CLIMIT
Circular Livestock-based agri-food systems for Climate Change Mitigation and Territorial Development

Fostering circularity through livestock in small-scale territories of Madagascar highlands: a preliminary study of their protometabolism

Session 52-From theory to practice: how livestock-based circularity can contribute to sustainable and healthier food systems?

27/08/2025

M. Vigne, M. Feillet, J. Vayssières, L. Rasolofo, ***T. Teixeira Da Silva Siqueira***

Cette action est cofinancée par l'Union européenne, la Région Réunion et le Cirad

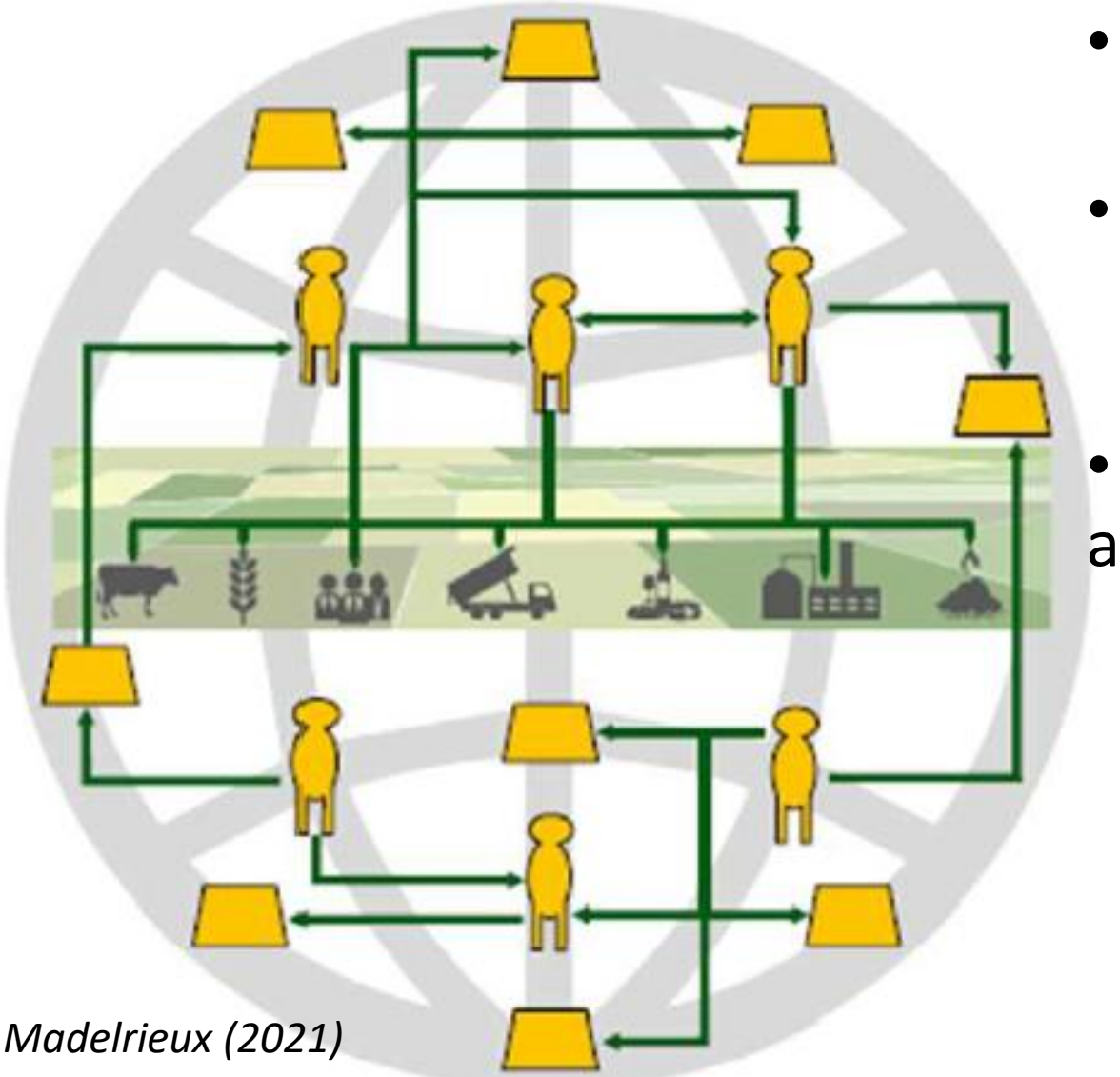
Challenges for smallholders in malagasy highlands

