Attribution of climate change imprint on riverine nutrient export to African coastal waters

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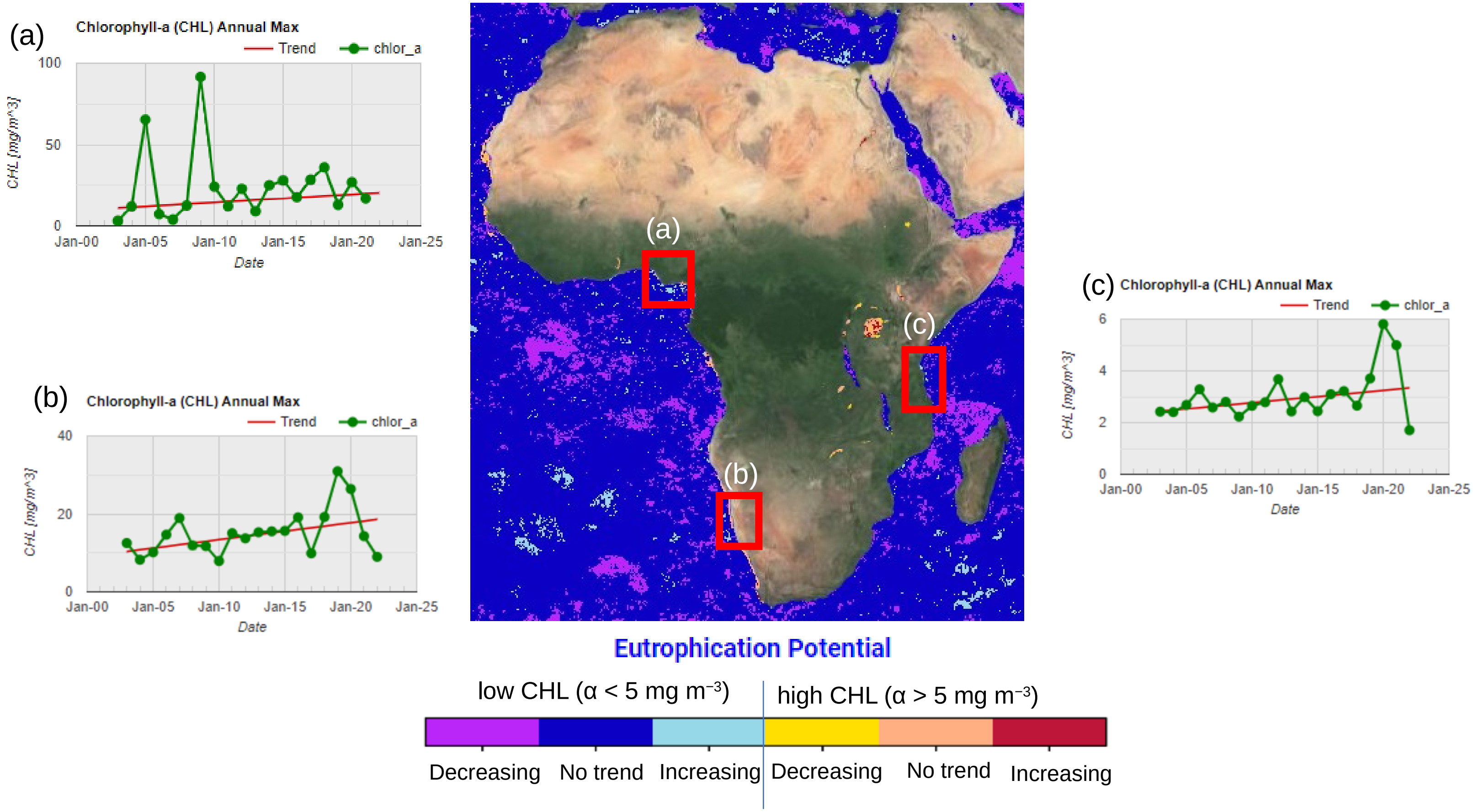
Context

Context – Coastal eutrophication

Eutrophication is a global issue associated with increasing anthropogenic **nutrient loading**

Global Eutrophication Watch – (Extract)



Globally, coastal waters covering ~1.15 million km^2 are eutrophic potential.

(Maúre et al., 2021; Nat. comms)

> 20 occurrences of eutrophication in African coastal waters *(Selman et al. 2008)*

(Maúre et al., 2021; Nat. comms)

