Project brief

Thünen Institute of Rural Studies 2025/28a

Quantification of the Irrigation Demand and Water Security for Agriculture, Horticulture, and Viticulture in Hesse, Germany

Jacob Jeff Bernhardt[1], Franziska Potts[1], Maximilian Zinnbauer[1]

- **Climate change-induced alterations in precipitation and evaporation have led to an increased demand for agricultural irrigation in the Hesse province in Middle Germany. Since the severe droughts of 2018 and 2019, concerns have grown regarding the future trajectory of agricultural irrigation demands.**
- **Climate forecasts predict a decline in water availability for agricultural production during the growing season.**
- **A spatial model covering the area of Hesse was applied to quantify the effects on irrigation demands. Model projections until 2100 indicate a rise in agricultural irrigation demand in Hesse, particularly in southern Hesse.**

Background and objectives

Manifestations of climate change are already noticeable today, not only as rising average temperatures, but also as changes in precipitation patterns. Precipitation levels are increasingly variable, and a shift in precipitation times from summer to winter can be observed. Evaluations of climate projections indicate that water availability for plants and agriculture will decrease during the growing season. As a result, water is becoming a scarce resource and increasingly limiting factor in agricultural production.

In Germany, only a few spatially explicit, comprehensive projections of future agricultural irrigation demands exist. There is even a lack of comprehensive data on the irrigation amounts actually used to the present day.

The project's aim was to model the regional irrigation requirements and water needs for frost protection in agricultural, horticultural, and viticultural crops considering climate change, and to explore adaptation strategies to these changes.

The research focused on the following questions:

- What was the regional irrigation need and water requirement in agriculture, horticulture, and viticulture in Hesse during 1991-2020?
- What is the economic efficiency of irrigation of selected crops in Hesse in 1991-2020?
- How will the regional irrigation need and water requirement for frost protection irrigation develop until 2100?
- What is the economic viability of irrigation (irrigation suitability)?
- What potential do collected rainwater, surface water, and treated wastewater offer for irrigation?

Approach

The project builds on previous work by the Thünen Institute for Rural Studies. Key components of the project included:

- Adapt and enhance a model previously applied to Bavaria, to better determine regional agricultural irrigation demand.
- Develop models to assess water demand for frost protection irrigation and to determine economic irrigation efficiency.
- Discuss the methodology and assumptions with a panel of regional experts in Hesse, and adjusting model parameters based on their feedback.
- Calculate regional irrigation demand for the historical period (1991-2020) and incorporate regional climate projections for the reference period (1970-2000), the near future (2031-2060), and the distant future (2071-2100).

The models used spatial data with daily resolution. These include measured climate data (potential evapotranspiration, precipitation, minimum daily temperature, relative humidity), information on soil type or water retention capacity of a location, and land use data. For future climate conditions, regionalized climate projection data from the core ensemble of the German Weather Service (RCP 8.5) was used. Land use information was linked to an index representing the crop-specific water requirements, the growth stages of the crops throughout the year, and the optimal soil moisture for each crop. Regional cultivation areas of agricultural crops were derived from the land use data of the Integrated Administration and Control System (IACS). In total, 20 crop groups from arable farming, vegetable cultivation, and special crop cultivation were analyzed. The model for irrigation suitability uses annual crop-specific irrigation needs from the

irrigation needs model, producer prices, and data on irrigation costs. Future projections were modelled for the near future (2031-2060) and the distant future (2071-2100), using the period from 1971 to 2000 as reference.

Results

The model results on agricultural irrigation demands indicate that, on average, during 1991 to 2020, most parts of northern Hesse exhibited no (0–25 mm) or low (25–50 mm) irrigation

