



RESHAPE
nature-inspired water-system solutions



IVM Institute for
Environmental Studies

Deltares

04.05.2026

Sensitivities of mean and extreme streamflow to precipitation variability across Europe

Anna Luisa Hemshorn de Sánchez^{1,2,3},

Wouter Berghuijs¹, Anne van Loon², Dimmie Hendriks³, Ype van der Velde¹

¹ Department of Earth Sciences, Vrije Universiteit Amsterdam

² Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam

³ Department of Soil and Groundwater Systems, Deltares

contact



abstract

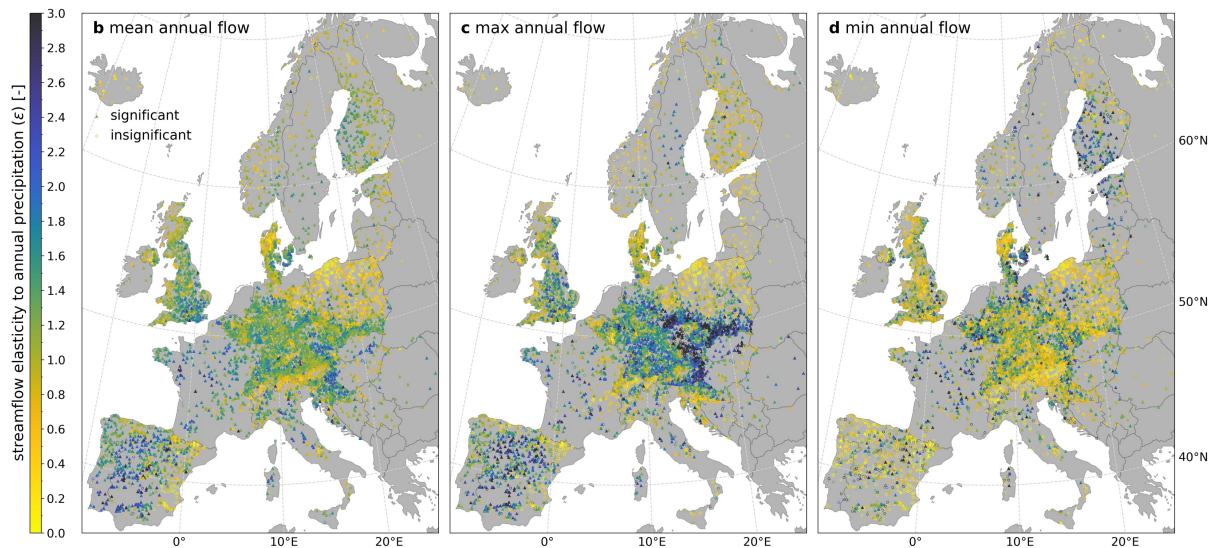


Annual streamflow sensitivity to annual precipitation

1% precipitation change 

Amplified response: >1% streamflow change

Dampened response: <1% streamflow change

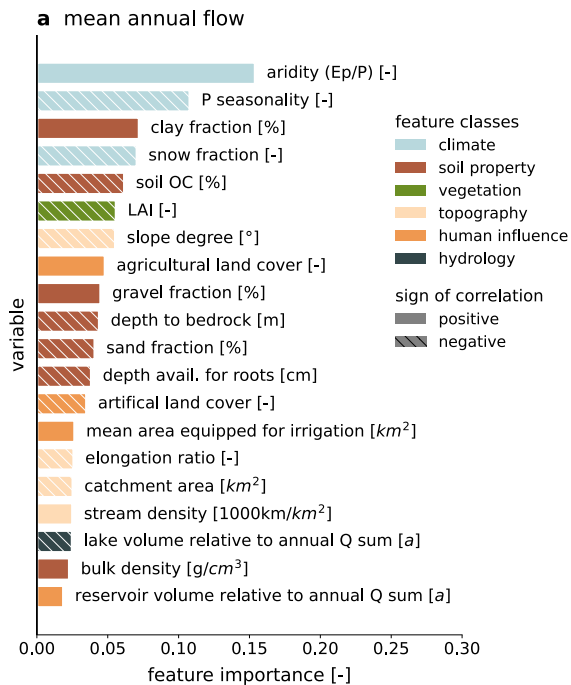


Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe”

abstract



Climate features more strongly related to streamflow sensitivity



This model explains roughly 50% of the streamflow sensitivities to precipitation



PICOA.5

Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe“

abstract





RESHAPE
nature-inspired water-system solutions



IVM Institute for Environmental Studies

Deltares

04.05.2026

Sensitivities of mean and extreme streamflow to precipitation variability across Europe

