A modeling framework for designing innovative sustainable agricultural land systems: application to Guadeloupe

Pierre Chopin, Jean-Marc Blazy, Loic Guinde, Thierry Doré

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Application to Guadeloupe

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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…

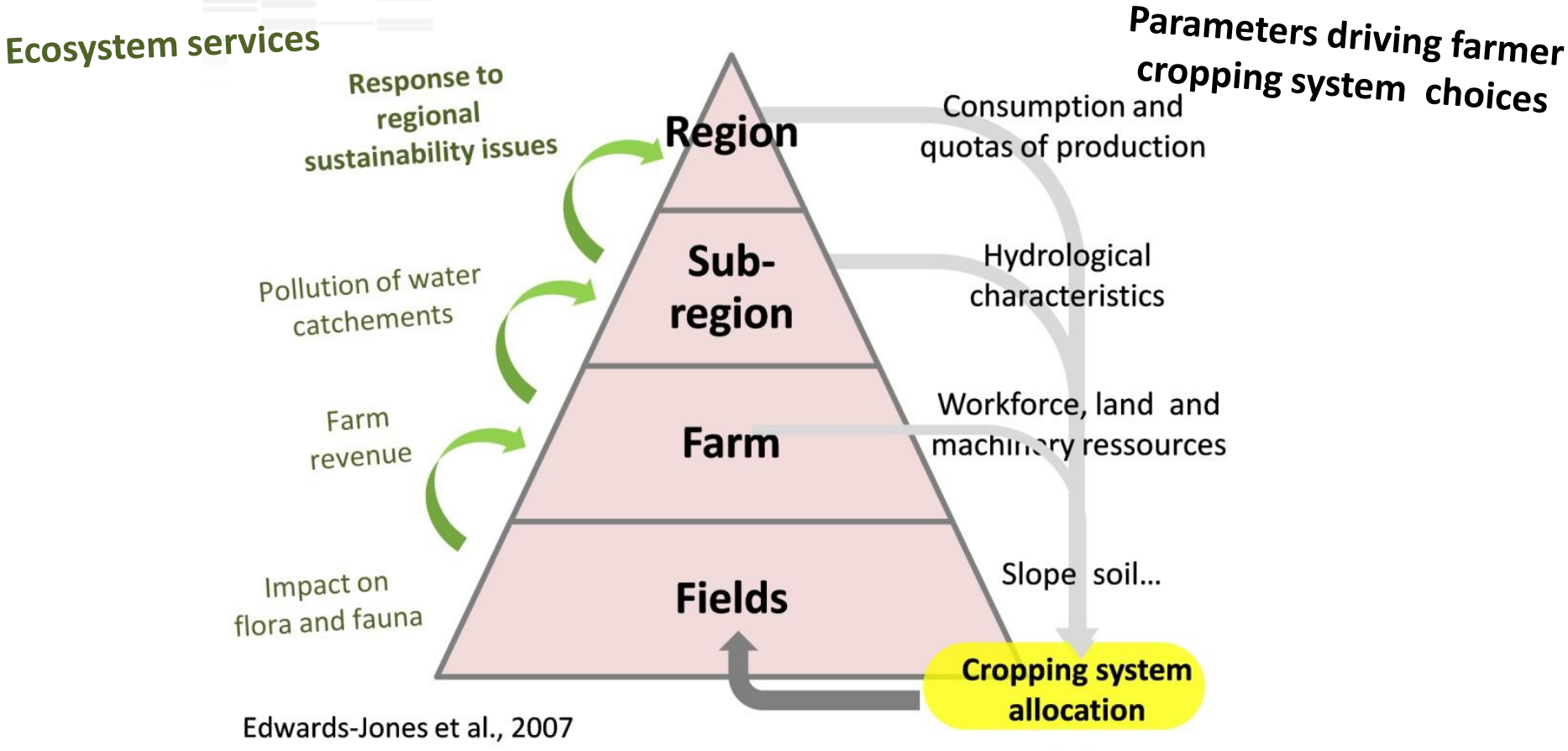
Limits in adressing global and local sustainability issues

