Spatial and temporal explicit catchment modelling in aquatic risk assessment using the modular framework CMF

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1. Introduction

The EFSA Guidance Document on Aquatic Risk Assessment (EFSA, 2013) indicates a key role for effect modelling in future aquatic risk characterization in a tiered risk assessment framework. Such approaches require correspondingly adapted exposure tools and scenarios ranging from simple edge-of-field to spatio-temporally explicit landscape-scale catchment models. These approaches should be sufficiently flexible and transparent in order to design lower- and higher-tiers of consistent protection levels.

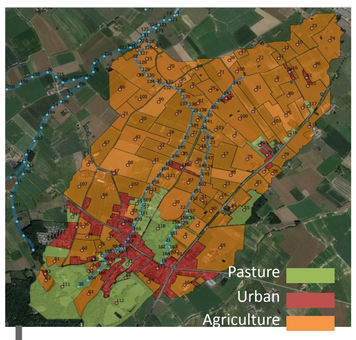
2. Methods

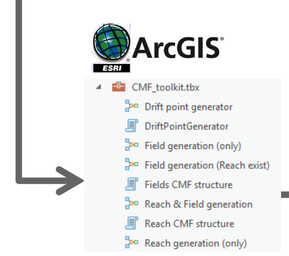
A flexible and modular landscape model (Python package) for water and pesticide transport is being developed which allows for stepwise adaption of model complexity to address tiered risk assessments. The approach is based on the open-source hydrological programming library CMF ('Catchment Modelling Framework', Kraft et al., 2011, https://github.com/philippkraft/cmf). A model evaluations study has been performed for a small agricultural catchment in Belgium for four years and one substance. The impact on *Lemna spp* has been investigated by using the mechanistic Toxicokinetic-toxicodynamic (TK/TD) and growth model developed by Schmitt et al. (2013).

Study site

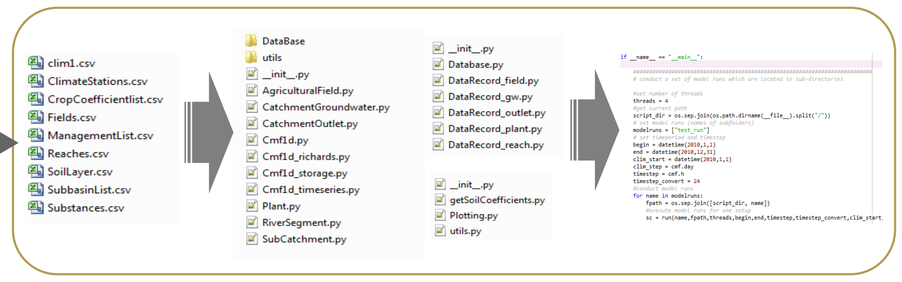
- ~350 ha
- Intensive agriculture, Drained soils
- Altitude: 28m – 92 m
- Rainfall: ~700mm
- 4 climate stations
- Regional info on 12 soil types (4-6 layers)
- Sub-daily observations for 4 years
- Monitored variables: Various substances and stream discharge

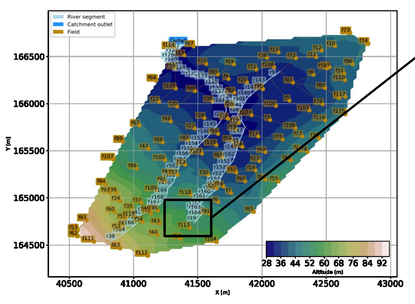
- 126 fields modelled with MACRO 5.2
- Setup according to FOOTPRINT soil types (Dubus et al., 2009)
- 66 streams with a triangular shape
- Stream flow: Manning's equation
- Storage flow: kinematic wave

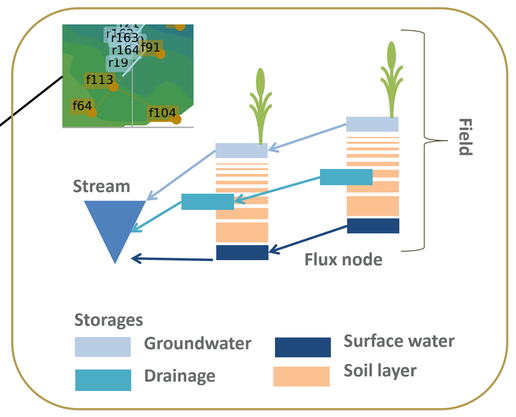




Landscape model (.py)

