Effects of climate change on the Nossana karst spring (northern Italy): future discharge projections and water distribution system sustainability

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Objectives

- Quantification of the expected changes in precipitation and temperature in the study area (reference period 1998-2017)
- Calibration and validation of a hydrological lumped-parameter model based on observed data
- Recognition of possible limits in the future utilization of the spring as a drinking supply (2021-2100)
Study Area

Legend

- Nossana Spring
- Main town
- Meteorological station
- Mountain peak
- Fault
- Thrust
- Nossana catchment
- Main rivers
- Slope deposit
- Alluvial deposit
- Low permeable unit
- High permeable unit
- Intense karst area
Methods

Input:
- RCMs P
- RCMs T
- Obs P
- Obs T
- Calculated E
- Obs Q

Methodology:
- Climate Model Evaluation
  - Performance Indices
- Selected Climate Models
- Statistical Downscaling
- GR4J + CemaNeige Calibration – Vadation
  - Performance Indices
  - Warning Thresholds
- Calibrated hydrological model

Output:
- Local scale Climate Change signature
- Future local time series
  - Precipitation
  - Minimum Temperature
  - Maximum Temperature
  - Calculated Evapotranspiration
- Future discharges

For RCP future scenarios:
- RCP 2.6 → 3 models
- RCP 4.5 → 3 models
- RCP 8.5 → 3 models
Reference 1998-2017
p1 2021-2040
p2 2041-2060
p3 2061-2080
p4 2081-2100
**Step 1- Climate Model Evaluation**

Precipitation → NSE > 0.0; MAE < 20%

Temperature → NSE > 0.8; MAE < 20%

Reference → 1998-2017

<table>
<thead>
<tr>
<th>Model</th>
<th>Precipitation</th>
<th></th>
<th></th>
<th>Temperature</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NSE</td>
<td>MAE (mm)</td>
<td>%MAE</td>
<td>NSE</td>
<td>MAE (°C)</td>
<td>%MAE</td>
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<tr>
<td>Mod_1 RCP 2.6</td>
<td>0.79</td>
<td>12.35</td>
<td>10.71</td>
<td>0.96</td>
<td>1.10</td>
<td>17.69</td>
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<td>Mod_1 RCP 4.5</td>
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<td>12.97</td>
<td>0.97</td>
<td>1.00</td>
<td>17.19</td>
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<td>11.20</td>
<td>0.97</td>
<td>1.00</td>
<td>15.96</td>
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<tr>
<td>Mod_2 RCP 2.6</td>
<td>0.31</td>
<td>19.81</td>
<td>17.16</td>
<td>0.97</td>
<td>0.90</td>
<td>14.20</td>
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<td>Mod_2 RCP 4.5</td>
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<td>17.44</td>
<td>15.12</td>
<td>0.97</td>
<td>1.00</td>
<td>16.13</td>
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<tr>
<td>Mod_2 RCP 8.5</td>
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<td>22.90</td>
<td>19.85</td>
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<td>Mod_3 RCP 2.6</td>
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<td>15.96</td>
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<td>0.37</td>
<td>17.17</td>
<td>14.88</td>
<td>0.98</td>
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<td>12.79</td>
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<tr>
<td>Mod_3 RCP 8.5</td>
<td>0.52</td>
<td>17.78</td>
<td>15.41</td>
<td>0.98</td>
<td>0.80</td>
<td>12.69</td>
</tr>
</tbody>
</table>
**Step 2 - Statistical Downscaling**

**Using**

\[ \frac{P_{\text{Fut}}^{\text{Fut}}}{P_{\text{Obs}}^{\text{Obs}}} = \frac{P_{\text{RCMFut}}^{\text{RCMFut}}}{P_{\text{RCMCon}}^{\text{RCMCon}}} \]

where \[ \frac{P_{\text{RCMFut}}^{\text{RCMFut}}}{P_{\text{RCMCon}}^{\text{RCMCon}}} = \alpha \]

\[ P_{\text{Fut}}^{\text{Fut}} = \alpha \cdot P_{\text{Obs}}^{\text{Obs}} \]

\[ P = \text{any variable} \]

**Model Parameters**

- Storm origin time \((\lambda)\) [h\(^{-1}\)]
- Number of raincells \((\nu)\) [-]
- Raincell origin delay \((\beta)\) [h\(^{-1}\)]
- Raincell intensity \((\xi)\) [h/mm]
- Raincell duration \((\eta)\) [h\(^{-1}\)]

