Diversification of crop-livestock systems: nutrient cycling and food efficiency implications

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Context & objective

Context

Negative impacts of specialization and concentration of agricultural systems (Therond et al., 2017)

Specialization of both farms and territories : crop and livestock disconnection (Jepsen et al., 2015; Billen et al., 2014)

Agroecological principles to improve sustainability : diversification and crop-livestock integration (Altieri et al., 2012; Gliessman, 2004; Dumont et al., 2020)

Problematic

Assessing performances of agrosystems – ermergent properties (Bonaudo et al., 2014)

Capacity of these systems to produce food.

Relate performance to environmental conditions

Objective

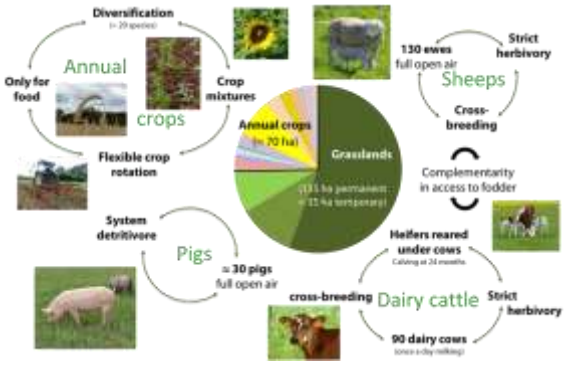
Assess the agroecological and food production performance of two configurations of integrated crop-livestock farming systems

Material

		Dairy system (2011-2015)	Diversified system (2018-2020)
Strategic choices			
Self-sufficiency		**No fertilizer or feed inputs**	
Degree of diversification		**Specialised** in dairy cattle production (pastures and annual feed crops) and milling wheat	**Highly diversified**: 3 animal species (dairy cattle, meat sheep, pig) 20 annual food crops
Food/feed principles		Annual crops divided between **food and feed** (for dairy cattle)	Annual crops for **food only** / Ruminants strictly grass-fed / Pigs fed on waste
Cropping systems			
Permanent Grassland (ha)		135	135
Arable land	Temporary grassland (ha)	47.2	41.8
Arable land	Annual crops (ha) → Feed	33.3	**0**
Arable land	Annual crops (ha) → Food	26.0 (wheat and rye)	**64.7** (20 crops : wheat, oats, barley, lentils, peas, vegetables…)
Livestock systems			
Dairy cattle (LU)		170.7 (Holstein & Montbéliard // grazing + hay + cereals // twice a day milking // first calving at 36 month)	**124.2** (crossbreeding // strict herbivory // once a day milking // heifers with nurses = first calving at 24 month)
Sheep (LU)		0	**18.8** (full open air, strict herbivory)
Pigs (LU)		0	**3.9** (full open air, fed only with non-marketable products)
Livestock density (LU/ forage area)		0.8	0.85

