BUILDING SUSTAINABLE CROP-LIVESTOCK SYSTEMS

Pierre Gerber
January 9, 2016
Kansas State University
Demand growth and Global sustainability issues.
**LIVESTOCK SECTOR'S GROWTH**

Most of the growth expected to take place in rapidly growing economies.

<table>
<thead>
<tr>
<th>Region</th>
<th>Per caput consumption of meat (Kg/person per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>58</td>
</tr>
<tr>
<td>North America and Europe</td>
<td>83</td>
</tr>
<tr>
<td>East-South Asia and the Pacific</td>
<td>28</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>11</td>
</tr>
<tr>
<td>Central-West Asia and North Africa</td>
<td>20</td>
</tr>
</tbody>
</table>

FAO, 2009
GLOBAL TRENDS

Population growth:
• + 30% since 1990
• + 31% or 9.6 billion people by 2050

Income growth:
• + 1.5%/year since 1980, + 5-7%/year in Asia
• + 2%/year to 2050

Urbanization:
• 20% in 1900, 40% in 1990, >50% in 2010
• 70% of people in cities by 2050

World demand for livestock food products since 1990:
• Milk + 30%  Meat + 60%  Eggs + 80%
• + 70% by 2050
MIXED CROP-LIVESTOCK SYSTEMS

“Farming systems that to some degree integrate crop and livestock production activities so as to gain benefits from the resulting crop-livestock interactions”

Sumberg, 2003

Four possible trajectories of crop and livestock systems.

Thornton and Herrero, 2015
ESTIMATED DISTRIBUTION OF LIVESTOCK PRODUCTION SYSTEMS

FAO, 2006
An overview of livestock supply chains

**Landscape**
- Feed
- Animal production
- Transport and processing

**One health**
- Consumer

**Watershed**
- Retail

**Diet**
TRENDS IN LIVESTOCK SYSTEMS

Increase in livestock numbers:

Change in feeding system:
intensive use of limited land resources

Change in scale:
smallholders increasing in size and development of large scale operations, driven by economies of scale and access to market

Geographical concentration:
at small/medium and large scale farms, driven by economies of scope and transport costs
After Tarawali, 2015

Livestock and inclusive, sustainable economic growth

Livestock and equitable livelihoods

Animal source foods for nutrition and health

Livestock and sustainable ecosystems
CLIMATE CHANGE
TODAY - THE FOOD SYSTEM IS PART OF THE CLIMATE CHANGE PROBLEM

LAND USE CHANGE
~11% OF TOTAL
- FOREST LAND 63%
- CROPLAND 25%
- BURNING BIOMASS 11%

TOTAL EMISSIONS
- Land Use Change 11%
- Agriculture 13%
- Building 6.4%
- Transport 14%
- Industry 21%
- Other Energy 9.6%
- Electricity & Heat Production 25%

AGRICULTURE
~13% OF TOTAL
- LIVESTOCK 62%
- FERTILIZATION 16%
- RICE - 10%
- OTHER - 12%

IPCC 2014
TOMORROW — THE FOOD SYSTEM COULD BE THE CLIMATE CHANGE PROBLEM

Projections of Global, Agriculture and Land Use Change Related Emissions towards 2050 (Gt CO$_2$e)

- **TODAY**
  - Global Emissions: 49.1 Gt
  - 5.4 Gt LULUCF*
  - 6.4 Gt Agriculture
  - 11% of Total
  - 14% of Total

- **2050 - ‘2C’ Ensuring Emission Level**
  - Agriculture Business As Usual
    - Global Emissions: 21-22 Gt
    - 5.4 Gt LULUCF*
    - 9.5 Gt Agriculture
    - 25% of Total
    - 45% of Total
  - Ag. Reduces Proportional to Other Sectors
    - Global Emissions: 21-22 Gt
    - 4 Gt Agriculture

- **By 2050, Agriculture and Land Use Change could represent 70% of Global Emissions** - if global emissions are reduced in accordance with a 2C goal, while Agriculture were to remain in business as usual.

*Land Use, Land Use Change and Forestry

By 2050, Agriculture will have to reduce its emission intensity by 60%, if it is to maintain its footprint in parallel with overall emissions reductions. This assumes emissions from Land Use Change will have fallen to zero.
GHG EMISSIONS IN LIVESTOCK SUPPLY CHAINS

System boundary

Carbon dioxide ($CO_2$)

Methane ($CH_4$)

Nitrous oxide ($N_2O$)

C sequestration
RELATIVE CONTRIBUTION OF LIFE-CYCLE PHASES — GLOBAL LIVESTOCK SECTOR

Total GHG emissions: 7.1 Gt CO₂-eq

FAO, 2013
Recent price spikes for food commodities have been linked to extreme weather events. World Bank 2008, Reuters Eikon.

