SUSTAINABLE FUTURES FOR VEGETABLE FAMILY FARMERS IN URUGUAY: A MODEL-BASED EXPLORATION

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INTRODUCTION

In a context of continued decreasing product prices on the internal market and increasing costs of inputs over the past 20 years, vegetable family farms in Uruguay have been intensifying and specializing their production systems, putting more pressure on already deteriorated soils and on limited farm resources. Researchers from the Faculty of Agronomy in Montevideo, later joined by Wageningen University, started a series of learning cycles in order to identify alternative options for vegetable growers in Southern Uruguay. A first extended learning cycle comprised one-year long interactions of many generations of students of the Faculty of Agronomy with farm families that helped developing relations between the farmers and the Faculty. A next cycle was completed by Dogliotti et al. (2005), involving a formal model-based diagnosis of the problems in the farms, and an assessment of alternatives. Existing and potential farming systems for a number of selected farms were evaluated in terms of objectives thought relevant for the farmers, including environmental objectives (soil fertility, exposure to pesticides, nutrients balances) and social-economic objectives (family income, gross margin, labor availability). The results showed great promise for ecological-economic win-win situations if farmers would drastically alter their strategies and base them on wider rotations, fewer crops and use of (green) manure. These results constituted the hypotheses to be tested during a third learning cycle, which was implemented during the EULACIAS[20] project. In this project 16 farms were diagnosed and redesigned in very close interaction with the farm family and the most promising farm strategy was tested in the farmer practice. Positive results were found after 2-3 years of interaction with most farmers.

Next objective was to extend the study and get results not only for the pilot farms but also at regional scale that could inform regional policy, farmer union activities and the research agenda. A regional farm typology was combined with a set of scenarios in a model-based exploration of development options for each of the farm types. Here we describe the approach and present preliminary results of the exploration of options for a real farm belonging to one of the two most abundant farm types. Ultimate goal is to contribute to construction of policies that foster sustainable family farming in Southern Uruguay.

MATERIAL AND METHODS

Study area, farm typology and scenarios

The study area was located in the temperate region of Canelones, South Uruguay, which concentrates more than 50% of the vegetable producers of the country. The main structural problems of horticultural farms in the area are (i) deteriorated soil quality, (ii) high incidence of soil erosion, (iii) limited surfaces of productive areas, (iv) insufficient irrigation water. Availability of off-farm labor is becoming a problem in the region and experts predict that it will be increasingly scarce and expensive. Seven representative types of vegetable production farms were identified in the region using a

[20] EU FP6-2004-INCO-dev-3; contract nr 032387 ; http://www.eulacias.org/

quantitative typology method based on cluster analysis, multidimensional scaling and similarity percentages analysis (Righi et al., 2009). The types differed in use of off-farm labor, mechanization endowment and irrigation potential. Three scenarios of major agricultural changes concerning social and economic regional drivers for a time horizon of 10 years were defined by local experts using Delphi methods (Contini et al., 2010): an ‘organic’, a ‘supply chain’ and a ‘conventional’ scenario. Scenarios were associated with optimistic and pessimistic trends in prices of products and inputs, resulting in 6 scenario-trend combinations.

Modeling toolkit

Based on the previous work of Dogliotti et al. (2003, 2004, 2005) a modeling toolkit was developed to explore the effect of scenarios and farm endowment on the design and assessment of new farming systems. This toolkit was divided into two components: (i) one that generates and evaluates production activities *at field level* and (ii) another one that selects combinations of production activities *at farm level* to reveal trade-offs between environmental and social-economic objective functions based on interactive multiple goal linear programming (IMGLP) (Fig. 1). *At field scale*, generation of crop rotations was based on ROTAT (Dogliotti et al., 2003) and rotations were later combined with management levels (e.g. irrigation) to create what are denoted ‘production activities’. Each production activity was then evaluated with sustainability indicators that represent economic (labor requirements, production costs, gross margin) and environmental (nutrient balances, evolution of soil organic matter balance, evolution of erosion[21], exposure to pesticides) considerations. *At farm scale*, an ‘optimal’ combination of production activities was selected with an improved and extended version Farm Images model (Dogliotti et al., 2005), revealing trade-offs among multiple objectives that are subject to internal and external constraints (Fig. 1). Social-economic objective functions at farm-scale were gross margin ($\$U.yr^{-1}$), family income ($\$U.yr^{-1}$), capital requirements ($\$U.yr^{-1}$) and ‘family labor use’ (i.e. ratio of family labor hours used over the total family labor hours available). Environmental objective functions were Environment Exposure to Pesticides (EEP) for soil ($kg\text{-}days.yr^{-1}$), N surplus ($kg.ha^{-1}.yr^{-1}$), erosion ($Mg.ha^{-1}.yr^{-1}$) and soil organic matter (SOM) balance ($kg.\ ha^{-1}.yr^{-1}$).

