



# Designing innovative agricultural land systems in the Caribbean: Application to Guadeloupe

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# Definitions

- Land system:
  - The composition and organisation of land uses (urban, forest, agriculture...) all over a given region
- Agricultural land system // cropping system mosaic:
  - The composition and organisation of cropping systems within a region or a landscape
- Cropping system:
  - Crop rotation + Crop management system



## Design of agricultural systems for a sustainable agriculture

- Contribution at field scale
  - Agronomic diagnosis
  - Crop modelling & biophysical modelling
  - Field trials...
- Contribution at farm scale
  - Farming system experiment
  - Integrated assessment of farming systems...

**Limits in addressing  
global and local  
sustainability issues**

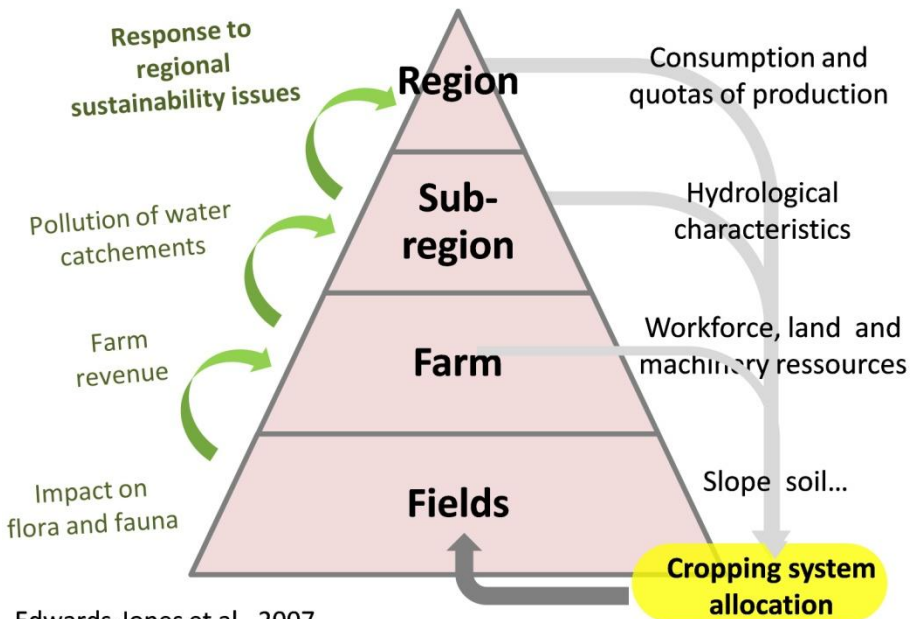
⇒ **low scaling integration**

⇒ **lack of spatially explicit approaches (Dale et al., 2013)**



# Multi-scale & spatially explicit approaches

Elements at different spatial scales impact farmer's cropping system choices



Spatial dependence in the assessment of agricultural land systems



Same area of canola but... decrease of risk of phoma stem canker & reduce use of pesticides  
=> **Spatial location matters**

