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A VIABILITY MODEL OF FARMING SYSTEMS, THE CASE OF FRENCH WEST INDIES

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Abstract

One the aims of the multidisciplinary research project Gaia-Trop on viability and adaptive management of small tropical islands agro-systems, was to devise a new model of farm system using tools of the mathematical viability theory. It has been constructed in close cooperation with French West Indies farmers to take into account their needs and expectations. The main emerging points focused on soil degradation, pest disease and climatic risks and economic constraints. A specific software is being developed for the viability calculus that will be made available for this community. We present first insights of this model and results obtained for only one parcel and without taking uncertainties at this stage. It highlights that the objective of restoring the soil quality in the long term can be unstainable for farmers facing with financial constraints. The issue of sharing the costs of the agro-ecological transition must be asked.

Introduction

Farm modeling has a long history from a mainly microeconomic approaches to maximize an agricultural income to bio-economic models that take into account the functioning of various biological processes or probabilistic models and simulation-based approaches to get a grasp of the market or production uncertainties. Nowadays agriculture is required to provide income and food security, to preserve environmental resources and cultural identities while being able to adapt to climatic change or to abet its mitigation. The aim of the Gaia-Trop project was to propose a new modeling approach relying on viability theory. It focused on soil preservation, a main problem in French West Indies confronted with a limited space for agricultural lands along with a growing population and soil degradation due to past practices of banana export sector. Other concerns was to take into account the agronomic constraints and traditional habits as well as economic profitability in order for the results to be appropriated by the farmers.

Materials and methods

Viability theory is a set valued mathematical analysis designed for the control of dynamical systems with constraints and submitted to uncertainties (Aubin et al., 2011). Unlike the usual approaches based on simulations techniques, viability theory relies on an inverse approach allowing to know the set of all the current states variables for which there exist controls such that the evolution of the state variables governed by these controls always comply with a set of constraints. The main mathematical and computational challenge has been to handle the various agro-ecological, economic and cultural dimensions of farming systems with a limited number of state variables. Soil functioning and its interactions with agricultural practices are highly complex. We then used a synthetic global indicator of soil quality (GlSQ, Velasquez et al., 2007) which is modified by each agricultural cycle. Impacts of various crops or cattle and agricultural practices on the value of the GISQ indicator are data provided upstream by expert knowledge. The model allows to say if it is exists, or not, some sequences of crops or livestock and agricultural practices such that a low soil quality parcel can be brought to a higher wished quality in a given period of time while complying agronomic and economic constraints. Calculus have been done with a set of crops, livestock and agricultural practices: intensive agriculture with high level of inputs (fertilizers, pesticides, enclosed breeding …) or reasoned agriculture with limited plant treatments. They are representative of main French West Indies agricultural productions, have different sowing seasons and cycle durations that span over months or years. The number of agricultural productions and practices is not limited except by the high amount of agronomic and economic data to document and a higher time of computation. The yields and therefore the economic returns, depend on soil quality while the evolution of soil quality depends in turn on crops and practices successively implemented. The farm strategies and the various decisions made successively at different times on a parcel determine the evolution of the farmer's global income and the evolution of the soil quality of the parcel. Farmers are not equal and have not the same freedom to choose their activity. Some of them rely on unpaid family workforce while other resort to salaried workers, some of them are limited by loans to repay while other, less financially restricted, can invest in more profitable productions. To take account these different situations, we introduced in the model a monthly economic constraint that can be adjusted to represent various configurations. When "viable strategies" exist, we computed the best economic performance that can be obtained on the whole period and provided the associated optimal farm management that must be followed.

Main results

Computations have been realized with test data obtained from surveys of farmers and expert knowledge. Due to the huge number of data to collect, only eight crops have been documented so far: plantain banana, tomato, eggplant, lettuce, cabbage, bean, capsicum, yam along with conventional and reasoned practice, as well as cow and goat breeding, long fallow for land resting and short fallow for the matching between two agricultural seasons. The spanning exercise has been set to forty years, roughly a farmer's active life, with the objective to assess the possibilities to transmit the next generation a soil with GISQ value fixed to 0.9 whatever is the initial soil quality. Computations have been made for the case of salaried workforce only and for two situations of financial capacity: with an economic constraint impeding any monthly deficit on all the period and without any economic constraint. Starting from a parcel with a low GISQ value fixed to 0.2, a comparison of the optimal farm management for these two cases shows striking differences. Without economic constraints, the optimal strategy providing the best economic performance is to restore the soil quality as quickly as possible right from the beginning of the exploitation by a 12 years period of fallow and then by a rotation of the more profitable production with short fallow. The optimal strategy of a farmer unable to sustain such preliminary investment, will be to improve the soil quality to the target level in the last few years after having cumulated some earnings through a sequence of productions and practices not degrading the soil but with a low return. The gap between the expected best economic performances is huge. The cumulated income on 40 years of a farmer willing to restore the soil quality but confronted with financial constraints, is extremely low. Sharing the cost of agro-ecological transition is then a question that must be raised.

Conclusions

These first results, obtained with a limited set of test data, show the main principles and interest of this viability model. Ongoing development focuses on the collection of additional agricultural productions and practices with accurate economic and agronomic data, to represent the high diversity of agricultural products and practices in French West Indies, including agro-ecological practices, various forms of labor compensation, level of economic constraint and of subsidies. Multi-parcel farm management, price and yields uncertainties will be handled in a second step.

Figures

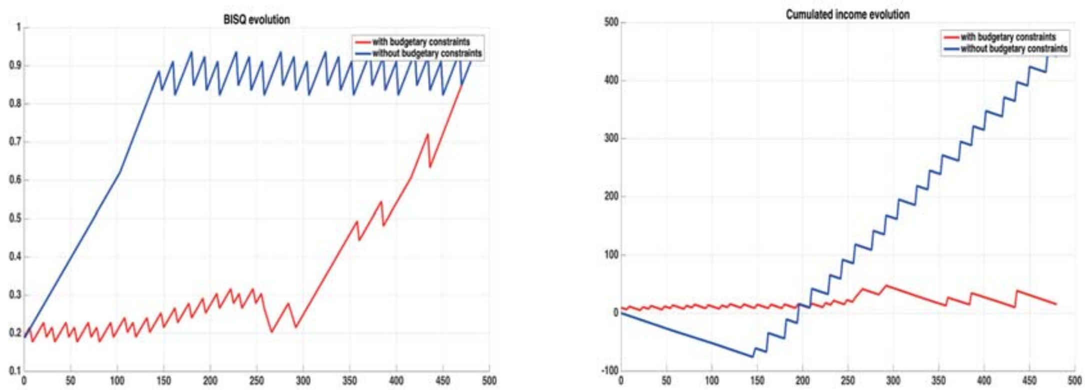

Figure 1. GISQ evolution (left) and cumulated net income evolution (right) for the optimal strategy, with (red) and without (blue) economic constraints (I_0=0,2; I*=0,9; calculus made for a 40 years period)

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