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A modeling framework for designing innovative sustainable agricultural land systems:

Application to Guadeloupe



Pierre Chopin*¹, Jean-Marc Blazy ¹, Loïc Guindé ¹, Thierry Doré ^{2,3}

¹INRA, UR1321 ASTRO Agrosystèmes tropicaux, F-97170 Petit-Bourg (Guadeloupe), France

²AgroParisTech, UMR 211 Agronomie, F-78850 Thiverval-Grignon, France

³INRA, UMR 211 Agronomie, F-78850 Thiverval-Grignon, France



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Definitions

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



Introduction

Design of agricultural systems for a sustainable agriculture

- Contributions at field scale
 - Agronomic diagnosis
 - Crop modelling & biophysical modelling
 - Field trials...
- Contributions at farm scale
 - Farming system experiment
 - Integrated assessment of farming systems...
- Partial contributions at landscape scale
 - e.g. Impact of agriculture on ecological processes...

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

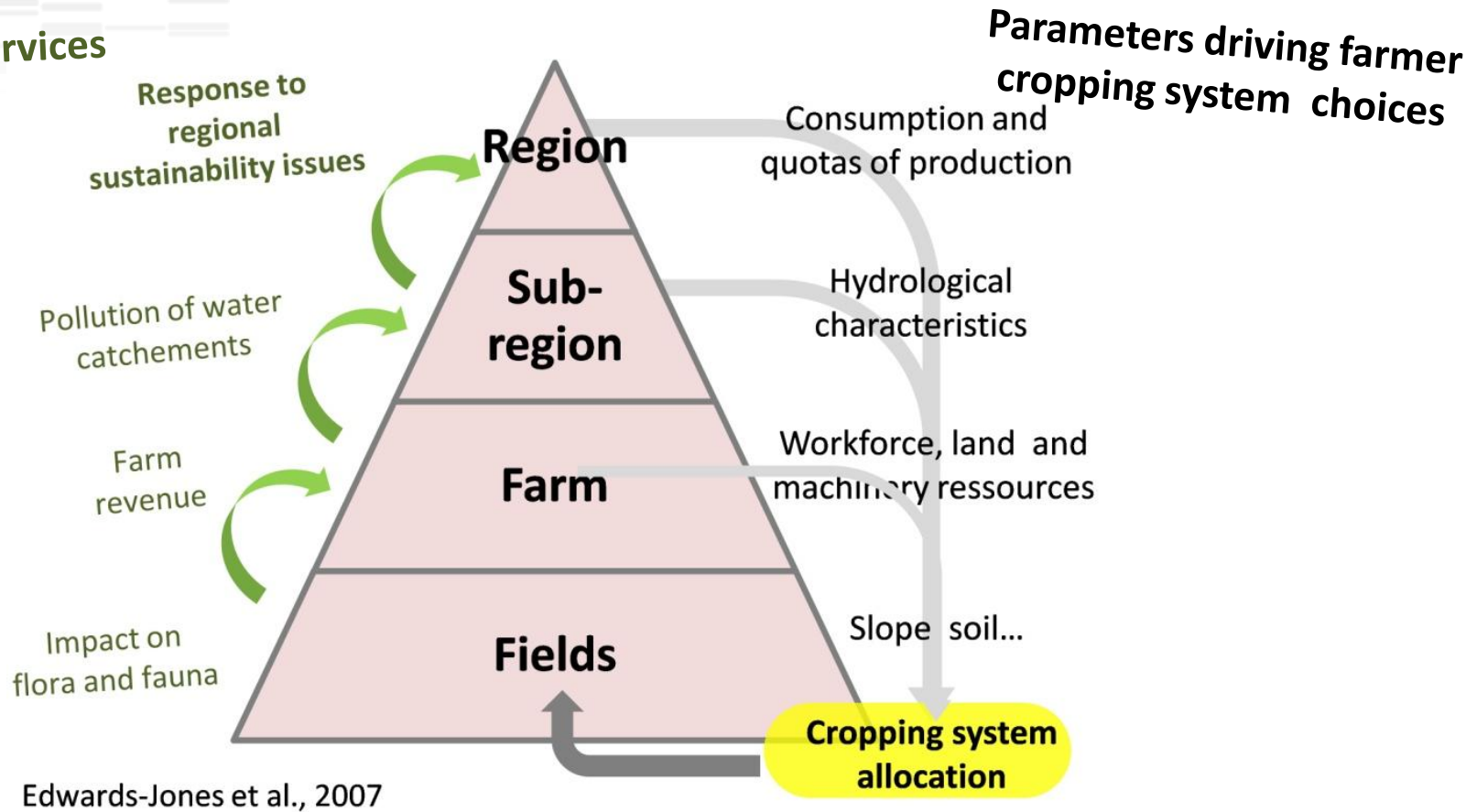
⇒ **low scaling integration**

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

Chopin and Blazy 2013. (Agriculture, Ecosystem & Environment)