Hossard et al., 2015

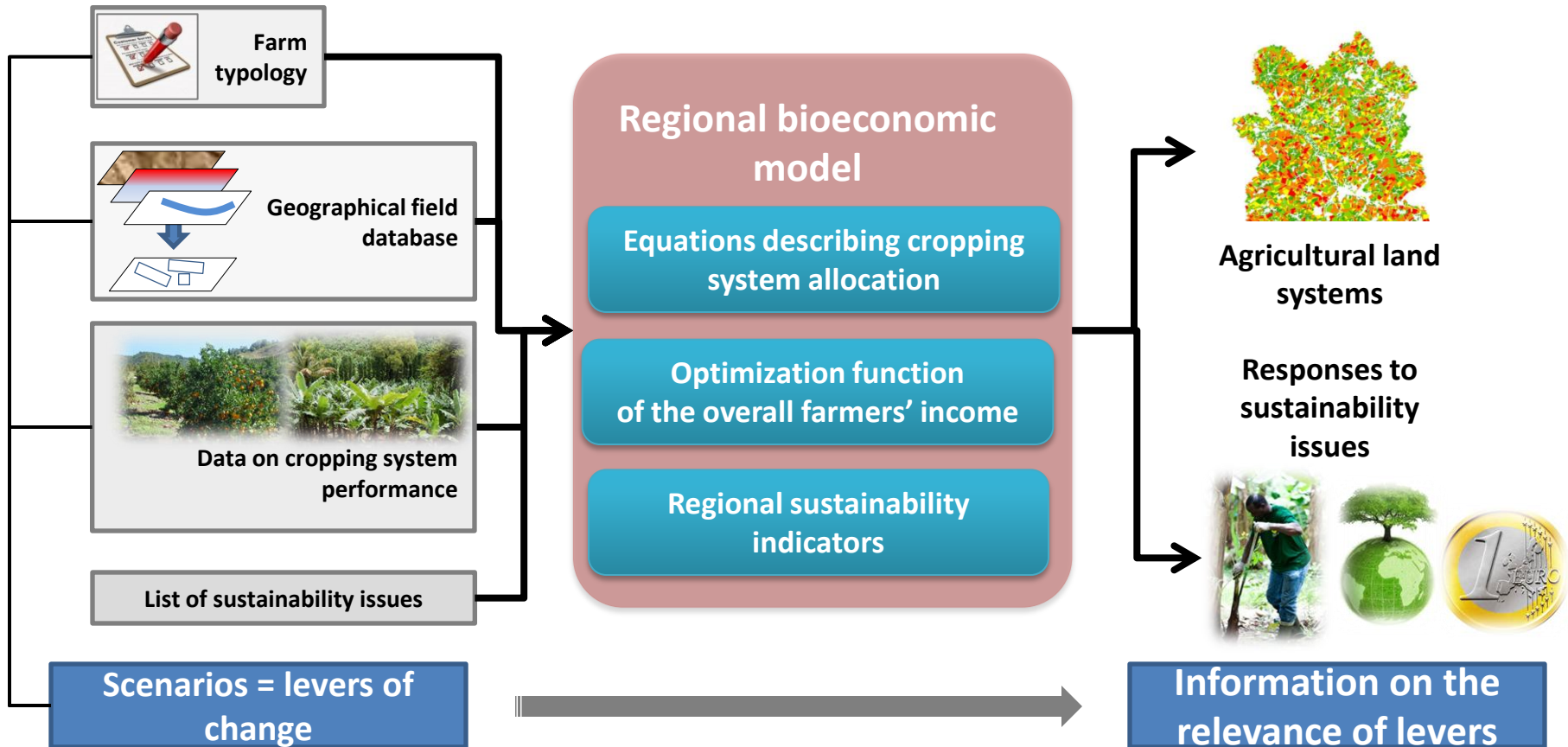


# Objectives of the study

- Designing sustainable agricultural land systems at the regional scale accounting for parameters at field, farm and regional scales (*scale integration*)
- Assessing the response of these agricultural land systems to sustainability issues by taking into account the location of cropping systems (*spatially explicit approach*)



