Modelling Surface Water–Groundwater Interactions to Assess Climate Change Impacts in Southern Estonia, North-Eastern Europe

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INTRODUCTION

- Past hydrological changes must be understood before assessing future climate-change impacts on surface water–groundwater interactions.
- The PRMS hydrological model was applied to the Piigaste stream catchment in Southern Estonia.
- The model was used to evaluate 20th century climate change impacts on key hydrological components.
- Model reliability was assessed using both statistical performance measures and independent validation methods.
- The calibrated model enabled further analysis of long-term hydrological trends and regime shifts.

CONCLUSION

- Model evaluation showed satisfactory representation of historic hydrological processes and surface water–groundwater interactions.
- Hydrological components showed a clear regime shift, with the strongest change detected around 1989–1990, indicating a broader hydrological change in the catchment during the late 20th century.
- The modelling approach provides a reliable basis for future climate-change impact assessments in Southern Estonia.

RESULTS

The model was calibrated and validated using two periods:

- 01.01.1952 – 31.12.1981
  - Calibration 01.01.1952 – 31.12.1967, KGE 0,74
  - Validation 01.01.1968 – 31.12.1981, KGE 0,64
- 01.01.1980 – 31.12.2017
  - Calibration 01.01.1980 – 31.12.1995, KGE 0,55
  - Validation 01.01.1996 – 31.12.2017, KGE 0,37

All values exceed the calculated KGE benchmark, which was 0,24.

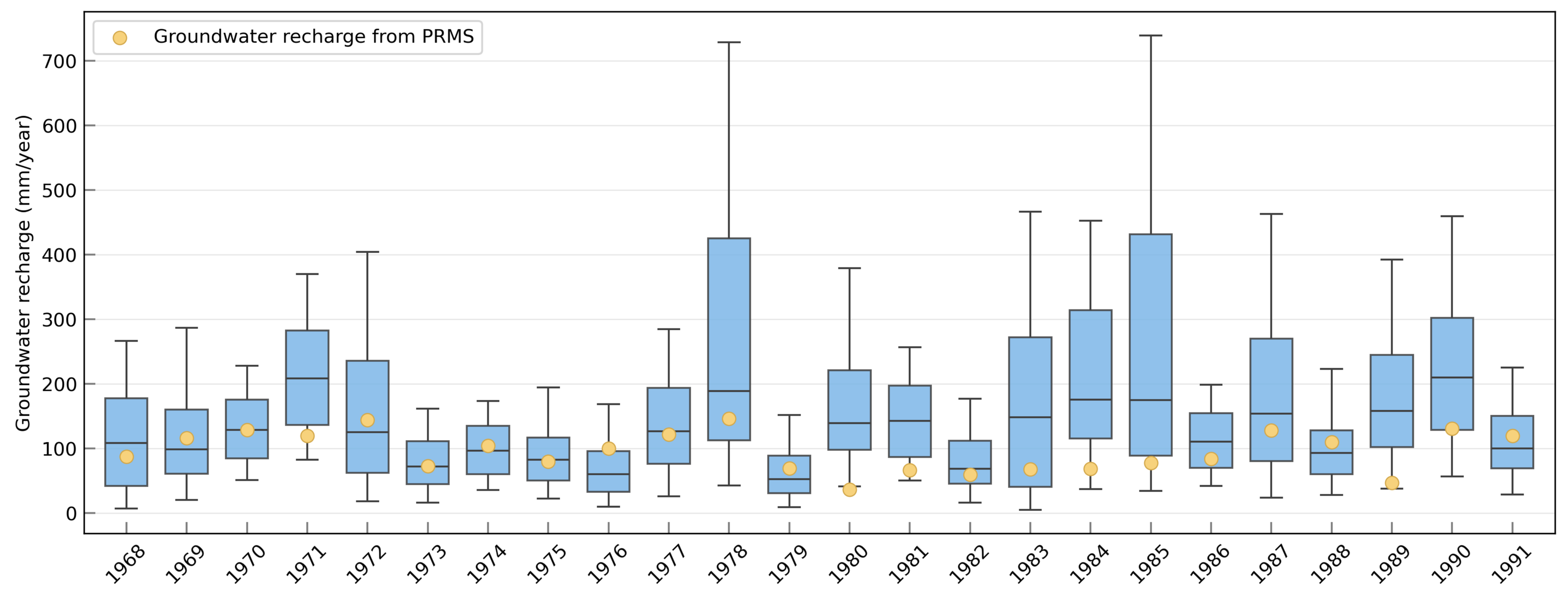

Fig 1. Boxplot of calculated annual groundwater recharge with recharge values from the PRMS model

The figures above and below show that the modelled and calculated hydrological components follow similar overall patterns and long-term trends, indicating good model performance.