- High land pressure (0.5ha per household - Bélières et al., 2016)
- Low soil quality (Balasubramanian et al., 1995)
- Low income & investment capacity (Harvey et al., 2014)
- Strong competition for local biomasses (manure, natural grasses, crop residues – Alvarez, 2012)

=> Need for low inputs intensification

=> Improving biomass circularity as a lever for sustainable intensification ?

Conceptual framework: territorial metabolism



Madelrieux (2021)

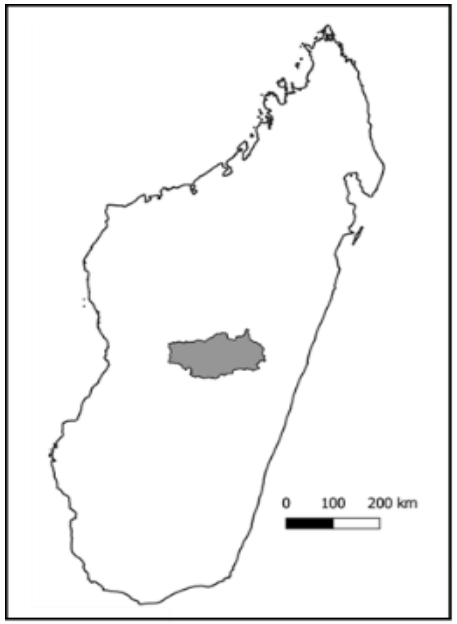
- Derived from Industrial Ecology *(Barles, 2010; Wassenaar, 2015)*
- Framework for quantitative and qualitative assessment of **matter & energy flows in a socioecosystem** (=territory)
- Interrelations between the **technosphere** and the **biosphere** *(Georgescu-Roegen, 1972)*
  - A systemic and transdisciplinary approach
  - Performance of a territorial functioning (socio-economic, environmental, energetic…) *(Grillot et al., 2021)*
  - Identifying breaks and levers for fostering circularity trough the efficient use of resources and recycling (« closing the loop »)