Multi-scale & spatially explicit approaches are required

Ecosystem services



Location of cropping systems matters => magnitude of ecosystem service provision



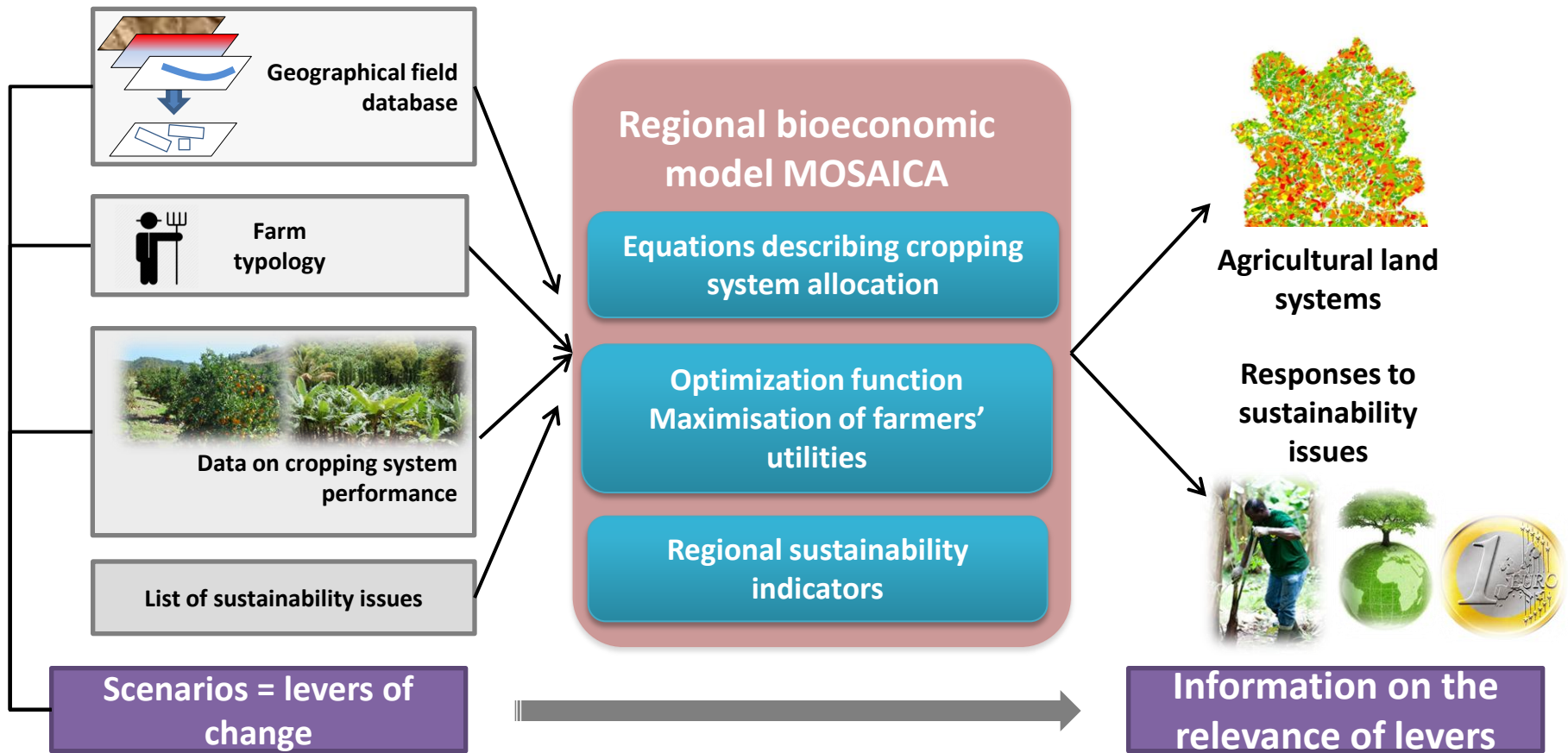
Objectives of the study

- 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*)