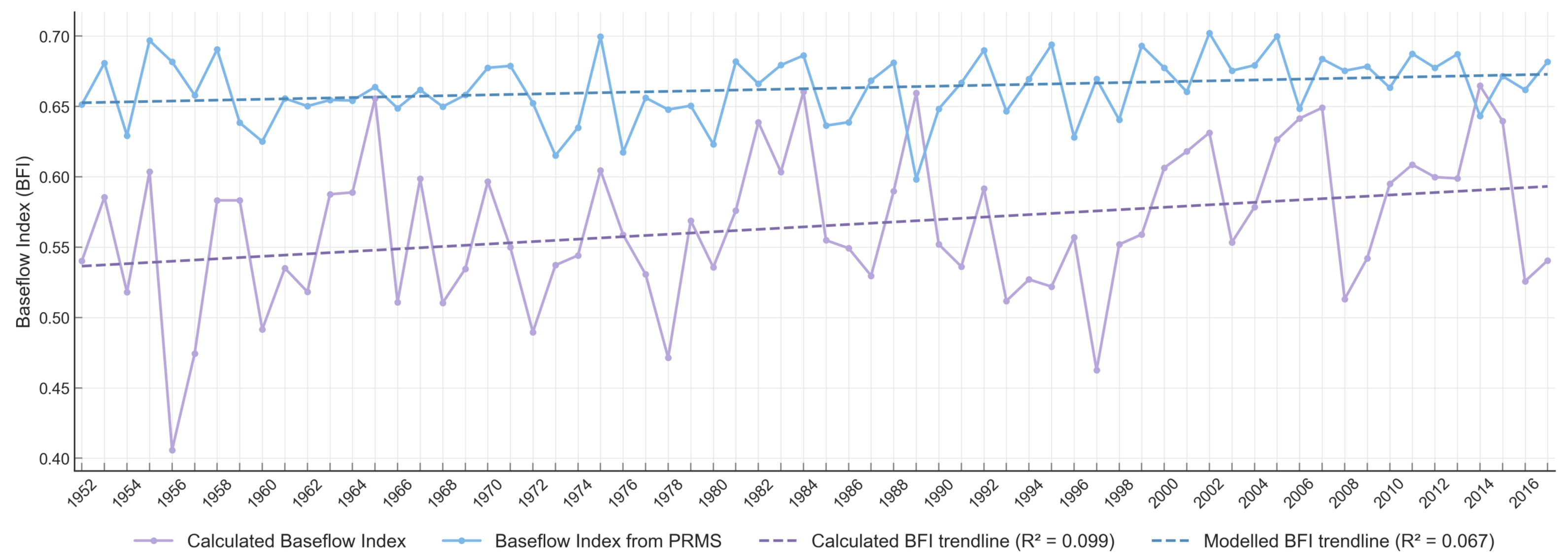

Fig 3. Annual baseflow indices for calculated and modelled baseflow with corresponding trendlines

