The economic impact of changes in climate variability on milk production in the area of Grana Padano

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Objectives…

…of our work to assess the ECONOMIC impact of Climate Change (CC) at short medium term on dairy cattle farms of Grana Padano (GP) region

HOW


FARM-SCALE resolution, with projection of modeling results at REGIONAL scale, based on territorial representativeness of sample farms.

…of this presentation to present the approach, the area, the model and its main results …… with some weakness we are working on
Climate Variability in the Economic Modelling

Meteorological Variability is intrinsic in each climate, with different states of nature that may occur both in Present and in Future climate. CC modifies representative values and probability of these states, affecting achievable economic results.

A Discrete Stochastic Programming model represents management choices in the GP area at representative dairy farms level, under the uncertainty conditions generated by this variability (Dono et al., 2013).

Uncertainty affects yields and water needs of crops, and nutritional needs of cattle: these can be managed by farmers through Corrective Actions (CA), like additional water pumping and feed purchasing.

Impacts on milk productivity and quality traits are also considered, but cannot be mitigated by CA.
Study area

- Po Valley (Northern Italy)

6,868 dairy farms, producing PDO milk in the 13 Provinces where GP is produced

- 2 Provinces (NUTS3) as representative of the entire GP area
  - Cremona
  - Piacenza

where 1,014 dairy farms operate

Source: ISTAT 2010, 6th Agricultural Census
Main differences:
- Structure and productive dimension
- Productivity

More intensive cropping schemes and breeding techniques in Cremona than in Piacenza

Tab.1: Weighted averages of representative farms characteristics

<table>
<thead>
<tr>
<th></th>
<th>Cremona</th>
<th>Piacenza</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilized Agricultural Area (UAA, Ha)</td>
<td>90.5</td>
<td>46.1</td>
</tr>
<tr>
<td>For farm re-use (Ha)</td>
<td>78.8</td>
<td>85.7</td>
</tr>
<tr>
<td>% alfa-alfa</td>
<td>18.7</td>
<td>39.9</td>
</tr>
<tr>
<td>% silage maize</td>
<td>62.2</td>
<td>27.8</td>
</tr>
<tr>
<td>% grain crops</td>
<td>6.7</td>
<td>14.8</td>
</tr>
</tbody>
</table>

Tab.2: Weighted averages of productivity indicators

<table>
<thead>
<tr>
<th></th>
<th>Cremona</th>
<th>Piacenza</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUs × UAA⁻¹</td>
<td>3.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Milk (t) × LU⁻¹</td>
<td>5.1</td>
<td>3.8</td>
</tr>
<tr>
<td>LEUs × LU⁻¹</td>
<td>70.9</td>
<td>46.0</td>
</tr>
<tr>
<td>Income per LEUf (.000 €)*</td>
<td>155.6</td>
<td>63.6</td>
</tr>
<tr>
<td>Return On Equity (ROE) (%)**</td>
<td>6.3</td>
<td>6.5</td>
</tr>
</tbody>
</table>

* Compensating Farm-owned capital at 1.5 % rate
** Remunerating L.E.f. with 32.500 €×Year⁻¹
Climatological datasets

a. Regional Atmospheric Modelling System simulates local climate at DAILY time-scale for:

- 2000-2010 → Present scenario (Ps)
- 2020-2030 → Future scenario (Fs)

b. 2 synthetic time series of 150 years each are generated with WXGEN

Livestock modelling relevance

- Air Temperature \((T_{\text{min}}, T_{\text{mean}}, T_{\text{max}})\)
- Relative Humidity \((RH_{\text{min}}, RH_{\text{mean}}, RH_{\text{max}})\)
- Wind Speed \((WS_{\text{mean}})\)

Agronomic modelling relevance

- Daily precipitation
- Net Radiation

c. \(THI_{\text{max}}, ET_n, \) crop yield, irrigation needs are computed

d. Probability Distribution Functions (PDFs) of these variables are fitted
Climate Change and THI\textsubscript{max} distributions

Daily values of THI\textsubscript{max} for 150-year series of Ps and Fs to identify the annual period of incidence of heat stress: quarter June-August

PDFs estimated on these data through a maximum likelihood algorithm: PDF of Future THI shifts towards higher values

Present and future PDFs of THI\textsubscript{max} divided in 3 states of nature: Low, Intermediate and High with 25%, 50%, 25% probability of occurrence
## Climate scenarios: states of nature

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Present</th>
<th></th>
<th>Future (Δ% on Present)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Ryegrass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (t ha(^{-1}) Corn d.m.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{long cycle}</td>
<td>25.0</td>
<td>26.2</td>
<td>27.4</td>
</tr>
<tr>
<td>\textit{short cycle 1}</td>
<td>20.4</td>
<td>21.6</td>
<td>22.7</td>
</tr>
<tr>
<td>\textit{short cycle 2}</td>
<td>12.5</td>
<td>13.4</td>
<td>14.1</td>
</tr>
<tr>
<td>THI (June-August)</td>
<td>75.9</td>
<td>76.8</td>
<td>77.7</td>
</tr>
</tbody>
</table>
The DSP model can be compactly written as follows:

$$\max_{x_{n,j}, c_{at_{n,s}}} z = \sum_n \sum_j \sum_s P_s \cdot (G_{I,n,j,s} \cdot x_{n,j} - C_{ca} \cdot c_{at_{n,s}}) + P_m n \cdot Q_m n + V_E n \cdot N_E n$$

subject to

$$\sum_j A_{n,j} \cdot x_{n,j} \leq B_n \quad \forall n$$

(2)

$$\sum_j N_j \cdot Y_{t_{n,j,s}} \cdot x_{n,j} + c_{at_{n,s}} \geq R_{t_{n,s}} \quad \forall n, s$$

