Design and Assessment of water-energy-food-environment Mega-Systems

# A framework to assess cooperation benefits of new infrastructure in transboundary river basins without formal water sharing arrangements and operating rules

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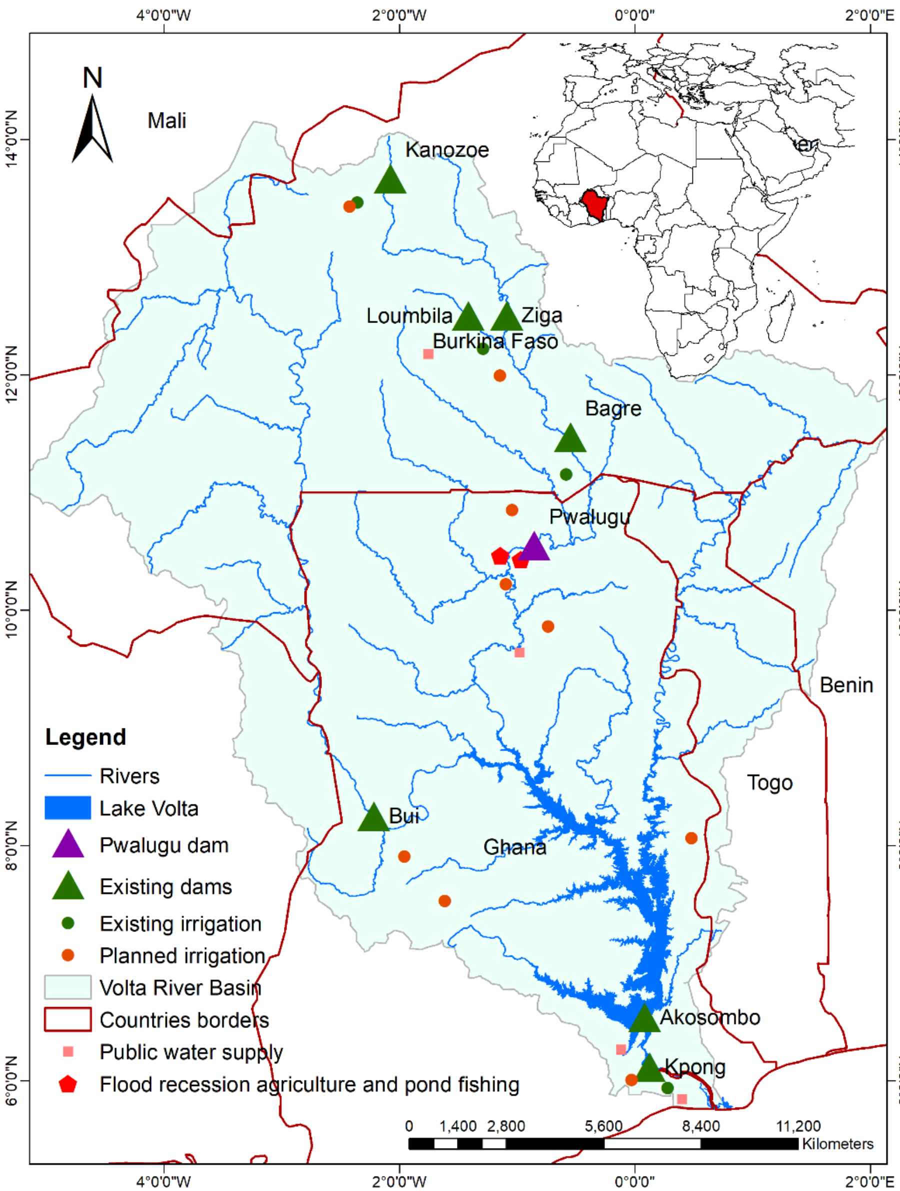
# Introduction