Context – Taking account of climate change

Interplay of Land-use, Socio-economic & **Meteorological forcing**

Climatic changes

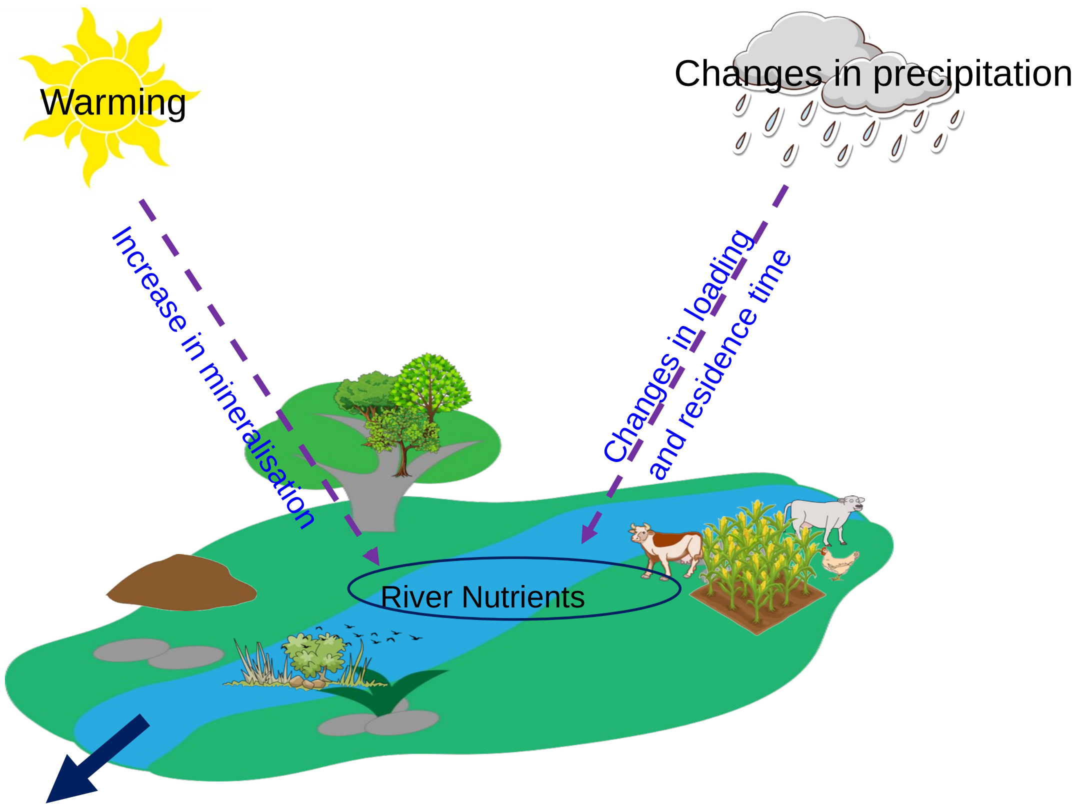
↓

Hydrologic variability

↓

Modulates the N and P loading

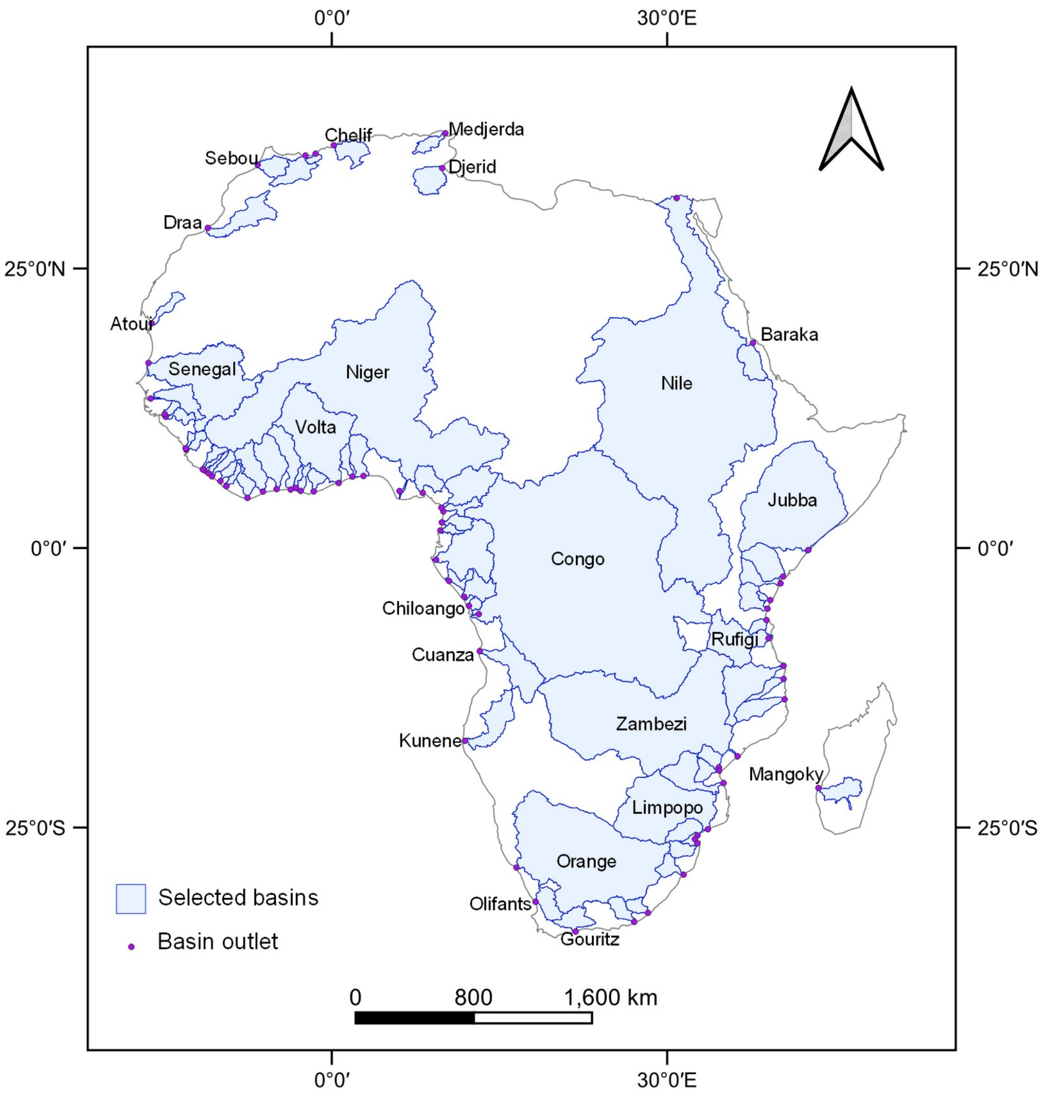
Link between climate change and riverine nutrient export



Ocean export

Changes in:
- Cyanobacteria
- Algal blooms
- Eutrophication
- Floating vegetation, etc

Study Focus – Africa



Studies on riverine nutrient export to African coastal wasters are **scarce** *(Yasin et al., 2010)*

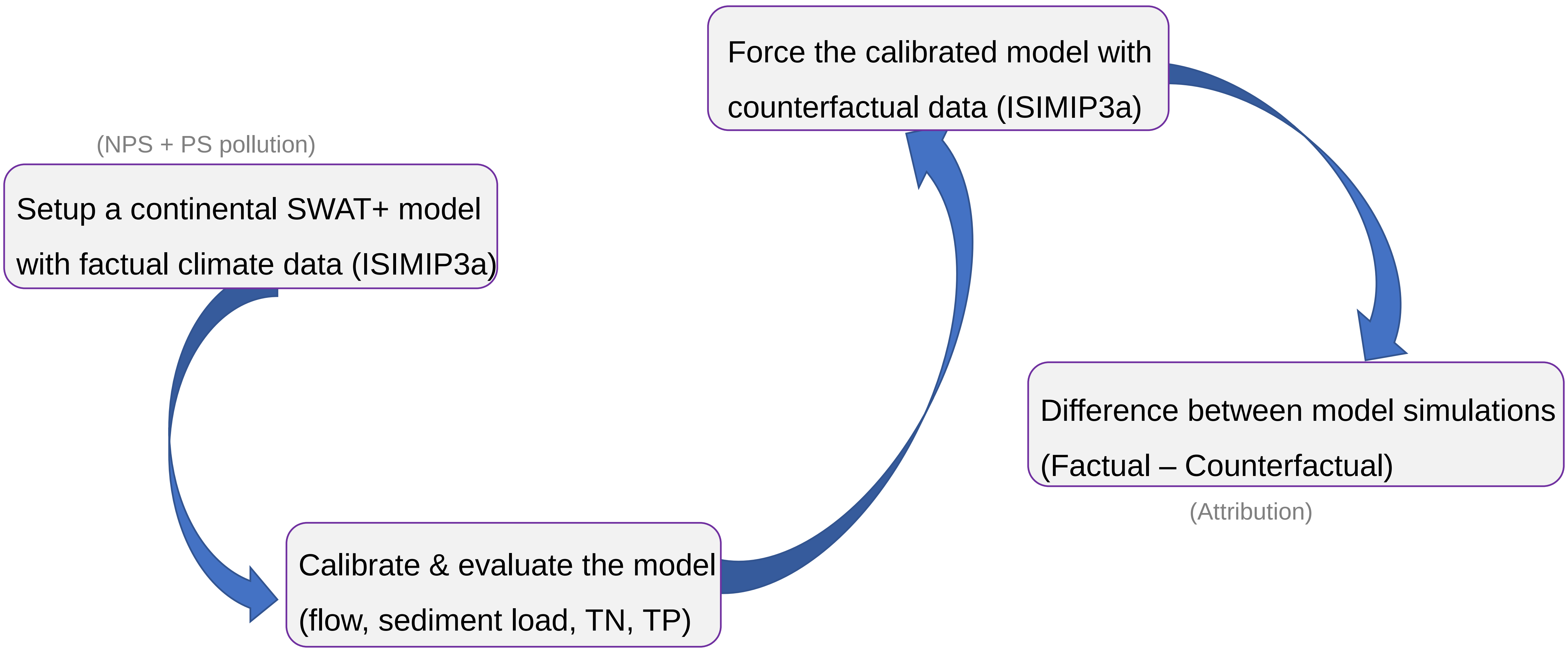
Linkages between climate & nutrient export by rivers to coastal waters has not been explored

