Understanding the potential impact of the Grand Ethiopian Renaissance Dam on floods in Sudan

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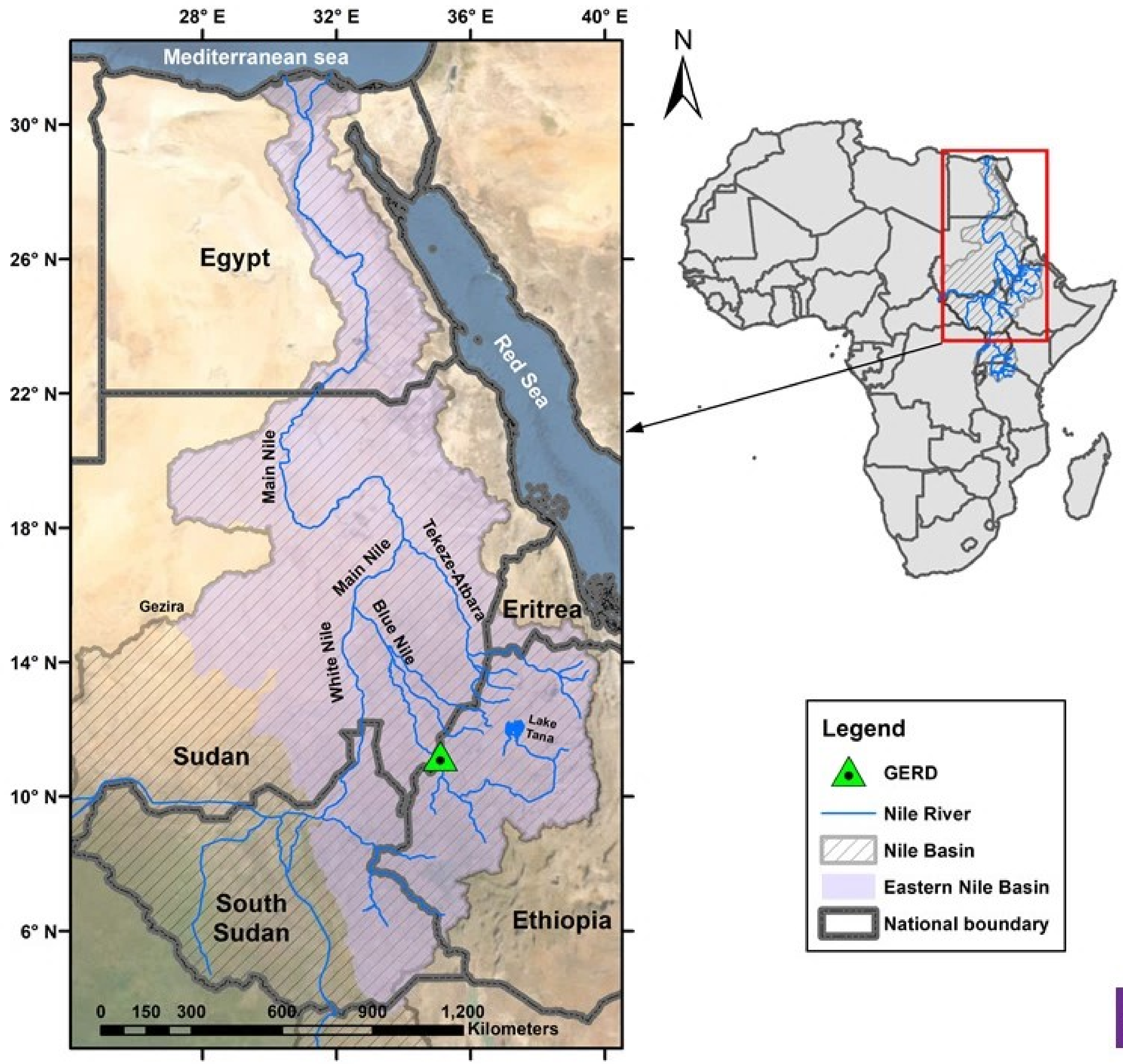
Presentation outline

1. Introduction
2. Assessment method
3. GERD role in 2020 Nile floods
4. GERD potential long-term impacts on riverine floods
5. GERD potential downstream environmental impacts
6. Conclusions

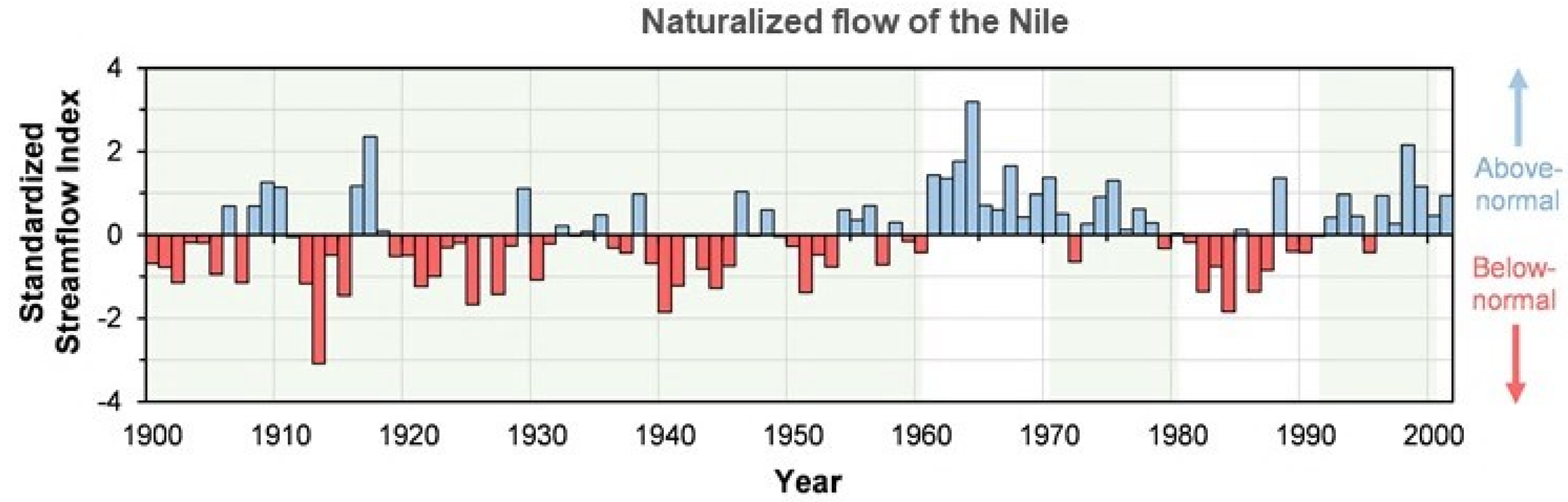
1- Introduction

Grand Ethiopia Renaissance Dam (GERD)