Traditional spatial organization of the Malagasy Highlands landscapes

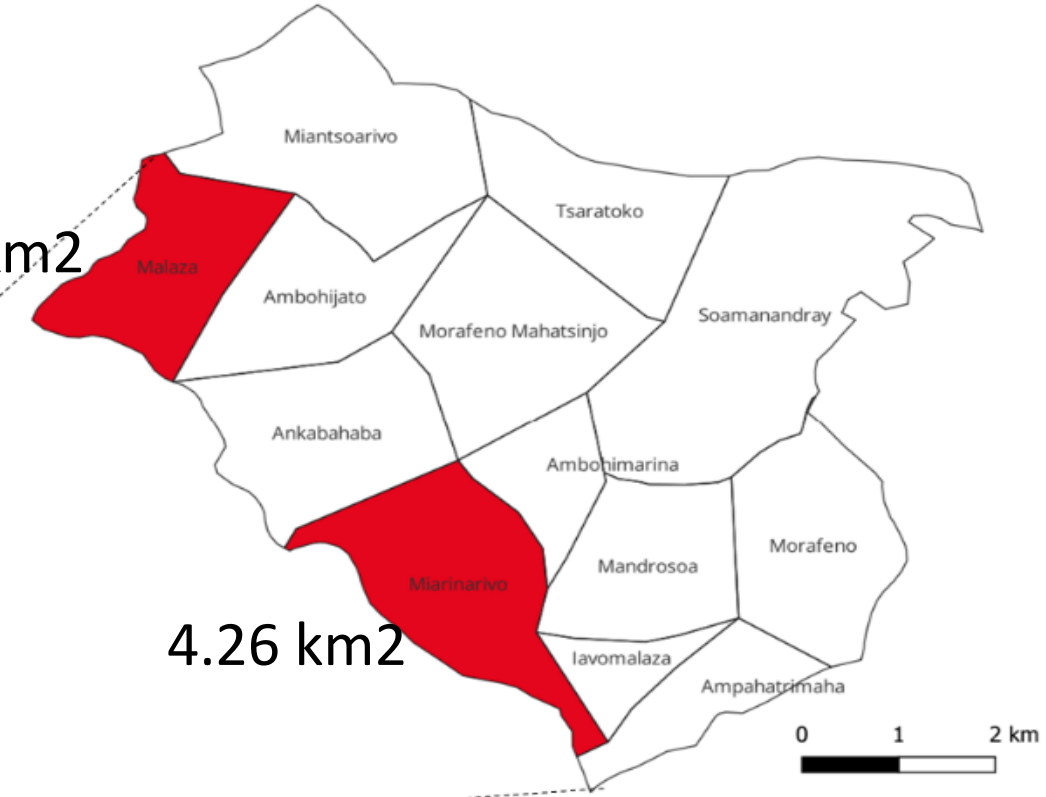
(©Castro Pacheco, 2024)

Build representations of the territorial metabolism

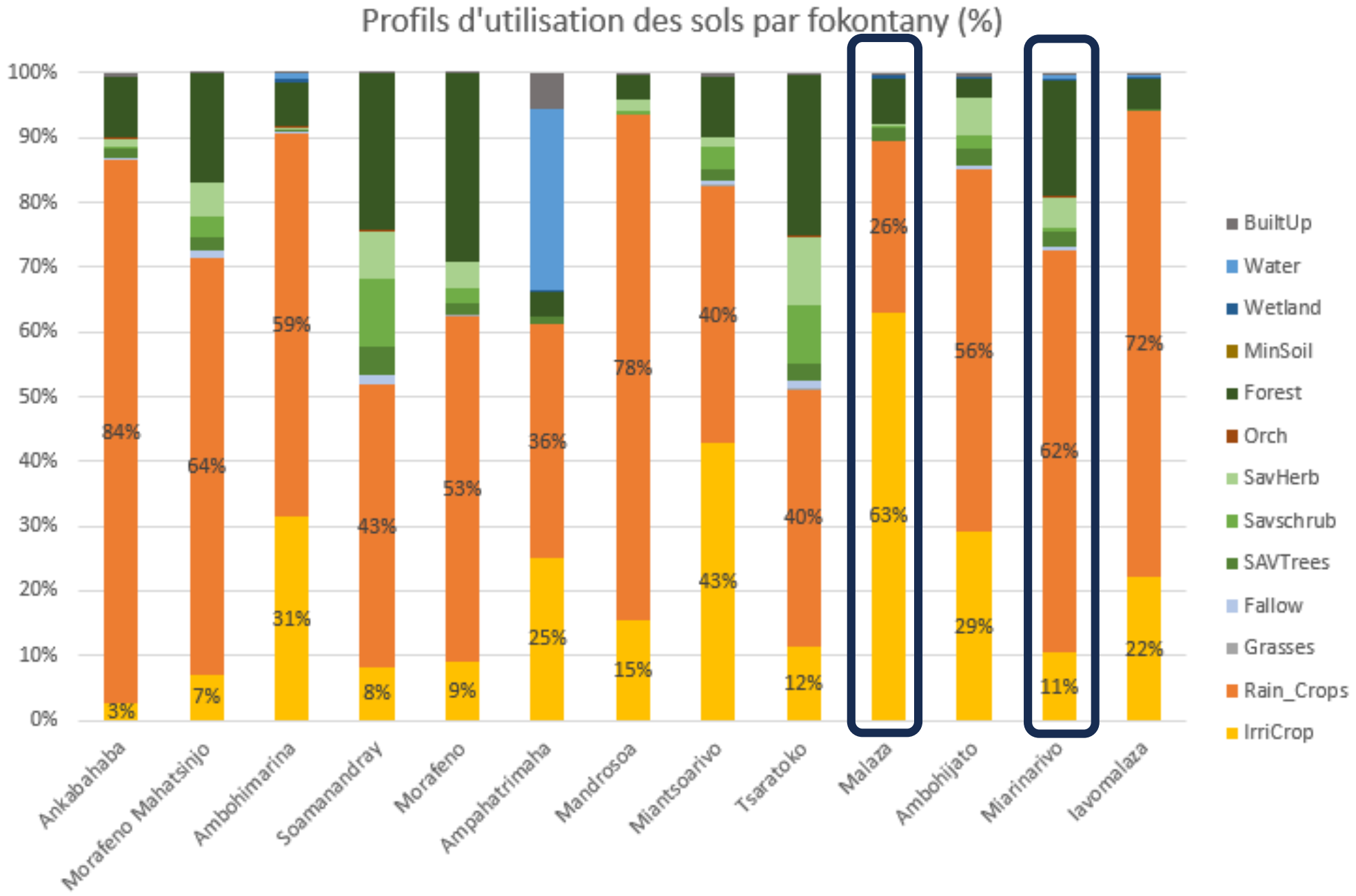
Fokontanys: the decision-making crossroad (household, local and states)