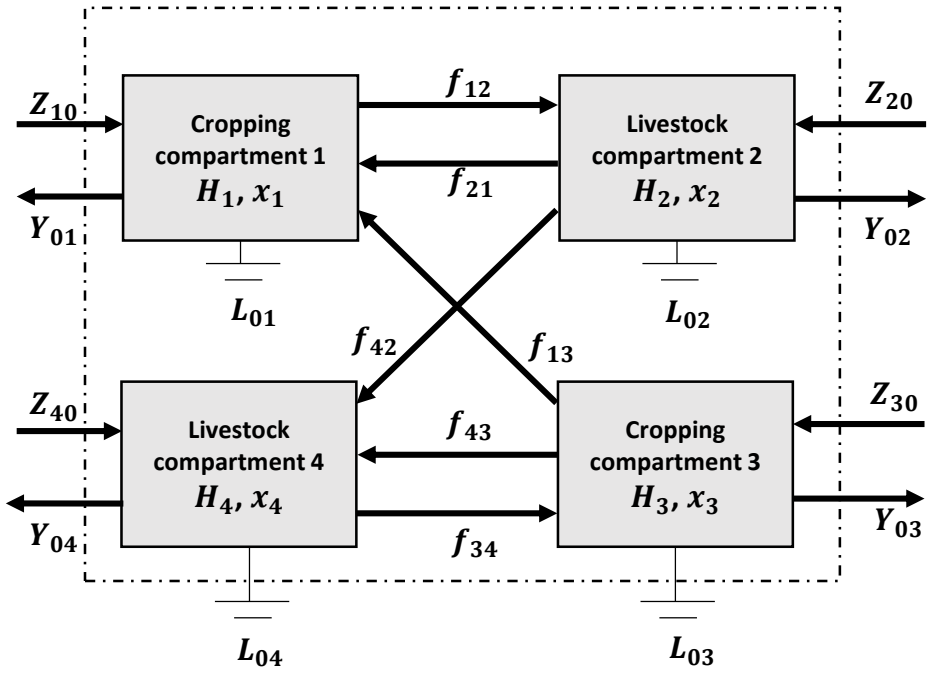
Method

Mixed-farming system



1. Conceptualization

Flow Diagram



2. Modelling

N assessment

Flow Matrix

	Import	H_1	H_2	H_3	H_4
H_1	$Z_{1,0}$	0	$f_{1,2}$	$f_{1,3}$	$f_{1,4}$
H_2	$Z_{2,0}$	$f_{2,1}$	$f_{2,2}$	$f_{2,3}$	$f_{2,4}$
H_3	$Z_{3,0}$	$f_{3,1}$	$f_{3,2}$	$f_{3,3}$	$f_{3,4}$
H_4	$Z_{4,0}$	$f_{4,1}$	$f_{4,2}$	$f_{4,3}$	$f_{4,4}$
Export	0	$Y_{0,1}$	$Y_{0,2}$	$Y_{0,3}$	$Y_{0,4}$
Dissipation	0	$D_{0,1}$	$D_{0,2}$	$D_{0,3}$	$D_{0,4}$
Stock	0	X_1	X_2	X_3	X_4

3. Analysis

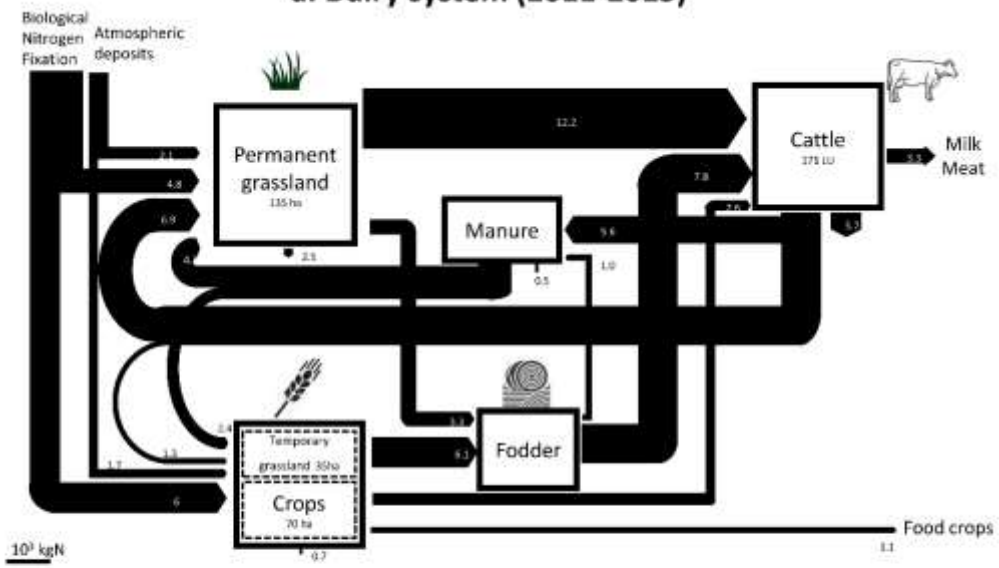
Crop-Livestock Integration	System activity Intensity Organization	
Agroecological performances Bonaudo et al., 2014	Efficiency Productivity Self-sufficiency Resilience	**Assessment in relation to food performances**

