



Department of Civil and Environmental Engineering
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Modelling Runoff at an Agricultural Field



10th International Drainage Workshop of ICID Working Group on Drainage
Helsinki, Finland | Tallinn, Estonia, July 6th - 11th 2008

Objectives of the study

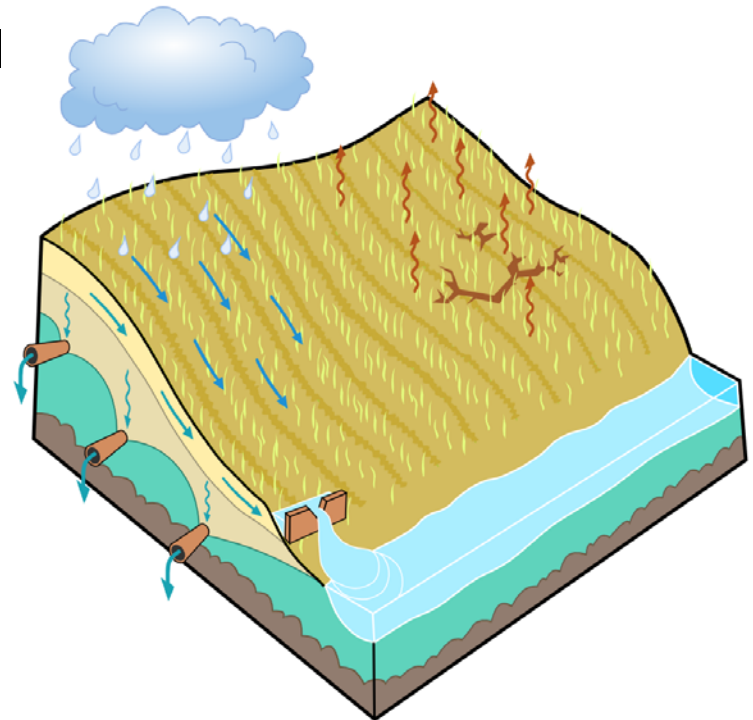
- Design and develop a new field-scale model to simulate the flow of water at clayey subdrained fields
- Apply the model to the Sjökulla experimental field and later to another field (Hovi)
- The flow model will form a basis to an erosion and transport model
- Why a new model?



Erosion at the Sjökulla field

Model design goals

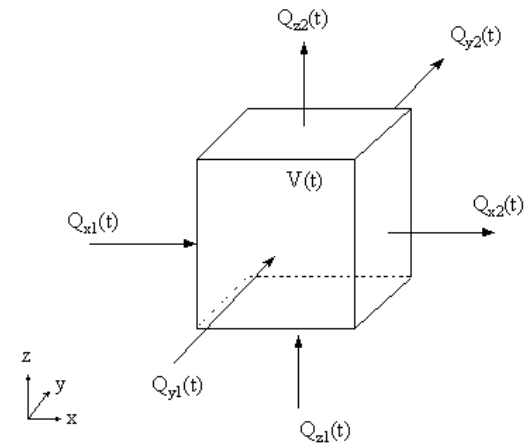
- Distributed 3-D field-scale model
- Long-term simulations
- Precipitation and evapotranspiration
- Soil- and groundwater flow including macropore flow
- Soil swelling and shrinkage
- Overland flow
- Simulation of tile drainage, surrounding ditches and deep groundwater flow



Conceptual model of the field

Inner workings of the numerical model

- Soil matrix and macropores in *dual-permeability* subsurface flow are modelled with *Richards equation*
- 2-D overland flow is (*kinematic approximation*) calculated with Mannings equation
- A simple PET – Precipitation deficit based swelling/shrinkage model
- Partial differential equations are solved with implicit *finite volume method*

