Assessing farm responses to the uncertainty of climate change: Application to an irrigated area in Northern Tunisia.

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Decision-makers are often confronted with contradictory demands when it comes to developing projects to evaluate and foster suitable strategies for adapting to global warming. In fact, few quantitative methods for assessing the impact of climate change on resilience and adaptive capacity have been defined and used. Furthermore, the tendency has been to treat the impact of climate change as a stand-alone activity, whereas it should be integrated into development projects, plans, policies, and strategies, in order to reach a compromise solution, a trade-off between the costs and benefits of different criteria (economic, social, environmental etc.). This paper presents a study using a bio-economic model to assess, at farm level, the impact of climate change in northern Tunisia by analyzing farm production systems behaviours as well as economic and environmental variables.

Materials and Methods

The BVM irrigated area, a 33000 ha in Northern Tunisia, was created for the use of the Medjerda river water in irrigated cereal, fodder and vegetables crops and fruit trees. However, the use of the irrigated water showed a risk of soil degradation. Agricultural systems in the area are characterized by a great diversity of agricultural management, in terms of crop rotations and of the amount of water applied. The traditional crop rotation system is based on rain-fed and irrigated cereals, forages crops during winter and maize and sorghum forage in the summer. Yield varies significantly from year to year based on the effect of weather, soil types, and farm management on soil salinity and availability of water. To simulate the key aspects of agricultural systems and the impact of climate change from field to farm scale a bio-economic model was developed based on an intelligent combination of an already calibrated and evaluated cropping system model (CropSyst, 1) and a bio-economic farm model (2). The bio-economic model, set for a time horizon of 2030, was used to identify which farm layouts and agro-ecological technologies would be favored by the implementation of the baseline and the scenarios simulating the impact of climate change. The baseline scenario involved a projection in time including mainly the inflation rate. It is the reference for the relative comparison and analysis of the climate change scenarios investigated. In our case study, the baseline scenario considered the current climate without, any modification in terms of temperature, rainfall frequency or CO2 concentration. The climate change scenario included projected weather, the expected increase of average temperature, rainfall distribution and CO2 concentration (1). The impact of climate change on crop yield and soil salinity accumulation was simulated using the CropSyst model (2). Twenty actual and representative arable farming systems in the study area were selected. The farm selection took into account the heterogeneity of farms and biophysical endowments. Based on a farm structural survey, this farm typology provided a set of typical farms defined by 3 criteria: size, land use and specialization. Each farm type represented a given number of actual farms.

Results and discussion

Figure 1 shows, for all farm types, the relationship between the relative difference of farm net margin and farm area when the climate change scenario is compared to the baseline one. From this graph, four farm behaviours can be distinguished: i) farms (FT1) for which farm area and net margin remain the same (the difference is less than 10%). Those farms were dominated by cereal and forage in sandy soil (more than 50%), with a very low percentage of fruit trees (less

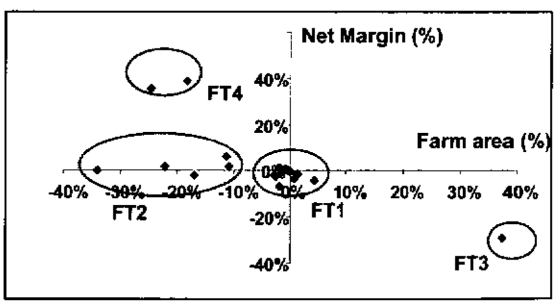

Fig.1- Relative differences in farm net margin and farm area between baseline and climate change scenario

