Effect of controlled drainage and sub-irrigation on groundwater level, drain discharge, nutrient loadings and yields

Seija Virtanen, Maija Paasonen-Kivekäs, Jaana Uusi-Kämppä, Helena Äijö, Kari Ylivainio and Rainer Rosendahl

The focus of this study was to get a larger view on the effect of controlled drainage on groundwater level, run-off, nutrient leaching and crop yields. We surveyed the results of the old as well as ongoing field experiments concerning controlled drainage and sub-irrigation in Finland. The data consists of field experiments which represent various types of soil from mineral to peat soils.

Controlled drainage and sub-irrigation have been proposed an option to decrease nutrient leaching from agricultural fields. In the studies carried out in different countries under humid climate it was found that in dry summers controlled drainage enhanced yields by way of providing water for transpiration. In addition, the total leaching of nutrients was found to decrease. The main reason for the decreased leaching was decreased runoff but also lower nutrient concentrations in runoff waters due to denitrification of nitrate and sorption of phosphorus.

In Finland, controlled drainage and sub-irrigation have been studied in order to improve the quality and quantity of yields already in the beginning of the 20th century. At that time dry summers prevailed and crops suffered from droughts. However, subsequently the technique was set aside when normal and wet summers occurred and drainage was the most important issue. The interest in controlled drainage studies rose again in the 1990's focusing on the mitigating of nutrient loads from cultivated fields. As a result of these studies the decrease in nitrogen leaching by controlled drainage was calculated to be 15% compared to conventional subsurface drainage. Accordingly, farmers started to get subsidies to their investments in controlled drainage and its maintenance in Finland in 1995. Later on feasibility of controlled drainage and sub-irrigation of decreasing harmful environmental effects of drained acid sulfate and peat soils have been investigated.

At the moment environment subsidies for controlled drainage and sub-irrigation are granted to acid sulfate and peat soils only in order to mitigate acid loadings and to decrease greenhouse gas emissions. Until now controlled drainage has been implemented on an area of ca. 70 000 ha. However, it has been estimated that controlled drainage would be feasible for 600 000 – 800 000 ha of agricultural fields.

All the surveyed controlled drained fields were very flat (slope < 1%) and thus suitable for controlled drainage. The field measurements indicated that the groundwater table level in the single fields under controlled drainage dropped sharply below the drain depth during dry spells. In the studied sub-irrigated fields the pumping of water into the drainage system was found to increase groundwater level but not in the furthermost field area. However, in dry summers shortage of water has restricted sub-irrigation.

The effect of controlled drainage on drain discharge was estimated using occasional manual measurements. No drain discharge was observed from the controlled drained fields even though there was drain discharge from the fields without control at the same time. In the ongoing acid sulfate soil field experiment the drain discharge has been continuously measured. There the annual drain discharge decreased from 9% to 39% due to controlled drainage.

Slightly decreasing trends were observed in the concentration of nitrogen in the drain discharge in the fields. However, the differences were not significant. On the contrary, the total phosphorus

concentration increased significantly in the discharge water of the controlled and sub-irrigated fields in acid sulfate soil. This phenomenon might be related the reduction of iron and aluminum oxides, which serve sorption places for phosphorus. In the surveyed acid sulfate soil fields, phosphorus concentrations in drain water was very low, 20 – 30 µg l^{-1}, contrary to nitrogen concentrations which were up to 32 mg/l.

Based on the results from the surveyed controlled drainage fields the decrease in drain discharge means decrease in nutrient leaching. In the acid sulfate soil experimental field, the decrease of drain discharge by the 50 mm would mean a decrease in the total nitrogen load by 8.5 kg ha^{-1} $year^{-1}$ (the average long-term N_{tot} concentration of drain water in the experimental field 17 mg l^{-1}) and in the total phosphorus load by 0.01 kg ha^{-1} $year^{-1}$ (the average long-term P_{tot} concentration of drain water in the experimental field 20 µg l^{-1}).

The crop yields have been increased and the quality of crop has improved by controlled drainage and especially by sub-irrigation. The most pronounced effect has been found on potatoes, crop yield of which increased by 80% compared to a field without drainage or irrigation at the same year. The respective increase in the crop yield of barley was 40%. In an 8-year-long study period in an acid sulfate soil, no statistical differences were detected in crop yields among conventional drainage, controlled drainage and sub-irrigation, but differences in the yields varied annually. For example in a dry growing season, the crop yield of barley was increased by 920 kg/ha (20%) and 370 kg/ha (8%) by sub-irrigation and controlled drainage, respectively, compared to conventional drainage (4690 kg/ha). In a rainy summer, however, the conventional drainage system gave 140–450 kg/ha (2–7%) higher crop yield of wheat compared to controlled drainage (6790 kg/ha). There were no statistical differences in test weights of grain (hectoliter weight and 1000 seed weight).

The importance of controlled drainage will be pronounced due to the climate change, which has been predicted to cause more frequent and higher rainfalls causing further increase in nutrient leaching in Finland. Furthermore, irrigation might be needed in a larger scale than nowadays to ensure profitable crop production. To improve function of controlled drainage and sub-irrigation effective management of water table level in a single field and also in a main ditch is needed. Therefore, automatic valves (Water Gate) in collector pipes and control wells and an automatic dam powered by solar energy are being studied.

Keywords: Controlled drainage, Sub-irrigation, Nutrient loadings, Yields