Information systems and efficiency of sustainable livestock production systems

Philippe LECOMTE (CIRAD)
and D. Berre, X. Juanes, J. Vayssieres, M. Vigne, E Tillard
SELMET, UMR (112) Mediterranean and Tropical Livestock Systems
UMR SELMET

Who we are

• A French « mixed » research unit CIRAD INRA SupAgro
• Dedicated to Mediterranean, Tropical, Pastoralism, Crop /Livestock Systems
• 45 scientists, 9 CDD (post doc,..), 20 Adm. & Tech. 16 PhD, 45 master trainees
• 22 pers. overseas: Brazil (Amazonia), F Guyana, French mediterranea, Egypt Saudi Arabia, (Mali) Senegal, Burkina, Reunion Isld, Madagascar, Vietnam
a) Scope and framework of the livestock development assessment
b) Defining and measuring efficiency
c) Methodological approaches and models used (concepts, modeling, tools, variables measured, etc.)
d) Livestock information systems currently used
e) What this information system is measuring
f) Regional coverage and current projects
Scope and framework of the livestock development assessment

**Grazed Ecosystems**

- **Dry**
  - Nomadic S.
  - Fencing S.

- **Humid**
  - Forage trees
  - Annuals
  - Perennial
  - Crop residues
  - Improved grasslands
  - Crop Livestock S.
  - Agroindustrial by products
  - Peri Urban S.
  - Industrial S.

**Scope and framework**

- **Low input** → **High input**

- **Population**
  - Low
  - Shifting
  - Dry/poor
  - Some OP
  - Traditional

- **Agriculture**
  - Low
  - 1 month
  - Dry/poor
  - Some OP
  - Traditional

- **Vegetation**
  - Low
  - Shifting
  - Dry/poor
  - Some OP
  - Traditional

- **Climate/soils**
  - Low
  - Shifting
  - Dry/poor
  - Some OP
  - Traditional

- **Chains**
  - Low
  - Shifting
  - Dry/poor
  - Some OP
  - Traditional

- **Societies**
  - Low
  - Shifting
  - Dry/poor
  - Some OP
  - Traditional

- **Low input**
  - Dense
  - Intensified
  - 8 à 12 months
  - Humid /rich
  - Interprofession
  - Modern

- **High input**
  - Low input
Scope and framework of the livestock development assessment

Around
Resources, Animals, Systems
Adaptation, Resiliency, Efficiency
Agroecology, Ecological Intensification ... 

Focus areas
• « Closing the efficiency gap »
• « Restoring value to grasslands »
• « Waste to worth »

Changes are needed in all systems ..
Scope and framework of the livestock development assessment

Stakes, Postulates, Challenges

• More production, less producing impact
• Efficiency shift: a real challenge for the future
• Complexity in addressing multiple goals efficiency
• Performance diversities
  • Large Diversity of systems // landscapes
  • Comparative "value(s)" of eco-efficiency very diverse
  • Inside each LFS // landscapes a large diversity of efficiency exist
• How to exploit diversity and progress
• Still a lot to do to observe, compare, reconsider, experiment
Defining and measuring efficiency

• Efficiency vs Efficacy a major shift in ag. research
  • “efficacy”: maximising goals without really specifying the means.
  • “efficiency”: being effective in making efficient use of resources - natural, human, informational, material, financial, etc.:
  • ecoefficiency, sustainable efficiency (Van passel et al 2009…

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>USA</td>
<td>11,789</td>
</tr>
<tr>
<td>2</td>
<td>Brazil</td>
<td>9,300</td>
</tr>
<tr>
<td>3</td>
<td>EU-27</td>
<td>7,920</td>
</tr>
<tr>
<td>4</td>
<td>China</td>
<td>5,550</td>
</tr>
<tr>
<td>5</td>
<td>Argentina</td>
<td>2,800</td>
</tr>
</tbody>
</table>

Top 10 cattle and beef producing countries[43]
Methodological approaches and models used (concepts, modeling, tools, variables measured, etc.)

