Improved GEM scenario for aquatic risk assessment of plant protection products applied to soil-bound crops grown in greenhouses

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Background & objectives

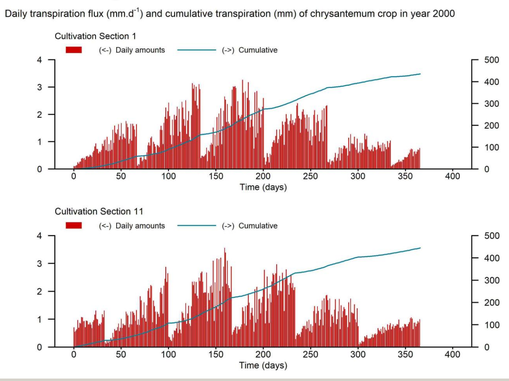
The Greenhouse Emission model (GEM) is used to assess the exposure of aquatic organisms to plant protection products (PPPs) applied in soil-bound crops in greenhouses. After introduction of the GEM model, it was found that the predicted environmental concentration (PEC) in surface water is extremely sensitive to the date of PPP application. This sensitivity was found to be related to two issues: (1) an overly simplistic representation of irrigation; (2) the assumption of a macropore network through the complete soil profile. We present several improvements to the GEM soil-bound surface water scenario to repair these issues.

The Greenhouse Emission Model

The GEM model for soil-bound cultivations simulates PPP concentrations in water and sediment of a ditch adjacent to a greenhouse due to discharge via drainage. It comprises three numerical models: SWAP (soil hydrology), PEARL (PPP fate in soil), and TOXSWA (PPP fate in surface water). To perform an assessment, the user provides properties of the PPP, application method, dosage, and timing of application. All other model input is part of the surface water scenario for a chrysanthemum crop, which results in the 90th percentile concentration (PEC90) of the PPP in surface water.

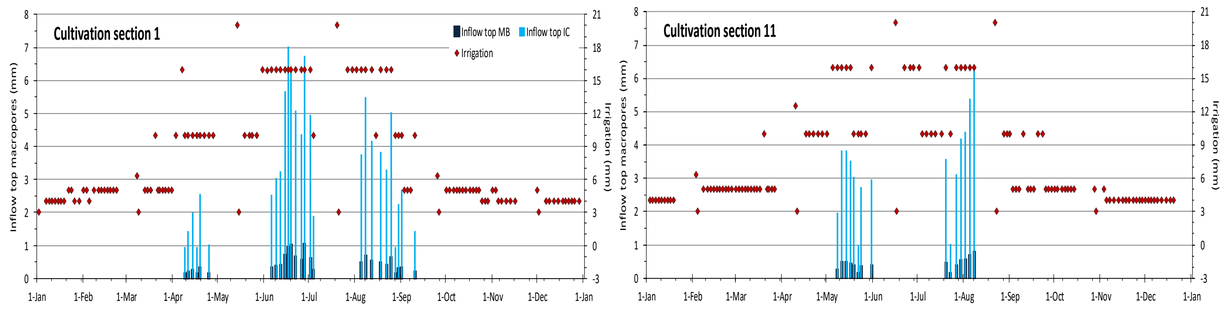
Cultivation sections

The previous GEM version assumed a single full-grown crop. In reality greenhouses include multiple sections with crops in different stages. The new surface water scenario explicitly represents four cultivation sections. Each section has a different crop cultivation calendar (single rotation 65 d) and irrigation and ploughing schedule. Timing of PPP application can be specified as absolute date or relative to date of planting or harvest. The drainage flux from the four sections is flux-weighed averaged to calculate the drainage flow into the ditch.



Irrigation and drainage

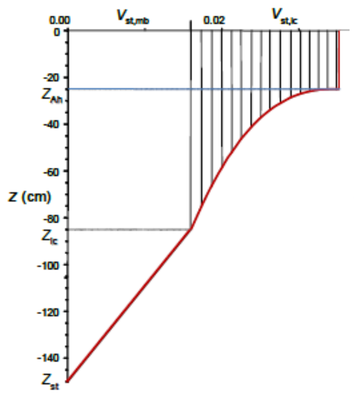
Irrigation is calculated according to the crop demand, using an ET-model, which is based on cropping stage and greenhouse climate data and by applying an irrigation surplus of 25 %. For each cultivation section, irrigation events and quantities are determined. Irrigation events occur when a specific threshold is exceeded, after which the cumulative crop water demand is reset to zero. Hence, irrigation and drainage patterns differ per section.



