Climate change, vulnerability, and adaptation in agriculture – the situation in Italy

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Land use on Italy

<table>
<thead>
<tr>
<th>Land Type</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built up area</td>
<td>5</td>
</tr>
<tr>
<td>Agricultural area</td>
<td>51</td>
</tr>
<tr>
<td>Forest</td>
<td>41</td>
</tr>
<tr>
<td>Wet land</td>
<td>0.2</td>
</tr>
<tr>
<td>Water</td>
<td>3</td>
</tr>
</tbody>
</table>
Agricultural land use in Emilia Romagna

Agricultural area 40%

The most important crops: winter wheat (soft and durum, in the last years), tomato, mais, forage crops (alfalfa)
Tree crops: peach, apple, pear

The most important problems:
Reduction of water resources for irrigation
Irrigation as ordinary practice (corn, alfalfa..)
Early flowering and late frost (for tree crops)
No yield for alfalfa in summer
Agricultural land use in Puglia-Basilicata

Agricultural area 43%

The most important crops: durum winter wheat, tomato, winter vegetable, water melon, cabbage

Tree crops: vineyard, olive, almond, citrus

The most important problems:
- Reduction of water resources for irrigation
- Salinization in the costal areas
- Increase of irrigation practice
- Supplemental irrigation for winter crops
- Early flowering and late frost (for tree crops)
The Temperature variability in Italy

Three Regions on Temperature Basis

Alpine Region: AL
Po Plain: PP
Peninsular Plain: PI

From:
TEMPERATURE AND PRECIPITATION VARIABILITY IN ITALY IN THE LAST TWO CENTURIES FROM HOMOGENISED INSTRUMENTAL TIME SERIES
M. BRUNETTI, M. MAUGERI, F. MONTI and T. NANNI
The Temperature Variability in Italy

Adapted from Brunetti et al. 2006
The Temperature Variability in Italy

Quite a uniform temperature trend was observed in the different regions, with an increment of 1 K per century all over Italy on a yearly basis.

Also on a seasonal basis the situation is quite uniform and no significant differences are evident, either for the different regions or for the different seasons.

Adapted from Brunetti et al. 2006
The Precipitation Variability in Italy

Six Regions on Precipitation Basis

Adapted from Brunetti et al. 2006
The Precipitation Variability in Italy

Precipitation trend analysis showed a decreasing tendency. But the decreases are very low and rarely significant. Considering the average all over Italy, there is a 5% decrease per century in the annual precipitation amount, mainly due to the spring season (−9% per century)

Adapted from Brunetti et al. 2006
What is changing in this century?

- Increase of global mean temperature: from 2 to 6°C and consequently increase of soil evaporation
- Increase of emission and concentration of CO₂
- About the rainfall:
  - Increase or decreasing annual rainfall.
  - Increase rainfall intensity.
  - Changing of rainfall distribution.
Temperature change (°C, 2071-2100 minus 1961-1990), MGME ensemble average, A1B scenario

from Giorgi and Lionello, submitted
The Authors conclude, for the end of the century, forecasting:
1) a reduction of summer precipitations in Southern Italy
2) little changes for the Northern Italy with a little increase for the winter rains

Concerning the temperature, they forecast an increase quite uniform among the regions.

*from Giorgi and Lionello, submitted*
The Climatic data used for the Pilot Assessments

The Regional Circulation Models adopted in this work was **HadRM3P**, developed by the Hadley Centre, UK. HadRM3P has a spatial resolution of 0.44° latitude by 0.44° longitude and is the result of a dynamical downscaling. It takes boundary conditions from a coarser resolution global model and provides a higher spatial resolution of local topography and more realistic simulations of fine-scale weather features. In particular, the outputs from **HadCM3** experiments provide the boundary conditions to drive a high resolution (~120 Km) model of the global atmosphere (HadAM3P). In turn, the outputs from this model provide the boundary conditions to drive the HadRM3P.

