Session 6 . Mixed farming systems
Does diversity bring any benefits and at what scale?

Does the diversity of integration practices enhance the resilience of mixed crop-livestock systems?

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Does the **diversity** of integration practices enhance the **resilience** of **mixed crop-livestock systems** ?

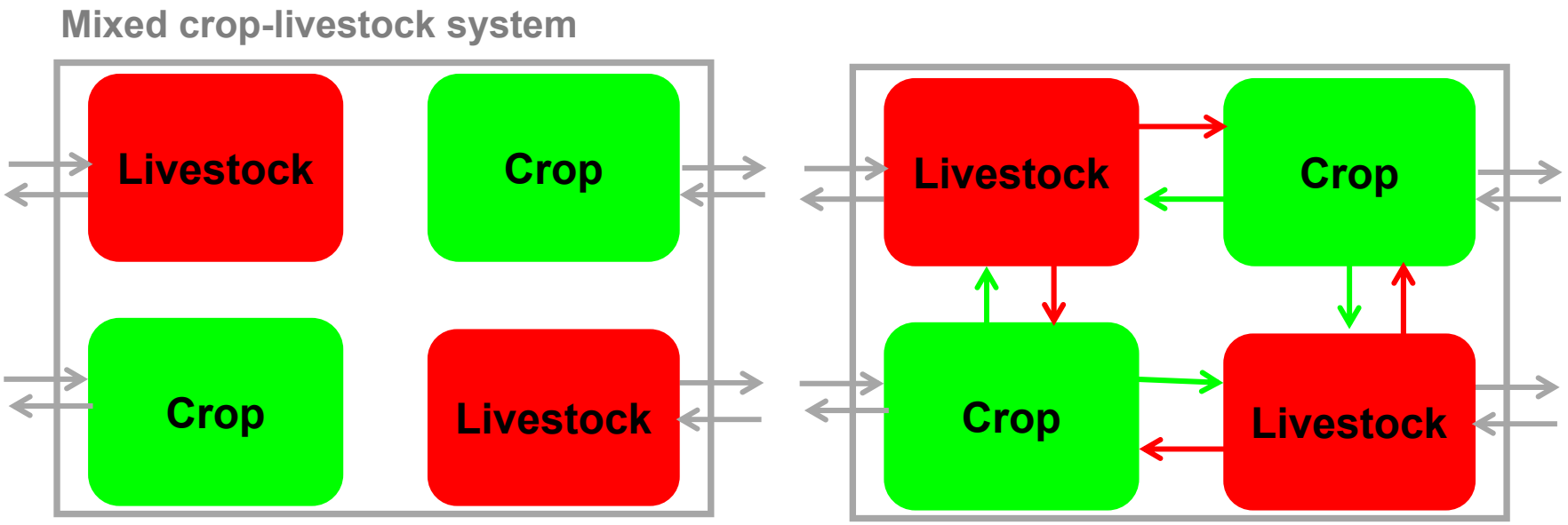
Mixed crop-livestock systems : at the farm scale

Four emergent properties : **resilience,** productivity, efficiency and self-sufficiency (Bonaudo et al., 2014)
related to the ecological and management principles of mixed farming systems

Diversity : a feature often linked in scientific literature to the performances, the robustness, the **resilience** of agricultural production systems.

> "*Diversity and connectance are properties which can affect the overall performance of the system*" (Viglizzo, 1994).
>
> *"a system […] requires diversity and resilience to cope with unlikely perturbations"* (de Goede et al., 2013)

What is **diversity** in the **mixed crop-livestock systems**?



Diversity

- **Number of activities**

Activities side by side
Heterogeneous, non articulated

Diversity

- **Number of activities**
- **Flows between activities**

Crop-Livestock Integration
Heterogneous, articulated

Can we exhibit the link between **diversity** and **resilience**?

