



HAL
open science

Multiobjective feed formulation for swine - economic and environmental aspects

Florence Garcia-Launay

► **To cite this version:**

Florence Garcia-Launay. Multiobjective feed formulation for swine - economic and environmental aspects. 34. Annual meeting of CBNA (Colégio Brasileiro de Nutrição Animal), Colégio Brasileiro de Nutrição Animal, Mar 2023, Campinas & Sao Paulo, Brazil. <hal-05426236>

HAL Id: hal-05426236

<https://hal.inrae.fr/hal-05426236v1>

Submitted on 19 Dec 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

INRAE



➤ Multiobjective feed formulation for swine - economic and environmental aspects

Florence Garcia-Launay

PEGASE, INRAE, Institut Agro, 35 590 Saint-Gilles,
France

florence.garcia-launay@inrae.fr



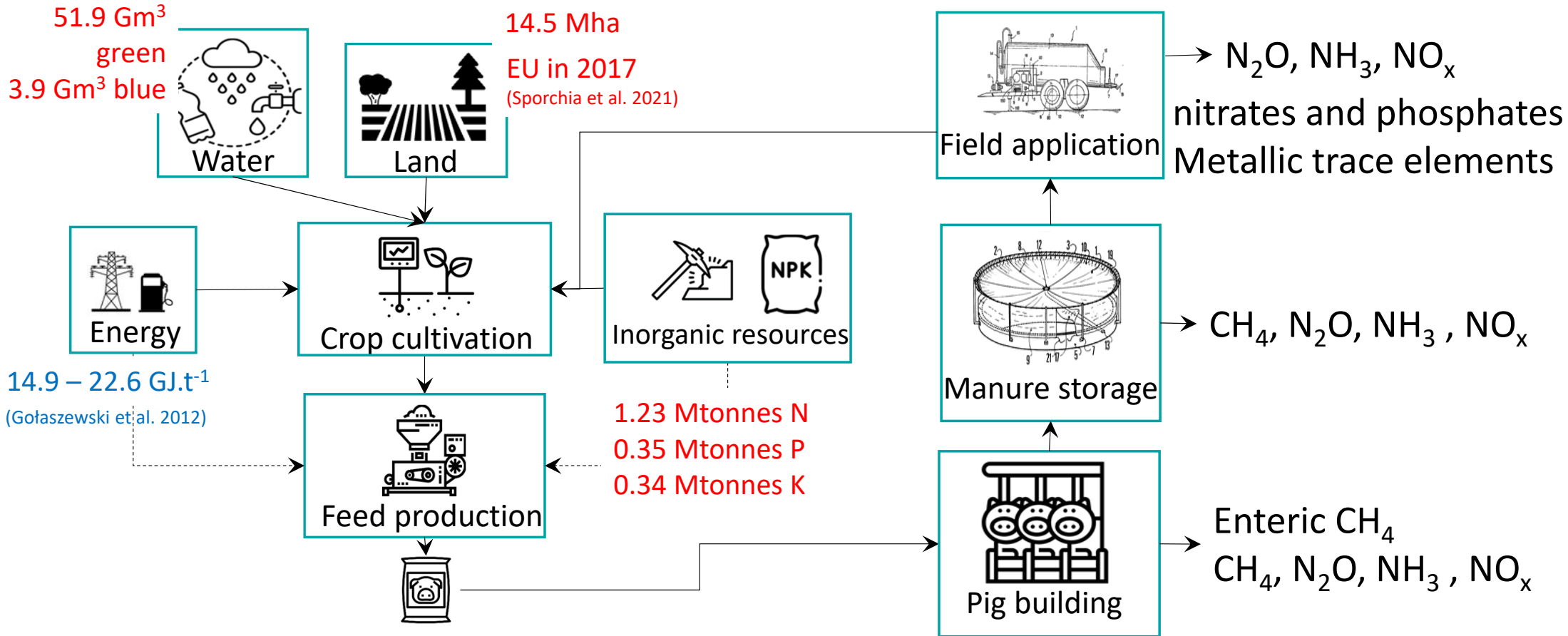
34ª Reunião Anual do CBNA - 2023

A Nutrição e as Demandas do Consumidor:
Bem-Estar Animal e Meio Ambiente

AVES . SUÍNOS . BOVINOS

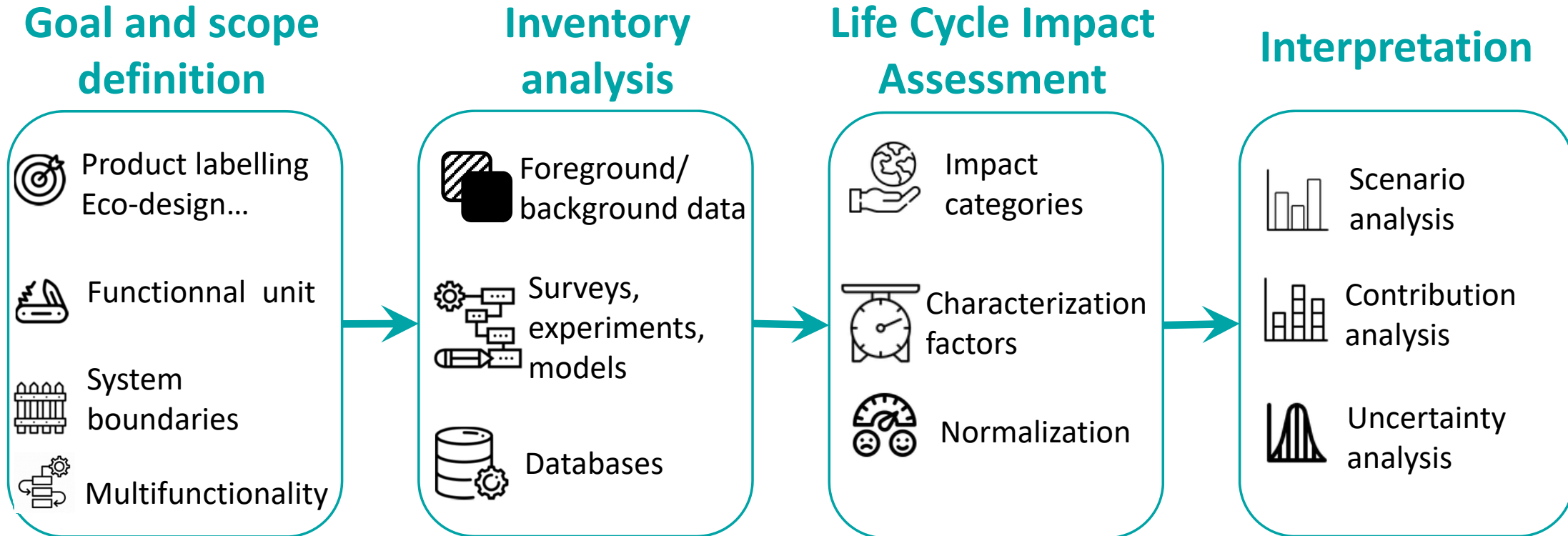
21, 22 e 23
de março

➤ Swine production systems (SPS) and the environment



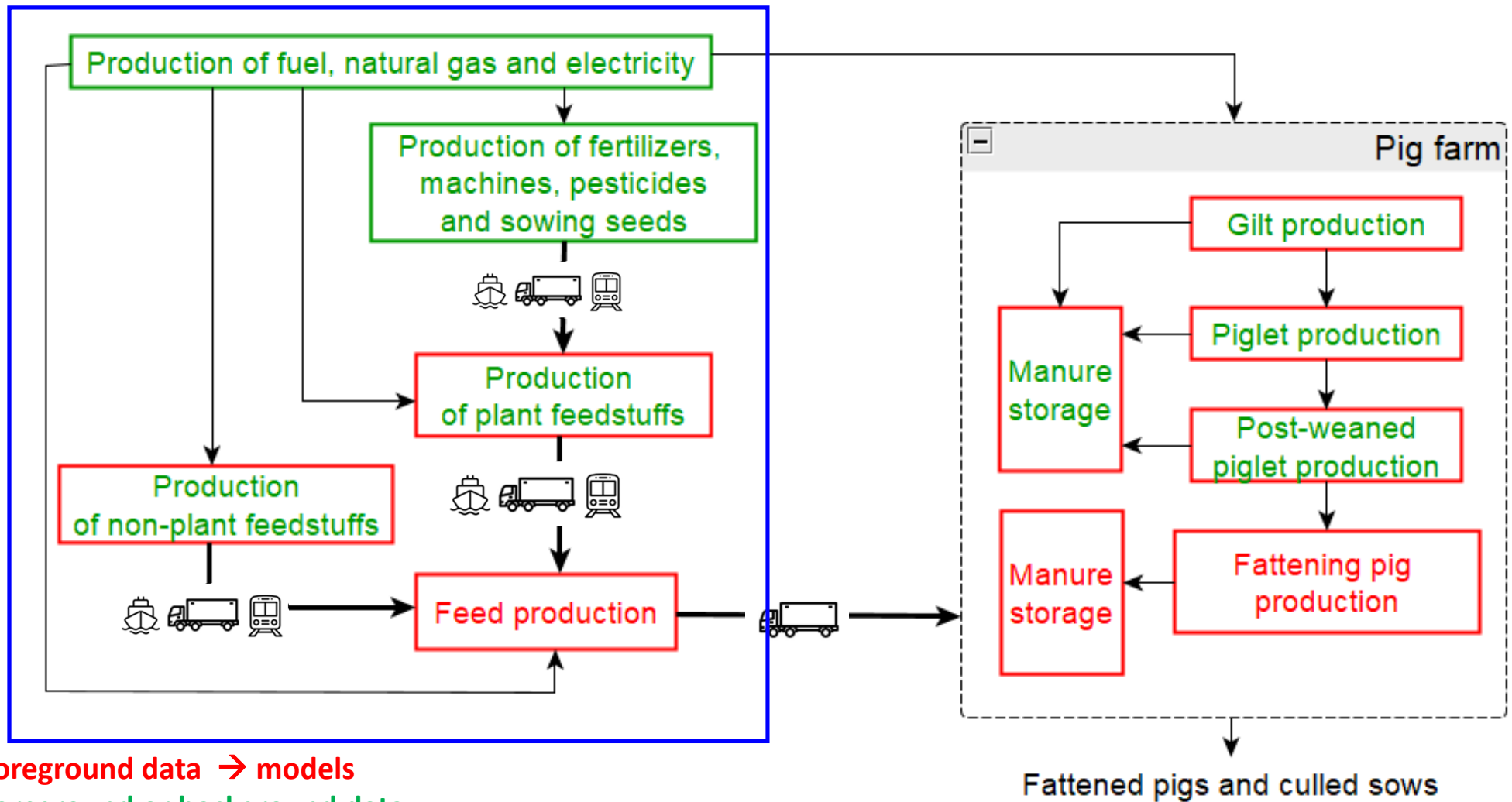
Feed production and manure emissions are major contributors to most environmental impacts

➤ Life Cycle Assessment framework into 4 steps



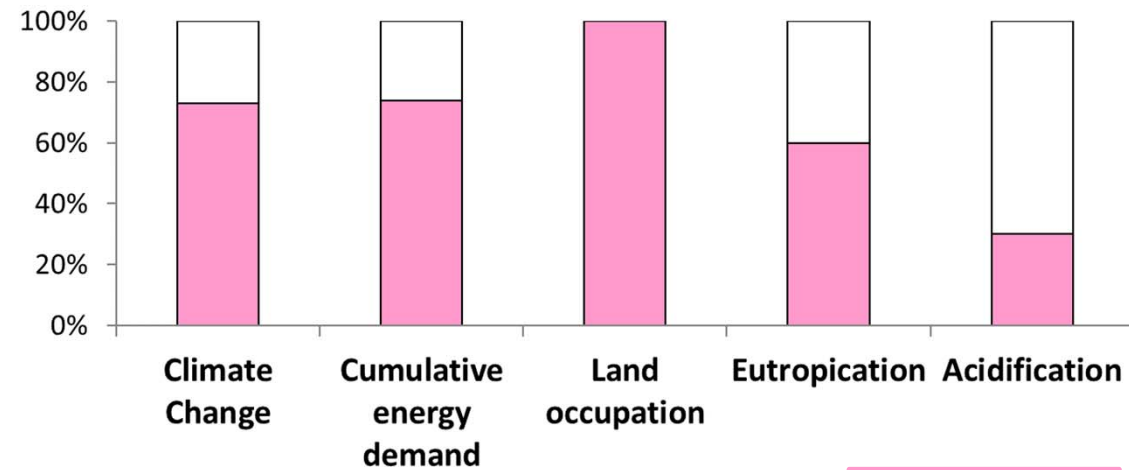
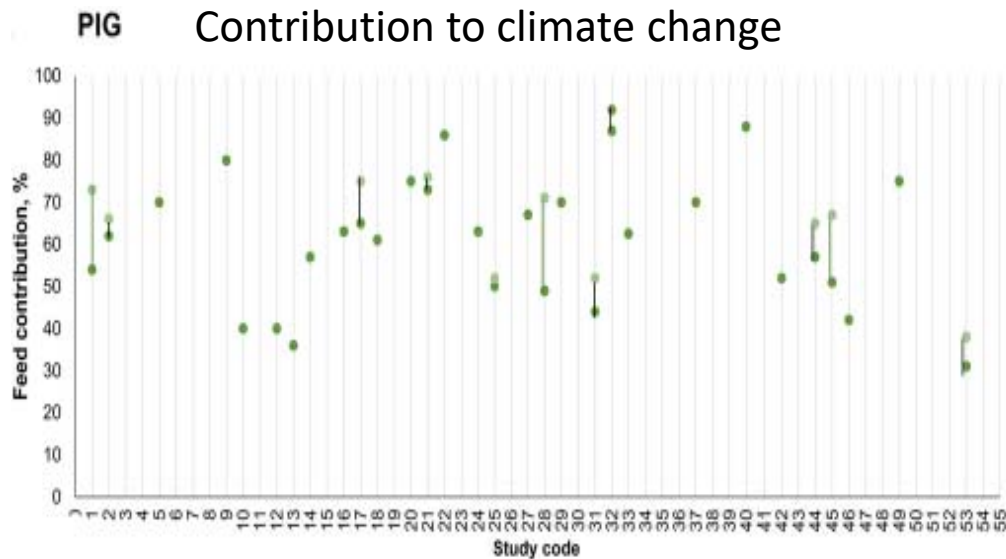