Ecological Network Analysis : Rufino et al. (2008), Ulanowicz et al. (2009), Fath et al. (2019)
Agronomy : Allwood et al. (2013), Godinot et al. (2020),

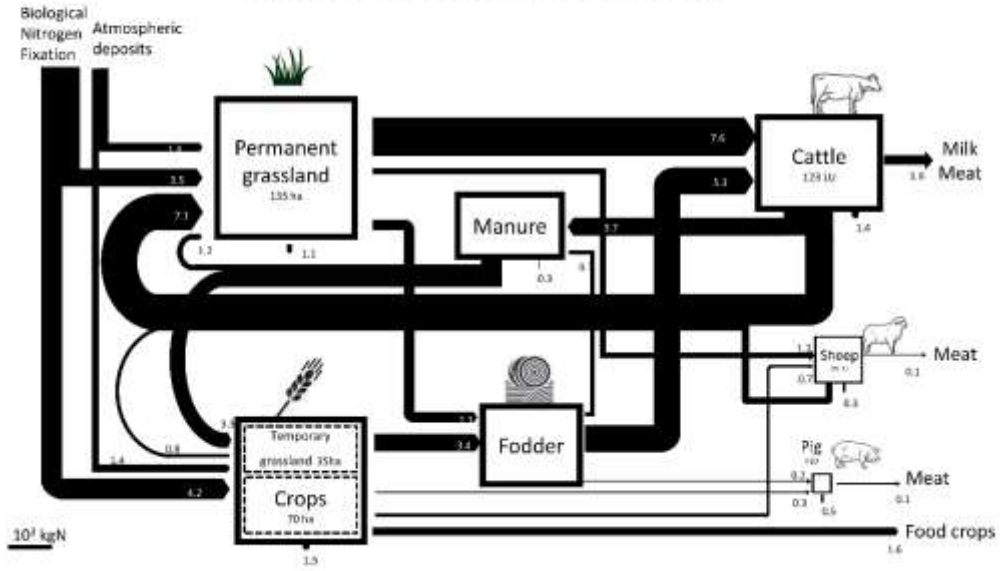
Results

	Dairy system (2011-2015)	Diversified system (2018-2020)
Animal products exported (milk + meat)	3,258 kgN	2,088 kgN
Food crops exported	1,146 kgN	1,614 kgN

a. Dairy system (2011-2015)



b. Diversified system (2018-2020)



➔ Animal products ➔ crops products

➔ Reduction of total food production of the diversified system (-16%)

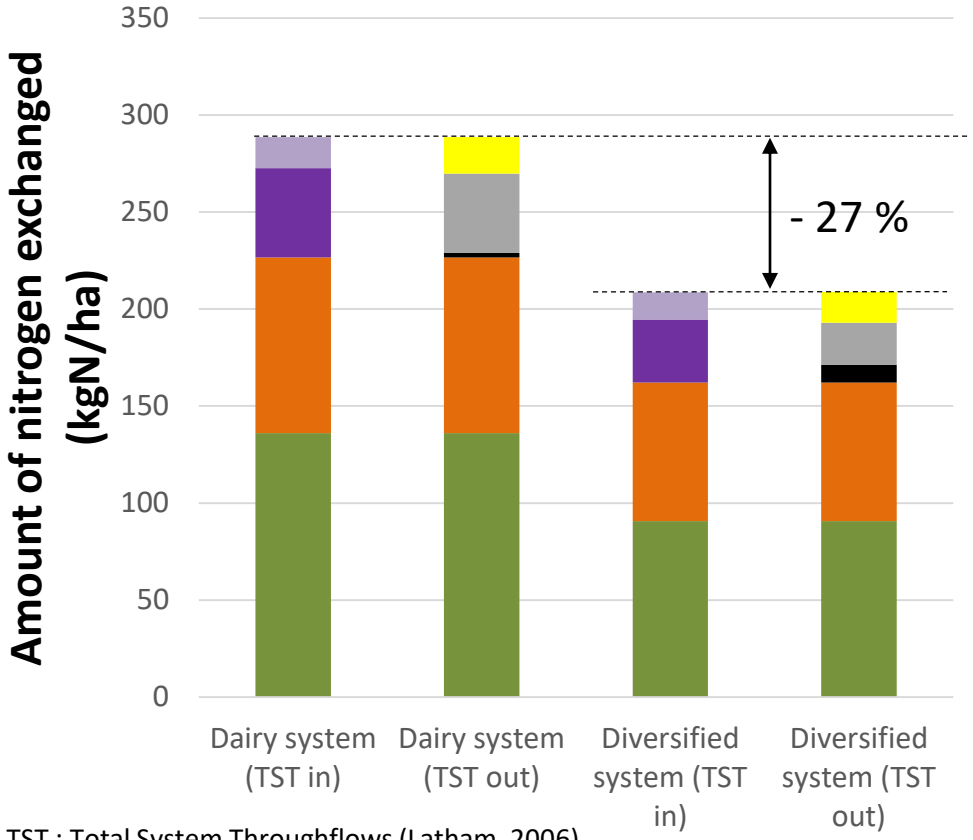
➔ A diversified system metabolism dominated by dairy cattle subsystem