Anna Luisa Hemshorn de Sánchez^{1,2,3},

Wouter Berghuijs¹, Anne van Loon², Dimmie Hendriks³, Ype van der Velde¹

¹ Department of Earth Sciences, Vrije Universiteit Amsterdam

² Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam

³ Department of Soil and Groundwater Systems, Deltares



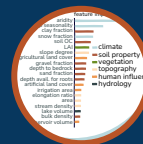
Abstract



Response to precipitation



Response to temperature



Catchment characteristics



Dutch case



Hydrological signatures



Outlook



contact



abstract

European streamflow sensitivities

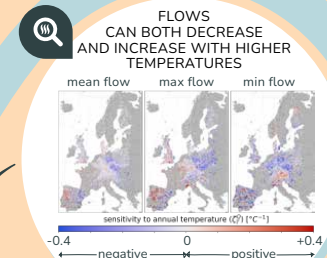
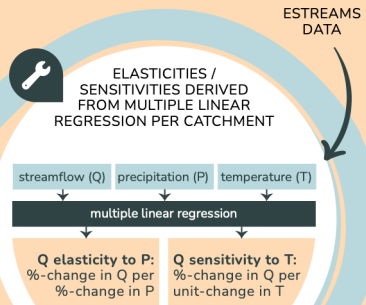
What?

Mapping streamflow sensitivity to climate variability across Europe

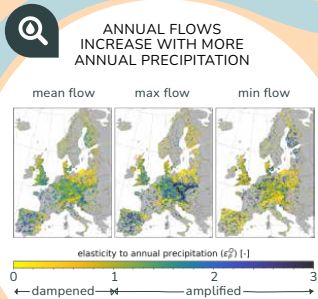
Why?

Identify where and why streamflow changes more when the climate gets drier/wetter and warmer/colder

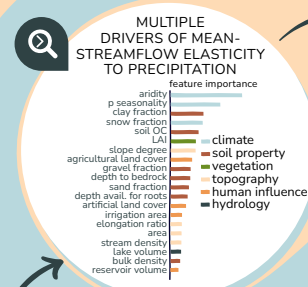
? HOW DOES ANNUAL MEAN AND EXTREME STREAMFLOW RESPOND TO VARIABILITY IN CLIMATE?



BUT TEMPERATURE HAS LIMITED INFLUENCE ON ANNUAL STREAMFLOW



MAX FLOWS ARE MOST AND MIN FLOWS ARE LEAST SENSITIVE TO ANNUAL PRECIPITATION



RANDOM FOREST MODEL

WITH THESE CHARACTERISTICS WE CAN ONLY DESCRIBE ~50% OF THE ELASTICITY

! FIRST PAN-EUROPEAN QUANTIFICATION OF ELASTICITIES OF ANNUAL MEAN AND EXTREME FLOW TO PRECIPITATION PROVIDING A BASIS TO ASSES REGIONAL EXPOSURE TO CLIMATE VARIABILITY AND SUPPORT TARGETED WATER AND CLIMATE RISK MANAGEMENT ACROSS EUROPE.

HEMESHORN DE SÁNCHEZ ET AL. (ACCEPTED, HESS).



European streamflow sensitivities

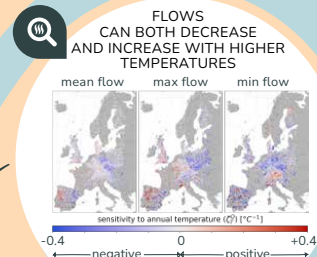
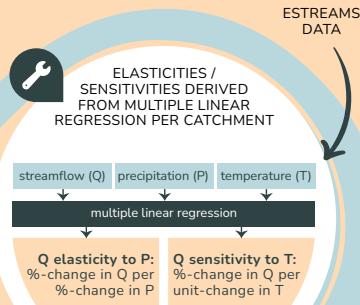
What?

