Feedback

What is the water saving potential in irrigation in the particular context of the highly structured moraine landscapes of Brandenburg, in Germany?

The moraine soils of the state of Brandenburg are highly heterogeneous due to the fluctuating inputs of glacial and fluvio-glacial sediments over time. Due to their sandy nature, the agricultural and horticultural use of these soils requires sustained irrigation in a context of increasingly restricted access to water resources. In this article, the authors take a critical look at the various irrigation water saving strategies they have implemented in recent years, with less conclusive results for some innovative experiments, particularly in relation to the recurrent droughts of 2018 and 2019.

In the East German state of Brandenburg, a negative climatic water balance during the vegetation season coincides with mostly sandy soils. An increasing number of farmers therefore invest in new or revive former GDR built irrigation infrastructure. To date, about two percent of the state's arable land is under irrigation, mainly for the production of potatoes, field vegetables, maize, winter wheat and other cereals. As well as in other states of Germany, water savings in irrigation become more and more important, especially due to increasing overall demands by agriculture and horticulture and restricted or locally declining supply by groundwater tables.

In 2016, we started a European Innovation Partnership (EIP) with the objective to develop a user-friendly solution for steering site-specific and sustainable irrigation. At the farm of one of our partners, we selected a field of about 30 ha, which is irrigated with a center pivot irrigation machine. For the purpose of our project, we equipped two spans of the machine with a variable-rate irrigation system, which consists of valves for regulating the pulses of water application on every single sprinkler and a special control unit.

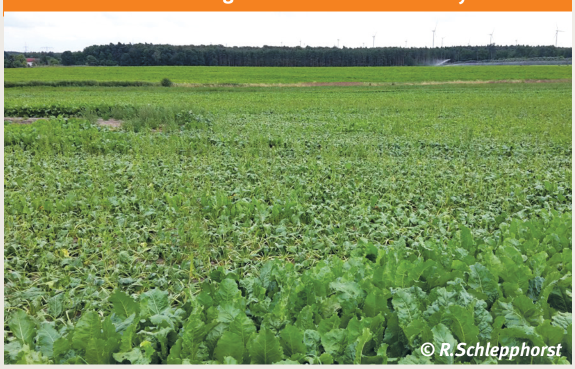
Site-specific irrigation is only useful when site conditions or management vary across a field. In Brandenburg, soil variation is mainly caused by varying glacial and fluvial-glacial sediments and their subsequent translocation. For instance, the presence or absence of a loamy subsoil horizon in otherwise pure sands may dictate the soil water availability for plants within the root zone (Photo ❶).

To map this variation, we sampled the soil after a proximal soil sensing survey. Initially a geoelectrical mapping with a mobile mapping system was carried out, to record the apparent electrical resistance in several soil depths in a systematic grid. This was followed by an intensive soil survey.

The statistical analysis of this data resulted in four irrigation management zones (IMZ hereafter), which are based on a map of the plant-available soil water capacity (Figure ❶). To determine the irrigation timing and amount for each IMZ and for each day within the irrigation season, we use the soil moisture and evapotranspiration model Irrigama steering (called BEREST in an earlier version) that is coupled to an irrigation steering module. The model inputs include the current weather conditions, the weather forecast as well as soil and plant parameters. The recommendation for each management zone is translated into an application map, which is then transferred to the control unit of the pivot (Figure ❶).

In our project, we already tested site-specific irrigation at our trial field in the years 2018 and 2019. In 2018, when Germany and almost whole Europe suffered from a severe agricultural drought, the field was planted with silage maize. The overall irrigation water demand was very large (278 to 287 mm) regardless of the management zone, because the large potential transpiration overrode the differences in soil water storage capacity.

❶ Stressed beets on pure sand in the direct vicinity of their unstressed neighbors on sand with loamy subsoil.

