Nutrient cycling and efficiency: a comparative flow analysis of meat and dairy sheep farming systems

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Context and problematic

- Sustainability of livestock farming systems is widely questioned
- Which challenge our ability to assess the expected performance of these systems
- Design innovative livestock farming systems based on agroecology principles
- Nutrient cycling as a relevant option to meet these challenges

To what extent integrated specialized livestock farming systems be more sustainable ?

Study site: small ruminant experimental farm

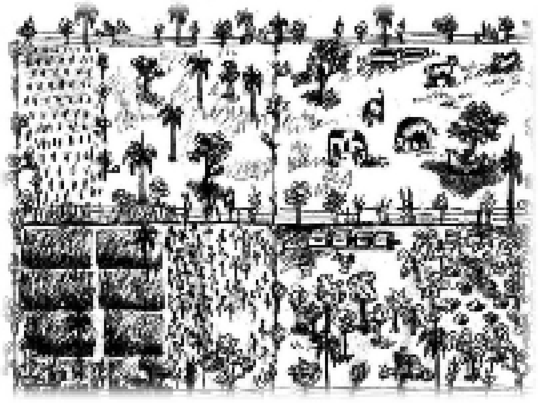
- **La Fage Experimental Farm (INRAE)**
  - South of France, Aveyron, Causse du Larzac, a high French karst plateau in the south of the Massif Central
  - **2** contrasting farming systems : **2** breeds with **2** different productive purposes and **2** types of livestock management
  - **100 ha** of arable lands and **200 ha** of rangelands

- 600 **dairy** ewes (Lacaune)
- **Semi-intensive** (indoor & summer grazing)
- AOC **Roquefort** system (cheese)

- 400 **meat** ewes (Romane)
- **Extensive** (fully **outdoor**, rangeland)
- Highly **prolific** breed; **natural suckling** system