LCA offers a comprehensive framework to support eco-design in many areas, including swine production

➤ Goal and scope in Swine Production Systems (SPS) LCAs



- a Foreground data → models
- a Foreground or background data
- a Background data → databases

➤ Contribution of feed production to most environmental impacts



Andretta et al. 2021

*Basset-Mens &
van der Werf, 2005
Dourmad et al. 2014*

Decreasing the environmental impacts of pig feeds is potentially an interesting lever of mitigation

**Associating LCA to feed formulation
for swine production systems
should contribute
to mitigate the environmental impacts
of swine production
while addressing the best trade-off with feed cost**



INRAE



L'INSTITUT
agro Rennes
Angers

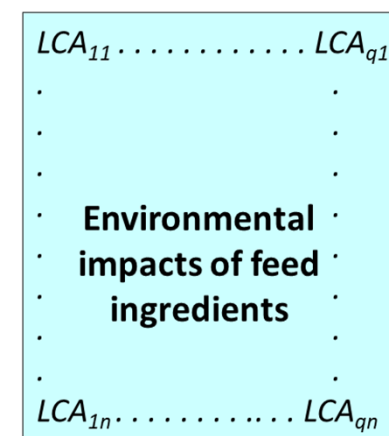
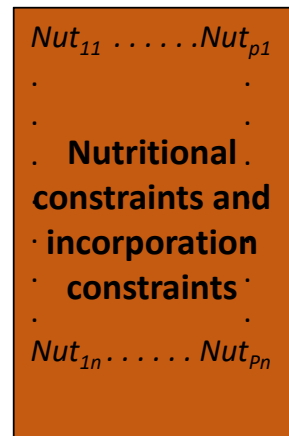
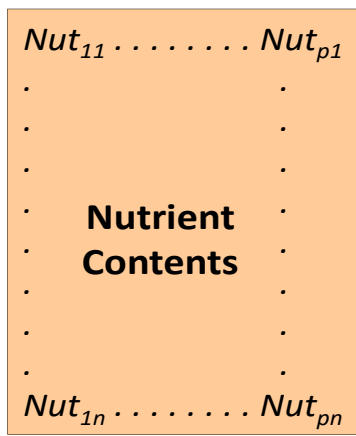
Multiobjective feed formulation for swine

March 23rd, 2023 / 34th CBNA meeting / Florence Garcia-Launay

➤ The story of multiobjective feed formulation

1. **First story - Dealing with multiple objectives to overcome potential transfer of impacts**
2. Second story - Dealing with multiple objectives to overcome potential transfer of impacts
3. Supporting decision with multiobjective feed formulation
4. Conclusions and implications

➤ Multiobjective feed formulation – what are we talking about?