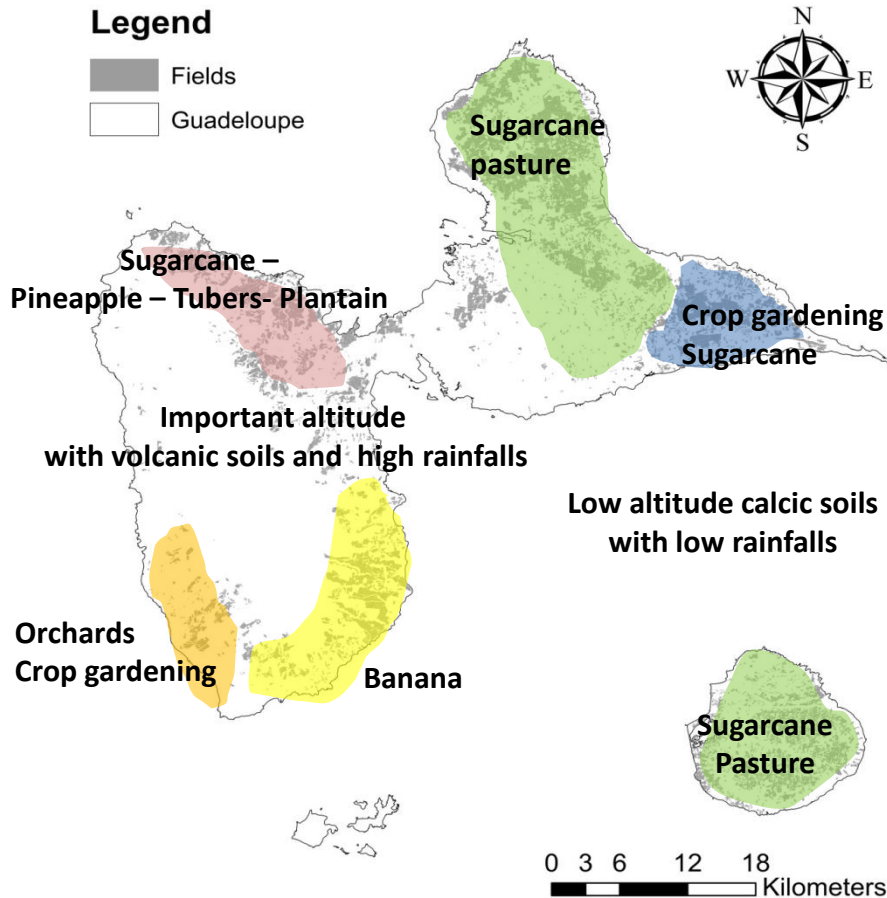


Method

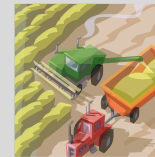
Overview of the method



Method: Geographical database & sustainability issues



**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...



Method: Typology

Farm typology:

