2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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The effect of additional subsurface drainage on water discharge and nutrient load on clay soil

Helena Äijö[1], Maija Paasonen-Kivekäs[2], Merja Myllys[3], Jyrki Nurminen[1], Mika Turunen[4], Heidi Salo[4], Lassi Warsta[4], Harri Koivusalo[4], Markus Sikkilä[1], Laura Alakukku[5], Markku Puustinen [6]

[1]Finnish Field Drainage Association, [2]Sven Hallin Research Foundation, [3]Natural Resources Institute of Finland, [4]Aalto University, School of Engineering, Department of Built Environment, [5]University of Helsinki, Department of Agricultural Sciences, [6]Finnish Environment Institute

List all authors, then all addresses, using superscripts as needed.

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ABSTRACT. In the southern parts of Finland 75% of the arable land area has subsurface drainage. Most of the subsurface drainage systems have been installed 40-50 years ago. At present, there is need to improve drainage efficiency of the old drainage systems. The aim of this study is to find out how the additional subsurface drainage affect groundwater table depth, discharge, nutrient load and crop yield. The study has been carried out on experiment site in Jokioinen, in south-western Finland. The soil is heavy clay and the mean slope is 1%. The drain depth was 1.1 m and gravel was used as envelope material. Drain flow and tillage layer runoff from each field section have been continuously measured since May 2007. Concentrations of total nutrients and suspended solids have been determined from flow weighted composite water samples. Depth of the groundwater table and soil moisture have also been measured. According to the results additional drainage decrease in groundwater level following snow melt and rainfall events was more rapid than before the drainage. Additional drainage increased drain outflow and also the nutrient loads from the drains. The results suggest that additional drainage did not affect the nutrient concentrations, apart from the peak in total nitrogen concentration in the first year after the additional drainage.

Keywords. *Additional subsurface drainage, clay soil, nutrient load, subsurface discharge*

INTRODUCTION

In the southern parts of Finland 75% of the arable land area has subsurface drainage. In this region, clay soils with a low permeability are common. Most of the subsurface drainage systems have been installed 40-50 years ago. Accordingly, there is need to improve drainage efficiency of the old drainage systems to prevent water logging and soil compaction. In Finland, the typical drain depth is 1.0-1.2 m. Nowadays, the drain spacing varies from 8 to 24 meters depending on the soil type, when earlier the common drain spacing was between 14 and 40 meters. Gravel is the most common envelope material. The aim of this study is to find out how the addition of new drains to an old subsurface drainage system affect groundwater table depth, discharge, nutrient load and crop yield.

The results presented here are based on long-term field-scale measurements under different tile drainage systems in south-western Finland. The experimental site, measurements and results from the period 2007-2013 have been presented in more detail by Äijö et al. (2014). The field hydrology and drainage systems have also been studied using 3-D modeling by Turunen et al. (2013, 2015) and by Salo et al. (2016). Nitrogen transport in the experimental site has been modelled by Salo et al. (2015).

EXPERIMENTAL SITE AND MEASUREMENTS

The study has been carried out in three field plots B (1.3 ha), C (1.7 ha) and D (3.4 ha) in Jokioinen, in south-western Finland. The soil is heavy clay and the mean slope is 1%. In all the plots the tile drains were installed in 1954 with spacing of 16 m (B and C) and 32 m (D). The drain depth was 1.1 m and gravel was used as envelope material.

In June 2008, additional drain pipes were installed into section C between the original drains resulting in 8 m drain spacing. In June 2014, drainage of plot D was improved installing two drains between the original ones resulting in 10.7 m drain spacing. In the installation of the new drains gravel was used as envelope and special deposits along the trench. Section B with 16 m drain spacing was left as a control plot.

Drain discharge and tillage layer runoff from each plot have been continuously measured since May 2007. Concentrations of total P, PO_4-P, total N, NH_4-N, NO_3-N and total suspended solids have been determined from flow weighted composite water samples. Depth of the groundwater table have been measured both automatically and manually (weekly or biweekly) . Soil moisture in the tillage layer (0-0,2 m) has been measured manually using TDR during frost free periods. Crop yield and quality have been measured from each plot since 2008. Precipitation has also been measured on site excluding the winter periods. Soil properties from each field were determined in autumn 2006 before the additional drainage measures and in autumn 2013.