# Overview of the method





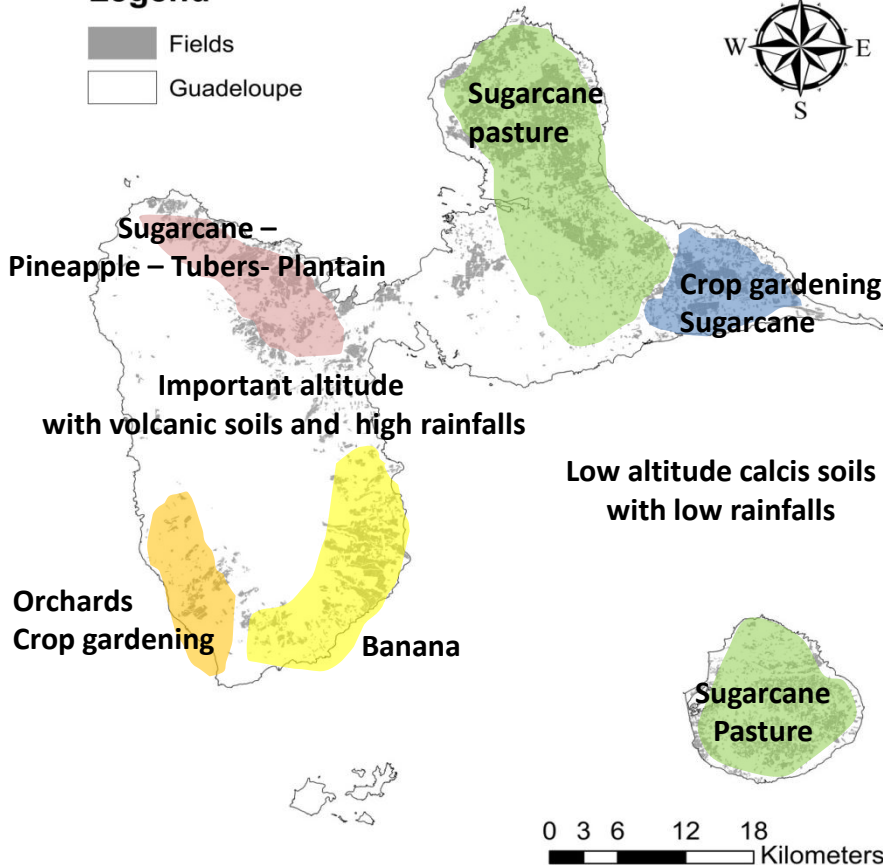
# Study area



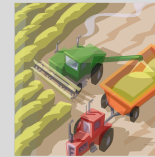


### Legend

-  Fields
-  Guadeloupe



**x 8.000 farms  
(information on 5300 farms)**



**x 31.000 ha of agricultural production  
(information on 27.000 hectares)**

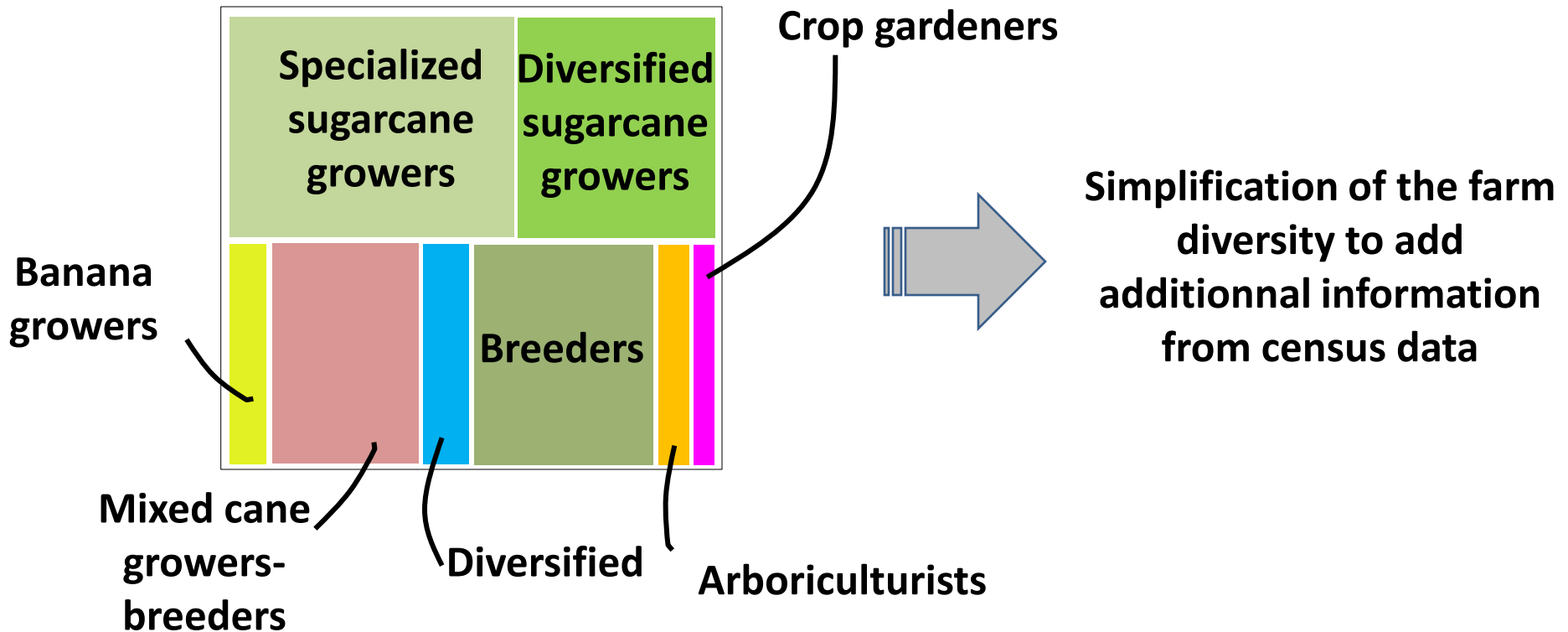
### Sustainability issues

- Increase food and energy self-sufficiency
- Increase local employment and added value
- Decrease dependence from subsidies
- Protect water bodies, biodiversity, landscape...





# Results in Guadeloupe : 8 farm types





## Results: Description of characteristics of cropping system and their location

- Characteristics & performance:
  - Literature on the performance of banana (Blazy et al., 2009), orchards (Le Bellec et al., 2012), Sugarcane (CTCS, 2011), Yam (Barlagne, 2014)
  - Farm surveys for: pineapple & other tubers
  - Expertise with the Delphi method for crop-gardening
  - ⇒ **32 cropping systems with information on yield, pesticide & fertilizer use, workforce needs...**
- Allocation rules: if-then rules (Leenhardt et al., 2011; Murgue et al., 2015)
  - Fuzzy expert knowledge
  - Descriptive and multivariate statistics

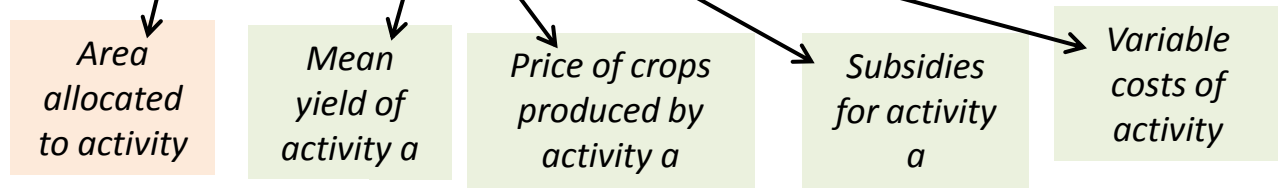


# Results : Regional bioeconomic model MOSAICA

- **M**ulti-scale model of the cr**O**pping **S**ystems **A**rrangement and Its **C**ontribution to sust**A**inable development
- It simulates the choice of cropping systems by farmers and their allocation to farmer's plots
- Optimization of quantitative variables : farmer's income

