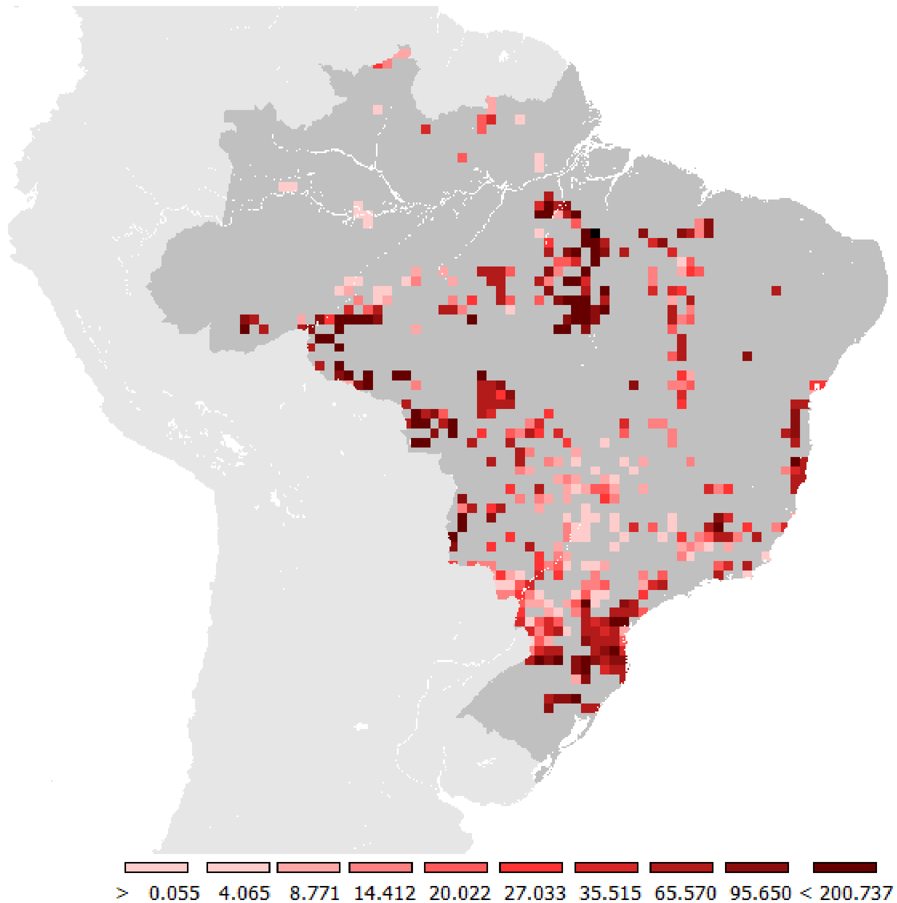
Beef herd in 2030 [1000 TLUs]



Cohn et al., 2014

Brazil: REDD potential of pasture intensification policies

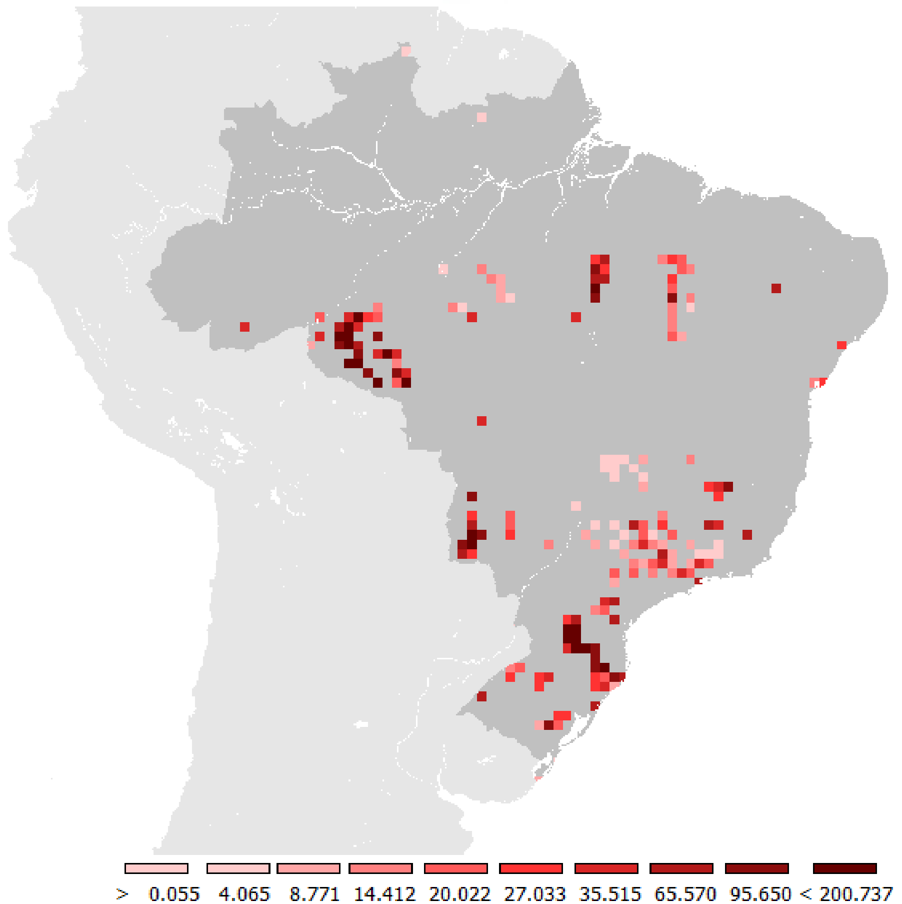
Deforestation due to pasture expansion: 2030 baseline [1000ha]



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

ANIMAL CHANGE

SEVENTH FRAMEWORK PROGRAMME

CGIAR

RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

CCAFS

Thank you !

havlikpt@iiasa.ac.at
valin@iiasa.ac.at

www.globiom.org

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