(3)

$$x_{n,j} \geq 0 \text{ and } c_{at_{n,s}} \geq 0 \quad \forall n, j, s$$

(4)

Decision-making on $t$ stages, $s$ states of nature for uncertain variables, with land allocation $x_{n,j}$ in the $n$ farms for each $j$ crop activity and corrective action $c_{at_{n,s}}$. OF (1), expected gross income $z$, weights values and probabilities $P_s$ in the states of nature. Uncertainty involves gross margins $G_{I,n,j,s}$ and corrective actions $c_{at_{n,s}}$. $P_m n$ and $Q_m n$ are price and quantity of milk. $V_E n$ and $N_E n$ are unitary values and entitlements for Single Payment of CAP. (2) restrains availability of resources $B_n$ and technology matrix $A_{n,j}$ of activities. (3) affects animal feeding: $N_j$, $R_{t_{n,s}}$, $Y_{t_{n,j,s}}$ are unitary contributions of nutritional elements, nutritional needs of cattle categories and crop yields. Corrective actions $c_{at_{n,s}}$ can be done at stage $t$ for state $s$. 
## Model results: land and input uses

<table>
<thead>
<tr>
<th></th>
<th>Present</th>
<th>Future % Δ on Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>corn silage for feed</td>
<td>31,744</td>
<td>-1.3</td>
</tr>
<tr>
<td>corn silage for biogas</td>
<td>5,286</td>
<td>+20.2</td>
</tr>
<tr>
<td>grain maize</td>
<td>4,246</td>
<td>+16.2</td>
</tr>
<tr>
<td>alfalfa</td>
<td>14,479</td>
<td>-10.5</td>
</tr>
<tr>
<td>ryegrass</td>
<td>1,311</td>
<td>+28.3</td>
</tr>
<tr>
<td>soybean</td>
<td>443</td>
<td>+4.7</td>
</tr>
<tr>
<td>tomato processing</td>
<td>7,834</td>
<td>-2.8</td>
</tr>
<tr>
<td>nitrogen (tons)</td>
<td>8,450</td>
<td>+3.3</td>
</tr>
<tr>
<td>water (000 m3)</td>
<td>275,637</td>
<td>+8.3</td>
</tr>
<tr>
<td>feeds (tons)</td>
<td>573,590</td>
<td>-6.8</td>
</tr>
</tbody>
</table>
# Model results: economic variables

<table>
<thead>
<tr>
<th></th>
<th>Present</th>
<th>Future % Δ on Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total revenues</td>
<td>532,901</td>
<td>-0.8</td>
</tr>
<tr>
<td>milk and meat</td>
<td>503,563</td>
<td>-1.5</td>
</tr>
<tr>
<td>Direct payments</td>
<td>52,050</td>
<td>0.0</td>
</tr>
<tr>
<td>Costs</td>
<td>224,153</td>
<td>0.5</td>
</tr>
<tr>
<td>fertilizers, pesticides, seeds</td>
<td>12,607</td>
<td>6.3</td>
</tr>
<tr>
<td>water</td>
<td>4,169</td>
<td>1.0</td>
</tr>
<tr>
<td>extra labour</td>
<td>33,474</td>
<td>-0.2</td>
</tr>
<tr>
<td>animal feeds</td>
<td>116,977</td>
<td>-6.4</td>
</tr>
<tr>
<td>Net income</td>
<td>240,783</td>
<td>-2.1</td>
</tr>
</tbody>
</table>
Economic results: typologies of farms ordered by intensity of CC impact

<table>
<thead>
<tr>
<th>Present Net Income (NI)</th>
<th>Future NI % Δ on Present</th>
<th>Represented farms</th>
<th>Represented hectares</th>
<th>NI per farm</th>
<th>NI per hectare</th>
<th>hectares per farm</th>
<th>% in the Piacenza province</th>
</tr>
</thead>
<tbody>
<tr>
<td>32,704,946</td>
<td>-3.9</td>
<td>284</td>
<td>21,289</td>
<td>115,234</td>
<td>1,536</td>
<td>75.0</td>
<td>78</td>
</tr>
<tr>
<td>85,666,959</td>
<td>-2.1</td>
<td>213</td>
<td>19,291</td>
<td>401,990</td>
<td>4,441</td>
<td>90.5</td>
<td>17</td>
</tr>
<tr>
<td>122,410,748</td>
<td>-1.7</td>
<td>359</td>
<td>24,274</td>
<td>341,124</td>
<td>5,043</td>
<td>67.6</td>
<td>14</td>
</tr>
</tbody>
</table>

Smaller and less intensive farms in the Piacenza province suffer a stronger impact of the CC
Conclusions

A major intensification impact in the use of inputs and water, and reduced purchases of feed

Milk production appreciably decreases in the summer, when it is already low

The model ignores market effects of this variation in the demand of the inputs in the entire area of the GP

The model ignores the effects on the dairy sector, which in the summer might have difficulty even to make cheese

Different effects by farm typology, with the suffering of the less intensive

Types to be better defined. A three years FADN average reduces the sample and requests to widen the representative area: this requires climatic and agronomic data from other GP territories
For further information please visit: www.macsur.eu