All the experimental plots have been cultivated using similar crops (oats and barley), and tillage methods for several years before and during the experiments. The measurements started with a calibration period (6/2007 – 5/2008). It has been followed by eight year-long experiment periods: I (6/2008–5/2009), II (6/2009–5/2010), III (6/2010–5/2011), IV (6/2011–5/2012), V (6/2012–5/2013), VI (6/2013–5/2014), VII (6/2014–5/2015) and VIII (6/2015-5/2016).

Runoff

The annual precipitation in the different periods was: Calibration 715 mm, Exp. I 646 mm, Exp. II 575 mm, Exp. III 526 mm, Exp. IV 693 mm, Exp. V 623 mm, Exp. VI 564 mm, Exp. VII 628 mm and Exp. VIII 544 mm.

Additional drainage in plot C

Drain discharges in plot C (drain spacing 16 m) and in the reference plot B (16 m) were almost equal in the calibration period. After the additional drainage the annual drain discharge in plot C (drain spacing 8 m) was on average 1.8 times higher than in the reference plot B (Fig. 1). However, the calibration data encompassed only one year before the additional drainage measures. Whereas, the experimental periods covered eight years with varying hydrological conditions.

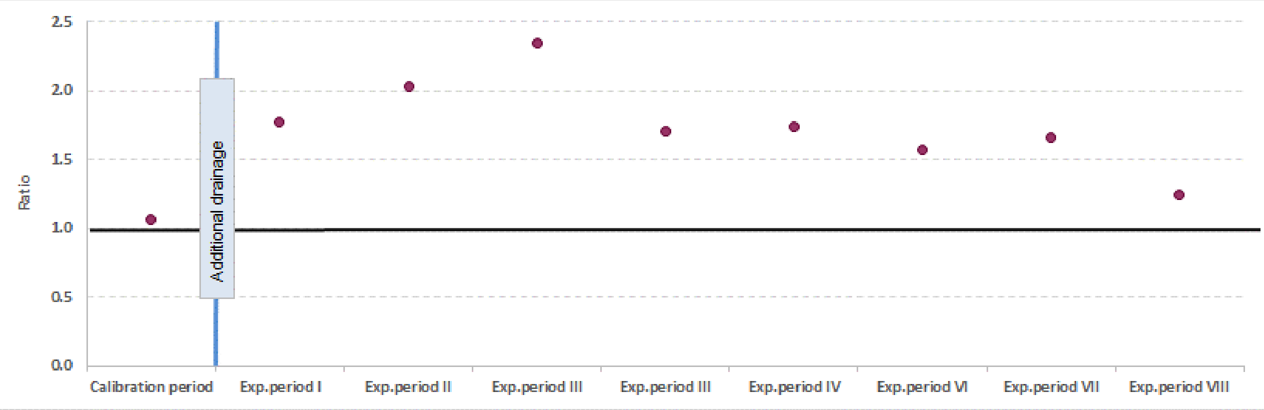

Figure 1. Ratio (plot C/plot B) of the drain discharges in plots C and B before and after the additional drainage of plot C.

Additional drainage in plot D

In plot D (32 m) the annual drain discharge and tillage layer runoff were approximately equal before the additional drainage. The ratio of total runoff (drain discharge + tillage layer runoff) to precipitation was 0.22. The denser drain spacing (10.7 m) produced a substantial amount of drain discharge. During experiment periods VII and VIII the respective ratio of drain discharge was on average 0.27 (Fig. 2). The improved subsurface drainage resulted in smaller tillage layer runoff. Before the additional drainage, the tillage layer runoff ratio to precipitation was on average 0.11, while during periods VII and VIII the ratio was 0.07 and 0.03, respectively (Fig. 2).