No long time series available

- Focus on 70 major exorheic basins
- Basin sizes ranging: 3.7 million km^2 to 6700 km^2
- Total Nitrogen (TN) & Total Phosphorus (TP)

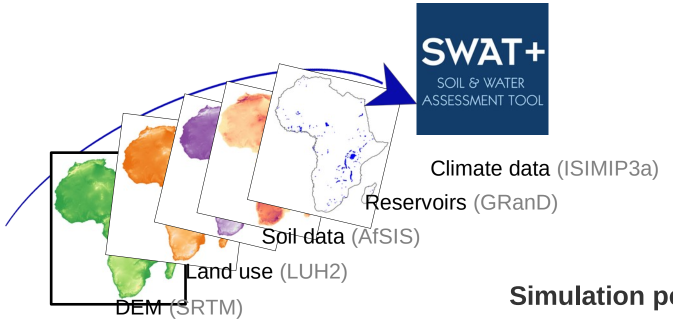
Approach

Modeling Approach

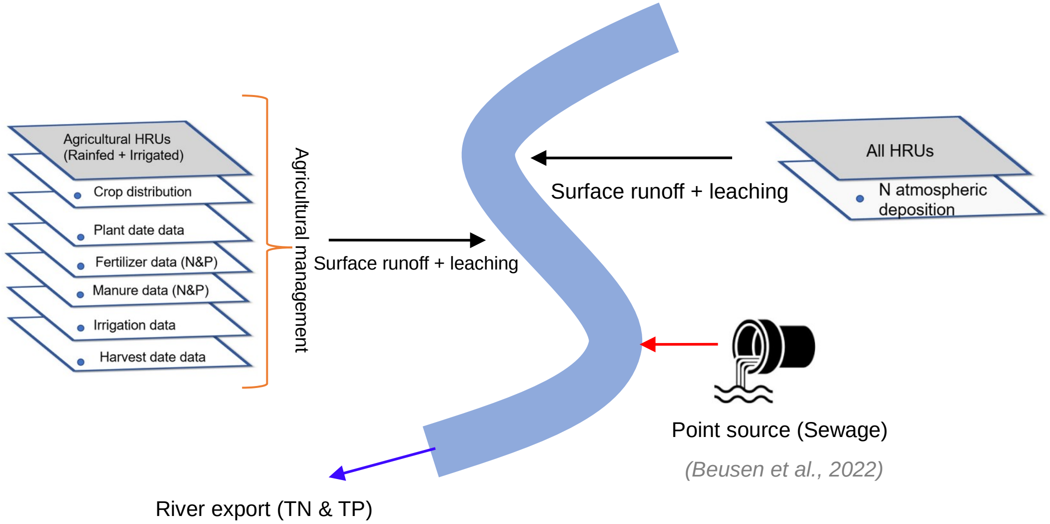


Model setup & Evaluation

(a) Set up

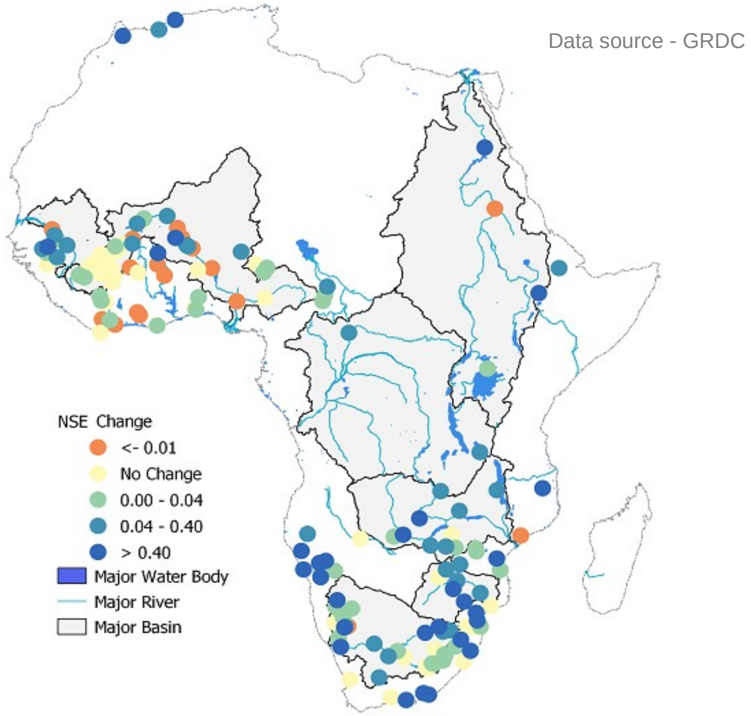


Simulation period □ 1951 – 2019



(Beusen et al., 2022)

(b) Hydrological evaluation



(Chawanda et al., 2023, HESS)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Hydrology and Earth System Sciences Discussions

Combined impacts of climate and land-use change on future water resources in Africa