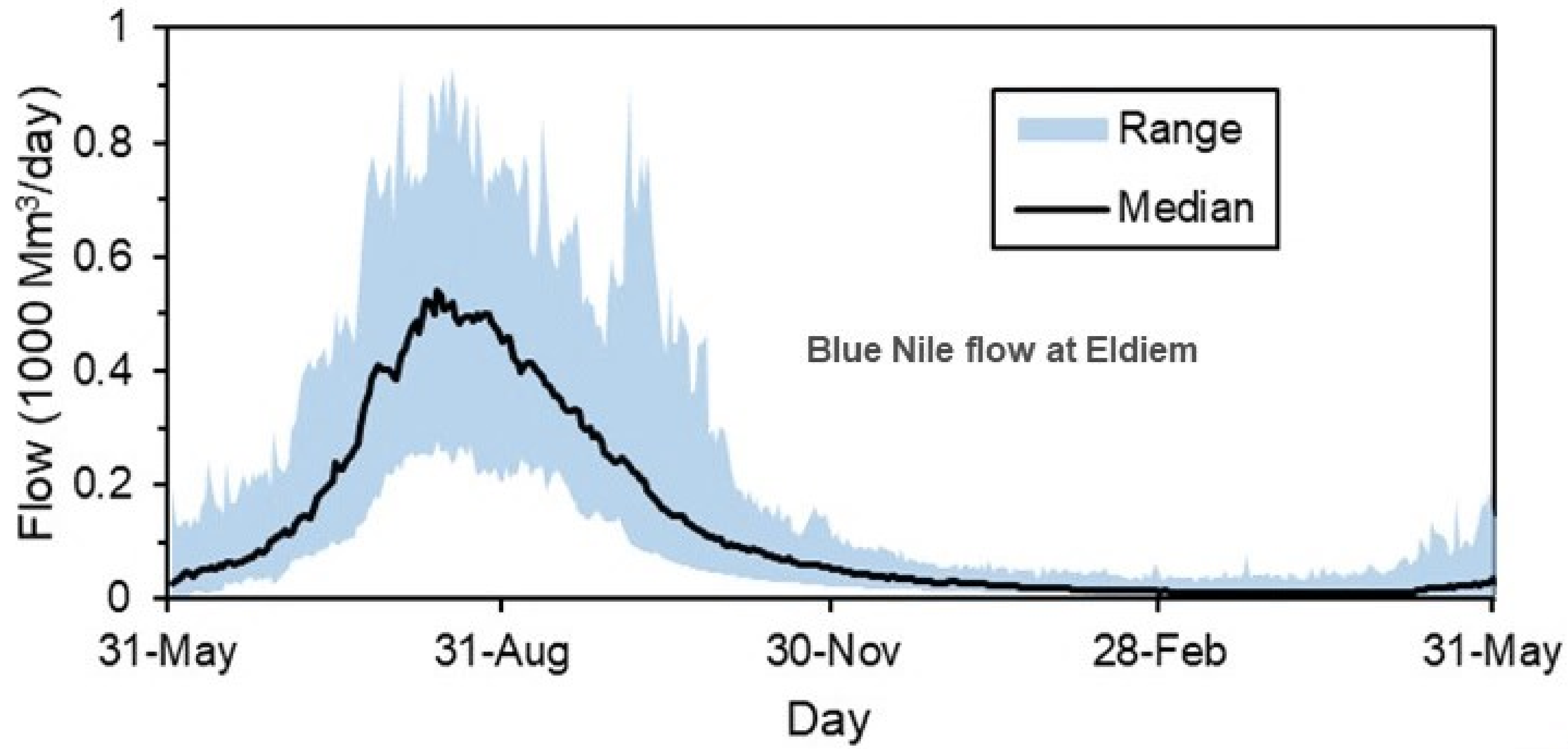
- GERD has a hydropower capacity of 5,150 MW.
- Mean annual energy generation of around 15,000 GWh.
- Will increase Ethiopia’s electricity generation twofold.



1- Introduction



- The Nile flow has high inter-annual variability.



- The Blue Nile flow is highly seasonal with around 80% of the flow occurring from July to October.