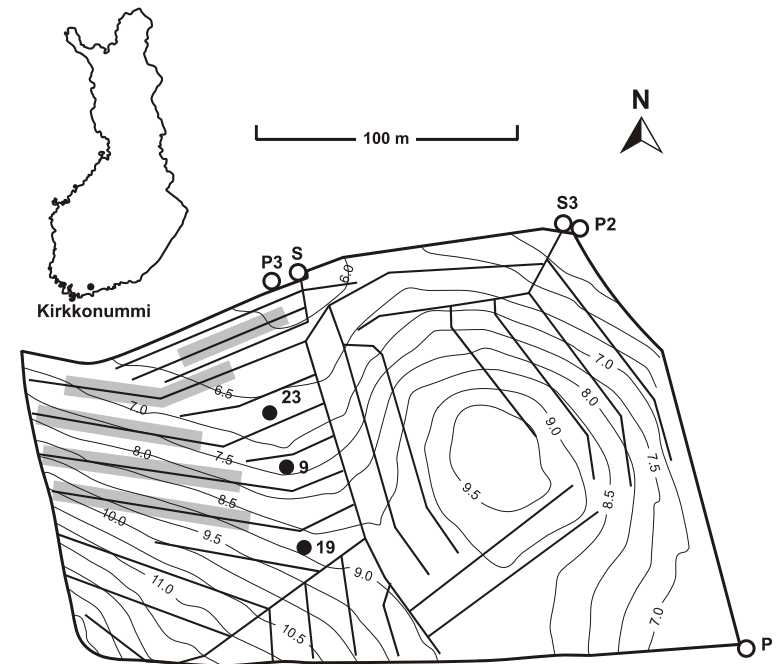


Finite volume method



Description of the Sjökulla field

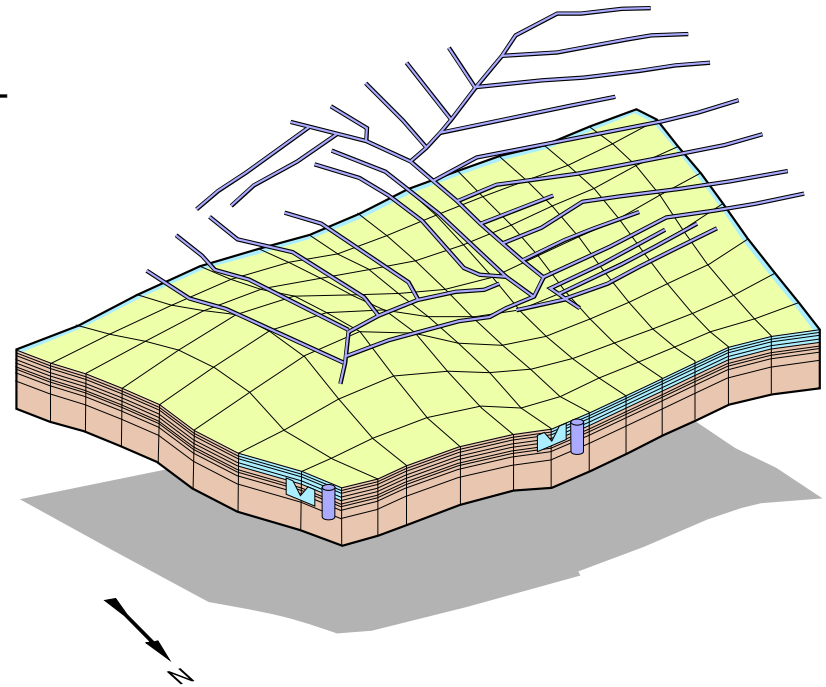
- Located in Kirkkonummi in southern Finland
- Clayey soil, field area 3.3 ha
- Undulating, max slope 5%
- Subsurface drained
- Precipitation 600-700 mm/a and evapotranspiration 300-400 mm/a
- Measurements from 1996 (calibration) and 1998 (validation)
- Soil data on macroporosity and K_s
- More information about the field is available in IDW 2008 article by Paasonen-Kivekäs, M.



Location of the Sjökulla experimental field and a map of the field

Computational model of the field

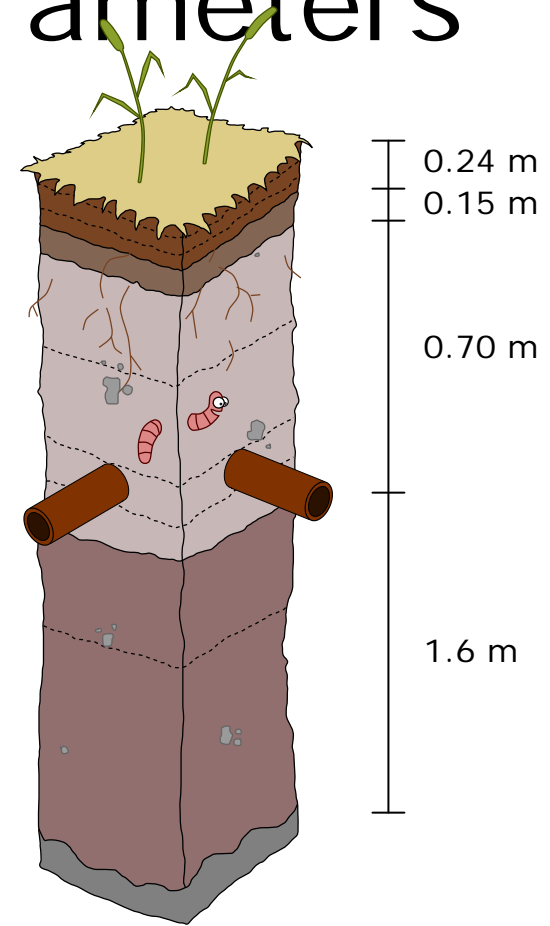
- Simulation periods range from May–December (1996) and May–November (1998)
- Unique initial conditions (hydraulic heads) for both years
- Boundary conditions:
 - Side ditches (overland flow)
 - Deep groundwater flow
 - Subsurface drains
- Four different resolution grids (12x8x11, 24x16x11, 48x32x11 and 24x16x20)