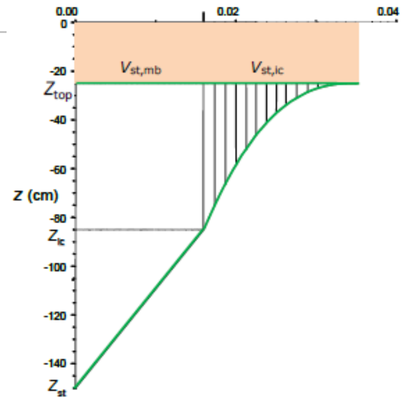
Ploughing and macropores

Macropores are preferential pathways of water flow that can facilitate rapid transport of PPPs. In the previous GEM version (3.3.2) macropores throughout the upper 1.4 m of the soil profile were assumed. This is not realistic since the topsoil in greenhouses is frequently ploughed up to 15 cm after every crop rotation and once per year up to 25 cm depth, which implies complete homogenization of the topsoil. Consequently, in the revised surface water scenario of the new GEM version (4.4.3), the top 25 cm of the soil has no macropores. Moreover, the soil is ploughed up to 15 cm after every crop rotation and once per year up to 25 cm, causing homogenization of the substance in the plough layer.

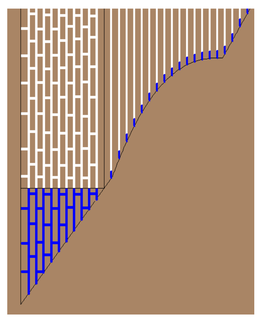
GEM 3.3.2



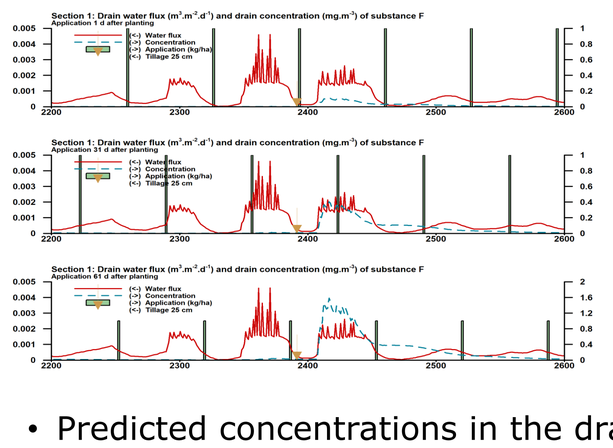
GEM 4.4.3

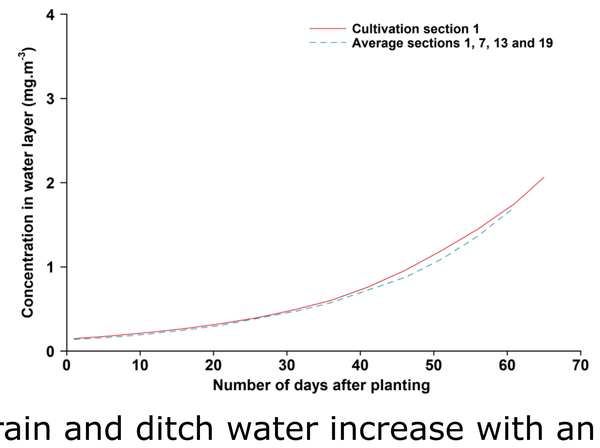


Soil macropore system



Sensitivity to relative application date





- Predicted concentrations in the drain and ditch water increase with an increase in the time interval relative to the planting date.
- This is explained by the effect of ploughing which results in mixing of the substance down to the top of the macroporous subsoil.

Conclusions

- Substantially lower sensitivity of PEC90 to application date.
- Remaining sensitivity is related to the effect of ploughing events (relative application date) or the seasonal pattern of drainage fluxes (absolute application date).
- A greenhouse experiment is recommended to test the improved GEM model concepts in the revised surface water scenario.

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