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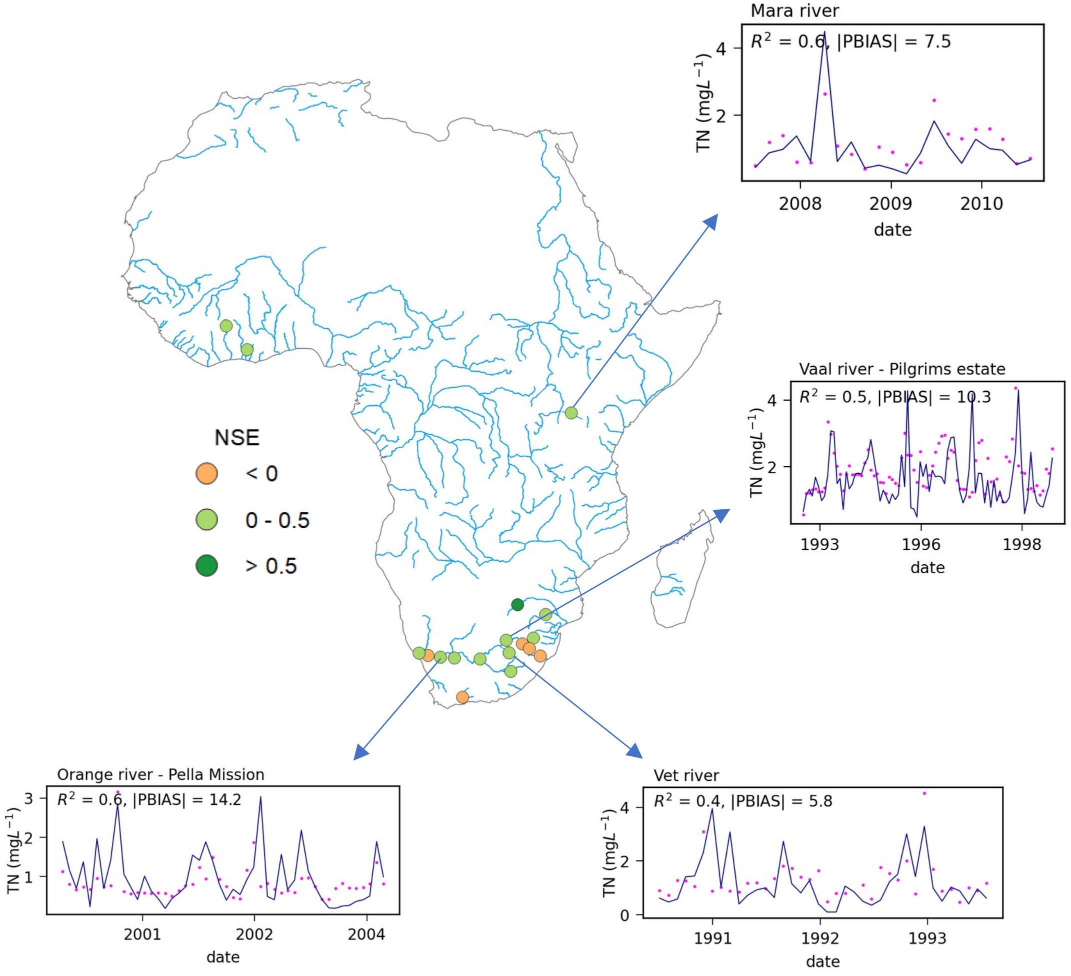
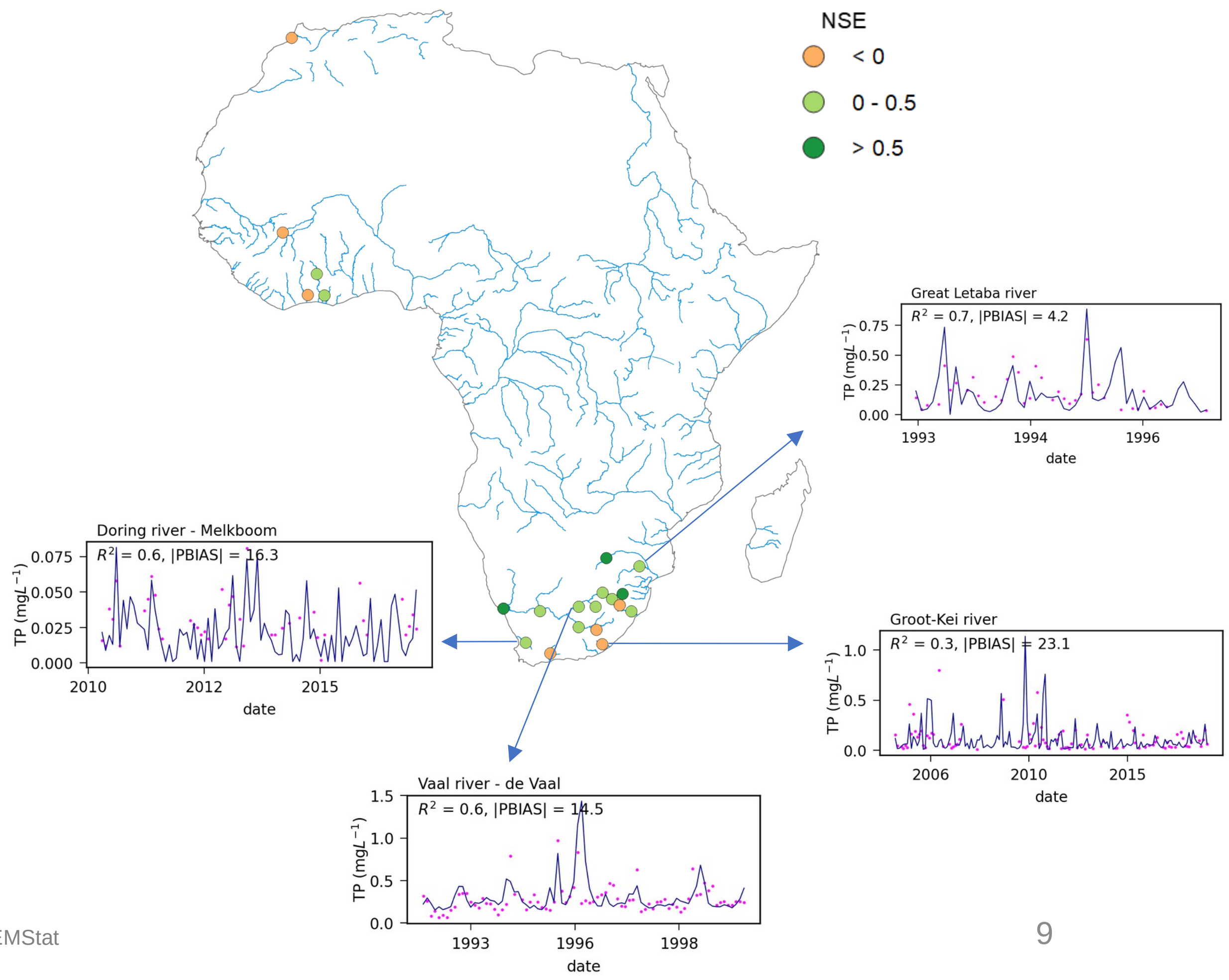
Model setup & Evaluation

(a) Total Nitrogen (TN)



(b) Total Phosphorus (TP)