Results

Difference mainly due to :

➔ decrease in livestock numbers

➔ 3 years drought (2018-2020)



TST : Total System Throughflows (Latham, 2006)

Inputs : only from natural resources

➔ 70% from biological N fix, 30% atm. deposits

Outputs & stocks variation

Internal fluxes : crop-livestock integration

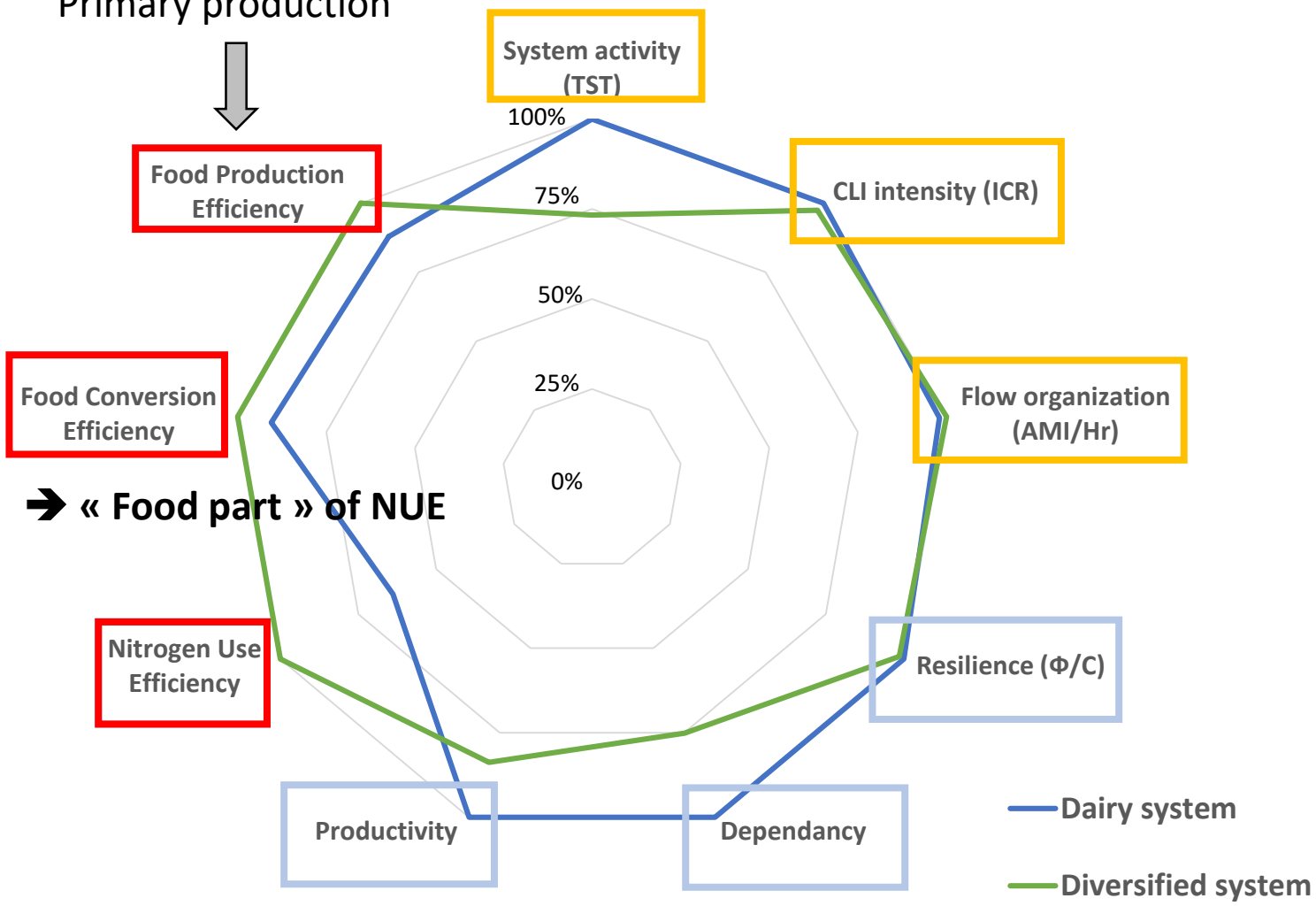
➔ 75% of total system activity

➔ **Self-sufficiency only based on crop-livestock integration and renewable resources**

Results

- Crop-livestock integration:
  - Total system activity is quite higher for the « more intensive » configuration
  - CLI characteristics are similar (in term of intensity and flows organization)
- Agroecological performances :
  - Resilience proxy are similar (same flows network)
  - Dairy system productivity and dependancy are higher
- Efficiency
  - The diversified configuration is more efficient than the specialized one (on all efficiency dimensions)

Food production / Primary production



➔ **« Food part » of NUE**

Values are expressed as % of the highest values of the two systems

