Mitigating agricultural water shortages by recycling industrial residual water


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Treated residual water from the Bavaria brewery was used for the subirrigation of a plot of agricultural land. The water table rose and the water available to the crop increased. The use of industrial residual water can mitigate water shortages.

We are increasingly confronted with drought damage in agriculture and nature as well as an increasing pressure on the availability of water for high-grade applications such as the production of drinking water. Strategies are being developed to control these risks and to secure long-term supplies of freshwater. This includes increasing regional self-sufficiency in meeting the demand for freshwater and improving the utilization of the available water sources. This requires an approach in which various sectors jointly search for solutions for their water needs and the water needs of others.
A number of industrial sectors discharge their treated residual water to surface water despite water shortages in agriculture. Using this residual water in the area rather than discharging it unused can contribute to the mitigation of water shortages.

Bavaria wishes to cooperate with farmers and water managers in the use of its treated residual water (effluent from the wastewater treatment plant) to meet agriculture's water requirements and reduce the risk of water shortages. The agricultural sector's reuse of Bavaria's residual water is one of the objectives of the "Boer Bier Water" initiative (www.boerbierwater.nl) and F2Agri (www.f2agri.eu).
Within the context of "Boer Bier Water", and in cooperation with TKI-Watertechnology, the reuse of Bavaria's residual water by neighbouring farms has been brought into practice. This included a field trial in which some of the residual water was infiltrated into agricultural soil using a controlled drainage system (figure 1).

