Simulating management policies on stock supplied by multiple production units: Application to a pig slurry treatment plant

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Introduction

- Pig slurry:
  - An heterogeneous product with an important polluting capacity,
- Development of intensive animal farming

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- Organic wastes surpluses

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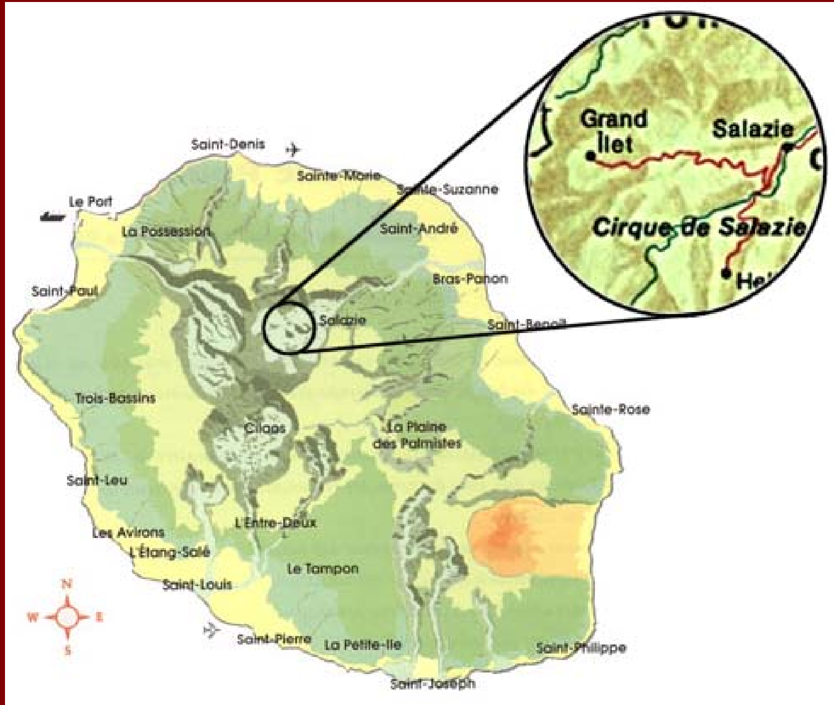
- Treatment (regulation rules, environment)

Contents of presentation

- **Application background**
  - Reunion Island distinctive features
  - System description
  - Supply policies
- **Model description**
  - Block diagram representation
  - Stock evolutions
  - Transportation organization
- **Simulations**
  - Specification of the scenarios
  - Comparison of supply policies