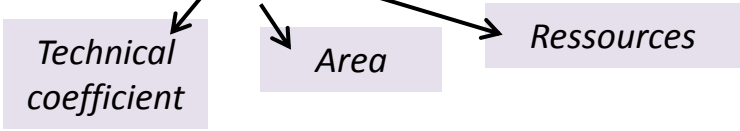
*c* : plots  
*a* : activity

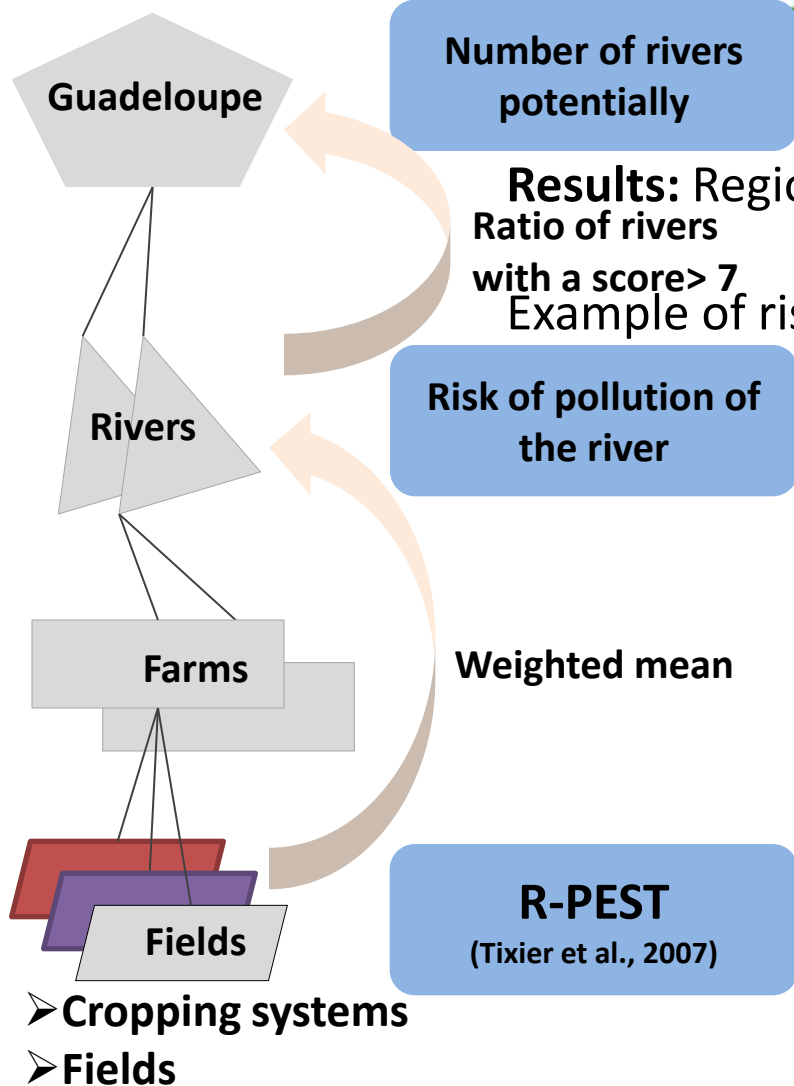
$$MAX \sum_c X_a ( \sum_A ( \bar{y}_a p_a + S_a ) - C_a )$$



...under the constraints:

$$Ax \leq B ; x \geq 0$$

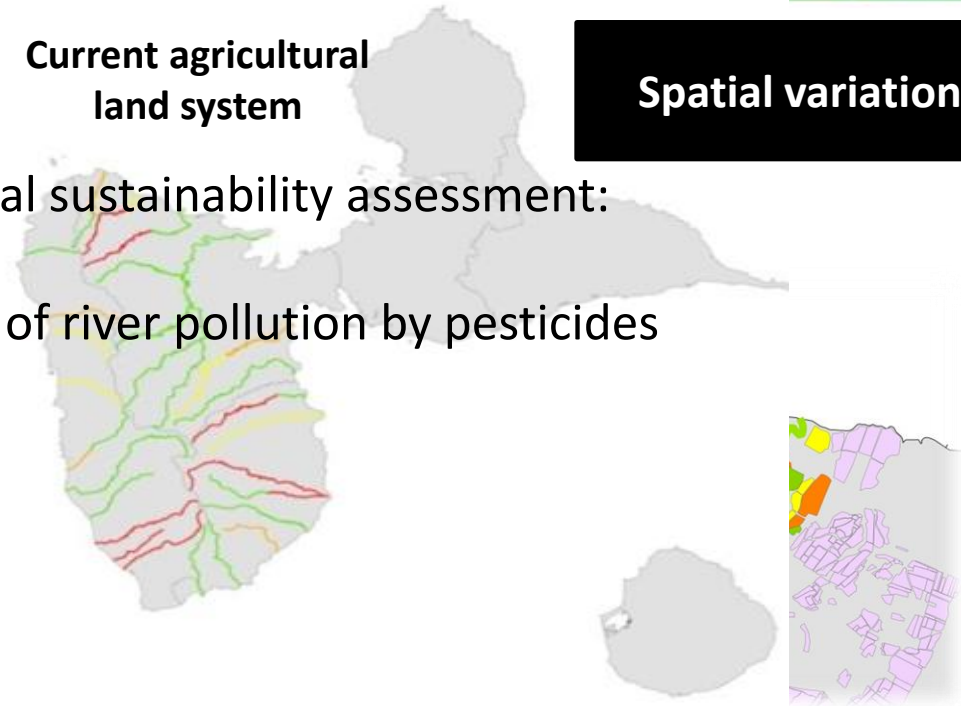




**Current agricultural land system**

**Spatial variation**

**Results:** Regional sustainability assessment:  
Ratio of rivers with a score > 7  
Example of risk of river pollution by pesticides

