Utrecht University

Rijkswaterstaat
Ministry of Infrastructure and Water Management

Exploring and Optimizing Water Management Strategies for Mitigating Local Drought Impacts in the Netherlands using a Multi-Target LSTM Model

Sandra Hauswirth[1], Marc FP Bierkens[1,2], Vincent Beijk[3] and Niko Wanders[1]
1 Utrecht University, Department of Physical Geography, Utrecht, Netherlands, 2 Deltares, Utrecht, Netherlands, 3 Rijkswaterstaat, Water, Verkeer en Leefomgeving, Utrecht, Netherlands

Motivation

Recent drought events in Europe showed that these type of extremes can have a large-scale impacts throughout Europe. Having a better understanding of potential drought impacts, their development and how humans can mitigate these is needed to increase preparedness for future events.

Current challenges lie in **assessing** and **modelling** of **drought impacts** at various spatial scales. Furthermore, it is also important to understand how human responses, including **water management decisions**, can either **alleviate** or **intensify drought severity** and its **impacts**.

An interesting case to study these aspects is **the Netherlands**, a country well known for its **intensive water management** and recent challenges with extreme drought events.

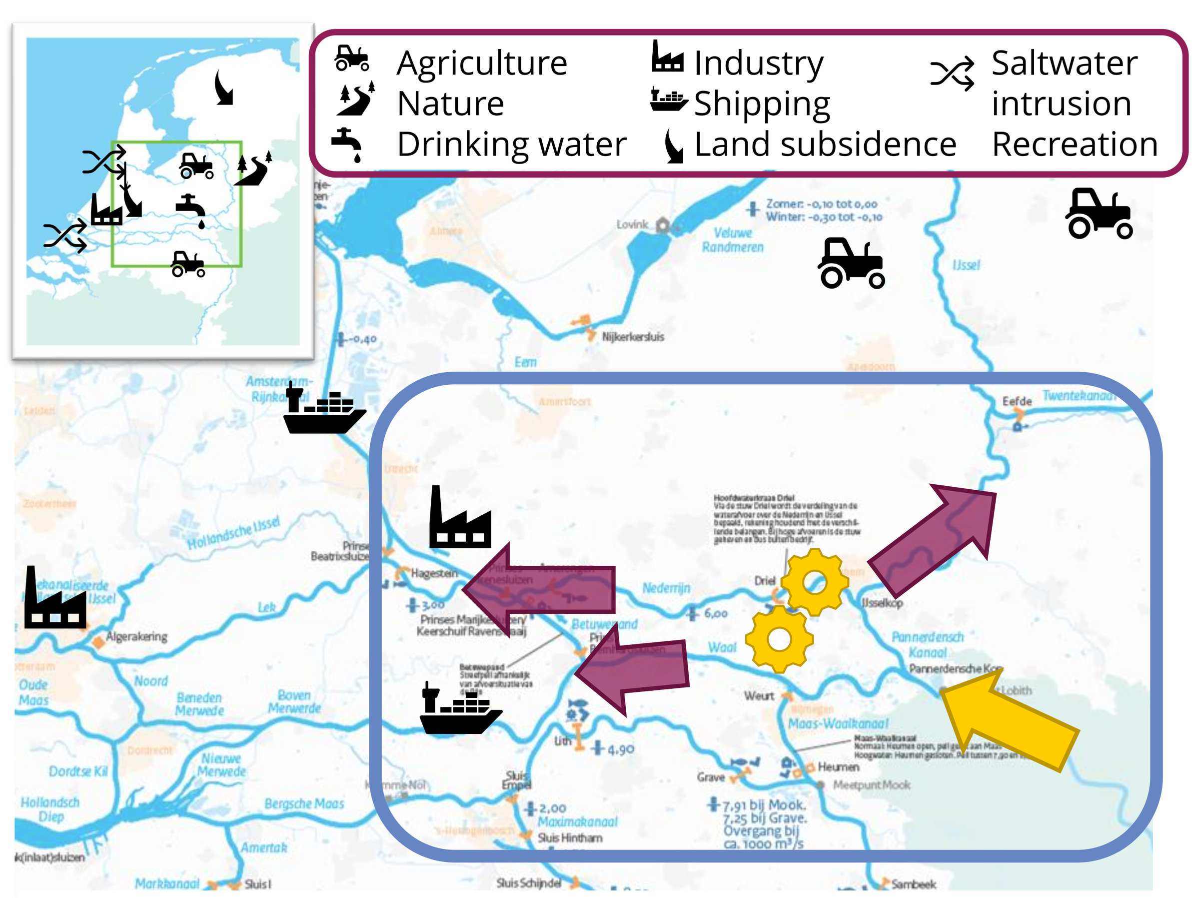

Figure 1
Case area located in the Netherlands:

- *three main river branches linked to a major water infrastructure upstream and Rhine river*
- *for every river branch: dedicated drought impact function based on its main purpose (shipping, water storage for agriculture, hydropower and saltwater intrusion)*

Multi-target LSTM was developed for blue area, input variables (yellow) include water management and river Rhine, target variables (magenta) are three river branches further downstream. Icons indicate drought impacts.