Method: Flow analysis and performances evaluation

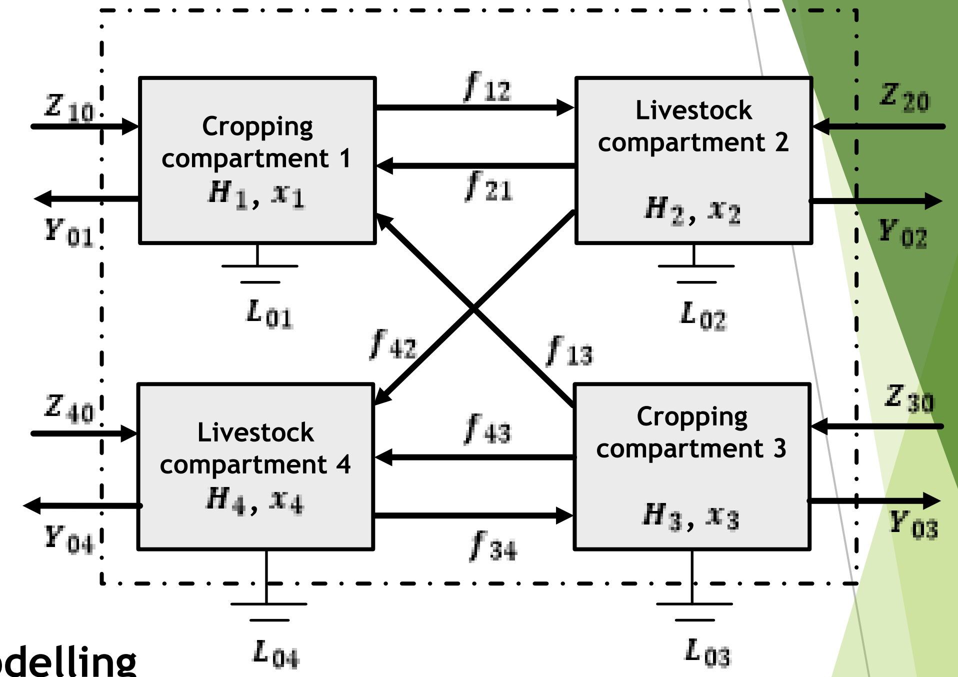
Agroecosystem



F. Funes-Monzote, 2009

1. Conceptualization

Flow Diagram



2. Modelling