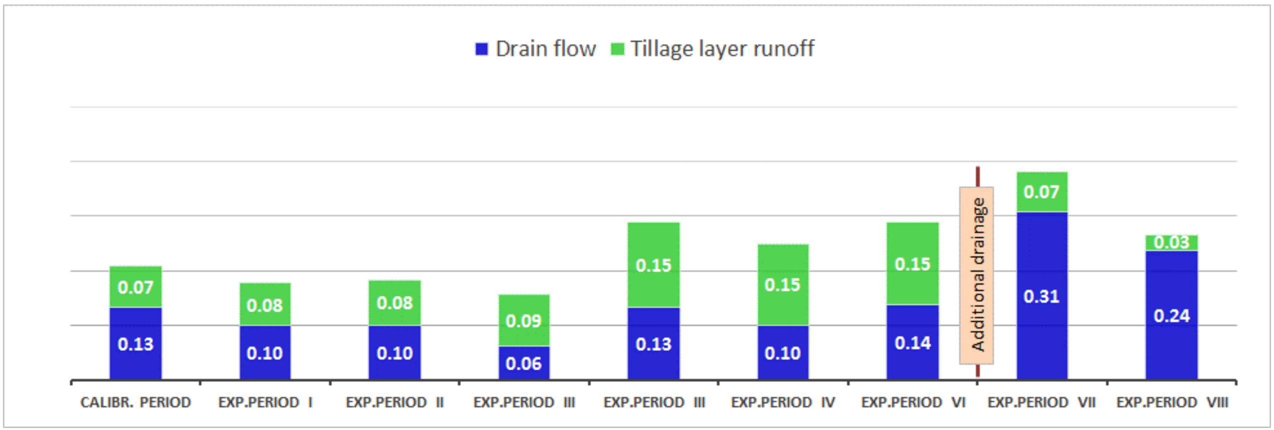

Figure 2. Ratio of drain discharge and tillage layer runoff to precipitation.

Groundwater level

The additional drainage improved soil moisture conditions in plot C keeping the groundwater level below the soil surface even during wet periods.

In plot D under 32 m drain spacing the groundwater level remained higher than in the plots with 8 m and 16 m drain spaces. Groundwater level of plot C also reacted more rapidly to rainfall, and during the wet periods the groundwater level almost reached the soil surface.

The additional drainage clearly brought down the groundwater level in plot D. For example in spring 2013 before the drainage improvement, the groundwater level in plot D declined to the depth of 0.6 m from the soil surface 17 days later than in plot B (Fig. 3a). After the additional drainage in spring 2015, the groundwater level in plot D dropped to the depth of 0.6 m 7 days earlier than in plot B (Fig. 3b).