⇒**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



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

Objectives of the study

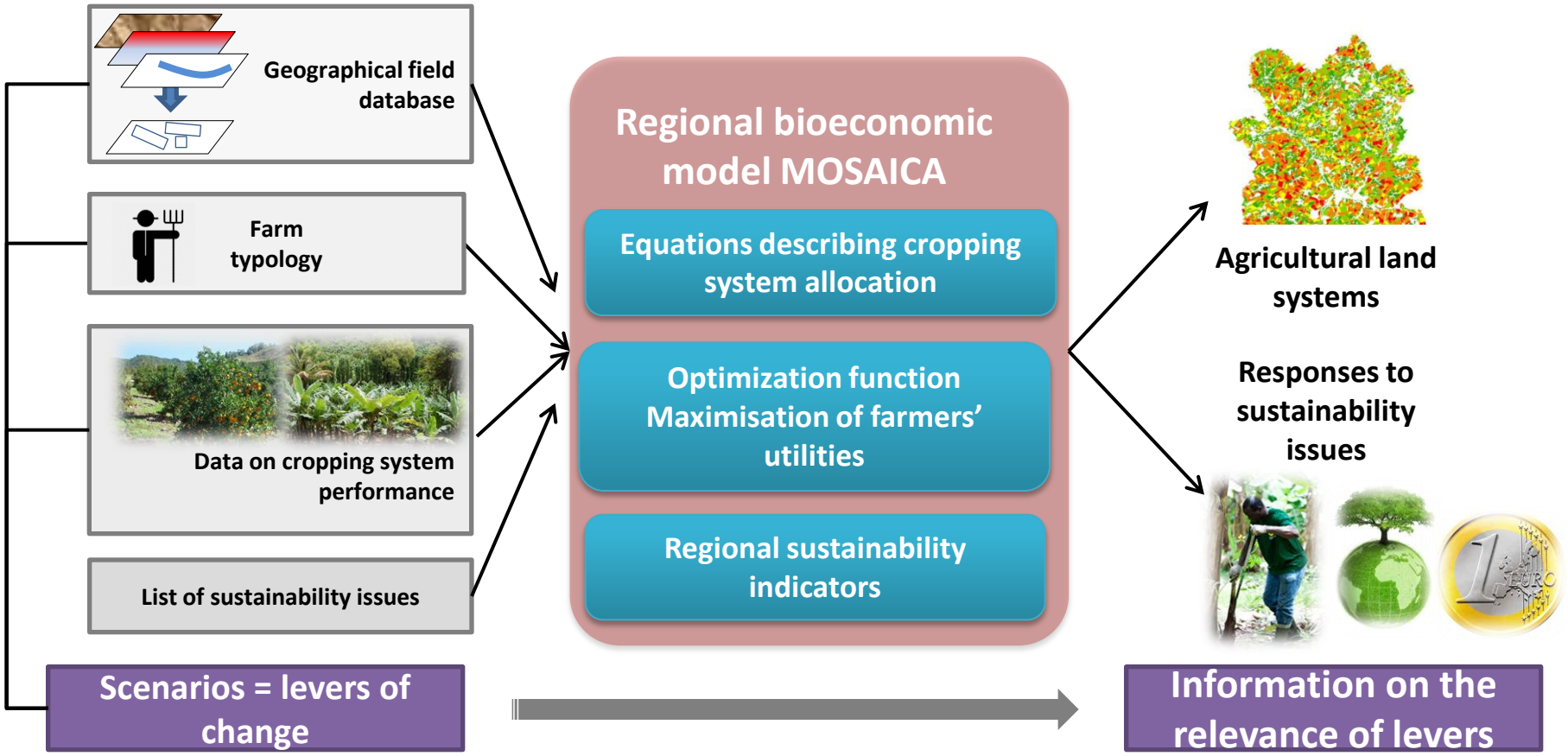
- Designing sustainable agricultural land systems at the regional scale accounting for parameters at field, farm and regional scales ***(scale integration)***

- Assessing the response of these agricultural land systems to sustainability issues by taking into account the location of cropping systems