RainSim V3.0 (Burton et al., 2008),

**Stochastic rainfall model**

Neyman-Scott Rectangular Pulses (NSRP) model

**Rainfall Generator**

- Image by De Luca and Galasso (2019)

Step 2 - Local Scale Climate Change

**SUMMARY**

- Not all models agree on mean annual precipitation trends in different periods
- General precipitation decrease in summer
- Temperature increases up to ≈ 5 °C

Changes in monthly climatology (precipitation and temperature) for twenty-year periods

Relative changes (%) in mean annual precipitation

<table>
<thead>
<tr>
<th>Period</th>
<th>RCP2.6</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
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<tbody>
<tr>
<td></td>
<td>Mod_1</td>
<td>Mod_2</td>
<td>Mod_3</td>
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<tr>
<td>p1</td>
<td>-3.8</td>
<td>2.7</td>
<td>2.4</td>
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<tr>
<td>p2</td>
<td>6.6</td>
<td>-5.2</td>
<td>0.7</td>
</tr>
<tr>
<td>p3</td>
<td>-4.4</td>
<td>5.4</td>
<td>-13.4</td>
</tr>
<tr>
<td>p4</td>
<td>-4.4</td>
<td>8.3</td>
<td>-2.0</td>
</tr>
</tbody>
</table>
Step 3 - Hydrologic Model Calibration

- Random generation of 10,000 model parameter sets
- Calibration: 2000-2008
- Validation: 2009-2017
- Criteria 1: KGE > 0.70; INSE > 0.5
- Criteria 2: number of days and consecutive with discharge below warning thresholds
Step 3 - Hydrologic Model Calibration

- **10 parameter sets**
- **Underestimation number of days below warning thresholds**
- **Maximum number of days below the warning threshold best indicator**

<table>
<thead>
<tr>
<th>Q 1.32</th>
<th>Obs_Cal</th>
<th>Obs_Val</th>
<th>Mod_Cal</th>
<th>Mod_Val</th>
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<tbody>
<tr>
<td>758</td>
<td>335</td>
<td>141-310</td>
<td>102-207</td>
<td></td>
</tr>
<tr>
<td>Q 1.52</td>
<td>992</td>
<td>522</td>
<td>307-513</td>
<td>219-391</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Max days</th>
<th>Obs_Cal</th>
<th>Obs_Val</th>
<th>Mod_Cal</th>
<th>Mod_Val</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q 1.32</td>
<td>71</td>
<td>47</td>
<td>57-63</td>
<td>33-44</td>
</tr>
<tr>
<td>Q 1.52</td>
<td>74</td>
<td>59</td>
<td>63-66</td>
<td>44-53</td>
</tr>
</tbody>
</table>
Step 4 - Future discharges

**SUMMARY**

- Variation of recharge periods
- Variation of annual cycle trend
- Decrease in mean discharge
Step 4 - Future discharges

**132 m$^3$/s threshold**

- Longest period below the 1.32 m$^3$/s warning threshold 36 extra days

**152 m$^3$/s threshold**

- Longest period below the 1.52 m$^3$/s warning threshold 64 extra days.

**After 2060**

- Longest period below the 132 m$^3$/s warning threshold 36 extra days
- Longest period below the 152 m$^3$/s warning threshold 64 extra days.
Conclusion

- Considered bias-corrected EURO-CORDEX RCMs have very good skills in reproducing observed temperature climatology while larger errors persist regarding precipitation.
- Mean temperature will likely increase throughout the rest of the XXI century, from 0.7 °C in 2021-2040 (RCP4.5, Mod_2) to 5.8 °C in 2081-2100 (RCP8.5, Mod_1).
- No clear trend for precipitation, changes in mean annual rainfall varies between −18.5% (2041-2060, RCP4.5, Mod_2) and 15.1% (2041-2060, RCP8.5, Mod_2).
- Pronounced decrease of precipitation is expected in the summer period after 2060.
- Mean discharges are generally projected to decrease in comparison to observed flow.
- After 2060, the length of the periods with discharge lower than the warning thresholds is expected to increase. These periods could last up to 64 days (86%) longer than in 1998-2017.
- Additional water resources might be needed to satisfy the population water demand in the Nossana Spring area, especially after 2060.
THANK YOU

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Extras

- Average monthly SPck Obs
- Average monthly SPck Mod_1
- Average monthly SPck Mod_2
- Average monthly SPck Mod_3
- 30-day average discharge Obs
- 30-day average discharge Sim Mean
- 30-day average discharge Sim
- 30-day average discharge Mod_1
- 30-day average discharge Mod_2
- 30-day average discharge Mod_3