Simulating impacts of land-use, topography and hydrology on sediment loading in clayey subsurface drained agricultural fields in high-latitude conditions

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Introduction

Comprehensive understanding of the dominating erosion and sediment transport processes is a prerequisite for the design of effective water protection measures in agricultural fields. In this study sediment loading pathways and effects of different factors on erosion and sediment loads were studied with two long-term field-scale datasets and a an application of a process-based three-dimensional (3D) FLUSH model.

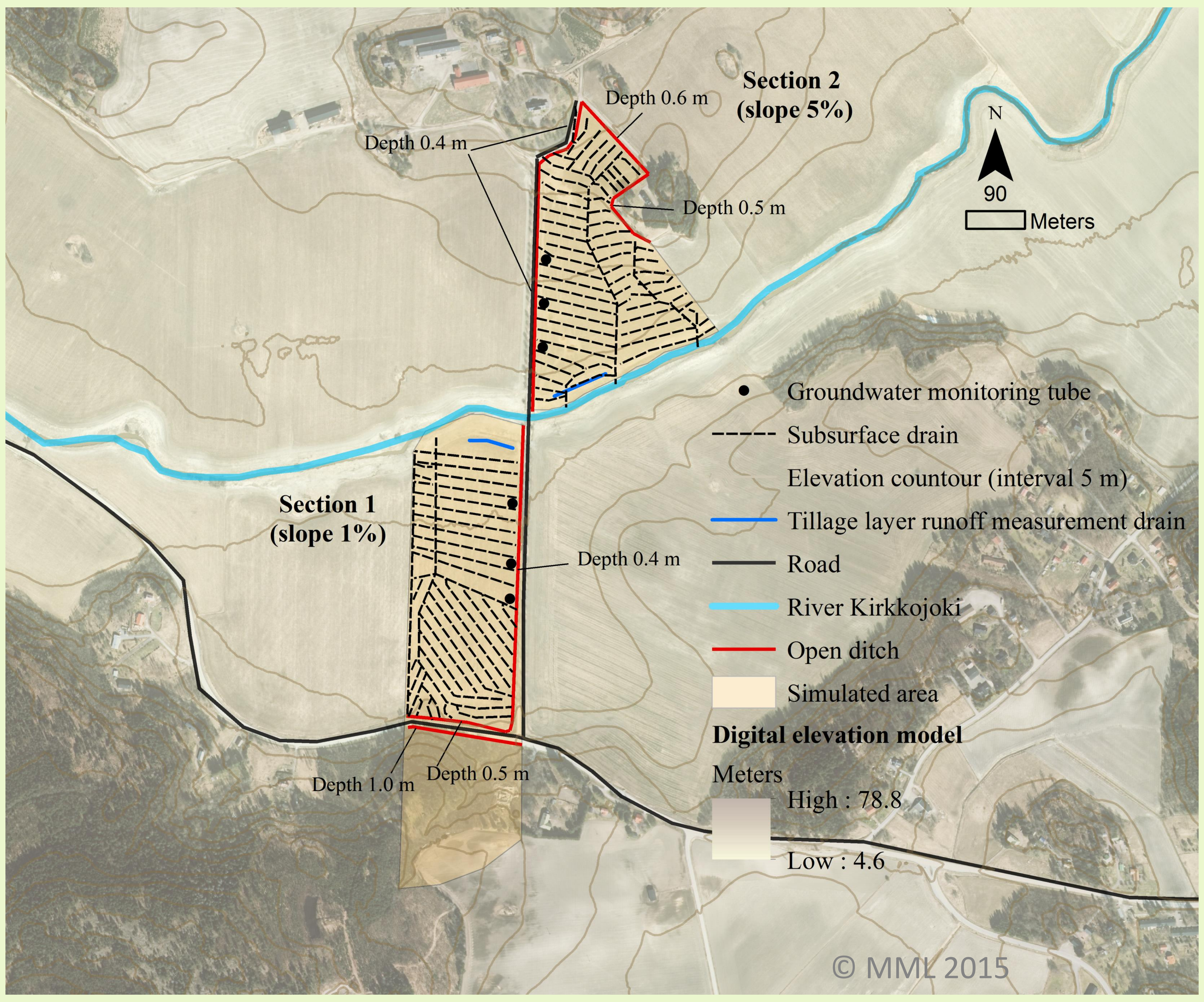
Materials and methods

The experimental site

The experimental field consisted of two intensively monitored field sections in southern Finland (Fig. 1). Section 1 (5.7 ha) had a slope of 1% and Section 2 (4.7 ha) a slope of 5%. Both sections had clayey soils and were subsurface drained (depth 1 m and spacing 16 m). The sections were in conventional agricultural use with a changing land-use including annual grain crops, pastureland and grassland

Sediment concentrations in drain discharge (DD) and tillage layer runoff (TLR) waters were determined by composite sampling. An automatic system collected a sample for each 50 m³ of water. The composite samples were analyzed weekly or biweekly in the laboratory for total suspended solids (TSS). TSS was measured by weighing the evaporation residue and used as a measure of soil erosion.