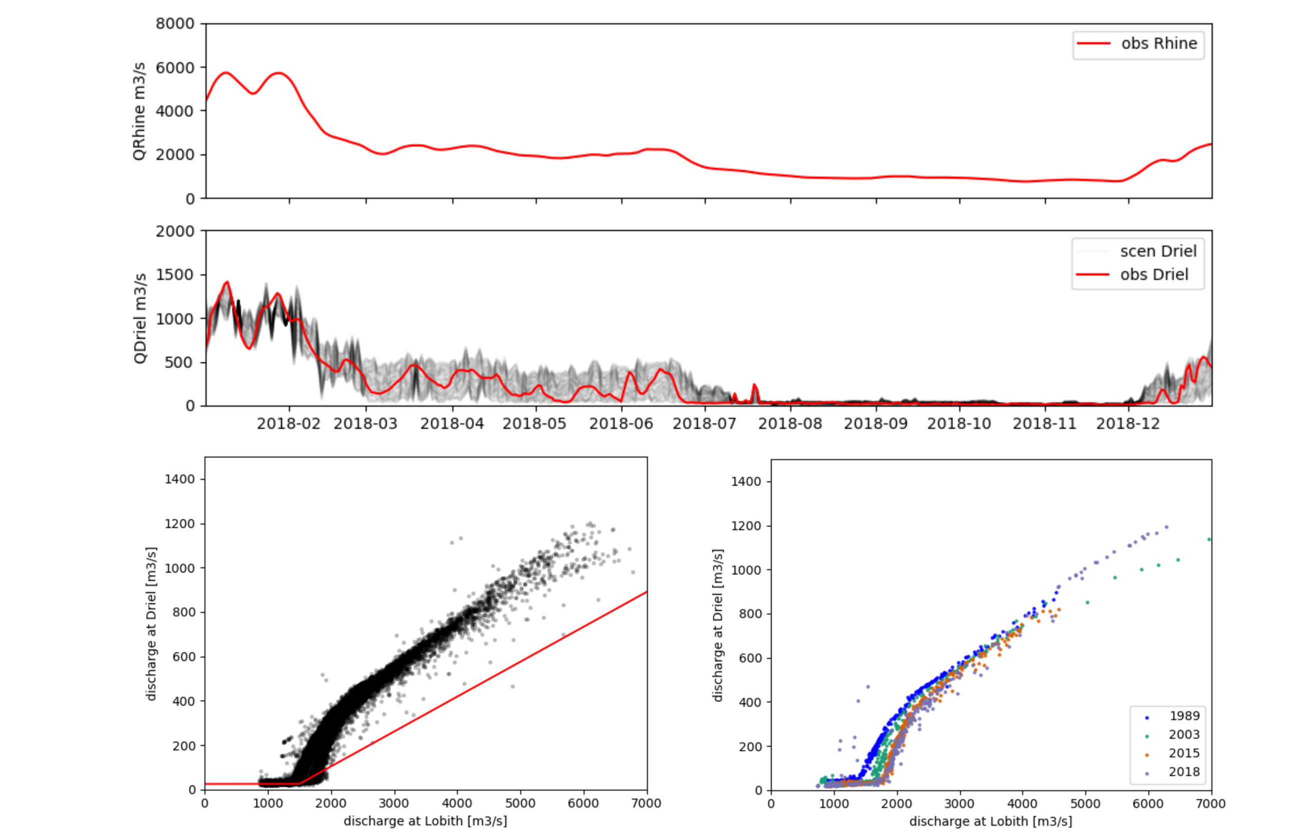

Figure 2
Lower panel: water management (observed vs. operational plan) and selected drought years. Top panel: water management scenarios created based on observed operational range (example for 2018)

