Hydrological and water resource responses to climate change for a temporary river: implications for river ecosystems

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Objectives

• To analyze the potential impacts of future climate scenarios on water balance and flow regime in intermittent rivers.
• To contribute to the scientific understanding of climate change impact on water resources in Mediterranean Basin and provide information to support long-term water resources management and planning.

Steps

• Adopt 3 climate scenarios (2030-2059) and implement a statistical downscaling procedure.
• Use SWAT to simulate water balance at basin scale and streamflow in a number of river reaches for all the climatic scenarios.
• Assess flow regime alterations under changing climate by using the Indicators of Hydrological Alterations (IHA)
Study area: the Candelaro River

- The basin is located into the second large plain in Italy.
- It includes large intensive irrigated agricultural areas (cereals, horticulture, energy crops). Irrigation uses water resources from groundwater and neighbouring Regions. Trade-off of such resource use has been matter for complex negotiations between Regions.
- Water for irrigation is distributed by the largest irrigation consortium in Italy (and in the EU).
- Part of the catchment belongs to the Gargano National Park including an important wetland (Ramsar site).
- The area has been classified as a hot spot area under risk of desertification.
- Severe flood events happen frequently (damages and casualties) and alternate with droughts.
Relevance of the flashy / intermittent rivers

- **Streamflow affects numerous processes**, including sediment regime, channel formation, floodplain and flood processes, groundwater and surface water interactions, nutrient delivery, water quality and ecosystem support to living communities.

- In the Mediterranean region intermittent and ephemeral streams are **very common** fluvial systems.

- These rivers show a **high rate of change** in streamflow, high peak discharges and low baseflow.

- A large part of their annual volume flows in a **few days**, delivering a great part of their sediment and nutrient loads.

- The **EU Water Framework Directive** pays little attention to this kind of rivers (classification, monitoring, program of measures, ...)

- Despite the limited streamflow, these rivers play a huge role in securing **water resources** to a large number of human communities
The baseline period (1980-2009) is representative of the recent average climate in the study region and features a range of climatic variations, including severe droughts and cold seasons (IPCC, 1994).

Climate scenarios (A1 family):
- (S1) **KNMI_RACMO_ECHAM5**
- (S2) **MPI_REMO_ECHAM5**
- (S3) **SMHI_RCA_ECHAM5**

Baseline: 1980-2009
Future: 2030-2059
Measured and downscaled Tmax daily data for the months of January over the validation period (2000-2009) at one of the gauges (Troia). Non linear regression (NLN; R²=0.995) and linear regression (LIN; R²=0.979).
All the scenarios gave rather similar results
Slight increase of temperature all along the year
Decrease in precipitation, mostly in January-April
Water Balance changes

• No land use changes has been assumed for the future
• An increase of 4% in irrigation has been considered only for currently irrigated areas
• A decrease of blue water forecasted for all scenarios (up to 18%)
• A decrease in Eta (up to 3%)
### Change in available water resources

#### Table:

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm)</td>
<td>635</td>
<td>614</td>
<td>3</td>
</tr>
<tr>
<td>Diff. in rain (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue water (mm)</td>
<td>142</td>
<td>146</td>
<td>120</td>
</tr>
<tr>
<td>Diff. blue water (%)</td>
<td></td>
<td></td>
<td>-18</td>
</tr>
<tr>
<td>Green water flow (mm)</td>
<td>497</td>
<td>475</td>
<td>459</td>
</tr>
<tr>
<td>Diff. Green water flow (%)</td>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

#### Chart:

- **Legend:**
  - Blue line: Mean flow baseline
  - Red line: Mean flow future scenario (MPI)

#### Note:

- **2.3 million cubic meters of water no more available in the Celone Dam = \(\frac{1}{8}\) of available volume**
“Zero flow” days tendency

Increase of over 20 days of “zero flow”
## Permanent, intermittent-pools, intermittent-dry or episodic?

<table>
<thead>
<tr>
<th>Stream type</th>
<th>Flow duration</th>
<th>Pools duration</th>
<th>Dry period</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Permanent</td>
<td>≥ 10 months per year</td>
<td>≤ 2 months per year</td>
<td>No occurrence</td>
</tr>
<tr>
<td>I-P - Intermittent-pools</td>
<td>≥ 3 months per year</td>
<td>≤ 9 months per year</td>
<td>≤ 1 month</td>
</tr>
<tr>
<td>I-D - Intermittent-dry</td>
<td>≥ 3 months per year</td>
<td>≥ 1 but &lt; 3</td>
<td>≥ 1 month</td>
</tr>
<tr>
<td>E - Ephemeral-Episodic</td>
<td>&lt; 2 months per year</td>
<td>&lt; 2 months</td>
<td>≥ 10 months</td>
</tr>
</tbody>
</table>
Changes in stream classification

Mf: relative annual number of months with flow
Sd6: six-month dry season defined by the Equation:

\[ S_{d6} = 1 - \left( \frac{\sum F_{d1}}{\sum F_{dj}} \right) \]

Where

- Fdi is the multi-annual frequency of the zero-flow months for the contiguous six wetter months per year
- Fdj is the multi-annual frequency of the zero-flow months for the remaining drier six months.

P: Permanent
I-P: Intermittent-Pools
I-D: Intermittent-Dry
E: Ephemeral-Episodic
Types of temporary streams (baseline)

<table>
<thead>
<tr>
<th>General Classification</th>
<th>Number of River Segments</th>
<th>River Length, Km</th>
<th>Total Length %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Episodic</td>
<td>123</td>
<td>350.01</td>
<td>31.57</td>
</tr>
<tr>
<td>Intermittent Dry</td>
<td>55</td>
<td>368.46</td>
<td>33.23</td>
</tr>
<tr>
<td>Intermittent Pools</td>
<td>53</td>
<td>316.49</td>
<td>28.55</td>
</tr>
<tr>
<td>Permanent</td>
<td>12</td>
<td>73.70</td>
<td>6.65</td>
</tr>
</tbody>
</table>
Relevance of elongated low flow period in ecohydrology

• River segment remained dry for a long time and the water content in the alluvial soil constituting the river bed became similar to the surrounding terrestrial soil. Consequently, a different ecosystem may colonize the stream whose river bed may be invaded by plants and terrestrial fauna.

• Flow permanence can become too short for aquatic fauna to re-colonize the stream (Munné and Prat, 2011)

• An increase in lentic flow-related habitat may determine a decrease in the values of metrics used to evaluate Ecological Status. Thus, if these conditions are due to a natural variability in streamflow, a correction of ES assessment systems is needed in order to avoid an underestimation of the ecological quality (Buffagni et al., 2009).
Conclusions

• In the Mediterranean area **accurate downscaling** of climate models is needed

• **Moderate expected changes** in forcing variables can result in **sensible changes in the water balance**, in the flow regime and in the capability of river systems to support biological communities

• Sensible **water resources reductions** can be expected

• **Longer low and zero flow conditions** can be expected, that can impair the survival and reproductive success of several organisms

• The **classification of streams** (WFD) can change along the time

• River Basin management (**POMs**) must **adapt** to changing climate
Thank you for your attention!