Sustainability of irrigated crops under future climate: the interplay of irrigation strategies and cultivar responses

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introduction

• Climate evolution will cause significant changes in the quality and availability of water resources

• Present irrigation practices will be sustainable in the future?

• With respect to crop productivity, which adaptation measurements will protect primary production?

• Our point of view - the biodiversity of agricultural crops is a powerful mean to cope with the effects of the changing climate
Outline

- the AGROSCENARI project
- the research approach and the study area
- the case study on processing tomato crop
  - temporal and spatial pattern of soils’ water balance
  - crops’ yield responses to water availability
  - adaptation options
the AGROSCENARI project

OBJECTIVE - to identify adaptation options to climate change of the most important Italian agricultural systems

Poster session SSS 11.3
Bonfante et al The use of an hydrological physically based model to evaluate the effects of climate change and of irrigation strategy on maize crop: the case study of an irrigation district in Southern Italy

funded by the Italian Ministry for Agricultural, Food and Forest Policies (MIPAAF, D.M. 8608/7303/2008)
the representation of climate in AGROSCENARI

reference climate 1961-90
grid with 35 km spatial resolution

daily data
  Tmax
  Tmin
  rain

future climate 2021-50
focused on grid points in the study areas
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three components of the research approach

climate scenarios

hydrological model of the soil - plant - atmosphere system at landscape scale

inputs
climate soil crop management

outputs
actual ET actual T soil water content soil matric potential irrigation volume

climatic requirements of crops and cultivars

yield response functions – variety specific

EGU General Assembly 2012 Vienna 22-27 April
the study area “destra sele”
Campania region

soils

- heterogeneous parent material: conoid, terraces, alluvial plain
- very different soil types: mollisols, alfisols, inceptisols and entisols
- see Bonfante et al – Poster session SSS 11.3

irrigation

- 15,000 ha irrigated surface
- pipeline pressurized network
- on-demand schedule

crops

- protected: 3500-4000 ha
- horticulture
- field: spring-summer 3300 ha
- horticulture: winter 8000 ha
the study area “destra sele”

climate change projections

from reference (1961-90) to future (2021-50) climate scenario

summer maximum temperatures
1961-90 and 2021-50

% variation of seasonal precipitation
2021-50 vs 1961-90
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**The case study on processing tomato crop**

- Tomato crop from May to August (rotation: tomato cauliflower melon fennel)
- Two climate scenarios: 1961-90 and 2021-50
- Three scenarios of water management:
  - Unlimited on-demand irrigation schedule
  - 20% and 40% reduction of irrigation volumes

**Environmental and management variables (May-August)**

<table>
<thead>
<tr>
<th>Climate</th>
<th>ETp</th>
<th>Rain</th>
<th>Seasonal irrigation volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>mm</td>
<td>optimal</td>
</tr>
<tr>
<td>1961-90</td>
<td>556 (±16)</td>
<td>104 (±46)</td>
<td>392 (±51)</td>
</tr>
<tr>
<td>2021-50</td>
<td>596 (±9)</td>
<td>116 (±37)</td>
<td>435 (±44)</td>
</tr>
<tr>
<td>Δ 2021-50 vs 1961-90</td>
<td>+ 7%</td>
<td>+ 11%</td>
<td>+ 11%</td>
</tr>
</tbody>
</table>
**estimation of potential ET in the future climate scenario**

- Yates and Strzepek (1994) WP - International Institute for Applied System Analysis (A)
- 4 river basins spanning a range of size and climate variability
- Sensitivity analysis to temperature variations of methods to estimate potential ET

**variation of ET\(p\) with temperature increase**

<table>
<thead>
<tr>
<th>method</th>
<th>change in potential ET estimates per 1°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
</tr>
<tr>
<td>Penman</td>
<td>3.75%</td>
</tr>
<tr>
<td>Priestley-Taylor</td>
<td>3.5%</td>
</tr>
<tr>
<td>Hargreaves</td>
<td>5.5%</td>
</tr>
<tr>
<td>Thornthwaite</td>
<td>8.75%</td>
</tr>
<tr>
<td>Blaney-Criddle</td>
<td>4.75%</td>
</tr>
</tbody>
</table>

**estimation of potential ET**

1961-90 ➔ Priestley-Taylor
2021-50 ➔ ET1961-90 \(\times\) T difference 2021-50 vs 1961-90 \(\times\) rate of change

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results: the soil water availability in the two climate scenarios

optimal irrigation scheduling

deficit irrigation - future climate

irrigation volumes

Crop Water Stress Index

Crop Water Stress Index

relevant impact of soil properties on irrigation volumes and plant water availability

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results: the spatial distribution of ET deficit

variations of CWSI in the future climate scenario – deficit irrigation

increase of CWSI vs optimal irrigation

<table>
<thead>
<tr>
<th>Irrigation Volume - 20%</th>
<th>Irrigation Volume - 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01 0.03</td>
<td>0.21 0.23</td>
</tr>
<tr>
<td>0.03 0.06</td>
<td>0.09 0.12</td>
</tr>
<tr>
<td>0.06 0.09</td>
<td>0.12 0.15</td>
</tr>
<tr>
<td>0.09 0.12</td>
<td>0.15 0.18</td>
</tr>
<tr>
<td>0.12 0.15</td>
<td>0.18 0.21</td>
</tr>
<tr>
<td>0.15 0.18</td>
<td></td>
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yield response functions to soil water availability

threshold-slope regression model fitted to experimental data

tomato cv Brigade

cultivar’s specific critical value of CWSI

Cultivars’ specific critical values of CWSI

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brigade</td>
<td>0.25</td>
</tr>
<tr>
<td>Solerosso</td>
<td>0.18</td>
</tr>
<tr>
<td>Design</td>
<td>0.15</td>
</tr>
<tr>
<td>Season</td>
<td>0.13</td>
</tr>
</tbody>
</table>

The indicator of soil water availability (e.g. CWSI) in each soil unit and for each realization of climate scenario is compared with the cv-specific critical value to identify adaptation options.
adaptation options

extent and spatial distribution of areas where 2 cvs will be adapted in the future climate scenario

cultivars were considered adapted when the simulated CWSI in the soil unit resulted above cvs’ critical values in at least 90% of realizations

optimal irrigation scheduling
full adaptability for both cvs

adaptability cv Solerosso
critical value 0.18

deficit irrigation -20%

adaptability cv Design
critical value 0.15

EGU General Assembly 20
concluding remarks

• impacts of CC on agro-ecosystems can be analyzed by simulation models, coupled with GCMs, accounting for local climate variability

• studies that combine experimental results with simulation models of water regime allow to identify critical environmental conditions

• the (already existing) intra-specific biodiversity of crops is relevant, and can provide significant opportunities for adaptation of agro-ecosystems