3.17 Km2



4.26 km2


Profils d'utilisation des sols par fokontany (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
84%
3%
64%
7%
59%
31%
43%
8%
53%
9%
36%
25%
78%
15%
40%
43%
40%
12%
26%
63%
56%
29%
62%
11%
72%
22%
Ankabahaba
Morafeno Mahatsinjo
Ambohimarina
Soamanandray
Morafeno
Ampahatrimaha
Mandrosoa
Miantsoarivo
Tsaratoko
Malaza
Ambohijato
Miarinarivo
Iavomalaza
BuiltUp
Water
Wetland
MinSoil
Forest
Orch
SavHerb
Savschrub
SAVTrees
Fallow
Grasses
Rain_Crops
IrriCrop

Data collected

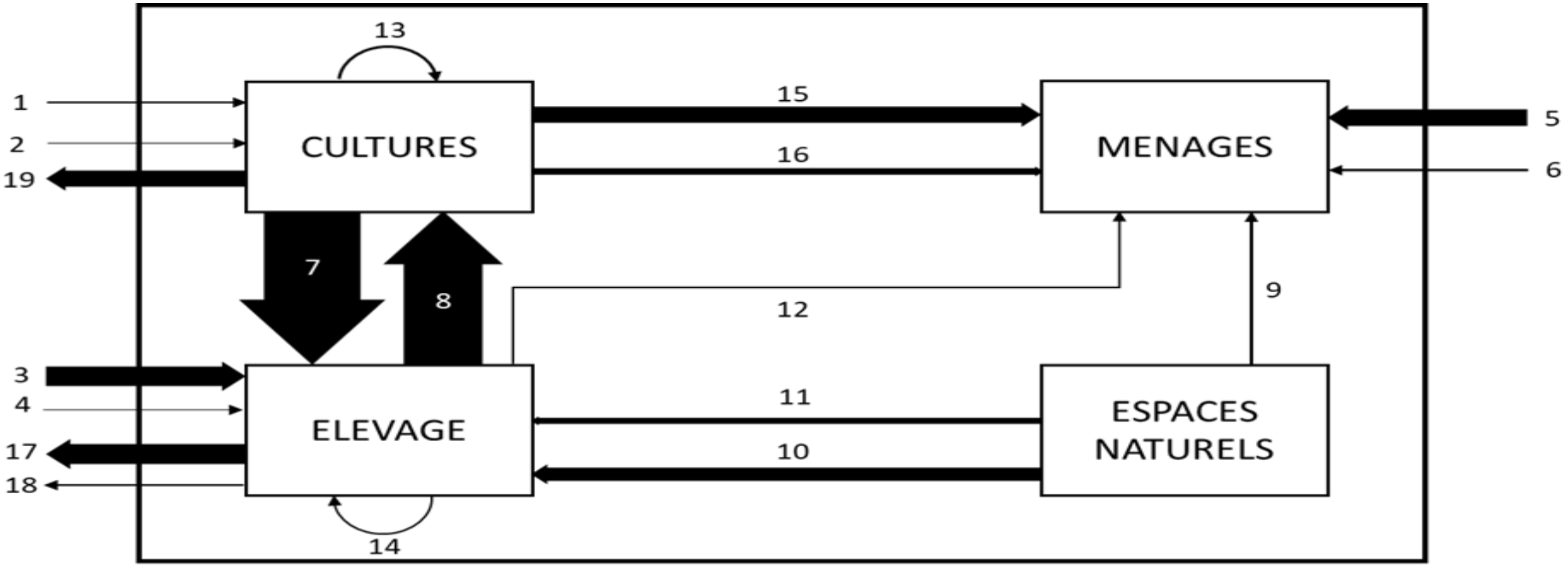
Random sampling (electoral list)
Inquiry : 17% of hoseholds