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

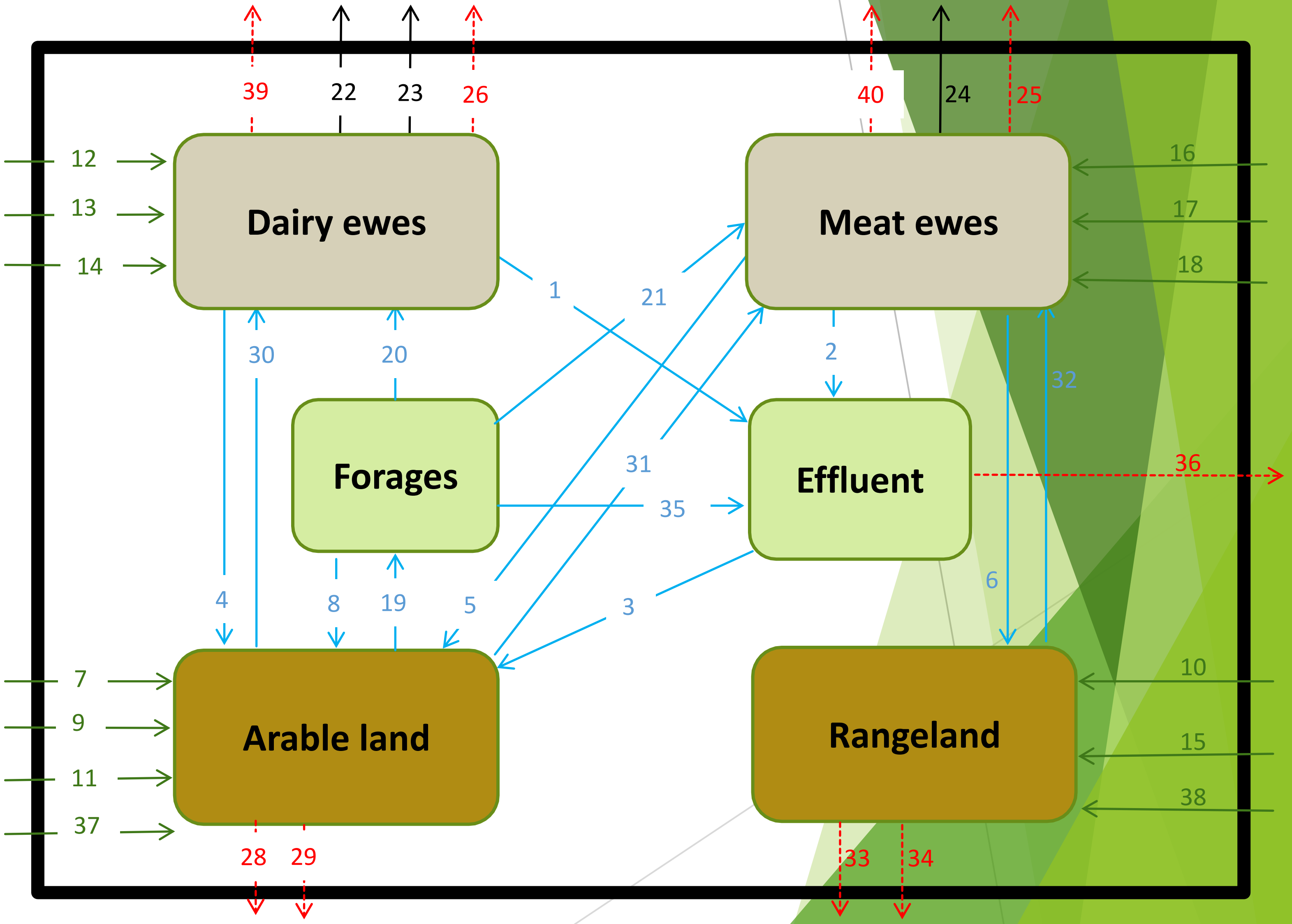
Indicators

	Self-sufficiency
Agroecological performances	Productivity
	Efficiency
	Resilience

