A BIO-ECONOMIC MODELING APPROACH TO ASSES THE ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY OF FARMING PRACTICES IN A TUNISIAN WATERSHED.

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Introduction

In agriculture, short-term objectives to increase farm income often conflict with long-term objectives to maintain soil fertility. In semi-arid regions such as Northern Tunisia, deficit irrigation to reduce water use and nitrate leaching may reduce the long-term production potential due to soil salinization. Until now, the impact of water management on nitrate leaching, soil salinization, production potential and economic performance of irrigated farms has not been quantified. This study aims at analyzing the effects of different water and nutrient management on three farm performance indicators, i.e. nitrate leaching, soil salinization and farm income. We use a new analytical bio-economic approach to assess the environmental and economic performance of irrigated farming systems in northern Tunisia (Cebalat region) taking into account inter and intra-annual rainfall variability and different soil types and crop rotations.

Methodological framework

In semi-arid regions with highly variable rainfall, stochastic programming methods are appropriate to study the effect of water and nutrient management practices on farm performance (Li et al., 2005). In this paper, we use a new hybrid methodology based on a recursive stochastic programming method (RSP). In general, a farmer has an expectation regarding the response of the soil-crop system to his/her management decision(s). However, the result of any decision is uncertain because of the partial information at the time of decision-making. The RSP method consists of solving dynamic problems using a series of sequential dynamic optimization sub-models. After the first decision and taking into account the development of the system the farmer can adapt future decision(s) based on newly available information. The recursive stochastic model allows to test the research hypothesis, namely that farmers prefer short-term profit over long-term profit and neglect possible negative effects of soil degradation. In order to assess the sustainability of the system, two different discount rates have been considered: a 10% discount rate (base scenario), reflecting the current situation (farmer's preference for present over future income) and a zero discount rate (sustainable scenario), illustrating a more sustainable scenario (valuing the future as much as the present)."

The modelling approach here combines a linear programming model (LP) of economic farm behaviour with a cropping systems model, consisting of two steps and scales: i) quantification of the relationships between crop production and environmental factors at field level using the Cropping Systems Simulation Model (CropSyst) (Stöckle et al., 2005) for a range of management alternatives taking into account information on previous crops, soil and rainfall characteristics, and ii) application of a recursive-stochastic bio-economic farm model in which farm income is maximized and data of step 1 is used as the set of production activities to select from.

Results

Soil salinization

The rate of soil stalinization is higher in the base scenario. For example, in year 4 the salt content of the soil is 12.6 kg/ha for the base scenario and only 6.2 kg/ha for the sustainable ones due to differences in crop choice and in the amount of water used for irrigation and for salt leaching. In fact, the amount of water used is higher for the scenario of sustainable soil fertility showing that, in this scenario, a portion of water is used not for meeting crop requirements but for soil salinity leaching. This difference reaches 55% for the sequences K20 (dry autumn, wet winter) and K21 (dry autumn and winter). For all crops the amount of irrigation water is higher for the sustainable scenario (Table 1). For oats even 63% more water is used for leaching of salts to sustain the long-term productivity.

Table 1- Comparison of the area and the amount water applied for each irrigated crop using two discount rates, i.e. 0% and 10%.

Crops	Area (ha)			Amount of Water supply (mm)		
	0%	10%	Difference* (%)	0%	10%	Difference* (%)
Sorghum forage	26.2	33.0	20.7	419	378	9.8
Alfalfa	27.4	29.7	7.6	1331	943	29.2
Oats	6.4	8.3	22.6	590	218	63.0
Maize forage	0.80	1.2	34.4	1260	950	24.6
Berseem	6.8	0.7	-868.6	897	771	14.1

Nitrogen leaching

Nitrate leaching is lower for rainfed crops than for the irrigated crops as illustrated with rainfed wheat and irrigated maize (Figure 1). The amounts of nitrogen applied and leached for the maize are higher for the sustainable scenario compared to the base one. This difference becomes less important for rainfed wheat showing a very low nitrogen leaching (<10 kg/ha).

Farm income

Figure 2 compares farm income for the two discount rates. Under Mediterranean conditions farm income is correlated with rainfall variability. Income variation for the two scenarios is similar but income difference between the sustainable and the base scenarios increase over time with 45% after 10 years due to a lower soil salinization associated with a more diversified cropping pattern and surplus water application for leaching of salts.

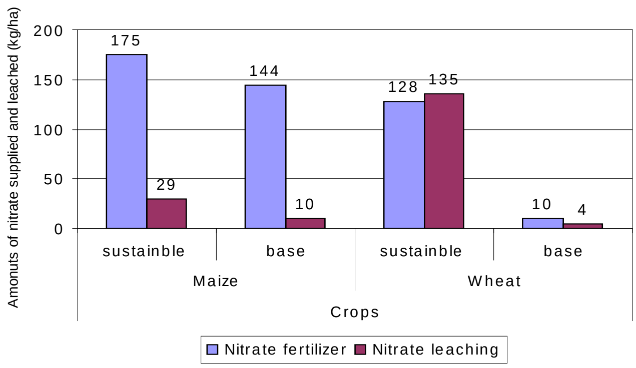

Figure 1. Amounts of nitrogen applied and leached for irrigated maize and rainfed wheat testing the two types of scenario.

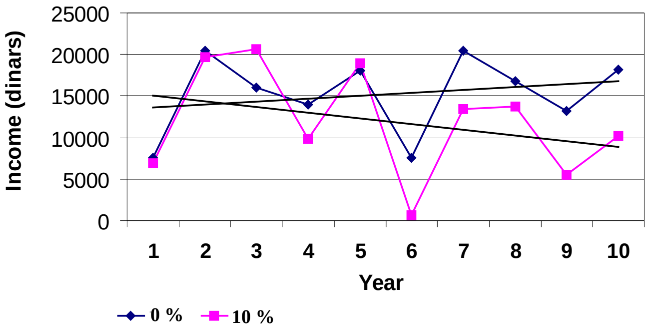

Figure 2. Simulated farm income over 10 years and testing the sustainable (0%) and the base (10%) scenarios

Conclusions

In this paper, we address the challenging topic of agricultural sustainability by means of a bio-economic approach. The amounts of water and nitrate fertilizer used for the sustainable scenario are higher compared to the base one, except for wheat where the nitrate fertilizer applied is higher for the base scenario compared to the sustainable scenario. However, the gross margin is higher for the sustainable scenario than for the base one. This result is explained by the fact that the profit gain due to an increase in crop yields is higher than the costs of supplement of water and nitrogen observed for the sustainable scenario, procreated by the low costs of water, which is usually greatly under priced in developing countries.

References

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