Case study farm

We studied a farm specialized in vegetable crops, belonging to the largest farm category of the region, characterized by a small area of Typical Argiudoll soil (3.2 ha), a comparatively low supply of irrigation water (1.5 ha) and a low mechanization level. The modeling toolkit was used to explore options for sustainable farming systems for each scenario-trend combination. *At field level,* agronomic criteria for generating rotations were scenario dependant; intercrops were used to improve soil quality. Rotations included irrigated and rain-fed crops according to three levels of irrigation (none, intermediate and high). *At farm level*, for each scenario-trend combination we performed 3 optimization rounds, with different values for constraints, where we optimized the 8 objective functions one by one. For the third round, minimum family labor use was set to 50%, minimum family income was set to the current income of the farm (187000 $U\$.yr^{-1}$) and minimum soil erosion was set respectively to 5, 6.5 and 7 $Mg.ha^{-1}.yr^{-1}$ for ‘supply chain’, ‘organic’ and ‘conventional’ scenarios, to reduce soil erosion compared with current conditions. Results presented below are the selected production activities of the third round when maximizing family income.

RESULTS AND DISCUSSION

Field level Results

At field scale, the ROTAT model generated 2800, 3495 and 9147 rotations for ‘conventional’, ‘organic’ and ‘supply chain’ scenarios, respectively. After applying the three possible levels of irrigation, 5672, 7048 and 19734 productions activities were created for the ‘conventional’, ‘organic’

[21] In this preliminary study, erosion was overestimated by about 14% for rotations including alfalfa because we did not take into account its root biomass in the calculations.

and ‘supply chain’ scenarios, respectively. The higher number of rotations and production activities for the ‘supply chain’ scenario is mainly due to a higher diversity of candidate crops compared to the ‘conventional’ scenario and higher crop frequencies allowed in the rotations compared to the ‘organic’ scenario. Economic indicators (family income and gross margin) always showed higher values for production activities associated with irrigation (either intermediate or high level of irrigation), whatever the scenario and trend studied. Under an optimistic price trend, production activities without irrigation were not reaching gross margin over 70,000 $U.ha^{-1}.yr^{-1}, whatever the scenario while irrigated rotations could reach more than 250,000 $U.ha^{-1}.yr^{-1}.

Farm level Results

At farm scale, either 2 or 3 production activities were found to optimize family income while respecting environmental and farm endowment constraints for each scenario-trend combination (Tab. 1). They were associated either with intermediate or high level of irrigation, which positively contributed to economic performance compared to no irrigation. Moreover, for each scenario tomato was cropped and this crop is related to higher gross margins. Thus, IMGLP selected those production activities which had higher economic performances. In case of ‘organic’ and ‘supply chain’ scenarios, production activities selected and their areas were exactly the same for the two price trends. As a result environmental performances were the same for both trends, while economic performances of pessimistic trend were naturally lower than optimistic trend (Tab. 1). In case of the ‘conventional’ scenario 2 out of 3 selected production activities were the same for both trends. The third production activity differed for one crop from one trend to the other. This showed that whatever the trend, the combination of production activities leading to the best trade-off between environmental and economic performances would be similar for a given scenario.

The extrapolated value of current family income in rural areas of this region for a time horizon of 10 years was estimated to be 328,337 $U yr^{-1}, an increase of 50% compared to the current level. The ‘Conventional’ scenario was the only scenario to reach this value for both trends and was the most desirable scenario in terms of family income (Tab. 1). According to local experts labor price is expected to be 55 $U.hr^{-1} in 10 years. For all scenarios, labor productivity could reach this value but in the ‘organic’ scenario, with a pessimistic price trend, labor productivity was only 66 $U.hr^{-1} (Tab. 1), meaning that 11 $U.hr^{-1} should be enough to cover entrepreneurship of the farmer. The ‘Supply chain’ scenario was the most desirable in terms of labor productivity while requiring low capital compared with ‘conventional’ scenario and involving the lowest erosion rate (Tab.1). Heading towards such a future thus seems to be interesting for the type of specialized vegetable farm studied from an economic-environmental perspective. However, the ‘supply chain’ scenario implies contracts with industry that could be difficult to get. In this study, the ‘organic’ scenario does not seem the most desirable both regarding economic and environmental performances (Tab. 1). Environment exposure to pesticides (EEP) for soil reached high values especially for the ‘organic’ scenario because of the widespread use of mineral pesticides such as Bordeaux mixture (Tab. 1). Moreover the minimum value for EEP set in the optimization process constrained family income for each scenario. In order to increase income we could (i) release the constraint on EEP and accept more environmental impact and/or (ii) develop cropping practices using less mineral pesticides to get lower EEP values at farm scale.

This study offered the opportunity to develop a flexible modeling toolkit that could be usable for other research studies while providing information to farmers and policy makers about sustainable futures in the study region.

REFERENCES

Contini C., Gabbai M., Omodei Zorini L., B. Pugh, 2010. Involving stakeholders in the exploration of sustainability perspectives and innovations of farming systems: a case study from Latin America. Presentation held at the 9th European Symposium of the International Farming Systems Association in Vienna, Austria, 4-7 July 2010.