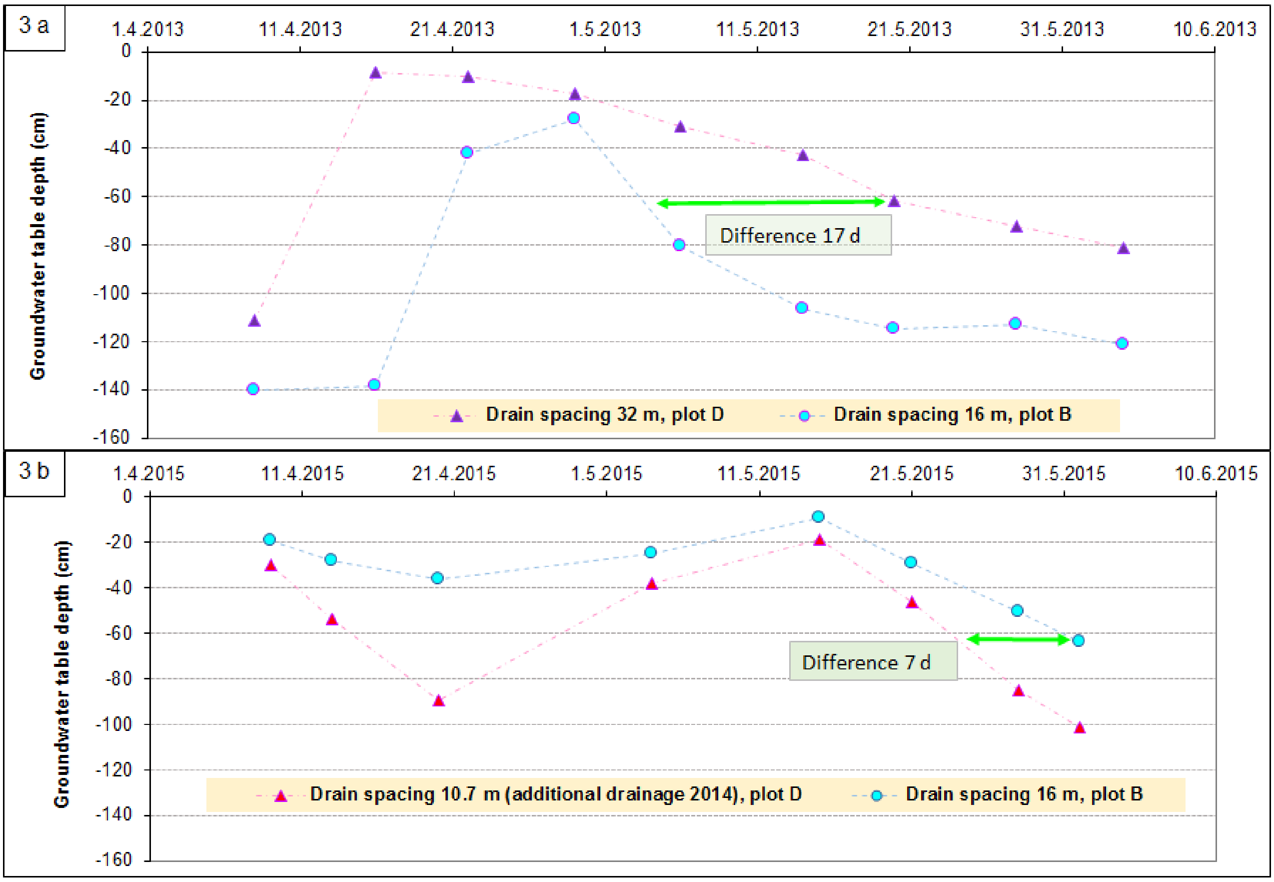

Figure 3. Groundwater table depth from the soil surface in plot D and in the reference plot B (a) before (spring 2013) and (b) after (spring 2015) the additional drainage of plot D.

Concentrations

Total nitrogen

During the calibration period, the total N concentrations in drain discharge were almost similar in plots C (16 m) and B (16 m). During the first year after the addition drainage, the N concentrations in plot C (8 m) were on average 1.5 times higher than in the reference plot B. However, the difference decreased to the level prior to the additional drainage in the following years (Fig. 4).

