Climate change impact assessment considering water discharge and nutrients in a mesoscale coastal watershed

- input from a catchment to its lagoon -

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• Ria de Aveiro watershed

• Methods and Materials
  ➢ SWIM Model
  ➢ Climate change scenario data

• Results and Discussion
  ➢ Hydrological and water quality calibration and verification
  ➢ CC impact assessment on water discharge and nutrients

• Conclusions and Outlook
Ria de Aveiro watershed

• interface between terrestrial environment and coastal waters

• under various anthropogenic pressures, increasing during last decades

• threats with regard to overall trend of climate change and regional development

• salinization, pollution, variations in water level influenced by processes taking place in watershed

area: 3600 km²
av. precip.: 800 mm/year
av. temp.: 14°C
major landuse: forest (64%), cropland (26%)
major river: Vouga
Methodology

Model set up for entire coastal watershed

Hydrological and water quality calibration

NSE, PBIAS, graph fitting

Changes in seasonal dynamics, Q10, Q90, nutrient loads and water temperature

DEM, Soil map, land use map, point sources, agricultural practices etc.

Observed daily water levels

Measured NO3-N, NH4-N, PO4-P and DOX concentrations & water temp.

ENSEMBLE of different climate change scenarios

Climate change impact studies on water quantity and quality on the total input to the lagoon
**Climate inputs:** Solar radiation, temperature & precipitation

**Hydrosphere**
- Glacier / Snow
- Shallow groundwater
- Deep groundwater

**River network**
- PO4-P
- Porg
- O2
- Algae
- Norg
- NH4-N
- NO3-N

**Pedosphere**
- Nitrogen cycle
  - NO3-N / NH4-N
  - Norg
  - Nres

- Carbon cycle
  - CPOM
  - CAM
  - Cmin

- Phosphorus cycle
  - PLab
  - Pm-ac
  - Pm-st
  - Porg
  - Pres

**Vegetation**
- Biomass
- Roots
- Wetland module
- Crop module
- Forest module

**Management:** land use pattern, land management & water management

**Methods and Materials**

**Results and Discussion**

**Conclusions and Outlook**
Model application

- Topography
- Landuse map
- Soil map
- Subbasin map
- Hydrotope map

Legend:
- ● abstraction points
- ● point sources
- ● climate stations
- ▲ Q gauges
Climate scenario data from a multi-model approach

- variety of different Regional Climate Model (RCMs)
- boundary conditions from different Global Circulation Models (GCMs)
- A1B emission scenario (balanced used of fossil and non-fossil energy resources; assumed growing population until 2050, afterwards decreasing; temp. rise on global scale 1.8 – 4.4 °C until end of 21st century)

resolution of scenarios: **25 or 50km**
simulation period: **1951 – 2050 or 1951 – 2100**

→ 15 climate scenarios
Conclusions and Outlook

Scenarios evaluation

Reference period $p_1 = (1971 – 2000)$
$1^{st}$ future period $p_2 = (2041 – 2070)$
$2^{nd}$ future period $p_3 = (2071 – 2098)$

→ e.g. identify average, wettest and driest
Trends in precipitation and temperature

→ decreasing precipitation

→ increasing temperature
Model performance

Vouga - gauge Ribeirada

NSE = 0.75
PBIAS = -0.64%

Cértima - gauge Ponte Requeixo

Águeda - gauge Ponte Águeda

Ponte Requeixo (av. Q = 5m³/s)

weir during summer

Ponte Águeda (av. Q = 7m³/s)

Ribeirada (av. Q = 25m³/s)
Water quality calibration

Estimations of total N and P for 2011 from ARH Centro

- most pollution from points sources in coastal area
- calibration possible for 2/3 gauges

Legend
- WQ gauges
- Q gauges

Ntotal in kg/year
- <10 kg/year
- <100 kg/year
- <1000 kg/year
- <10000 kg/year
- <50000 kg/year
- <100000 kg/year
- <200000 kg/year
- <500000 kg/year

Elevation in m
- High: 1097
- Low: -10

Ria de Aveiro watershed
Phosphorus calibration

Outlook

Ria de Aveiro watershed

Methods and Materials

Results and Discussion

Conclusions and

Phosphorus calibration
Nitrogen calibration

NH4-N Ponte Requeixo

NH4-N Frossos

NO3-N Estarreja

NO3-N Frossos
Oxygen and water temperature

Outlook

**DOX - Frossos**

**Temperature - Frossos**
Impact assessment on water discharge

Seasonal dynamics for reference period at lagoon’s inlet

• most scenarios project higher flow than observed during calibration period
• on average moderate reduction for both future periods
• high uncertainty in winter
• certainty during summer

Projected runoff for 1st and 2nd future period at main inlet

- 1971-2000
- 2041-2070
- 2071-2098

- Min/Max
- 10/90 Percentile
- 25/75 Percentile
- average
- observed (2002-2005)
- reference
Outlook

Changes of total inflow to the lagoon

- projected mean annual reduction of total inflow to the lagoon of 3% (2041-2070) and 7% (2071-2098)
- higher uncertainty for last half of the century
Outlook

Changes in annual runoff

2047-2070 compared to reference period

Average of simulations driven by all 15 scenarios

2071-2098 compared to reference period

mm/year

< -250  -200  -150  -100  -50  -25  0  < 25
Outlook

Changes in extremes – high flow

- magnitude of high flow (Q10) increases for 11 out of 15 scenarios for 2041-2070 and for 4 scenarios for 2nd period

- Q10 of reference period is reached/exceeded in more than 10% of the time by 7 scenarios in 2041-20710 and by 4 in 2071-2098
Changes in extremes – low flow

- all, except one scenario project a decrease of up to 30% in low flow for both future periods

→ higher risk of droughts
→ decrease of high flow in 2nd period but no clear signal from 1st period
Conclusions and Outlook

Changes in PO4-P loads

- increase during Jan – Feb for 1\textsuperscript{st} period → correlates with overall increase of Q10
- decrease especially during wet season → induced by overall reduction total runoff
- on average loads reduced by 3% (2041-2070) and 7% (2071-2098) with much higher uncertainty in 2\textsuperscript{nd} period
Outlook

Changes in NO3-N loads

- increase during Dec-Mar
  → induced by increased runoff in winter
- overall decreasing trend of 3% (2041-2070) to 7% (2071-2098)
  → correlates with decreasing trend in total runoff
Conclusions

• high deviations of Qmean among scenarios (up to 200%)

• overall decrease in total inflow: 3% in 2041-2070
  7% in 2071-2098

• higher peaks in near future projected by 70% of the scenarios
• decrease of high flows in 2nd scenario period projected by most scenarios
• high certainty about decrease of low flow!!!

• NO$_3$-N and PO$_4$-P trends correlate with overall changes in runoff but also with extreme events > overall reduction of nutrients in combination with increase of loads in months with high flow

• Uncertainty in all trends increases towards the end of the century
Outlook

- Evaluation of inter annual variability and of month of peak occurrence
- Impact assessment on NH$_4$-N, DOX and water temperature
- Development and implementation of future land use scenarios
- Combined impact assessment of climate and land use change
- Estimation of uncertainty
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Some examples for extremes at Frossos

- **Highest simulated daily discharge**
- **Lowest daily discharge in summer**
- **Minimum total annual discharge**
- **Highest total annual discharge**