Fig.1. The Gårdskulla Gård experimental site.

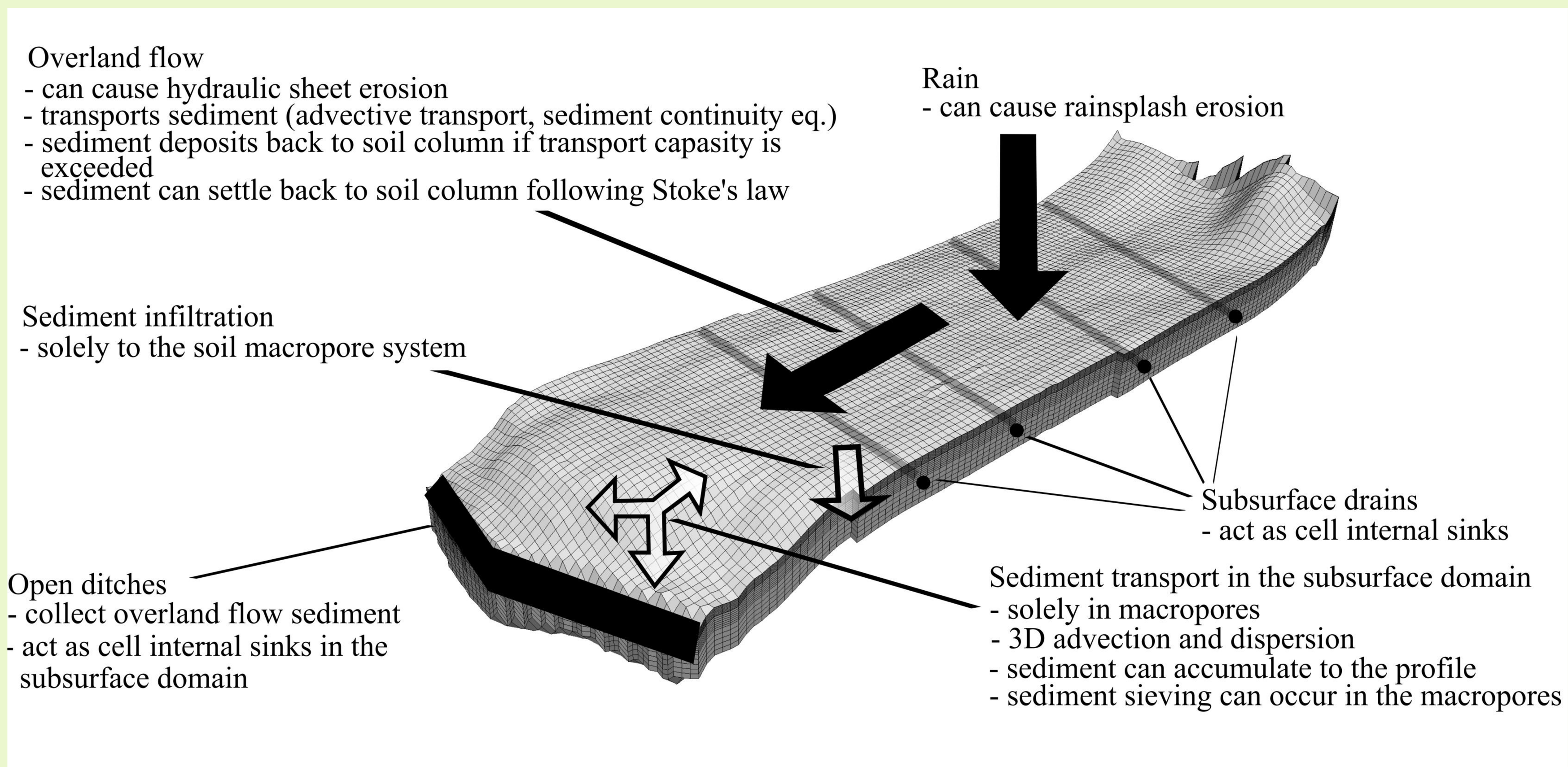


FLUSH model

FLUSH is a 3D process-based hydrological model. The governing equations are the Richards' (dual-permeability approach) and the Saint-Venant equations. Erosion and sediment transport processes are presented in Fig. 2.