Quantitative approach to assess

- Crop-livestock integration (configuration of the mixed system)
- Resilience of the system

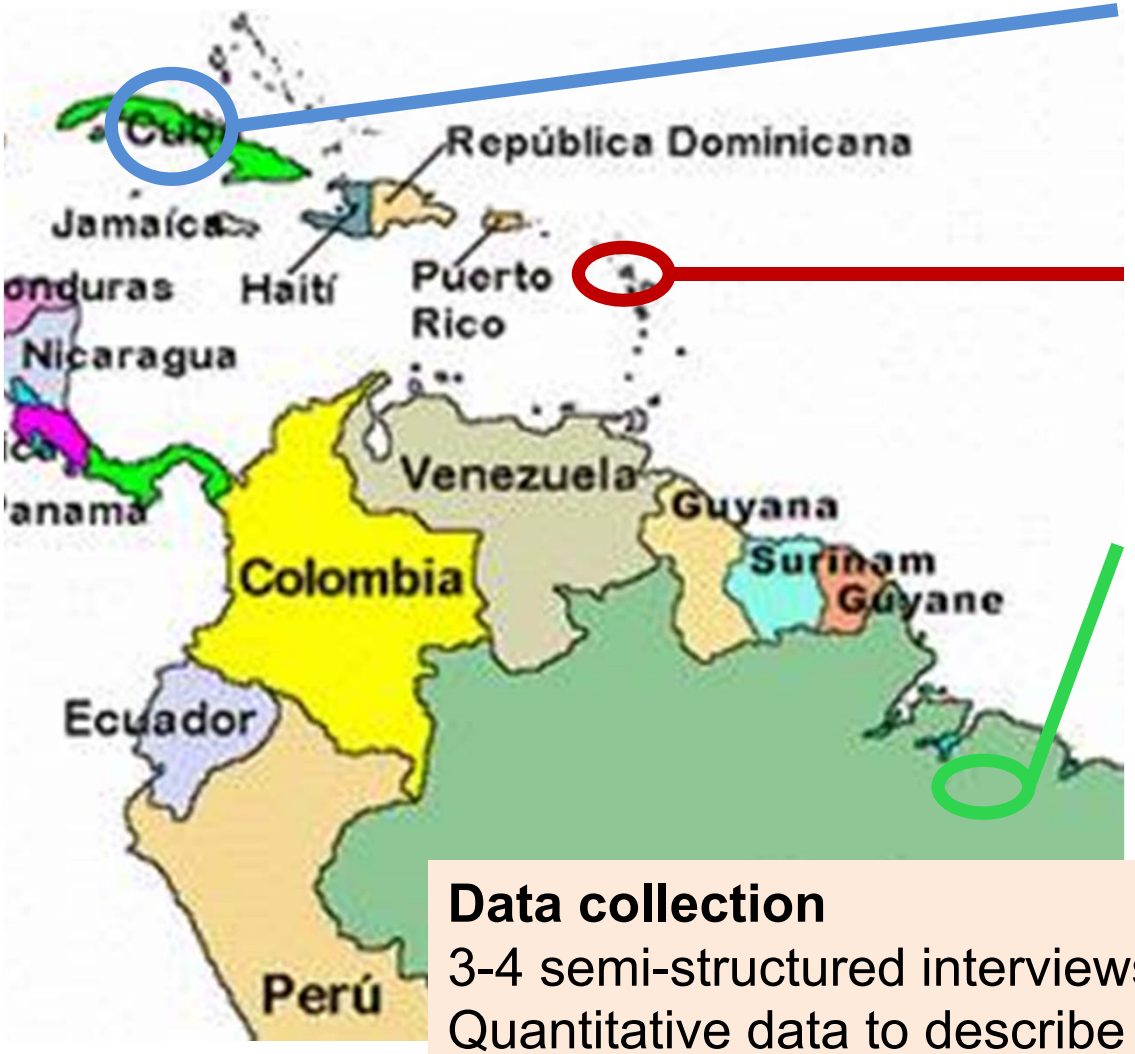
Use of the **Ecological Network Analysis** (ENA) (Hannon, 1973; Rutledge *et al*., 1976; Finn, 1980; Ulanowicz, 1997)