- Laboratory model (controlled condition trials)
- Field model (farm survey / upscaling / landscape, region)
- Action Research (participatory modeling, innovation...)

A combination of R&D activity models (Hatchuel, 2000)
A combination of hard and soft system approach

Modified after R. Bawden (1997) et Hubert 2004
Methodological approaches and models used
(concepts, modeling, tools, variables measured, etc.)

/ Efficiency

Some example along scales:
  Ressource
  Animals
  Farms
  Region
Resource management, Organic Fertilisation in la Réunion island, FR

4 trials sites:
Pl Cafres/ St Joseph/ Montvert/Palmiste
Long term experiment since 2004
10 treatments, 3 rep

Measures:
Biomasses 5/8 cuts/year
Phytosociology
Forage, soil composition

<table>
<thead>
<tr>
<th>Treat</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fertilisation null</td>
</tr>
<tr>
<td>2</td>
<td>Mineral Fert. (350)</td>
</tr>
<tr>
<td>3</td>
<td>Org Fert. Slurry (200)</td>
</tr>
<tr>
<td>4</td>
<td>Org Fert. Slurry (200) + min (150)</td>
</tr>
<tr>
<td>5</td>
<td>Org Fert. Slurry (350)</td>
</tr>
<tr>
<td>6</td>
<td>Org Fert. Compost (200)</td>
</tr>
<tr>
<td>7</td>
<td>Org Fert. Compost + 150 min + ajustt</td>
</tr>
<tr>
<td>8</td>
<td>Org Fert. Compost (350)</td>
</tr>
<tr>
<td>9</td>
<td>Org Fert. Compost + ajustt</td>
</tr>
<tr>
<td>10</td>
<td>Mineral Fert. (600)</td>
</tr>
</tbody>
</table>
Resource management, Organic Fertilisation in la Réunion island, FR

- 12 ton COMP + 48 kg N Min
- 7.2 ton COMP + 56 kgN Min
- 12 ton COMP
- 7.2 ton COMP
- 40 M3 LISIER + 30 Kg N
- **70 M3 LISIER**
- 40 M3 LISIER
- 120 kg N MinMin
- 70 kgN Min
- Nulle
<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2007</th>
<th>Changement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbone du sol mesuré %</td>
<td>12.4</td>
<td>12.9</td>
<td>Un rendement moyen, un net progrès dans le sol et un arrière effet prometteur</td>
</tr>
<tr>
<td>Azote du sol mesuré (g/kg)</td>
<td>10.9</td>
<td>11.8</td>
<td></td>
</tr>
<tr>
<td>FERTILITE (CEC, méqu)</td>
<td>17.6</td>
<td>23.0</td>
<td></td>
</tr>
<tr>
<td>Azote Tonne_ha estimé</td>
<td>17</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Carbone Tonne ha estimé</td>
<td>198</td>
<td>206</td>
<td></td>
</tr>
<tr>
<td>Progression du rendement</td>
<td>+ 370 kg/an</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Resource management, Organic Fertilisation

