Integrated Climate Risk Assessment in Agriculture & Food - Trade M

Parallel Session

Modelling improvements through integrated approaches

Chair: Franz Sinabell

Modelling the effects of Climate Change on dairy farms: an integration of livestock and economic models

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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

MULTIDISCIPILINAR APPROACH:
integration of Climatological, Livestock, Agronomic and Economic modelling.

FARM-SCALE resolution, with projecion of modeling results at REGIONAL scale, thanks to territorial representativeness of sample farms.

…of this presentation

to present how the impact of CC on the livestock system was considered and integrated in the economic core of the model.

Climate Variability in the Economic Modelling

Meteorological Variability is intrinsic in each climate. Different States of Nature may occur both in Present and in Future climate. CC modifies representative values and probability of these States, affecting achievable economic results

Discrete Stochastic Programming (DSP) models are used to represent decision making under uncertainty conditions generated by this variability (Dono et al., 2013)

A DSP model, calibrated on 2011 observed cropping schemes, is used to represent management of dairy farms in the GP area at **representative farms level**

Uncertainty affects crop yields and cattle nutritional needs, manageable by farmers through **'Corrective Actions' (CA)**, like additional water pumping and feed purchasing.

Impacts on milk productivity and quality traits are also considered in the model, but cannot be subjected to CA.

Impacts of climate on livestock performances

Heat stress negatively affects milk production traits

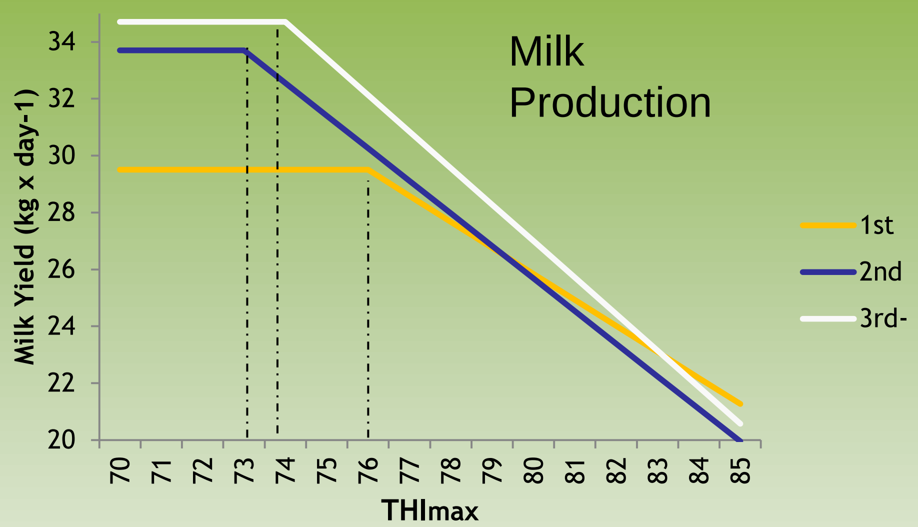
- Quantitatively (Bernabucci et al., 2014)
- Qualitatively (Bertocchi et al., 2014)

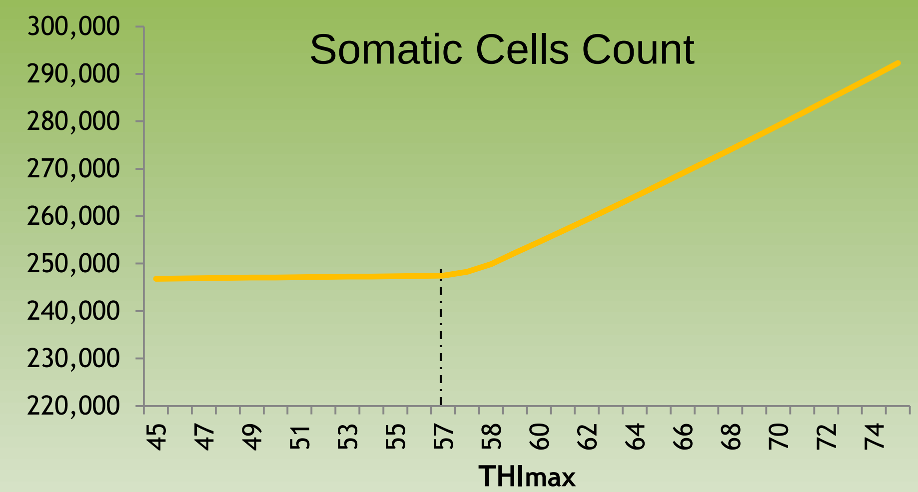
During Heat Waves stress reaches its peak, and dramatically increases cattle mortality rates (Vitali et al., 2009)