ENA is an adaptation of input-output analysis initially developed in economy

Few studies on agrosystems

Rice systems in Philippine (Dalsgaard et Oficial, 1997),
Mixed farming systems in East Africa (Rufino et al., 2009a et b)

A study of mixed systems in humid tropics, in 3 countries



Cuba.
Province of **Matanzas**
n=5 farms

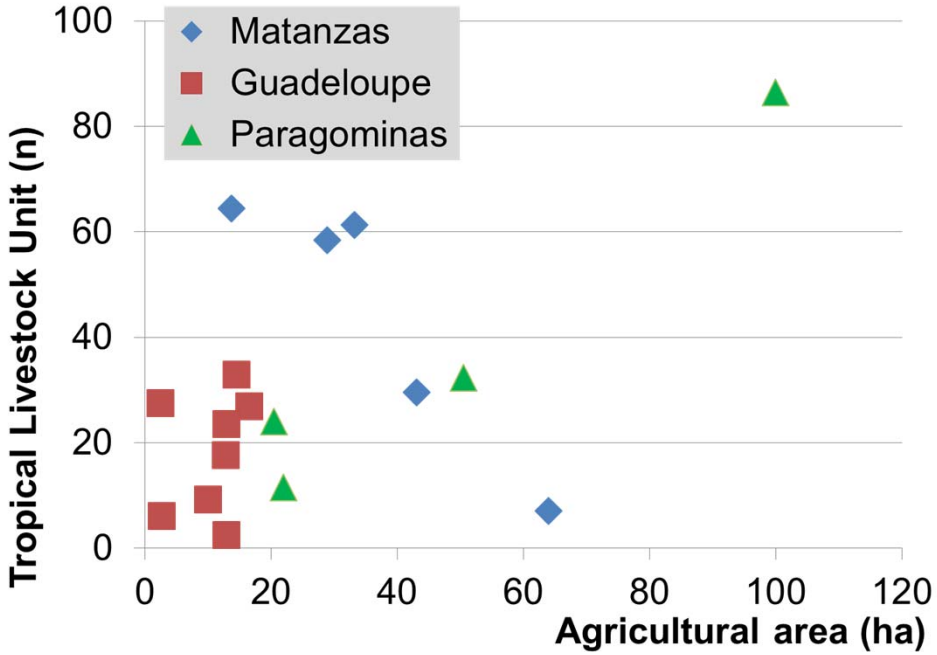
French West Indies.
Guadeloupe
n=8 farms

Brasil. State of Pará
Paragominas
n=4 farms

Data collection
3-4 semi-structured interviews with each farmers
Quantitative data to describe the farm annual functioning

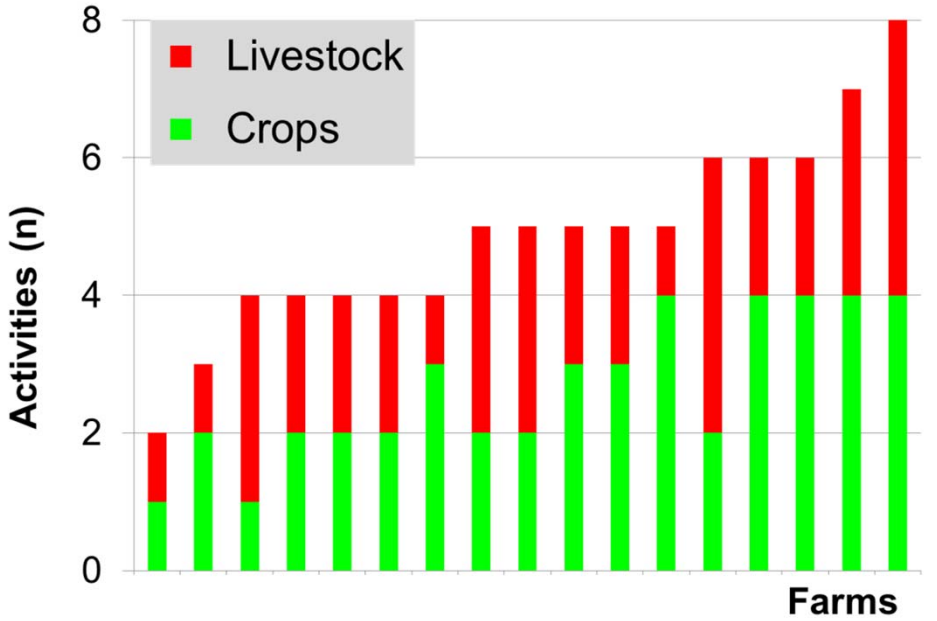
A sample for a wide range of integration practices