The case of Grand Ilet

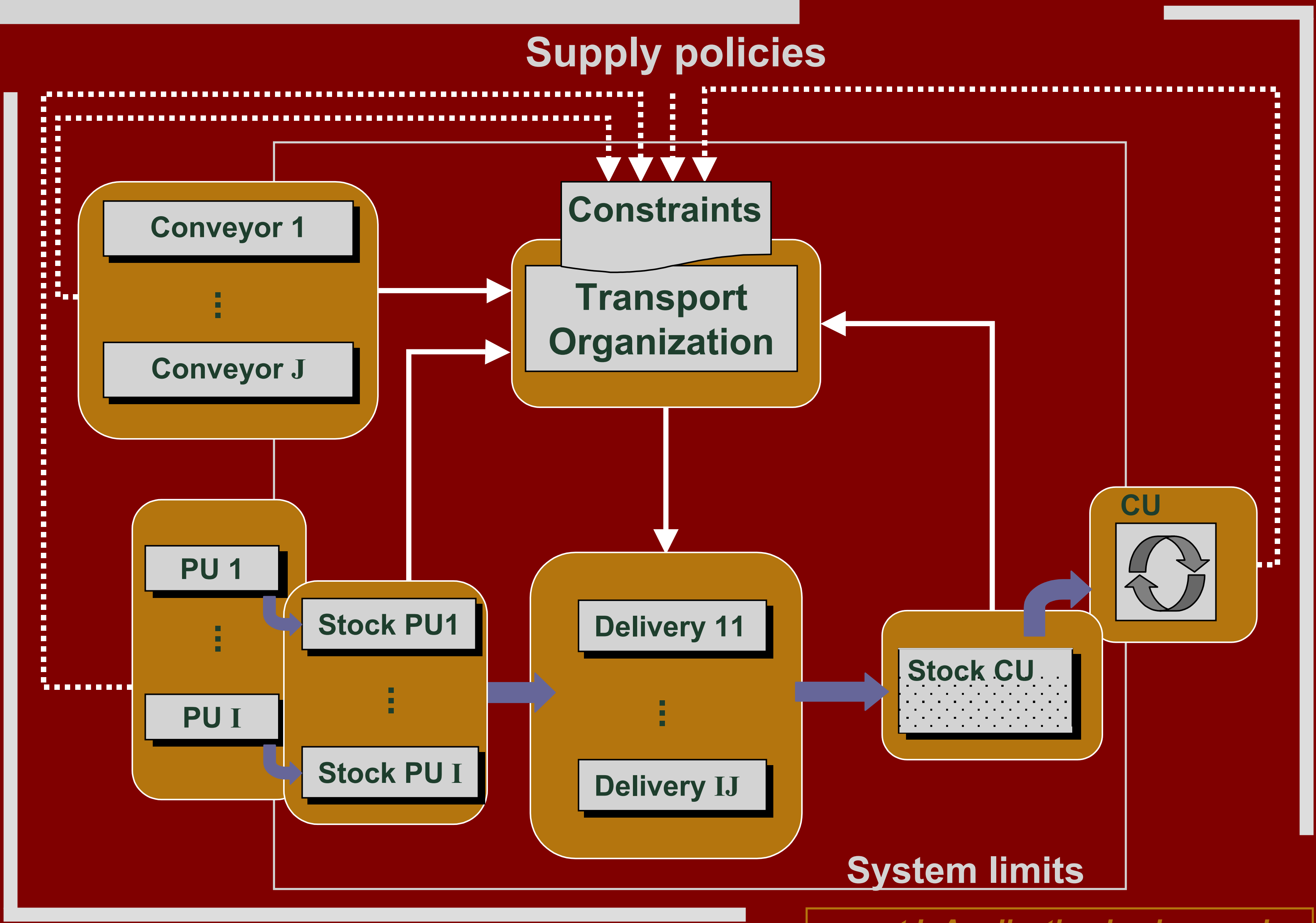
- Many small intensive animal farms
- Slopes, rainfalls, urbanization, tourism...
  - ↳ limited area for spreading
  - ↳ limitation of transportation