Environmental impacts at feed factory gate

Garcia-Launay et al. 2018 - <https://doi.org/10.1017/S0007114518002672>



➤ Step 1 : traditional least-cost feed formulation

$$\begin{cases} \min \mathbf{c}^t \mathbf{x} \\ \begin{pmatrix} \mathbf{q}_{\min} \\ \mathbf{n}_{\min} \\ 1 \end{pmatrix} \leq \begin{pmatrix} \mathbf{Q} \\ \mathbf{N} \\ \mathbf{1}^t \end{pmatrix} \mathbf{x} \leq \begin{pmatrix} \mathbf{q}_{\max} \\ \mathbf{n}_{\max} \\ 1 \end{pmatrix} \\ 0 \leq \mathbf{x} \leq 1 \end{cases}$$

In this first step, we produce a reference least-cost feed

I := set of feed ingredients

J := set of nutrients

$\mathbf{x} = (x_i)_{i \in I}$

Ingredient **incorporation rate** decision vector

$\mathbf{c} = (c_i)_{i \in I}$

Ingredient **cost** vector

$\mathbf{Q} = \text{Id} * 1000$

$\mathbf{q}_{\min} = (q_{\min j})_{j \in J}$, $\mathbf{q}_{\max} = (q_{\max j})_{j \in J}$

vectors of ingredient incorporation constraints

$\mathbf{N} = (n_{ij})_{i \in I, j \in J}$ matrix of **nutritional values**

$\mathbf{n}_{\min} = (n_{\min j})_{j \in J}$, $\mathbf{n}_{\max} = (n_{\max j})_{j \in J}$

Vectors of **nutritional constraints**



➤ Step 2 : multiobjective feed formulation

$$\left\{ \begin{array}{l} \min (1 - \alpha) \frac{\mathbf{c}^t \mathbf{x}}{\text{Cost}_{\text{ref}}} + \alpha \times \sum_{i \in I} \text{coef}_i \frac{\mathbf{impact}_i^t \mathbf{x}}{\text{impact}_{\text{ref}_i}} \\ \begin{pmatrix} \mathbf{q}_{\min} \\ \mathbf{n}_{\min} \\ 1 \end{pmatrix} \leq \begin{pmatrix} \mathbf{Q} \\ \mathbf{N} \\ \mathbf{1}^t \end{pmatrix} \mathbf{x} \leq \begin{pmatrix} \mathbf{q}_{\max} \\ \mathbf{n}_{\max} \\ 1 \end{pmatrix} \\ 0 \leq \mathbf{x} \leq 1 \\ \begin{pmatrix} \mathbf{impact}_1^t \\ \mathbf{impact}_2^t \\ \vdots \\ \mathbf{impact}_m^t \end{pmatrix} \mathbf{x} \leq \begin{pmatrix} 1,05 * \text{impact}_{1\text{ref}} \\ 1,05 * \text{impact}_{2\text{ref}} \\ \vdots \\ 1,05 * \text{impact}_{m\text{ref}} \end{pmatrix} \end{array} \right.$$

Impacts: climate change, non-renewable energy demand, land occupation, phosphorus demand

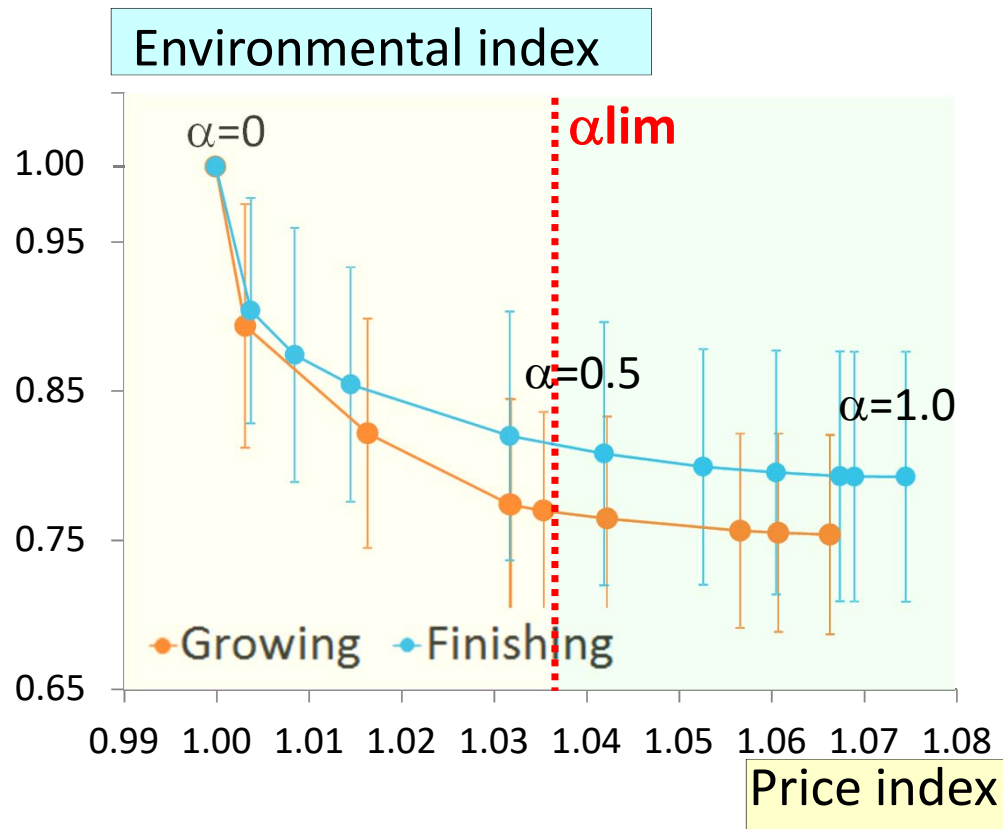
impact_i → vector of **impact** values *i* for feed ingredients

Variables with subscript "ref" → values obtained for the reference feed from least cost feed formulation