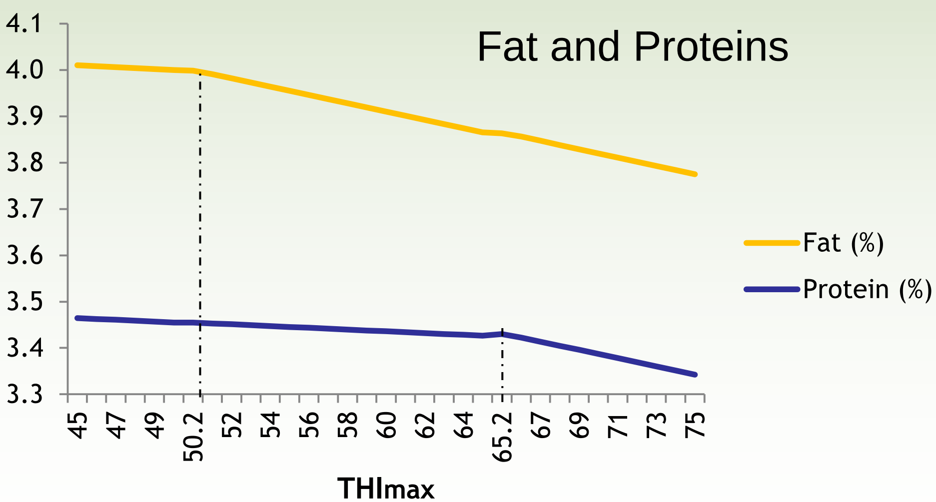
Heat stress is quantified through a synthetic indicator (THI_{max}): linearly combines maximum ambient temperature (T_{max}) and minimum relative humidity (RH_{min}) :

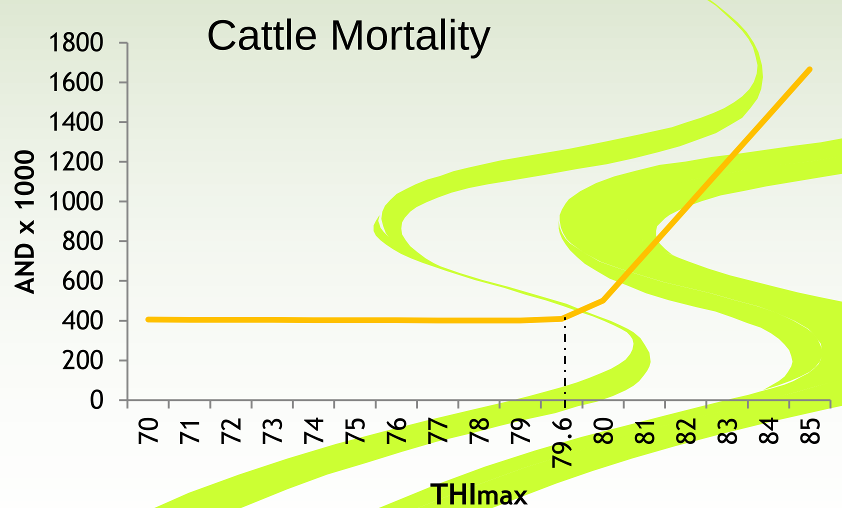
$$THI_{max} = (1.8 \times Tmax + 32) - (0.55 - 0.55 \times RH_{min}) \times [(1.8 \times Tmax + 32) - 58]$$