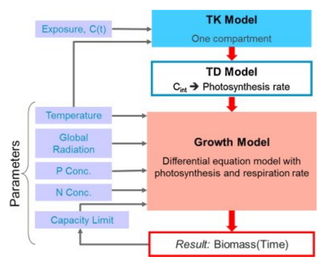






TK/TD model

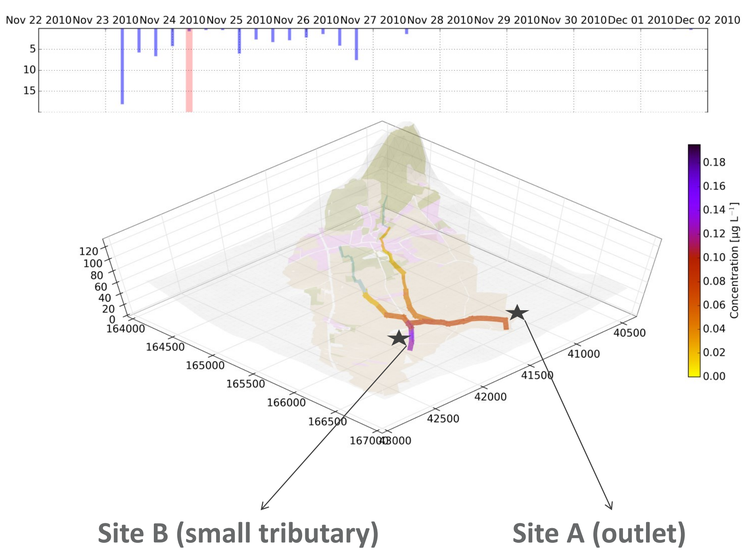
- Simulation of biomass under laboratory or environmental conditions
- Reduction of photosynthetic rate based on the internal concentrations of growth-inhibiting substances using a toxicodynamic sub-model
- Calculation of internal concentrations using a one compartment toxicokinetic model.



3. Results

Catchment modelling

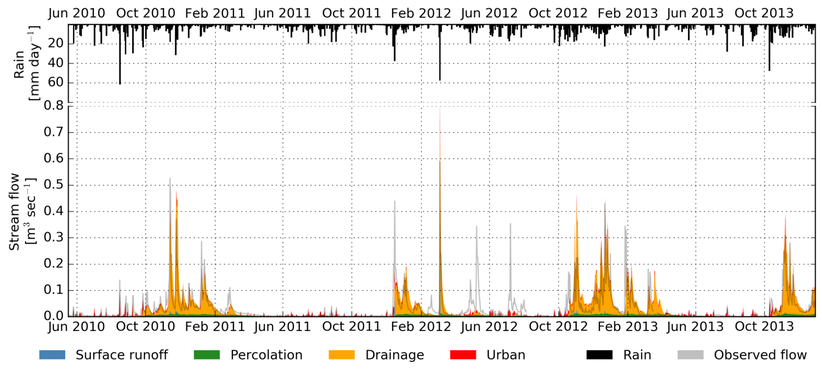
Snapshot: 24.11.2010, 6am

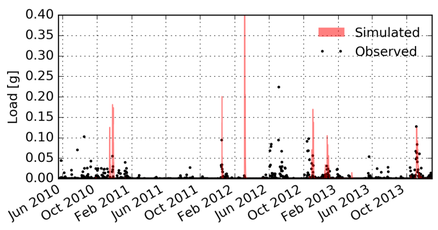


- Good results 2010/2011 (uncalibrated NSE: >0.5)
- Moderate fits in 2012/2013 in summer - Hortonian runoff missed?
- High contribution of urban fluxes to discharge in summer and autumn
- Fast response to several rainfall events

Spatial/temporal explicit exposure

Example Site A (outlet)

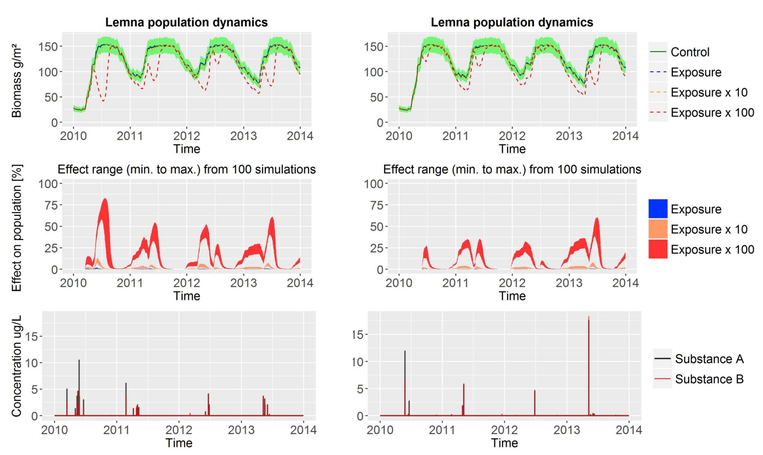




- Predicted annual loads in range of observed data
- No match of summer peaks
- Overestimation of concentrations in stream water
- Good prediction of stream loads in autumn / winter for single events
- Highest concentration in a small tributary

Spatial/temporal explicit effect

Site A (outlet) | **Site B (small tributary)**



- **Biomass**: impact of substance on biomass at the beginning of the growing season succeeded by full recovery at the end of the season
- **Effect on population**: scaling the exposure scenarios by factors (x10, x100) supports the assessment by providing safety margins and by showing that the model is able to produce considerable inhibitions of population dynamics
- **Concentration**: more frequent moderate concentrations at catchment outlet and single high peaks at small tributary (2013)
- Overall impact on population higher at catchment outlet

4. Conclusions & Outlook

- A coupled model setup of an established regulatory edge-of-field model (Macro 5.2) with a catchment model has been realized
- Prediction quality of exposure has to be further improved, but results are promising keeping in mind that no calibration was conducted
- Coupling the catchment approach with a TK/TD Lemna model enables to conduct higher tier aquatic risk characterizations on landscape scales according to Tier 4 (EFSA, 2013)

This work is conducted in preparation of a project (contact: T. Schad) by Bayer AG, Wageningen Environmental Research (Alterra) , University Giessen and Dr. Knoell Consult to develop a modular modelling approach for landscape scale aquatic risk assessment, including, eg.,

- Risk characterization and communication framework
- Modular model and data coupling at landscape-scale using a Python framework
- Individual modules of adapted complexity level (eg., CMF, Farming, Exposure , EFate , Effect)
- Uncertainty analysis (EFSA, 2018a; EFSA, 2018b)

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