Abstract

The effect of envelope material and drain spacing on field drainage, crop yield, nutrient transport and soil structure was studied in the *Field drainage methods and optimizing water management of agricultural fields* (PVO) project. The final report of PVO was published in 2010. The second phase (PVO2) included the years 2011–2013 and consisted of both experimental research and mathematical modeling. In the project, monitoring of the three experimental field sites, evaluation of on-farm field drainage systems and research on different envelope materials were continued.

In Nummela experimental site, in south-western Finland, drainage methods were studied in two heavy clay field areas with an original drain spacing of 16 m. New drains were installed (using a plow and a thin textile envelope) with a drain spacing of 6 m in one of the areas. In another area the drain spacing was decreased to 8 m by adding new drains (using a trencher and gravel as envelope material) between the old drain lines. Two field sections with drain spacings of 16 m and 32 m were used as reference plots. Gårdskulla Gård experimental site, in southern Finland, consisted of two field sections with slopes of 1 and 5%. The fields were silty clay and subsurface drained in 1940s. Depth of groundwater table, drainflow and tillage layer runoff and concentrations of nutrients and suspended solids in runoff waters were measured from each field section in both experimental sites. In Nummela, soil moisture (0–30 cm layer), crop yield and quality were also measured, and physical, hydraulic and chemical soil properties were determined in autumn 2006 and again in autumn 2013. The effects of subsoiling on drainflow and grain crop and grass cultivation were investigated in the Sotkamo field site, in northern Finland.

Suitability of different prewrapped envelope materials to drainage of clay and sandy soils were examined with field investigations. Organic coconut prewrapping and thin fabric sheet were studied by excavating 5–32 year old subsurface drains in different parts of Finland. The effect of soil texture and decay of prewrapped envelope material on the siltation of the drains was also studied.

Water balances of the Nummela and Gårdskulla Gård field sections were studied with applications of the three dimensional (3D) mathematical model FLUSH. The model describes hydrological processes in macroporous clayey soil and simulates the water balance components of the field. The model also includes erosion and solute transport submodels. The model simulations were used to estimate the quantity of tillage layer runoff, evapotranspiration, drain discharge and groundwater outflow under different field and hydro-meteorological conditions. Nitrogen reactions and leaching after harvest in autumn were also studied with the model. Annual and seasonal nitrogen balances were calculated for the Nummela site using the data.

Both drainage methods increased the effectiveness of drainage as the groundwater table levels and the soil moistures in the tillage layer were lower than in the reference areas of the Nummela site. Nitrogen leaching increased from both areas especially in the first year following the improved drainage. The renewed drainage had no clear effect on soil structure during the first six years. Also, there were no systematic differences in the crop yield between the 6, 8 and 16 m drain spacings. On average the crop yield and quality were lower in the area with 32 m drain spacing. Subsoiling did not have a clear effect on the crop yield, but during the

autumn the water table levels in the subsoiled field remained slightly lower than in the non-subsoiled field.

The nutrient and suspended solid loads from the clayey fields varied considerably between the different years. Major part of the loads from Nummela and Gårdskulla Gård fields were observed during the high drain discharge and surface runoff events outside the growing season. The annual loading came primarily from the tile drains. In the subsurface drainflow, the annual load of total P varied from 0.1 to 3.9 kg ha^{-1}, total N from 1 to 29 kg ha^{-1}, and suspended solids from 170 to 2 400 kg ha^{-1}. It should be noted that the drain discharge and the associated nutrient and suspended solid loads were also high from the field with a relatively steep slope (5%). Water pollution control measures from field cultivation needs more attention on reduction of concentrations both in tillage layer runoff and drainflow.

According to the modeling results the groundwater outflow from the clayey fields was substantial. This should be considered in the estimation of the total loads to surface water bodies. The model simulations also showed that topography of a field section and its surroundings had a remarkable effect on groundwater flow and drainflow generation, which should be taken into account in drainage design.

No clear connection between the amount of soil soluble phosphate phosphorus in the tillage layer and the PO4-P concentration in the tillage layer runoff and drain discharge was observed in the Nummela and Gårdskulla Gård field sites. The soil phosphorus concentrations were slowly decreasing after the mineral P fertilization was stopped in all the fields. However, no reduction of phosphate phosphorus concentration was observed in the tillage layer runoff or drain discharge. The possible change was partly imbedded by change from grain crop production to pasture.

The textile envelope material and coconut fibre had mostly decayed in the study sites situated in different parts of Finland. When the envelope around the drain pipe had decayed, silting was observed in most of the studied soils, which required an envelope material with good filtration properties. However, silting was also found in the pipes located in the soils with high clay content, which according to the theory should not require envelope material with good filtration properties. Use of organic envelope materials should be avoided in soils where organic materials are in risk of decaying and drainage pipes are susceptible to silting.

The study showed that there are many different ways to achieve effective subsurface drainage. The drain spacing, drain depth, quality and thickness of the envelope material, the timing of subsurface drainage and the type of installation machine affect the water balance components and flow paths in the soil and thus also the drainage conditions and nutrient transport.

Field scale studies are necessary in the research of subsurface drainage methods. The non-homogeneity of experimental areas, e.g. the differences in soil properties and field topography, causes uncertainties in the interpretation of the measurement results. However, long -term data before and after operations will increase the reliability of the field-scale results. 3D mathematical models can be used to study field hydrology, to analyze the measured data and to estimate the effects of subsurface drainage methods computationally.

Key words: *subsurface drainage, drain spacing, envelope material, nutrient transport, crop yield, mathematical modeling*