A modular catchment model to support regulatory landscape-scale aquatic risk assessment

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1. Introduction

Landscape modelling is key for future environmental risk assessment (ERA) of aquatic ecosystems related to plant protection products (PPP) (EFSA, 2013). Currently, field scale models are used at lower tiers to simulate transport and fate of PPP in edge-of-field surface waters due to runoff, drainage and spray drift deposition. These models predict the exposure concentration in predefined water bodies, i.e. streams, ditches and ponds. In a higher tier approach, a new generation of tools should provide more realistically concentration patterns for higher tier risk assessment. The theoretical background is presented by Wipfler et al. (2019, Poster MOPC15).

2. Methods

The new approach under development operates at the landscape scale. A so called 'system model' integrates various modules into one consistent framework, which is seen by the user. The overall target is the provision of a numerical fundament for risk assessment. Modules simulate environmental processes, e.g. exposure, fate or runoff generation.

The newly developed hydrological module, developed using the hydrological programming library CMF (Kraft et al., 2011) is presented here. To allow for water and solute fluxes across entire landscapes, single fields are connected with each other and to river segments by flux connections. This approach allows to predict exposure concentrations at any location at a flexible time step. Water and solute input fluxes from single fields can be either simulated by the model or by using predefined time series from other field scale models, e.g. the FOCUS models MACRO or PRZM.

2.1 Hydrological catchment module

The catchment with all its components, i.e. forests, fields, rivers and urban areas is divided into a set of cells and river segments. A unique feature of the model is its flexibility in terms of hydrological detail and spatial representation. The user selects from different options for the simulation of:

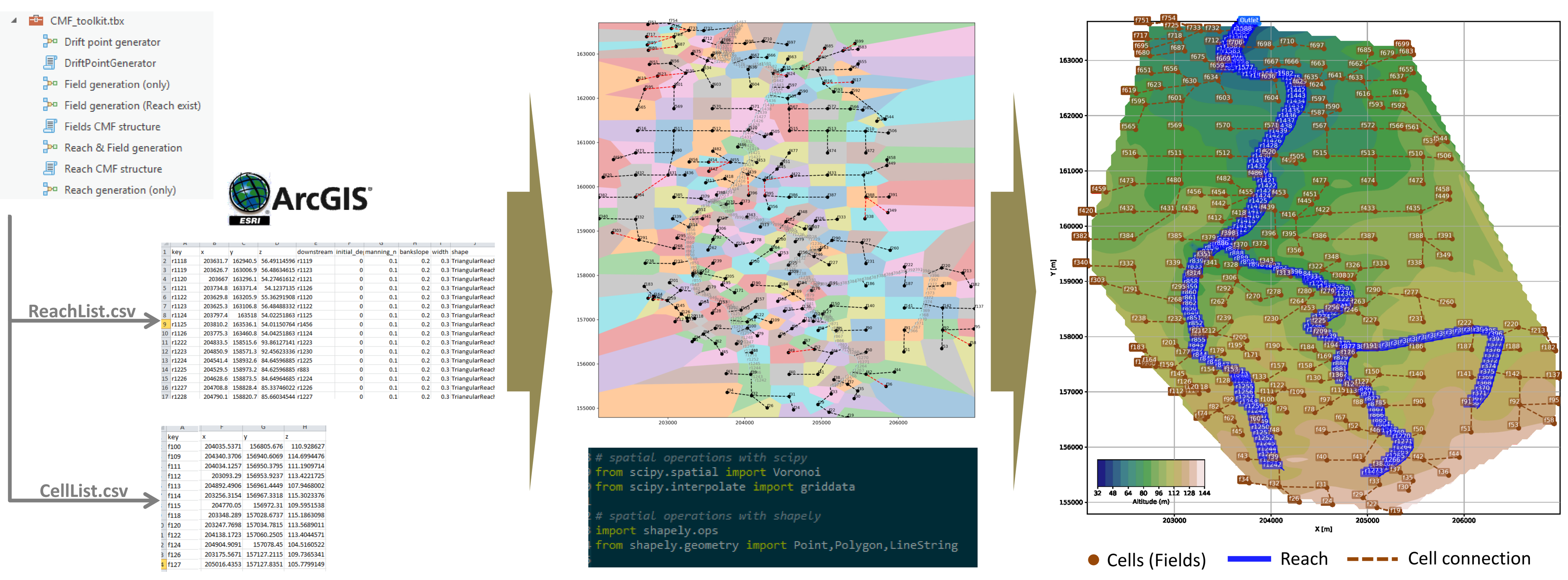
(a) The stream network - **areayieldCatchment** (see case study).

(b) The entire flow network of the catchment – **completeCatchment**.