**Production Volatility Impacts Food Prices**

**Price Volatility Impacts Share Prices**

A price hike in corn (black) drives down the share price of Tyson Foods (red).

1. Australia wheat. 2. US maize. 3. Russia wheat. 4. US wheat, India soy, Australia wheat. 5. Australia wheat. 6. Argentina maize, soy. 7. Russia wheat. 8. US maize.

World Bank 2008, Reuters Eikon
GEOGRAPHICAL CONCENTRATION AND THE NUTRIENT ISSUE
Estimated distribution of industrialized produced pig populations

Globally-900,000,000 hogs

FAO, 2006
Total 60,000,000 pigs

Honeyman, Duffy, 2006. Iowa State Univ
PIGS IN NORTH CAROLINA

9,800,000 hogs and pigs

45% are in 2 of the 100 counties of the state and are on the coastal plain.
ESTIMATED SOYMEAL SURPLUS/DEFICIT

FAO, 2006
DISLOCATED RESOURCES.

NITROGEN BALANCE

PHOSPHORUS BALANCE

MacDonald G K et al. PNAS 2011;108:3086-3091
THE RELEVANCE OF MIXED CROP-LIVESTOCK SYSTEMS

Comparative advantage of integrated systems.
WHERE DOES THE SECTOR NEED TO DELIVER?

Effectiveness

Efficiency ↔ Social adequacy
EFFECTIVENESS

The sector shall supply the required mix of goods and services, in a safe and robust manner.

Respond to growth – mixed crop-livestock system is the dominant form of production
- output per animal;
- number of animals.

Be resilient to shocks – diversification and integration
- climate change;
- input and output prices;
- animal health.

Ensure food safety – issue of farm size.
Livestock yield gaps can be large. 2.5 – 4 times larger compared to the highest performers. (Herrero et al. 2015)
REducing demand - evidence

Strong rationale
- Livestock products are generally more resource intensive than others food items
- Health co-benefits
- Reduced demand: dietary change and reduction in food losses and wastes
- Direct and indirect mitigation effects of reduced demand

Uncertainties in the analyses
- Effect on farming systems: use of crop residues and food byproducts, fertilization, traction
- Results highly dependent on hypothesis made about alternative land use
- Rebound effect (50% in Sweden, Grabs 2015)

Constraints to implementation
- Instruments and willingness to influence consumers’ choice
- Alternative sources of nutrients aren’t always accessible / more environmentally friendly.
NUTRITIONAL DIVERSITY MATTERS

(a) Rice + carrots
(b) Rice + carrots + orange
(c) Rice + carrots + orange + lentils
(d) Rice + carrots + orange + meat
(e) Rice + carrots + orange + meat + spinach
(f) Rice + carrots + orange + meat + spinach + lentils
EFFICIENCY

The sector shall minimize the resources mobilized and noxious emissions generated per unit of output.

Ecological efficiency:
- unit of natural resource used per unit of output generated;
- unit of noxious emissions generated per unit of output generated.

Economic efficiency:
- minimize price of outputs (given quality and input prices), especially countries with high food insecurity prevalence.
CYCLE PRINCIPLE

- **Inputs**: Animals, Crops, Nutrients & Organic matter
- **Outputs**: Manure (10 - 20 %), Biogas, Losses
GHG EMISSIONS ARE LOSSES

Methane
- CH₄ emissions are energy losses
- Total enteric methane emissions: equivalent to 144 Mt oil equivalent per year
- Total manure methane emissions: equivalent to 29 Mt oil equivalent per year

Nitrous oxide
- N₂O losses are N losses from manure and fertilizers
- Manure N₂O emissions (direct and indirect) from manure application on crops and application on pasture: 3.2 Mt of N

Carbon dioxide
- CO₂ emissions are related to fossil fuel use and organic matter losses
- Soil organic matter is key to land productivity

➢ There is a strong link between Ei and resource use efficiency
SYNERGIES BETWEEN GHG MITIGATION AND BIODIVERSITY PRESERVATION

Synergies between the two performances across agro-ecological zones

For dairy cattle

MSA: Mean Specie Abundance

Teillard et al., 2014
SOCIAL ADEQUACY

Food chains need to develop in a manner that suits societal ethical expectations.
DRIVERS OF CHANGE IN THE FOOD CHAIN: FROM FORK TO FARM

- Sufficiency, Ownership
- Ethics
- Urbanisation
- Health
- Well Being
- Convenience
- Sustainability
- Climate and environmental protection
- Pleasure
RESEARCH AND DEVELOPMENT NEEDS
WHAT WILL TRIGGER CHANGE?