Stark et al., 2018

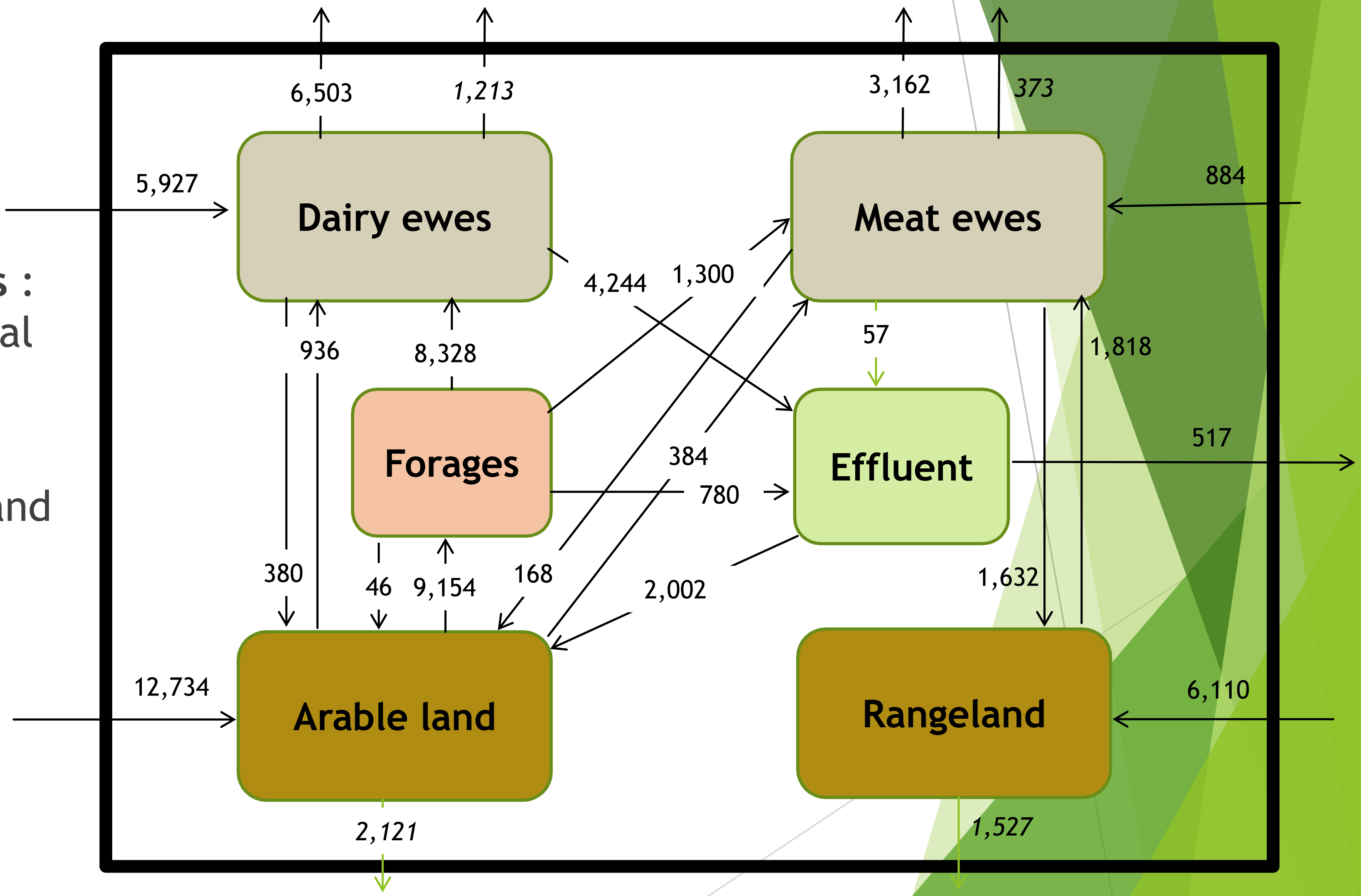
Method: Flow conceptualization

Flow	Description	Category
9, 10	Mineral fertilizer	Inputs
11, 15	Atmospheric deposition	Inputs
12, 16	Concentrate purchase	Inputs
13, 17	Fodder purchase	Inputs
14, 18	Straw purchase	Inputs
37, 38	Symbiotic fixation	Inputs
22, 24	Animal sales	Outputs
23	Milk sales	Outputs
25, 26	Animal loss	Losses
28, 33	Lixiviation	Losses
29, 34, 36, 39, 40	Volatilization loss	Losses
19	Forage produced	Internal flows
20, 21	Forage consumed	Internal flows
30, 31	Cultivated area grazing	Internal flows
32	Rangeland grazing	Internal flows
35	Straw for litter	Internal flows
1,2	Manure stored	Internal flows
3	Organic fertilizer	Internal flows
4, 5, 6	Direct manure to lands	Internal flows
7	Seed purchase	Internal flows
8	Seed produced	Internal flows



Method: Flow modelling

- **Quantification of each flows :** monitoring data, experimental data, bibliography
- **Device selection:** nitrogen (relevant for both livestock and crops)
- **Temporal scale:** annual data over a 5-year period



2019 (annual average), nitrogen (kg/year)

Results: Flow analysis

↵	Inputs	Dairy ewes	Meat ewes	Arable land	Rangeland	Forages	Effluent
Dairy ewes	5,927	0	0	936	0	8,328	0
Meat ewes	884	0	0	384	1,818	1,300	0
Arable land	12,749	380	168	0	0	46	2,002
Rangeland	6,110	0	1,632	0	0	0	0
Forages	0	0	0	9,154	0	0	0
Effluent	0	4,244	57	0	0	780	0
Outputs	0	6,503	3,162	0	0	0	0
Losses	0	1,213	373	2,122	1,527	0	517