1- Introduction

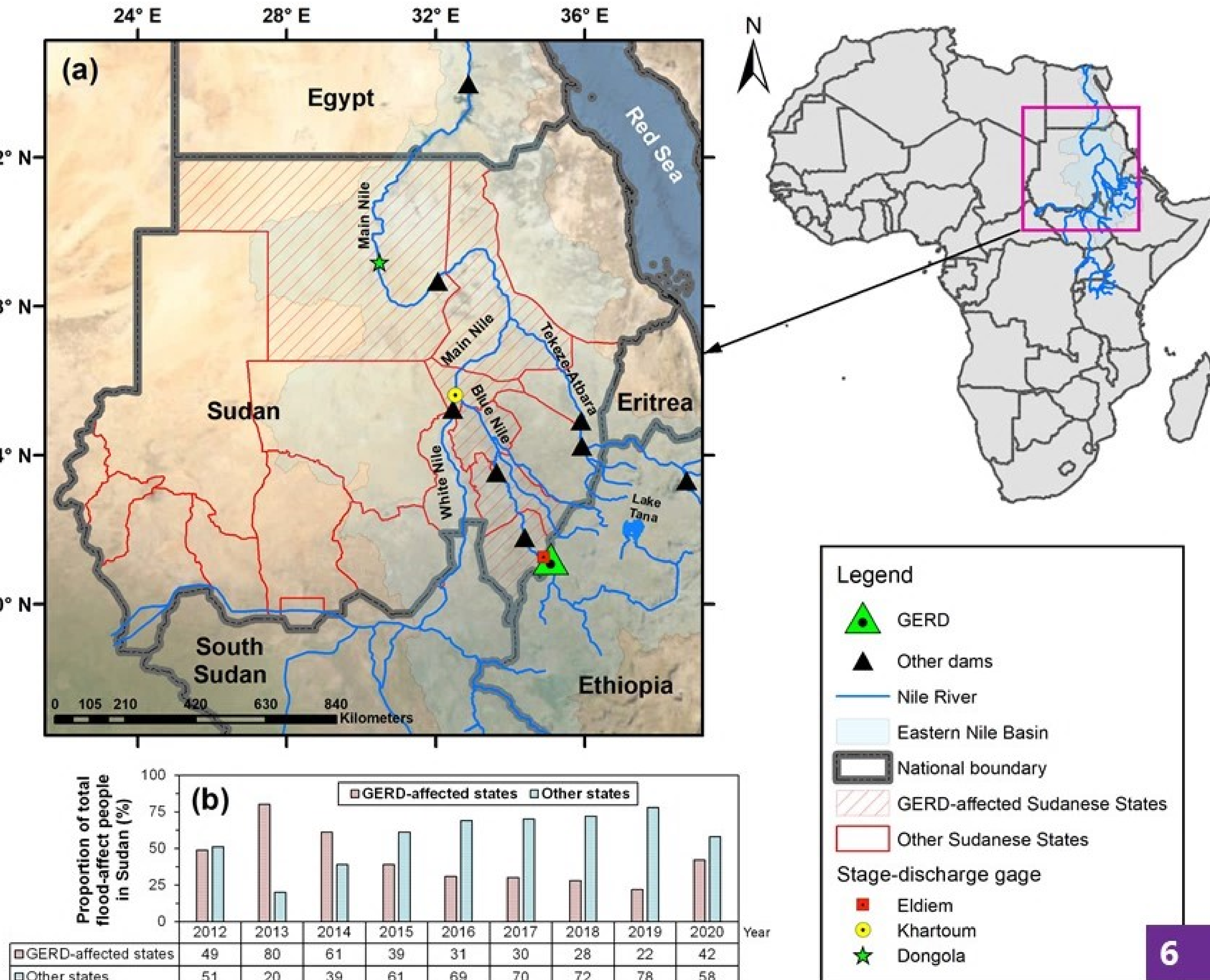
Types of floods in Sudan

- ❑ <u>Riverine floods</u>
  - Occurs due to river overflow outside the river channel to the floodplains.

- ❑ <u>Flash floods</u>
  - Caused by intense local rain.
  - Occurs in most parts of Sudan.

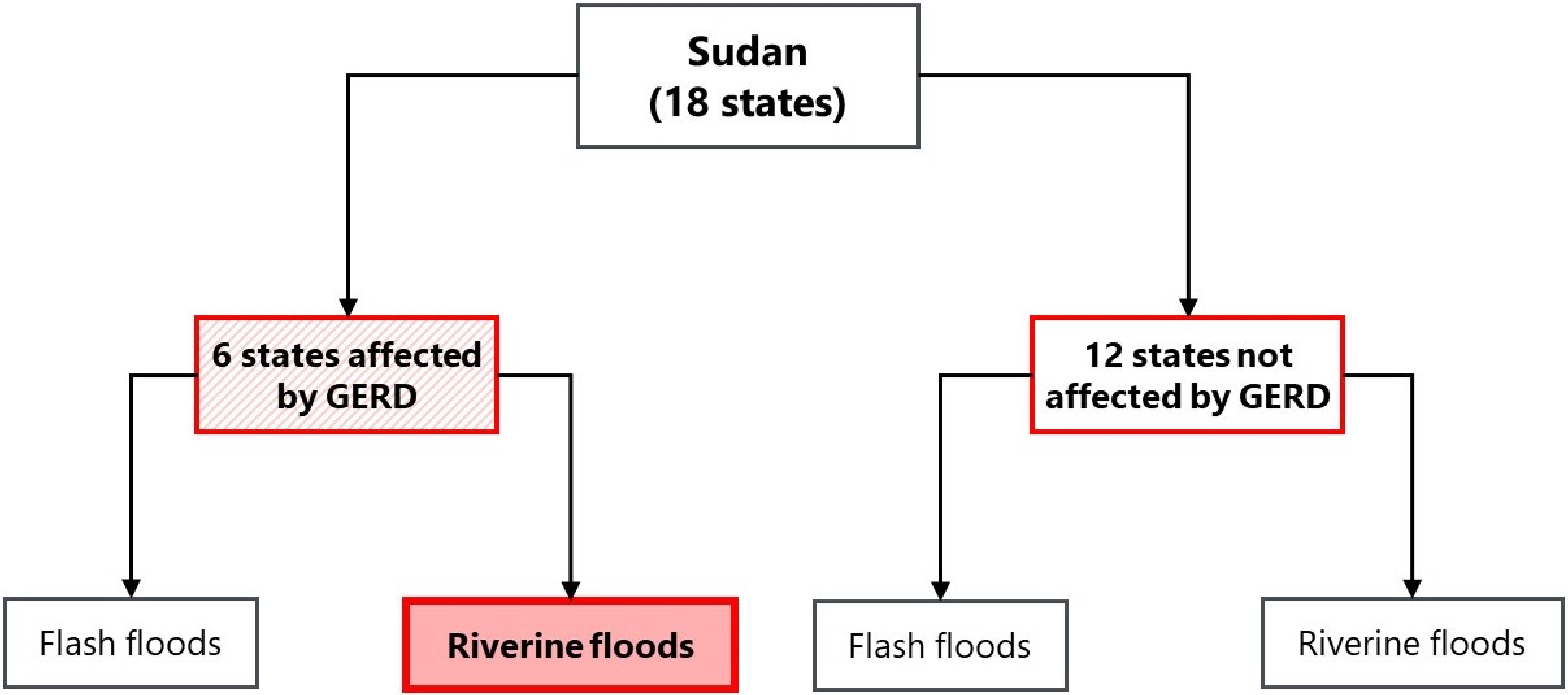
1- Introduction

- GERD's long-term operation would reduce the risk of riverine flooding in 6 of the 18 states of Sudan.