Computational model of the field with different features

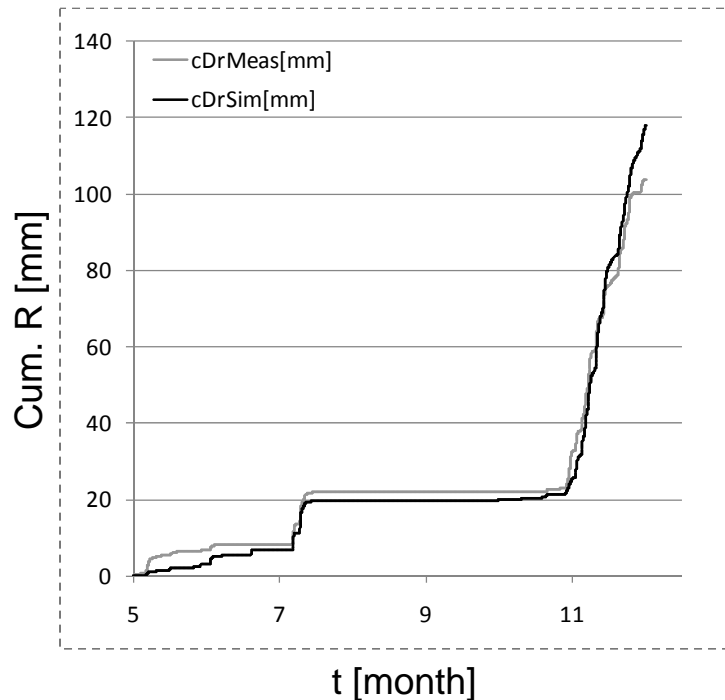
Soil layers and parameters

- Ten layers with four different soils in the profile (2.7 m)
- Soil profile is currently the same everywhere at the field
- Separate van Genuchten water retention curves for tillage layer and the rest of the profile
- K_s for macros 1.0-0.001 m/h
- Macroporosity 3.5-0.001%