## Pwalugu Multi-purpose Dam

Benefits

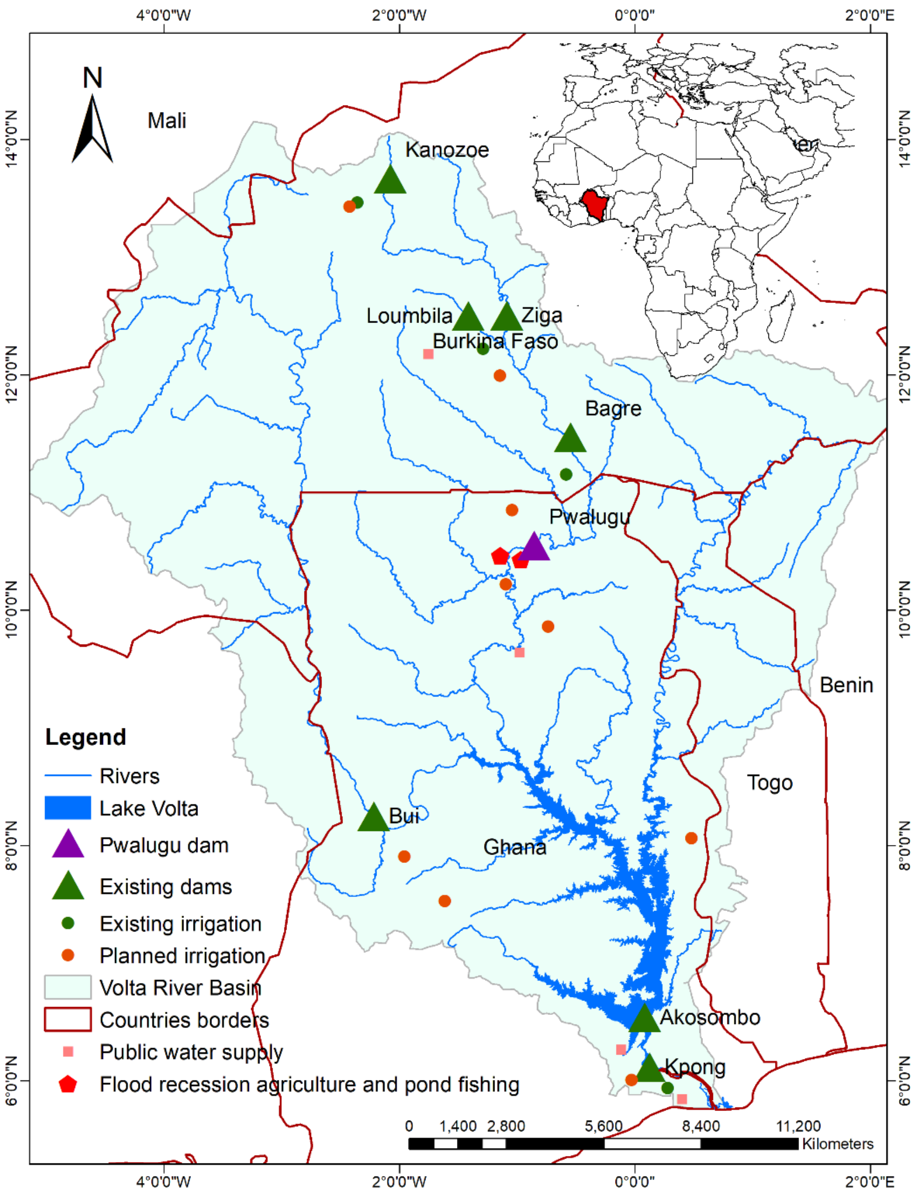
- Improve living conditions in Northern Ghana
- Supply growing water and energy demands
- Reduce floods

Possible impacts

- Hydropower loss in Akosombo
- Loss in flood recession benefits

Potential irrigation expansion and reservoir operation in Burkina Faso can aggravate negative impacts