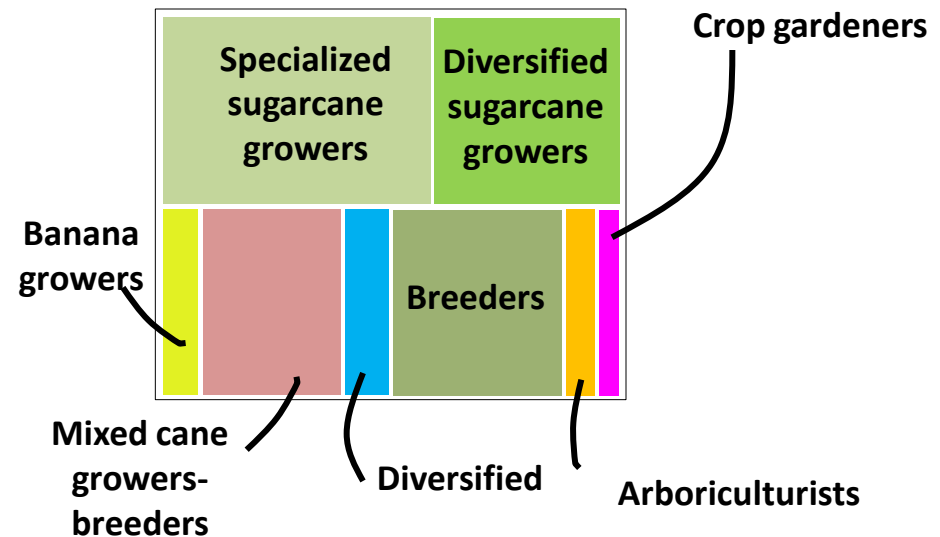
=> Groups of farmers based on the similarity of their decision process:

-Statistical analysis

(Principal component analysis + Ascending hierarchical clustering + Regression Tree)

-Expert based grouping

help to add additional information from census data



Method: Description of characteristics of cropping system and their location

- Characteristics & performance of cropping system in the area:
 - Literature on cropping systems performance (e.g. banana in Blazy et al., 2009)
 - Farm surveys
 - Expertise with the Delphi method

=> **32 cropping systems with information on yield, pesticide & fertilizer use, workforce needs...for indicator calculation**
- Allocation rules of cropping system in the area:

=> if-then rules (Leenhardt et al., 2011; Murgue et al., 2015)

 - Fuzzy expert knowledge
 - Descriptive and multivariate statistics

Method : Regional bioeconomic model MOSAICA

- It simulates the choice of cropping systems by farmers and their allocation to farmer's plots
- Optimization of quantitative variables : farmers' expected incomes with positive and negative variations

$$MAX U = \sum_f \sum_p \sum_a [X_{a,p} (\bar{m}_a - \phi_f (Z_a^+ + Z_a^-))]$$

c : plots

a : activity

Area of activity
a allocated to
plot *p*

Mean
gross
margin of
activity *a*

Risk aversion
coefficient of
farmer *f*

Positive and negative
expected deviations of gross
margin of activity *a*

...under constraints
Socio-economic or
biophysical constraints:

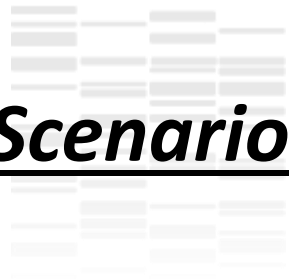
$$\sum_p \sum_a (X_{a,p} W_a) \leq \sum_p (X_{init_{a,p}} W_a)$$

Workforce
demand

Current farm
workforce



Results



Scenario 1: Change of subsidy regime in Guadeloupe


- Current:
 - Subsidies coupled to production
 - Agri-environmental payments
- Scenario : Common Agricultural Policy (CAP) 2003
 - Decoupling of subsidies from production
=> Payment of 1500€ per ha per yr
 - Maintaining of agri-environmental payments