	2012	2013	2014	2015	2016	2017	2018	2019	2020
GERD-affected states	49	80	61	39	31	30	28	22	42
Other states	51	20	39	61	69	70	72	78	58

1- Introduction

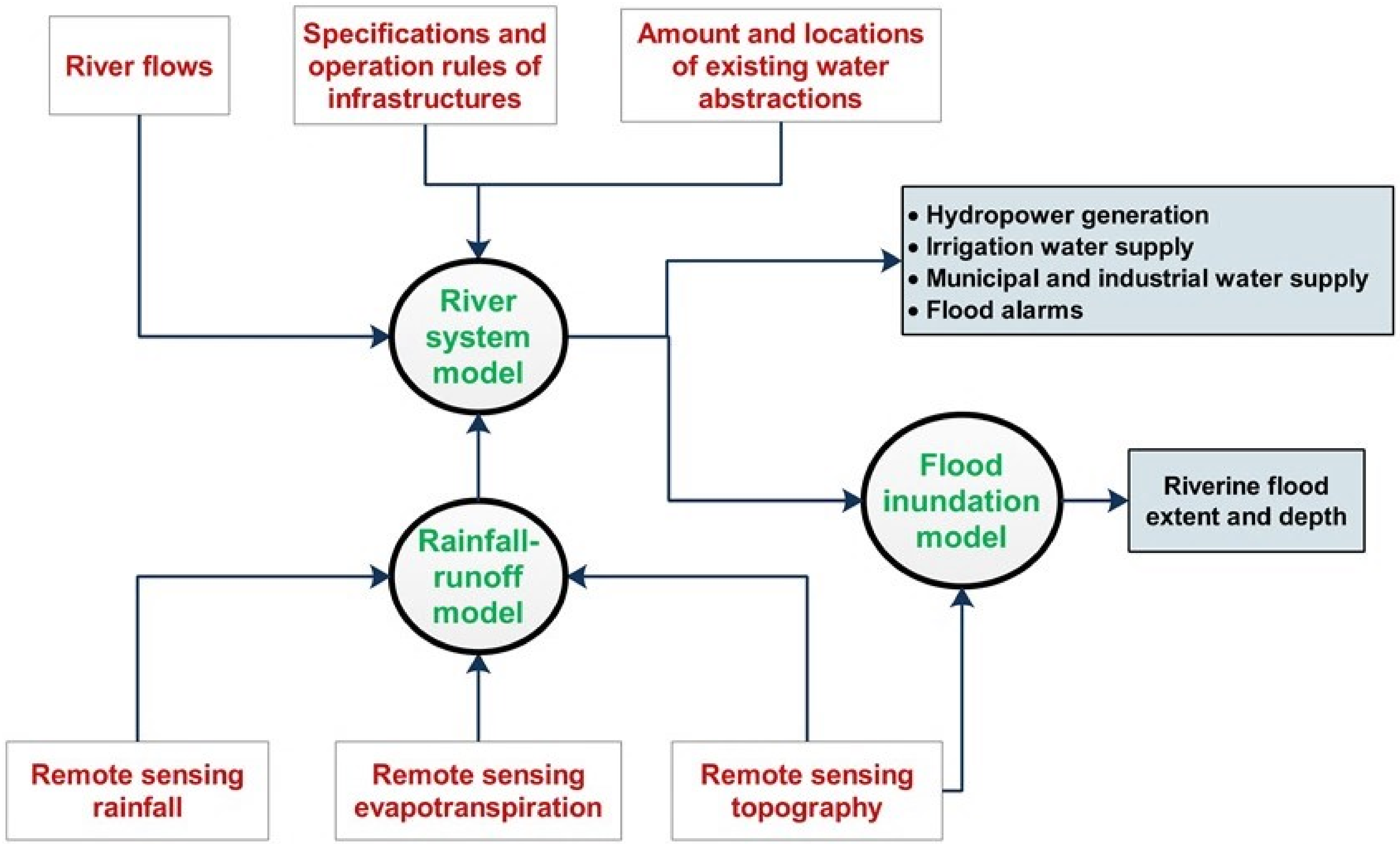


2- Assessment method

Modelling framework:

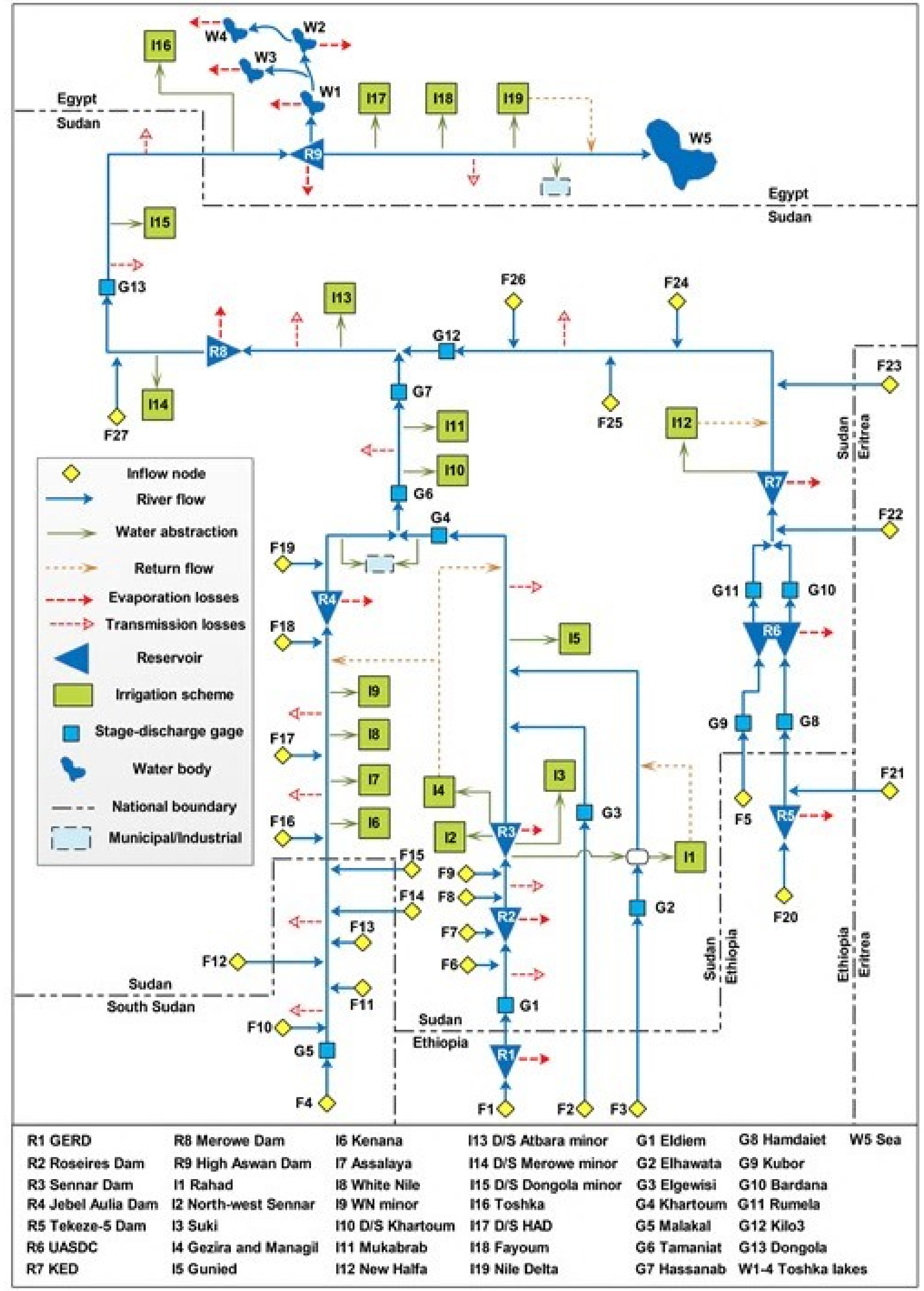
- A daily suit of models for the Eastern Nile