α is the weighting factor between **cost index** and **environment index**



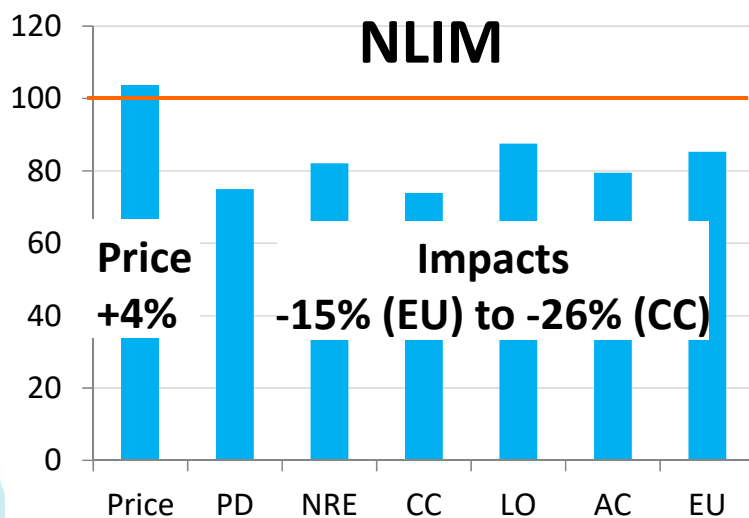
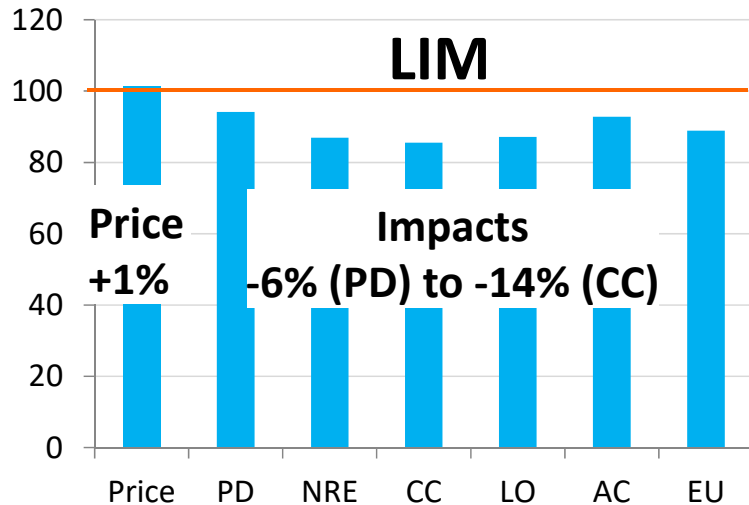
➤ Trade-off economy | environment



Feed formulas and mitigation of impacts calculated at α_{lim}



➤ Mitigation of environmental impacts



Current limited availability of feed ingredients (LIM)

Increased potential availability of some feed ingredients such as protein seeds and co-products (NLIM)

PD: phosphorus demand

NRE: non-renewable energy demand

CC: climate change

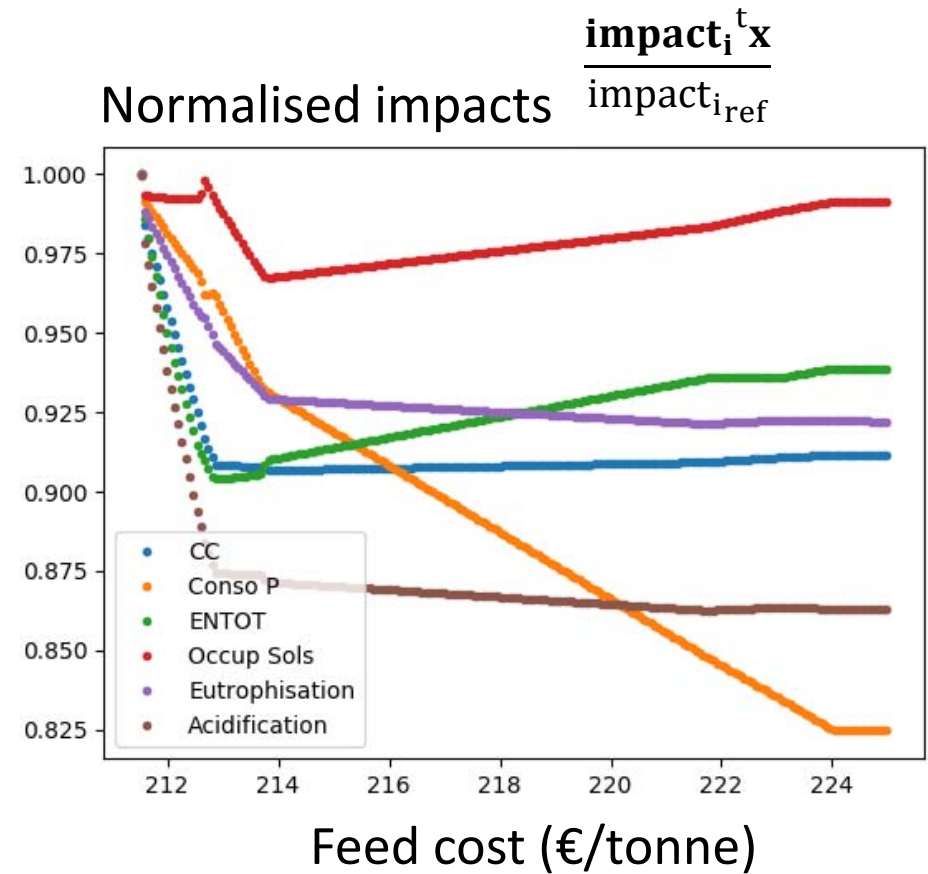
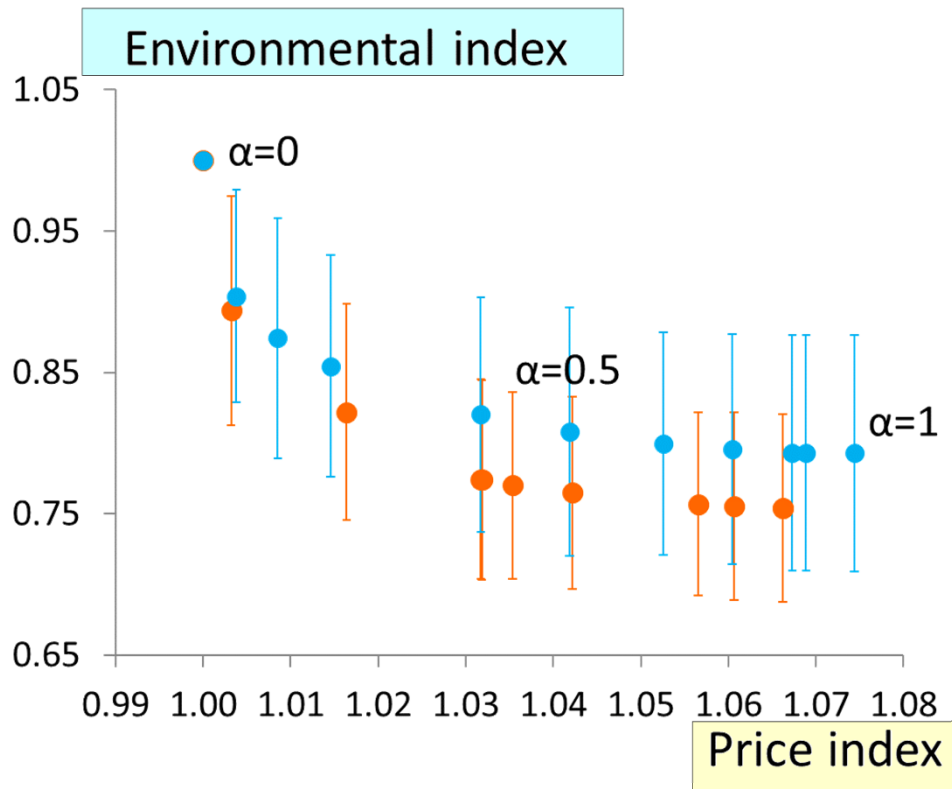
LO: land occupation


AC: acidification

EU: eutrophication

No transfer of impacts

➤ However ! Remaining problems...