Dogliotti, S., Rossing, W.A.H., M.K. Van Ittersum, 2003. ROTAT, a tool for systematically generating crop rotations. European Journal of Agronomy 19: 239-250.

Dogliotti, S., Rossing, W.A.H., M.K. Van Ittersum, 2004. Systematic design and evaluation of crop rotations enhancing soil conservation, soil fertility and farm income: a case study for vegetable farms. Agricultural Systems 80: 277-302.

Dogliotti, S., Van Ittersum, M.K., W.A.H. Rossing, 2005. A method for exploring sustainable development options at farm scale: a case study for vegetable farms. Agricultural Systems 86: 29-51.

Righi, E., Pacini G.C., Dogliotti S., Aguerre V., W.A.H. Rossing, 2009. Farm typology identification by multi-variate analysis as a method to scale-up results of integrated impact assessment. Presentation held at the AgSAP Conference in Egmond aan Zee, The Netherlands, 10-12 March 2009.
Wijnands F.G., 1997. Integrated crop protection and environmental exposure to pesticides: methods to reduce use and impact of pesticides in arable farming. European Journal of Agronomy 7: 251-260.

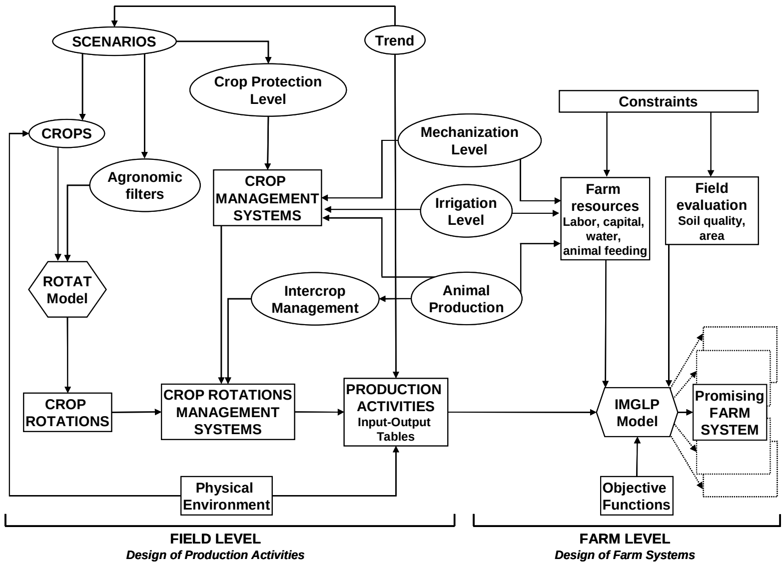

Figure 1. Overview of the modeling toolkit

Table 1. Selected production activities and their economic and environmental performances for the 'organic', 'conventional' and 'supply chain' scenarios.

	Organic		Conventional		Supply chain	
	Optimistic	Pessimistic	Optimistic	Pessimistic	Optimistic	Pessimistic
Number of selected production activities	2	2	3	3	2	2
Rotation length (yr)	7 and 8	7 and 8	6	6	6	6
Number of crops on the farm	9	9	5	5	5	5
Area used (ha)	2.0	2.0	3.2	3.0	3.0	3.0
Irrigated area (ha)	1.2	1.2	1.5	1.5	1.0	1.0
Family income ($\$U.yr^{-1}$)	295,391	191,576	457,421	417,991	290,982	218,109
Capital requirements ($\$U.yr^{-1}$)	193,092	221,755	263,457	302,886	179,312	211,290
Farm production costs ($\$U.yr^{-1}$)	170,897	199,560	198,785	237,379	157,117	189,095
Return to assets ($\$U.yr^{-1}$)[1]	194,408	90,593	190,102	183,088	212,987	140,114
Family labor use (-)	0.7	0.7	0.8	0.8	0.6	0.6
Labor productivity ($\$U.hr^{-1}$)	102	66	95	92	117	88
EEP soil ($kg\text{-}day.yr^{-1}$)[2]	150000	150000	100000	100000	100000	100000
EEP water ($ppm.yr^{-1}$)[2]	894	894	5306	5306	5298	5298
EEP air ($kgAI.ha^{-1}.yr^{-1}$)[2]	0.2	0.2	7.1	7.1	6.7	6.7
N surplus ($kg.ha^{-1}.yr^{-1}$)	46.6	46.6	53.0	53.0	70.4	70.4
Erosion ($Mg.ha^{-1}.yr^{-1}$)	6.5	6.5	7.0	7.0	4.6	4.6
SOM ($kg.ha^{-1}.yr^{-1}$)	744.3	744.3	570.9	570.9	340.2	340.2

[1] Return to assets (land, own capital and management of farm) is defined as the gross margin minus the costs of hired and own labor
[2] Environment exposure to pesticides for soil, water and air refers to the indicators of Wijnands (1997)