La Fage, 2019, Kg N.year^{-1}

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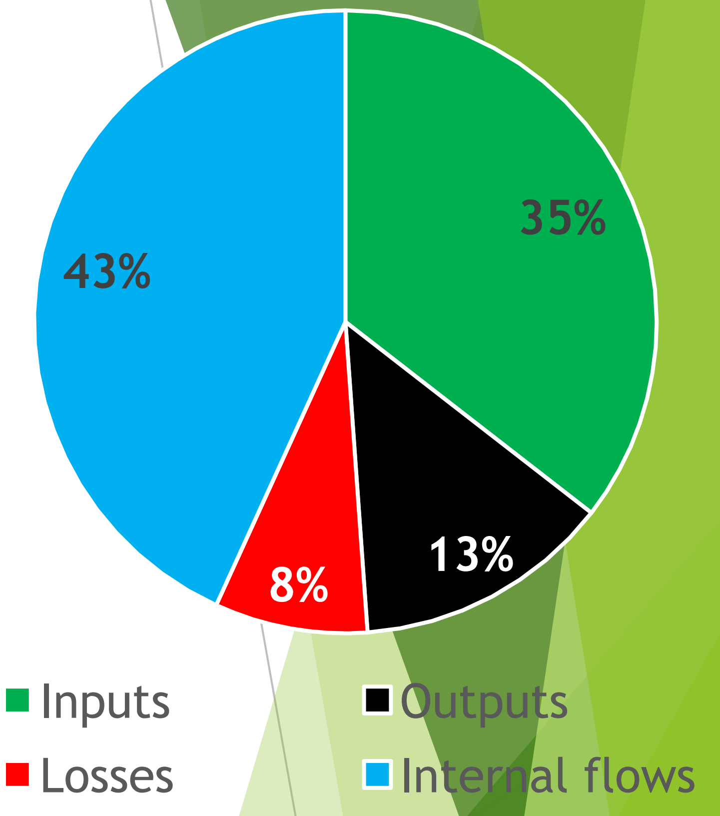
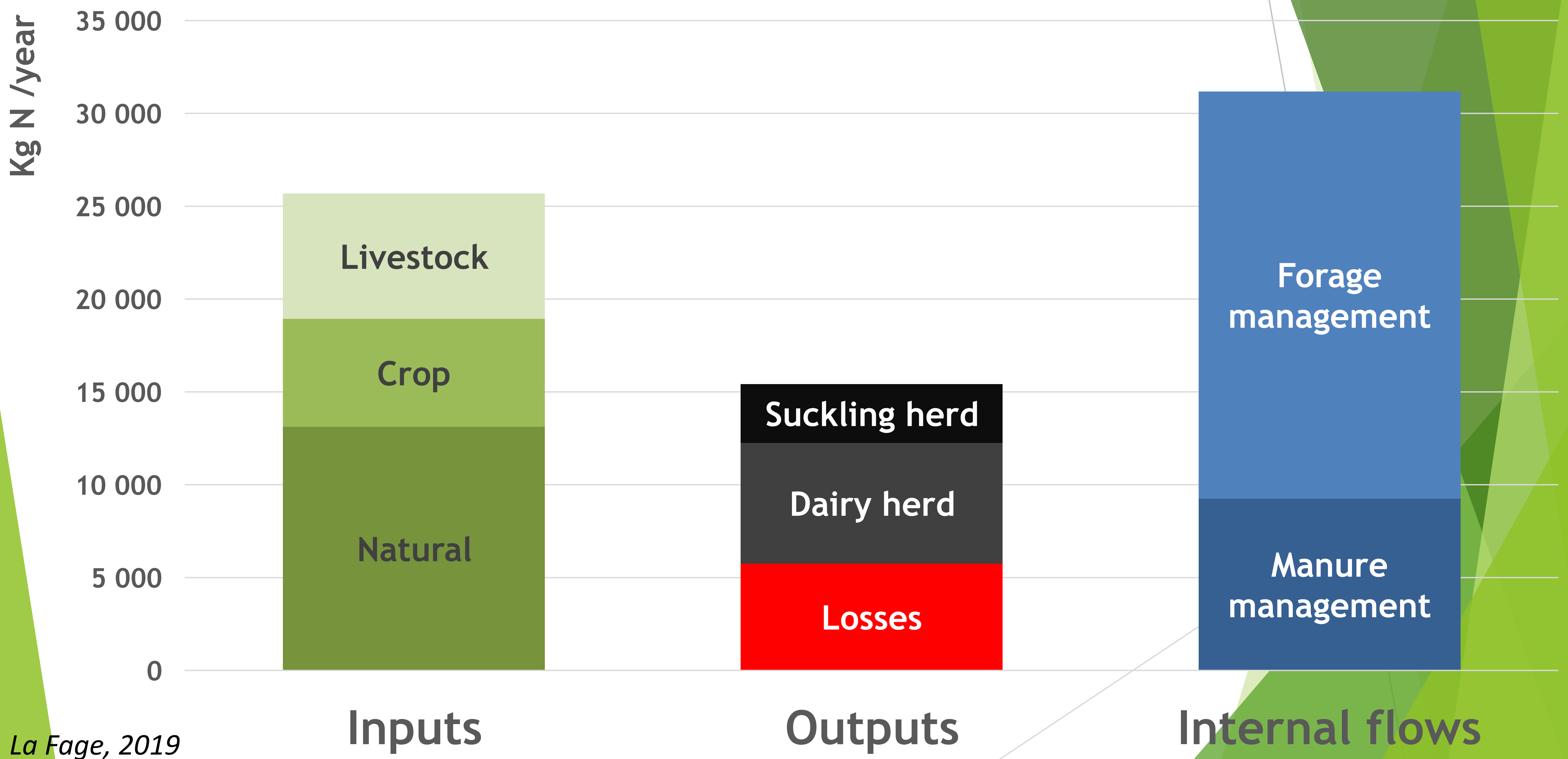
Efficiency of 77% (without natural inputs)



