The field scale phosphorus loading model ICECREAM improves the water quality simulation of the Finland-wide VEMALA modeling system

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Aim

More data on the amount and sources of phosphorus (P) loading into rivers and lakes is needed for the planning of water protection measures. As water quality measurements are expensive and time-consuming, the required information is not possible to achieve by measurements only. The diffuse P loading from agriculture is especially difficult to measure. Modeling together with available observations is cost-effective and can be used for estimating P loads in various conditions, if the models used are accurate enough. The aim of this work was to improve the simulation of P loading from agriculture in the Finland-wide VEMALA water quality model. For this purpose, the field scale phosphorus loading model ICECREAM was modified and coupled with VEMALA.

Methods

The VEMALA model (Huttunen et al., submitted) simulates nutrient transport and leaching from terrestrial ecosystems, including agricultural fields and forested areas, as well as the transport and processes of nutrients within rivers and lakes. In the earlier version of VEMALA (version V1) the simulation of P loading from land area is based on a concentration-runoff relationship and an estimate of the annual loading from each field by the VIHMA tool (Puustinen et al. 2010). In the new version (V2), agricultural phosphorus loading is simulated by the field scale process based ICECREAM model.

ICECREAM is based on CREAMS and GLEAMS models, applied to Finnish conditions by Rekolainen and Posch (1993), and further developed by for example Tattari et al. (2001) and Jaakkola et al. (2012). In this work, some of the equations in ICECREAM have been changed to statistical equations representing Finnish fields to better simulate the loading of phosphorus from all the 1,100,000 field plots in Finland. The main changes include

- **revisions to the initialization of phosphorus pools**
- **changes in the balance calculations between the P pools**
- **a new method for calculating phosphorus concentration in surface runoff**
- **modifications to the hydrological part of the model**

A schematic picture of the phosphorus pools in the model and P exchange between them is shown in Figure 1.

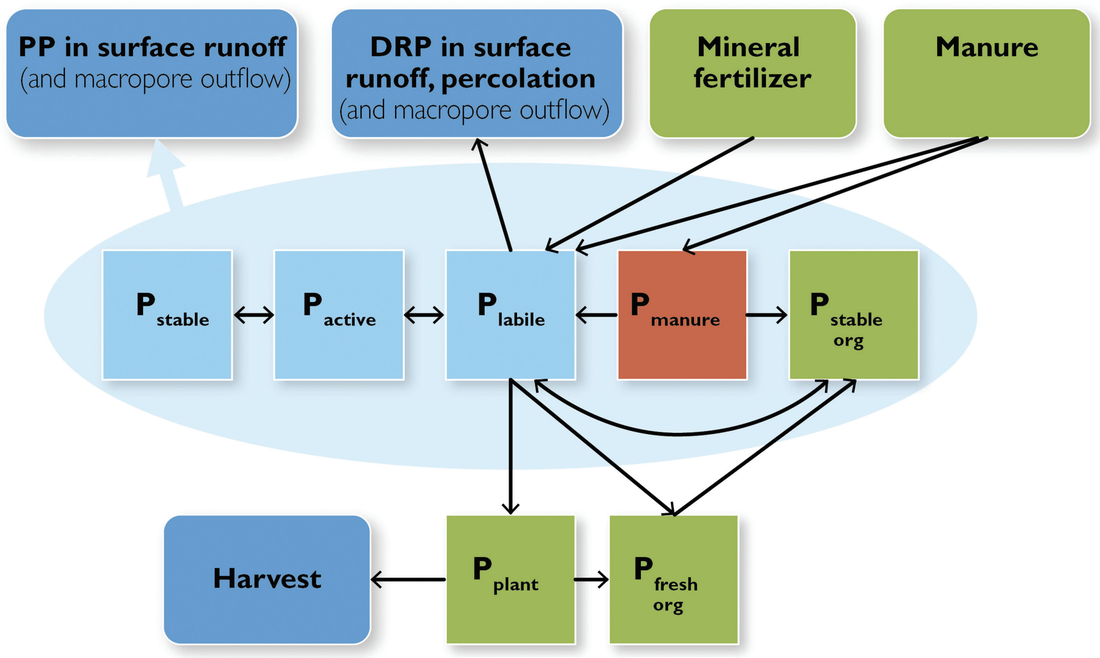

Figure 1. Simulation of phosphorus fluxes in the ICECREAM model.

Results

In large catchment areas, the performance of both model versions is usually quite satisfying (Figure 2a). However, in small catchment areas, or when water quality observations are scarce, the V1 version may produce unrealistic concentration patterns (Figures 2b and 2c). Version V2 has not been performing well in the Ostrobothnian area, where a considerable proportion of the P loading originates from organic soils. About half of the organic soils in this area are peat soils. The P loading dynamics of peat soils differs from that of mineral soils, so that relatively higher fraction of the loading is formed during the low flow periods. However, a new version of ICECREAM has been developed for peat soil simulation. The preliminary results of this new version are promising, although the model cannot reach the high concentration peaks in the spring time (Figure 2d). One explanation might be, that part of the fields in the Kalajoki catchment are covered by floodwater in the spring, and the additional leaching caused by the flooding is not considered in the simulation. The locations of the simulation points are shown in Figure 3.