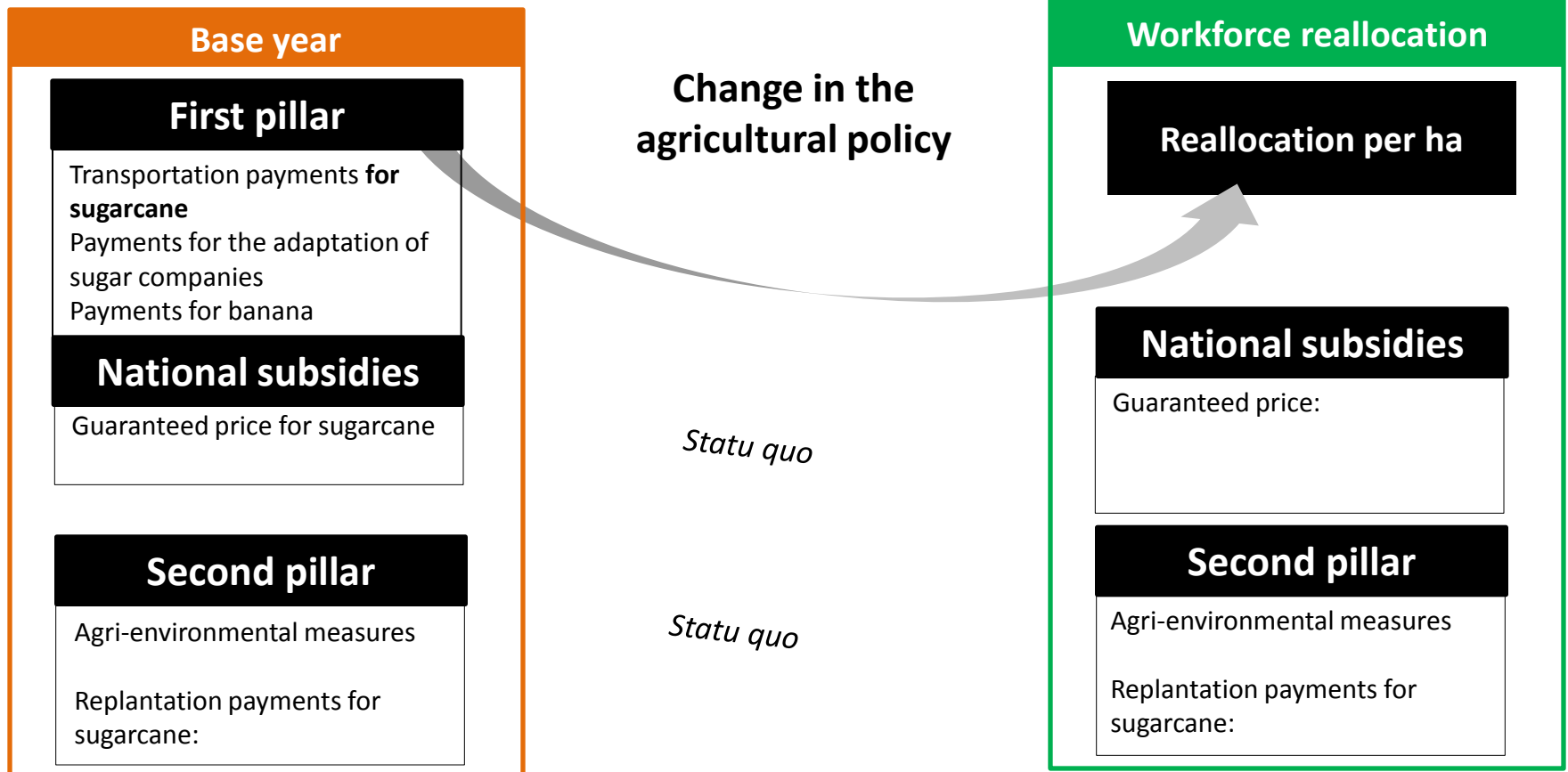


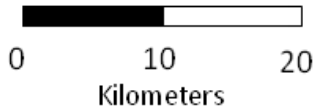
**Regional score:**  
**8/36 rivers potentially polluted = 22%**





# Results : Change of subsidy regime in Guadeloupe

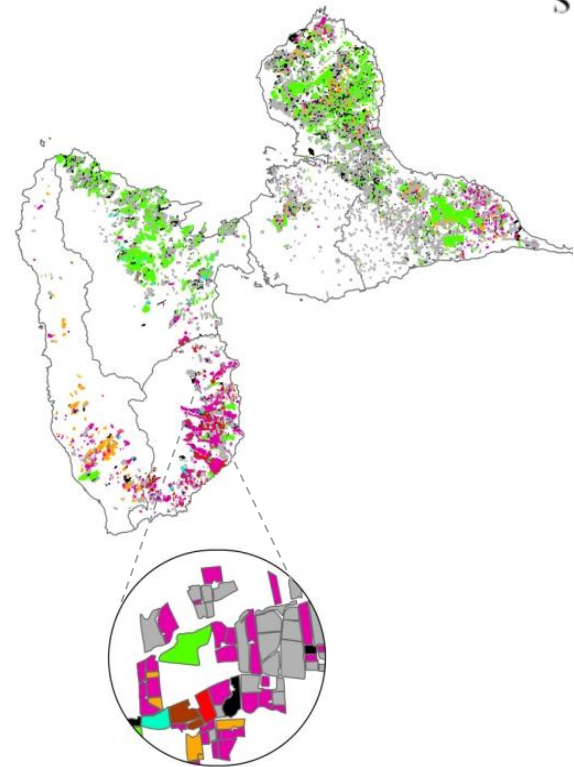
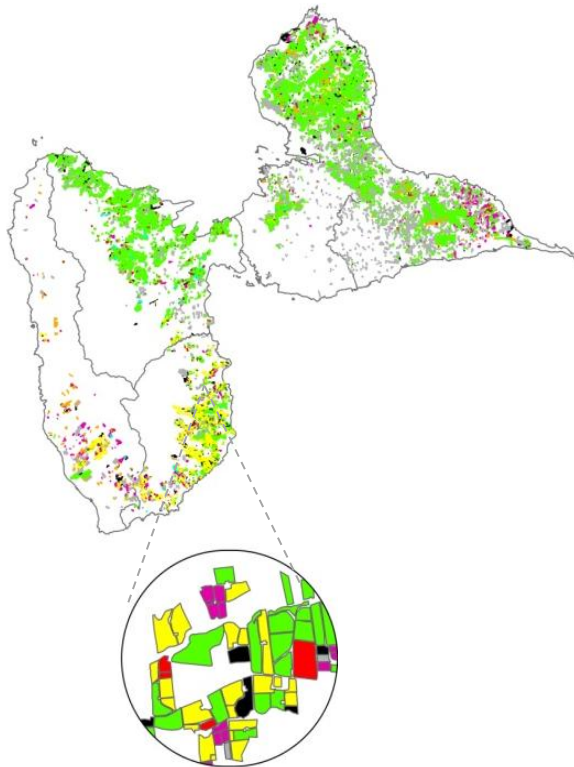