observed TP
simulated TP



Data source - GEMStat

Results - Attribution

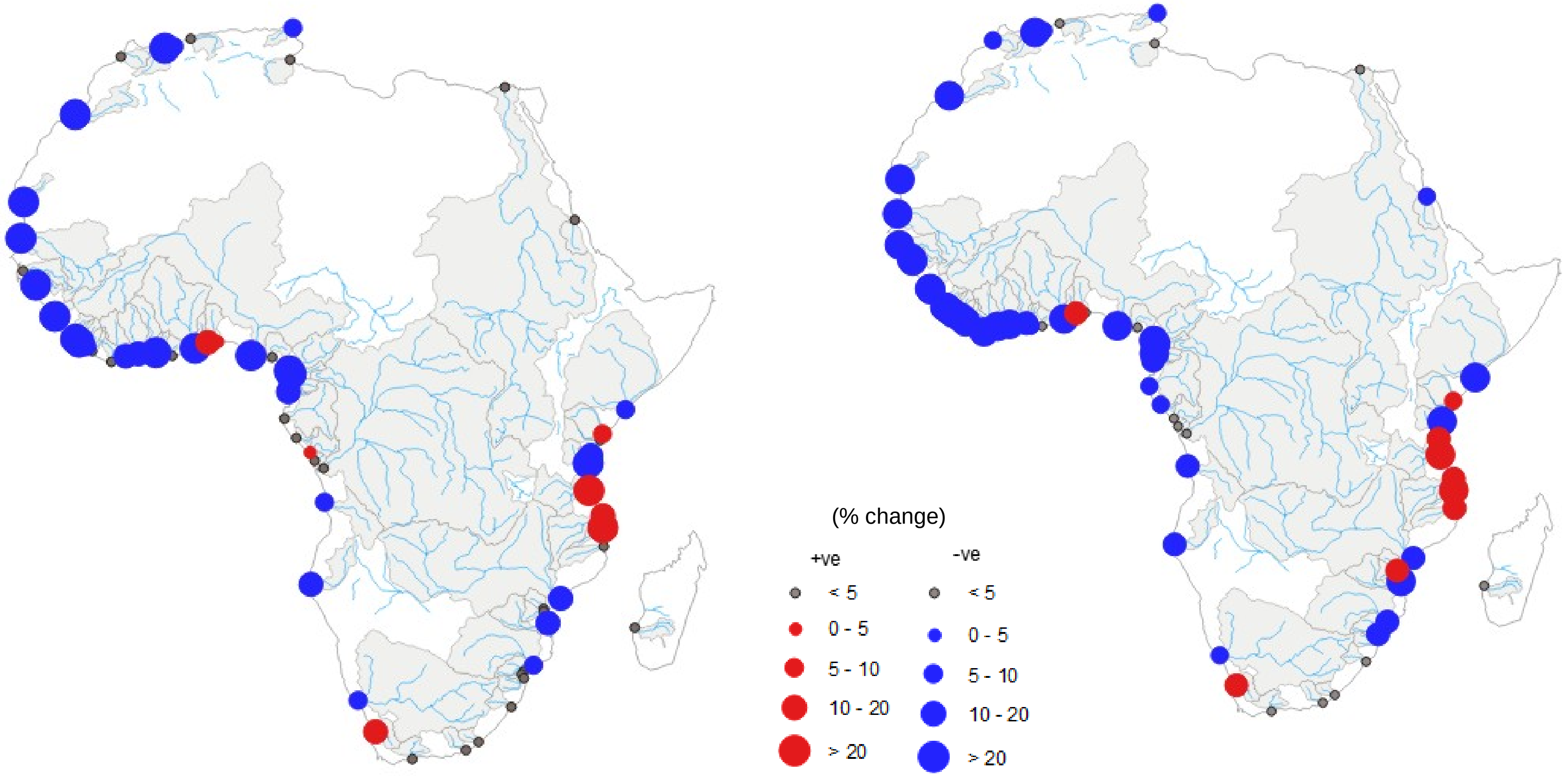
(Factual vs Counterfactual simulations)

TN & TP attribution

Long-term annual river load change

(a) TN

(b) TP



$$_{i} = \left(\frac{S_c - S_o}{S_c} \right) x\,100$$

is the historical impact of climate change (%)

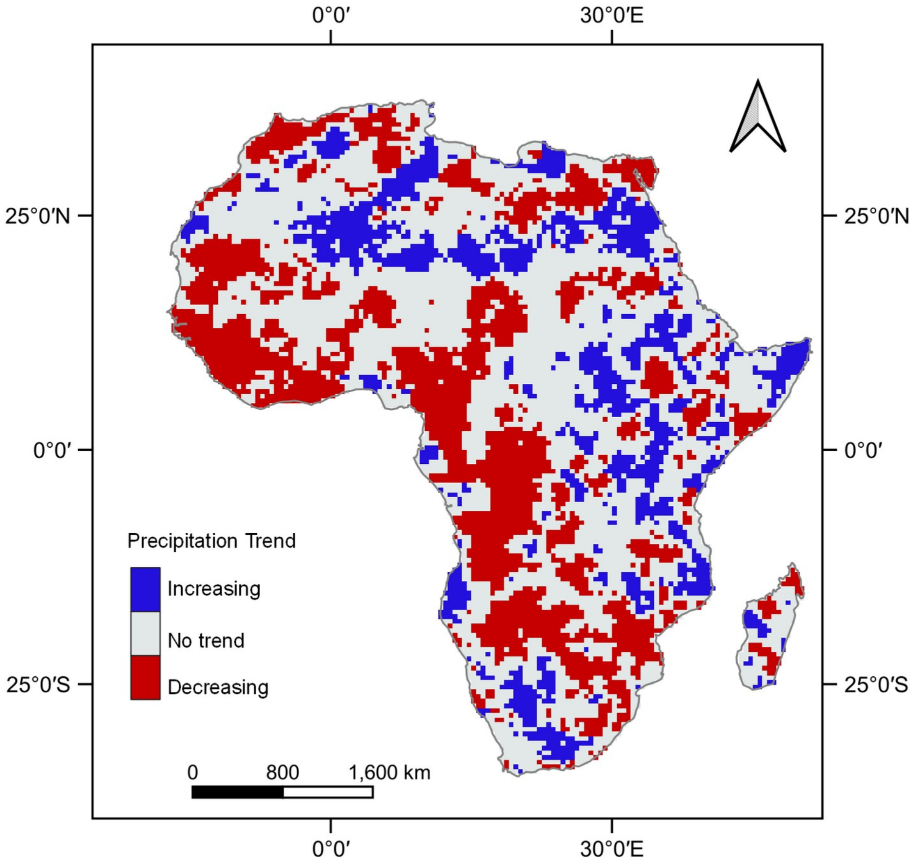
is the annual average model output of simulations forced with **counterfactual climate data**

is the annual average model output of simulations forced with **factual climate data**

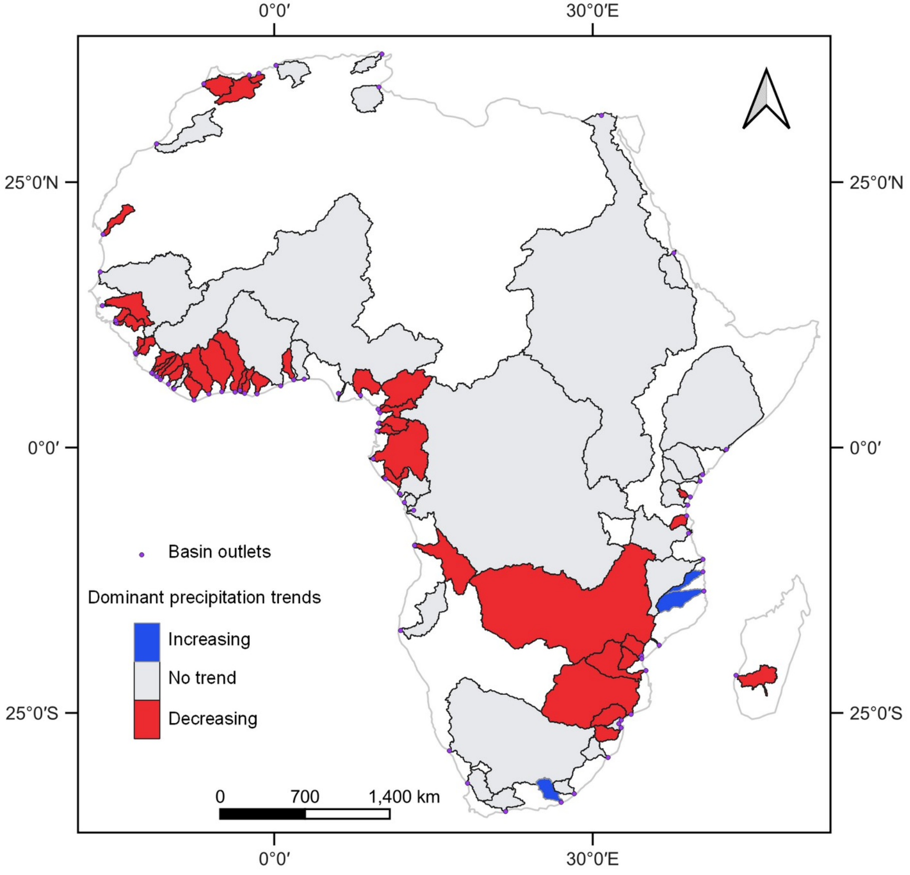
Climate change mostly contributing to a **decrease** in N & P export