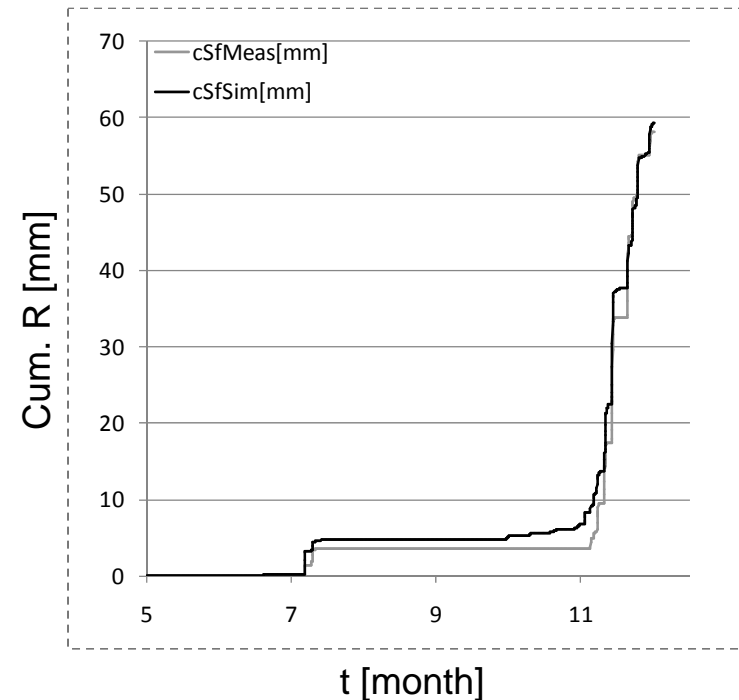


Soil layers

Cumulative drainage and overland runoffs Calibration year 1996

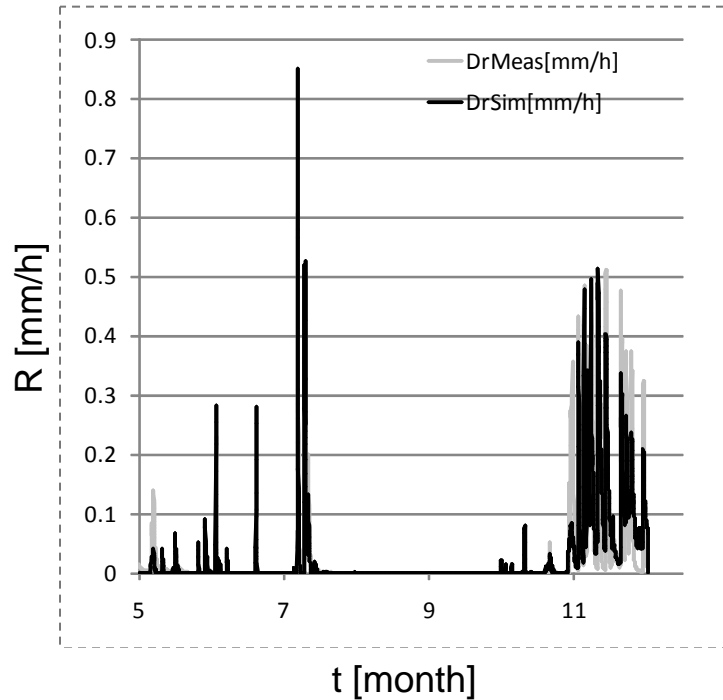


Cumulative drainage runoff

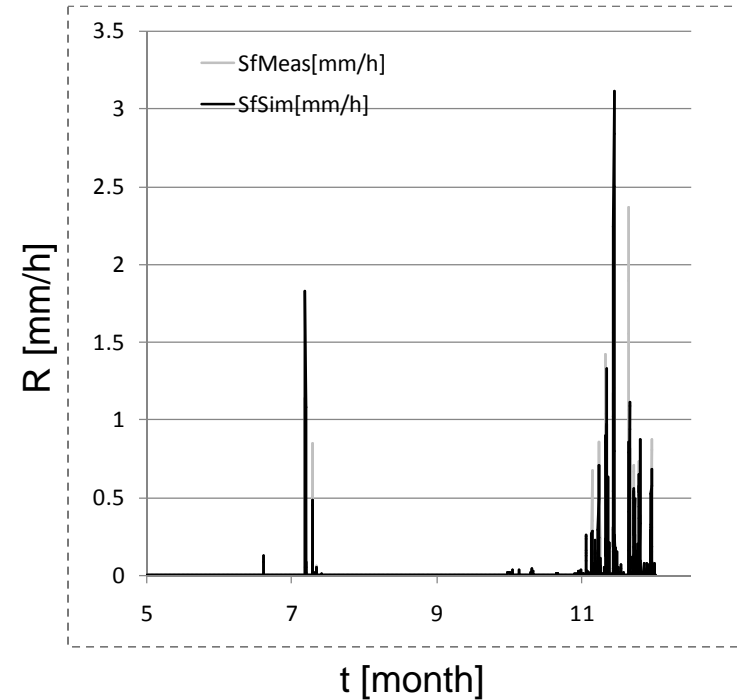


Cumulative overland runoff

Drainage and overland runoffs Calibration year 1996

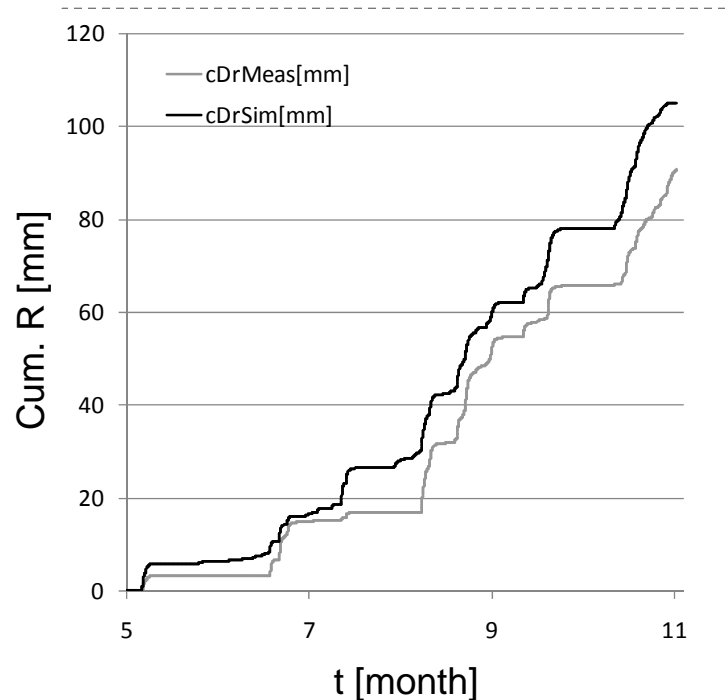


Drainage runoff

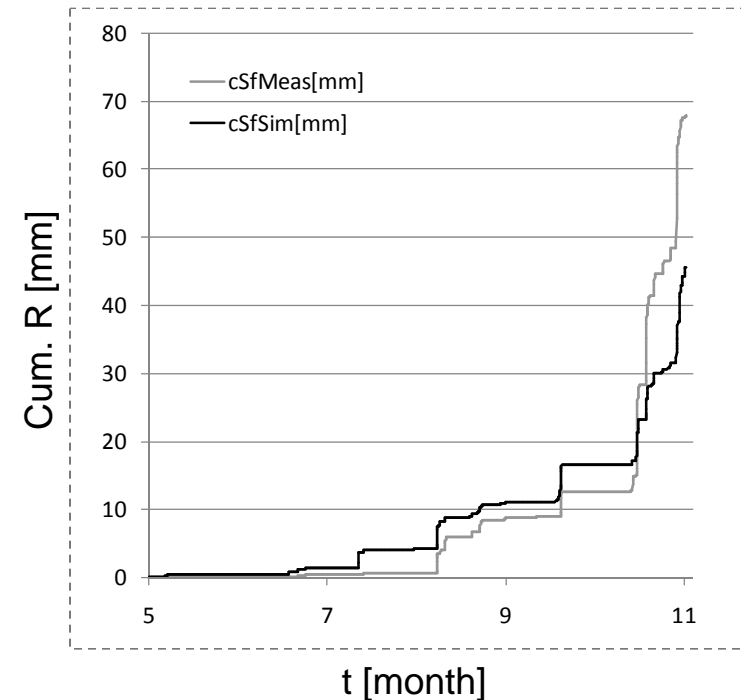


Overland runoff

Cumulative drainage and overland runoffs Validation year 1998

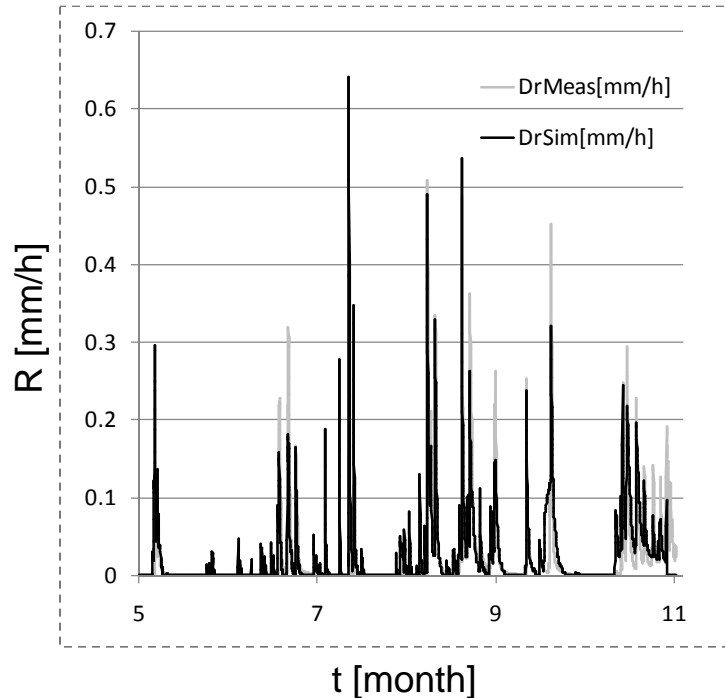


Cumulative drainage runoff