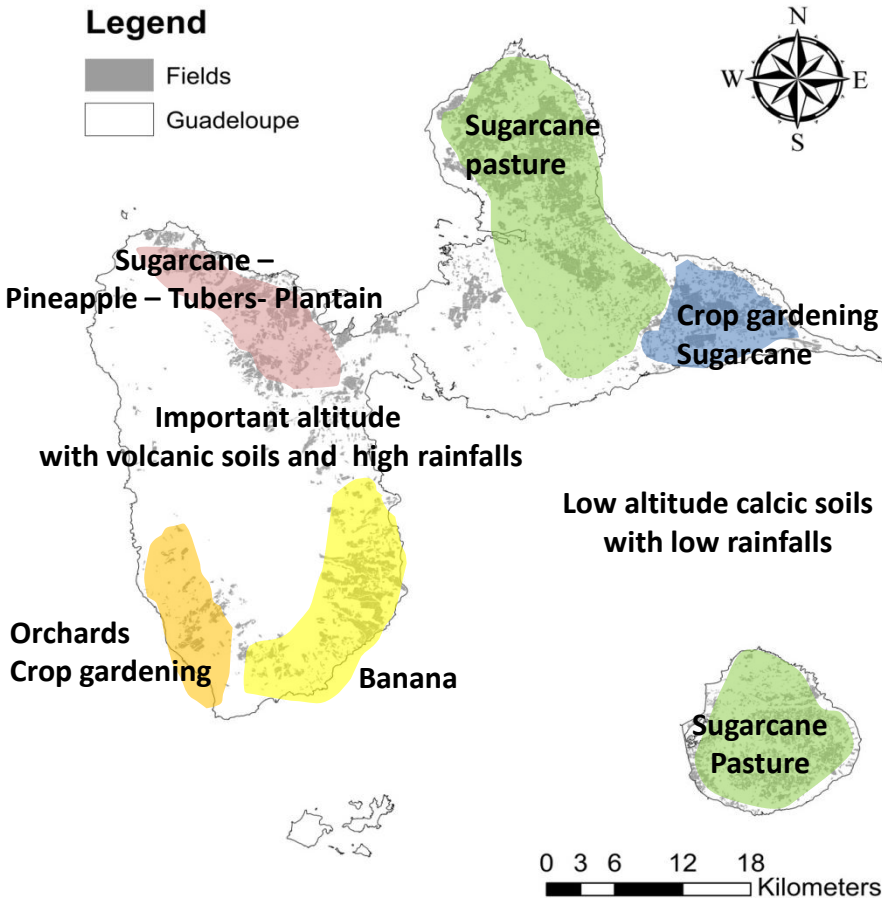
  (spatially explicit approach)

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)

<u>Sustainability issues</u>

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

Method: Typology

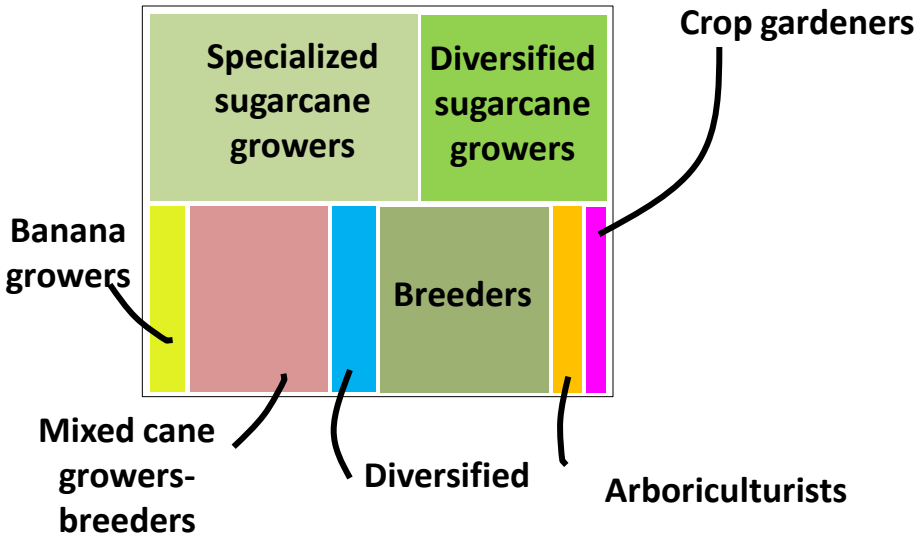
Farm typology:

=> 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 additionnal information from census data



Chopin et al., 2015. (Agronomy for sustainable development)

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

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

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 contraints:

$$\sum_p \sum_a \left(X_{a,p}\, W_a \right) \leq \sum_p \left(Xinit_{a,p}\, W_a \right)$$

Workforce demand

Current farm workforce

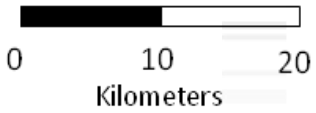
Results

Scenario 1: Change of subsidy regime in Guadeloupe

- Current:
  - Subsidies coupled to production
  - Agri-environmental payments

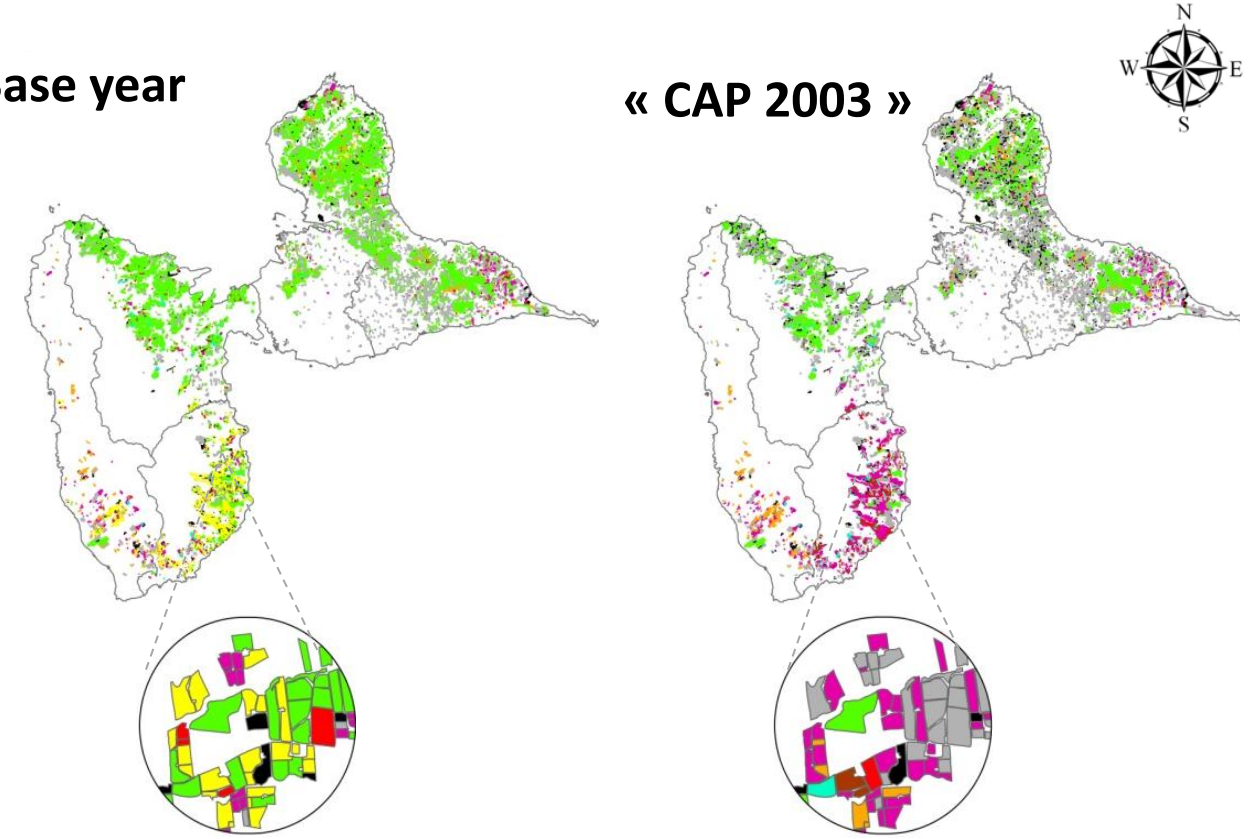
- Scenario : Common Agricultural Policy (CAP) 2003
  - Decoupling of subsidies from production