LEVERAGE POINTS

Illustration By: Glen Lowry
PUBLIC POLICIES: WHERE DO WE NEED TO FOCUS?

Pannel, 2008
PUBLIC POLICIES: WHERE DO WE NEED TO FOCUS?

- Technology transfer
- Access to finance
- Risk mitigation
- Safeguard against trade-offs (water, animal welfare, ...)
PUBLIC POLICIES: WHERE DO WE NEED TO FOCUS?

- Research
- C markets / payments for emission reduction
- Subsidies (e.g. biogas, renewable energy production)
PUBLIC POLICIES: WHERE DO WE NEED TO FOCUS?

- Regulations (e.g. on manure management, on agricultural land expansion)
- Price of resources (e.g. fossil fuel)
RESEARCH NEEDS (I)

**Broad picture:**
- From field to farm to farming system to food system modelling

**System level:**
- Reconnecting specialized (large scale) crop and livestock production: manure, crop residues, food by-products.

**Technology adoption and effectiveness:**
- Drivers of practice change, innovation processes
- Metrics for sustainability assessment and benchmarking
RESEARCH NEEDS (II)

Field and animal level:

- Crop breeding for edible residues
- Rapid assessment of manure content (NIR techniques)
- Manure processing, crop residues management
COMPELLING FIGURES

+70% in 2050
1 person out of 4
40% agri GDP

1 Billion
Poor livestock keepers

25% of proteins
13% of kcal
30% of land

14.5% of GHG
25% synthetic nitrogen
8 to 15%
SPATIAL DISTRIBUTION OF HUMAN, LIVESTOCK AND CROP DENSITIES AT THE PERIPHERY OF BANGKOK

Gerber et al., 2005
WHAT WILL IT TAKE - FEEDING 9 BILLION PEOPLE IN 2050

Changing Consumption

Food Consumption by Region 2005/07 vs 2050

Percentage Increase 05/07 – 2050

183%  81%  79%  43%  30%  11%

Changing Diets

Demand for animal protein is increasing.

Source: PBL, 2009

Big Facts
ccafs.cgiar.org/bigfacts

CEA 2013 based on FAO
2012, CCAFS 2015
CHANGES IN MANURE MANAGEMENT PRACTICES, WHAT CAN MAKE IT HAPPEN?

Government
- Policy framework
  - Law
  - Regulatory enforcement
  - Financial incentives

Extension services
- Awareness
- Technical capacity

Farmers
- Technical capacity
- Recognition

Farmers associations
- Social/moral pressure
- Accountability

General public
- Economic and technical changes

Market
- Incentive for “clean” products

Motivation
- Incentive for "clean" products
MEETING CURRENT DEMAND ALREADY UNSUSTAINABLE (GREEN = SAFE SPACE)

Role of Agriculture
Ocean acidification
Nitrogen cycle
Phosphorous cycle
Current status

Planetary Boundaries

Climate change
Biodiversity loss
Global freshwater use
Change in land use
Rockström et al. (2009); Bennett et al. (in prep.)
Slide courtesy of B. Campbell
RESPOND TO DEMAND IN THE CONTEXT OF LOCALLY RELEVANT INSTITUTIONS AND AGRO-ECOLOGICAL CONDITIONS.

Effectiveness

Efficiency

Social adequacy

Locally relevant institutions

Agro-ecological conditions

Diversity, adaptability, inclusive processes
RELATIONSHIP BETWEEN TOTAL GREENHOUSE GAS EMISSIONS AND MILK OUTPUT PER COW — MITIGATION OPTIONS

- Strategic feed supplementation
- Animal health
- Protection against climate and predators
- Feed ration balancing
- Reproduction management
- Offtake management
- Animal health, genetic imp.
- Energy use efficiency
- Manure management
- Feed additives
- Precision agriculture
- Risks
- Equity
- Multi-functionality
- Other environmental objectives

Gerber et al., 2011
CATEGORIES OF INFLUENCE THAT LIVESTOCK HAVE ON BIODIVERSITY
IMPACT OF ANIMAL PRODUCTION ON BIODIVERSITY – LAND USE AND CLIMATE CHANGE

PDF: Potentially Disappeared Fraction of species
POVERTY, HUNGER, CLIMATE AND CLIMATE SMART AGRICULTURE

WHAT IS THE CHALLENGE?
To build food systems that meet increasing demand while remaining profitable and sustainable in the face of Climate Change.