In order to simulate climate change, two emission scenarios (**A2** and **B2**) were selected among those proposed by the Special Report on Emissions Scenarios (IPCC 2000), to have a wide and representative range of changes in temperature patterns. The climatic daily data of the scenarios **A2** and **B2** (from 2071 to 2100) and reference period (**REF**, from 1961 to 1990) were utilized for SWAP and DSSAT applications with unique initializations.
Temperatures (maximum) anomalies of A2 scenario for January-February-March
Temperatures (maximum) anomalies of A2 scenario for April-May-June
Precipitation anomalies of A2 scenario for April-May-June
Precipitation anomalies of A2 scenario for October-November December
## Universities and Applicants for Italy

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marco Bindi</td>
<td><strong>Università di Firenze</strong>&lt;br&gt;Dipartimento di Scienze Agronomiche e Gestione del Territorio Agroforestale</td>
</tr>
<tr>
<td>Maurizio Maugeri</td>
<td><strong>Università di Milano</strong>&lt;br&gt;Istituto di fisica generale applicata – Climatologia storica</td>
</tr>
<tr>
<td>Pietro Santamaria</td>
<td><strong>Università di Bari</strong>&lt;br&gt;Dipartimento di Scienze delle Produzioni Vegetali</td>
</tr>
<tr>
<td>Michele Perniola Stella Lovelli</td>
<td><strong>Università degli Studi di Basilicata</strong>&lt;br&gt;Dipartimento di Produzione Vegetale</td>
</tr>
<tr>
<td>Ricercatori</td>
<td><strong>CRA-UR per i sistemi colturali degli ambienti caldoaridi – Bari</strong>&lt;br&gt;<strong>CRA-UR per lo studio dei sistemi colturali – Metaponto (MT)</strong></td>
</tr>
<tr>
<td>Emanuele Scalcione</td>
<td><strong>Agenzia Lucana di Sviluppo e di Innovazione in Agricoltura</strong></td>
</tr>
<tr>
<td>Luigi Trotta</td>
<td><strong>Regione Puglia</strong> - Assessorato Risorse Agroalimentari - Settore Agricoltura</td>
</tr>
<tr>
<td>Paolo Mannini</td>
<td><strong>CER</strong> Consorzio di bonifica di secondo grado per il Canale Emiliano-Romagnolo</td>
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<tr>
<td>Franco Zinoni</td>
<td><strong>ARPA</strong> - Agenzia Regionale Prevenzione Ambiente dell’Emilia Romagna&lt;br&gt;Direzione Tecnica</td>
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<tr>
<td>Giovanni Lacertosa</td>
<td><strong>Metapontum Agrobios</strong></td>
</tr>
<tr>
<td>Antonino Drago</td>
<td><strong>Regione Sicilia</strong> Servizio Informativo Agrometeorologico Siciliano</td>
</tr>
</tbody>
</table>
The workshop in Bari

Three Sections:

- general aspects of climate change and effects on physiology and productivity
- case studies in different regions
- results of Pilot Assessments
The vulnerability analysis consisted:

1 Herbaceous crops:

Pilot assessment by using DSSAT, SWAP and Cropsyst for

Tomato

Horticultural species – winter and summer cultivations

Sorghum, Durum/soft wheat
The vulnerability analysis consisted:

2 Tree Crops and durum wheat: Statistical analysis to evaluate the impact of CC on phenological aspects (time of flowering) and productivity using data-set collected in Italy.

Durum wheat collection

Yield

Flowering date

APPULO  CAPEITI  CRESO  DUILIO  MESSAPIA  SIMETO  TRINAKRIA  VALNOVA

Data di spigatura (gg)


Resa (q-ha-1)

0 10 20 30 40 50 60 70 80
Peach tree Collection

Yield

- Spring Crest
- May Crest
- Sun Crest

Flowering date

- Spring Crest
- May Crest
- Sun Crest
Statistical analysis to evaluate the impact of CC on phenological and productivity aspects of durum wheat

Domenico Vitale, Domenico Ventrella

1) Preliminary analysis on meteo data: quality control, Homogenization and gap filling, test to evaluate presence of trend

2) Relationship between flowering time and: (i) cumulated daily temperatures with three different threshold; (ii) precipitation

3) Relationship of flowering time and yield with monthly data of temperature (minimum and maximum) and precipitation
1) Correlation between temperature and precipitation

T min – T Max

T min – Prec

T max – Prec
2) Relationship between flowering time and:
(i) cumulated daily temperatures with three different threshold 0-10-15°C;
(ii) precipitation

