Climate change impacts on water availability in three Mediterranean watersheds of Catalonia (NE Spain)

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The project

**MAIN AIMS:**

- Assess **territorial vulnerability** of three diverse Mediterranean watersheds in Catalonia with regard to the main effects of **global change** on **water availability**

- **Define** possible **adaptive options** based on the assessment of territorial and social vulnerability

The project has been developed during **three years** by **four** different **research institutions** with an interdisciplinary approach.
Study areas are three medium size watersheds:

- **Fluvià** (977 mm, 13 °C)
- **Tordera** (819 mm, 14 °C)
- **Siurana** (589 mm, 13 °C)
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**Background**

Mediterranean basin might become one of the **most vulnerable areas** in Europe regarding **climate change** at the end of the Century.

Mediterranean basin might suffer a **significant decrease in runoff** at the end of the Century.

Source: IPCC, Christensen et al. and Alcamo et al. 2007
A 1.9 °C temperature increase since 1979 has been monitored at the three watersheds.
Precipitation in March (mm/year) from 1951-2000

Precipitation changes in March (mm/year)

Significant area at 95% confidence level

Annual precipitation (mm)

FLUVIÀ Castelló d'Empúries 0.67 mm/year

CLIMATE: OBSERVED PRECIPITATION TRENDS

No significant changes in annual precipitation...

...but significant changes in certain months
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Model calibration: Based on stream flow series from 12 gauging stations and climatic series from 23 meteorological stations

Available data: 1984-2008 (25 years)

Calibration and validation: Daily time step, 3 - 4 years periods

Objectives:

- simulated hydrograph similar to observed one,
- mean flow values and total contributions similar between simulated and measured data,
- Adequate values of statistics (Nash and Sutcliffe efficiency coefficient (NSE) and RMSE-observations standard deviation ratio (RSR))
SWAT calibration and validation

Daily stream flow (m$^3$/s)

Fluvià

Tordera

Siurana

Observed data
SWAT simulated data

Daily data

<table>
<thead>
<tr>
<th></th>
<th>Simulated mean daily discharge (m$^3$/s)</th>
<th>Observed mean daily discharge (m$^3$/s)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluvià (Garrigàs)</td>
<td>9.1</td>
<td>7.1</td>
<td>NSE 0.5</td>
</tr>
<tr>
<td>Tordera (Can Serra)</td>
<td>4.3</td>
<td>3.6</td>
<td>RSR 0.7</td>
</tr>
<tr>
<td>Siurana (Cornudella)</td>
<td>0.2</td>
<td>0.2</td>
<td>RSR 0.7</td>
</tr>
</tbody>
</table>
SWAT calibration and validation

Fluvia

<table>
<thead>
<tr>
<th>Simulated mean daily discharge (m³/s)</th>
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<tr>
<td>Fluvià (Garrigàs)</td>
<td>8.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Tordera (Can Serra)</td>
<td>3.9</td>
<td>3.5</td>
</tr>
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Climate projections at global scale

- CO₂ emissions global scenarios (IPCC): B1, A2

- Atmospheric and Oceanic General Circulation Model (AOGCM): ECHAM5

- Dynamic downscaling (SMC): high temporal and spatial resolution (6 h and 15 km), period 2001-2100 and reference period 1971-2000

Source: IPCC (Intergovernmental Panel on Climate Change), SMC (Meteorological Service of Catalonia)
Climate projections at regional scale

FUTURE PRECIPITATION TRENDS

FUTURE TEMPERATURE TRENDS

2006-2030: -2.4 to -3%
2076-2100: -12.2 to -15.3%

2006-2030: -7.6 to -9.6%
2076-2100: -24 to -28.3%

Source: SMC 2010 (Meteorological Service of Catalonia)
Climate projections at regional scale

FUTURE PRECIPITATION TRENDS

FUTURE TEMPERATURE TRENDS

2006-2030: +0.51 to +0.58 ºC  
2076-2100: +2.2 to +2.3 ºC

2006-2030: +0.26 to +0.47 ºC  
2076-2100: +3.4 to 3.6 ºC

Source: SMC 2010 (Meteorological Service of Catalonia)
Precipitation spatial distribution

**PRECIPITATION REDUCTION AT XXI CENTURY (mm/decade)**

A2 climate scenario predicts stronger and significant reductions, specially on headwaters

Source: SMC 2010 (Meteorological Service of Catalonia)
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**Results**

**RELATIVE STREAM FLOW CHANGES RESPECT 1984-2008 (%)**

### Short term (2006-2030)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Stream flow variation at headwater</th>
<th>Stream flow variation at river mouth</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>-14 -9 +4%</td>
<td>-9 -9 +5%</td>
</tr>
<tr>
<td>A2</td>
<td>-20 -13 -16%</td>
<td>-14 -18 -16%</td>
</tr>
</tbody>
</table>

- Fluv | Tord | Siu |

- Generalized stream flow reduction, more severe at A2 scenario (-33 to -39 % at long term, scenario A2)

### Long term (2076-2100)

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<tr>
<td>B1</td>
<td>-31 -22 -22%</td>
<td>-22 -25 -22%</td>
</tr>
<tr>
<td>A2</td>
<td>-48 -33 -32%</td>
<td>-39 -37 -33%</td>
</tr>
</tbody>
</table>

- Fluv | Tord | Siu |

- Stronger reductions are expected at **Fluvia headwater** (-20 to -48 % at A2 scenario)

- Scenario B1 predicts a **slight** stream flow increase in **Siurana** basin at short term
Autumn and summer will be the most affected seasons in both scenarios by the end of the Century.

Seasonal changes can affect water supply for agricultural and urban uses.
By the end of the Century, a **14 to 25 %** reduction of **real evapotranspiration** is expected.
Results

ECOLOGICAL FLOW VARIATION (FLUVIÀ)

By the end of the Century, the number of days per year with stream flow lower than ecological flow will increase (more than 90 days in A2)
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Discussion and conclusions

- SWAT is an appropriate tool to assess climate change impacts on Mediterranean watersheds.

- A strong alteration on water dynamics is expected during the XXI Century:
  - 22% to 48% reduction of stream flow, more severe in the A2 scenario than in the B1.
  - Reductions especially severe in the wetter headwaters (Fluvià and Tordera).
  - Autumn and summer are expected to be the most affected seasons.
  - 14% to 25% reduction of real evapotranspiration.

- Greater vulnerability of wet watersheds in northern Catalonia, where present ecosystems are more sensitive to changes in environmental conditions.

- Results highlight the strong impact of climate change on regional water resources and stress the need for incorporating these analyses into adaptive management in the Mediterranean region.
Thank you!

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