WHAT WILL IT TAKE?
1. Increasing productivity sustainably
2. Enhancing the resilience of producers and supply chains
3. Reducing Emissions

CAN IT BE DONE?
Yes, but we need to connect Climate Change with the bottom line of farmers and food businesses

CSA = SUSTAINABLE AGRICULTURE + RESILIENCE + EMISSIONS
Effective tools for implementation

BUT, are new technologies the answer to the demands of consumers? What is the best strategy of the food industry when using technology?
Visioning a Sustainable Food System for 2030 (work in progress)
THE FARMER’S DILEMMA
THREE MAIN GHG GASES

- CH4: 44%
- N2O: 29%
- CO2 - fossil f.: 27%
- CO2 - LULUC: 0%
BROAD MITIGATION STRATEGIES

Efficiency

- CH4
- N2O
- CO2 - fossil f.
- CO2 - LULUC

Land use

C sequestration
EMISSION INTENSITY GAP — CHICKEN MEAT IN EAST AND SOUTHEAST ASIA

FAO, 2013
POTENTIAL MITIGATION IN THE LIVESTOCK SECTOR

No change in farming systems scenario, based on existing and applied technology

- 18% reduction in emissions (= 1.1 GtCO₂ eq.)
- 30% reduction in emissions (= 1.8 GtCO₂ eq.)

No change in farming systems scenario

- 20% reduction in emissions (= 1.2 GtCO₂ eq.)
- 32% reduction in emissions (= 1.9 GtCO₂ eq.)

FAO, 2013
RETHINKING LIVESTOCK SYSTEMS FOR FOOD SECURITY AND MITIGATION

Food Security

CC mitigation

Emission intensity reduction

C sequestration and avoided C loss from LUC

Efficiency

Consumption

Production reduction

LU and LUC

0.7 to 7.8 Gt CO₂eq. Year⁻¹

1.1 to 1.9 Gt CO₂eq. Year⁻¹

0.3 to 0.9 Gt CO₂eq. Year⁻¹

2.1 to 10.6 Gt CO₂eq. Year⁻¹
LAND USE MANAGEMENT FOR C SEQUESTRATION IN PRACTICE

Interventions
- Grazing management, animal mobility
- Legumes introduction
- Sylvopastoral systems

Synergies
- Biodiversity conservation, water cycles

Limitation
- Saturation, reversibility
- Intervention costs are high (targeting, access, capacity development, monitoring)
SOIL CARBON SEQUESTRATION

Tschakert, 2000

Holland et al. 2011
GLOBAL NET SOIL C SEQUESTRATION

- Grazing management = 110 MtCO$_2$ yr$^{-1}$ (0.23 tCO$_2$ ha$^{-1}$)
  - applied over 470 million ha
- Legume sowing = 147 MtCO$_2$-eq yr$^{-1}$ (2.0 tCO$_2$-eq ha$^{-1}$)

Henderson et al., 2015
RELATIONSHIP BETWEEN TOTAL GREENHOUSE GAS EMISSIONS AND MILK OUTPUT PER COW — MITIGATION OPTIONS

- Strategic feed supplementation
- Animal health
- Protection against climate and predators
- Feed ration balancing
- Reproduction management
- Offtake management
- Animal health, genetic imp.
- Energy use efficiency
- Manure management
- Feed additives
- Precision agriculture

Risks
Equity
Multi-functionality
Other environmental objectives

Gerber et al., 2011
LIVESTOCK AT THE WORLD BANK
US$41 Billion IBRD/IDA (2015)

- Financial & Private Sector Development 22%
- Transportation 17%
- Energy 16%
- Water, Sanitation, Flood Protection 11%
- Health & Social 8%
- Education 8%
- Agriculture, Fishing, Forestry 7%
- Finance 5%
- Industry & Trade 4%
- Information and Communications 1%
ANNUAL WB COMMITMENT (IDA/IBRD/TF) IN LIVESTOCK WITHIN TOTAL AGRICULTURE SECTOR 2000-2014 (US $ MILLION)
COMMITMENTS IN LIVESTOCK BY SOURCE OF LENDING

[Diagram showing the commitments in livestock by source of lending from 2000 to 2014, with data points for each fiscal year.]
LIVESTOCK RELATED PROJECTS BY WB COMMITTED AMOUNTS 2000-2014