- 
- The story of multiobjective feed formulation
 1. First story - Dealing with multiple objectives to overcome potential transfer of impacts
 2. **Second story - Dealing with multiple objectives to overcome potential transfer of impacts**
 3. Supporting decision with multiobjective feed formulation
 4. Conclusions and implications

➤ Resolving the remaining problems

$$\min \sum_{i \in I} \text{coef}_i \frac{\text{impact}_i^t \mathbf{x} - \text{Min}_i}{\text{impact}_{\text{ref}_i} - \text{Min}_i}$$

$$\mathbf{c}^t \mathbf{x} \leq \epsilon$$

$$\begin{pmatrix} \mathbf{q}_{\min} \\ \mathbf{n}_{\min} \\ 1 \end{pmatrix} \leq \begin{pmatrix} \mathbf{Q} \\ \mathbf{N} \\ \mathbf{1}^t \end{pmatrix} \mathbf{x} \leq \begin{pmatrix} \mathbf{q}_{\max} \\ \mathbf{n}_{\max} \\ 1 \end{pmatrix}$$

$$0 \leq \mathbf{x} \leq 1$$

$$\begin{pmatrix} \text{impact}_1^t \\ \text{impact}_2^t \\ \vdots \\ \text{impact}_m^t \end{pmatrix} \mathbf{x} \leq \begin{pmatrix} 1,05 * \text{impact}_{1\text{ref}} \\ 1,05 * \text{impact}_{2\text{ref}} \\ \vdots \\ 1,05 * \text{impact}_{m\text{ref}} \end{pmatrix}$$

Multiobjective feed formulation for swine

March 23rd, 2023 / 34th CBNA meeting / Florence Garcia-Launay

ϵ – constraint method

$$\epsilon = \{\text{Cost}_{\text{ref}}, \dots, \text{Cost}_{\text{max}}\}$$

impact_i → vector of **impact** values *i* for feed ingredients

Cost_{max}: price of feed when formulating without ϵ -constraint

Min_i: level of impact *i* when formulating at lowest impact *i*

De Quelen et al. 2021 -

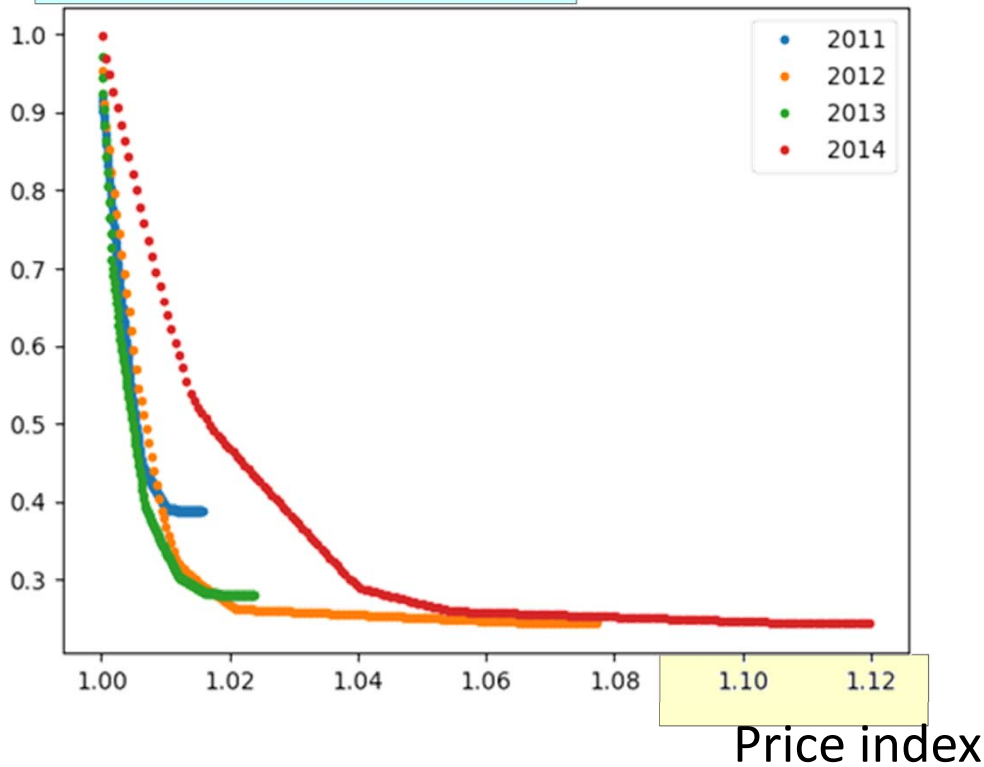
<https://doi.org/10.3389/fvets.2021.689012>

Wilfart et al. 2022 -

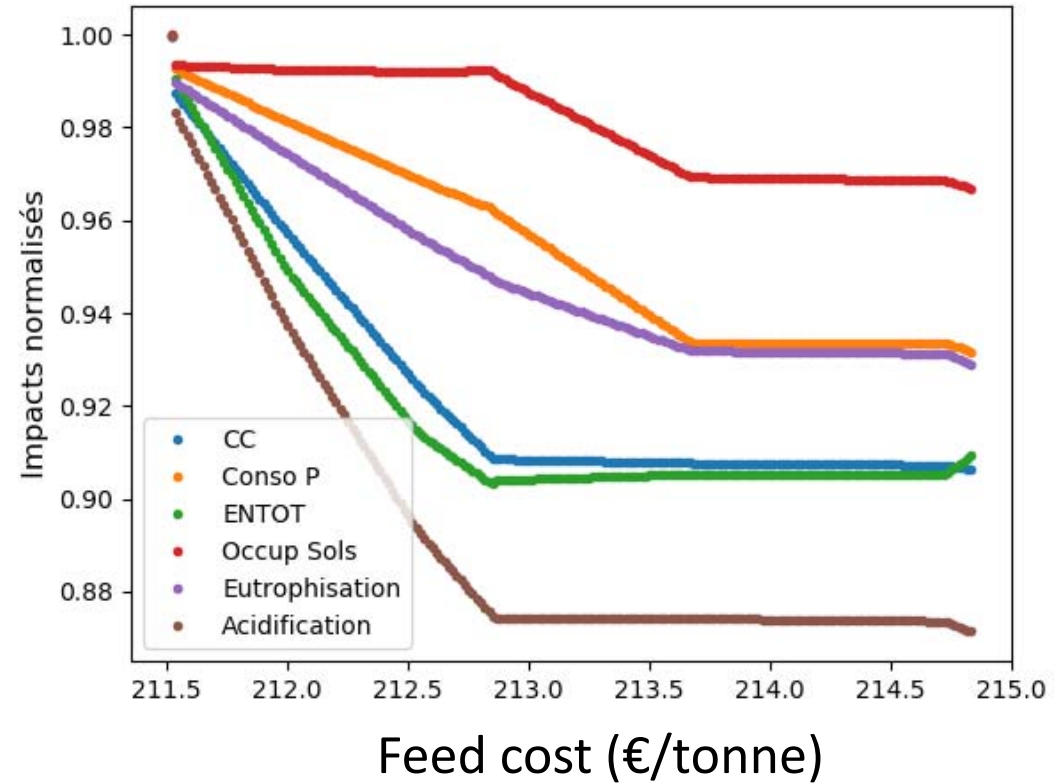
<https://doi.org/10.1016/j.aquaculture.2022.738826>

➤ Resolving the remaining problems !

Environmental index



Normalised impacts $\frac{\text{impact}_i^t \times}{\text{impact}_{i_{\text{ref}}}}$



➤ Application to swine production

- ❖ **Formulation considers animal requirements, feed cost and different environmental impacts by Life Cycle Assessment (LCA) approach**
- ❖ **3 different formulation approaches :**
 - **Control diet** = least-cost formulation in accordance with practices in commercial farms
 - **Ecodiet** = multiobjective formulation considering feed cost and environmental impacts calculated by Life Cycle Assessment (LCA) (Ecoalim)
 - **Local diet** = multiobjective formulation using feed ingredients locally produced by farmers to reduce the impact of feed transport



➤ Environmental impacts of diets calculated through LCA (per kg average feed)

	Control diet	Ecodiet	Local diet	Control diet to Ecodiet	Control diet to Local diet	Ecodiet to Local diet
CC (kg CO₂ eq)	485	342	376	↓ 29.5%	↓ 22.5%	↑ 9.9%
CED (MJ)	4073	3486	3286	↓ 14.4%	↓ 19.3%	↓ 5.7%
Acidification (molc H⁺ eq)	9.39	7.65	7.76	↓ 18.5%	↓ 17.3%	↑ 1.4%
Eutrophication (kg PO₄³⁻ eq)	3.68	3.22	3.79	↓ 12.5%	↑ 3%	↑ 17.7%
Land occupation (m².y)	1412	1374	1674	↓ 2.7%	↑ 18.5%	↑ 21.8%

CC (climate change (kg CO₂ eq)) = global warming potential; CED = non-renewable and fossil energy demand (MJ); AC = acidification (molc H⁺ eq); EU = eutrophication (kg PO₄³⁻ eq); LO (land occupation (m²/y)) = area of the land required to produce one kg of feed.