  => Payment of 1500€ per ha per yr
  - Maintaining of agri-environmental payments



Base year

« CAP 2003 »



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

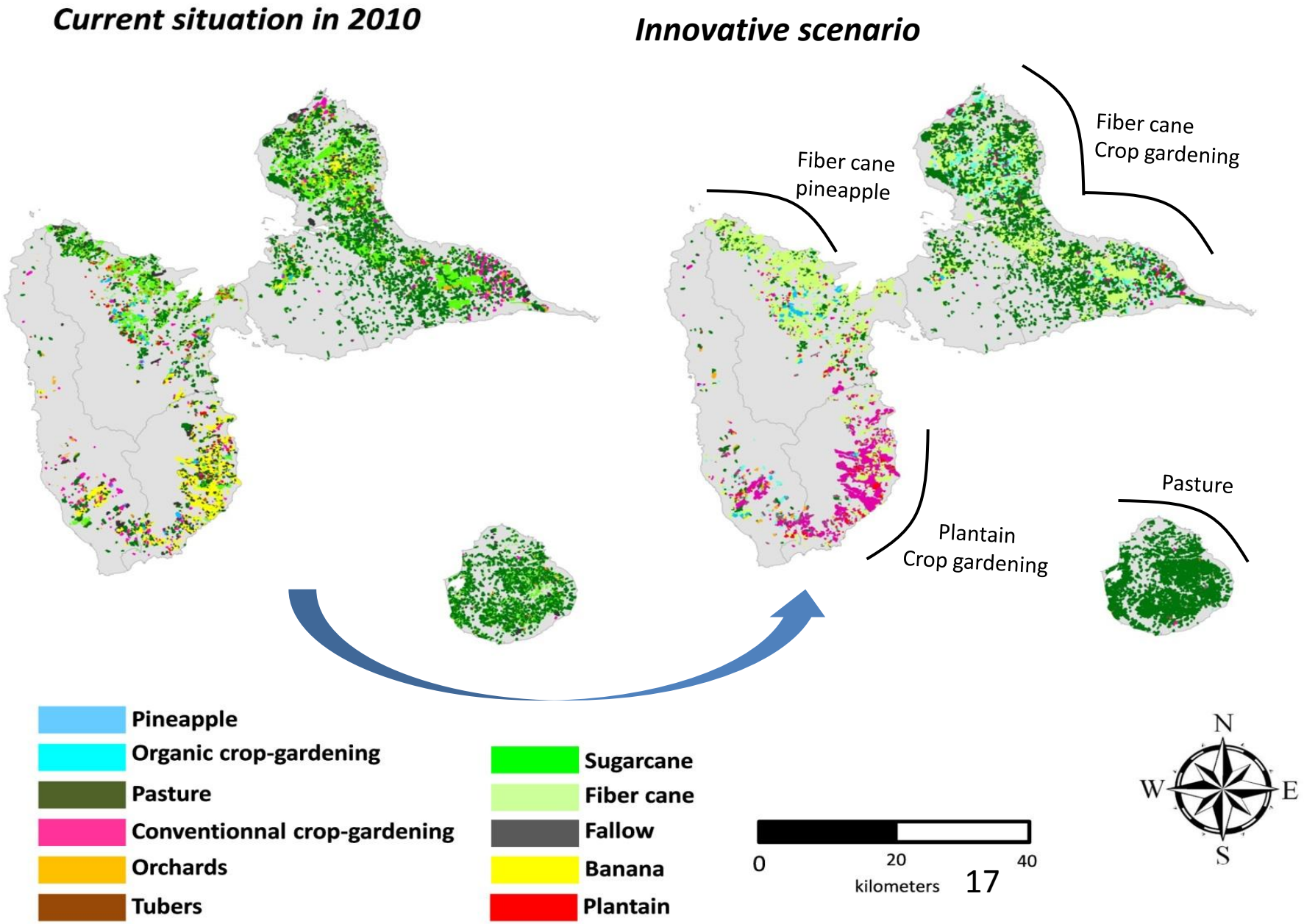
Dimensions	Indicators	Base year	Area reallocation
Economy	Agricultural added value (M€.y^{-1})	96	138
	Total amount of subsidies (M€.yr^{-1})	75	60
Social	Total needs of workforce (persons)	3105	2566
	Area of risk of contamination of food crops	1170	2013
Environment	Ratio of water catchments potentially 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
Fiber cane
pineapple
Fiber cane
Crop gardening
Plantain
Crop gardening
Pasture
Pineapple
Organic crop-gardening
Pasture
Conventionnal crop-gardening
Orchards
Tubers
Sugarcane
Fiber cane
Fallow
Banana
Plantain
0
20
40
kilometers
N
W
E
S