Trends - Precipitation

Factual precipitation



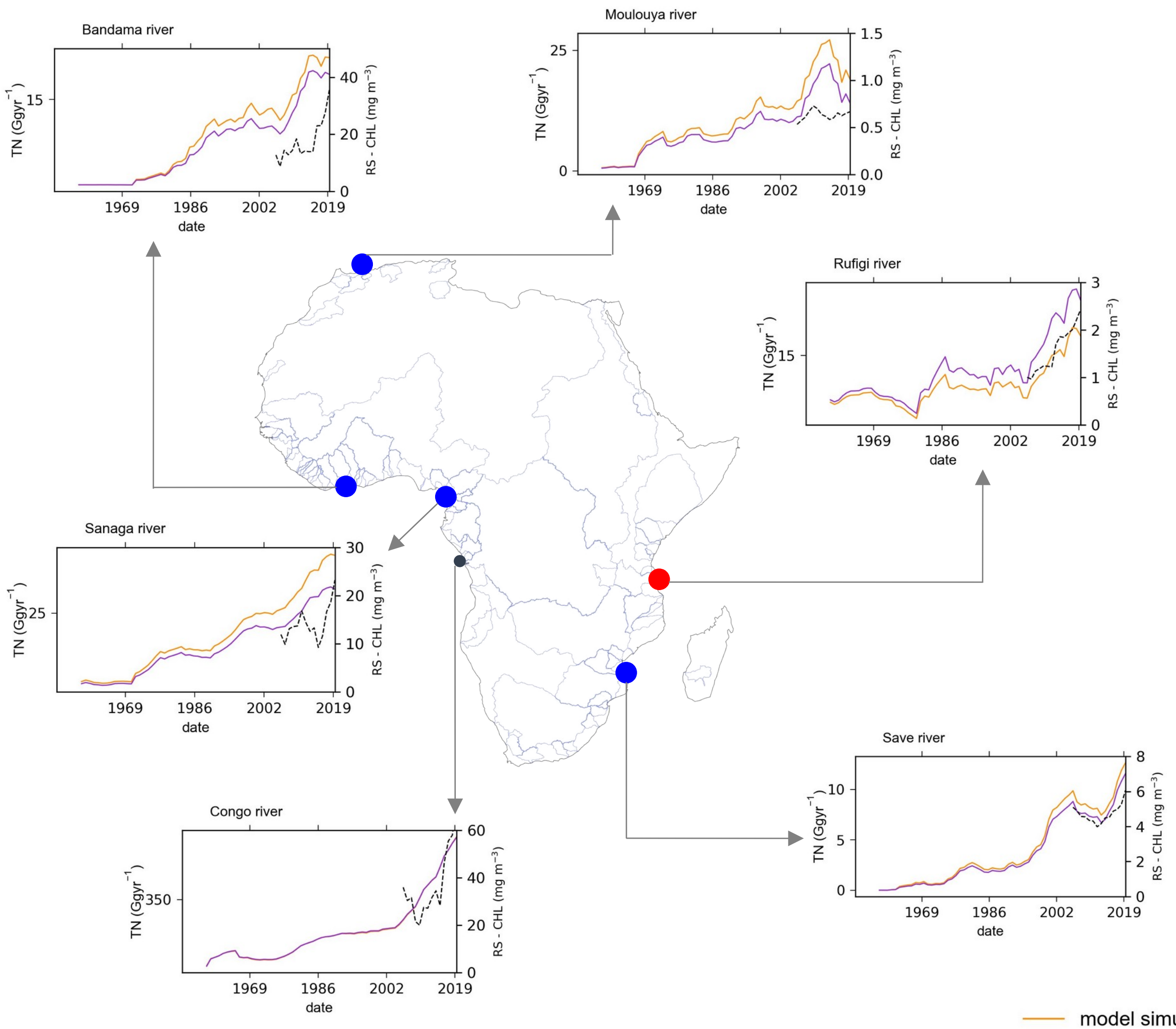
Dominant trend in major basins



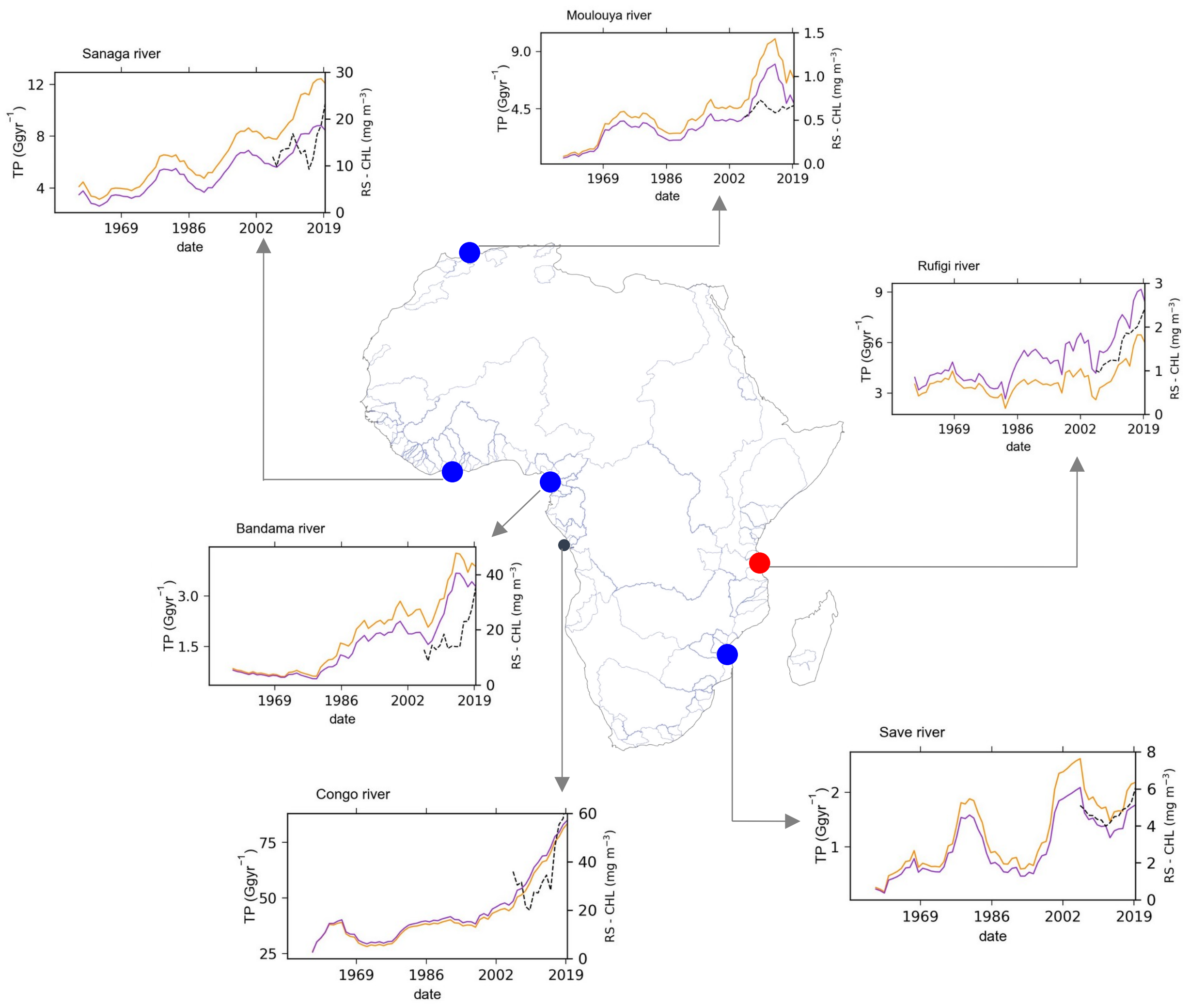
Historic precipitation patterns show that much of Africa is **drying** (Hartmann et al. 2013).