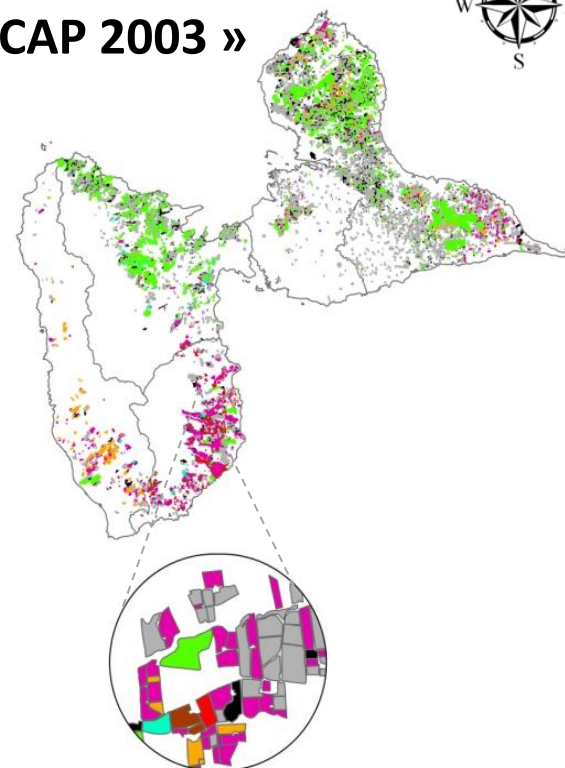
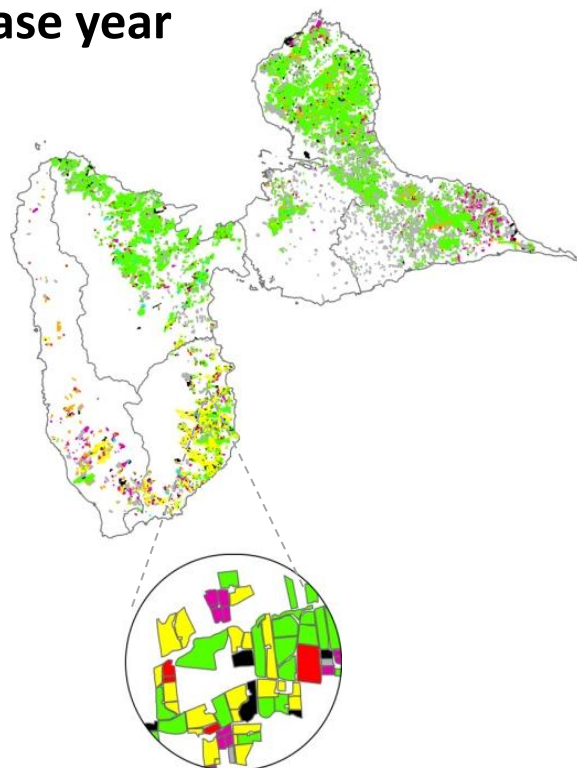


Base year

« CAP 2003 »



 Pedoclimatic areas



Dimensions	Indicators	Base year	Area reallocation
Economy	Agricultural added value (M€.y ⁻¹)	96	138
	Total amount of subsidies (M€.yr ⁻¹)	75	60
Social	Total needs of workforce (persons)	3105	2566
	Area of risk of contamination of food crops	1170	2013
Environment	Ratio of water catchments potentially polluted	30%	12%
	Amount of water needed for irrigation	17.7	14.7

Scenario 2: Building a sustainable agricultural land system

- Mix of scenarios to select relevant levers:

- Optimized scenarios
- Exploratory
- Normative

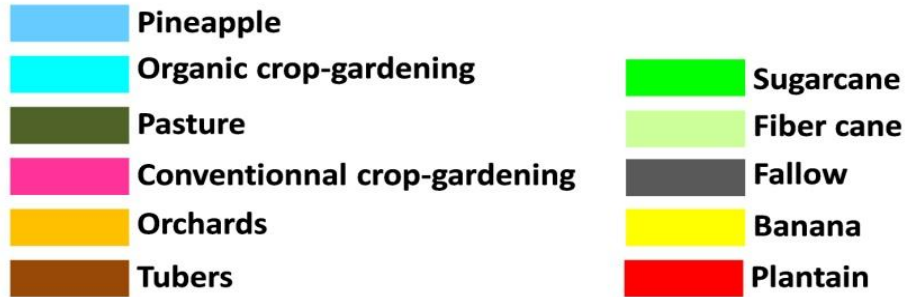
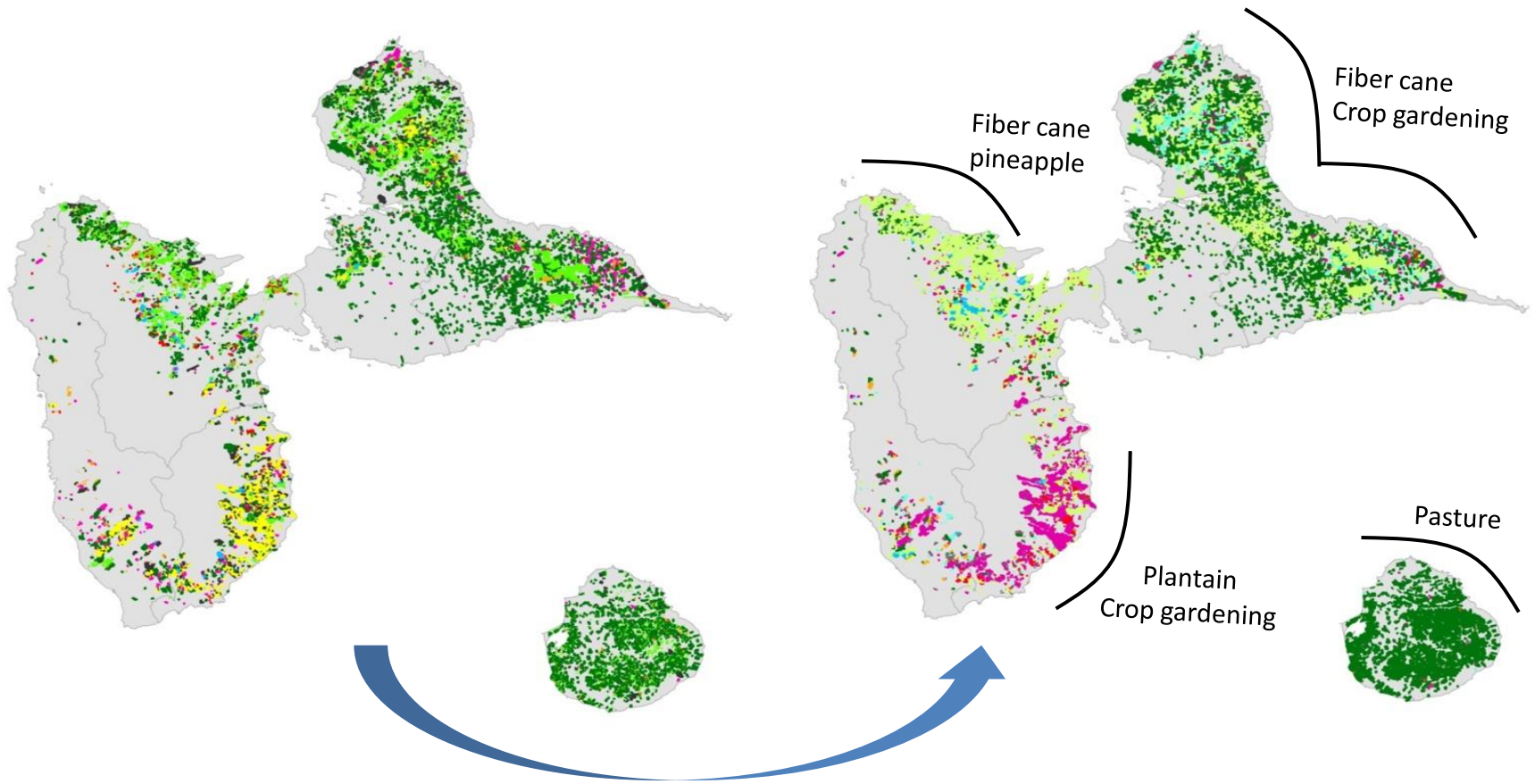
=> When levers help reach a target objective, have an overall positive impact on the contribution of agriculture to sustainable development => ***selected***

- 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 at regional scale)