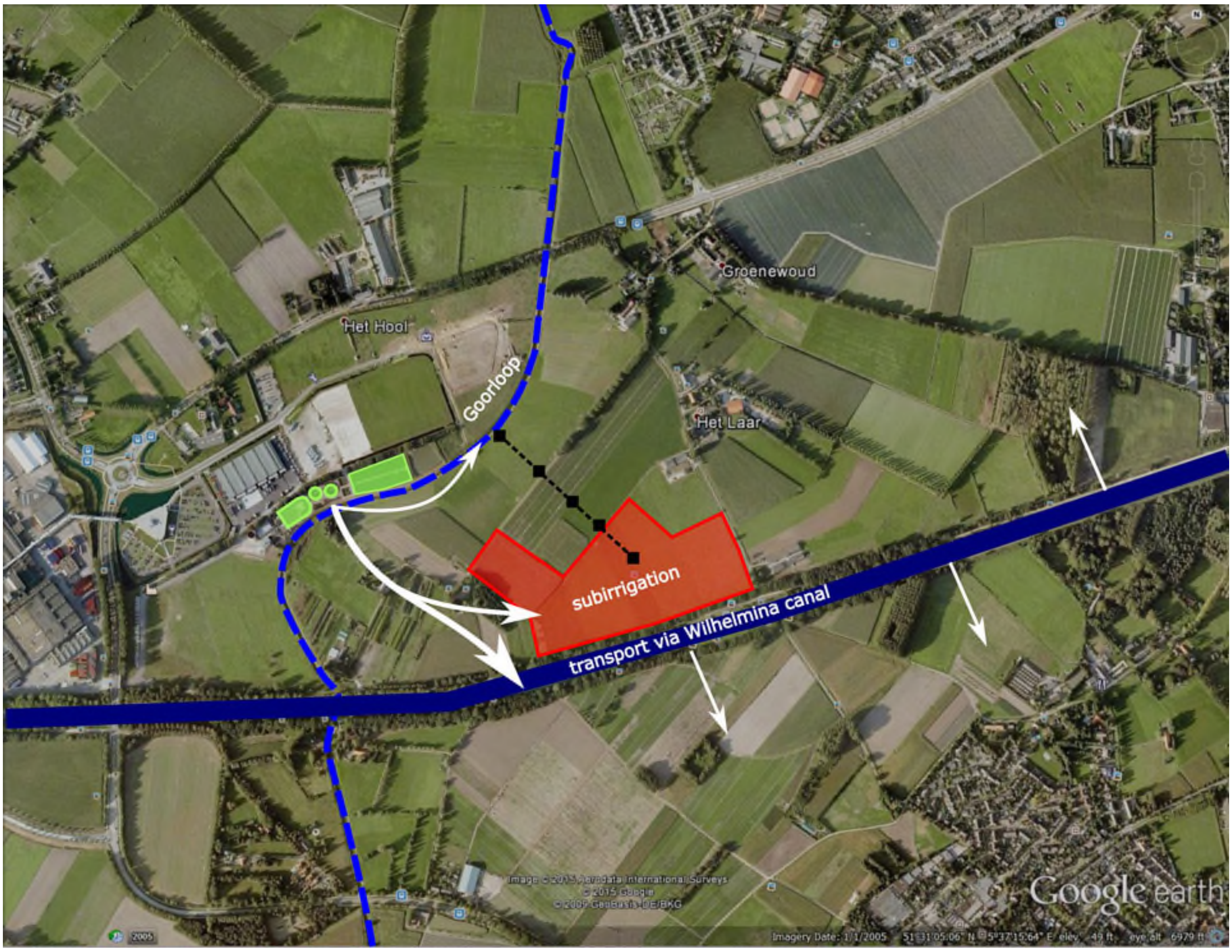

Figure 1: Treated residual water from the Bavaria wastewater treatment plant (green) is discharged via three routes: an Archimedean screw discharges the water directly to the plot of agricultural land (red) and to the Wilhelmina canal (dark blue). The canal transports treated water to fields at a greater distance from the plant. The (conventional) discharge to the Goorloop (light blue) is minimized. The black dashed line indicates the transect from the plot to the Goorloop in figure 2; the black dots are soil drilling locations in the transect.

Subirrigation

Controlled drainage systems have been developed both to discharge and to retain water (e.g. Stuyt, 2013). A further advantage is that they provide opportunities for the active control of the groundwater level and the soil moisture conditions in a plot of land (Bartholomeus et al., 2015). The feasibility of this active optimization of soil moisture contents depends on the availability of water. Additional options for the optimization of the water supply for the crop arise when water is actively fed and infiltrated via controlled drainage. This is referred to as “subirrigation” the objective of which is to raise the water table and increase the soil moisture content.

Field trial

A subirrigation system was laid out in a plot of agricultural land (8.5 hectares) in the vicinity of the Bavaria brewery, supplied with residual water from the brewery’s wastewater treatment plant (figure 1) (Bartholomeus et al., 2018). The plot was an area of grassland at a relatively high elevation and with summer water table levels at more than two metres below the surface (figure 2). With these initial dry conditions, it was questionable whether subirrigation would improve the water supply to the crop.

The local soil profile is of great importance to subirrigation. It ideally consists of a highly permeable top layer around the drainage/infiltration pipes and resistant lower layers that retard downward seepage of the subirrigation water.

A network of sensors laid out to monitor the effects of subirrigation collected information about the local effects and the radiating effects on the surrounding land. Precipitation depth, feed flow rates, groundwater levels, soil moisture contents and groundwater compositions were measured for the analysis.