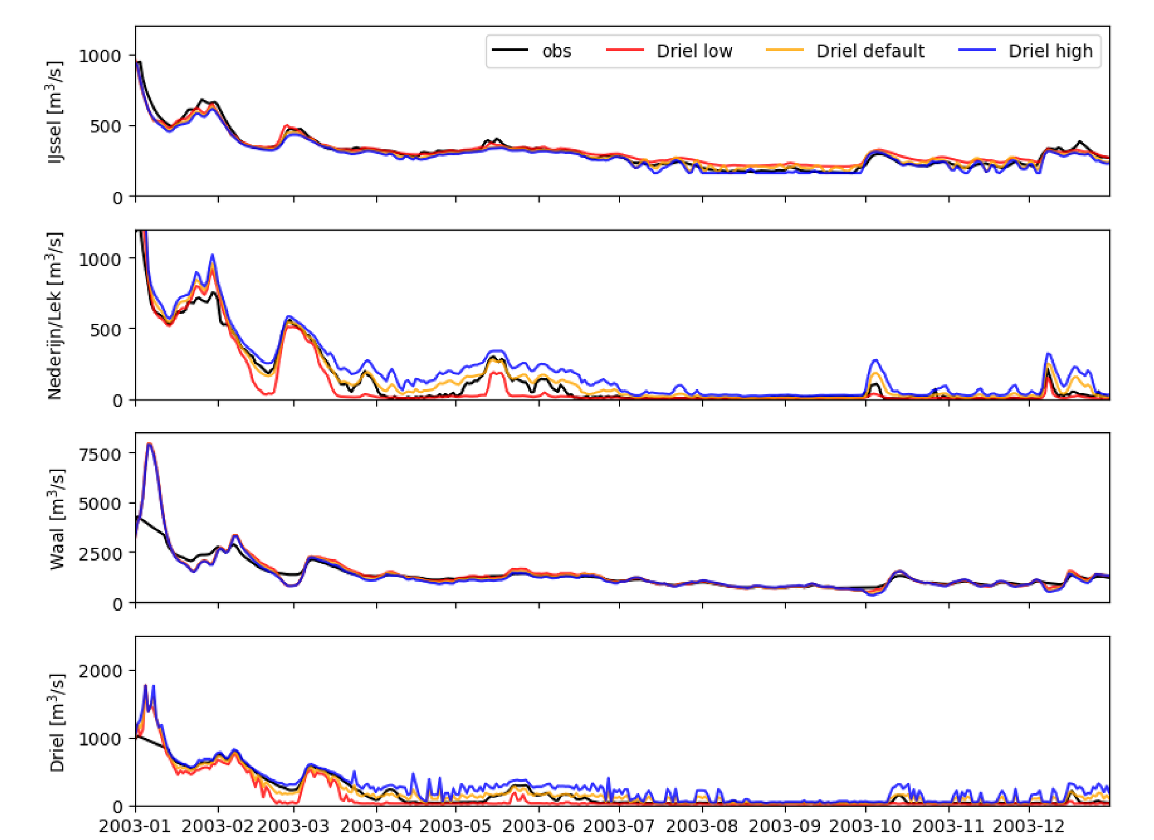

Figure 3
Simulation results for three main rivers (Waal, IJssel and Nederrijn/Lek) based on lowest, default and middle water management scenario.