Number of World Bank Livestock Projects by Commitment Amounts (US$ million)

- <$1 m: 56
- $1-5 m: 133
- $6-15 m: 79
- $16-30 m: 24
- $31-50 m: 5
- >$100 m: 11
AGGREGATE WB COMMITMENT BY LIVESTOCK THEMES IN MILLION US DOLLARS

2000-2004

2005-2009

2010-2014

- Natural Resource Management
- Livestock Waste & Pollution Mgmt.
- Animal Health, Welfare & One Health
- Animal Husbandry, Breeding & Nutrition
- R&E, Communications, financing, insurance, Institution Strengthening
- Value chain, agri-business, food safety
LIVESTOCK PROJECTS NOT INCLUDED IN THIS STUDY

World Wide Daily Drought Risk Map
EMERGING THEMES AND APPROACHES IN THE PORTFOLIO

Role of agri-business
Value chains
One health
Food safety
Adaptation to, and mitigation of climate change
Natural resource management

- A System approach addressing the many interfaces of livestock with global public goods
Growing portfolio
Focus on Low Income Countries in Africa and South Asia
Focus on poverty alleviation
Livestock intervention usually integrated in multi-area projects
Increasing attention to objectives related to the SDGs.
## The Demand for Livestock Products to 2050

Rosegrant et al 2009

<table>
<thead>
<tr>
<th></th>
<th>Annual per capita consumption</th>
<th>Total consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Meat (kg)</td>
<td>Milk (kg)</td>
</tr>
<tr>
<td>year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>28</td>
<td>44</td>
</tr>
<tr>
<td>2050</td>
<td>44</td>
<td>78</td>
</tr>
<tr>
<td>Developed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>78</td>
<td>202</td>
</tr>
<tr>
<td>2050</td>
<td>94</td>
<td>216</td>
</tr>
</tbody>
</table>
TRENDS IN ANIMAL PRODUCT DEMAND

Changing Wealth and its distribution is driving demand dynamics

Kharas, 2011
A SCHEMATIC REPRESENTATION OF FARMING SYSTEMS (DIXON ET AL., 2001)
Current status of key planetary boundaries

A. Phosphorus

B. Nitrogen

C. Land-system change

D. Freshwater use

- Beyond zone of uncertainty (high risk)
- In zone of uncertainty (increasing risk)
- Below boundary (safe)
THE “GRAND CHALLENGE”


Gton CO2-eq/yr

Emissions from food - Baseline
Emissions from food - Increased livestock productivity
Emissions path 50% probability

2-degree climate target

Source: Hedenus, Wirsenius, Johansson (2011)
Estimated contribution of livestock to total $P_2O_5$ supply on agricultural land, in areas presenting a $P_2O_5$ mass balance of more than 10 kg per hectare.

FAO, 2006
IMPACT OF LIVESTOCK ON WATER AND SOIL POLLUTION
NUTRIENT FLOWS IN FARMING SYSTEMS

Adapted from Saleem, 1998
GLOBAL ASSESSMENT

Manure is utilised poorly by farmers, 40 – 60 % does not use dung, urine flows away

Main barriers for (small) farmers: awareness, knowledge, labour and investment opportunities

Awareness of the value of manure is limited, this also holds for local extension and policy makers

Policies are mainly driven by biogas, public health, pollution, *almost never by the fertilizer value*. Coordination is often lacking

Commercial input suppliers not interested
Decreasing
Maize and wheat yields show climate impacts

- Maize
  - China: -7%
  - Brazil: -8%
  - France: -3%
  - Global: (-4%)

- Wheat
  - China: -2%
  - Russia: -14%
  - France: -5%
  - Global: (-5%)

Increasing
Price for beef increasing steadily due to pressure from feed and pastureland markets

Beef from 2009-2014: +100%

CCAFS 2014; Reuters Eikon
PRODUCTION INTENSIFICATION AND EXPANSION: MONOGASTRICS IN THE «BIG THREE»
INDIA, CHINA AND BRAZIL
PASTURE DEGRADATION

Degradation of the vegetation cover resulting in:

lower productivity,

loss of SOM,

disrupted water cycles,

biodiversity erosion.

**Immediate cause:** management issue (grazing pressure, fertilization, ...)

**Driven by:**

Land availability

Limited awareness of environmental consequences

Lack of technical and financial capacity
ENVIRONMENTAL DEGRADATION

Between 30 -60% of agricultural land is degraded leading to loss of carbon stocks and emission of greenhouse gases.

Livestock farmers are more vulnerable to climate change and or Variability.