than 10%). They represent 71% of all farms in the studied area, ii) farms (FT2) for which the farm area remained the same with the climate change scenario, but the farm net margin decreased between 10 and 40%. Those farms were dominated by clay-loamy soil (more than 85%), and more than 30% of its surface area given over to perennial crops (trees). They represent 28% of all the farms in the studied area, and iii) very marginal (less than 1%) farms (FT3 and FT4) characterised by a large modifications in farm area and farm net margin. In this study we focussed only on the FT1 and FT2 categories. Figure 1 presents, for the F1 and F2, the land use variation between baseline and climate change scenarios. Regarding FT1, figure 1 shows also that in the climate change scenario less irrigated cereals and fallow land are cultivated compared to the baseline one. To compensate for this drop in cereal and fallow areas, more irrigated summer vegetables and rainfed forage were grown. This strategy allowed the farmer to save water and to cultivate more profitable crops. In fact, the most changes took place in sandy soil with a low water retention capacity. The cereals, which are often irrigated, with high water demand (specifically durum wheat), were replaced with irrigated vegetables (mainly tomatoes). In addition, cereals are often irrigated with a sprinkler system, which is less efficient than the drip irrigation usually used for vegetables. This strategy, even though it could maintain farm profitability, appears not to be sustainable for the long term. In fact, the increase of irrigation in the sandy soil associated to the drip irrigation doubles the soil salinity accumulation. In FT2, the gross margin dropped by almost 20%. For this farm type, the irrigated cereals and the follow decreased instead of rainfed cereals, and rainfed forage. The rainfed cereals, which were originally cultivated (in the baseline scenario) in sandy soil are now (according to the climate change scenario) grown more in soil with high water retention capacity (data not shown). In FT2, the area reserved for fruit trees remained the same. Globally, the proportion of annual crops in the total farm income remained the same (35%) for both scenarios. Therefore, the high decrease of farm income in FT2 was due to the reduction of fruit tree yield (-15%), due to increased soil salinity accumulation (+30%).

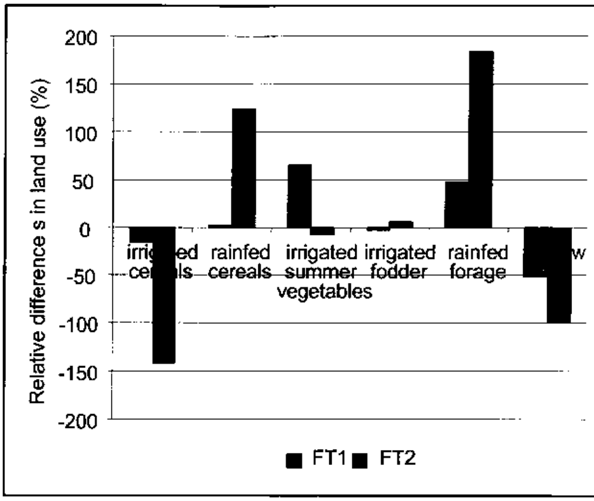

Fig. 2- Relative differences in land use by crop type between baseline and climate change scenarios.

Conclusion

From this study we may conclude that as expected, more diversified farms (e.g. FT1) respond less to climate change, and thus display greater resilience to environmental change, than specialized farms (e.g. FT2 dominated by fruit trees). However, short-term objectives to improve farm profitability often conflict with long-term objectives to increase the long-term adaptive capacity of the farm; e.g. such as in FT1 the use of drip irrigation in order to increase water efficiency progressively increased the soil salt concentration and then probably reduces the long-term adaptive capacity of the farming system. This methodology can be useful for simulating complex scenarios at farm scale. This work shows that further use should be made of the bio-economic model for simulating adaptation strategies, such as revising irrigation policies and shifting to more suitable activities, such as vegetable crops or stock-breeding, and their impacts on resilience and adaptive capacity in the study area.

References

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AGRO 2010
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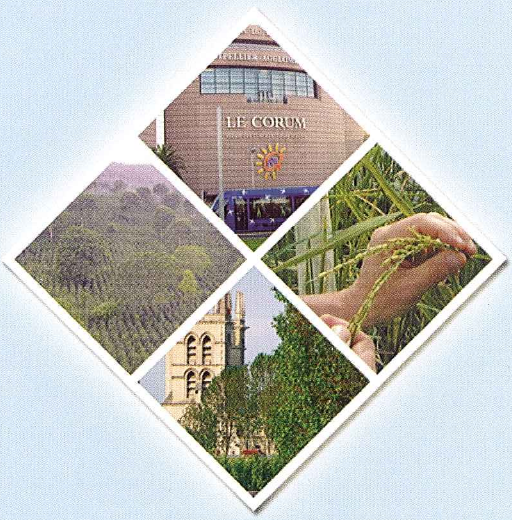

August 29th - September 3rd, 2010
Montpellier, France