Subsurface Drainage and Irrigation Automation for Cultivated Land Groundwater Management

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March 30, 2023

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Abstract: Automation of cultivated land groundwater management using subsurface drainage is considered. The necessary elements including actuating valves or gates, energy management, ICT infrastructure and model-based monitoring and control are discussed.

Keywords: water resources, agriculture, model predictive control

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1 Background

The need for joint improvements in mitigation of greenhouse gas emissions, water loading, carbon sequestration, and efficient use of water resources, act as novel driving forces for refining cultivation practices. The height of the water table is a necessary parameter for ensuring crop growth and enabling carrying capacity for farming operations (Häggblom et al., 2019), but also efficient for regulating greenhouse gas emissions from cultivated peatlands (Evans, 2021). Controlled management of water resources leads to efficient and timely use of water, enabling agriculture to adjust to changing weather and climate conditions. At the same time, the increase in size of farms and responsibilities on farmers has led to an overload of operational activities. As a consequence, there is a need for a holistic, adaptive, and anticipating monitoring and control of farming drainage and irrigation operations, and maintenance of water resources.

More than 60 % of cultivated peatland in Finland is equipped with subsurface drainage. Controlled subsurface drainage provides a potential means for automation assisted control of both drainage and irrigation for the management of time-varying groundwater table height, according to the requirements set by the users.

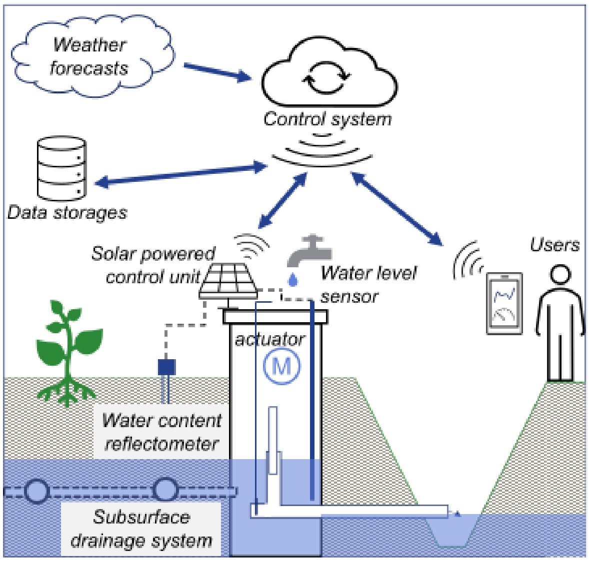

Fig 1. Remote-controlled subsurface drainage system.

2 Aims and methods

Monitoring and control of ground water table requires the development of suitable actuators, power supplies, data transmission, anticipating modeling capabilities, optimization facilities, and a user interface supporting the decision making of the farmer. The outline of the developed infrastructure is illustrated in Fig. 1.

A complete re-design of the control gate valve at the subsurface drainage well aims at improved robustness and minimal energy consumption. A prototype of a motorized valve unit shown in Fig. 2. attaches into an existing gate valve inside a manually controlled well. The design includes battery backed solar powered electricity supply and smart energy management, a suite of sensors for monitoring the ground water level and soil moisture conditions in and around the gated drainage well, and a cellular 3G radio device for communicating with information systems online. Means of interfacing with automated irrigation systems have been reserved, but not implemented at this stage.

The necessary two-way communications infrastructure from the devices to a de-centralized (cloud) or centralized local data storage/computing system has been implemented using common standard internet protocols. Each individual device comes with a backup interface over cellular short messaging services (SMS) for direct control access. A simplified user interface is provided and accessible through a computer or a smart device capable of displaying a web page.

A predictive ground water model together with weather forecasts provides anticipation of water table heights for the near future. A simplified dynamic 1-D model for the subsurface drained field water balance has been derived. The model has then been used in a nonlinear model predictive control (MPC) setup to adjust the ground water height under various constraints set by the system. From control point of view, a meaningful prediction window extends over a period of few weeks. The horizon is limited, due to uncertainties in weather forecasts, limited prediction abilities of system models, and MPC computational load with long horizons. For more details on the MPC design, see Ikonen *et al*. (2023).

3 Results

The control well hardware has been tested at various field sites around Kannus, Nivala, and Ruukki during the fall and summer of 2021 and 2022. The main challenges were in optimizing energy use and maintaining reliable communications. Some issues were found regarding the quality of components, especially the cellular radio modules which were found to be somewhat unreliable and inefficient. The tests, however, proved the concept feasible and means of improving reliability and energy use were identified and partially implemented for on-going tests through 2023. The results indicate that further hardware and software revision will make autonomous all-year-round operation possible regardless of the lack of sunlight during December and January.

Fig 2. Prototype of controlled well installed to test area.

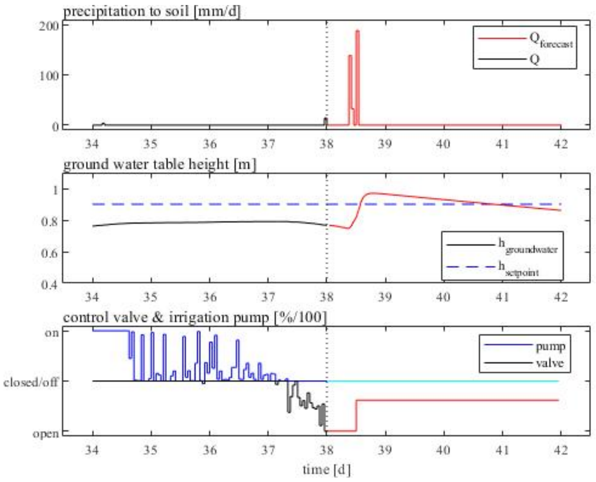

Fig 3. On-line snapshot of MPC in action at day 38. Past irrigation has changed to drainage, due to forecasted rain in the prediction horizon.

The MPC has been tested in simulations. Figure 3 illustrates the concept of MPC, with a 4-day prediction horizon. Ongoing work looks at more efficient MPC implementations, refining the system based on data from field measurements and getting experiences from both the performance and UI/UX from tests at the experiment site.

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The work was conducted in three projects from the Catch the Carbon (*Hiilestä kiinni*) research and innovation programme funded by the Ministry of Agriculture and Forestry of Finland: Vesihiisi (*Turvepeltojen hiilipäästöt kuriin innovatiivisella vesienhallinnalla*, 2021–2023), PeltoSäätö (*Peltomaan älykkään vesienhallinnan pilotit*, 2021–2023) and ESKE (*Etähallittavan säätösalaojakaivon kehittäminen ja pilotointi*, 2021–2022) in cooperation with Luke (Natural Resources Institute Finland) and Kpedu (Federation of Education in Central Ostrobothnia).