A modeling framework for designing and assessing multi-functional agricultural landscapes with scenario analysis

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

A MODELING FRAMEWORK FOR DESIGNING AND ASSESSING MULTI-FUNCTIONAL AGRICULTURAL LANDSCAPES WITH SCENARIO ANALYSIS

Pierre Chopin [*±1], **Jean-Marc Blazy** [1], **Loïc Guindé** [1], **Jacques Wery**[2] & **Thierry Doré** [3,4]

[1] INRA, UR1321 ASTRO Agrosystèmes Tropicaux, F-97170 Petit-Bourg (Guadeloupe), France
[2] Montpellier Sup Agro UMR System 2 place Viala, 24060 Montpellier, France
[3] AgroParisTech, UMR 211 Agronomie, F-78850 Thiverval-Grignon, France
[4] INRA, UMR 211 Agronomie, F-78850 Thiverval-Grignon, France

* Speaker
± Corresponding author: (pierre.chopin@antilles.inra.fr)

1 Introduction

In order to insure the provision of food and services by agriculture while limiting its negative impacts, innovative agricultural systems have to be designed. The design of such systems has shown some limits in addressing regional and global issues. For instance, at the field scale, some cropping systems may fail to reach the objectives defined at the regional scale due to the low scaling integration and the spatial heterogeneity in the region. Model-based prototyping of agricultural landscapes can allow the impact assessment at regional level of drivers that act at field, farm and regional levels. In order to ascertain whether a combination of levers can drive agriculture towards sustainability, we designed a modeling framework, to explore successive steps of scenario development and assessment with indicators. To this end we introduce an approach based on several types of scenarios.

2 Materials and Methods

The method is built to i) understand the potential levels of sustainability that can be reached by the cropping system mosaics and ii) gain knowledge on the potential levers of change of the cropping system mosaics (Fig. 1). The framework guides the assessment of the consequences of several types of scenario, with a regional bioeconomic model, on the organization of cropping systems. Indicators are used to assess the cropping systems externalities at regional scale. An iterative approach is presented to guide the use of the model with different phases (Fig. 1): scenarios are built in a pre-modeling phase; they are implemented in a modeling phase for visualizing their consequences on the cropping system mosaics; the post-modeling phase assesses the contribution of the cropping system mosaics to sustainable development.