Impact of Heat Stress on livestock performances









Climatological datasets

1. RAMS (Regional Atmospheric Modelling System) local climate simulations at DAILY time-scale for:

2000-2010 → Present scenario (Ps)

2020-2030 → Future scenario (Fs)

2. Generation of 2 synthetic time series of 150 years each

Livestock modelling relevance

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

Agronomic modelling relevance

- Daily precipitation
- Net Radiation

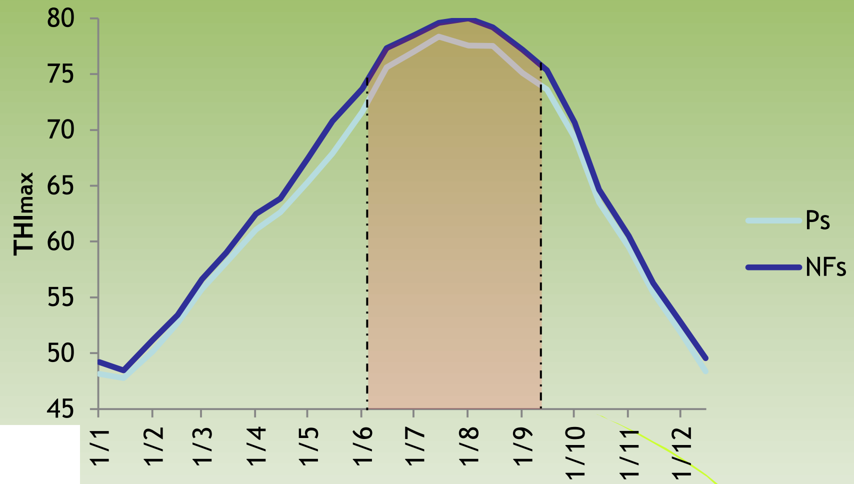
3. Computation of modelling variables: **THI_{max}**, ET_n, crop yield, irrigation requirements

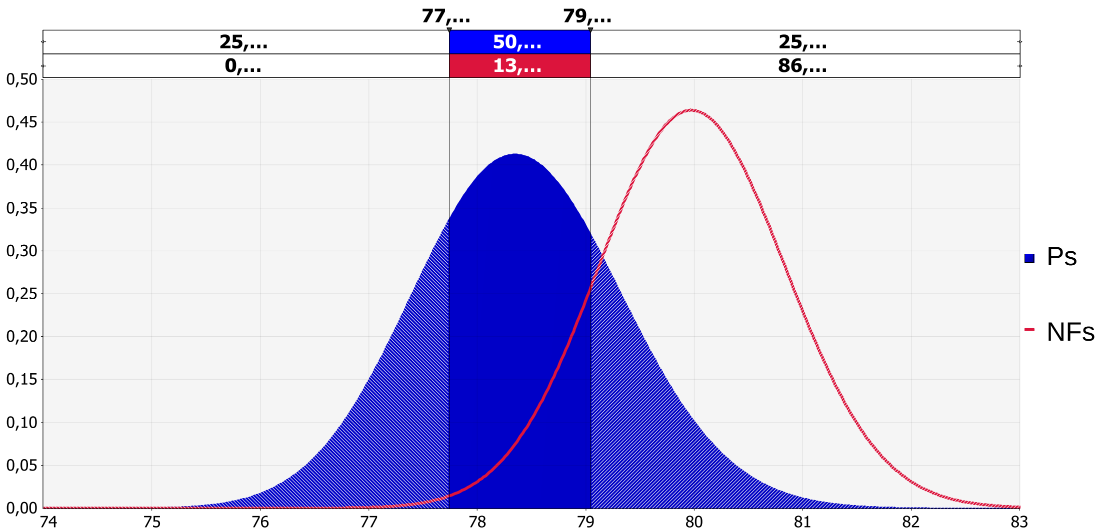
4. Fitting of Probability Distribution Functions (PDFs) on daily values of modelling variables