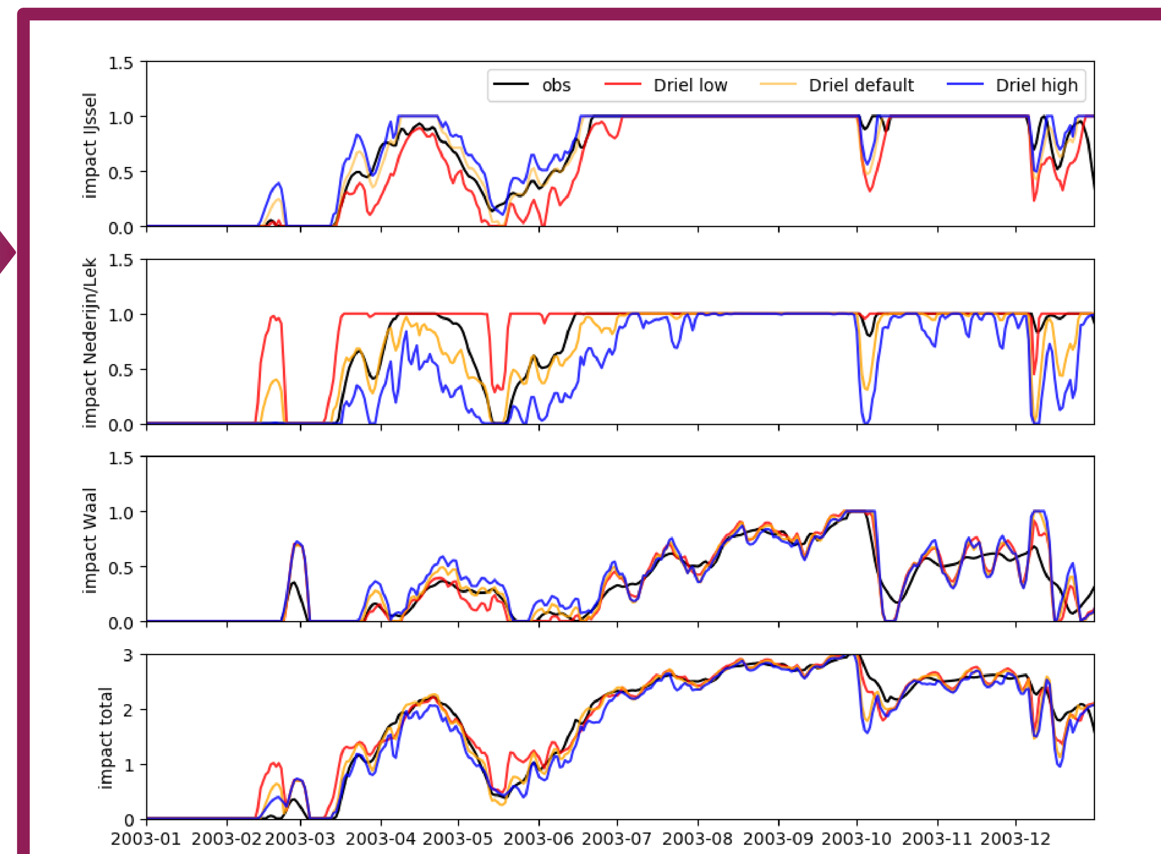

Figure 4
The impact corresponding to the same rivers and scenarios, bottom panel shows the total impact which is later used for optimisation goals.

Methods

To be able to assess and evaluate the potential of optimizing the water management to mitigate drought impacts, a modeling framework was setup, based on a **machine learning model simulating discharge**, **water management scenarios** and **drought impact functions.**

1) Developing multi-target LSTM simulating three main river branches (Fig. 1 and 3)

2) Developing water management scenarios (based on historical operational range) (Fig. 2, bottom panel)

3) Impact functions (linear impact functions based on water management reports)

4) Optimization: find the optimal scenario for past drought years by
   a) daily simulations, 30-day window (for drought years 2003, 2015 and 2018)
   b) lowest cumulative total impact

Results

1) Mutli-target LSTM for discharge simulation:
   a) simulation performance:
      RMSE and KGE average for rivers: nRMSE 0.08, KGE 0.95
   b) Sensitivity experiment for quick water management changes → reasonable sensitivity, response time of around 7 days

2) Water management scenarios: creation of 100 scenario options of infrastructure Driel for every discharge value of river Rhine (Fig. 2, top panel)

3) Impact functions:
   a) Impact relationships connected to simulated discharge, impact range between 0 and 1 (Fig. 4)
   b) Min and max impacts outside of observed impacts due to water management scenarios → potential for impact mitigation (Fig. 4)

4) Optimization:
   a) Mitigation potential of up to 6% for optimization experiment (drought years 2003, 2015 and 2018, Fig. 5)
   b) After 2003 drought: water management seem to have been adapted (more preventative water management)
      → less mitigation potential remains.

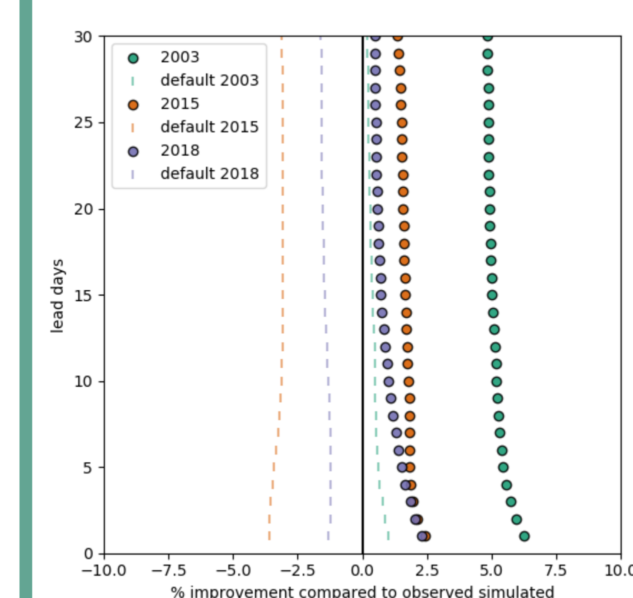

Figure 5
Percentage of impact mitigation compared to observed impacts for optimised simulations and default management

Conclusion

While the current assessment already shows the **potential of combining the three pillars, machine learning, human action and drought impact functions**, for optimal drought impact mitigation, a **major challenge remains** the **data availability** of **water management information** and the derivation of **drought impact functions** from past drought events and the **limited impact observations**.