- The model is calibrated and validated over the period 1983-2017



2- Assessment method

- ❑ 27 inflow nodes
- ❑ 9 storage dams
- ❑ 21 water withdrawal locations
- ❑ 13 stage-discharge gages
- ❑ 252 operating rules

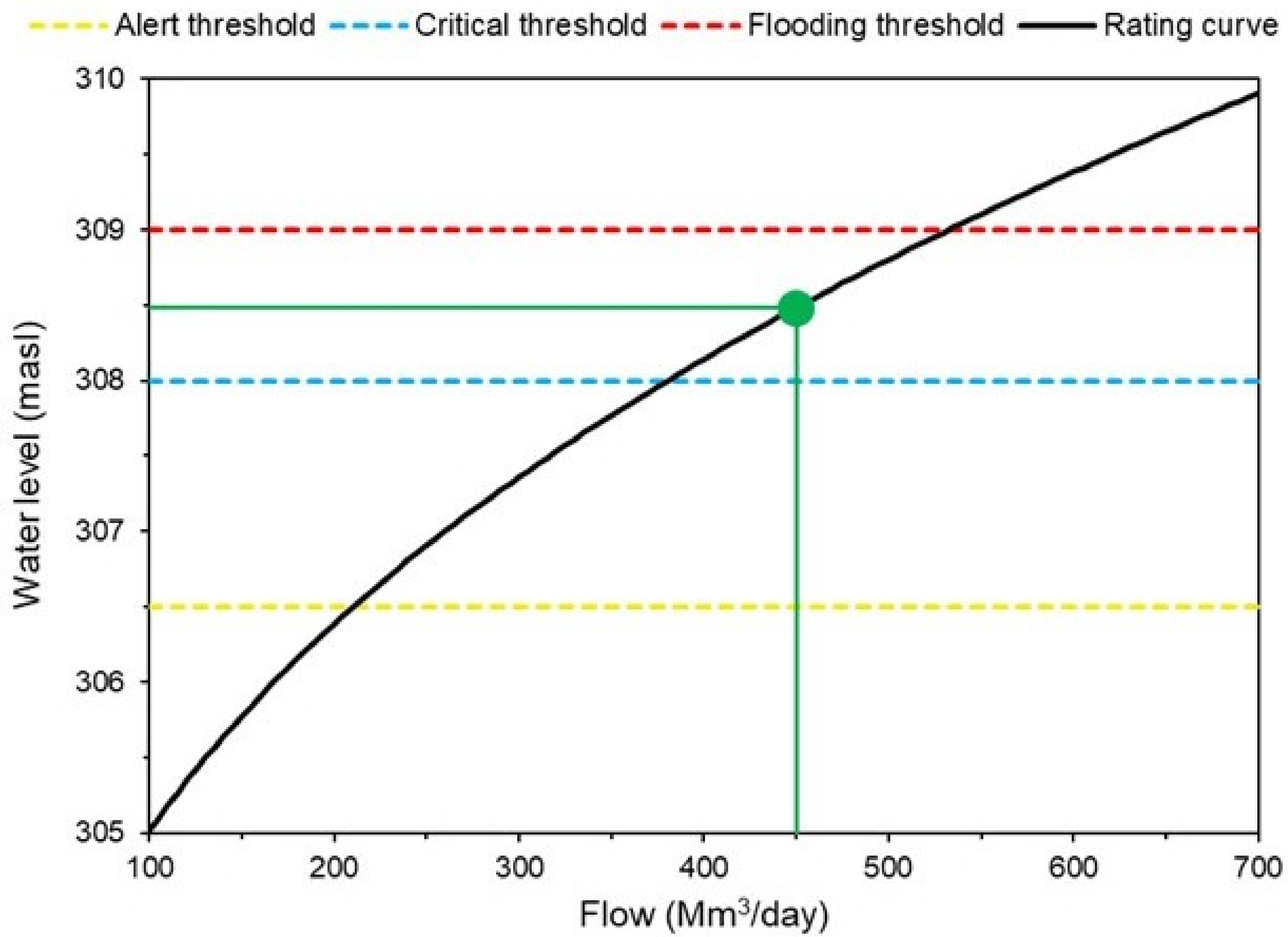


2- Assessment method

- ❑ Rating curves are used to translate river flows to river water levels.