(c) Single cells - **1dField** (results serve as inputs for option b).

The model is implemented by an object-oriented programming approach using Python3. Natural entities and their relation to each other are defined by a has-a-relationship. The numerical calculations are done by the CMF core library (C++, CVODE solver). Data are stored in compressed binary files in HDF5 file format.

2.2 Geodata processing & Flow connections



3. Case study

The Rummen catchment in Belgium is dominated by orchards. For pest management, pome fruit farmers apply insecticides, which may impact aquatic communities by spray drift input into water bodies. All minor and major river reaches are simulated, corresponding to a total river length of 150 km. Hourly hydrological data is provided for all reaches (n=1,835) with a length between 50 and 100 m and a v-shape geometry for a representative hydrological year (50%-percentile, 30years). The compound balance has been simulated for the Velm sub-catchment (~30km²).

Test compound):
505.2 g/mol
KOC=1,024,000
1/n=0.93
$DT50_{water}$ = 1000d
$DT50_{sediment}$ = 76d.

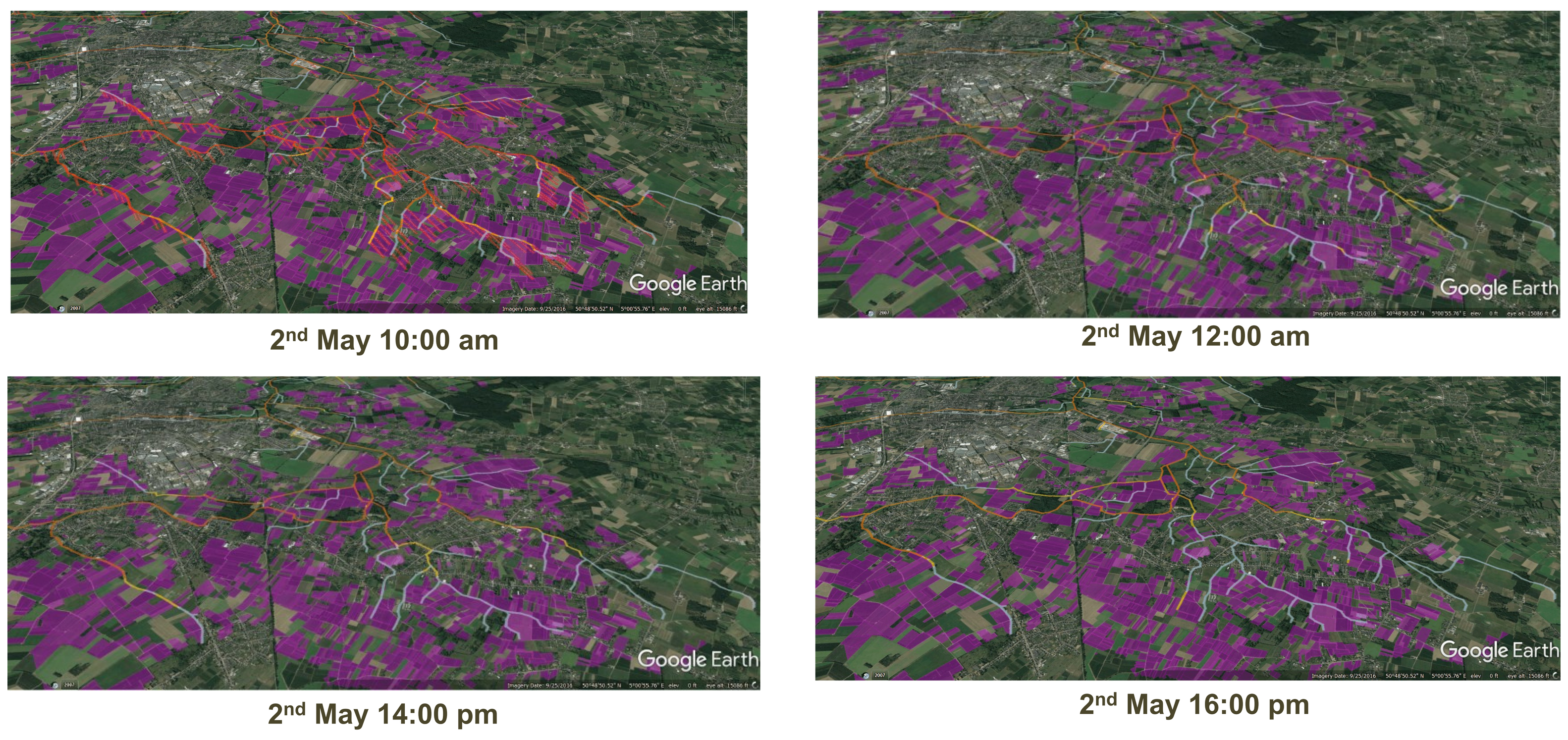
GAP: 1 x 12 g a.s./ha on May 2nd at 10 am; orchards are directly connected to the stream.