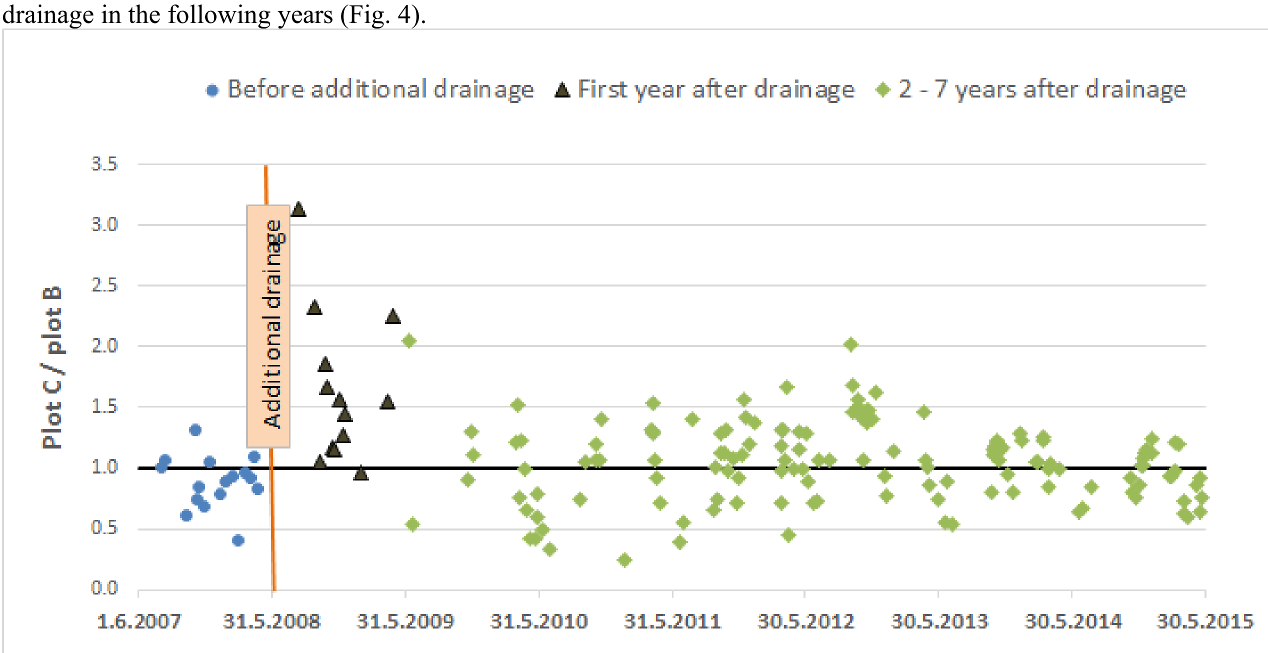

Figure 4. The ratio (plot C/plot B) of the total nitrogen concentrations in drain discharge from plots C and B before and after the additional drainage of plot C.

Total phosphorus

During the calibration period, the total P concentrations in drain discharge were at the same level in plots C (16 m) and B (16 m). After the additional drainage, the P concentrations in drain discharge of plot C (8 m) were slightly lower compared to the reference plot B (16 m). (Fig. 5).

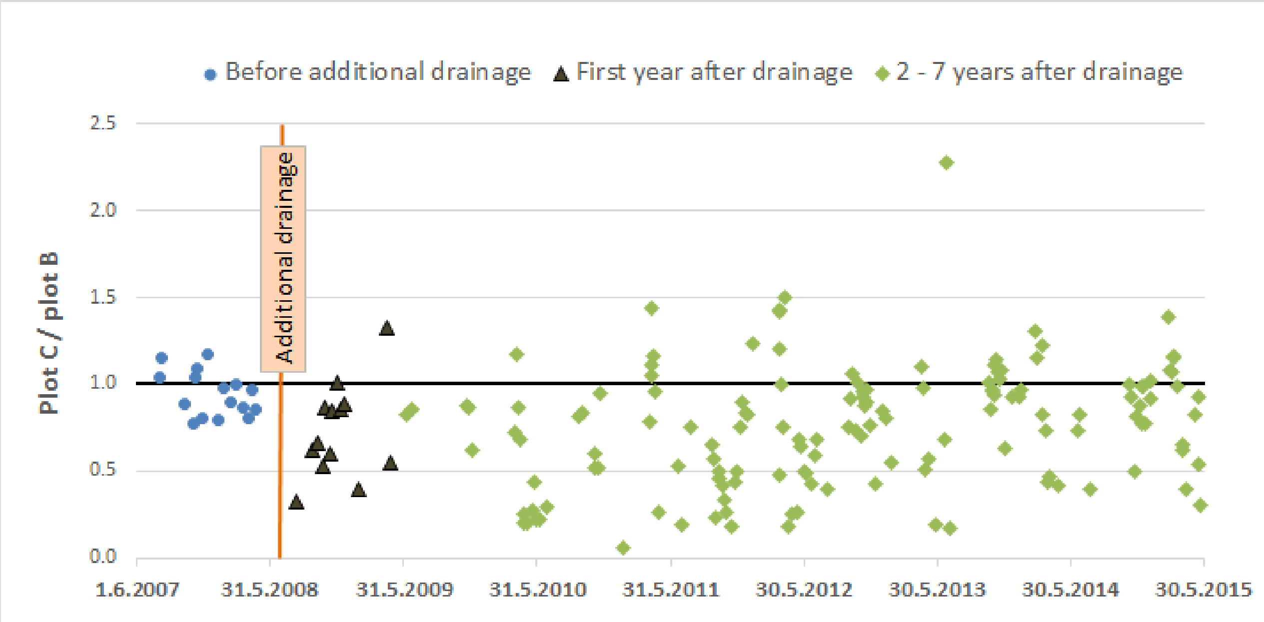

Figure 5. The ratio (plot C/plot B) of the total phosphorus concentrations in drain discharge from plots C and B before and after the additional drainage of plot C.

