Impacts of climate and land use changes on the water quality of a vineyard-dominated Mediterranean catchment

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Background

- The Mediterranean Basin has been identified as one of the most vulnerable regions to future climate change.
- Intense vine culture have been recognized to cause high nutrient exports and high soil losses.
- Vine culture is highly dependent on agrochemicals mainly due to the degraded state of Mediterranean vineyard soils and the plant’s sensitivity to pests and diseases.

Aim

- Evaluate the impacts of climate and land use changes on the surface water quality of a vine-dominated catchment (São Lourenço).

Specific goals:

i. Calibrate and validate the SWAT model for nutrient (total nitrogen and phosphorus) and pesticide (total copper) exports in the São Lourenço catchment (present conditions).

ii. Simulate the individual effects of climate and land use change on nutrient and pesticide export under two different gas emission scenarios.

iii. Simulate the combined effects of climate and land use change on nutrient and pesticide export under the same emission scenarios.
Methodology

Study area

Cértima river basin

Land use
- Vineyards - 44%
- Urban areas
- Permanent pasture
- Maritime pine
- Mixed forests
- Eucalypt
- Annual crops

Soil
- Humic Cambisols
- Fluvisols
- Chromic Luvisols
- Calcaric Cambisols
- Cambisols

São Lourenço catchment - 6.2 km²
Modelling approach and scenario development

1. SWAT calibration and validation
   São Lourenço hydrometric station

2a. Simulation of climate change scenarios under current land uses

2b. Simulation of land use change scenarios under current climate conditions

3. Simulation of combined climate and land use scenarios

ECHAM5 GCM
Statistical downscaling
Climate change scenarios

Scenario A1B (2071-2100) - severe
Scenario B1 (2071-2100) - moderate

European land use trends
Linear downscaling
Analysis of local trends
Land use change scenarios

Scenario A1B (2071-2100)
Scenario B1 (2071-2100)
Results and Discussion

Model performance: streamflow

**CALIBRATION**

**VALIDATION**

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NSE = 0.83  
RSR = 0.41  
PBIAS = 0.44

NSE = 0.84  
RSR = 0.40  
PBIAS = -3.34

**Good performance**

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*NSE* – Nash-Sutcliffe coefficient  
*RSR* – Root Mean Square error/ Standard deviation  
PBIAS – Percent of bias
Results and Discussion

Model performance: sediments

Moriasi et al. (2007) indicators:
NSE – Nash-Sutcliffe coefficient
RSR – Root Mean Square error/ Standard deviation
PBIAS – Percent of bias

CALIBRATION

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VALIDATION

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Satisfactory performance

Model underestimation - no continuous measurement of sediment concentrations in the catchment
Results and Discussion

Model performance: total nitrogen

**Moriiasi et al. (2007) indicators:**

- **NSE** – Nash-Sutcliffe coefficient
- **RSR** – Root Mean Square error/ Standard deviation
- **PBIAS** – Percent of bias

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<td>NSE</td>
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<td>RSR</td>
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<td>PBIAS</td>
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Model performance:

- Total nitrogen: Satisfactory performance
- Model consistently underestimated the major export peaks – variation of fertilization practices and non-continuous measurements
Results and Discussion

Model performance: total phosphorus

Moriasi et al. (2007) indicators:

NSE – Nash-Sutcliffe coefficient
RSR – Root Mean Square error/Standard deviation
PBIAS – Percent of bias

NSE

RSR

PBIAS

Good performance

Model performance:
total phosphorus

NSE = 0.76
RSR = 0.50
PBIAS = -22.8

NSE = 0.80
RSR = 0.45
PBIAS = 18.8
Results and Discussion

Model performance: total copper

Model reasonably reproduced daily exports with some underestimation of peaks - Cu levels were not measured continuously but just at selected water levels during storm hydrograph
Results and Discussion

Climate change scenarios

Baseline: 1971-2000

Future Scenario A1B (2071-2100) - severe
Future Scenario B1 (2071-2100) - moderate

São Lourenço

- 12% reduction in annual rainfall
- 19% increase in winter rainfall
- Temperature increase
  - Scenario A1B = 2.2°C
  - Scenario B1 = 1.1°C
## Results and Discussion

### Land use change scenarios

<table>
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<th>LAND USE</th>
<th>Baseline</th>
<th>A1B</th>
<th>B1</th>
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<tbody>
<tr>
<td>Vineyards</td>
<td>43.9</td>
<td>37.1</td>
<td>43.9</td>
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<tr>
<td>Maritime pine</td>
<td>26.5</td>
<td>26.5</td>
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<td>Corn</td>
<td>12.1</td>
<td>23.9</td>
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<td>Potato</td>
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<td>Urban area</td>
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<td>Permanent pasture</td>
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<tr>
<td>Eucalypt</td>
<td>2.7</td>
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<td>Mixed forests</td>
<td>1.5</td>
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- **Less subsistence agriculture** (potatoes, pasture, small vineyards)
- **More corn** (for biofuel)
- **More forests** (eucalypt or pine)

Future land use scenarios predict a replacement of traditional agricultural crops such as potato, pastures and small vineyards by corn (for biofuel production) and commercial forests.

Existing permanent pastures and mixed forests would be replaced by more economically valuable eucalypt plantations in scenario A1B, and by more sustainable maritime pine forests in scenario B1.
Results and Discussion

Scenarios analysis - individual effects and combined effects

- **Reduction in precipitation** as a result of climate changes is likely to **reduce** streamflow
- **Increase in irrigated crops** (e.g. corn) **adds** water to the system
- **Combined scenarios** had off-setting effects on stream discharge

- **Decrease** in precipitation **reduces** soil erosion
- **Cultivation of more soil protective crops** (e.g. eucalypt and pine) **reduces** soil erosion
- **Climate and land use changes** have **cumulative effects** on soil erosion
Results and Discussion

Scenarios analysis - individual effects and combined effects

- **Climate changes** tend to reduce nutrient and copper exports
- **Land use changes** might have a greater effect than climate changes on contaminant export
- **Additive effects** were observed in the combined scenarios
Conclusions

- **Climate changes** have a more pronounced effect on water yields than land use changes.

- **Land use changes** have a marked effect on sediment and contaminant export, which reinforces the importance of land management for minimizing the effects of climate changes on water and soil resources.

- **Land use practices that can mitigate** the impacts of climate changes on viticulture-impacted basins include: maintenance of vegetation with permanent cover, reduction of tillage operations, **adjusted fertilizer** management, proactive pesticide use.

Future work

- Upscale the model for the Cértima catchment, to evaluate the future chemical and ecological status of this water body, which is presently one of the most polluted in Portugal.
Acknowledgements

Thanks for your attention
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Impacts of climate and land use changes on the water quality of a small Mediterranean catchment with intensive viticulture

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