# Introduction



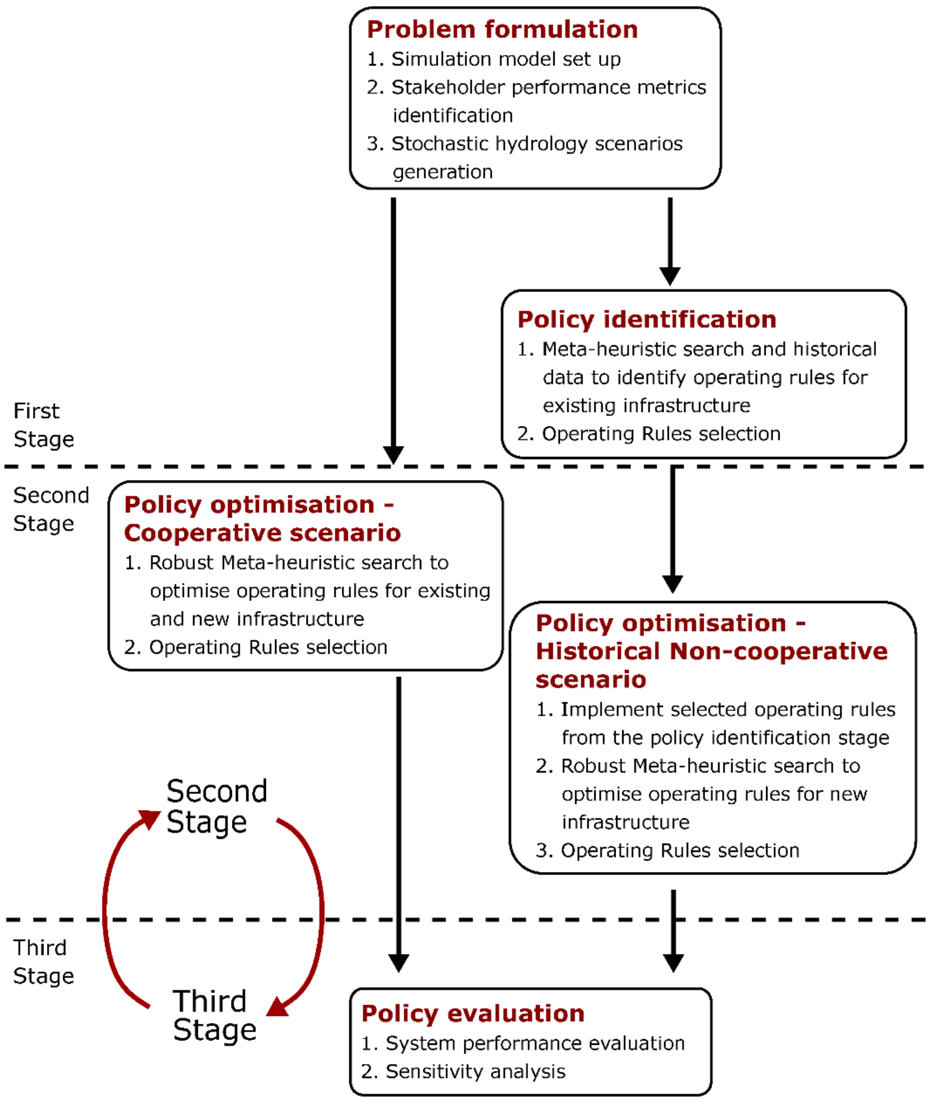

## Pwalugu Multi-purpose Dam

- 176 GWh/year
- 16 MW Firm Power 90% exceedance
- Flood protection
- Energy exports
- 20,000 ha irrigated area