### Nitrogen fertiliser efficiency

<table>
<thead>
<tr>
<th>Tableau 1</th>
<th>Production annuelle en Tonnes de MS/Ha/an</th>
<th>Indice</th>
<th>N EFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apport moyen/coupe/ha</td>
<td>St Jos.</td>
<td>Pl Palm.</td>
<td>Mtvert</td>
</tr>
<tr>
<td>Aucun</td>
<td>11.8</td>
<td>11.7</td>
<td>11.9</td>
</tr>
<tr>
<td>70 kg N Mineral</td>
<td>19.9</td>
<td>19.4</td>
<td>18.7</td>
</tr>
<tr>
<td>120 kg N Mineral</td>
<td>24.1</td>
<td>20.2</td>
<td>23.3</td>
</tr>
<tr>
<td>40 M³ LISIER seul</td>
<td>17.4</td>
<td>16.8</td>
<td>17.3</td>
</tr>
<tr>
<td>70 M³ LISIER seul</td>
<td>21.6</td>
<td>21.9</td>
<td>21.6</td>
</tr>
<tr>
<td>40 M³ LISIER + 30 Kg N Min</td>
<td>21.4</td>
<td>19.9</td>
<td>22.9</td>
</tr>
<tr>
<td>7.2 T COMPOST seul</td>
<td>12.4</td>
<td>11.5</td>
<td>12.3</td>
</tr>
<tr>
<td>12 T COMPOST seul</td>
<td>14.5</td>
<td>13.5</td>
<td>13.1</td>
</tr>
<tr>
<td>7.2 T COMPOST + 56 kg N Min</td>
<td>19.3</td>
<td>17.6</td>
<td>18.0</td>
</tr>
<tr>
<td>12 T COMPOST + 48 kg N Min</td>
<td>19.6</td>
<td>17.7</td>
<td>16.5</td>
</tr>
</tbody>
</table>

Nombre moyen de coupes/an | 7.5 | 6.1 | 5.7 | 6.1 |
Animal Diet efficiencies

144 Diets Database La Réunion, Vietnam
Diet compositions (Fiber Protein Intake milk)
Multivariate analysis PCA, Clustering
Hiep et al., 2006
**Diet efficiencies**

- Around mean efficiencies variation coeff. Extend: 14 - 35 %
- Large progress margins inside groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
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<tbody>
<tr>
<td>Diet classes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE (n=44), %</td>
<td>39</td>
<td>61</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VN (n=70), %</td>
<td>13</td>
<td>17</td>
<td>24</td>
<td>46</td>
</tr>
<tr>
<td>Diets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage</td>
<td>Prot.+</td>
<td>Mj+</td>
<td>Hémic+</td>
<td>Cell+</td>
</tr>
<tr>
<td>Supplement</td>
<td>Prot.+</td>
<td>Starch+</td>
<td>Cell+</td>
<td>Starch+</td>
</tr>
<tr>
<td>DM intake total, kg DM/d</td>
<td>18.3</td>
<td>19.5</td>
<td>12.2</td>
<td>15.7</td>
</tr>
<tr>
<td>Suppl., kg DM/d</td>
<td>11.1</td>
<td>11.2</td>
<td>5.4</td>
<td>6.6</td>
</tr>
<tr>
<td>Forages C4 type, %</td>
<td>66</td>
<td>81</td>
<td>100</td>
<td>98</td>
</tr>
</tbody>
</table>

**Animal prod. Efficiencies**

| Milk 4% fat, kg/d | 19.7 | 19.6 | 8.3 | 15.3 |
| Milk/DM intake | 1.06 | 1.00 | 0.68 | 0.95 |
| Milk/DM Suppl. | 1.8 | 1.8 | 1.6 | 2.3 |

**Environmental Efficiencies**

| CH₄, litre/d | 502 | 552 | 439 | 490 |
| CH₄/kg DM intake, litre/d | 28 | 29 | 36 | 32 |
| CH₄/ Milk, litre/d | 27 | 30 | 61 | 37 |
| N total excreted, g/d | 320 | 286 | 130 | 196 |
| N excrété/N intake, dl | 0.72 | 0.69 | 0.71 | 0.66 |
| N excr./Milk, g/kg | 16.2 | 14.6 | 15.8 | 12.9 |
Farm Level

*stake of Nutrient Use Efficiency improvement*

Crop-Livestock Farm

\[
\frac{\sum \text{(Output)}}{\sum \text{(Input)}}
\]

- **Input**
  - Crops
  - Livestock
- **Output**
  - Forage S.
  - Organic fertiliser

Forage S. is a key component in the nutrient cycle between crops and livestock.
Diversity of manure residues, wastes management practices in Mali