THI$_{max}$ distributions

Daily values of THI$_{max}$ 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 likelyhood algorithm: PDF of Future THI shifts towards higher values





Present and future PDFs of THI$_{max}$ divided in 3 *states of nature*: Low, Intermediate and High with 25%, 50%, 25% probability of occurrence

Estimation of cattle Nutritional Requirements

The CNCPS model (Cornell Net Protein and Carbohydrate System) (Fox et al., 2004) was employed:

- it accounts for the effects of microclimatic parameters
- has a modular structure: total requirement per head sums the needs for individual physiological functions (maintenance, growth, pregnancy, lactation)

CNCPS expresses needs of Net Energy, Dry Matter Intake, Net Protein; these were subsequently converted in Metabolizable Energy and Protein needs, to meet with their content in feed (NRC, 2001)

Concentrate and hay composition of DMI were also set as complementary feeding constraints, for a proper satisfaction of nutritional requirements

Feed purchase simulation

Farm production of grains and fodder is insufficient to completely meet nutritional requirements: feed purchasing is critical, and is the main component of Variable Costs in all studied farms.

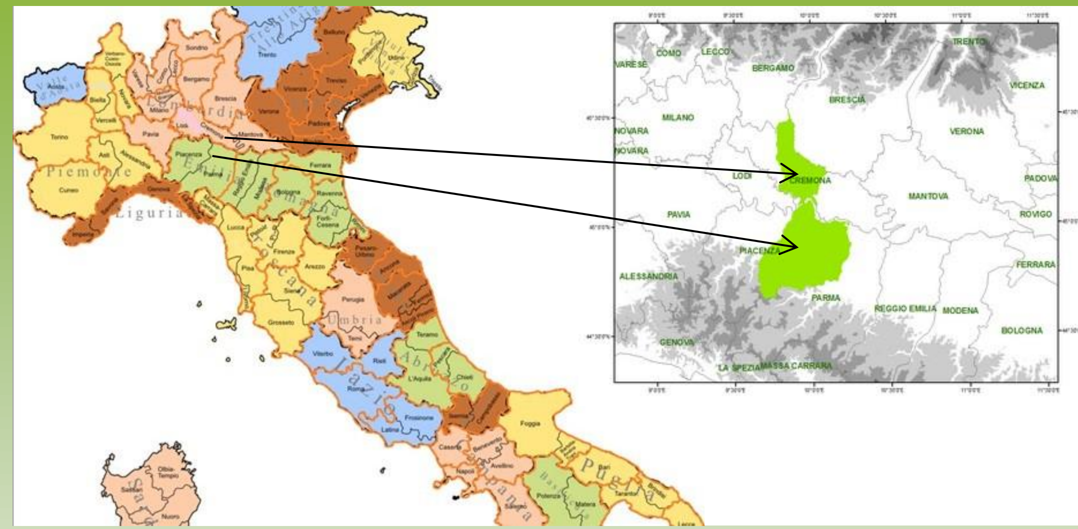
An on-site survey was conducted to reconstruct the ordinary composition of purchased feed in the area and their price:

Feed		Price (€×t^{-1})
Concentrated feed	Soybean Meal	345.0
	Cotton seed Meal	310.5
	Grain corn Steam-flaked	207.0
Hay	Grass hay	149.5

Study area

- Po Valley
  (Northern Italy)

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



- 2 Provinces considered (NUTS3)
  - Cremona
  - Piacenza

24% of GP produced in this area in 2014 (CLAL, 2015)

where 1,014 dairy farms operate

Source: ISTAT 2010, 6 th Agricultural Census

Data sources

- FADN (Farm Accountancy Data Network)