- General structural farm data (household size,herd structure by species and animal type,farm's crop rotation plan, agricultural equipment)
- A detailed description of technical itineraries and production by cropping system
- A detailed description of livestock management practices and production,
- A detailed description of livestock manure management and other fertilizing materials,
- Energy consumption and management of energy resources,
- Household food consumption.

Indicators

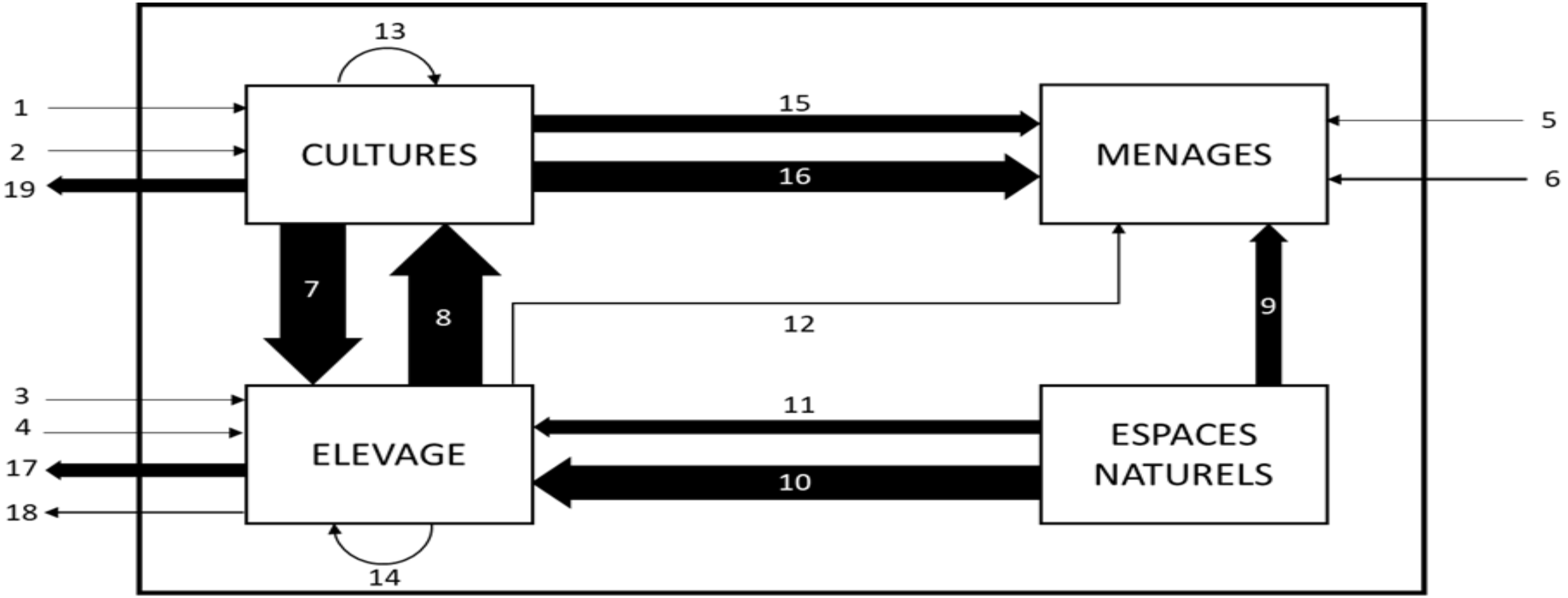
Indicators	Units	Calculation methods
Overall efficiency	(sd)	outgoing biomass (in kgRM) / incoming biomass (in kgRM)
Autonomy	(sd)	internal biomass (in kgRM) / (incoming biomass (in kgRM) + internal biomass (in kgRM))
Circularity	(sd)	internal biomass (in kgRM) / total circulating biomass (in kgRM)
Coverage of local population's food needs from local biomass	(%)	food biomass produced in the territory and consumed by the local population (in kgRM) / total food biomass consumed by the local population (in kgRM) × 100
Coverage of households' energy needs for combustion from local biomass	(%)	biomass for combustion used by the local population and produced in the territory (in kgRM) / total biomass for combustion used by the local population (in kgRM) × 100