- Domestic fertiliser
  - WC
  - Home
  - Garbage pile

- Organic fertiliser /animal waste
  - Shelter
  - Cattle pen
  - Small ruminants pen

- Organic fertiliser /crop residues
  - Home area pits
  - Field pits

- Human faeces
  - Garbage pile
  - Manure
  - Soil + faeces powder
  - Home compost

- Field compost

Organic fertiliser produced

Blanchard, 2010
A typical family household in Mali

Cotton field

Surface Fumée (1.8 ha)

7,188 kg/ha

Low C and N recycling efficiencies 70 to 90% are lost, wasted in the processes ...

Corn field

Structure
13 Manpower
1 Cart, 1 Oxen
10 cattle
12 Small ruminants
10.8 ha cultivated land

Organic Fertilisers
12.9 Tons

 Structure  
13 Manpower  
1 Cart, 1 Oxen  
10 cattle  
12 Small ruminants  
10.8 ha cultivated land
Farm Gate Balances

- Efficiency diversity 36 dairy farms (La Réunion)
Farm scale efficiencies

- Life cycle analysis (LCA)
- 31 dairy farms in tropical landscapes
A large variability around means
Not a landscape attribute
Efficiency and Ecological intensification

- EI, a way toward multiefficiency progress
- Not only a matter of feeding
- Importance of daily management practices: Health, reproduction, mortality, culling... on the efficiency
Network analysis of main N flows for crop-livestock farms of the Malagasy highlands.

….. combination of more N efficient scenarios showed that farm N efficiency could increase from 2 to 50%; recycled N from 9 to 63%, food self-sufficiency about 12 to 37% in comparison with observed baseline …..

Alvarez et al. 2013 Options to improve nitrogen cycling and profitability of rice-dairy farms of the Madagascar highlands: an application of network analysis Agricultural systems (accepted)
Input:
- Decision rules
- Farm Structure
- Météo Data
- Input availabilities
- Output demand

Output:
- Sustainability Indicators

Development of a farm global model

« action Research» model

Global Activity Model for Evaluating the Sustainability of Dairy Enterprises
Collective approach in model, innovation conception

Étapes de conception et de validation:

- Changement des opérations et des flux représentés par le modèle
- Une nouvelle structure conceptuelle
- Prise en compte de différents niveaux de paille des animaux
- Échantillonnage
- Évaluations sur l'exploitation

Moments d'échanges:

- Évaluer l'impact environnemental de systèmes de production existant et de l'effet d'innovations techniques
- Évaluer l'effet des innovations sur la durabilité sociale et économique
- Outil d'aide à la gestion agro-écologique
- Support de discussion, d'apprentissage et de diffusion d'innovations

Élargissement des objectifs:

- Nouvelles objectifs
- Échantillonnage
- Prise en compte de différents niveaux de paille des animaux
- Échelles

Légende:

- Modèle Global
- Système décisionnel
- Module production fourrages
- Mod. productions animales
- Mod. pâturage
- Mod. démographique
- Mod. émissions azotées
- Mod. conditionnement fourrages
- Mod. économique
- Réunions individuelles
- Réunions collectives
- Validation par des éleveurs
- Validation par des chercheurs
- Immersions
- Influence des éleveurs sur le processus de modélisation et la nature du modèle

2003 | 2004 | 2005 | 2006 | 2007

2004

2005

2006

2007
Étudier les pratiques décisionnelles
Actions/ Contrôle

Programme prévisionnel / saisons pratiques

Planification

Règles de réalisation des actions et d’ajustements éventuels

Réalisation

Objectifs de conduite

Stratégie

« décisionnal » Sub-System..

Système biophysique

(Duru, 1967; Vayssières, 2004)
Data Envelopment Analysis (DEA) : non-parametric frontier model

OUTPUTS (milk, meat, GHG, nitrogen...)