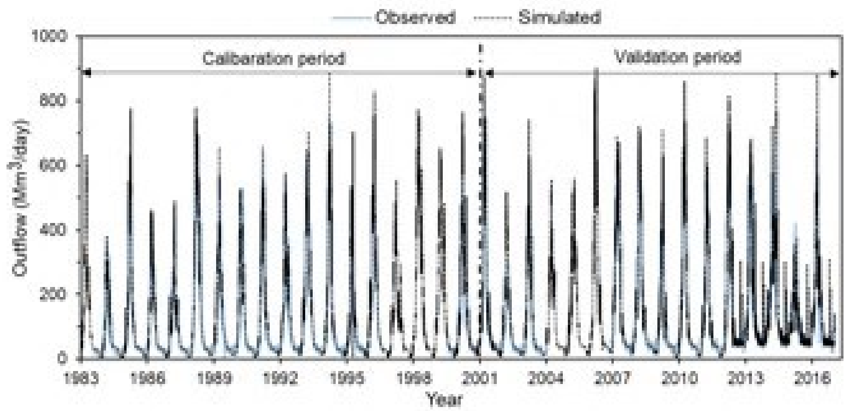
- ❑ The generated water levels are used to calculate the number of days within each of three flood alarm categories.

General illustration

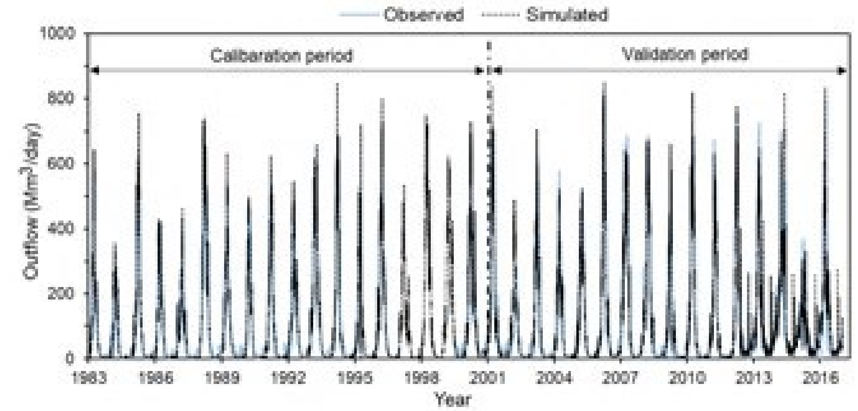


2- Assessment method

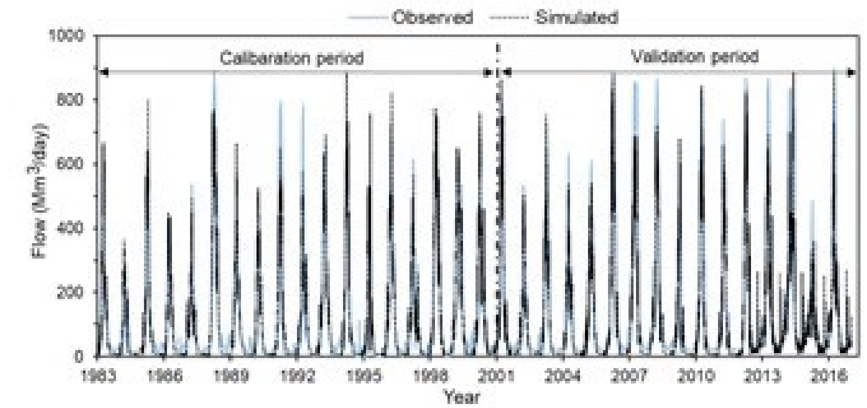
Roseires Dam



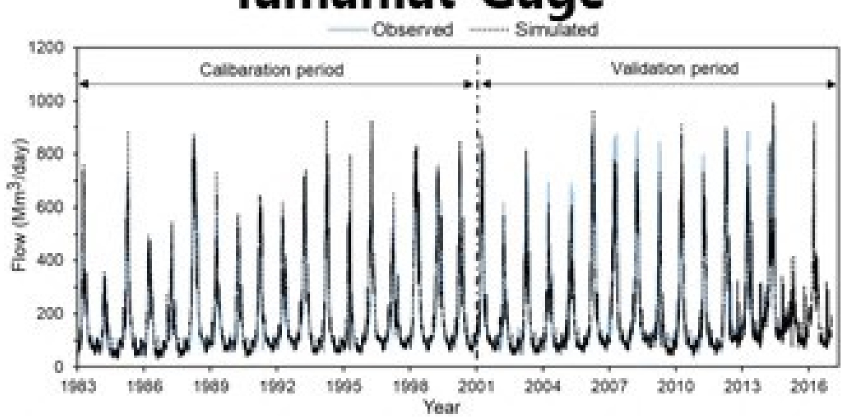
Sennar Dam