- n=17 farms
- Smallholders
- 1 to 5 family workers

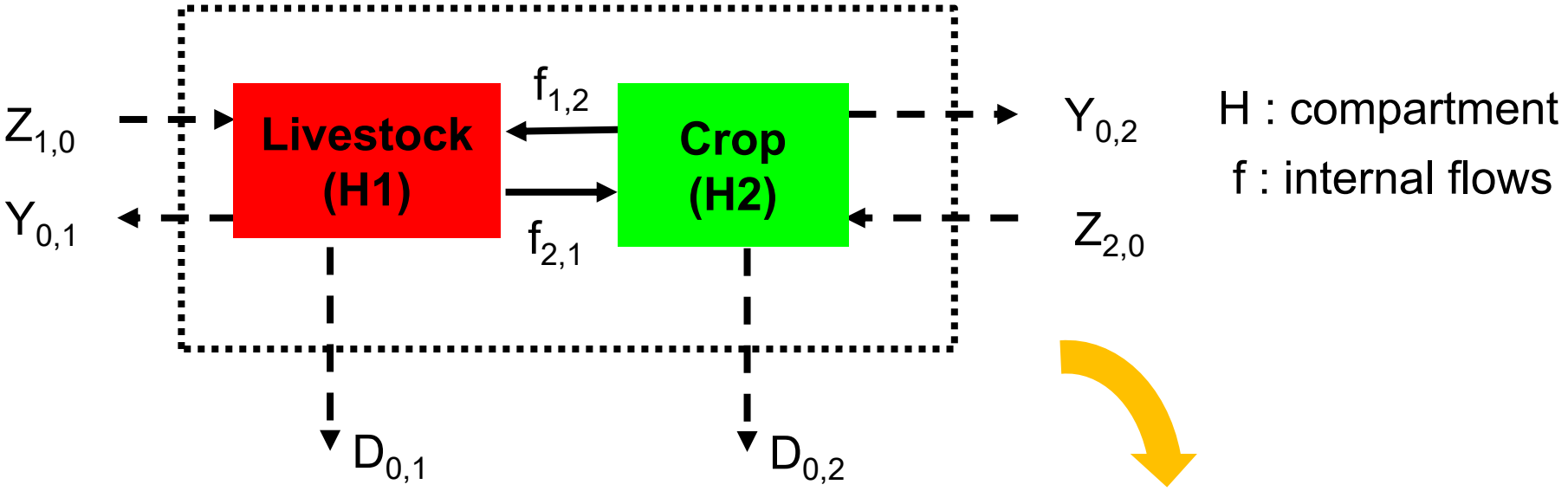


Livestock Cattle (n=13)
Pigs (n=12)
Poultry, rabbit, sheep

Crops Sugarcane
Staple food crop
Fruits
Market gardening
Cultivated forage



Data analysis: from a flowchart of **nitrogen flows** to a matrix for indicators calculation



	Import	H_1	H_2
H_1	$Z_{1,0}$	0	$f_{1,2}$
H_2	$Z_{2,0}$	$f_{2,1}$	0
Export	0	$Y_{0,1}$	$Y_{0,2}$
Dissipation	0	$D_{0,1}$	$D_{0,2}$

Indicators to assess the **crop-livestock integration**

Intensity = sum of the internal flows / agricultural area (kg N / ha)

Organization = 1 – (AMI / Hr)

AMI (average mutual information) quantifies the organization of the flows in the network

More AMI is high, more the network is heterogeneous.