Nutrient loads

Total nitrogen

During the calibration period and experiment periods I–VI, the annual total N load was the smallest in plot D and the highest in plot C (Fig. 6. In the first period following the additional drainage (VII) of plot D, the increased drain discharge in plot D resulted in in a higher N load than in the other plots. The total N load via drain discharge was also relatively high in the reference plot B during the experiment period VII. The reason was the higher total N concentrations during this period compared to the previous periods.

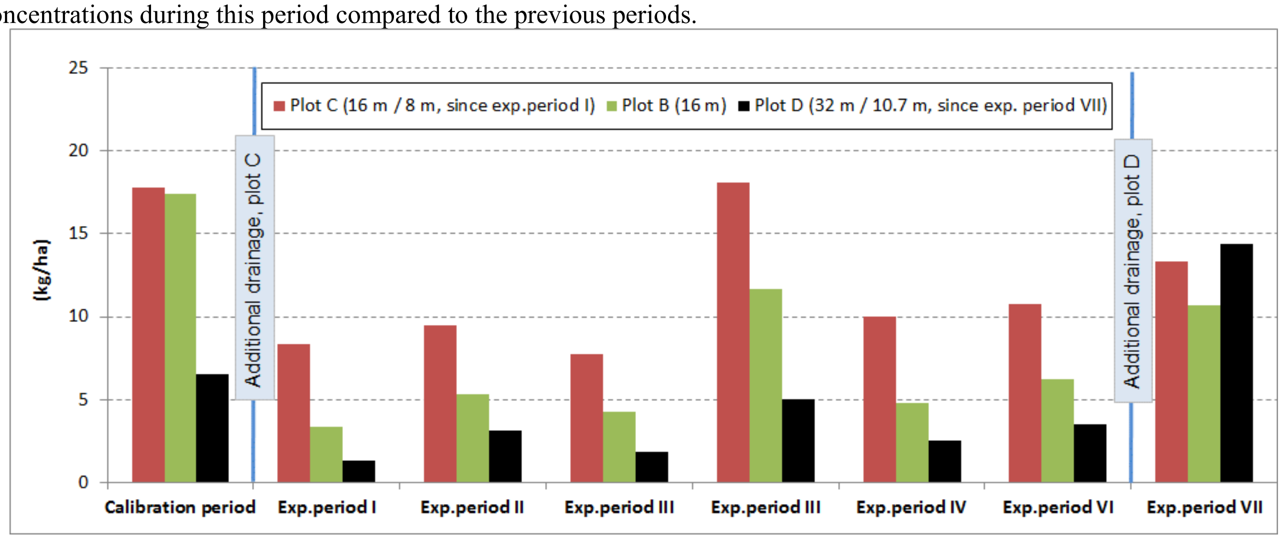

Figure 6. Annual total nitrogen loads in drain discharge of plots B, C and D in the calibration period and experiment periods.

Total phosphorus

The highest total P loads via drain discharge resulted from plot C (16 m/8m) and the smallest from plot D (32 m/ 10.7 m). The highest total P load (3.4 kg ha^{-1} a^{-1}) was generated from plot C (Fig. 7) in period VI when exceptionally high losses were also measured in the other plots. The relatively high loads in experiment period VI were mainly a result of the high total P concentrations. Furthermore, the increased drain discharges following the additional drainage in plots C and D enhanced the total P loading.