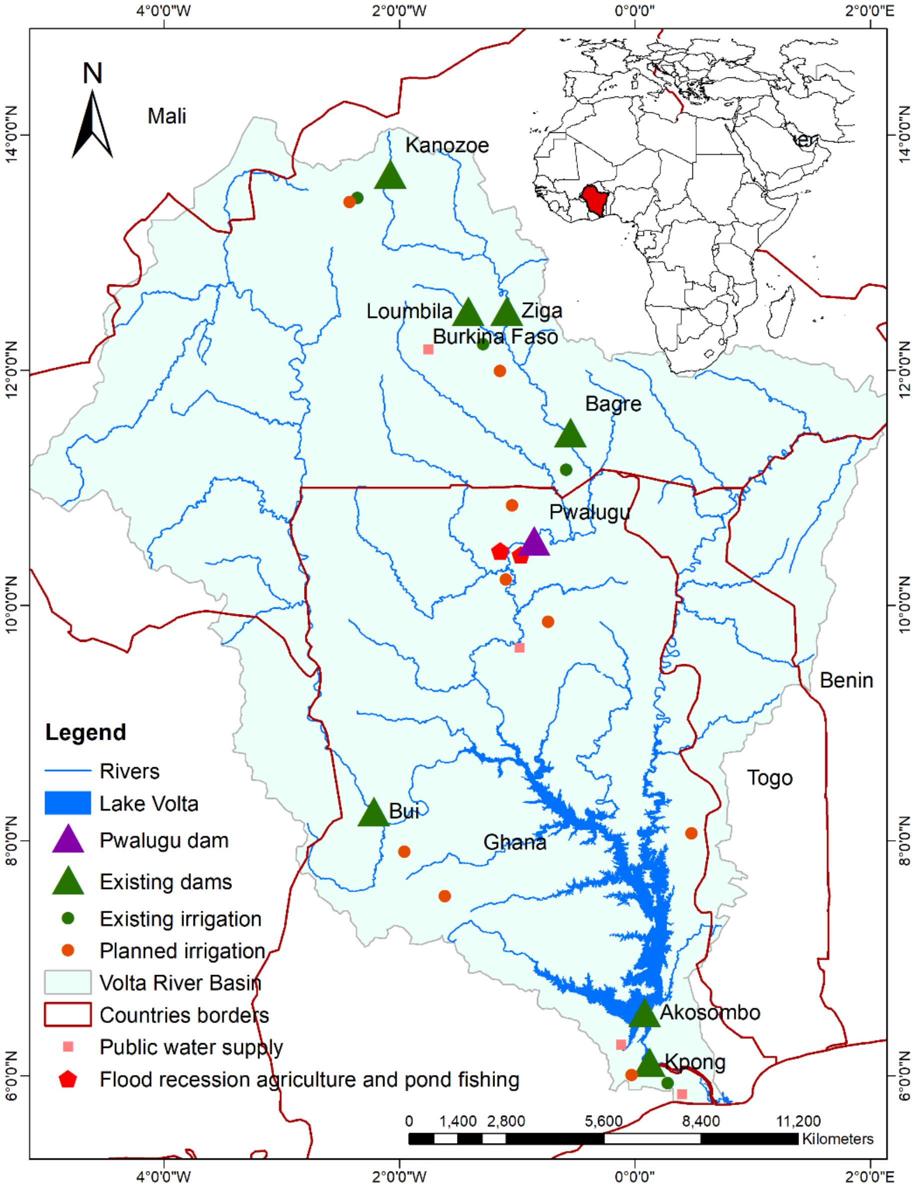
# Method

## Many-objective Direct Policy Search

- Policy identification
  - Variables (operating rules parameters)
  - Objectives (Nash-Sutcliff efficiency)
  - Data (Historical releases and volume time series
- Policy optimisation
  - 30 hydrologic scenarios
  - Variables (operating rules parameters)
  - Objectives (Basin performance metrics)
- Sensitivity analysis
  - 100 hydrologic scenarios