Hr (statistical uncertainty) is the upper boundary for AMI

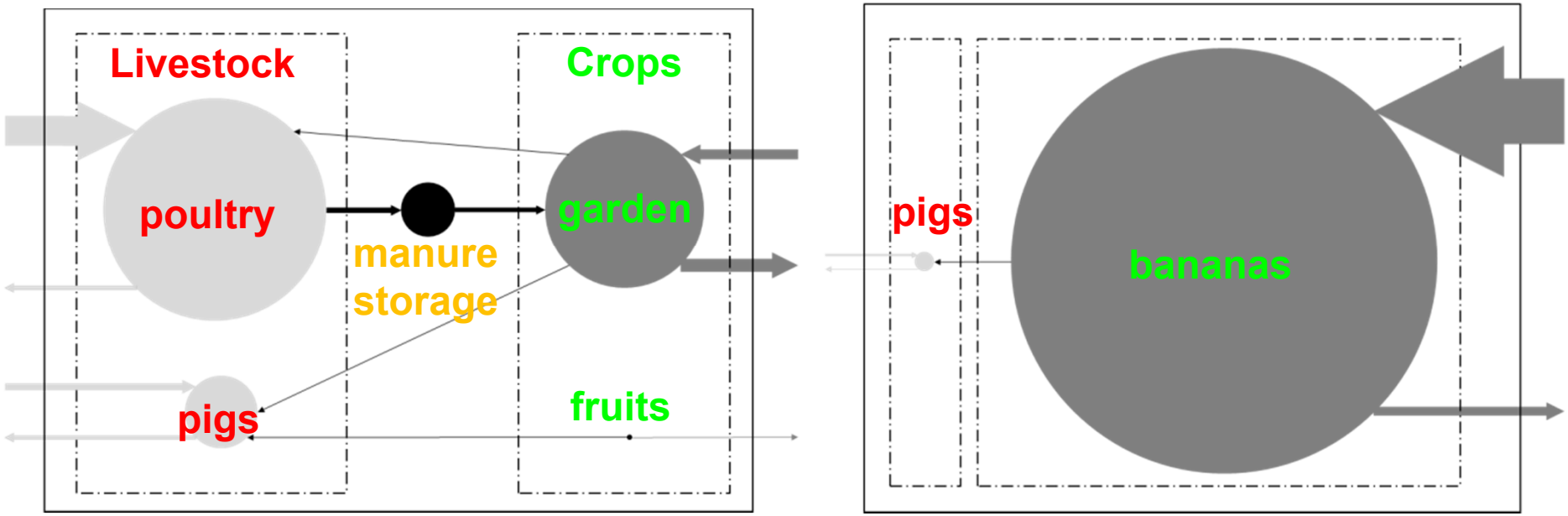
Organization varies from 0 to 1

More **Organization** is closed to 1, more the network is homogeneous

Crop-livestock integration: comparison of 2 farms in Guadeloupe

Intensity = **24,3** kg N / ha
Organization = **0,35**
Mid-heterogeneous network

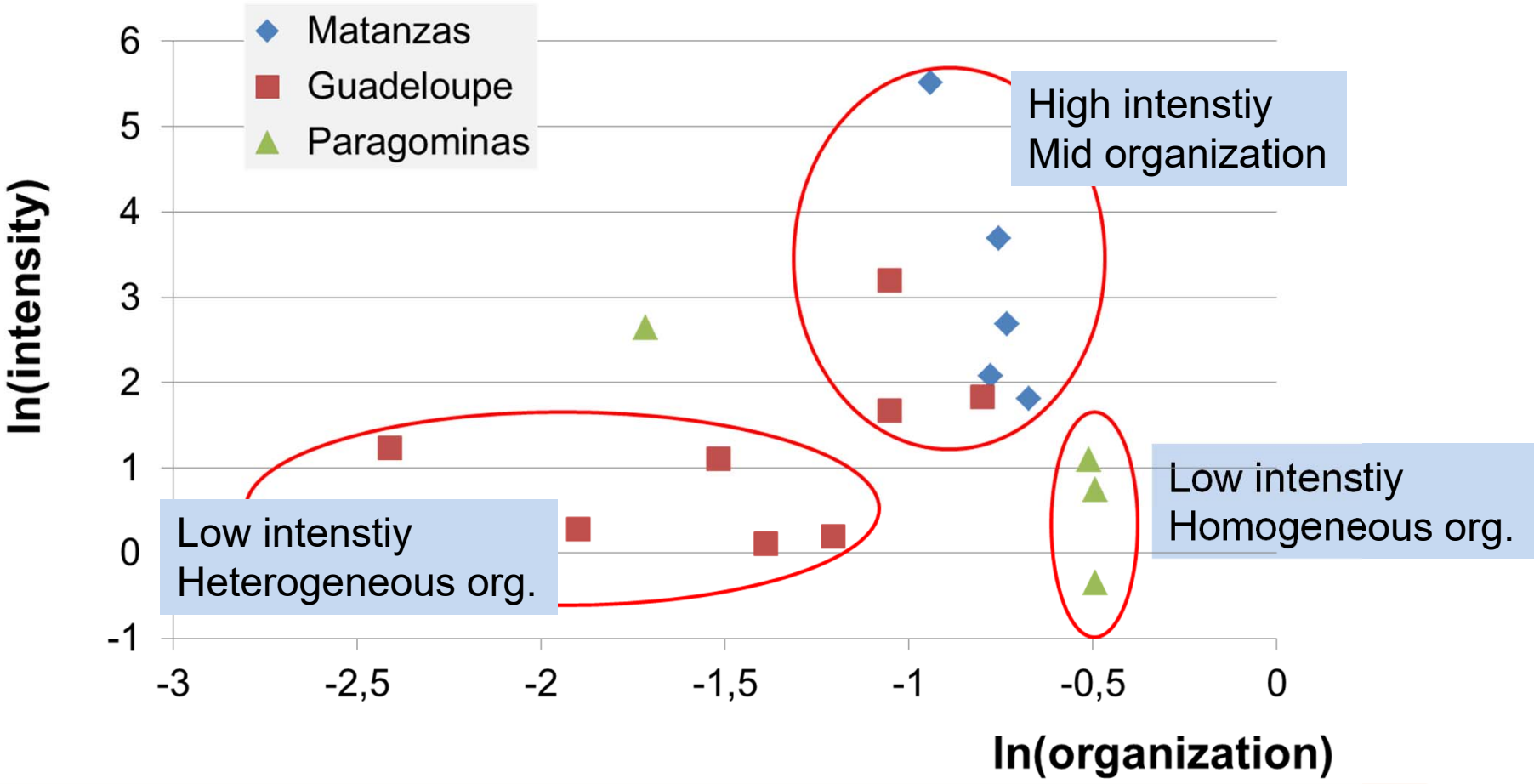
Intensity = **3,8** kg N / ha
Organization = **0,09**
Heterogeneous network



Compartment size is proportional to the annual amount of N circulating through the compartment

Flow size is proportional to the annual amount of N

Quantitave assessment of crop-livestock integration through two dimensions: intensity and organization



Calculation of one single indicator

Crop-Livestock Integration = ln (intensity x organization)