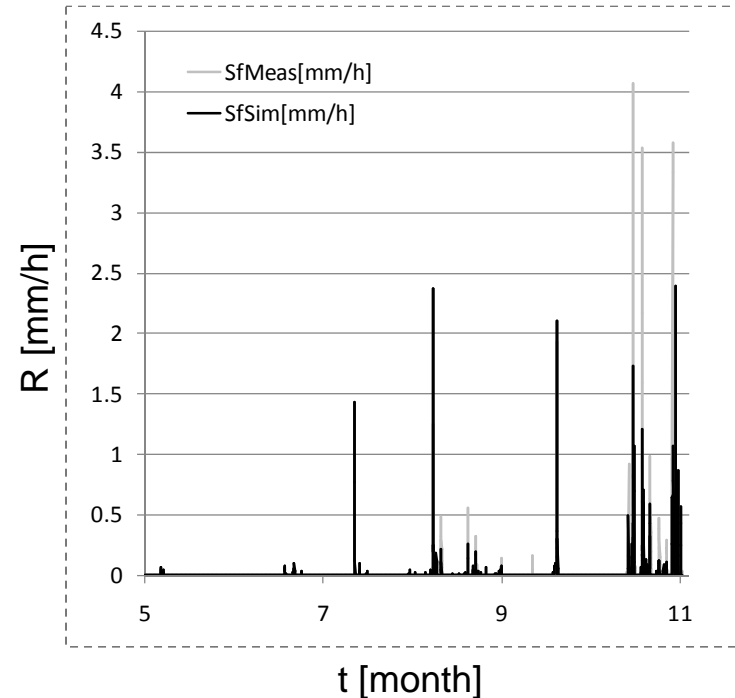


Cumulative overland runoff

Drainage and overland runoffs Validation year 1998

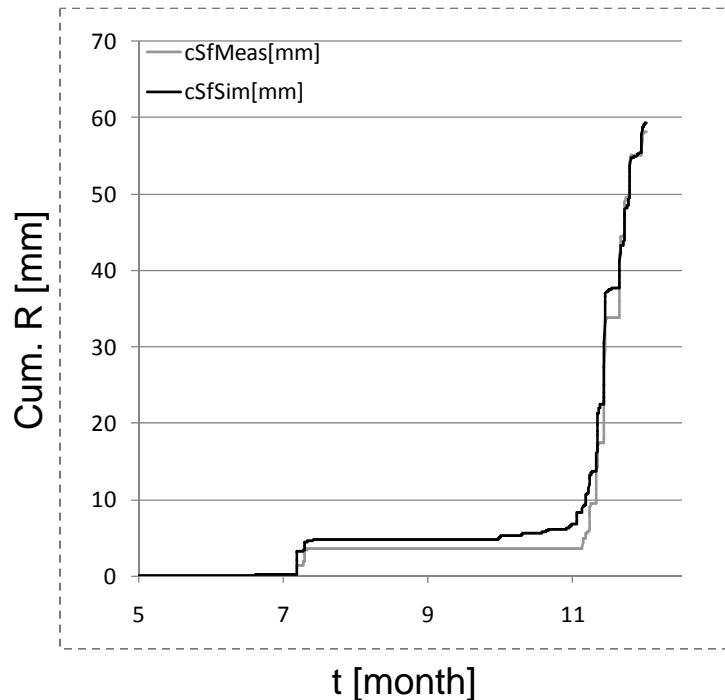


Drainage runoff

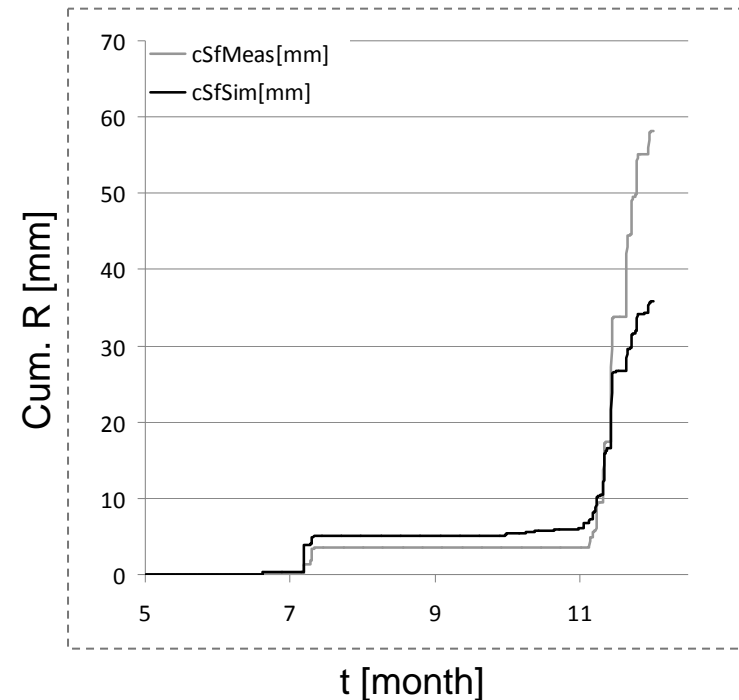


Overland runoff

The effect of swelling/shrinkage model on overland runoff in year 1996

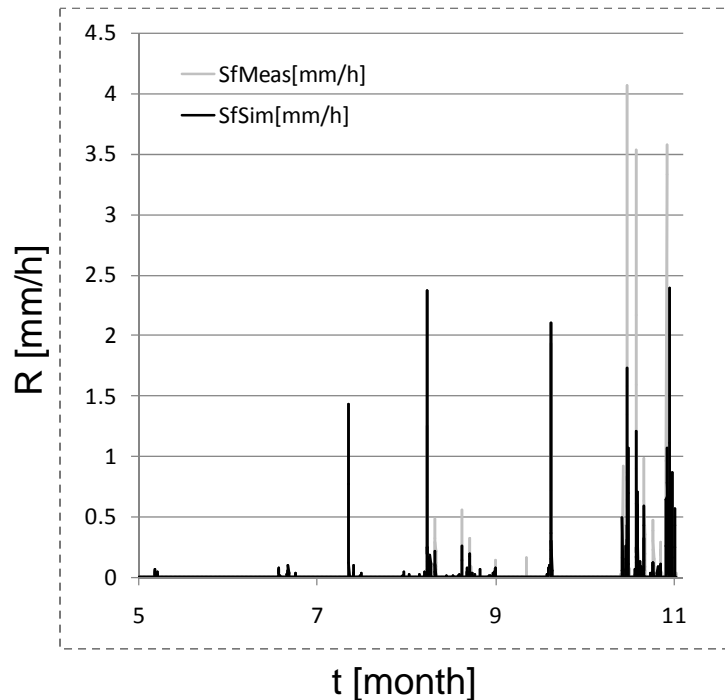


*Cumulative overland runoff
with a shrinkage model*

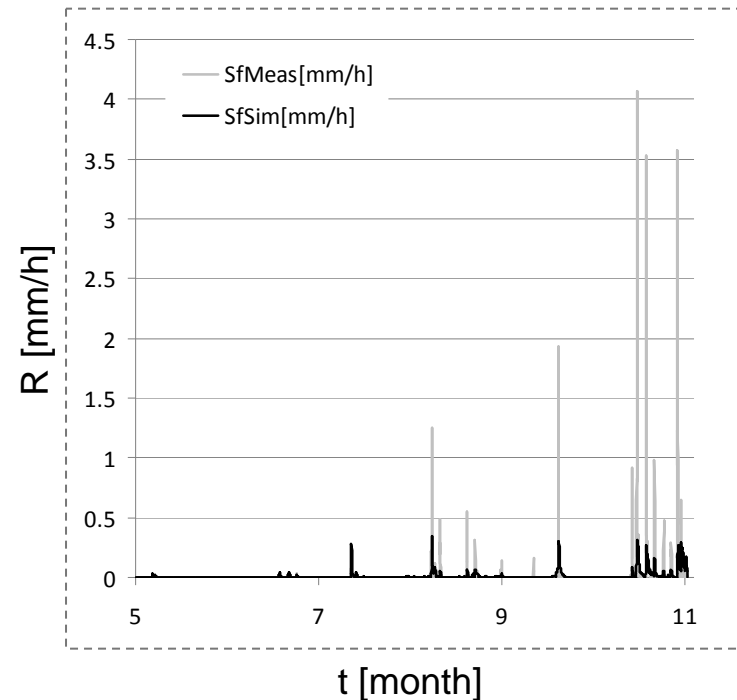


*Cumulative overland runoff
without a shrinkage model*

The effect of Mannings n on overland runoff in year 1998