Mapping streamflow sensitivity to climate variability across Europe

Why?

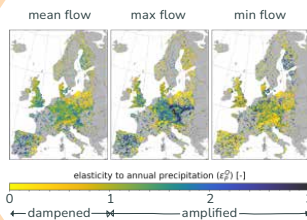
Identify where and why streamflow changes more when the climate gets drier/wetter and warmer/colder

? HOW DOES ANNUAL MEAN AND EXTREME STREAMFLOW RESPOND TO VARIABILITY IN CLIMATE?

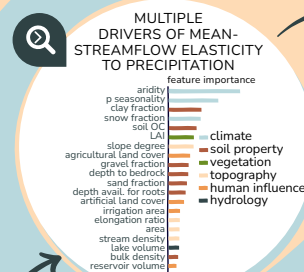


BUT TEMPERATURE HAS LIMITED INFLUENCE ON ANNUAL STREAMFLOW

? ANNUAL FLOWS INCREASE WITH MORE ANNUAL PRECIPITATION



MAX FLOWS ARE MOST AND MIN FLOWS ARE LEAST SENSITIVE TO ANNUAL PRECIPITATION



RANDOM FOREST MODEL

WITH THESE CHARACTERISTICS WE CAN ONLY DESCRIBE ~50% OF THE ELASTICITY

! FIRST PAN-EUROPEAN QUANTIFICATION OF ELASTICITIES OF ANNUAL MEAN AND EXTREME FLOW TO PRECIPITATION PROVIDING A BASIS TO ASSES REGIONAL EXPOSURE TO CLIMATE VARIABILITY AND SUPPORT TARGETED WATER AND CLIMATE RISK MANAGEMENT ACROSS EUROPE.

HEMESHORN DE SÁNCHEZ ET AL. (ACCEPTED, HESS).



European streamflow sensitivities to annual precipitation variability

Streamflow elasticity to precipitation

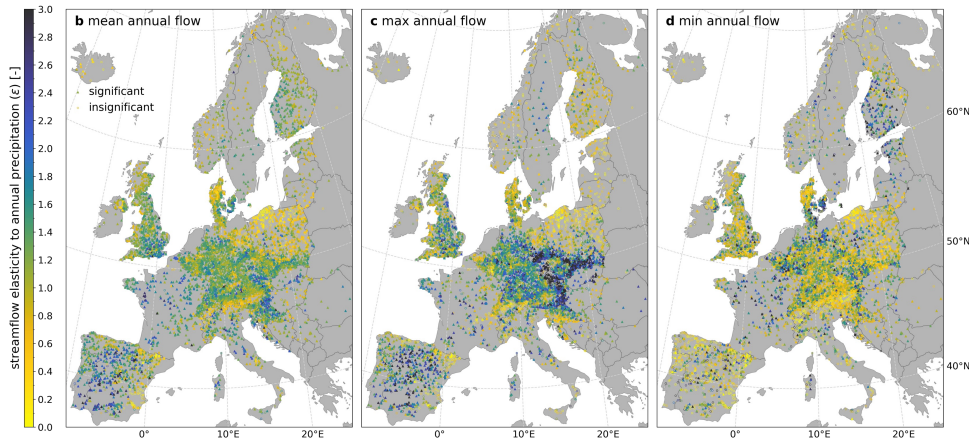
%-change of streamflow per %-change
in precipitation

Dampened response

1% P change \rightarrow <1% Q change

Amplified response

1% P change \rightarrow >1% Q change



abstract



Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe”