INPUTS (land, labor, forage, feeds)

Efficient firm

Inefficient firm

Efficiency of firms assessed by mathematical formulation of a production technology characterized by inputs and outputs

Allows integration of undesirable outputs (GHG, Nitrogen excess, ...)

Directional distance function characterize path of inefficiency reduction

Adressing diversity of efficiencies
Directions in inefficiency reduction

- Efficiency can be considered / different projection direction on the frontier

Farmer’s view: optimize milk production,
Society’s view: reduce pollution

Dairy coop. view: increase inputs to reach the optimal amount of good production
Progress margin can be assessed according to different point of view:

<table>
<thead>
<tr>
<th></th>
<th>Milk production</th>
<th>Emissions, Surpluses</th>
<th>Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GHG</td>
<td>Feed charges</td>
</tr>
<tr>
<td>Cooperative</td>
<td>25.65%</td>
<td></td>
<td>31.19%</td>
</tr>
<tr>
<td>Society</td>
<td>-22.79%</td>
<td>-24.12%</td>
<td></td>
</tr>
<tr>
<td>Farmers</td>
<td>13.04%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A potential milk production raise of 25.65% is possible if farmers accept to increase their inputs by more than 30%.

If inefficiency reduction only focus on pollution reduction, GHG and nitrogen surpluses can be reduced by 22.79% and 24.12% respectively.

Farmers can increase their milk production by 13.04%, given their current inputs and pollution levels.
Exploring beyond the frontiers the domain of possible efficiencies

Promising approach to measure potential inefficiency reduction in different context by generating large datasets and identifying the optimal amount of production (and pollution) for given levels of inputs.
• Explore the eco-efficiency determinants beyond the score analysis
• Territorial approach close to the Agrimonde scenario AG1:
  Identify exogenous parameters linked to efficiency in different contexts
Sustainable value: research on the implementation for livestock's production efficiency issue

- Basics: reallocate resources of one farm to a benchmark and assess whether the benchmark is able to produce more than the considered farm
- Sustainability is assessed via an efficiency perspective
- Existing Literature link frontier efficiency method and sustainable value approach (Van Passel et al., 2009; Ehrmann, 2008)
- Promising approach to assess a “sustainable value” of different livestock production (need eco soc envirt data)
On going research
Gap efficiency assessment: an inter-systemic approach of efficiency

- Assuming the same frontier for different livestock systems is incorrect as it assumes the same exogenous parameters.
- Different frontiers must be implemented to assess the gap efficiency.
- In this theoretical example, red frontier is better than the blue for low-input systems.
- The final objective is to appreciate the progress margin in each agronomic context.
- ... A promising approach to define a detailed assessment for the “gap”
Livestock information systems currently used
What this information system is measuring
Regional coverage and current projects

EPAD
SIPSA
ALIVE
REVALTER
ELVULMED
AnChange WP 10, FERLO
Climed
Sustainable intensification (WA)
ECOTERA
CERAO

WAW World agricultural watch
Complexity of getting synthetic data

→ Lack of data’s problem of units
Analyse de la BDD

- Analyse comparative INTER systèmes de production
  SE tempérés vs tropicaux, intensifs vs extensifs
  - Elevages laitiers Bretagne, Poitou Charente, Réunion et Mali (Matthieu Vigne)

Consommation d’énergie à l’échelle du troupeau laitier

⇒ Profils de consommation des différentes énergies (NRE, EB, Travail) relié aux pratiques
  - ML : énergie lié au travail (systèmes manuels), peu d’énergie fossile
  - RI : énergie fossile importée sous forme d’énergie brute (concentrés)
  - PC : utilisation de l’ensilage entraîne une énergie fossile plus élevée que BR (pâturage)
Conclusions

Diversity of local efficiencies
Global or localised “gap”
Scaling the efficiencies
Marginal cost of efficiencies improvements
Sum of small efficiency increase vs a unique integrated efficient model
Importance of “cognitive systems” are they efficient?