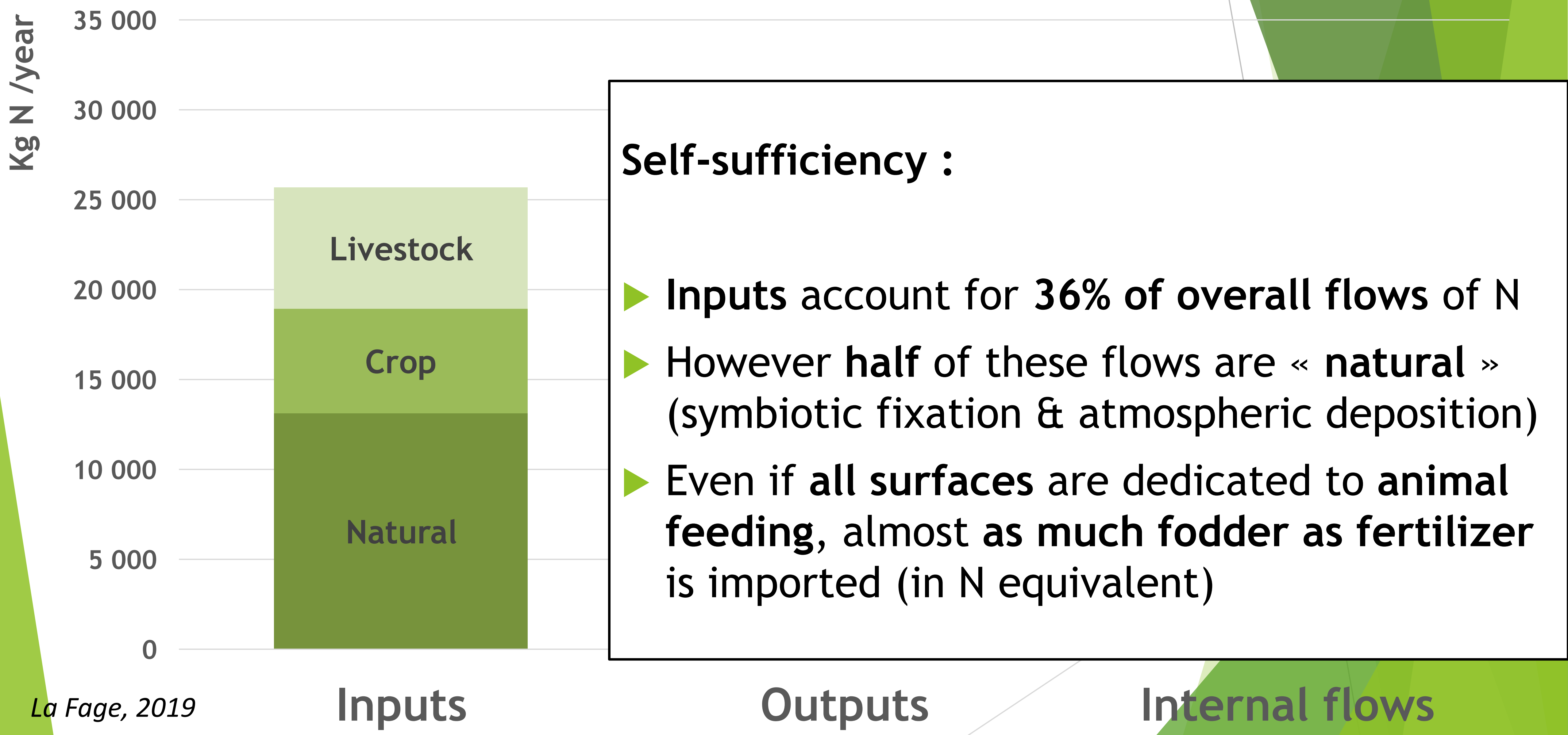
La Fage, 2019, Kg N.year^{-1}

Results: Flow analysis



La Fage, 2019

Results: Flow analysis



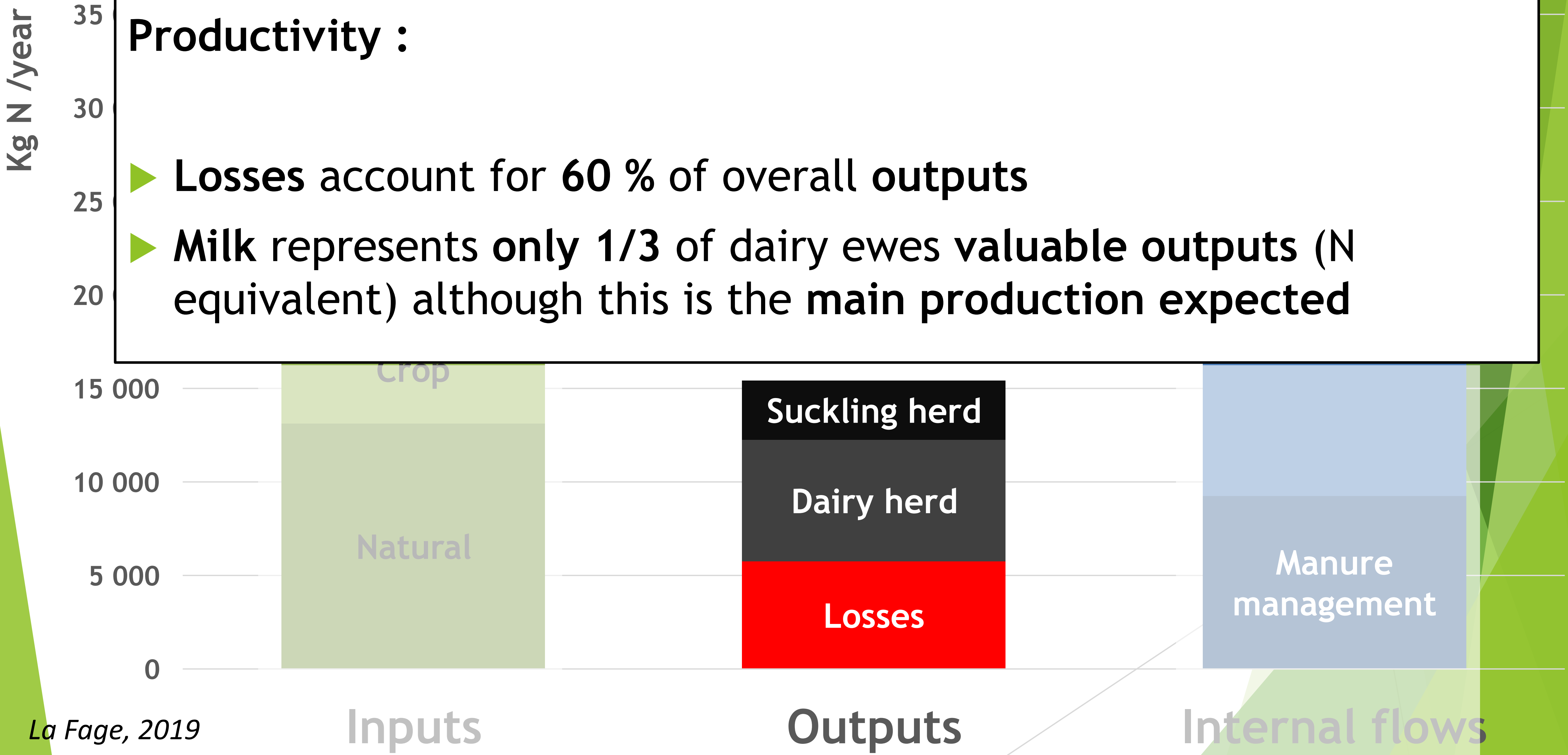
Self-sufficiency :

- **Inputs** account for **36% of overall flows** of N
- However **half** of these flows are « **natural** » (symbiotic fixation & atmospheric deposition)
- Even if **all surfaces** are dedicated to **animal feeding**, almost **as much fodder as fertilizer** is imported (in N equivalent)

Results: Flow analysis

Productivity :

- **Losses** account for **60 %** of overall **outputs**
- **Milk** represents **only 1/3** of dairy ewes **valuable outputs** (N equivalent) although this is the **main production expected**