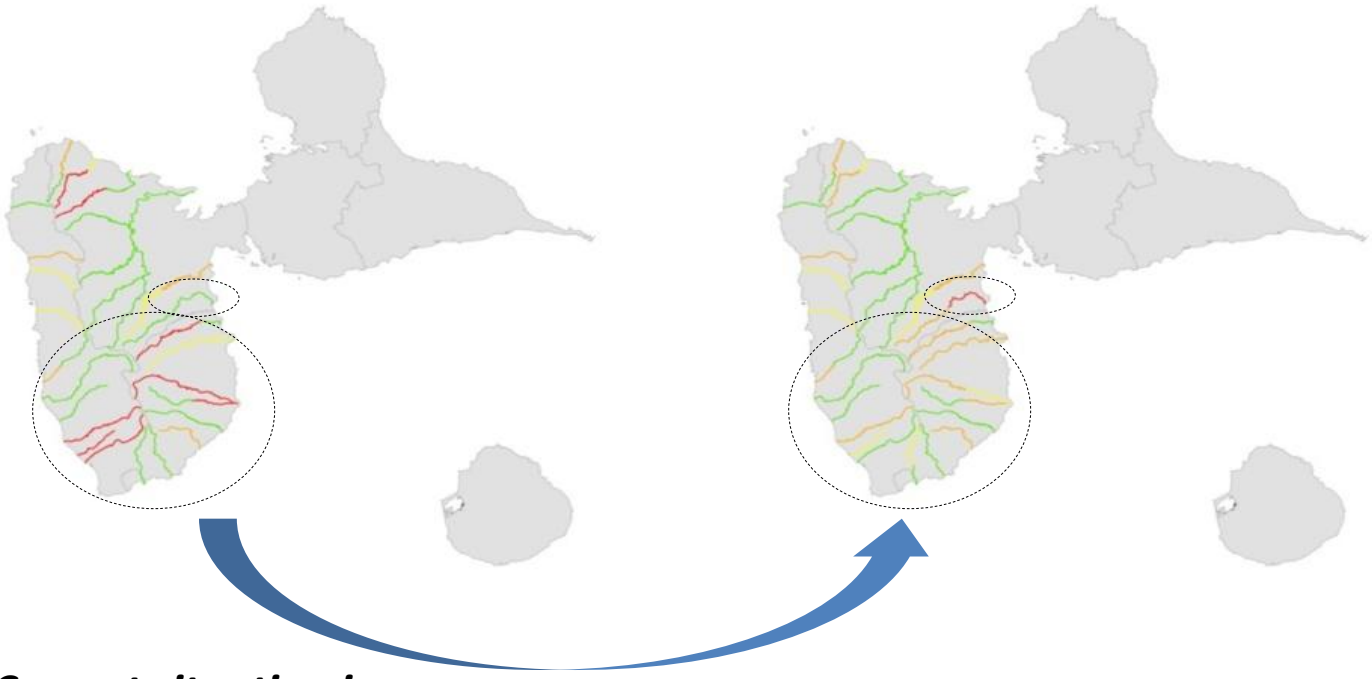
Scenario 2: Spatial variation of the response to « the decrease of the risk of pollution in rivers » issue