➤ Environmental impacts at farm gate (per kg of live pig)

❖ **Animals : 96 Pietrain x (Large White x Landrace) pigs**

❖ **Daily individual recording of animal performance from 40 to 115kg: live weight, feed consumption, water consumption**

❖ **Slaughterage at 115kg : carcass weight, lean meat percentage**

	Control diet	Ecodiet	Local diet	RSD	Statistics
CC (kg CO ₂ eq)	2.50 ^a	2.06 ^b	2.20 ^c	0.13	G**, S***, A***
CED (MJ)	14.58 ^a	12.47 ^b	12.43 ^b	0.12	G**, S***, A***
AC (molc H ⁺ eq)	0.155 ^a	0.144 ^b	0.154 ^a	0.108	G**, S***, A**
EU (kg PO ₄ ³⁻ eq)	0.295 ^a	0.273 ^b	0.308 ^a	0.113	G**, S***, A***
LO (m ² .y)	4.63 ^a	4.45 ^a	5.69 ^b	0.15	G**, S***, A***

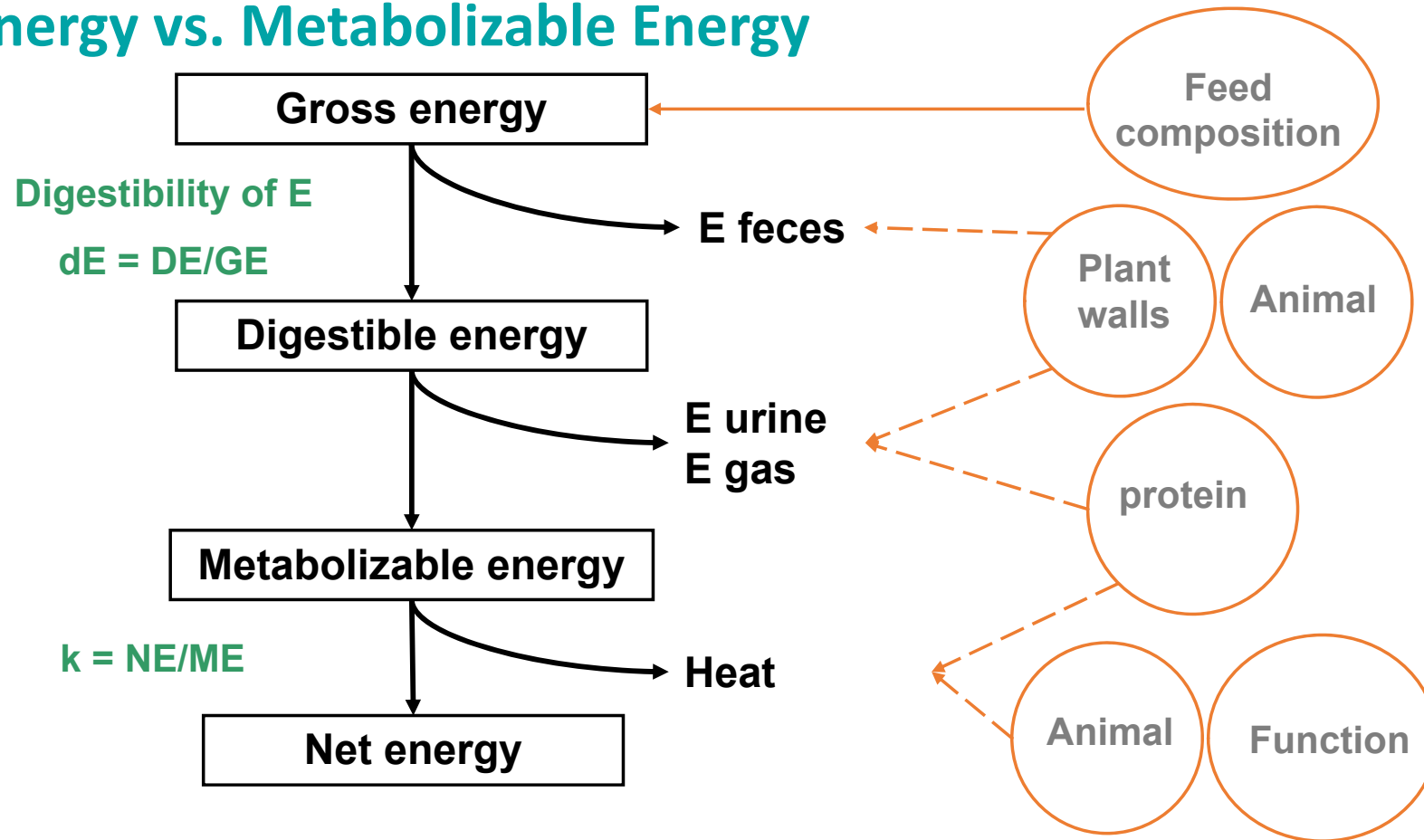
CC (climate change (kg CO₂ eq)) = global warming potential; CED = non-renewable and fossil energy demand (MJ); AC = acidification (molc H⁺ eq); EU = eutrophication (kg PO₄³⁻ eq); LO (land occupation (m²/y)) = area of the land required to produce one kg of feed.



➤ The story of multiobjective feed formulation

1. Dealing with multiple objectives to overcome potential transfer of impacts
2. Performing multiobjective formulation without degrading on-farm impacts
3. **Supporting decision with multiobjective feed formulation**
4. Conclusions and implications

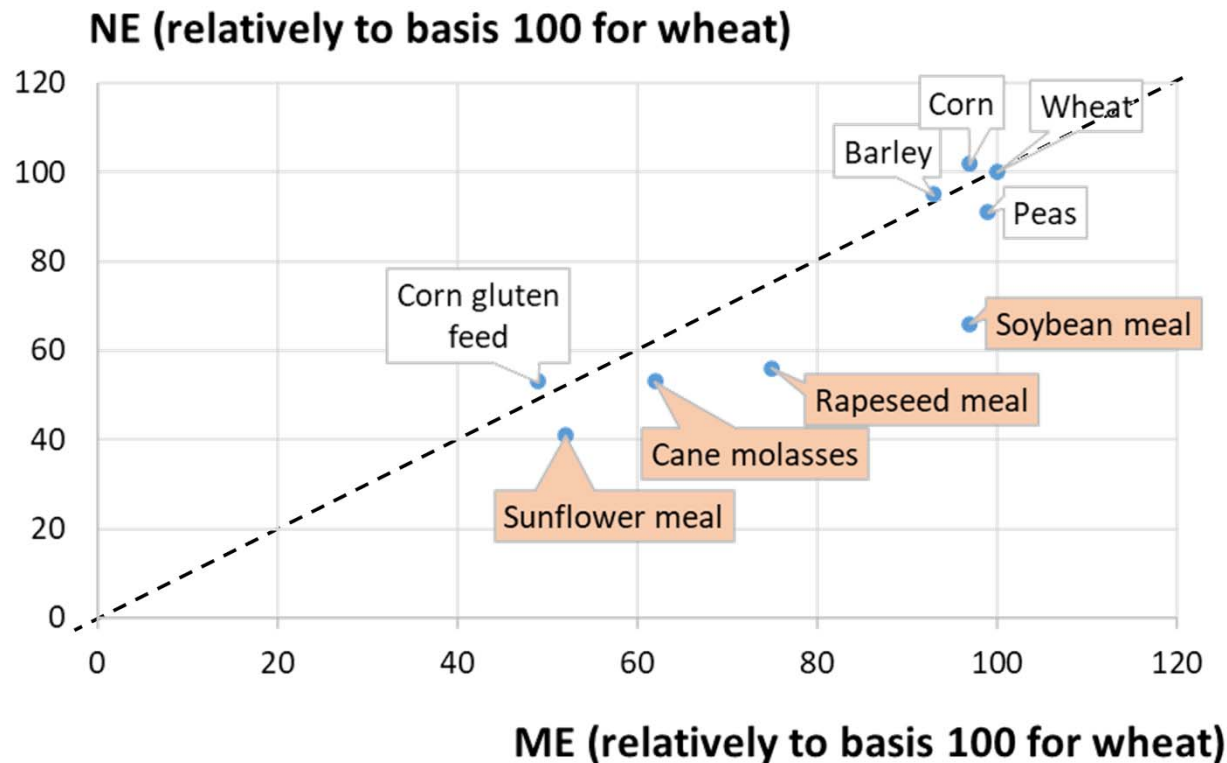
➤ Performing multiobjective feed formulation based on Net Energy vs. Metabolizable Energy



NE provides the true energetic value of feed ingredients, which is the energy really available for maintenance, growth...

