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Integrated modeling of transition scenarios towards climate-smart agriculture based on agro-ecology and territorial bio-economy.

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1 – Introduction

The emerging concept of climate-smart agriculture aims to provide an integrated approach of agriculture to address the triple challenge of food security, adaptation of agricultural systems and climate change mitigation (Lipper et al., 2014). If agro-ecology and territorial bioeconomy are levers advocated to achieve these objectives, the transition to such systems is hampered by socio-economic barriers to their adoption, which express at the farm and territory levels. Most of the research on climate change mitigation via soils has often focused on field-scale actions, without considering possible synergies and antagonisms with other farm and regional-scale issues. Few agricultural systems design methods are available to develop transition scenarios that explicitly consider interactions between spatial scales. To develop scenarios combining agronomic innovations at the field scale and economic levers at the regional scale, we propose an approach combining prototyping and regional bioeconomic modeling. In this paper, we present this approach and its application to the design of climate-smart market gardening in Guadeloupe.

2 – Materials and methods

The methodological framework follows the one proposed by Blazy et al. (2015) and is made of three steps (Fig. 1). First the territorial diagnosis consists in a farm survey and a census of residual biomasses available within the territory. The farmers were interviewed to characterize their current crop management systems and technical and economic performance (step 1). The analysis of the residual biomasses available serves to define several agro-ecological prototypes of innovative crop management systems based on organic inputs obtained from biomasses recycling. In the second step, we experimented prototypes mixing tomatoes and lettuce based on agro-ecological principles: use of local species, minimum tillage, biocontrol, use of organic inputs like mulch, composts and biopesticides. Their experimentation in station made it possible to identify the best combinations of practices and to evaluate their technico-economic performances (step 2). To evaluate the adoption potential of the best prototypes and transition scenarios at regional scale, we used the MOSAICA bioeconomic model (Chopin et al., 2015) and the results of steps 1 and 2 to calculate technico-economic coefficients to parameterize the



model. Then we simulated transition scenarios including socio-economic levers such as the technical improvement of cropping systems, the training of farmers, the creation of eco-markets, and the redesign of public policies (step 3).

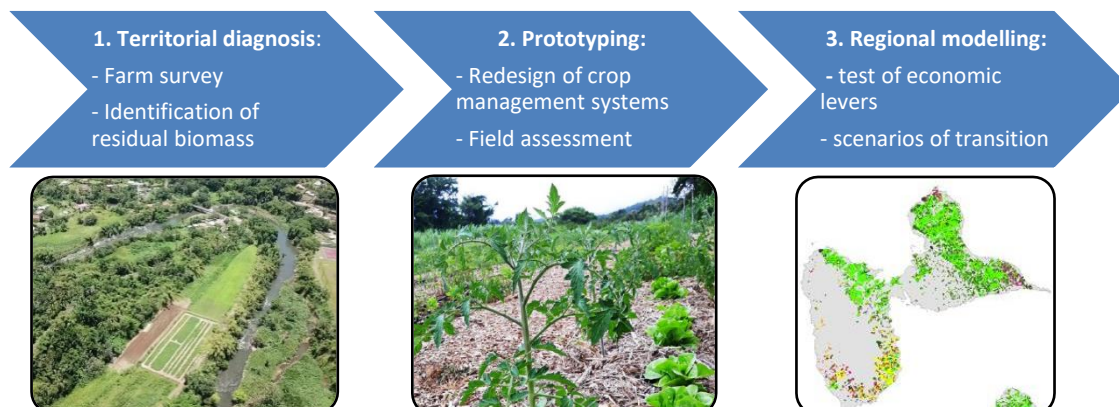


Figure 1. The three steps of the method for integrated design of agricultural systems.

3 – Results – Discussion

The experiment evaluated the agronomic and economic performance of 24 prototypes and statistical analysis identified the factors with most significant effects (Table 1). For both crops, mulching with bagasse allows for better yields. For tomatoes, all composts can improve yield. However, yields and economic results obtained for best performing prototypes remain lower than those of conventional systems do. This can be explained by low availability of nutrients and motivate the need for transition levers.

	Compost			Mulching		Interaction compost*mulch		
	Biogwa (B)	FertigwaB (F)	Vegegwa (V)	WPC	Bagasse	WPC*B	BAG*B	WPC*V
Lettuce	NS	NS	NS	NS	+	+	NS	NS
Tomato	+	+	+	NS	+	-	-	-

Table 1. Summary of significant results ($P < 5\%$) on yield of tomato and lettuce compared to the reference (no mulching, no compost, no irrigation). NS: not significant; WPC: wood paletts chips; Biogwa, FertigwaF and Vegegwa are three industrial composts of Guadeloupe.

Creating organic inputs rich in bioavailable nutrients from the residual biomass of the territory should be a priority area of research. The most promising results are obtained by combining the use of mulches and composts with an advantage for bagasse mulching and Biogwa and FertigwaB composts. We have not demonstrated a significant effect of irrigation, which can be explained by the beneficial effect of mulching, and confirms the interest of this practice in terms of adaptation to climate change in dry areas. The configuration of the plot in permanent cropping planks makes the work and the circulation easy and practical, however the time of work for the spreading of the biomasses, which has been realized manually, is high. Mechanizing these operations could significantly increase the profitability of the innovative systems. The association with lettuce is

promising to compensate for the inferiority of the yields obtained on tomato. The experimental results were used as the basis for the construction of territory-wide transition scenarios that were evaluated with the MOSAICA model. The best scenario combines 5 levers: 1) the best prototype of cropping system, 2) a mechanization of the spreading operations that allows to reduce by 10% the time of work, 3) an ecolabel that allows an increase in the price of sale of 50% in the market, 4) an agro-environmental and climate subsidy of 2600 €/ha/year, 5) a technical training of farmers which reduces by 20% their risk aversion. This scenario lead to substantial modifications in the agricultural landscape, with a doubling of market gardening areas, which would be fully converted into climate-smart systems. In terms of contribution of this scenario to the sustainable development of the territory, this scenario contributes to reducing the average GHG emissions of the agricultural sector by 26%, increasing farmers' incomes by 19% and decreasing by 10% the uses of pesticides and 9% the amount of mineral nitrogen used. These results make it possible to argue the positive impacts of such systems at the scale of the territory and thus justify a remuneration for the ecosystem services they provide.

4 – Conclusions

Through an integrated approach of farming system design, we developed prototypes of market gardening systems and identified scenarios to promote their adoption across the territory. The coherent arrangement of levers that relate to the technical improvement of cropping systems, the training of farmers, the creation of eco-markets, and the redesign of public policies, may be relevant for the transition to climate-smart systems based on agro-ecology and bioeconomy. To go further, we will continue to improve the prototypes and experiment on more sites and seasons, as well as co-build transition scenarios with stakeholders. The research priorities in this science front are scaling up agronomic innovations, taking into account spatial heterogeneity, systemic experimentation and the coupling of biotechnical and economic models operating at different spatial scales.

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