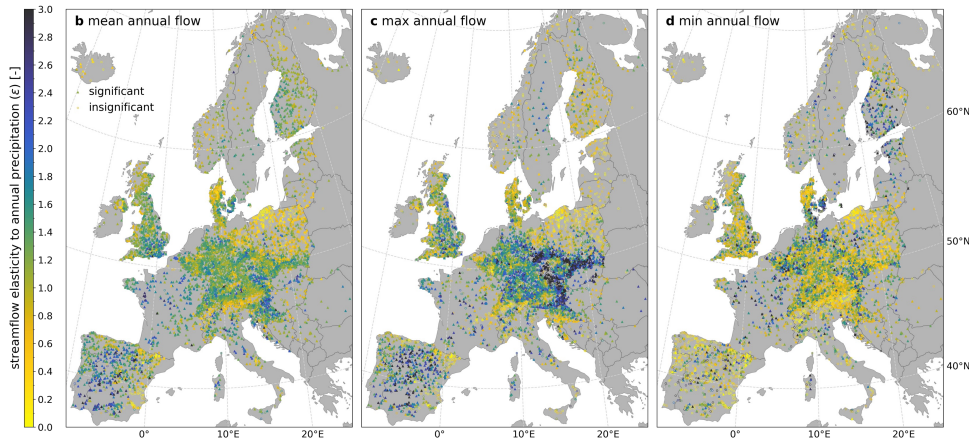


European streamflow sensitivities to annual precipitation variability

Typically, annual **mean and max flows amplify precipitation variations**, whereas **min flows dampen them**.

Northern Poland and Baltic States are remarkably **insensitive to annual precipitation variations**.

Elasticities of **low flows** tend to be **more localised** and less related to precipitation variability **compared to** elasticities of **mean and max flows**.



Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe“

abstract



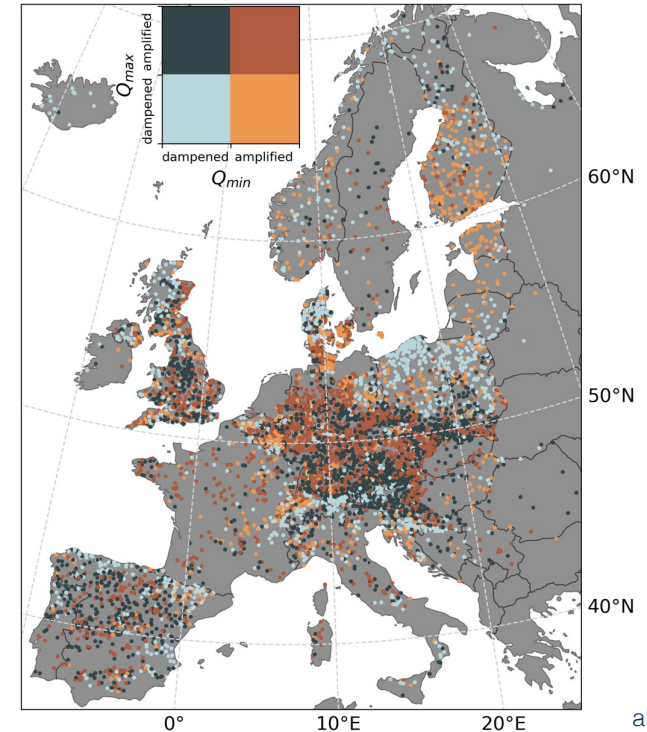
Combined streamflow elasticities as a measure of resilience in extreme flows

Considering elasticities of Q_{\max} and Q_{\min} combined as a measure of **resilience** in extreme flows.

In most catchments, max flows are sensitive to precipitation, but min flows are resilient .

Catchments that are sensitive in their min flows but that have resilient max flows are rare.