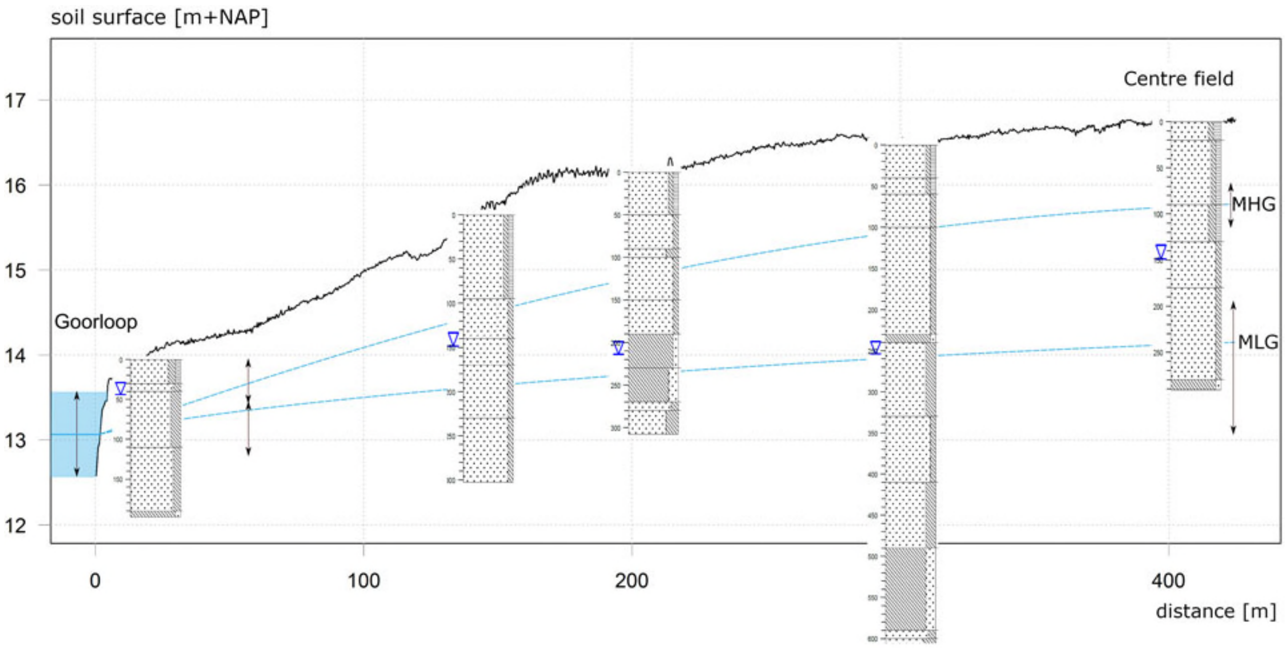

Figure 2: Cross section of the Goorloop to the centre of the plot (see figure 1 for the transect) including the overall locations of the soil profiles

in this transect (dotted = sand, obliquely hatched = loam) and a diagram of the average highest and lowest water table levels (MHG and MLG respectively) without subirrigation.

Results

The objective of subirrigation is to raise the groundwater level so that more water is available for the crop. This should increase crop transpiration and consequently increase the crop yield. Although the effect of subirrigation on crop transpiration was not measured directly, an insight into the relationship was obtained by carrying out simulations with the SWAP (Soil-Water-Atmosphere-Plant, swap.alterra.nl) hydrological model.

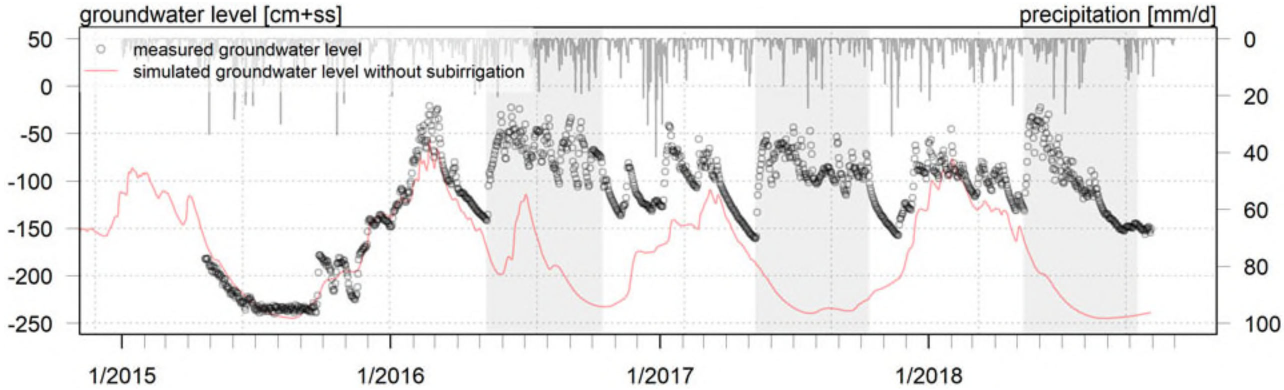

Figure 3: Precipitation depth (grey line), measured groundwater level (large dotted line) and simulated groundwater level without subirrigation (red line). The simulations are applicable to the situation without additional sprinkling. The grey areas indicate the subirrigation periods (from May 2016 onwards). It is clear that the groundwater level is considerably higher with subirrigation than without subirrigation.