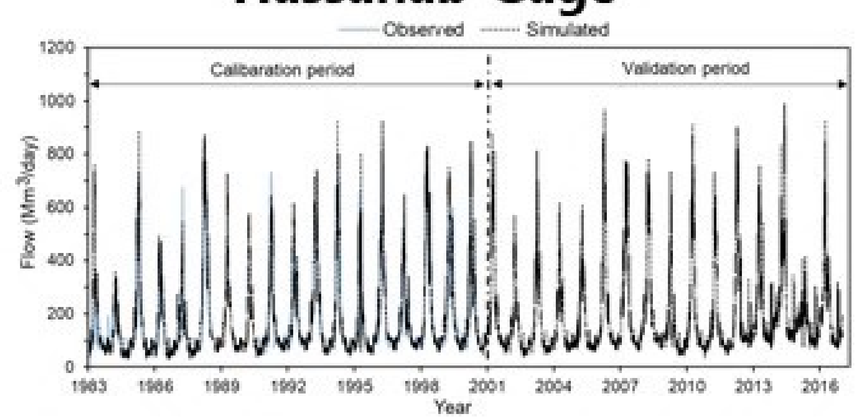
Khartoum Gage



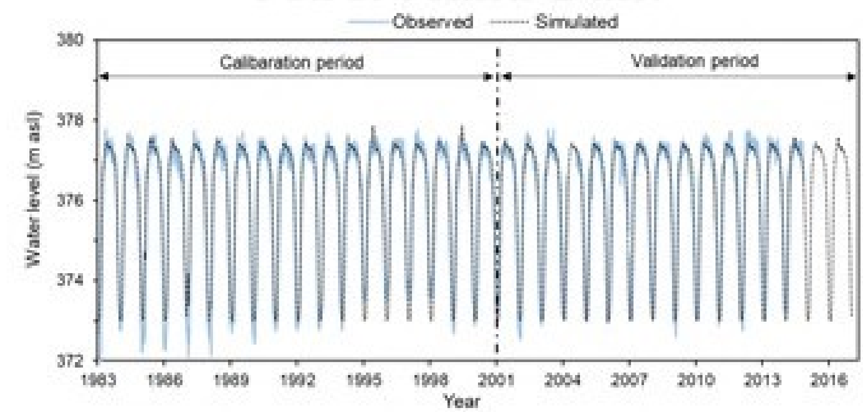
Tamaniat Gage



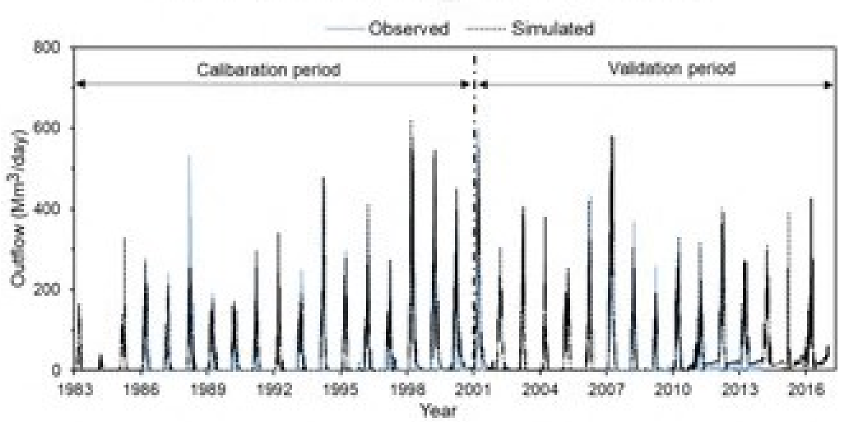
Hassanab Gage



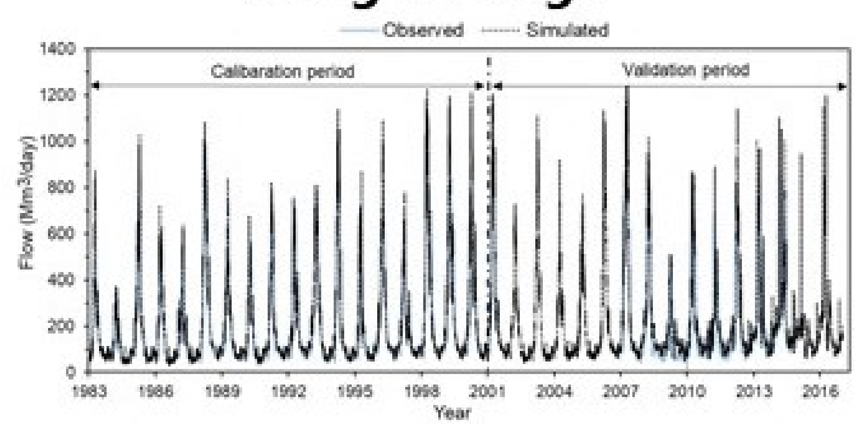
Jebel Aulia Dam



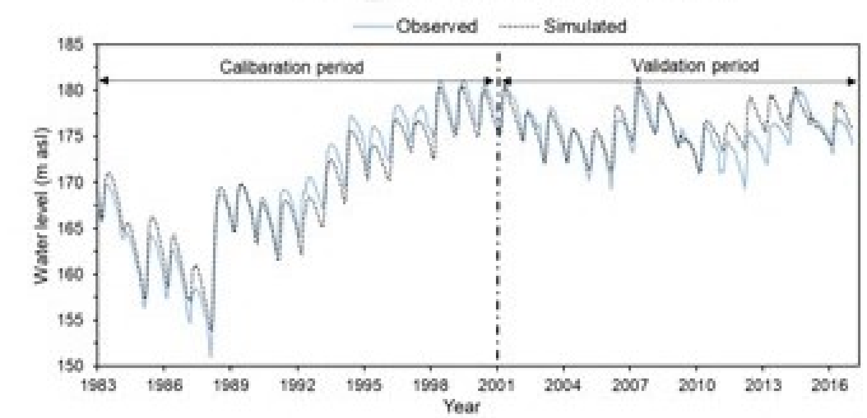
Khashm Elgirba Dam



Dongola Gage



High Aswan Dam

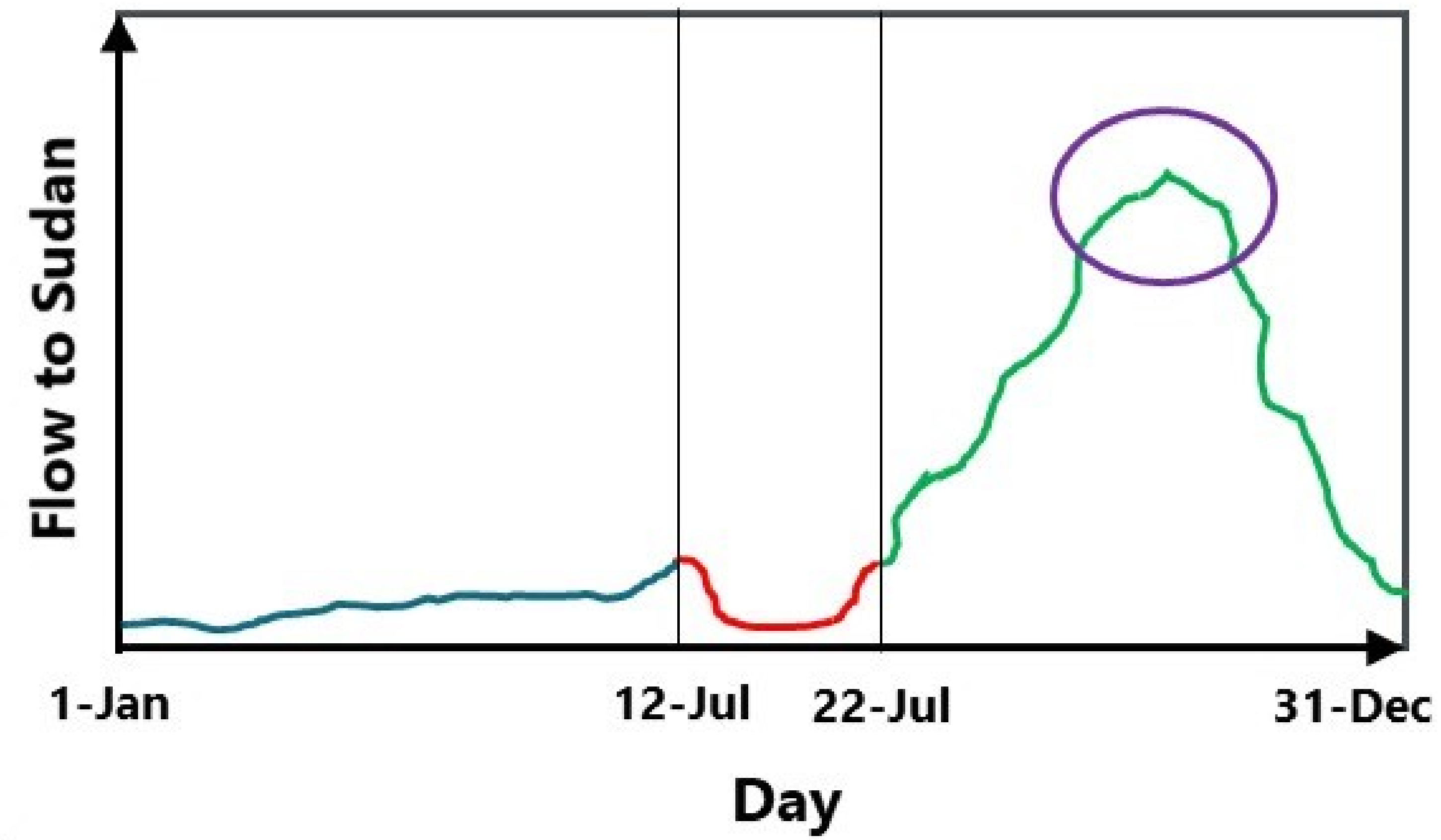