# Optimisation model



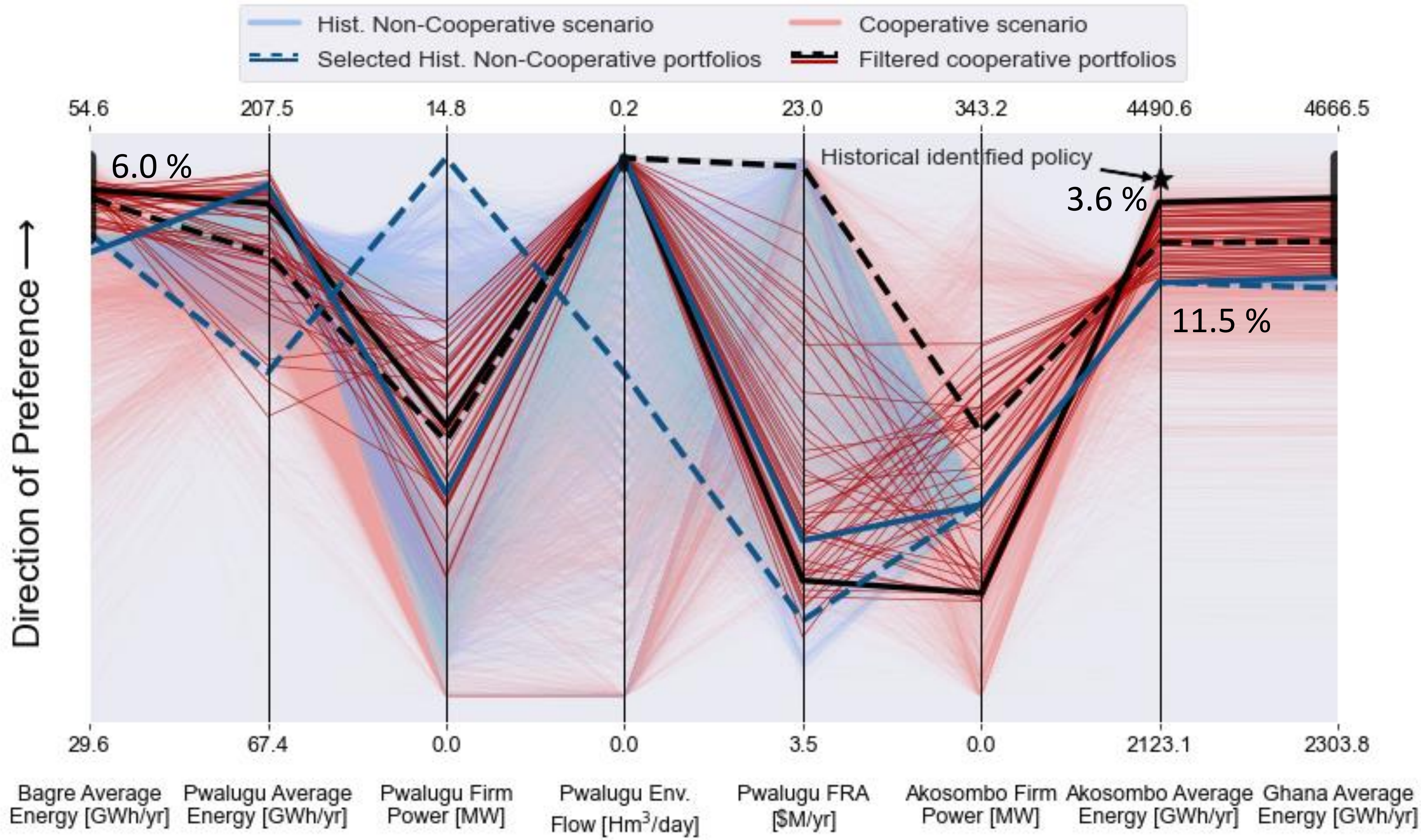

Objectives:

1) Max energy generation
2) Max firm power
3) Max agricultural production
4) Max environmental flows
5) Max benefits from flood recession activities