Classes are **regionally clustered** but also **show local spatial heterogeneity**



Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe“

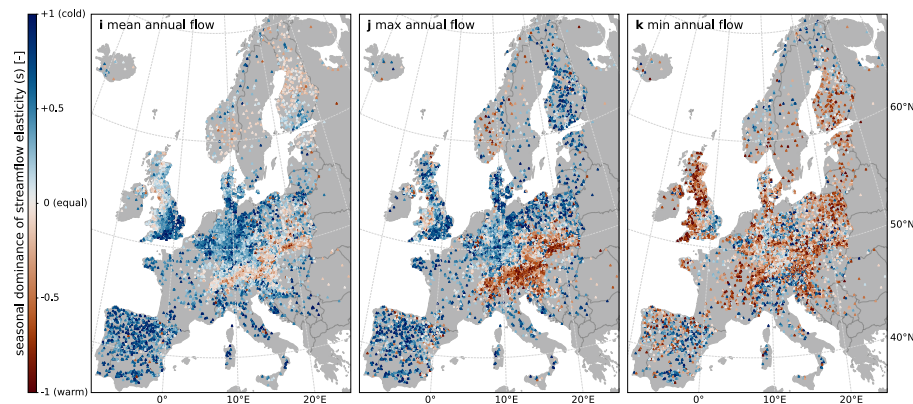
abstract



European streamflow elasticities to seasonal precipitation variability

Max flow in mountainous Central Europe is highly sensitive to summer precipitation.

Mean and max flows in Spain are particularly sensitive to winter precipitation.



Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe”

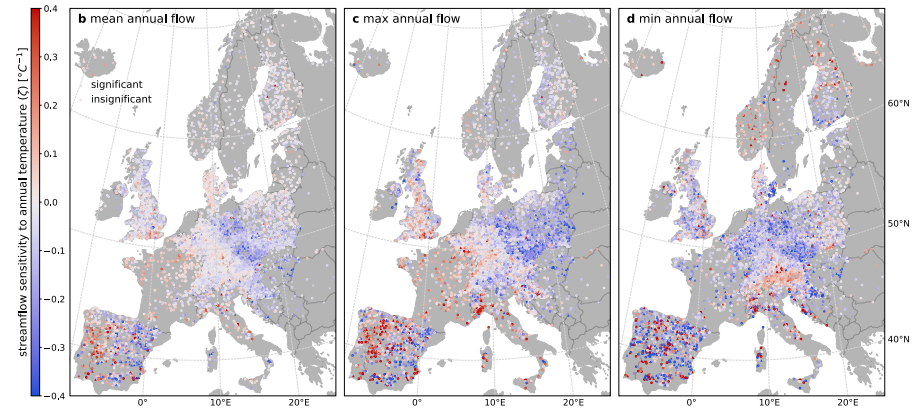
abstract



Streamflow sensitivities to temperature variability across Europe

Annual mean, max and min flows scale both negatively and positively with annual temperature