Flowering Time

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Messapia</td>
<td>0.90</td>
</tr>
<tr>
<td>Karel</td>
<td>0.89</td>
</tr>
<tr>
<td>Capeiti</td>
<td>0.66</td>
</tr>
<tr>
<td>Simeto</td>
<td>0.64</td>
</tr>
<tr>
<td>Appulo</td>
<td>0.59</td>
</tr>
<tr>
<td>Valnova</td>
<td>0.58</td>
</tr>
<tr>
<td>Trinakria</td>
<td>0.57</td>
</tr>
<tr>
<td>Creso</td>
<td>0.48</td>
</tr>
<tr>
<td>Duilio</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Yield

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simeto</td>
<td>0.93</td>
</tr>
<tr>
<td>Karel</td>
<td>0.89</td>
</tr>
<tr>
<td>Trinakria</td>
<td>0.83</td>
</tr>
<tr>
<td>Capeiti</td>
<td>0.82</td>
</tr>
<tr>
<td>Valnova</td>
<td>0.78</td>
</tr>
<tr>
<td>Messapia</td>
<td>0.68</td>
</tr>
<tr>
<td>Duilio</td>
<td>0.66</td>
</tr>
<tr>
<td>Appulo</td>
<td>0.61</td>
</tr>
<tr>
<td>Creso</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Vegetative period = f (+ Cumulated temperatures above 0°C)

Vegetative period = f (- Cumulated temperatures above 5 and 10°C)
3) Relationship of flowering time and yield with monthly data of temperature (minimum and maximum) and precipitation

3.1 Explorative analysis based on independent regressions between flowering time/yield and monthly means of meteo data: 18 for flowering time (6 months x 3 meteo data); 36 for yield (12 months x 3 meteo data)

\[ Y_t = aX_{j,t} + bX_{j,t}^2 \]

Problem: autocorrelation between meteo data (Tmax vs Tmin, Tmin vs Rainfall)
3) Relationship of flowering time and yield with monthly data of temperature (minimum and maximum) and precipitation

3.2 Choice of regression model with the three most significant climatic variables

\[ Y_t = aX_{1,J,t} + bX_{1,J,t}^2 + cX_{2,J,t} + dX_{2,J,t}^2 + eX_{3,J,t} + fX_{3,J,t}^2 \]
Examples of scatter plots for vegetative period length
Examples of scatter plots for Yield

CRESO

APPULO

CAPEITI

DUILIO

KAREL

MESSAPIA

31
3) Relationship of flowering time and yield with monthly data of temperature (minimum and maximum) and precipitation:

**Results**

| Vegetative period length | Maximum temperature of November (+)  
|--------------------------|---------------------------------------|
|                          | Maximum Temperature of March (-)  
|                          | Rainfall in March (for Creso, Duilio and Simeto)  
| Yield                    | Minimum Temperature and Precipitation in November  
|                          | Precipitation in April  
|                          | Minimum Temperature in March  

Case studies in Basilicata: winter scarola (lettuce), grain sorghum and water melon

Domenico Ventrella, Luisa Giglio

Agricultural Research Council
Research Unit for cropping systems in dry environments (CRA-SCA)  Bari, Italy
The area of reference:
The Maximum Temperature

![Graph showing the maximum temperature over different months for different series labeled RIF, B2, and A2. The x-axis represents the months from January to December, and the y-axis represents the temperature in °C. Each series is represented by a different symbol and color. The graph shows a trend where the temperature generally increases towards the end of the year.]
The Minimum Temperature

![Graph showing the minimum temperature over months with different symbols for RIF, B2, and A2 categories. The x-axis represents the months (Gen, Feb, Mar, Apr, Mag, Giu, Lug, Ago, Set, Ott, Nov, Dic) and the y-axis represents the temperature in °C. The graph includes data points for each category, indicating trends and comparisons.]
The Precipitations

![Bar chart showing precipitation data for different months and scenarios RIF, B2, A2.](chart.png)
SWAP (Soil-Water-Atmosphere-Plant)

A physical based model that simulates water and solute in saturated and unsaturated soils. The model is particularly useful for field scale.
The daily evapotranspiration = the evapotranspirative demand of the atmosphere

\[
\Delta_{ETp} = 100 \frac{ETp_{future} - ETp_{past}}{ETp_{past}}
\]