- Treatment required to transform slurry into an exportable product

↳ **A collective slurry treatment plant project**

System description

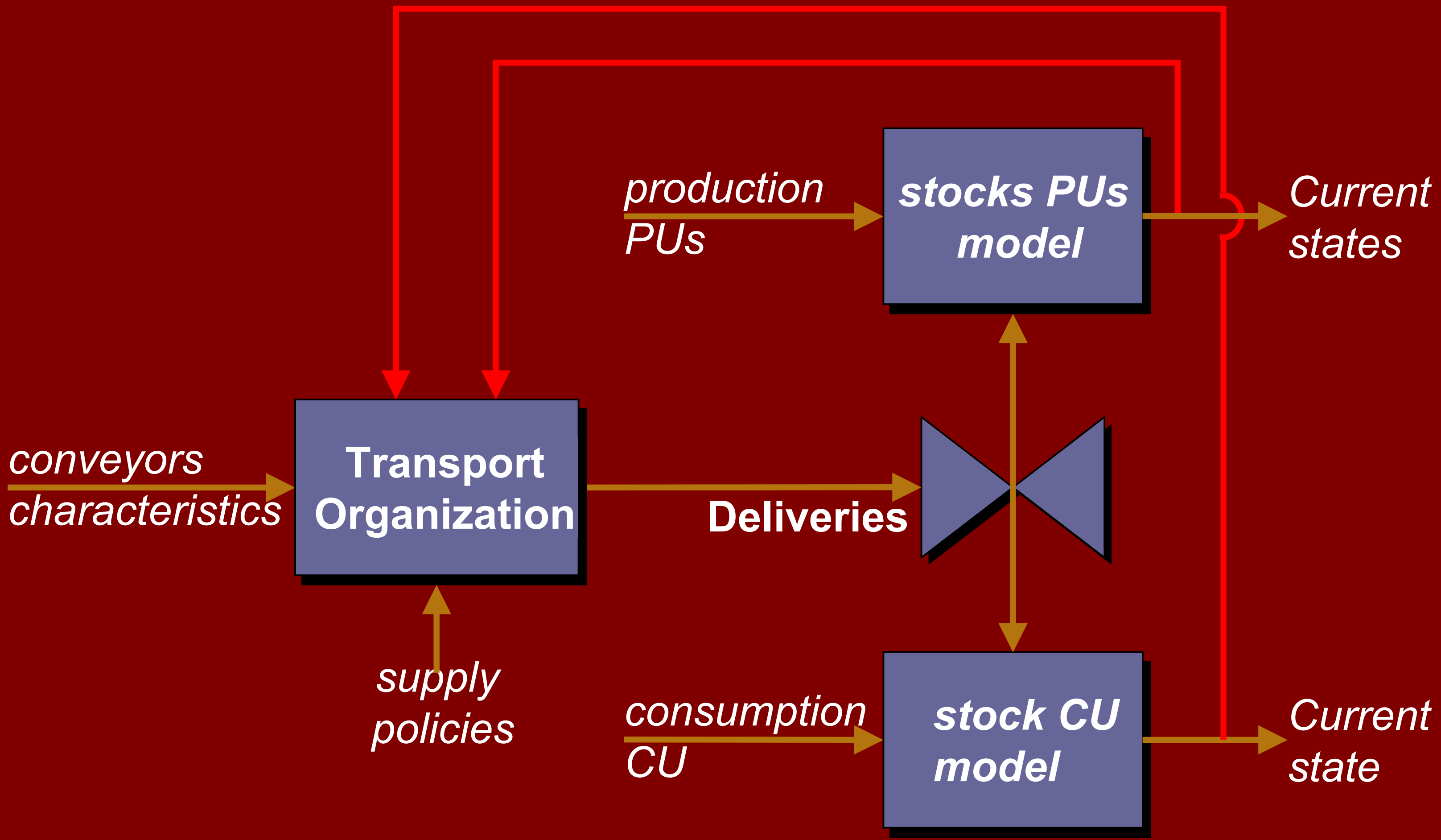


Slurry policies

- **“Who ?”** and **“When ?”** mean “When should each production units perform a delivery?”
  - A fixed period basis: T policy
  - An alarm threshold: S policy
- **“How much ?”**
  - A fixed quantity: Q policy
  - A variable quantity to move state back to a predetermined level: R policy

	T	S
Q	T - Q	S - Q
R	T - R	S - R

Block Diagram



Hybrid dynamical system

- Process: the continuous part
  - Stock evolutions (PUs and CU): volume and concentrations
  - Ordinary differential equations: mass balance equation
- Transport organization: the discrete part
  - Transport actions (boolean)
  - Constraints

Stock evolutions

- Ordinary differential equation:

$$\frac{dV}{dt} = \sum_{m=1}^{M} Qin_m - \left(\sum_{n=1}^{N} Qout_n + Qover \right)$$

$$V(0) = v_0$$

- with:

$$Qover = \begin{cases} \sum_{m=1}^{M} Qin_m - \sum_{n=1}^{N} Qout_n & \text{if} \quad V \geq v_{\max} \quad \text{and} \quad \sum_{m=1}^{M} Qin_m > \sum_{n=1}^{N} Qout_n \\ 0 & \text{otherwise} \end{cases}$$