Results 1 – Biomass circularity (Malaza)



- A territory characterized by dairy intensification and off-season production, made possible by good water management (64% of cultivated areas) and the occupation of *tanety* areas.
- A large quantity of products exported
- Large amounts of imported inputs despite the high amount of crop-livestock biomass flows
- Few natural areas and a strong dependence on imported energy resources.

Results 2 – Biomass circularity (Miarinarivo)



- A territory mainly characterized by subsistence farming
- A high presence of natural areas providing wood and food resources for extensive herds
- Difficulties in cultivating these areas (stones, limited access to water 11% of irrigated areas)
- Intensification through livestock farming oriented towards pig production systems

Results 3 – Biomass circularity Indicators

Indicators	MLZ	MRN
Overall efficiency (sd)	0.96	19.15
Autonomy (sd)	0.82	0.99
Circularity (sd)	0.71	0.89
Coverage of human food needs from local biomass (%)	86	81
Coverage of energy needs for combustion from local biomass (%)	38	99

Conclusion

- Difficulty of achieving the three objectives (self-sufficiency in human food, self-sufficiency in animal feed, and self-sufficiency in energy needs) in the face of a growing population.

- What role do animals play in the intensification required to produce more energy and food from crops? It is essential because it produces the manure necessary for crop fertility and supports field work (no mechanization).

How intensify without industrial inputs ?

- Improving the efficiency at all stages to conserve biomass and nutrients => identify potential losses
- Promote multifunctional crops: multi-service hedges (energy and fodder), food/fodder crop associations, all with more legumes => more biomass/ha

Perspectives

- Use flows to co-build scenarios and assess the sustainability of these proposals => do we have enough land and how much should be converted to associations/hedges, etc.
- OR if this is not enough, what compromise local people are ready to accept between the three objectives (what autonomy will them favor?)

CLIMIT

Circular Livestock-based agri-food systems for Climate Change Mitigation and Territorial Development

MISAOTRA

https://www.climit-io.org

https://www.linkedin.com/company/projet-climit/

siqueira@cirad.fr

Interreg Océan Indien

Union européenne

Liberté • Égalité • Fraternité
République Française

Region Reunion
www.regionreunion.com

cirad
La recherche agronomique pour le développement

SELMET

PRéRAD océan indien
Biomass Wood Energy Bioproducts

AVSF
Agronomes & Vétérinaires Sans Frontières
Réseau VSF International

FOFIFA

Cette action est cofinancée par l'Union européenne, la Région Réunion et le Cirad