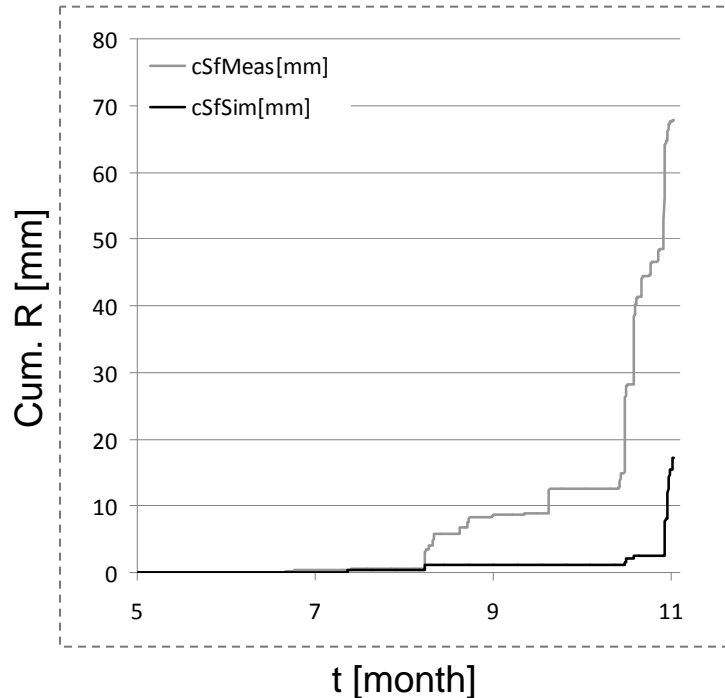


Mannings $n = 0.002$

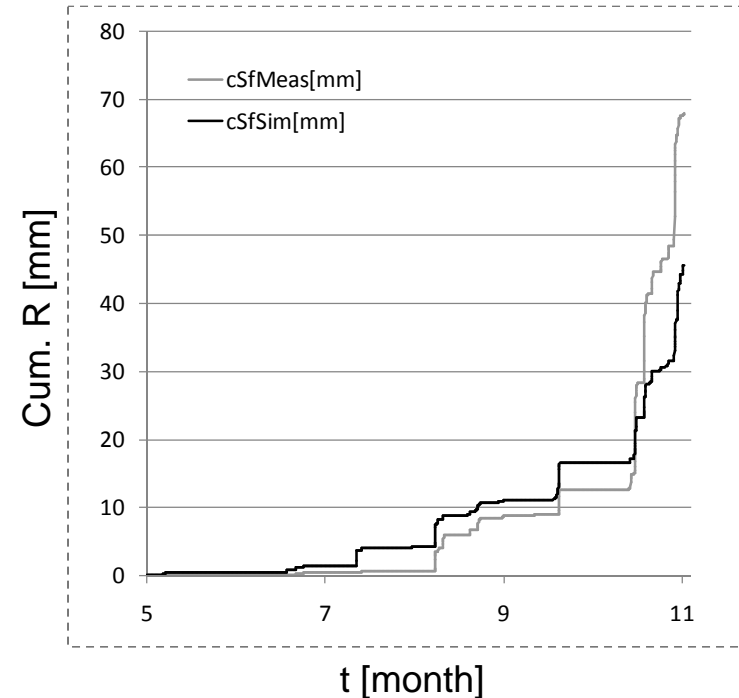


Mannings $n = 0.2$

1-D vs 3-D grid cumulative overland runoff in year 1998



Overland runoff from 1-D grid



Overland runoff from 3-D grid

Dealing with the excess water in Sjökulla

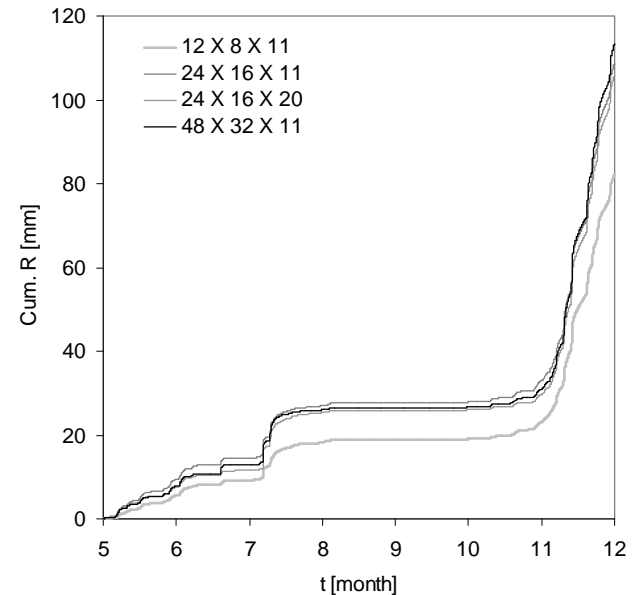
- Modelling at Sjökulla field indicated that there is an unknown sink at the field
- Some possible solutions are:
 - deep groundwater flow
 - seepage to surrounding ditches
 - too low PET values
- Deep groundwater flow was used in the model



Measurement well at the field

Results

- Dual-permeability model seems to work with clay soil
- 1-D and 3-D models do not give same results with the same parameterisation
- Some of the water vanishes through an unknown sink at Sjökulla field
- Change of trend in the runoffs in the late fall with Sjökulla data – soil swelling/shrinkage model corrects it



The effect of grid resolution on subsurface drain runoff

Some missing features

- More detailed evapotranspiration model connected to vegetation
- Heat conduction model
- Snow accumulation and soil freezing model
- More detailed soil swelling and shrinkage models



Micro-meteorological station at the field

Thanks to the audience!

- The study was financed by Maa- ja vesi tuki ry, Finnish Field Drainage Foundation and Ministry of Agriculture and Forestry
- We wish to thank Prof. Laura Alakukku and Dr. Visa Nuutinen for the soil data measured at Agrifood Research Finland MTT
- The contribution of Prof. Pertti Vakkilainen and Dr. Antti Taskinen to this study are appreciated
- Questions?



Muddy field in the spring