On average, temperature is weakly related to streamflow

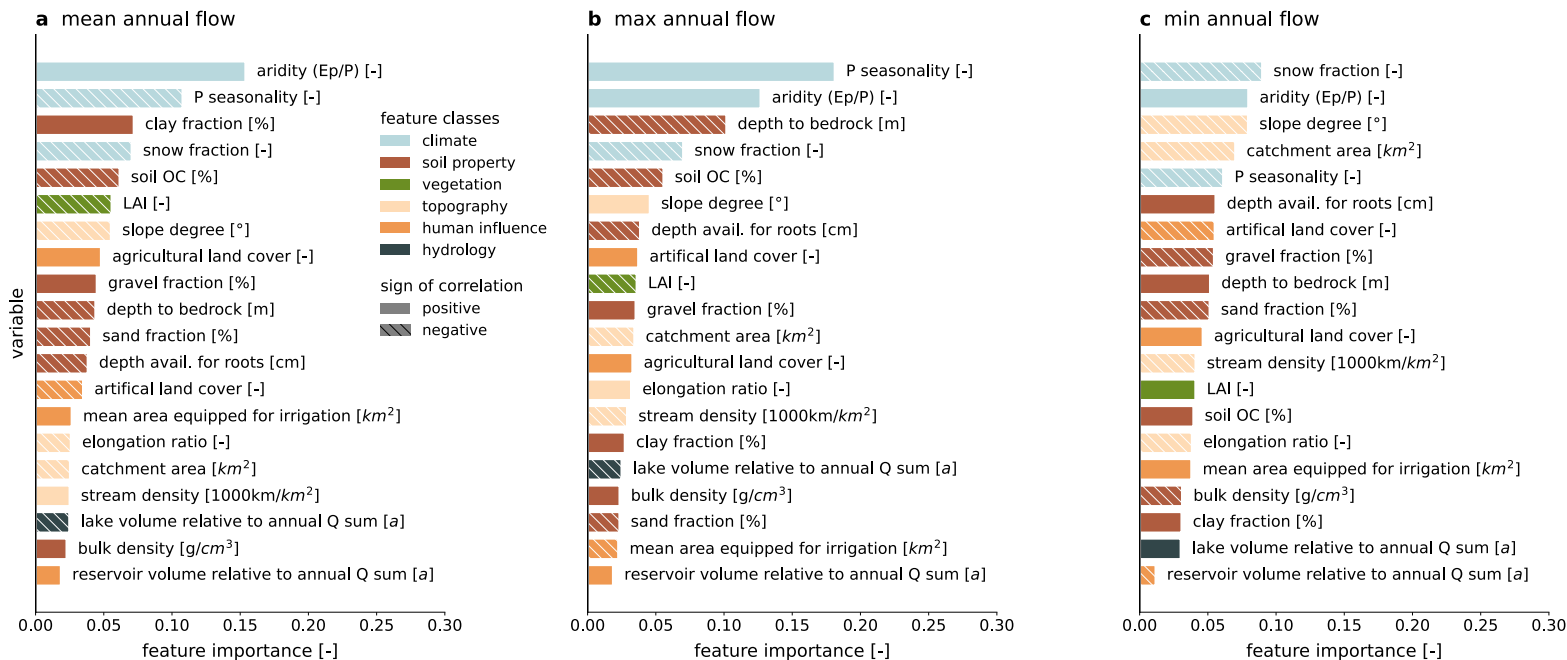


Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe”

abstract



Climate features are more strongly related to streamflow elasticity but no single characteristics dominates



This model explains roughly 50% of the streamflow elasticities to precipitation

Hemshorn de Sánchez et al. (accepted, HESS). “Sensitivities of mean and extreme streamflow to climate variability across Europe”

abstract



Further explore human influence on streamflow response to precipitation

What?

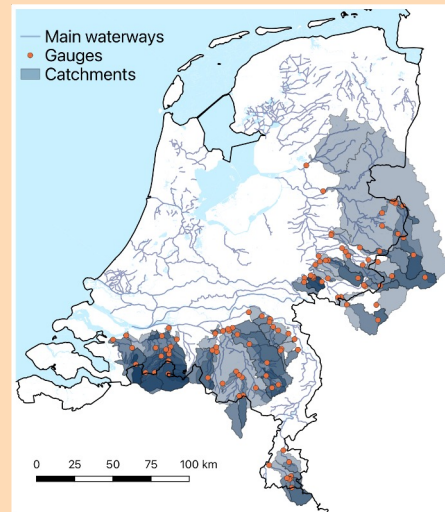
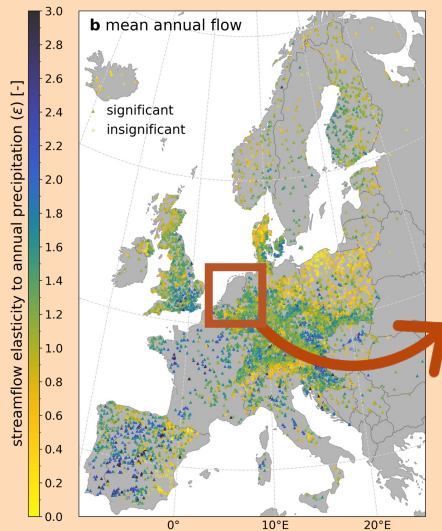
Assemble Dutch streamflow dataset and classify catchments according to their streamflow behaviour

Why?

Allow comparison of catchments and understand possible effects of water management practices

How to apply?

Target water management measures



abstract



Hydrological signatures: Outlook

Can we **associate signatures** to **catchments characteristics/processes**?

Can we **group catchments** into typologies of **similar streamflow behaviour**?



abstract