<table>
<thead>
<tr>
<th>Season</th>
<th>Crop</th>
<th>B2</th>
<th>A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn</td>
<td>scarola</td>
<td>+3</td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>scarola</td>
<td></td>
<td>+4</td>
</tr>
<tr>
<td>Spring</td>
<td>melon</td>
<td></td>
<td>+11</td>
</tr>
<tr>
<td>Summer</td>
<td>melon</td>
<td></td>
<td>+14</td>
</tr>
<tr>
<td></td>
<td>sorghum</td>
<td></td>
<td>+16</td>
</tr>
<tr>
<td></td>
<td>sorghum</td>
<td></td>
<td>+20</td>
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## Detailed approach (WOFOST) to simulate the sorghum growth

<table>
<thead>
<tr>
<th>Measured parameters</th>
<th>Calibrated parameters</th>
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<tbody>
<tr>
<td>$TSUMEA$</td>
<td>Temperature sum from emergence to anthesis</td>
</tr>
<tr>
<td>$TSUMAM$</td>
<td>Maximum rooting depth of crop</td>
</tr>
<tr>
<td>$RGRLAI$</td>
<td>Crop height</td>
</tr>
<tr>
<td>$SLATB$</td>
<td>Relative maintenance respiration of leaves, storage organs, roots and stems</td>
</tr>
<tr>
<td>$TDWI$</td>
<td>Efficiency of conversion of assimilates into leaves, storage organs, roots and stems</td>
</tr>
<tr>
<td>$CH$</td>
<td>Partitioning factors of dry matter into root, leaves, stems and storage organs.</td>
</tr>
</tbody>
</table>

**Cycle:** spring - summer  
**Date of sowing:** 01 may  
**Date of harvesting:** 7 september  
**Type of soil:** clay
The calibration for sorghum in 2000

\[ R^2 = 0.96 \]
\[ a = -0.50 \text{ ns} \]
\[ b = 1.13 \text{ ns} \]
\[ \text{RMSE} = 14.14\% \]

\[ R^2 = 0.98 \]
\[ a = -5.95 \text{ kg ha}^{-1} \text{ ns} \]
\[ b = 0.90 \text{ ns} \]
\[ \text{RMSE} = 15.24\% \]
The validation for sorghum in 1993

LAI

R² = 0.91
a = 0.35 ns
b = 0.98 ns
RMSE = 16.39%

Biomass (kg ha⁻¹)

R² = 0.97
a = 363.68 kg ha⁻¹ ns
b = 0.75 ns
RMSE = 31.04%
The validation for sorghum in 1994

**LAI**

- $R^2 = 0.89$
- $a = -0.28$ ns
- $b = 1.32$ ns
- RMSE = 45.64%

**Biomass (kg ha$^{-1}$)**

- $R^2 = 0.94$
- $a = 292.20$ kg ha$^{-1}$ ns
- $b = 0.84$ ns
- RMSE = 25.71%
The validation for sorghum in 1995

**LAI**

$R^2 = 0.92$

$a = -0.81$ ns

$b = 1.10$ ns

$RMSE = 18.88\%$

**Biomass (kg ha$^{-1}$)**

$R^2 = 0.94$

$a = -177.15$ kg ha$^{-1}$ ns

$b = 0.68$ **

$RMSE = 42.75\%$
Water Balance for Sorghum cultivation

\[ \Delta = 100 \frac{Y_{future} - Y_{past}}{Y_{past}} \]

Lc = cycle length
P = precipitation
I = Irrigation
Teff = Actual Transpiration
Eeff = Actual Evaporation
The Yield of Sorghum

![Graph showing the yield of biomass and grain for two different varieties, B2 and A2. The graph indicates a decrease in yield for both biomass and grain compared to a baseline.](image-url)
The cycle of Sorghum

- Vegetative period
- Reproductive period

Yield

Days from transplanting

Grain yield (q/ha)
**Scarola** (*Cichorium endivia* var. *latifolium* Hegi cv Grovers Giant)

- **Cycle**: winter
- **Date of transplanting**: 15 October
- **Date of harvest**: 3 March
- **Soil**: sand