➤ Performing multiobjective feed formulation based on Net Energy vs. Metabolizable Energy

Noblet 2015 - <https://hal.inrae.fr/hal-02742572>

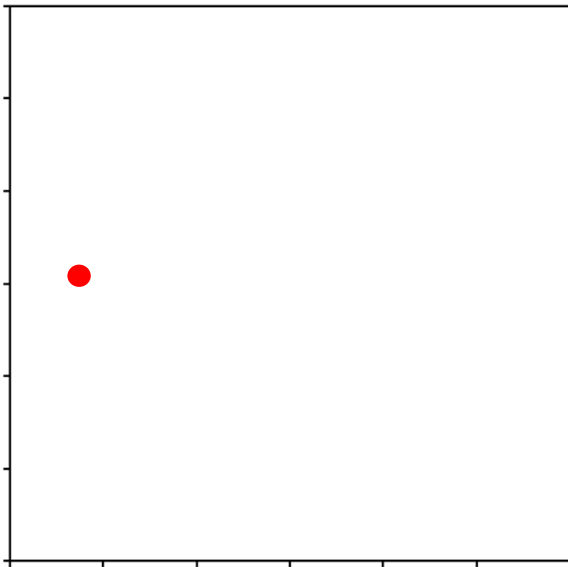


In practice, the efficiency NE/ME varies between the different feed ingredients, because this efficiency depends on the origin of ME (fat, starch, protein, fibres)
→ the energy value of protein-rich or fibrous feeds is overestimated when expressed on a ME basis.

Multiobjective optimization may produce ecofeeds with different NE/ME ratios than leas-cost formulated feeds → necessary to formulate on NE basis

➤ It is necessary to build the Pareto front!

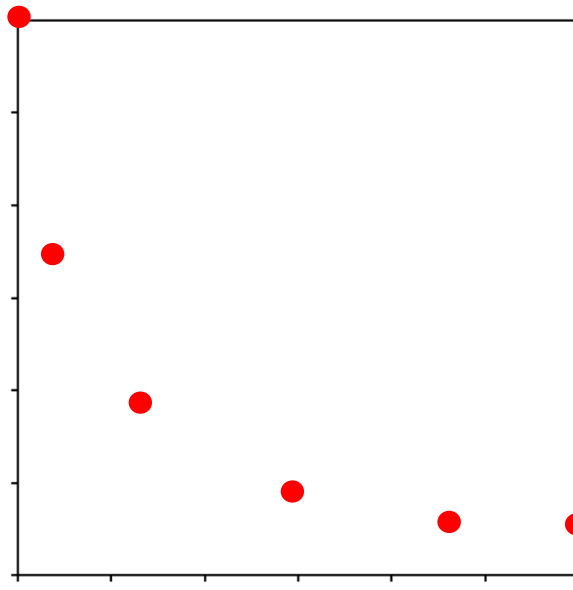
Cost index – $\alpha = 0.3$



Environmental Index
weight (0.7)

Fixed weighting factors

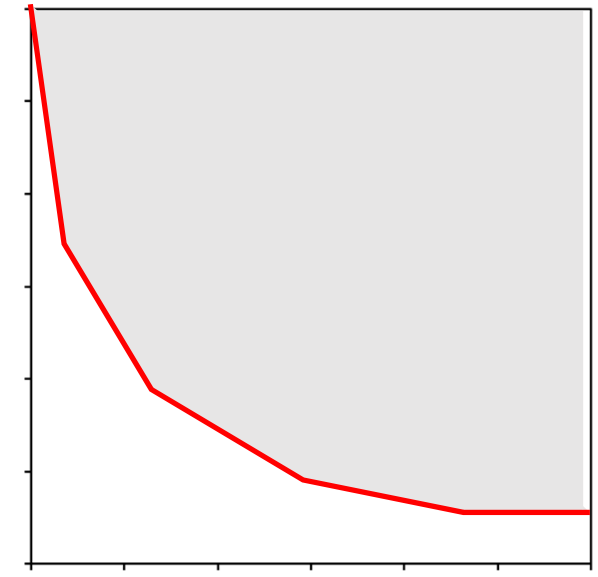
Cost index – weight α



Environmental Index
weight (1- α)

Weighted sum

Feed cost – ϵ -constraint



Environmental Index

ϵ -constraint

Necessary to get all the Pareto front before choosing a trade-off

➤ Multiobjective feed formulation with average values for environmental impacts of feed ingredients?

Feed formulation using average values of feedstuffs impacts in France



Ecofeeds

Multiobjective formulation



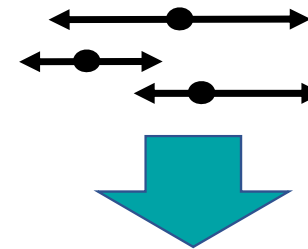
Profile of the feeds in terms of feedstuffs incorporations

Standard feeds

Least-cost formulation



Variability of the feedstuffs impacts in France

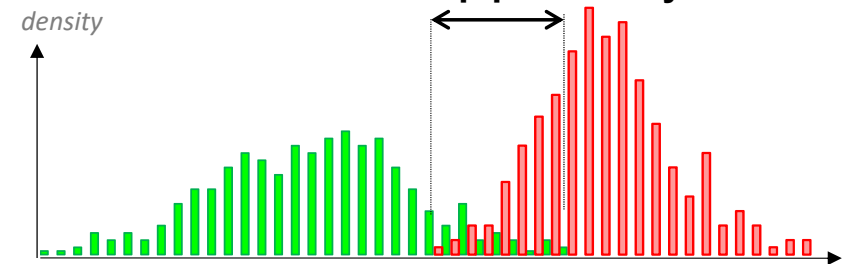


Impacts

Impacts



Overlap probability



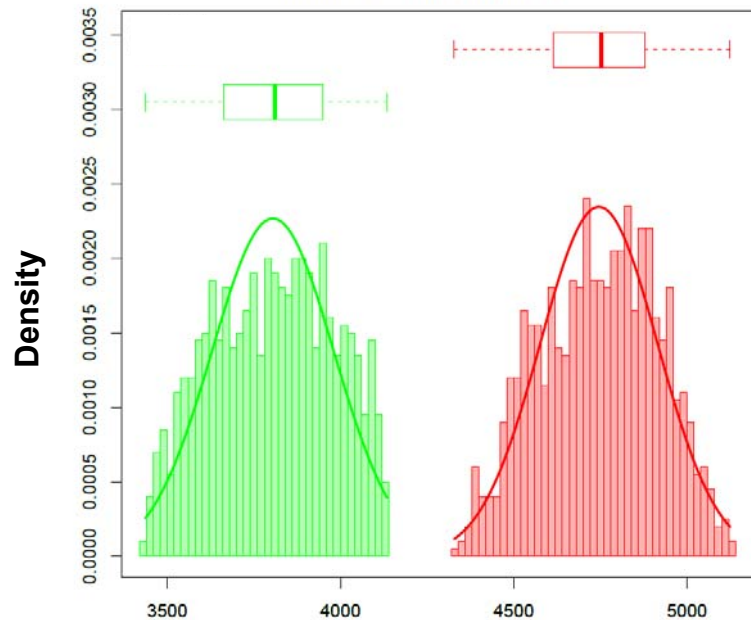
0 ---increasing environmental impacts---> +

Espagnol et al. LCA Foods 2018

➤ Multiobjective feed formulation with average values for environmental impacts of feed ingredients?