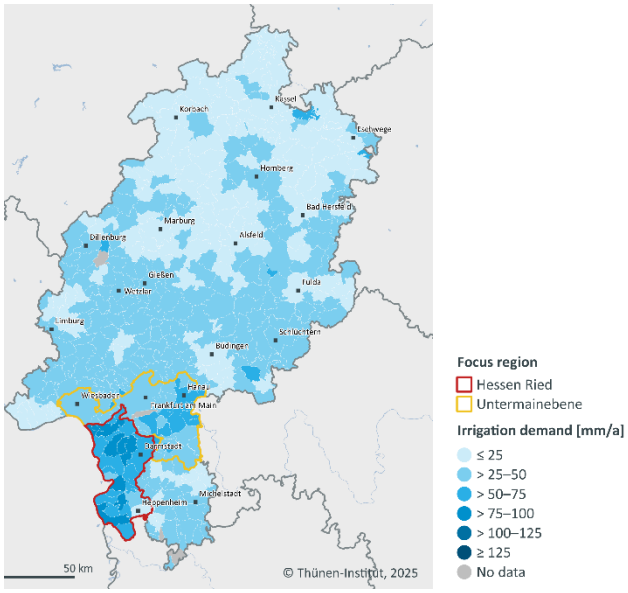

Figure 1: Regional potential irrigation demand in Hesse for the ex-post period (1991-2020) based on observation data (source: own illustration).

demands. In southern Hesse, there was a concentration of moderate (75–100 mm) to high (100–125 mm) irrigation demands, with a particular focus in the Hessen Ried. Across Hesse, the average potential irrigation demand in the ex-post period was 32 mm. The results from the ex-ante analyses suggest a widespread increase in average annual potential irrigation demand by 5–15 mm in the near future compared to the reference period. In the distant future, this increase is significantly more pronounced, especially in southern Hesse, where needs are expected to rise by more than 30 mm.

Overall, irrigation demand is projected to increase by an average of 41% in the near future, and a doubling of irrigation demand is expected in the distant future compared to the reference period. These developments are associated with uncertainties, as individual ensemble members indicate either stronger or weaker increases.

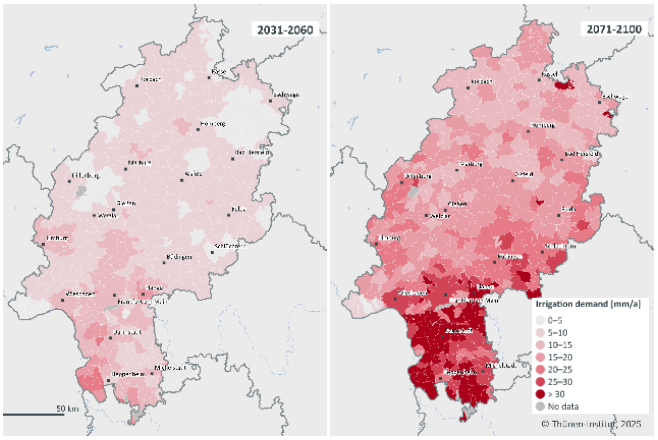

Figure 2: Change in potential irrigation demand in Hesse in the near (2031-2060) and distant future (2071-2100) compared to the reference period based on climate projection data from the RCP 8.5 scenario (source: own illustration).

Conclusions

For frost protection irrigation, there is an average water demand of 44 mm in Hesse. Early potatoes show a particularly high demand. In the future, frost protection irrigation will play a minimal role in Hesse. Here, water demands are expected to decrease by 94% in the long term compared to the reference period.

Irrigation economy efficiency varies greatly among crops. While irrigation of vegetable crops and potatoes proves to be economically viable over the years and in many regions, irrigating cereal crops is generally unprofitable, even when irrigation infrastructure is already in place. Overall, the economic feasibility of irrigation largely depends on product prices and the existing irrigation infrastructure.

Further information

Contact

[1]Thünen Institute of Rural Studies

Maximilian.Zinnbauer@thuenen.de

Run time

8.2022-1.2025

Project-ID

2450

Publications

Potts et al. (2025), Ermittlung des Bewässerungsbedarfs und dessen Sicherstellung für die Landwirtschaft (einschließlich Garten- und Weinbau) in Hessen (BEW-HE). Hrsg.: Johann Heinrich von Thünen-Institut, Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei (TI), 212 p.

Funding

HESSEN Hessisches Ministerium für Landwirtschaft und Umwelt, Weinbau, Forsten, Jagd und Heimat

DOI: 10.3220/253-2025-196