Modelling Tile Drainage Discharge Using a Linear Reservoir Model

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Introduction

- More than 50% of the Danish agricultural area is artificially drained.
- Drainage transport of water and nutrients to the aquatic environment is significant.
- Drainage filter technologies might be an effective tool to mitigate site-specific losses of nutrients from agricultural areas.
- Local prediction of drainage discharge is a prerequisite for an optimal and targeted implementation and dimensioning of drainage filters.

Objectives

- Test the ability of a simple reservoir model to predict tile drainage discharge.
- Investigate the relationship between model parameters and site specific variables.

Materials

- Eleven small tile-drained Danish catchments were used in the modeling.

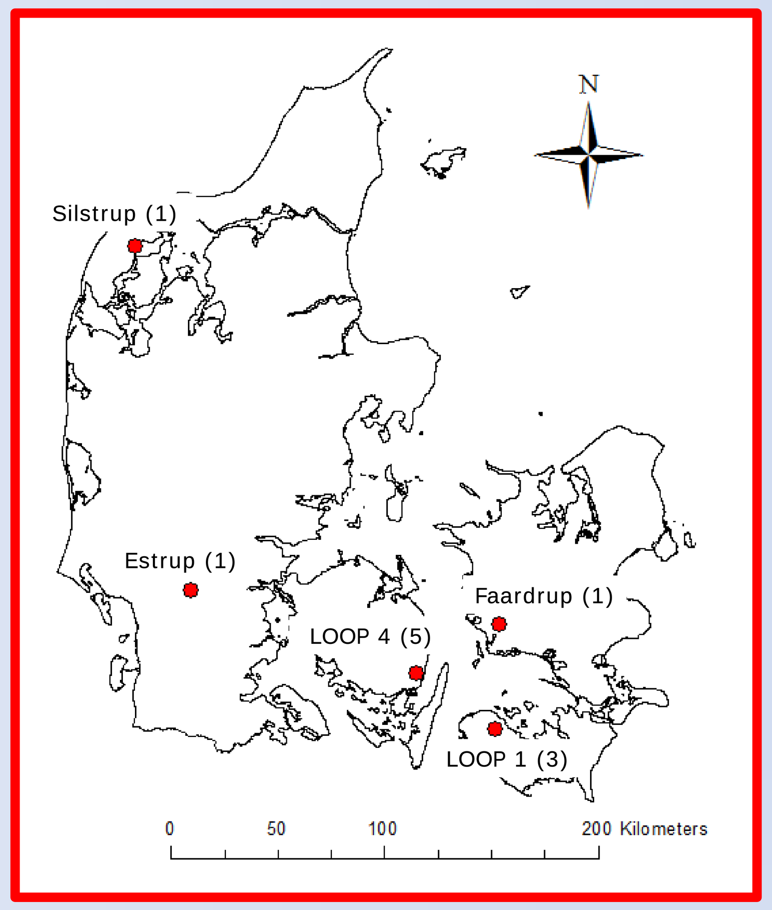

Fig. 1. Investigated sites in Denmark (number of stations).

- Size range: 1-5 hectares
- Texture range (clay %):
  - Ap horizon: 10-18 %
  - B horizon: 12-32 %
  - C horizon: 15-28 %
- Geology: Moraine (till) deposits
- Slope: 1-4 %
- Topographical wetness index: 7-11
- Time series: 8 to 20 years

Methods

Linear reservoir model:

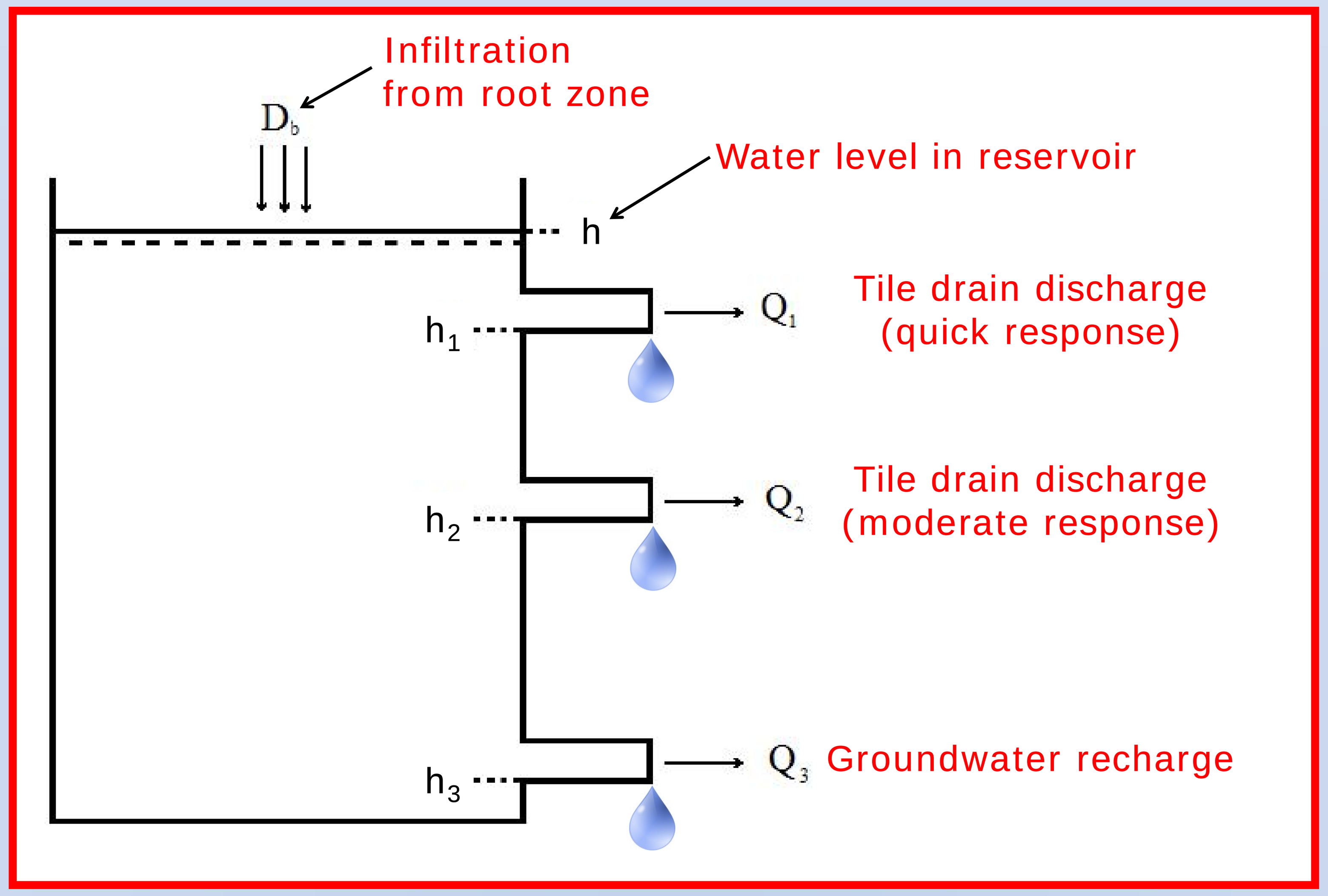

Fig. 2. Linear reservoir with three outlets. Infiltration out of the root zone was calculated by a simple root zone water balance model, EVACROP (Olesen and Heidmann, 1990) using soil type, land use, and climatic data as inputs.

Infiltration from the root zone, discharge through the outlets, and stage in the reservoir are related through the flow equations and the continuity equation:

$$Q_i = k_i(h - h_i) \text{ and } D_b = \Sigma Q_i + \frac{dh}{dt}$$

where i = 1 to 3, k_i is the response coefficient [1/T], and t is time.

Combining the two equations gives a first-order non-homogeneous differential equation which easily can be solved analytically:

$$D_b = \Sigma k_i(h - h_i) + \frac{dh}{dt}$$

Model calibration:

The model parameters were calibrated by nonlinear regression using the Gauss-Marquardt-Levenberg method as implemented in PEST (Doherty 2010). Calibration targets were **daily discharge**, **weekly discharge**, and **flow exceedance probabilities**. The Surface Water Utilities being part of the PEST suite of software was used for processing the time series data.