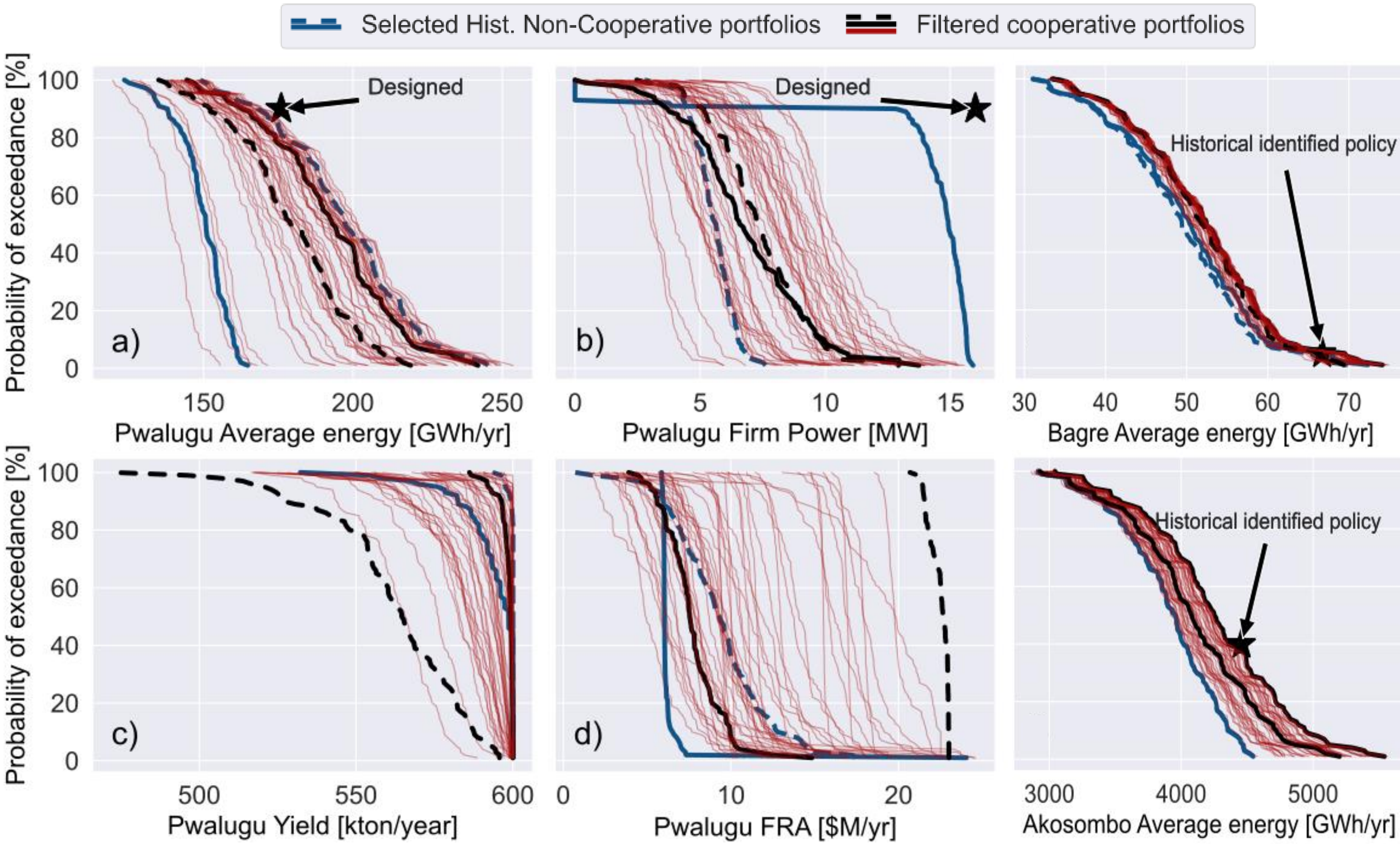
Decision variables:

- Reservoir operating rules (Bagre, Pwalugu, Bui and Akosombo)