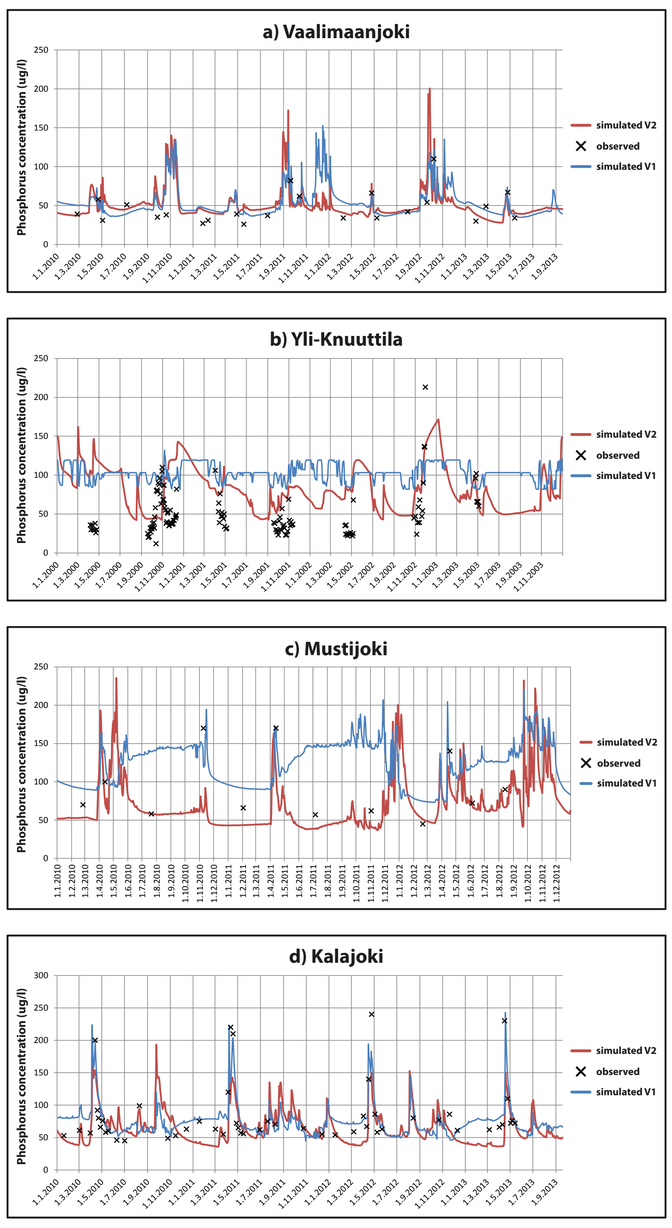

Figure 2. Phosphorus concentration simulation in Finnish catchments with the V1 and V2 versions of the VEMALA model. The catchment areas are a) 234 km^2 with 13 % of field, b) 6 km^2 with 22 % of field, c) 350 km^2 with 30 % of field, and d) 3118 km^2 with 16 % of field, of which 33 % is organic.

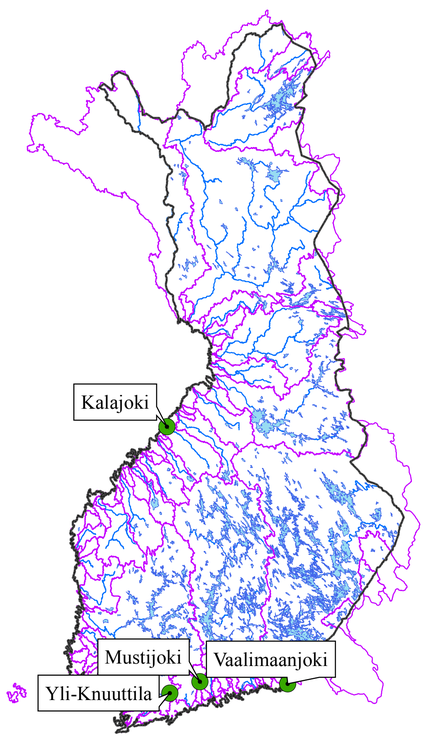

Figure 3. The locations of the water quality simulation points.

Conclusions

Field scale modeling of agricultural phosphorus loading with the modified ICECREAM model improves the VEMALA simulation in small catchment areas and areas with scarce or no water quality observations, as the process based model is less dependent on calibration. Comparing the results of the different model versions also gives an estimate of the uncertainty related to the simulation. There are still many challenges in Finland-wide simulation of agricultural P loading. One of the main difficulties is the poor availability of accurate input data. Also the field research is much concentrated on the clayey soils in the southern part of Finland, and the information on other soil types (eg. organic soils and coarse mineral soils) is scarce. However, by using the VEMALA model, useful information of the phosphorus loading in Finland can already be produced.

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VELHO Vesien- ja luonnonhoidon alueellinen ja paikallinen toteuttaminen Lounais-Suomen vesistöalueilla
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