### Base year

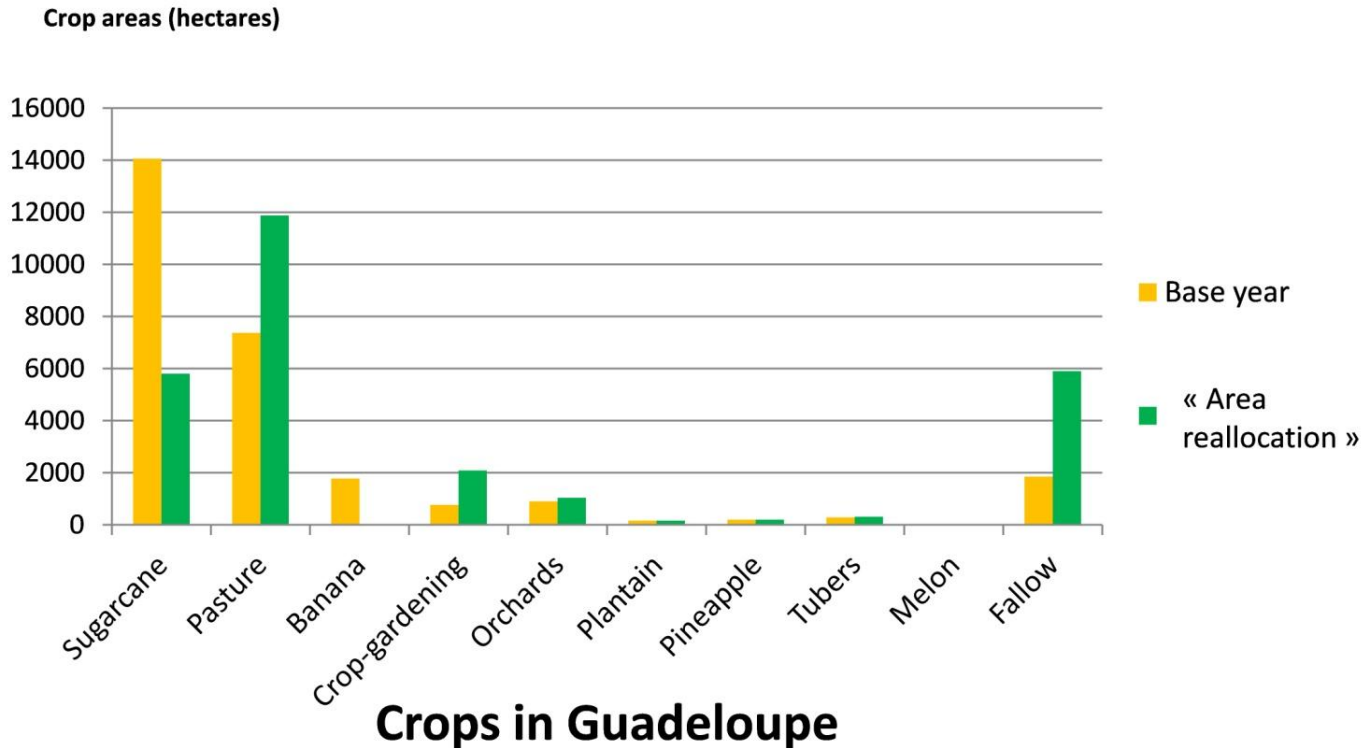
### « Area reallocation »

-  Sugarcane
-  Banana
-  Pasture
-  Orchards
-  Crop-gardening
-  Pineapple
-  Plantain
-  Tubers
-  Fallow
-  Pedoclimatic areas