SWAP WITH SIMPLE METHOD TO SIMULATE CROP GROWTH
Scarola: WINTER LETTUCE

Water Balance

Lc = cycle length  
P = precipitation  
I = irrigation  
ETeff = Actual Evapotranspiration  
D = Drainage
The Watermelon cultivation in Southern Italy

- Transplanting time: end of March – April
- Inter-row of 2.5-3 m – plant every 1-1.5 m
- Black Plastic Film of 0.50 m
- Drip irrigation
- Tunnel with transparent and plastic film in the first month of cultivation to bring forward the crop growth
Lc = cycle length
P = precipitation
I = Irrigation
T = Transpiration
E = Evaporation
D = Drainage
Climate change

- Increase of Temperature
- Variation on Rainfall

Increase of evaporative demand of atmosphere

Shortening of the crop cycle

Irrigation requirement at seasonal scale

+/−
VULNERABILITY OF TOMATO TO CLIMATE CHANGE IN PUGLIA

Michele Rinaldi and Domenico Ventrella

Consiglio per la Ricerca e Sperimentazione in Agricoltura
Unità di Ricerca per i sistemi colturali degli ambienti caldo-aridi,
ex-Istituto Sperimentale Agronomico di Bari
The area of reference:
CO$_2$ and CROPGRO

Photosynthesis at leaf scale  
**Upscaling Sub-model**  
Photosynthesis at canopy scale

Model that simulates the relationships between

Photosynthesis  
Water balance  
Canopy energy balance

Relationship between Co$_2$ and water balance

Water stress  
Stomata closure  
Reduction of flux of CO$_2$ in the canopy  
Reduction of Photosynthes is rate

High [CO$_2$]  
Stomata closure  
Decrease of plant transpiration
The calibration of CROPGRO

For biomass

For soil water content
Tomato simulated with CROPGRO model

Genotype: ibrid PS 1296

Soil: silt-clay soil
Transplanting time: first of May
Harvest time: half of August
Typical irrigation: localized method
Anomalies of T MAX

MAY - AUGUST

Anomalies of T MIN

MAY - AUGUST

Futuro B2
Futuro A2
Simulations with CROPGRO

Simulations:
- Potential
- With automatic irrigation

Climatic series:
- Past
- Future B2
- Future A2

1) Without CO\textsubscript{2} effect
   (Simulation 1)

2) With effect of CO\textsubscript{2}
   (Simulation 2)
Results
Simulazione 2 (with [CO₂])

Harvest Index

- Passato
- Futuro - B2
- Futuro - A2

Cycle length

- Passato
- Futuro - B2
- Futuro - A2

Number of Irrigations

- Passato
- Futuro - B2
- Futuro - A2

Irrigation depth (mm)

- Passato
- Futuro - B2
- Futuro - A2
CONCLUSIONS

The shortening of cycle, because of warming, determines very significant effects for Sorghum, Scarola and Watermelon causing reduction of rainfall, ET and yield (Sorghum). The variations of irrigation requirements are less consistent ranging from -15 to +5%.

Tomato, a C3 plant with a spring-summer cycle, has been simulated according taking and no-taking in account the CO₂ effect.

No taking in account the CO₂ the climate change for A2 and B2 determined shortening of cycle, increasing of water use, and yield, WUE and WUEIRR.

Taking in account the CO₂ overcomes the negative effect of Climate Change on tomato yield.
Outlook to WP3

1) Carry out the regional pilot assessment in order to define agronomic adaptation strategies by means of climate scenario analysis and modelling approach. The candidate agronomic practices will be:

- Early sowing (or transplanting) times
- Adoption of varieties with longer cycle
- Irrigation strategies to save water and increase the Water Use Efficiency
- Supplemental Irrigation for rainfed-crop (winter wheat)
- Possibility of extending the crop season to include other crops (if the water irrigation is not a limiting factor)
2) Above all for tree crops, to analyze available studies in national and international literature regarding the ongoing and feasible potential adaptation measures on selected and representative agroecosystems in Italy (Puglia/Basilicata regions and Emilia-Romagna region)

3) Analysis of uncertainties, cost/benefits, risks, opportunities for co-benefits of adaptation measures