Indicator to assess the **flow resilience**

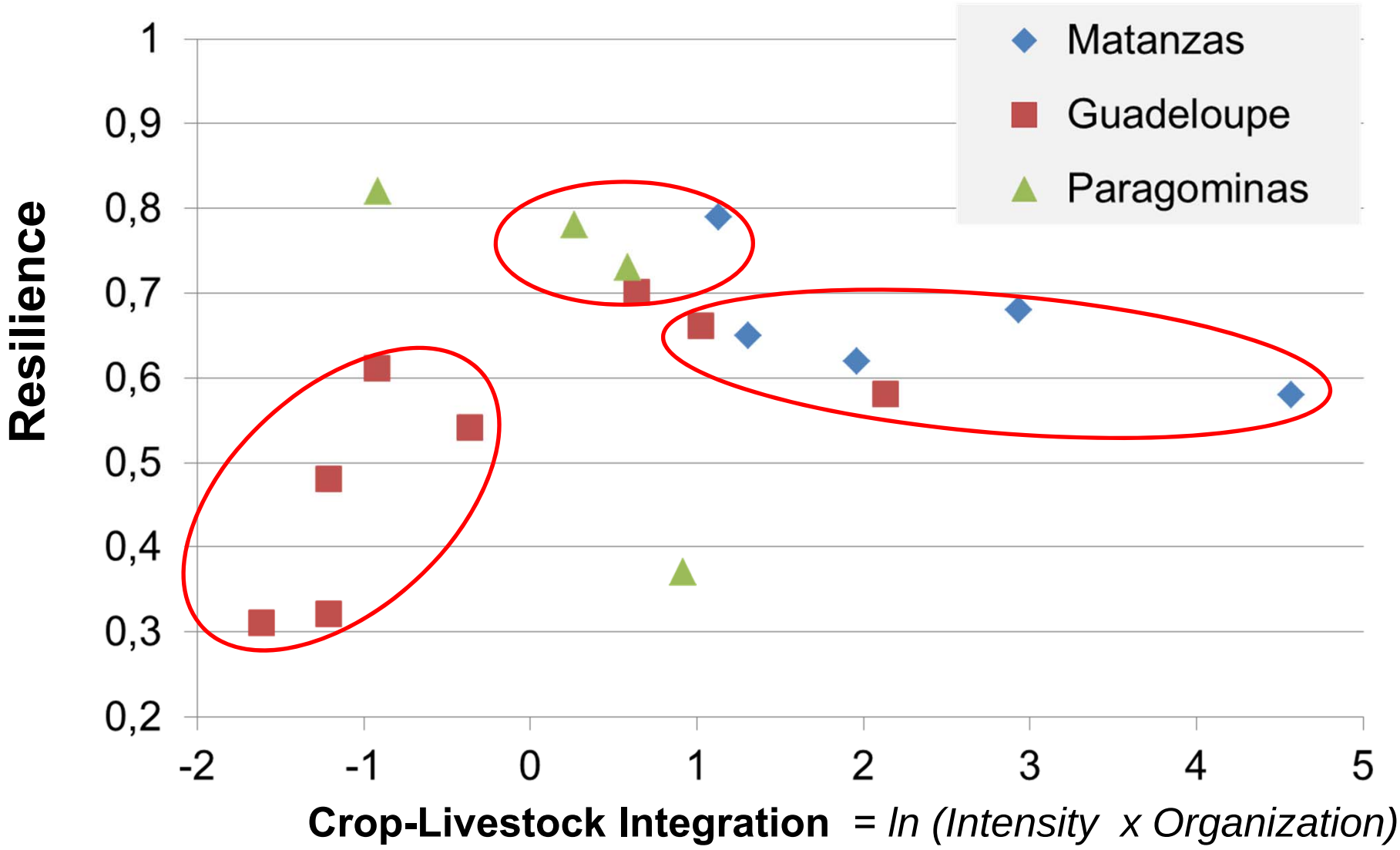
Introduction of information theory to characterize the capacity of an ecosystem for further development and for recovering from disturbances (Ulanowicz *et al*., 2009).

Flow resilience = the reserve capacity of the network of flows (Overhead) in terms of the maximum potential capacity of the system (Development Capacity).
From of the ascendency suite developed by Ulanowicz and Norden (1990).

The ratio Overhead / Development Capacity varies from 0 to 1.

More the ratio is closer to 1, more the system detains reserve capacity.

For the sample of 17 farms, the **maximum of resilience** is reached by **mid-integrated systems**



Discussion and conclusion

Relevant approach to study relationships between the configuration and the properties of systems

Trade-off between integration and resilience ? in the sample, the more integrated systems are not the more resilient (from a flow perspective)

-> Larger samples, other agrosystems…

A static approach of the resilience from observed farms

-> use of simulation to explore sensitivity to disturbances of the various configurations of mixed systems

Stark F. *et al*., 2016. Crop-livestock integration, from single practice to global functioning in the tropics: Case studies in Guadeloupe. *European Journal of Agronomy*, 80:9-20.

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