Current situation in 2010

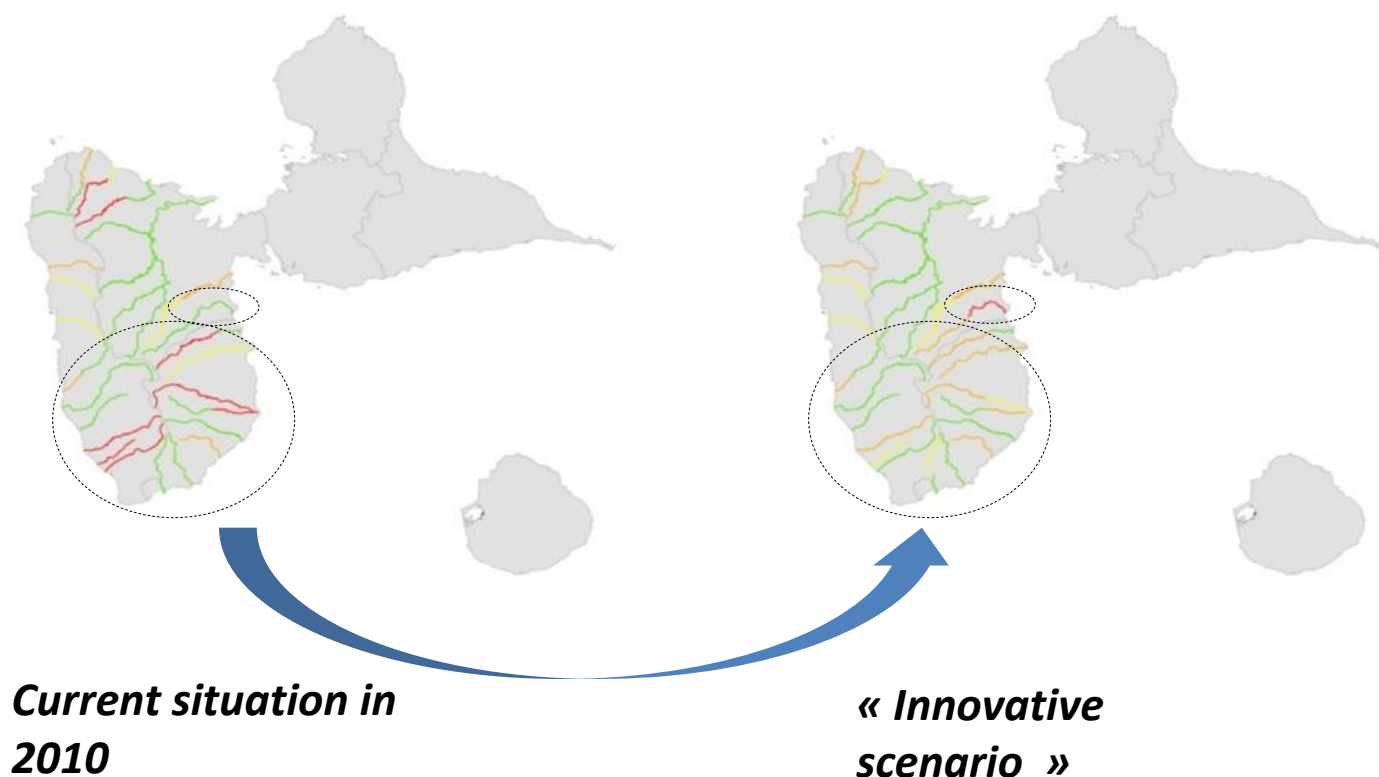
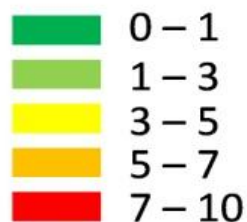
Innovative scenario