The following model parameters were calibrated:

- k_1, k_2, and k_3
- c_f (a correction factor taking into account errors in the size of the catchment, non-effective tile drains, etc.)

The following parameters and variables were fixed during calibration:

- h_1, h_2, and h_3
- Time step between discharge observations (one day)
- Baseflow (zero)

Results

Model performance:

In general the developed model performed fairly well. Calculated **Nash-Sutcliffe model efficiency coefficients** (between observed and modeled daily tile drain discharge) were in the range from 0.14 to 0.58 (a value of 1 means a perfect fit).

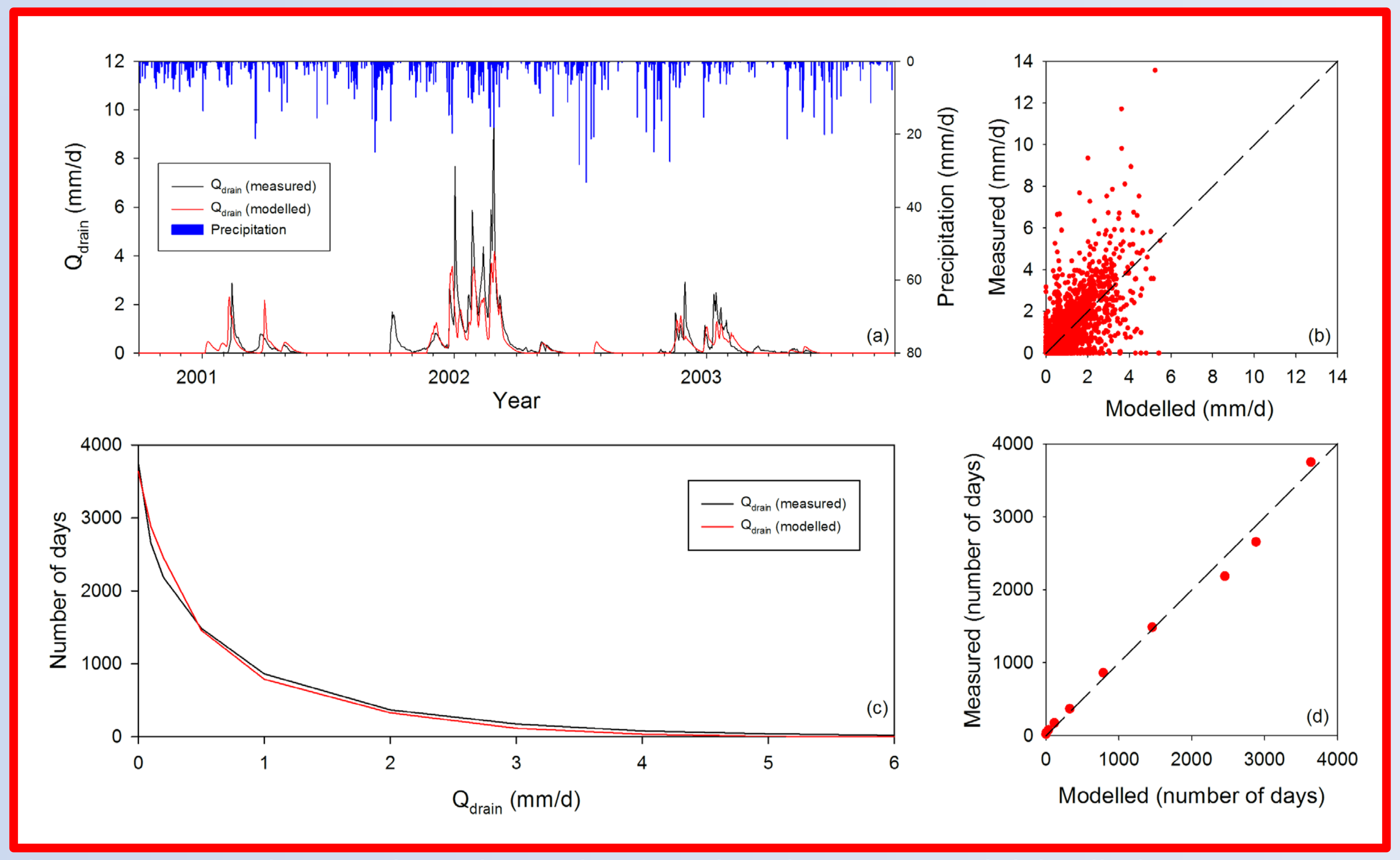

Fig. 3. Example of output from the model plotted against measured daily discharge values (Q_{drain}) (LOOP 1, station 5, time series of 20 years). (a) daily discharge (three years data only), (b) scatter diagram of daily discharge, (c) flow exceedance probabilities, (d) scatter diagram of flow exceedance probabilities (number of days).

Predicting tile drain discharge:

Comparing calibrated parameters and site specific parameters shows fairly good correlation between the clay percentage in the C horizon and the response factor k1 (R^2 = 0.52). For all other parameter combinations, no or only weak correlation was found.