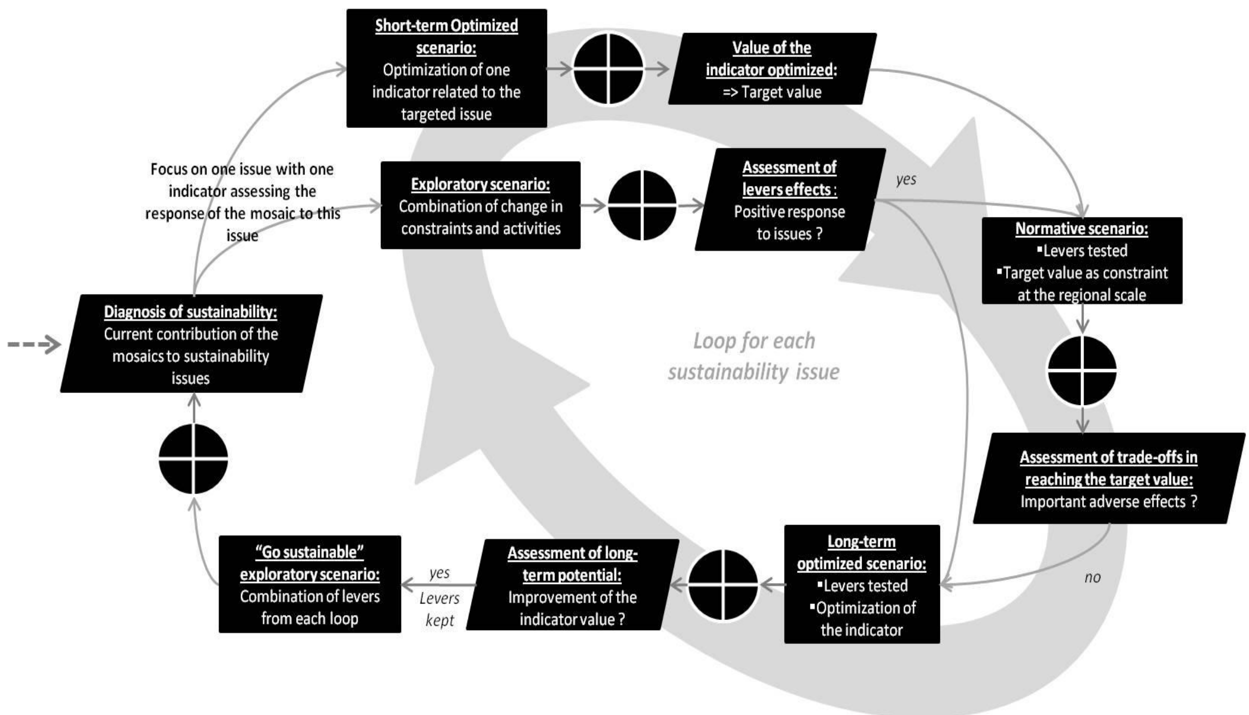

Fig.1. The modelling framework for building sustainable agricultural landscapes

We built our framework around the MOSAICA regional bioeconomic model (Chopin et al., *submitted*). MOSAICA optimizes the overall farmer's utilities by allocating cropping systems to their spatially located plots. The allocation process of cropping systems to plots, recorded in a geographical database, is driven by several types of constraints or objectives implemented at different spatial scales among which biophysical, economic, structure constraints at field, farm, sub-regional or regional scales. The optimization of farmer's utilities or other variables of the system produce new agricultural landscapes that are assessed with a set of sustainability indicators.
In our framework, the MOSAICA model is used with four different types of scenario for prototyping agricultural landscapes for one specific goal (such as energy self-sufficiency). First, short-term optimized scenario provides a target value by optimizing one given sustainability indicator (e.g. the production of biomass for electricity). Secondly, an exploratory scenario combines several types of levers (economic, agronomic...) to reach the target value defined before (the overall farmer’s revenue is maximized). Thirdly, normative scenario is introduced to assess whether or not the target can be reached with the levers from the exploratory scenario. Fourthly, a long-term optimized scenario is parameterized to assess the relevance of levers to improve the long-term potential of the system (by optimizing the production of biomass with the levers selected). The levers that improve the state of the system for each objective, (increase food production, employment...) are selected and combined in a last exploratory scenario called "Go sustainable" scenario to improve the overall response of agricultural landscapes to sustainable development.

3 Results - Discussion

Table 1. Results for the energy self-sufficiency objective with the different type of scenario

			Type of scenarios			
Sustainability objective	Indicator	Initial	**Short-term optimized**	**Exploratory**	**Normative**	**Long-term optimized**
Energy self-sufficiency	Potential production of electricity (MW)	30	52	56	56	93

We here present some results from the use of the framework in Guadeloupe, a French archipelago in the Caribbean for the energy self-sufficiency objective (Chopin et al., *to be submitted*). The levers tested are the decrease of subsidies for sugar, the setting up of a biomass industry for electricity production and the addition of a crop energy activity for farmers. The response to the sustainability objective increases with levers (Table 1) that help achieve the objective of producing 56MW.yr^{-1} and also improve the potential of response of the landscape in long-term scenario to 93MW.yr^{-1}.

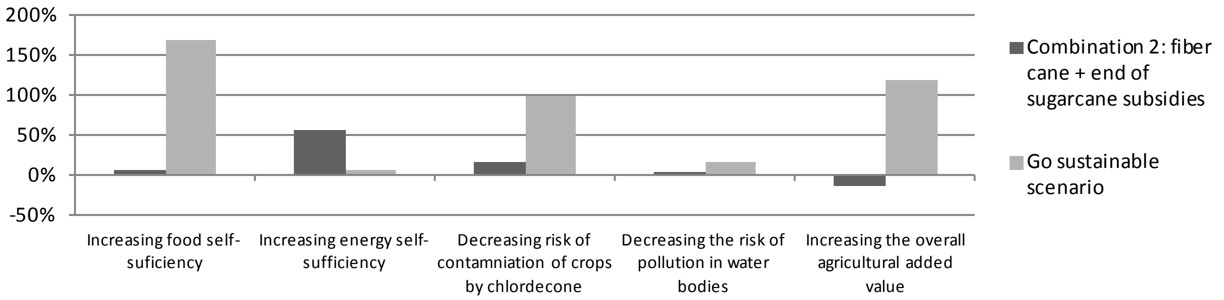

Fig. 2. Evolution of responses to sustainable issues compared to the initial situation

The "Go sustainable scenario" which combines all the relevant levers selected for each of the five objectives improves the system by increasing its contribution to each objective selected (Fig. 2). For instance, the response of the food self-sufficiency objective increased by 150% and the overall agricultural value doubled compared to the initial landscape due to the development of crop-gardening, in the south of Guadeloupe, and energy crops within the entire region.

4 Conclusions

The modeling framework guides the use of the regional model could be used in other regions to help identify the most appropriate levers to increase the response of agriculture to sustainable development. This holistic approach provides analysis of changes that occur at the regional, the farm and the field scale, and can highlight the evolution of externalities of cropping system mosaics in a quantitative and spatially explicit way.

References

Chopin, P., Blazy, J;-M., Guindé, Loïc., Doré, T. MOSAICA: a multi-scale bioeconomic model for the design and ex ante assessment of cropping system mosaics. Submitted to Agricultural Systems.
Chopin, P., Blazy, J;-M., Guindé, Loïc., Wery, J., Doré, T. Designing multi-functional landscapes in agricultural regions: Application to the Guadeloupe Island. To be submitted to Global Environmental Change.