Productive and economic adaptation of Mediterranean agriculture to climate change

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***Abstract* - Farmers programming is based on the inherent variability of the climate, here represented by probability distributions of crop production and livestock. A spatial model of agricultural supply accounts fot this variability in the economic decision under the current climate and future. The transition to future climate has diverse impacts on different farm types and areas irrigated and non-irrigated, requiring different adaptation policies.**

INTRODUCTION

Farmers base their annual planning on expectations about crop and livestock production that depend on inherent variability of climate. So, they may adapt to changes in climate variability (CCV) modifying their choices, which should be considered when estimating the agricultural impact of Climate Change (CC).

An extensive literature on the agricultural impact of CC ignores this, primarily modelling the optimal growing conditions to derive the economic impact of CC from yields drop or changes in other variables (Rötter, R.P. et al., 2012). They do not consider the possible adjustment of farmers to future variability of climate. Another approach is provided by Ricardian methods that estimate the econometric link between value of land and weather conditions in diverse climatic zones (Massetti and Mendelsohn, 2012). This link should measure the ability of farmers to adapt to the CC in the long term. However, it does not indicate how adaptation takes place and, hence, what policies can better support it.

The following interdisciplinary approach first synthesizes the influence of climate variability as probability distribution (pdf) of productive variables under current climate scenario and in the future. Second, simulates a choice process subject to the uncertainty caused by this variability, where the pdfs represent farmers' expectations on production in the two climate scenarios. Third, compares the productive and income results in these scenarios to assess the impact of transit in the future, and identify the types of farms that are more exposed to CC.

MATERIALS AND METHODS

The study area is located in central-west Sardinia, Italy. 36,000 hectares (Ha) are provided of irrigation water by a Water Users Association (WUA). Their major crops are wheat, corn and forage, and cow's milk is the key product. Vegetables are common, as also rice, citrus, olive trees and vineyards. 18,000 Ha are rain-fed and used for pasture and rye-grass, for sheep milk production, woods and set-aside; little irrigation is based on farm wells. This use of resources is derived from data of 6th Census of Agriculture, 2010, FADN and WUA. productive conditions of crop and livestock are defined with interviews to farmers, agronomists and managers of cooperatives.

The current and future climate scenarios of the area are obtained by nesting a Regional Atmospheric Modelling System, into an atmosphere-ocean model based on ECHAM 5.4 (Scoccimarro et al., 2011). Greenhouse gas scenario A1B of 2000–2010 denotes current climate, 2020–2030 is future. Errors due to poor geo-morphological description (mountains, land cover) from numerical models are reduced with a post-processing procedure based on observed data and reconstructed sea surface temperature. The footprint of CC is the increase of maximum and mostly of minimum summer daily temperature. Temperature increases slightly in Spring and markedly in Fall–Winter. Rain variability increases, coupled to a reduced rain.

The EPIC (Environmental Policy Integrated Climate) model is used to estimate the impact of temperature, rainfall and atmospheric CO_2 on yields of irrigated (silage maize, ryegrass, alfalfa) and rainfed (grasslands, haycrop) crops (Balkovic et al., 2013). Calibration is based on crop, soil and climate data from field experiments, and interviews to farmers. The cultivation of silage maize and rye-grass is simulated with fixed sowing dates; harvest is scheduled on heat units accumulation. Irrigated crops are simulated without water and nitrogen stresses. Rainfed haycrop is automatically N fertilized. Soil characteristics are yearly reset to remove soil dynamics and focus on climate effects.

The impact of climate on cattle is assessed using studies on the links between Temperature Humidity Index (THI) and mortality, milk yield and somatic cells (Bertocchi et al., 2014). The links between THI and those variables is verified with a 2-phase linear regression, that detects for an inflection point.

Those results are processed with maximum likelihood methods to estimate the pdf*s* of the productive variables. The pdf*s* are the expectations in a discrete stochastic programming (DSP) model that simulates the annual planning of farmers as a process prone to

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uncertainty on weather courses, and related productive results, in the incoming season (Dono et. al., 2013). DSP considers the probability of the various courses, and the possibility to correct the decisions once unfavorable events make them unsuitable.

The model is territorial supply based on 13 farm types. The climatically driven variability relates to summer water needs of crops, spring yields of pasture and hay from grasslands, autumnal yields of pastures and of grazed grasslands. Once unfavorable weather events occur, farmers apply corrective actions, i.e. pump water from wells or buy feeds: this causes sub-optimal results but minimizes the impact of adverse conditions.[2] The model is calibrated on 2010 with the PMP approach of Röhm and Dabbert. Comparing the results of current climate and future identifies the resilience of the system to CC or, inversely, the impact on income difficult to avoid.

RESULTS

Table 1 reports current net income (NI) per type, zone and total area, farm average, and NI variation in the future. In the last column the Finger-Kreinin index (FKI) on the similarity between the use of land in the two scenarios: when closer to zero indicates more pronounced changes in the cropping.

Table 1. Net Income (NI) per type, zone and farm (000 euros) under current climate; percentage change (%) of future NI over current; FKI on use of land.

	Current NI		Future NI % of current	FKI
	Type	Farm		
Rice	3,085	128.5	=	1.00
Citrus fruits	2,670	39.3	=	1.00
Dairy A	26,302	202.3	-10.5	0.89
Dairy B	6,666	166.7	-11.5	0.84
Greenhouses	1,238	26.9	+0.4	0.94
Mixed vegetables	18,695	33.3	-0.8	0.99
Mixed + Rice	4,898	89.0	+0.2	0.98
Mixed + Permanent	1,183	11.8	=	1.00
Veg. + Permanent	1,014	10.1	=	1.00
Mixed field crops	2,691	28.6	=	0.99
Sheep A	1,897	42.2	-12.2	0.85
Sheep B	1,894	10.1	-17.6	0.77
Sheep C	5,424	42.1	-10.5	0.96
Irrigated zone	64,736	63.2	-5.7	0.95
Rain-fed zone	12,920	23.2	-8.8	0.89
Total area	77,656	49.1	-6.2	0.95

Many types adapt to the new climate without NI falls. Total NI reduces mainly because of the drop in dairy farms, and also in sheep farms. The rain-fed zone is more affected than the irrigable zone. The last column shows that these changes associate to changed use of resources in many types.

DISCUSSION AND CONCLUSIONS

The impact of new climate in the study area mostly depends on the reduction of sales of cow's milk and worsening of its quality in the summer. The model reflects this effect but does not provide adaptation options to dairy farms. Instead, it captures the adaptation to new productive condition of silage corn, by changes in the use of land to increase its production. It also captures the reaction to the worse condition of non-irrigated grasslands: sheep farms reduce crops for sale to produce more feed, and increase purchase and production of hay. This reduces revenues and increases costs. The NI decline in the irrigated zone is smaller as water availability in the WUA meets the increased demand of future. In addition, the water pricing, based on fixed fees per hectare, prevents the increase of payments: volumetric systems would have completely different impacts.

This approach identifies better the impact of the CC because considers the adaptation in farm management. It also indicates how adaptation can take place in various cases helping to specify the different adaptation policies that should be used. Finally, the conclusions of the study, with the variety of productive situations considered, may be relevant to many Mediterranean areas.

[2] Instead, the impact of changes in temperature and humidity on milk quality, quantity, and head mortality is an ex post simulation.

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