# Scenario results : Change of subsidy regime in Guadeloupe





Dimensions	Sustainability objectives	Indicators	Base year	Area reallocation
Economy	Improving the agricultural added value	Agricultural added value (M€.yr <sup>-1</sup> )	96	138
	Increasing the independence from subsidies	Total amount of subsidies (M€.yr <sup>-1</sup> )	75	60
Social	Reaching food-self-sufficiency	Ratio of fats produced over needs	9%	13%
		Ratio of carbohydrates produced over needs	15%	20%
		Ratio of proteins produced over needs	22%	28%
	Producing local energy from agriculture	Potential of electricity produced by crops (MW.yr <sup>-1</sup> )	33	16
	Contributing to employment	Total needs of workforce (persons)	3105	2566
	Insuring safety of locally produced foodstuff	Area of risk of contamination of food crops	1170	2013
Environment	Improving the state of biodiversity	Mean quantity of toxicity in fields located in ZNIEFF areas	1.0	0.5
	Enhancing water quality	Ratio of rivers potentially polluted	22%	8%
		Ratio of water catchments potentially polluted	30%	12%
		Amount of water needed for irrigation	17.7	14.7
	Decreasing the contribution to climate change	Overall emissions of CO <sub>2</sub> from farming practices (kT eq CO <sub>2</sub> )	158	142
	Improving the diversity of agricultural landscapes	Diversity of crops across landscape	3.0	3.1



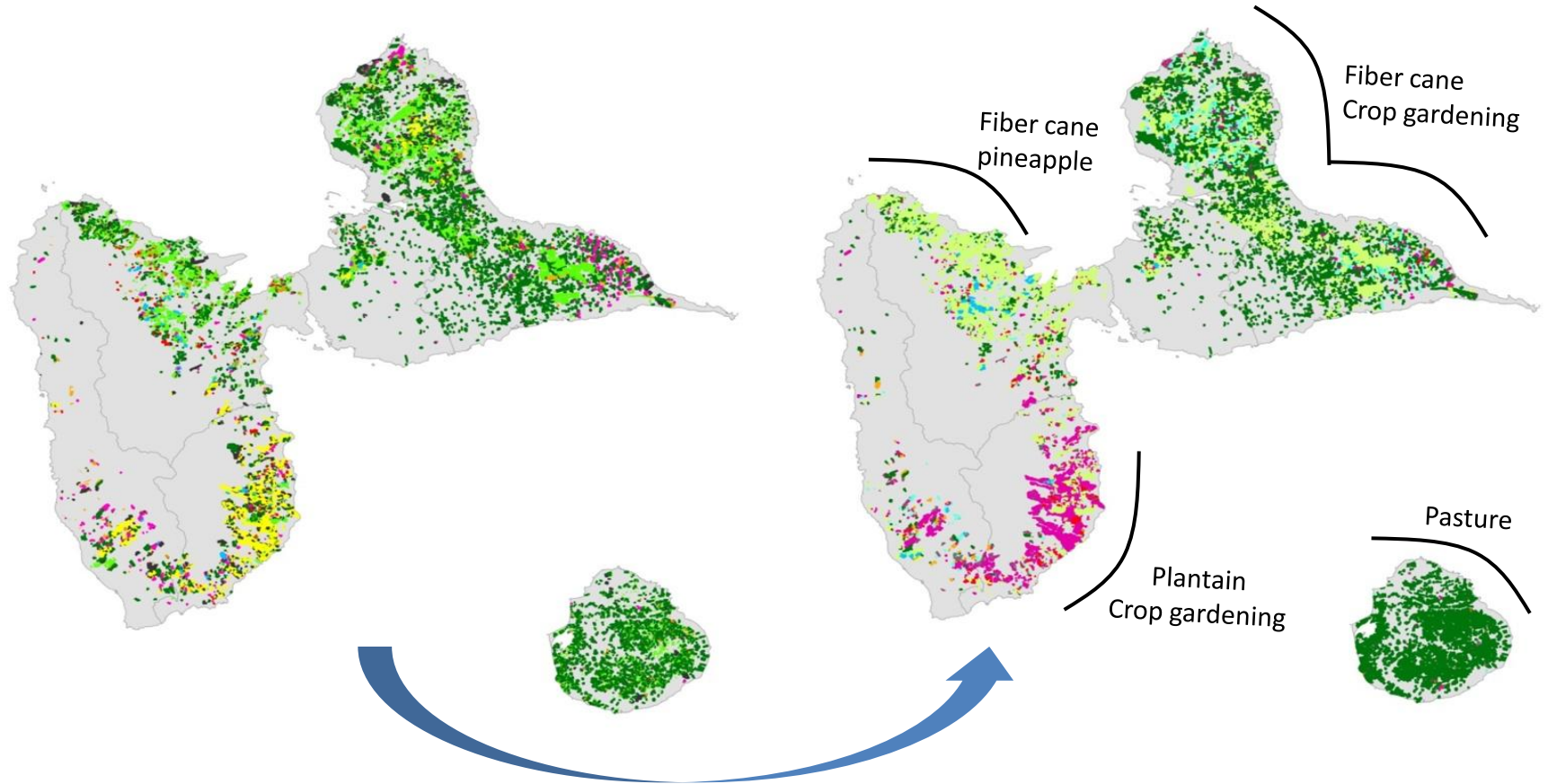


## Scenario results : 2°) Building a sustainable agricultural land system

- Mix of scenarios to select relevant levers:
  - Normative : reaching a given objective
  - Exploratory what if scenarios
  - Optimized scenarios: what is the optimal response to a sustainability issue
- => When levers help reach a target objective, have an overall positive impact on the contribution of agriculture to sustainable development => **selected**
- The “Innovative scenario” is a combination of the following levers:
  - Change in subsidy regime towards local food crops
  - New crop gardening cropping systems
  - Energy crop and electricity plant production with biomass
  - Increase of workforce for crop management (+ 1000 units of workforce)