TN & TP attribution - Trends

(a) TN



(b) TP



model simulations forced with counterfactual climate
model simulations forced with factual climate
Remote Sensing (RS) - Chlorophyll-a

Preliminary Take away(s)

- CC signal on nutrient loads more apparent in small rivers (basin area < 420,000km^2)
- The trends in nutrient loads cannot be explained by climate change
- CC has mostly contributed to a decrease in magnitude of nutrient loads to the ocean

Next Step (s)

- Run simulations of Fixed vs Dynamic **Land use change** & Fixed vs Dynamic **Point sources**
- Compare River Loads vs River concentrations

Thank you!

Extra slides

Input Datasets

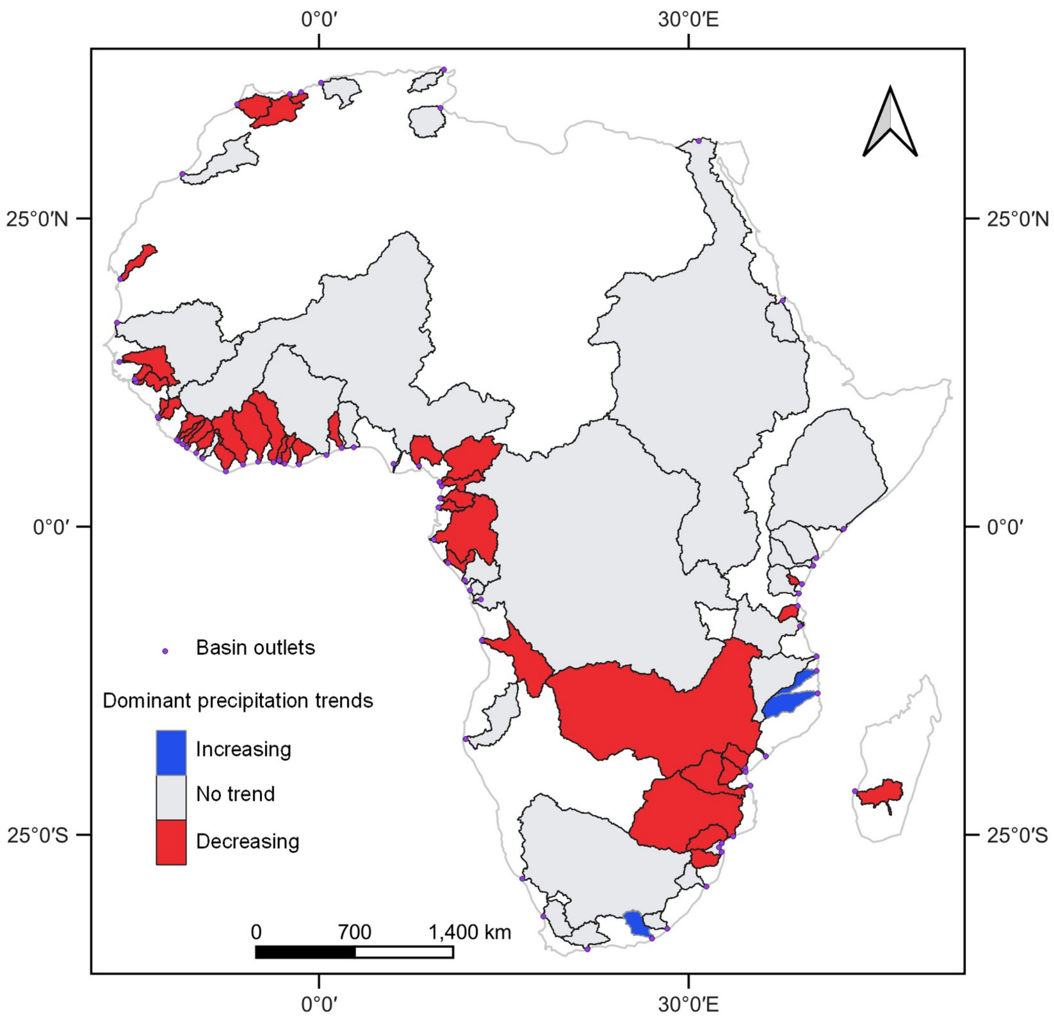
Global Datasets	Resolution	Source
Digital Elevation Model (DEM)	90m	Shutter Radar Topography Mission (SRTM; Farr et al., 2007)
Land use	0.25 º	Harmonized land use (LUH2; Hurtt et al., 2020)
Soil	250 m	Africa Soil information Service (AFSIS; Hengl et al., 2015)
Climate	0.5 º	ISIMIP (GSWP3-W5E5; Dirmeyer et al., 2006; Kim et al., 2017; Lange, 2019; Cucchi et al., 2020) (Factual & Counterfactual)
Irrigated areas	0.083 º	Food and Agriculture Organization (FAO; Siebert et al., 2013)
Plant and harvest dates	0.5 º	Global Gridded Crop Model Intercomparison (GGCMI; Jägermeyr et al., 2021)
Fertilizer – Nitrogen(N)	0.5 º	(Hurtt et al., 2020)
Fertilizer – Phosphorus(P)	0.5 º	(Lu and Tian, 2017)
Manure (N & P)	0.5 º	(Potter et al., 2010)
Point sources (N & P)	0.5 º	(Beusen et al., 2022)