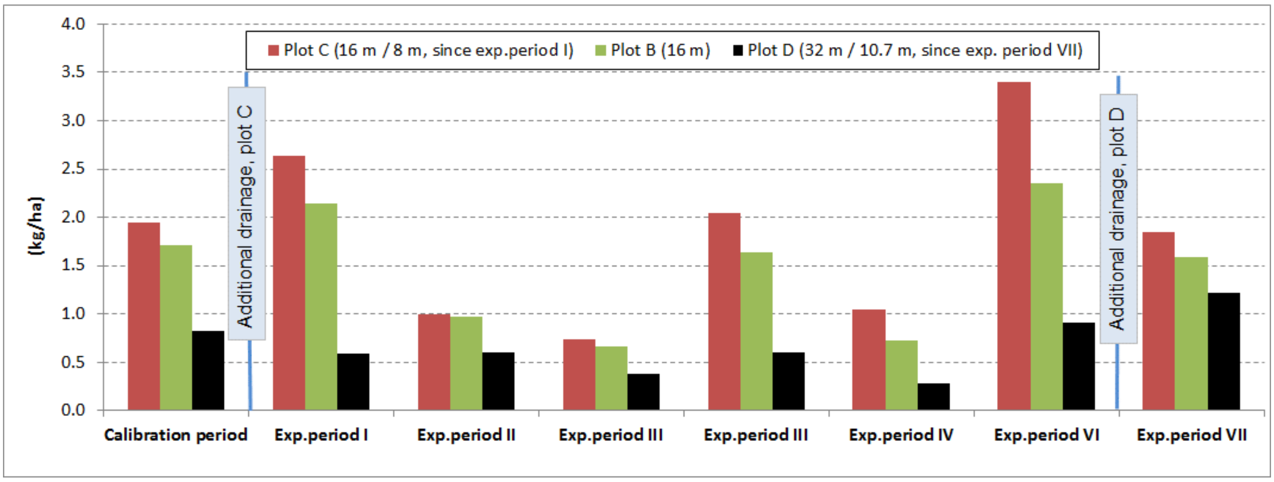

Figure 7. Total phosphorus loads in drain discharge of plots B, C and D in the calibration period and experiment periods.

Crop yield

The crop yield and quality parameters did not notably differ between plots B and C during the seven experimental periods after the additional drainage of plot C. However, in plot D with 32 m drain space the crop yield and quality were lower than in the other plots. The additional drainage in spring 2014 did not improve the crop yield or quality in plot D during years 2014 and 2015.

During the study, all the plots were sowed on the same date to simplify the experimental design and field work. If the sowing had been made in optimal soil moisture conditions for trafficability in each plot, the effect of the improved tile drainage on the crop yield and quality might have been more clearly emerged.

CONLUSIONS

1. In the plots with additional drainage, the decrease in groundwater level following snow melt and rainfall events was more rapid than before the drainage.
2. Additional drainage did not affect the nutrient concentrations, apart from the increased total nitrogen concentrations in the first year after the additional drainage.
3. Additional drainage increased the drain discharge and also the nutrient loads from the drains.
4. No effect of additional drainage on crop yield or quality was observed during the study, when the sowing date was the same for all the plots.

REFERENCES

Salo, H. et al. (2016). Simulating the Effect of Drain Trench on Water Movement from the Field Surface to Subsurface Drains with a 3-D Hydrological Model. 10th International Drainage Symposium September 6–9, 2016, Minneapolis, Minnesota. Manuscript.

Salo, H., Warsta, L., Turunen, M., Paasonen-Kivekäs, M., Nurminen, J., Koivusalo, H. (2015). Development and application of a solute transport model to describe field scale nitrogen processes during autumn rains. *Acta Agriculturae Scandinavica, Section B - Plant & Soil Science.* 65:sup1, 30-43 . http://dx.doi.org/10.1080/09064710.2014.971861

Turunen, M., Warsta, L., Paasonen-Kivekäs, M., Nurminen, J., Koivusalo, H. (2015). Simulating water balance and evapotranspiration in a subsurface drained clayey agricultural field in high latitude conditions. *Acta Agriculturae Scandinavica, Section B - Plant & Soil Science*. 65:sup1, 44-57. http://dx.doi.org/10.1080/09064710.2014.975834

Turunen, M., Warsta, L., Paasonen-Kivekäs, M. Nurminen, J., Myllys, M, Alakukku, L., ... Koivusalo, H. (2013). Modeling water balance and effects of different subsurface drainage methods on water outflow components in a clayey agricultural field in boreal conditions. Agricultural Water Management 121, 135– 148. http://www.sciencedirect.com/science/article/pii/S0378377413000334

Äijö, H., Myllys, M., Nurminen, J., Turunen, M., Warsta, L., Paasonen-Kivekäs, … & Puustinen, M. (2014). *PVO2-hanke - Salaojitustekniikat ja pellon vesitalouden optimointi - Loppuraportti 2014*. Salaojituksen tutkimusyhdistys ry:n tiedote 31. Helsinki: Finnish Field Drainage Association. 105 pp.