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

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EAAP 2016 - 67th Annual Meeting of the European Federation of Animal Science
Belfast, UK, 29 Aug – 2 Sept 2016
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
- Heterogeneous, 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 al.*, 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

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$H$: compartment

$f$: internal flows
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
Quantitative 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 ascendancy 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

References