Records from 23 dairy farms, with reference to the year 2011

14 in Cremona → 622 farms represented

9 in Piacenza → 234 farms represented

Information provided for the main technical and economic characteristics:

Operative dimensions (land extension, cropping systems, herd numerosity, overall herd composition)

Productive dimensions (milk, forage and grain crops production)

Capital endowment (with reference to the title of ownership)

Economic results (revenues and incomes)

Tab.1: Weighted averages of representative farms charachteristics

	Cremona	Piacenza
Utilized Agricultural Area (UAA, Ha)	90.5	46.1
For farm re-use (Ha)	*78.8*	*85.7*
% alfa-alfa	*18.7*	*39.9*
% silage maize	*62.2*	*27.8*
% grain crops	*6.7*	*14.8*
Livestock Units (LUs)	297.6	128.9
Annual milk production (tons)	1,509.4	495.1
Equity (.000 €)	4,260.5	1,194.0
Labour Employ Units (LEUs, 2200 h×year^{-1})	4.2	2.8
Family Labour (LEUf)	*39.3*	*69.4*
Permanent Labour (% L.E.)	*47.0*	*0.0*
Revenues from sales (.000 €)	1,079.8	333.2
% from milk sale	*61.4*	*69.6*
% CAP contribution	*6.8*	*7.7*
Gross Income (.000 €)	505.6	163.0
Net Income (.000 €)	320.8	141.2

Main differences concern:

- Overall structural and productive dimensions (Tab.1)
- Productivity (Tab.2)

Tab.2: Weighted averages of productivity indicators

	Cremona	Piacenza
LUs × UAA^{-1}	3.3	2.8
Milk (t) × LU^{-1}	5.1	3.8
LEUs × LU^{-1}	70.9	46.0
Income per LEUf (.000 €)*	155.6	63.6
Return On Equity (ROE) (%)**	6.3	6.5
* Compensating Farm-owned capital at 1.5 % rate		
** Remunerating L.E.f. with 32.500 €×Year^{-1}		

Dairy farms in Cremona adopt more intensive cropping schemes and breeding techniques, than in Piacenza

Herd demography reconstruction

Management indicators based on 6 th Census information on herd demography at provincial level, :

	Cremona	Piacenza
Calving Interval (days)	409.1	408.8
Replacement Rate (%)	30.2	26.7

Coupled with FADN data on herd demography, consistence of 7 livestock categories built in each farm:

	Cremona	Piacenza
Calves and young heifers (<1 y)	27.8	28.6
Non pregnant heifers(1-2 y)	14.2	13.7
Pregnant heifers(>2 y)	13.8	8.4
Dry cows	11.2	13.3
Lactating (1 st, parity)	11.1	11.0
Lactating (2 nd parity)	11.1	11.0
Lactating (3 rd - 4 th parity)	10.6	14.8

Impacts of Heat Stress on milk production (results)

June-August	Present			Future (% variation on Present)		
	Low	Intermediate	High	Low	Intermediate	High
THImax	75.9	76.8	77.7	2.2	2.3	2.3
Milk production variation						
1 st Parity	*27.2*	*26.6*	*25.9*	*-5.1*	*-5.7*	*-5.9*
2 nd Parity	*27.8*	*26.9*	*26.0*	*-6.5*	*-7.1*	*-7.5*
3 rd - 4 th Parities	*29.7*	*28.7*	*27.7*	*-6.7*	*-7.3*	*-7.7*
Qualitative Traits						
Fat(%)	*3.77*	*3.76*	*3.75*	*-0.4*	*-0.4*	*-0.4*
Proteins (%)	*3.34*	*3.33*	*3.32*	*-0.5*	*-0.5*	*-0.5*
Somatic Cells Count	*299,512*	*302,146*	*304,635*	*1.6*	*1.7*	*1.7*

No effect of increase in mortality rate emerged (threshold not exceeded)

Impact of Heat Stress on nutritional needs

Nutritional needs were estimated for each of the 3 States of Nature of the THI_{max} phenomenology in the Present and Future scenarios:

- In heifers and dry cows no substantial difference going from present to future
- In lactating dairy cows a slight, 1% reduction due to smaller lactation needs

Results of the economic model

CC impact in the Future simulated also in its aspects of closer livestock relevance:

- Present scenario constrained to replicate cropping schemes observed in 2011;
- Future cropping schemes only constrained to satisfy nutritional needs, along with purchased feed;
- Extent and composition of feed purchase to meet residual nutritional needs over farm-produced feed, and maximizing farm gross income.