Exposure: drift into 29 river segments simulated based on a fixed rate, calculated according to FOCUS surface water guidance:
Deposition=21.58%
Drift=0.27 mg/m²
fruit crops (early), no interception

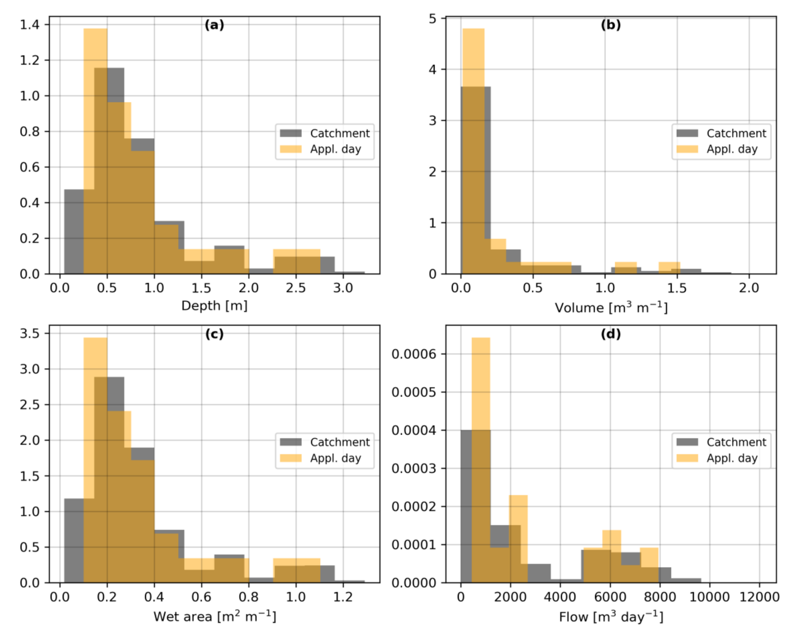
E-Fate: STEPS1-2-3-4 (Klein, 2017); one water layer, two sediment layers, degradation and adsorption as well as desorption.

Hydrology: areayieldCatchment option based on inflow from fields, calculated based on the area-scaled observed flow per reach.