Figure 3 shows the groundwater level measured at the centre of the plot during the year prior to subirrigation (2015) and during three seasons with subirrigation (2016-2018). The measurements were used to calibrate the SWAP model for the plot. The calibrated model was then applied to compare the groundwater level and the effects of too dry or too wet conditions on crop transpiration in periods with and without subirrigation. Without subirrigation, the groundwater level declines throughout the summer (figure 3), resulting in inadequate soil moisture contents for the crop if no sprinkling irrigation is applied. The effect of the extreme rainfall in June/July 2016 is evident from the peak in the groundwater level. Subirrigation used in 2016, 2017 and 2018 halted the natural decline in the groundwater level and substantially increased the levels in the three years.

Subirrigation raised the groundwater level by 100–150 cm compared with the reference without subirrigation. This shallow groundwater level alleviated the water shortages that would have otherwise resulted even in the very dry first half of the 2017 summer. The groundwater level was also raised substantially in 2018 although this was insufficient to meet the

crop’s high transpiration requirements during this extremely dry period. This meant that the farmer had to use additional sprinkling.
Groundwater level measurements revealed that subirrigation at this field trial scale did not have any waterlogging effects on adjacent plots and did not impact deeper aquifer layers. The groundwater recharge realized on the plot is small in comparison with the groundwater recharge from larger-scale precipitation. Consequently, subirrigation has a large local effect but is rapidly attenuated outside the area.
Although the groundwater level is raised substantially, the infiltration resistance of the subirrigation system increases during long water supply periods and the water supply capacity decreases. This increase in the infiltration resistance may be due to the clogging of drainage pipes. The infiltration resistance can be reduced to its original value by interrupting the water supply, draining the system and then reconnecting the water supply.
Although the infiltration resistance increased during 2017 (Bartholomeus et al., 2018), the system had recovered by the time that subirrigation was applied in May 2018 (see increase in groundwater level with subirrigation in figure 3). Alternating periods of infiltration and drainage could offer a suitable means of controlling clogging of the system.

Discussion

An insight needs to be gained into the opportunities and risks associated with the reuse of effluent (“recycled water”) for the supply of freshwater. The use of treated industrial residual water to combat drought, which is still rare in the Netherlands is an emerging form of (climate) adaptation in anticipation of the increasing water shortages confronting the Dutch agricultural sector.
Bavaria’s initiative to return residual water to its surroundings is a good example of these developments. Bavaria demonstrates that an industrial stakeholder can make a contribution to the self-sufficiency of a region and can cooperate in the realization of a more climate-robust water system. Achieving this requires cooperation between all stakeholders. This is provided for in the “Boer Bier Water” process. Nevertheless, little is currently known about this theme.
High sodium concentrations in the effluent need attention in view of the possibility of accumulation in the soil and salt damage to crops. The infiltration of the effluent also periodically results in high phosphate concentrations in shallow groundwater. As this is probably due to the mobilization of phosphate in the soil, the accumulation of phosphate will not be a bottleneck.
Some streams on the Pleistocene uplands of the Netherlands are partially or fully dependent on effluent to maintain base flows during the summer months. Using effluent for water supplies in agriculture should not result in streams drying up, and harm the ecology of the streams. More knowledge about this issue needs to be developed, and the interests of agriculture and nature will need to be considered in conjunction.

This project offers a good example of a solution provided by local cooperation in which a stakeholder with surplus water makes an active contribution to the water supplies for neighbouring farms. Utilizing these available alternative water flows for water supplies to agriculture can reduce the demand for shallow and deep groundwater for sprinkling purposes, which spares the groundwater for more high-grade applications. However, current groundwater policy would not appear to be tuned to new solutions of this nature. An insight is needed into the extent to which this approach contributes to buffering and groundwater availability and into its acceptability in relation to water quality. A carefully-considered policy stance can then be adopted at both regional and national level within the Delta Programme to prepare the Netherlands for more robust freshwater supplies.

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Summary

Industrial residual water can be used to combat drought in agriculture rather than simply being discharged to surface water. Bavaria has implemented the reuse of its treated residual water by farms in its surroundings. A pilot study has been carried out using Bavaria's residual water from its wastewater treatment plant for the subirrigation of a plot of agricultural land.
The results revealed that subirrigation raised the groundwater level and consequently increased the soil moisture content to a level that improved the water supply to the crop. Using industrial residual water to combat drought rather than discharging it unused can contribute to the alleviation of water shortages.

References

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