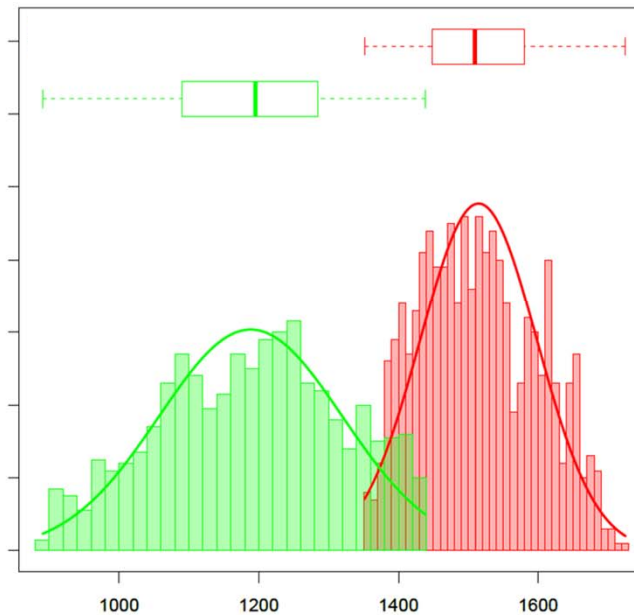
Ecofeed
Standard feed

Non renewable energy consumption



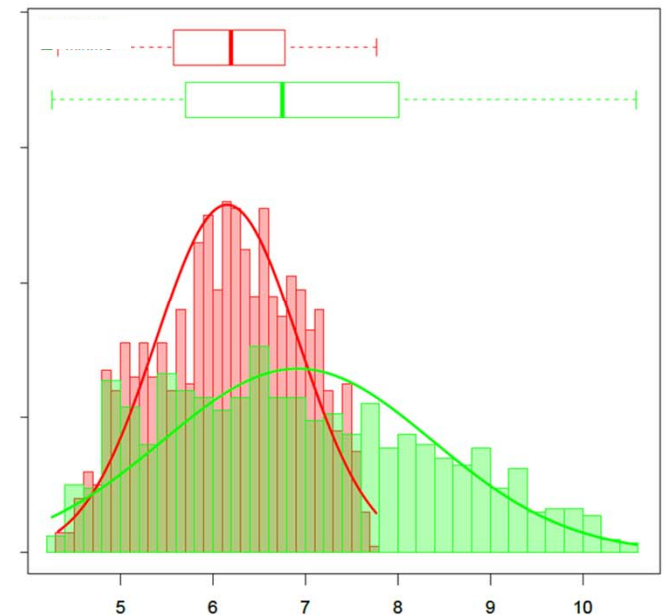
Overlap probability = 0

Land occupation



Overlap probability = 13%

Acidification



Overlap probability = 99%



➤ Multiobjective feed formulation with average values for environmental impacts of feed ingredients?

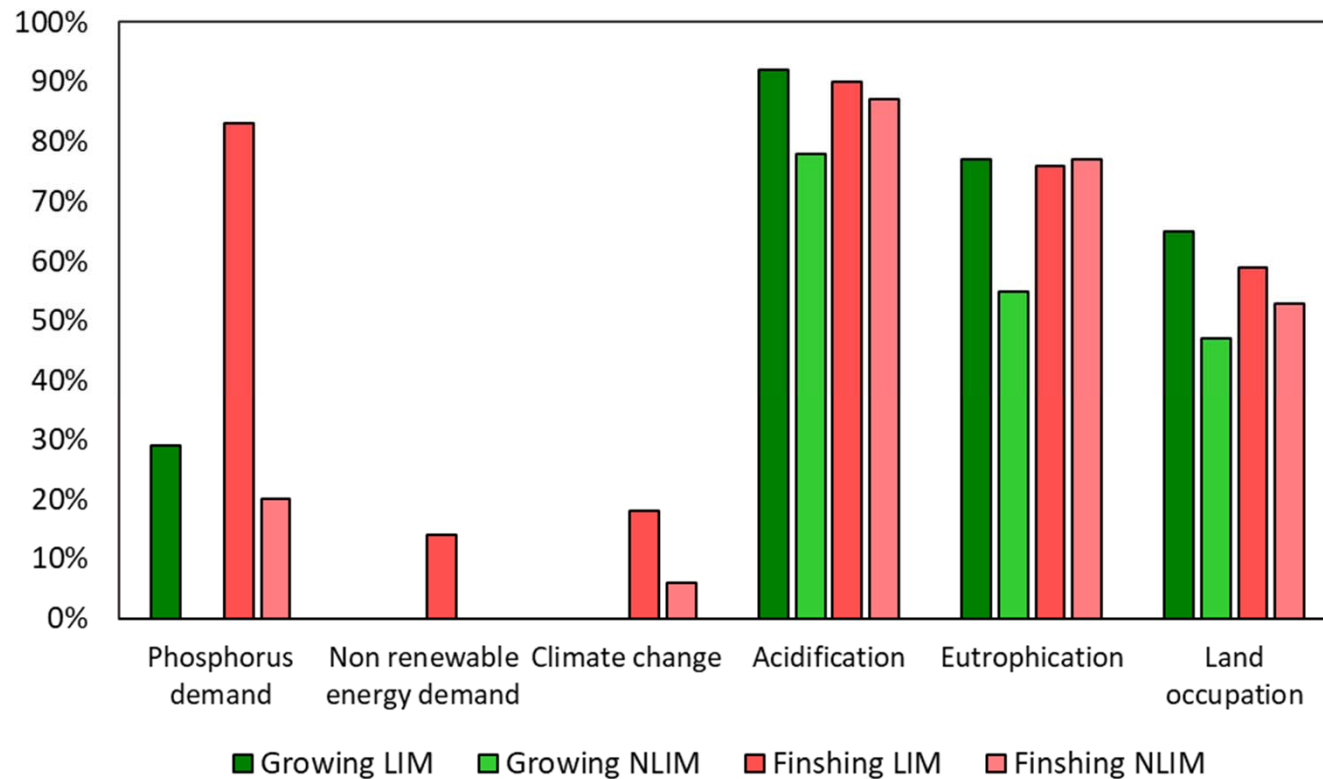
Espagnol et al. LCA Foods 2018

16 situations

2 feeds of the fattening period (growing and finishing)

4 contrasted economic contexts (2011, 2012, 2013 and 2014)

2 levels of feedstuff availability



LCA data on available feedstuffs should be as precise as much as possible

Robustness to variability for climate change and non renewable energy demand

➤ Eco-design in pig production supported by multiobjective feed formulation and LCA

Feed factory gate

- ❖ Various studies – models proposed – minimizing a single impact (Nguyen et al. 2011 in broilers)
- ❖ Methodology accounting for 4 global environmental impacts and feed cost (Garcia-Launay et al. 2018) – updated (de Quelen et al. 2021)

Pig farm gate

- ❖ Diet formulation tool that seeks for the feed formula and the levels of net energy, CP and AA that minimize a composite function including environmental impacts (McKenzie et al. 2016)

One should be careful when applying multiobjective optimization that the excretion of nutrients, in particular N & P, is not increased



➤ The story of multiobjective feed formulation

1. Dealing with multiple objectives to overcome potential transfer of impacts
2. Performing multiobjective formulation without degrading on-farm impacts
3. Supporting decision with multiobjective feed formulation
4. **Conclusions and implications**

➤ Multiobjective optimization to support eco-design in pig production

- ❖ Multiobjective optimization of pig feeds is efficient for reducing environmental impacts which are included in the objective-function
- ❖ Caution should be taken when applying feed formulation :
 - Formulating on a Net Energy basis
 - Making sure excretion of N & P are not increased
 - Looking at the whole Pareto front
 - Checking for effects of uncertainty in the impacts of feed ingredients

> Perspectives

- ❖ Optimizing of both feed formulas and feeding program
- ❖ Multiobjective optimization based on the environmental impacts of pig at farm gate.

- ❖ Decision support tools to make it easily available for feed producers, and for teaching purpose

INRAE



➤ Thank you for your attention

florence.garcia-launay@inrae.fr

Many thanks to my colleagues Lucile Montagne (INRAE) and Sandrine Espagnol (Ifip)