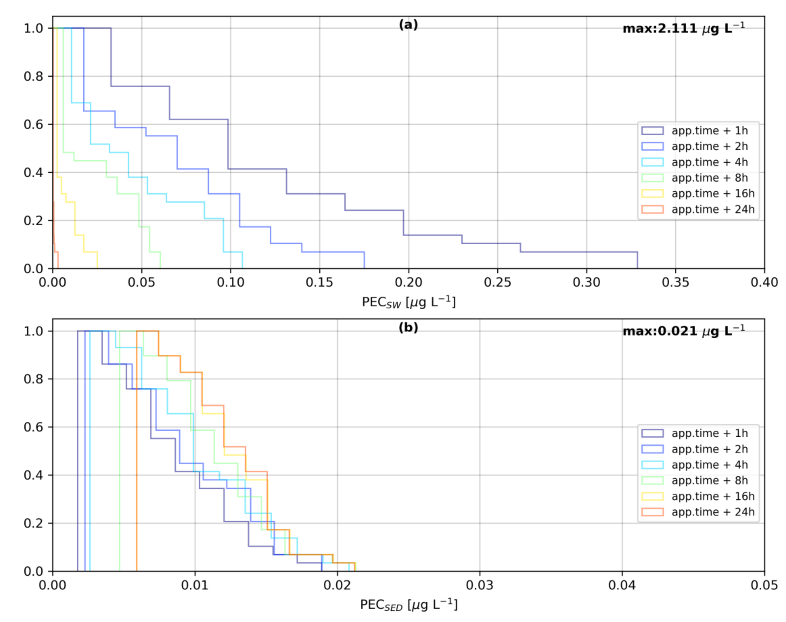
Catchment scale



2nd May 10:00 am — 2nd May 12:00 am — 2nd May 14:00 pm — 2nd May 16:00 pm



Normalised frequency distribution of hydrologic variables across the catchment



Normalised cumulative distribution function of PEC values across the catchment

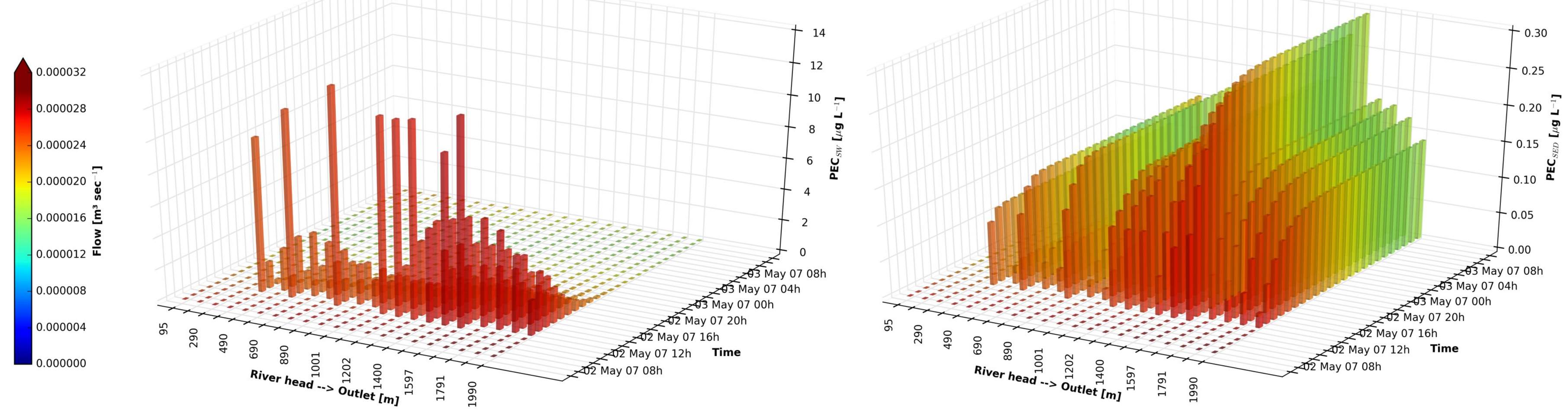
At a glance:
The wet surface of reaches in the Velm sub-catchment, which are exposed to drift (n=29), varied in size between <1 and 110 m². A resulting compound mass of 240 mg entered the water bodies.

A fast removal of the compound mass from the reaches could be observed due to mass transport with water.

The percentage of compound in the surface water was <1% after 10 days in relation to the initial load.

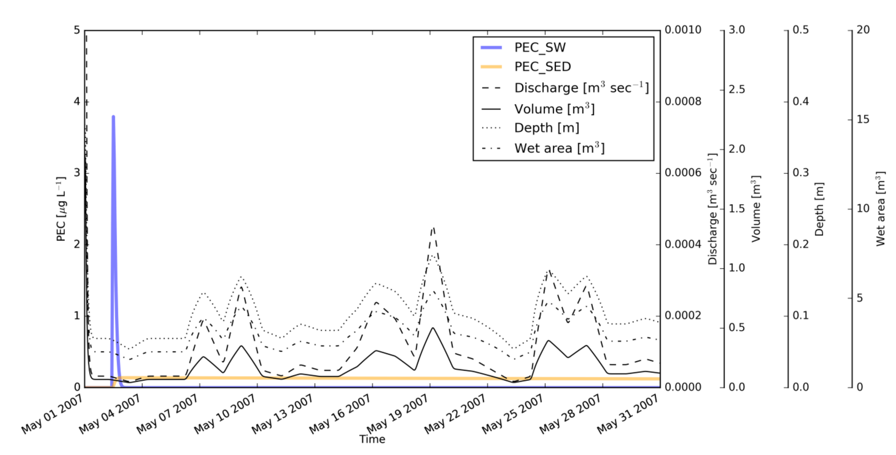
A low percentage of 0.1% was adsorbed by the sediment at the day of application. After six months, at the end of the year, the fraction was reduced to 0.07% in relation to the initial load.

Branch scale



PEC surface water (left) and sediment (right) of single reaches along a 2 km branch in the Rummen catchment between May 2nd, 08:00 am and May 3rd, 08:00 am. The bar height indicates PEC values and the color map water flow.

Reach scale



PEC values and hydrological state variables of a single reach.

4. Conclusions & Outlook

Water and pesticide fluxes in an orchard dominated catchment in Belgium were simulated. The available dataset allows for a detailed analysis of the spatial and temporal PEC patterns across the catchment at different scales (catchment, branch, reach). A large fraction of the compound is removed within10 days from the water bodies. 0.07% are still adsorbed to the sediment after 6 months in relation to the initial load.

The next step related to hydrological modelling is the simulation of water fluxed by using the *completeCatchment* approach and an analysis of the parameter and structural uncertainty addressing recent EFSA guidance's (EFSA, 2018a; EFSA, 2018b).

Moreover, the hydrological dataset will be used to simulate environmental fate with Cascade_TOXSWA in a related study by WUR using spatially explicit drift simulations.

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