# Results – Optimisation



# Results – Sensibility Analysis



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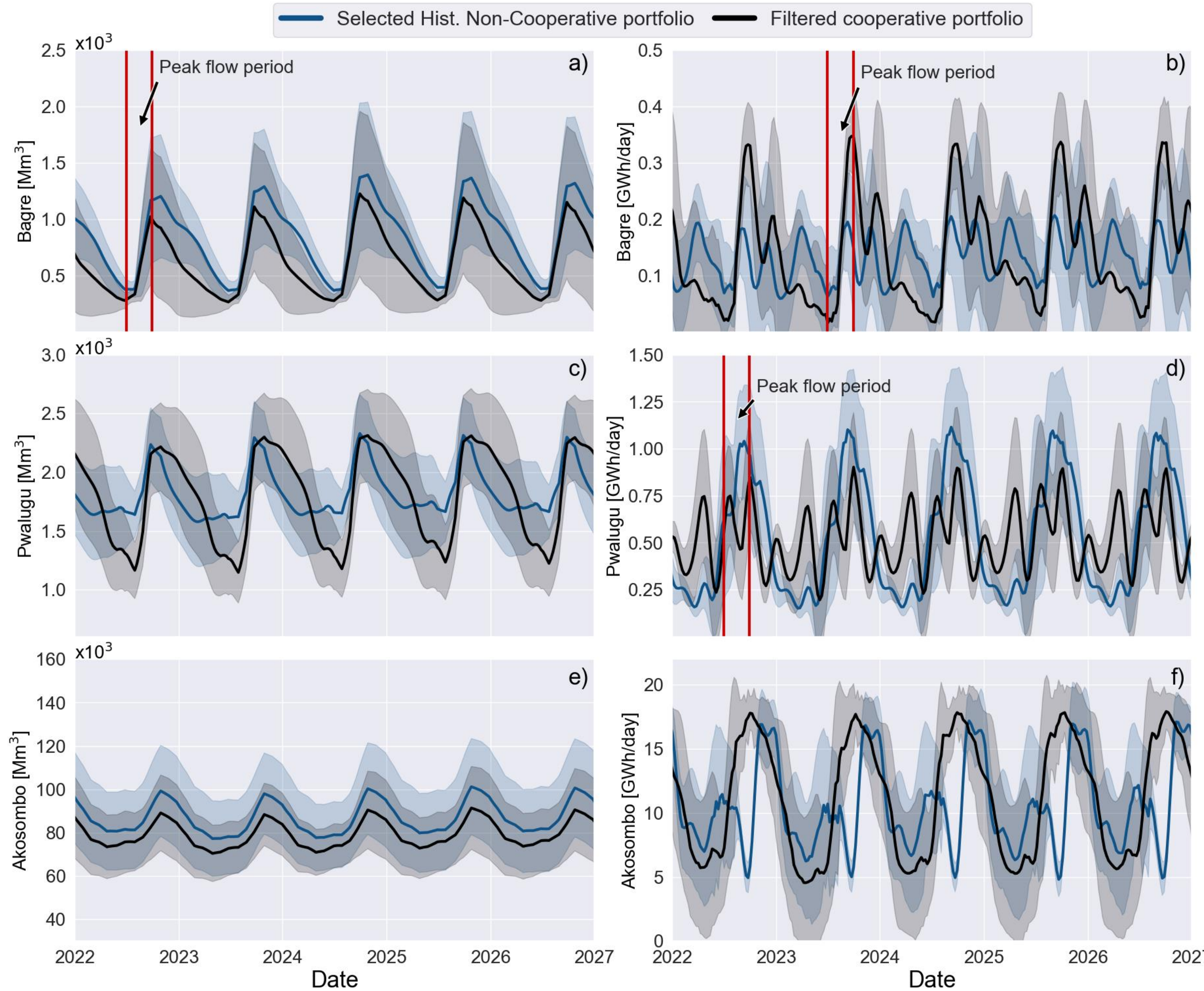

# Takeaway message

- If the operation of Bagre and Akosombo is not adapted to the new PMD development, hydropower generation in Ghana could be impacted negatively. Less hydropower generation in Ghana after built PMD.

- The new PMD could reduce the annual Akosombo generation by 11.5% compared to the historical annual generation.

- If operation of the existing reservoir is adapted this impact could be reduced to 3.6%. But resulting in positive net generation in Ghana after built PMD.

- The PMD designed annual energy is achieved only at 77% of exceedance.

- Results indicate that Bagre can increase hydropower generation by 6.0% by increasing generation in peak flood periods.

# Takeaway message

Potential consequences of cooperative operation:

- Reduction of floods in Northern Ghana. Lower volumes in Bagre before starting the flow peaks periods could be used to reduce spill.
- Overall more annual energy is generated in the basin.
- Burkina Faso will need to supplement energy during dry seasons with other sources (e.g. PV, GAS or increased imports from Ghana)
- Reduction in Flood Recession benefits because of reducing floods in Northern Ghana. However, new formal irrigation schemes in the region could compensate for this reduction in benefits.

GitHub

https://github.com/pywr/pywr

Future DAMS

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# Thanks!

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http://www.futuredams.org/
https://www.waterstrategy.org/
https://www.hydra.org.uk/

Gonzalez JM, Matrosov ES, Harou JJ., et al (2021) Quantifying Cooperation Benefits for New Dams in Transboundary Water Systems Without Formal Operating Rules. Front. Environ. Sci. 9:596612. doi: 10.3389/fenvs.2021.596612

Tomlinson JE, Arnott JH, Harou JJ (2020) "A water resource simulator in Python." Environ Model & Softw 126:104635. doi: 10.1016/j.envsoft.2020.104635