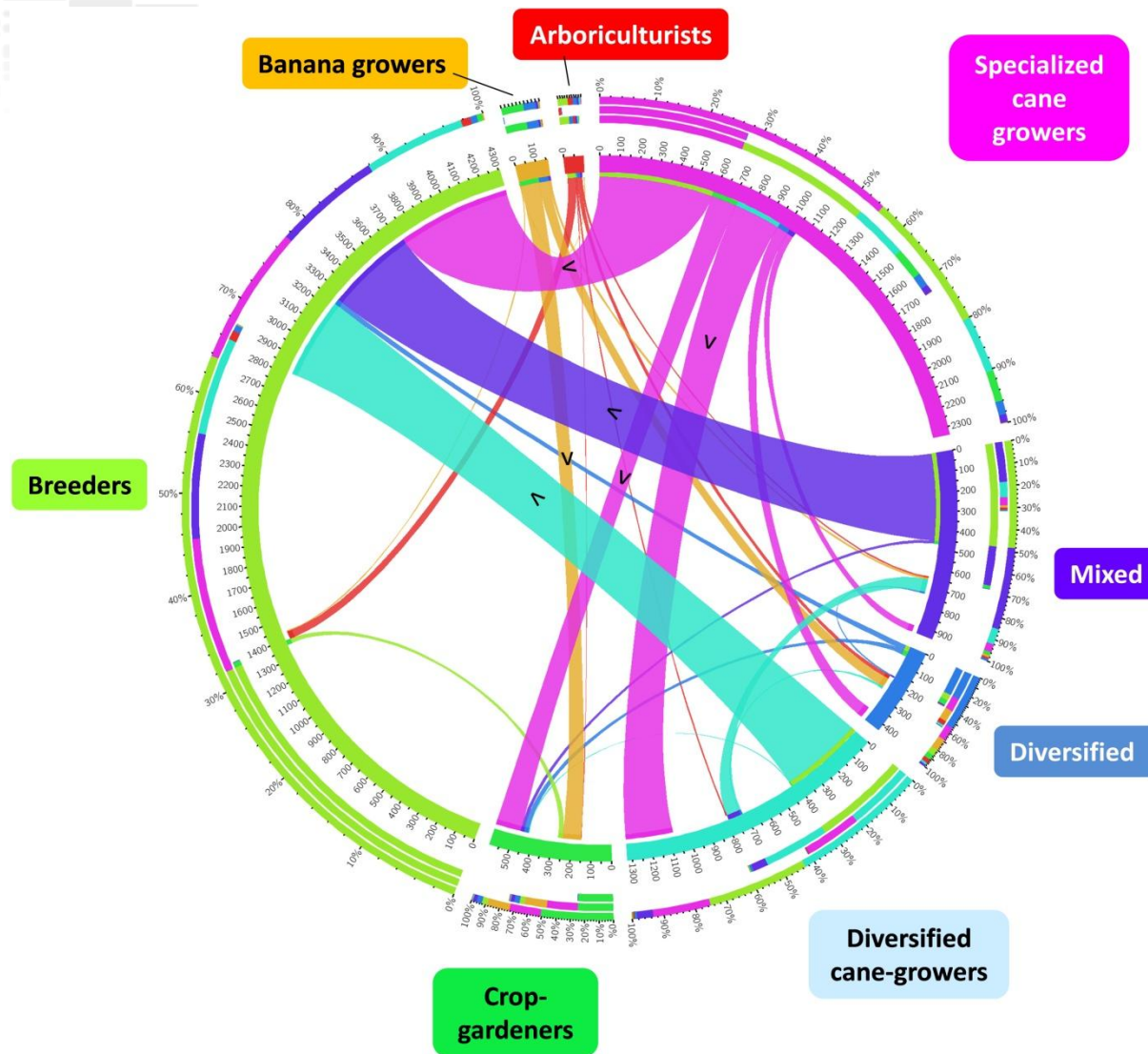
Scenario 2: Spatial variation of the response to « the decrease of the risk of pollution in rivers » issue

Risk of pollution in rivers

1: low
10: very high



Scenario 2: Farming system changes with the « innovative » scenario



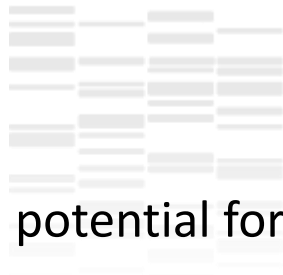


Discussion



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
 - Farmers' 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
 - e.g. Analytical research on climate on crop diseases, yield variability,...)
- 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 !