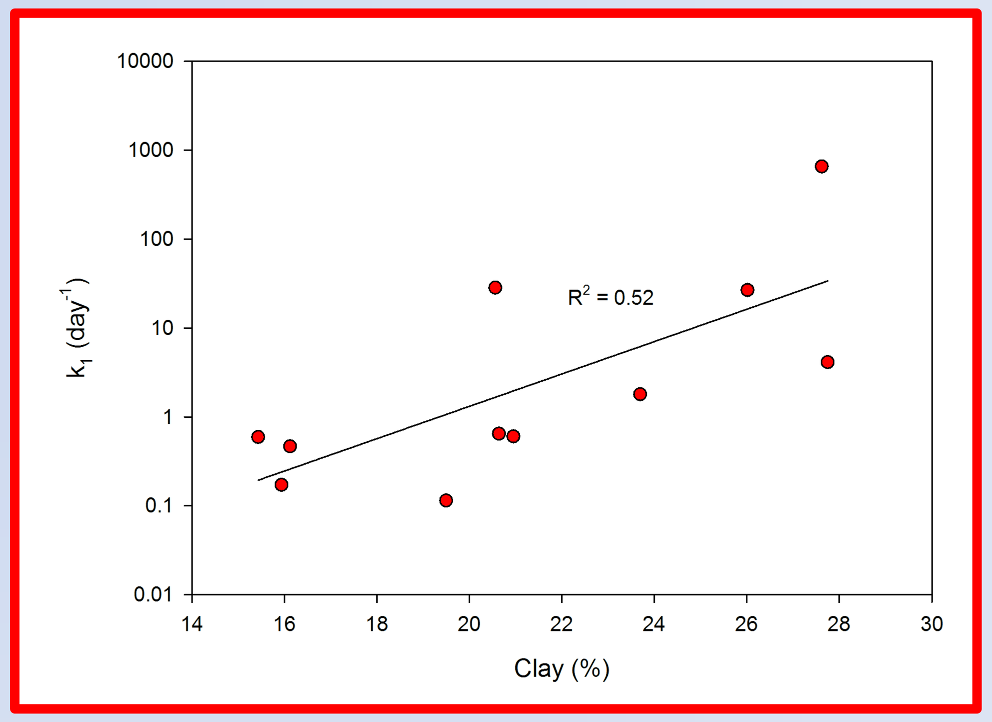

Fig. 4. Relation between clay content in the C horizon and the response factor, k_1.

Conclusions

- The simple linear reservoir model performed well with respect to modeling the dynamic discharge from the tile drainage system
- Fairly good correlation was found between the clay content in the C horizon (at the drain depth) and the response coefficient controlling the discharge peaks from the tile drains.
- The results contribute to an increased understanding of the dynamics of tile drain discharge.

Acknowledgements

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References:

Doherty, J. 2010. PEST, Model-independent parameter estimation-User manual (5th ed., with slight additions): Brisbane, Australia, Watermark Numerical Computing.
Olesen, J.E., and T. Heidmann 1990. EVACROP. Et program til beregning af aktuel fordampning og afstrømning fra rodzonen, version 1.00 (in Danish). Arbejdsnotat nr. 9. Dep. of Agrometeorology, Danish Inst. of Plant and Soil Science, Tjele, Denmark.

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