Risk of pollution in rivers

1: low

10: very high

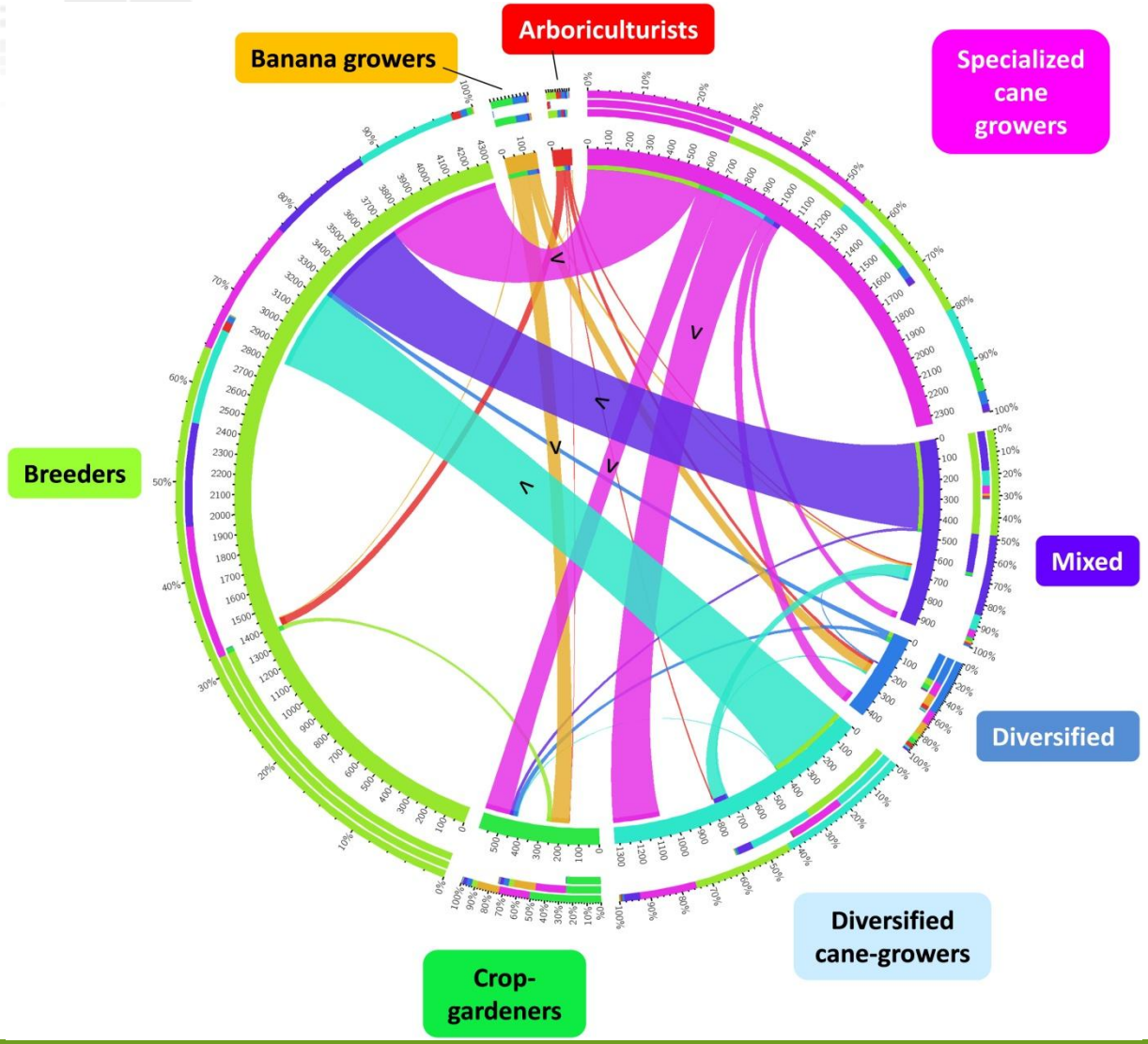
0 – 1
1 – 3
3 – 5
5 – 7
7 – 10



Current situation in 2010

« Innovative scenario »

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



Discussion

Discussion:

- Modeling approache 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 deseases, 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 !