Transport organization (1)

- Mixed-integer linear program (branch & bound)
- To each decision step
- Objective function:

$$Max \sum_{ijk} Pw_i \cdot x_{ijk}$$

- $x_{ijk} \in \{0,1\}$: delivery k from PU_i by conveyor j
- $Pw_i \in [0,1]$: cost accounting for a time delivery indicator in the case of policies T or S applied to the PU_i

Transport organization (2)

- Constraint's examples
  - PUs stock:

$$\sum_{jk} \mathrm{vc_j} \cdot x_{ijk} \le Ph_i$$

  - CU stock:

$$\sum_{ijk} \mathrm{vc_j} \cdot x_{ijk} \le P_{CU}$$

  - Conveyor cannot be at different places at the same time:

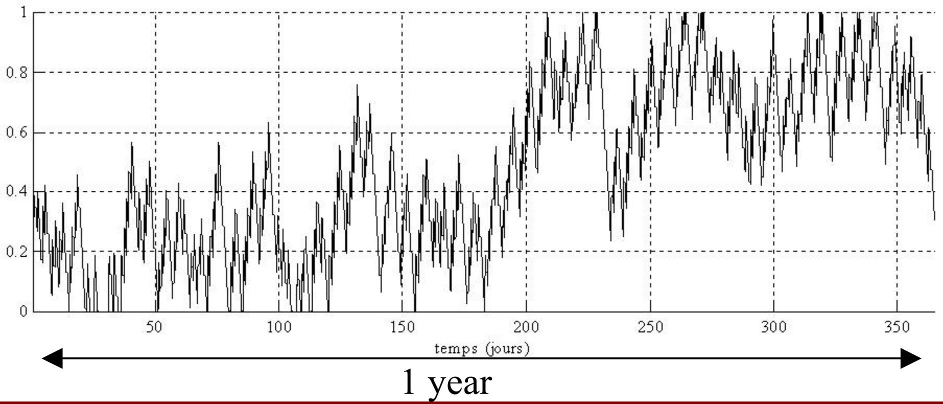
$$\sum_{i} x_{ijk} \le 1 \; \forall \; j,k$$

Test scenarios

- Stock Consumption Unit: 350 m^3
- 40 Production Units
- A collective conveyor (10 m^3)
- Scenario 1:
  - PUs policy: T-R *(fixed date and emptying the stocks),*
  - CU policy: Q *(fixed quantity processed each day).*
- Scenario 2:
  - PUs policy: S-R *(alarm threshold and emptying the stocks),*
  - CU policy: R *(refill the stock up to its limit capacity).*

Example 1

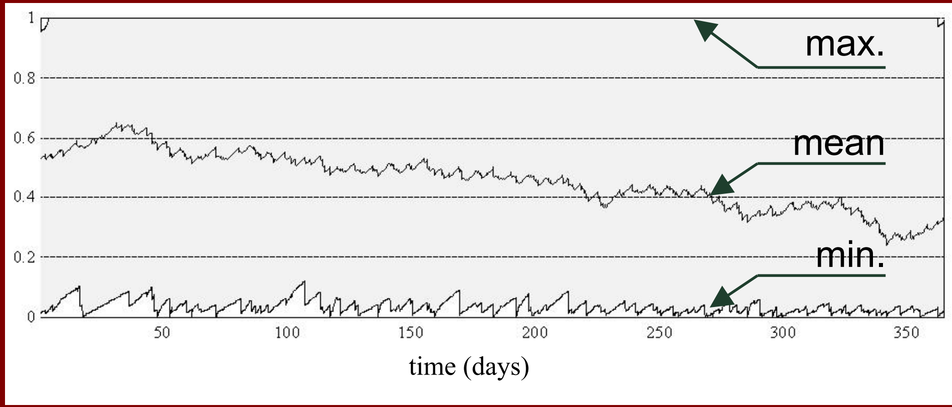
Stock evolution of the CU



Policies:

PUs⇨T-R, CU⇨Q

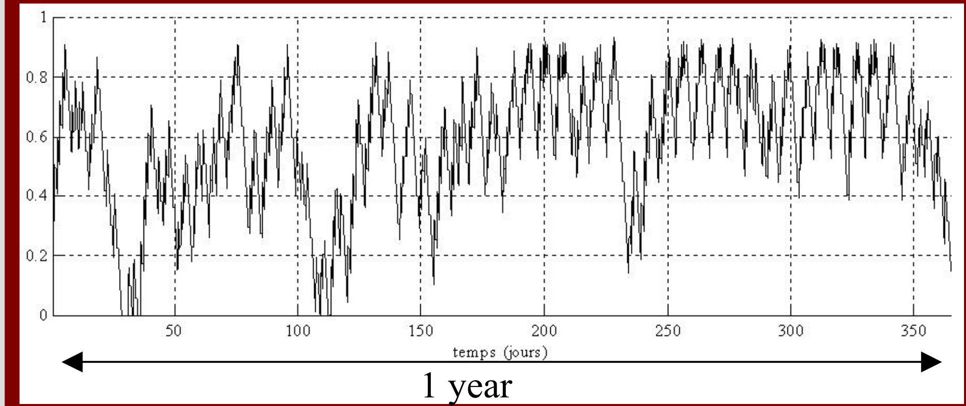
Stock evolutions of the PUs



↳ 1800 m^3 overflowing in the environment

Example 2

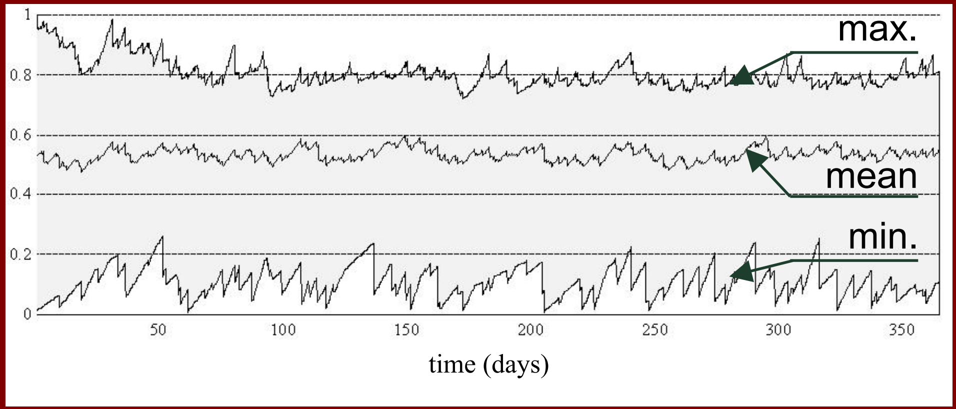
Stock evolution of the CU



Policies:

PUs⇨S-R, CU⇨R

Stock evolutions of the PUs



⇘No slurry overflows to the environment

Simulation's result

- Collective supply permits a better use of available resources.
- Security increases with the CU stock capacity.
- Usefulness of a closed-loop control:
  - CU policy: R,
  - PUs policy: S-R.

↳ **Increase reactivity to deal with stock limitations.**

Conclusion

- A hybrid dynamical system:
  - Continuous part: Stock evolutions encoded as ODEs,
  - Discrete part: Transport organization as a MILP.
- Application on the specific case of Grand Ilet:
  - Different policies and different parameter values,
  - Benefit of a closed-loop control.
- Perspectives:
  - Generalize this approach by a generic production/consumption model
  - Application to other problems (individual farm, inter-farms transfers)