In the current study, the erosion and transport model was calibrated and validated against the load and concentration data from the years when annual crops were sown on the fields. The simulations were run throughout the 7 years with one hour global timesteps, which were further divided into subhour local time steps.

Fig. 2. Conceptual presentation of the current erosion and sediment transport schemes of FLUSH.

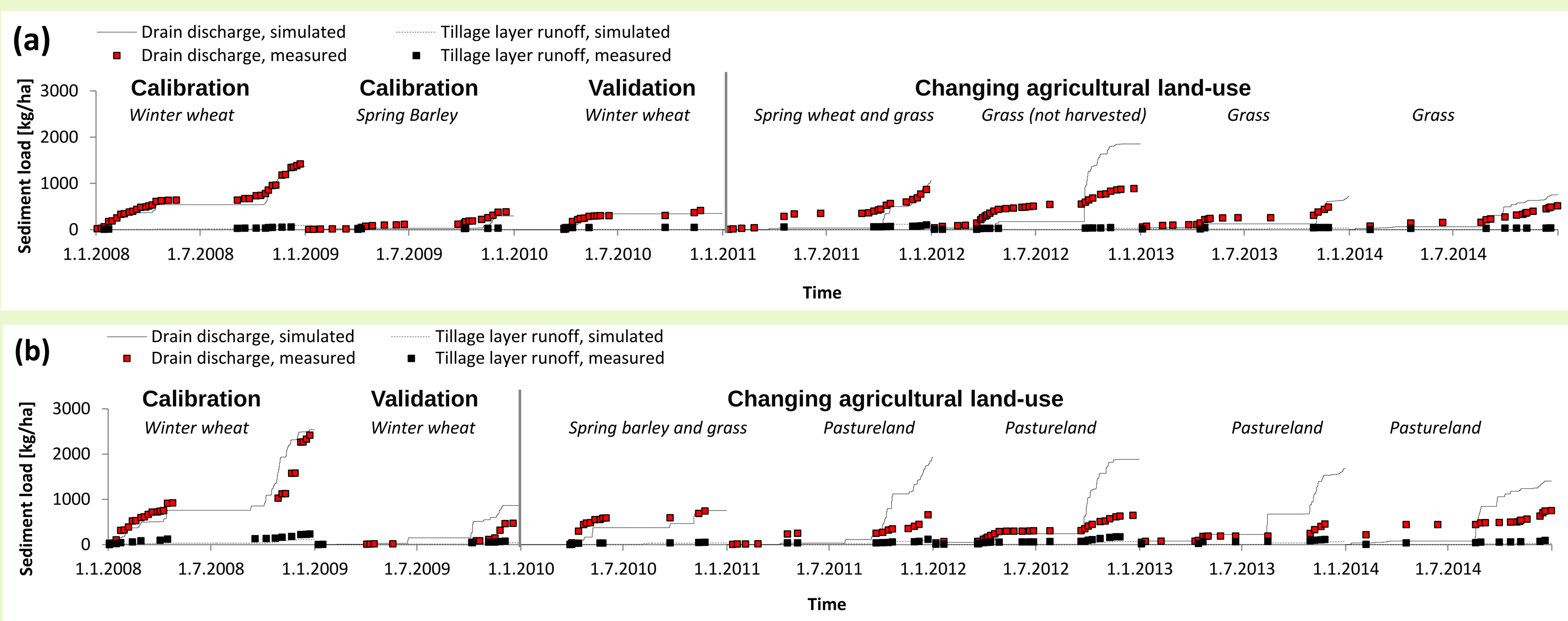


Results and discussion

Both measurement and simulation results show that in all studied conditions clearly most of the sediment loading from the field occurs via DD (Fig. 3a-b). Hydrometeorological variation controlled the annual sediment load generation the most. Land-use had a higher impact on sediment loads than the small change in terrain slope. Regarding winter and spring periods, highest loads occurred during mild winters with no permanent snow cover.

Mismatch between the simulated and measured concentration dynamics revealed that the erosion functions developed for frictional soils do not rigorously represent the erosion processes in structured soils.

Fig. 3. Measured and simulated sediment loads via drain discharge and tillage layer runoff in (a) Section 1 and (b) Section 2.



Conclusions

- Clearly most sediment loading occurred via subsurface drain discharge in all studied conditions, which should be taken into account when designing water protection measure on the field surfaces.
- High sediment loading can occur from grasslands.
- The results reveal knowledge gaps in the sediment loading processes and underline the need to include descriptions of dynamic erodibilities as well as erosion due to slaking and dispersion to the current models.
- Since mild winters can induce high sediment loading, climate change will probably increase loading from clayey fields in cold climate.

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Further information

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