Impact on cropping schemes (results)

	Present (% on UAA)			Future (% on UAA)		
	Total area	Cremona	Piacenza	Total area	Cremona	Piacenza
Alfa-alfa	22.2	20.4	31.3	19.2	17.9	25.4
Ryegrass	2.0	2.4	0.0	2.7	3.0	1.3
Meadows and Grasslands	6.3	4.8	14.2	5.9	4.5	13.1
Silage Maize (1st crop)	47.9	57.1	0.0	52.9	60.1	16.0
Silage Maize (2nd crop)	8.8	3.5	36.4	4.2	0.6	22.9
Other silage crops	1.9	1.5	3.6	1.8	1.5	3.4
Grain Maize	6.5	6.7	5.5	7.5	7.5	7.0
Other grain crops	3.5	2.5	8.9	4.3	3.2	10.0
Other Crops	1.0	1.1	0.0	1.5	1.6	0.9

Main changes concern Alfa-alfa surface extension, that is reduced in favor of silage maize (1 st crop) and grain maize crops, whose yields are expected to increase.

The spread of silage maize cultivation may involve a 9.1% increase in irrigation water demand (7% in Cremona and 28.9% in Piacenza, where this crop is currently absent)

Impact on feed purchase (results)

	Present			Future (% variation on Present)		
	Total Area	Cremona	Piacenza	Total Area	Cremona	Piacenza
Purchase (.000 tons)						
Grain corn steam-flaked	313.4	245.7	67.7	-14.5	-8.1	-37.8
Grass hay	178.2	139.8	38.3	1.0	-0.9	7.9
Cotton seed Meal	82.0	79.6	2.4	8.1	6.1	71.7
Variable Costs (.000 €)						
Cropping	16,775	14,579	2,196	12.6	9.1	35.9
Purchase	116,977	96,473	20,504	-6.1	-2.9	-21.0

General tendence to increase farm production, reducing feed purchase (partly due to grain maize yield increase)

Stable hay purchase, substitution of grain corn with cotton seed meal (for compensating reduction in alfa-alfa hay production)

Economic results and conclusions

	Present (.000 €)			Future (% Variation on Present)		
	Total area	Cremona	Piacenza	Total area	Cremona	Piacenza
Revenues from sales	535,430	473,354	62,076	-0.4	-0.6	0.7
from milk sale	460,603	407,014	53,589	-1.7	-1.7	-1.7
from crop sale	31,867	30,435	1,432	17.0	13.4	94.0
Variable costs (VC)	225,923	191,317	34,606	1.2	0.7	3.6
crop	16,775	14,579	2,196	8.1	4.6	47.4
feed purchase	116,977	96,473	20,504	-6.2	-3.0	-21.4
external labour	33,474	29,143	4,331	-0.2	-0.1	-0.7
other VC	58,697	51,121	7,575	15.5	7.5	69.0
Gross Income	361,557	328,570	32,986	-1.4	-1.3	-2.5
Net Income	241,542	213,651	27,891	-2.1	-2.0	-3.0

Overall CC impact appears moderate, with a slight reduction in Revenues (partly mitigated by the increase in crop sales) and a slight increase in variable costs (due to the increase in the component of crop cultivation expense and the ‘dual’ component of the quadratic cost function employed, mitigated by feed purchase reduction).

In Piacenza province, the impact is slightly more consistent.

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