(b) Evaluation

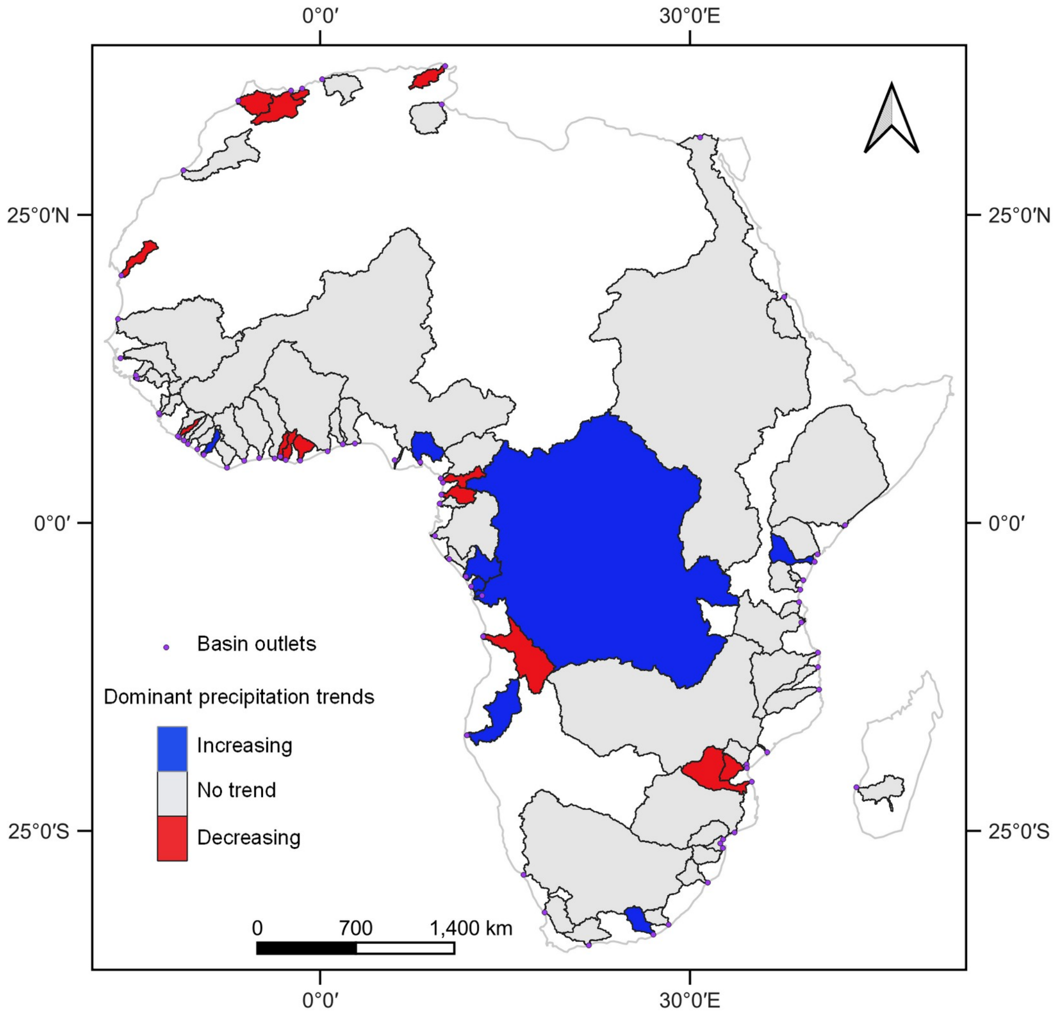
Dataset	Resolution	Source
Leaf Area Index (LAI)	1 km	CGLS (https://land.copernicus.vgt.vito.be/)
Evapotranspiration (ET)	250 m	WaPOR (FAO, 2018)
River Discharge	monthly	GRDC (http://grdc.bafg.de)
River nutrients (N & P)	Daily & monthly	GEMstat (https://gemstat.org/)

Trends - Precipitation

(a) Factual



(b) Counterfactual

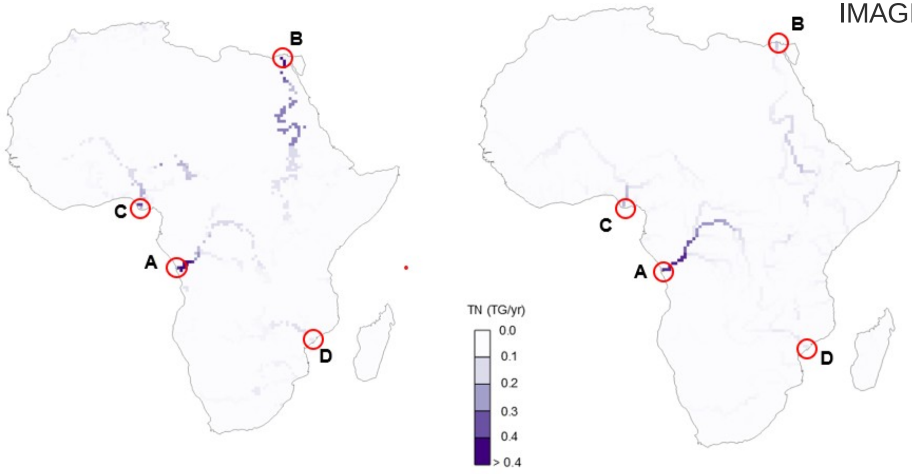


Model setup & Evaluation

TN river loads

This study — SWAT+

Beusen et al. (2022) — IMAGE-GNM



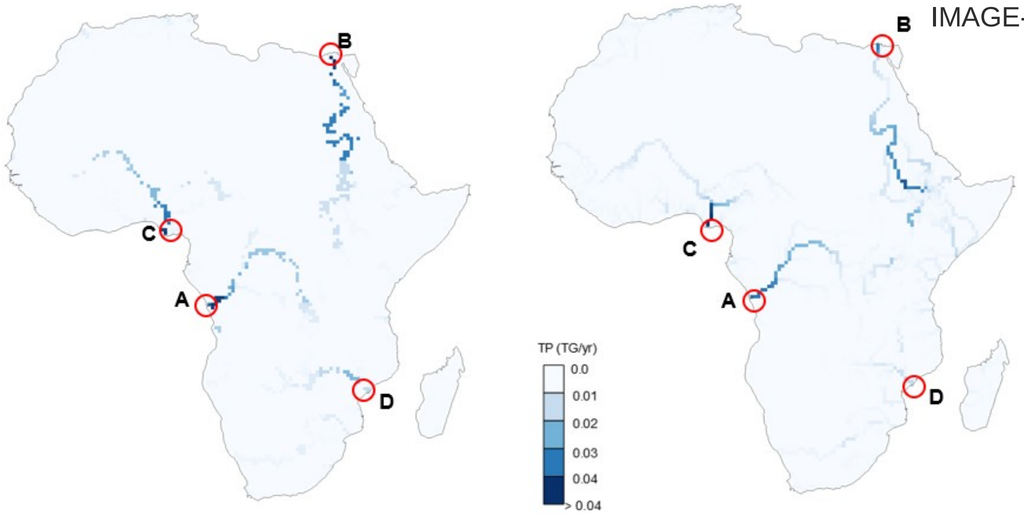
Year - 2015

	River	This study (TG/yr)	Measured/Reported (TG/yr)	Source
A	Congo	0.61	0.42 - 2.29	*Beusen et al. (2022), Mayorga et al. (2010), van Drecht et al. (2001)*
B	Nile	0.45	0.16 - 0.99	*Beusen et al. (2022), van Drecht et al. (2001)*
C	Niger	0.34	0.21	*Beusen et al. (2022)*
D	Zambezi	0.1	0.08 - 0.64	*Beusen et al. (2022), van Drecht et al. (2001)*

TP river loads

This study — SWAT+

Beusen et al. (2022) — IMAGE-GNM



Year - 2015

	River	This study (TG/yr)	Measured/Reported (TG/yr)	Source
A	Congo	0.08	0.02 – 0.25	*Beusen et al. (2022), Mayorga et al. (2010), van Drecht et al. (2001)*
B	Nile	0.07	0.03	*Beusen et al. (2022), van Drecht et al. (2001)*
C	Niger	0.08	0.03	*Beusen et al. (2022)*
D	Zambezi	0.004	0.008	*Beusen et al. (2022)*