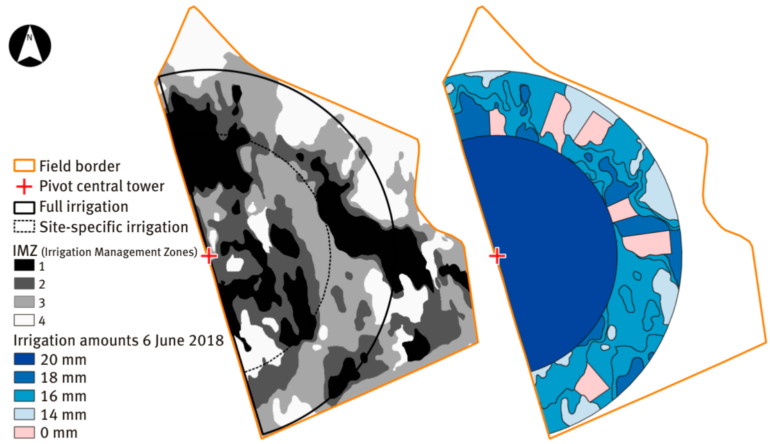


In other words, every drop of water was transpired immediately. It was therefore not surprising that the difference in irrigation water needs among the zones was very small and restricted to the beginning of the season. In total, site-specific irrigation of maize in 2018 saved less than 1% of water.

In 2019, which was a dry year too, the field was planted with winter wheat. The irrigation water amounts ranged from 174 to 175 mm. Thus, the differences in irrigation water requirements among IMZ were again small and limited to the beginning of the season; as a consequence, site-specific irrigation again saved only 1% of irrigation water. In the same year, we also tested a managed deficit irrigation strategy, which basically allows some water stress before irrigation is applied. This strategy saved about 15% of water, which makes it an attractive alternative to full irrigation particularly if water availability is limited.

As the amount of field data is always limited, we used our irrigation steering model to simulate the irrigation water requirements for a 12-year crop rotation consisting of silage maize, winter wheat, forage peas and potatoes. These crops were virtually grown at the same field as in the practical tests; that is, under the same local climate and soil conditions. The results show that savings of site-specific irrigation considerably vary both between crops and between years for a fixed crop. Regarding variations between years, larger savings often occur in wetter years and vice versa. As already mentioned, this is most likely due to the interplay between potential transpiration and soil water storage, the latter of which is only important in situations where the soil is at or near field capacity. Overall, the simulated saving potentials of site-specific irrigation are rather moderate and often much below 10%.

We also simulated the water saving potentials of our deficit irrigation strategy: although the saving potential again varies between crops and years, it is now always larger than 10%; in some cases, up to 50% savings are possible. Of course this comes at a cost: each mm of irrigation water applied at the right time is converted into biomass and hence, yield. It is also part of our project to assess the irrigation strategies from an economic point of view, which we already did for our two-year field experiment. We found that regardless of crop and irrigation management zone, irrigation always leads to a yield increase but if irrigation costs are high as in our case, irrigation is not always profitable. In our experiment, uniform irrigation always outperformed site-specific irrigation, which is not surprising if one considers the very small water (and hence, energy) savings compared to the high cost for the required extra equipment. With deficit irrigation of winter wheat in 2019, a certain yield decrease compared to full irrigation had to be taken into account (grain yield, full irrigation: 5.1 Mg/ha; grain yield, deficit irrigation: 4.4 Mg/ha; grain yield, no irrigation: 2.2 Mg/ha). Interestingly, the yield effect of deficit versus full irrigation was much more pronounced in the IMZ with adverse soil conditions (IMZ 1, Figure ❶), which seems to profit much more from full irrigation than the zones with a higher water holding capacity. On average, both full and deficit irrigation were profitable in this case. In addition, we assume that in regions where water costs are much higher than in our case (0,115 Euros/m³), all above mentioned irrigation strategies will produce other economic outcomes, at least for deficit irrigation.



**❶ Left: Map of irrigation management zones. IMZ 1 has a mean water holding capacity of 59 mm in the effective root zone, whereas zone 4 can hold 75 mm.
Right: Application map example. Site-specific irrigation is possible for part of the irrigated area(length of two spans), where non-irrigated reference areas are located too.**

In summary, we found:

- (very) small water savings with variable-rate site-specific irrigation compared to uniform irrigation;
- that in years with low within-season rainfall, water savings with site-specific irrigation are particularly difficult to achieve because potential transpiration dictates irrigation requirements; no economic benefit of site-specific irrigation under the conditions of our study region due to the imbalance between high equipment costs and low water and energy savings;
- that larger savings might be possible if within-field soil differences are larger than at our trial field;
- a considerably larger water saving potential of deficit irrigation but the most efficient deficit irrigation strategy has yet to be identified.

Finally, it is equally important for sustainable irrigation farming to invest in proper irrigation equipment, to cultivate drought-resistant crops and varieties and to use decision support systems for irrigation steering. ■

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