### Current situation in 2010

### Innovative scenario

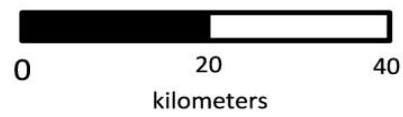
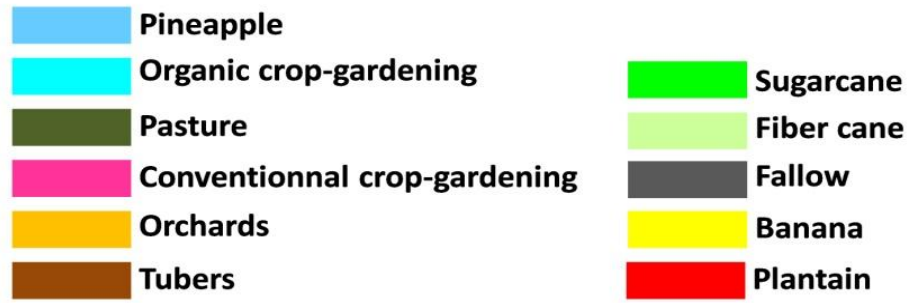


Fiber cane  
pineapple

Fiber cane  
Crop gardening

Plantain  
Crop gardening

Pasture





## Response to sustainability issues with the “innovative scenario”

- Increase of :
  - Agricultural added value of local products by 250%
  - Potential energy production by 12%
  - Overall agricultural added value by 110%
- Decrease of:
  - Risk of crop contamination by 100%
  - **Risk of pollution in rivers by 25%**

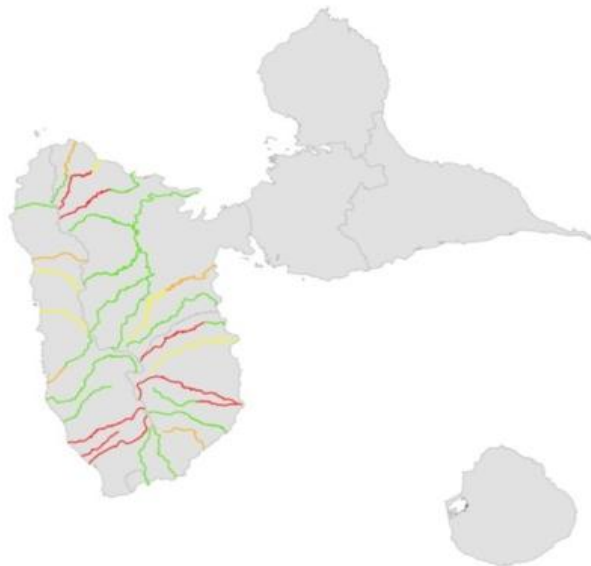
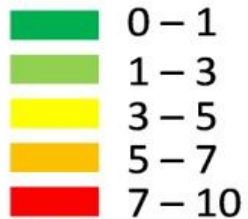


## Spatial variation of the response to « the decrease of the risk of pollution in rivers » issue

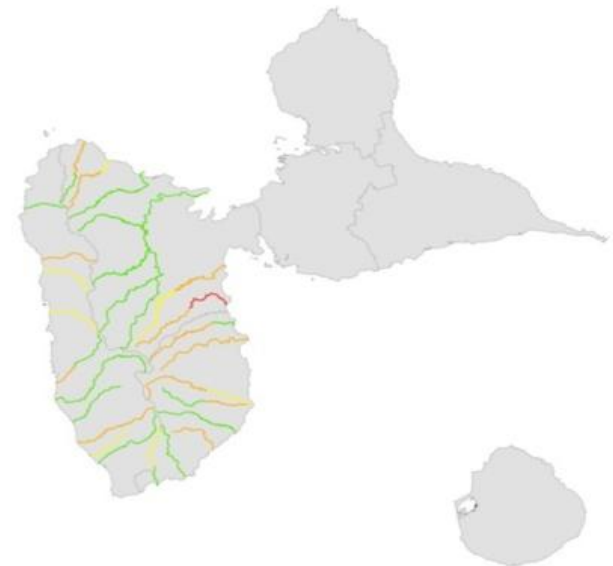
### Risk of pollution in rivers

1: low

10: very high



*Current situation in 2010*



*« Innovative scenario »*



## Discussion:

- Modeling approaches for integrating a wide range of knowledge in agronomy, agricultural economics and environmental sciences :
  - Cropping system performance
  - Cropping system location
  - Impact of cropping system on ecological processes & sustainability issues
  - Farmer's decision processes
  - Farm management
- Multi-scale modelling & spatially explicit method :
  - => **better identify the impacts of farming activities on the contribution of agriculture to sustainable development of regions**



## Discussion:

- High potential for helping decision-makers... in their decisions
- Potential for learning information on farming impacts
- Bring new research questions: identify knowledge-gaps
- Results at the regional scale can strongly impact the research of :
  - New cropping practices (e.g. new cultivar, machinery...)
  - Innovative cropping systems (IPM cropping systems)
  - Well organized sectors ...
- An agriculture-based contribution to land system architecture for sustainable islands



Thank you  
for your attention !