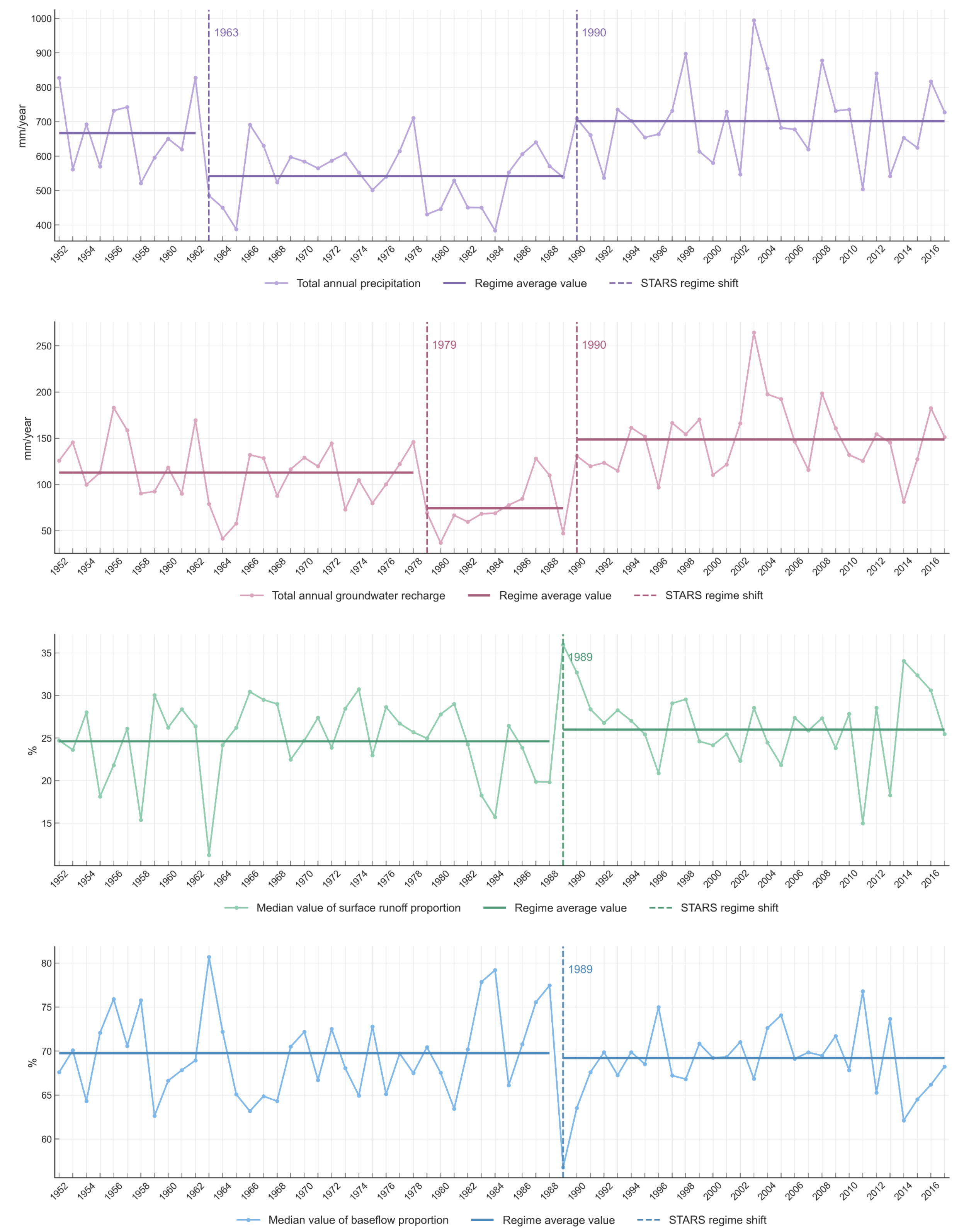

Fig 2. STARS regime shifts in different hydrological components

The figure above displays the regime shifts detected in different hydrological components using the Rodionov test. The most prominent regime shift was detected in 1989–1990, corresponding to the broader regime shift identified in Estonia in 1989 (Jaagus *et al.* 2017; Kotta *et al.* 2018).

METHODS

1 STUDY AREA AND INPUT DATA

- Model time series – 1952–2017
- Catchment area – 17,5 km^2
  - Quaternary sediments with heterogeneous lithology (till, sand, gravel), thickness 20–100 m.
  - Elevation 85–150 m. a. s. l.
- Input data –
  - Climate and Discharge data
  - Geology
  - Vegetation
  - Soil parameters
  - Surface topography data

2 CALIBRATION

- Automatic calibration – LUCA software

3 VALIDATION

- KGE and KGE benchmark
- Baseflow separation
- Water Table Fluctuation (WTF) method
- Potential ET – Penman–Monteith equation
- Regime shift detection – STARS (Rodionov) test

Jaagus, J., Sepp, M., Tamm, T., Järvet, A. and Mõisja, K. 2017. Trends and regime shifts in climatic conditions and river runoff in Estonia during 1951–2015. *Earth System Dynamics*, **8**(4), 963–976. https://doi.org/10.5194/esd-8-963-2017
Kotta, J., Herkül, K., Jaagus, J., Kaasik, A., Raudsepp, U., Alari, V., et al. 2018. Linking atmospheric, terrestrial and aquatic environments: Regime shifts in the Estonian climate over the past 50 years. *PLOS ONE*, **13**(12), e0209568. https://doi.org/10.1371/journal.pone.0209568

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