Discussion & perspectives

- Role of crop-livestock integration; divergent performances on the 2 systems

- Divergent dynamics between resilience and efficiency

➔ trade-off between emergent properties in agrosystems (Bonaudo et al., 2014) ?

- Taking into account environmental conditions (variability) to access agrosystems

  ➔ Dynamic systems analysis (climate changes)

- Studying systems **with a focus on food production** ➔ contribute to the feed/food/fuel debate.

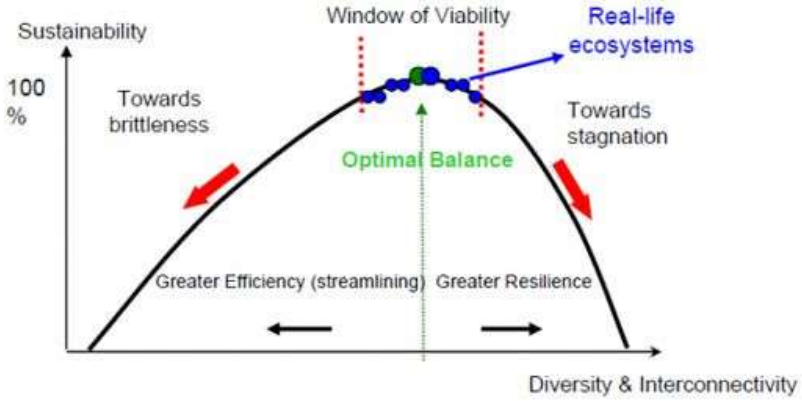


Figure 2: The "Window of Viability" in which all sustainable natural ecosystems operate. Complex natural ecosystems invariably operate within a fairly narrow range on each side of the Optimum point.

Tradeoffs between properties in ecosystems
Lietaer et al. (2010)






Thank for your attention








Puech, T., Stark, F. *Diversification of an integrated crop-livestock system: agroecological and food production assessment at farm scale.*
Submitted in Agriculture, Ecosystems and Environment

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