La Fage, 2019

Results: Flow analysis

Crop-livestock integration :

- **70%** of internal flows concern **animal feed** (vs. fertilization)
- **All forage** distributed are allocated to **dairy herd**
- **Only 25%** of forage produced are **grazed**
- **Mineral** fertilizer account for **one third** of overall fertilization
- **Manure** (directly or stored) account for **one quarter** of overall fertilization

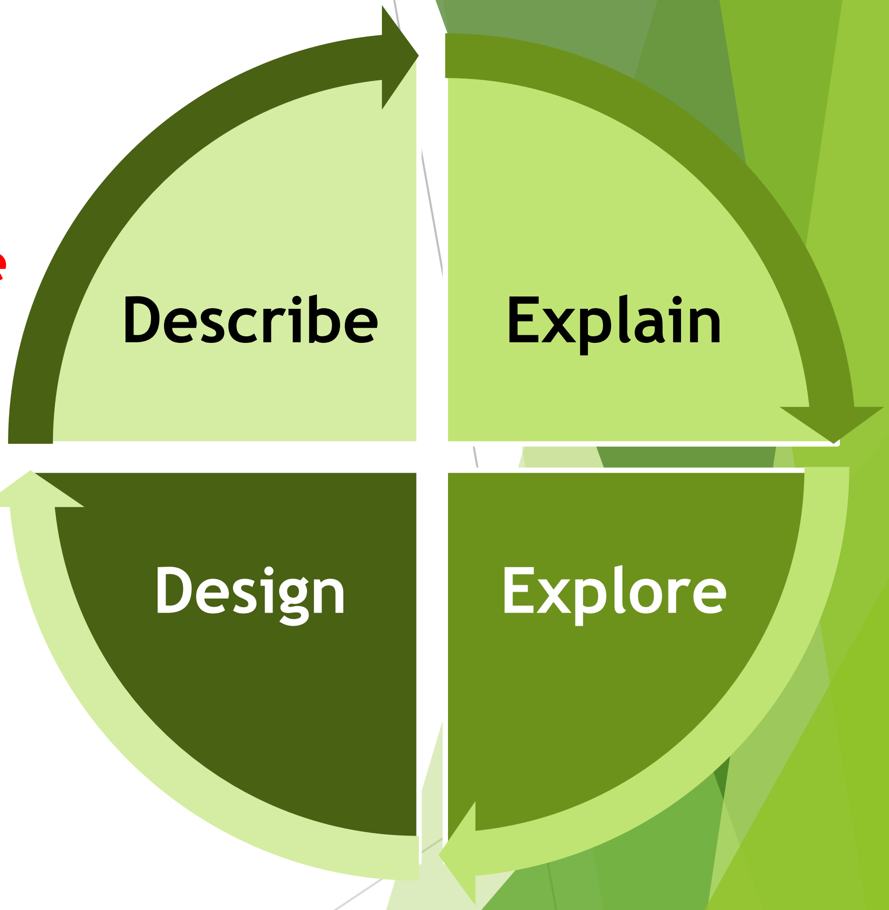
La Fage, 2019

Conclusion & perspective

- **Feed autonomy** remains a **major challenge**
- **Allocation** of production factors must be considered in relation to the performance of each flock
- Reduction **of losses** can be **improved, mainly by a better use of manure among other management innovations**

Conclusion & perspective

- **Feed autonomy** remains a **major challenge**
- **Allocation** of production factors must be considered in relation to the performance of each herd
- Reduction **of losses** can be **improved, mainly by a better use of manure, among other management innovations**
- identify and select agroecological innovations based on previous experiments (co-design process with stakeholders)
- simulate the impact of these innovations on the systems studied (simulation through modelling)
- test and implement/discuss innovations with stakeholders (trials/training)



Descheemaeker et al., 2019

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement N° 862555.
The project TRUSTFARM was carried out under the ERA-Net Cofund FOSC (Grant N° 862555), built upon and supported by the experience from the Joint Programming Initiative on Agriculture, Food Security & Climate Change (FACCE-JPI) and the ERA-Net Cofund LEAP-Agri

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