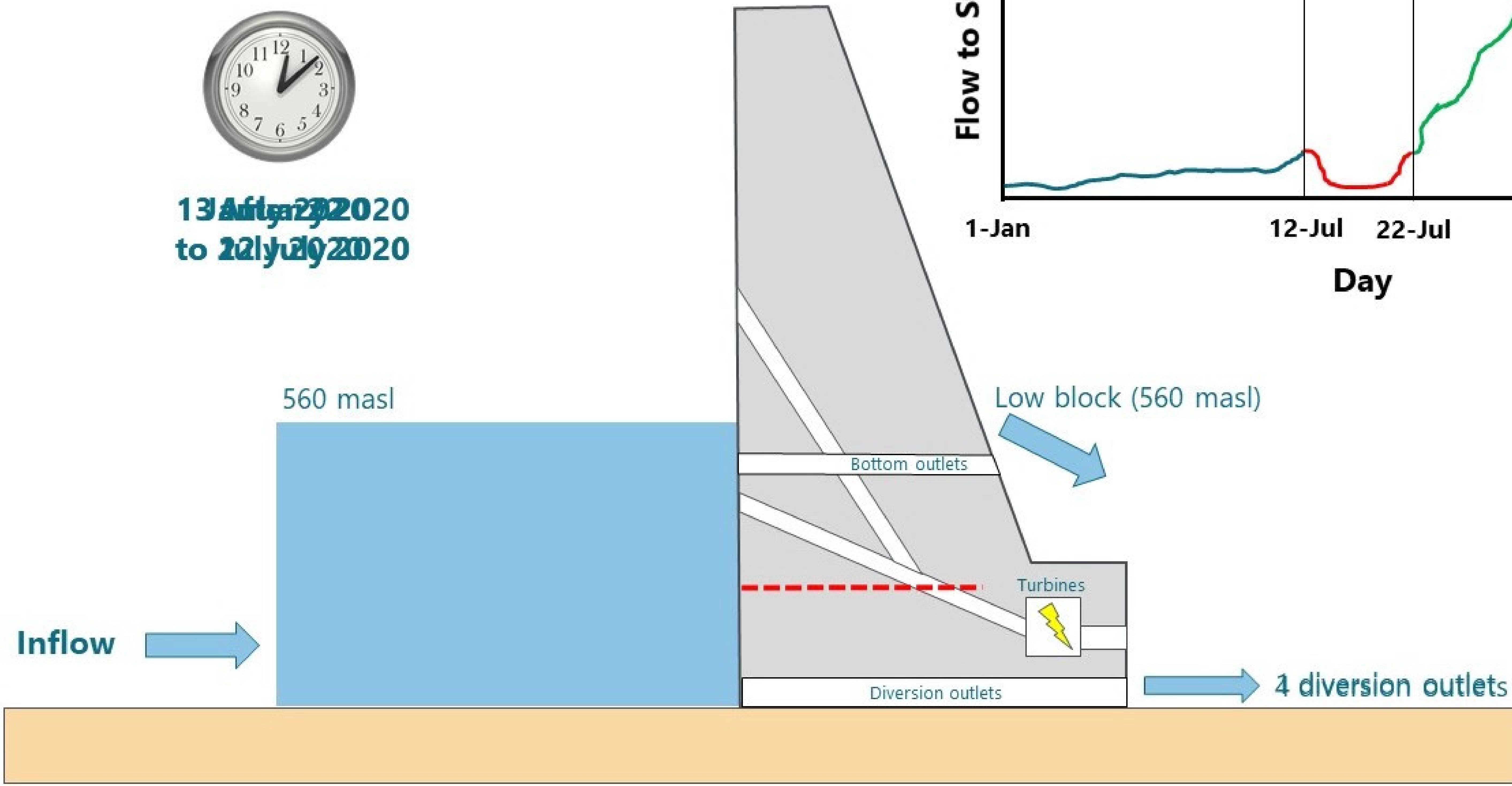
2- Assessment method

Parameter	Location	Performance metric	Calibration (1983-2000)		Validation (2001-2017)	
			Metric value	Ranking	Metric value	Ranking
Flow	Roseires Dam	MEP	0.76	Excellent	3.27	Excellent
		NSE	0.97	Excellent	0.94	Excellent
		R^2	0.97	Excellent	0.94	Excellent
	Sennar Dam	MEP	−1.81	Excellent	5.16	Excellent
		NSE	0.95	Excellent	0.93	Excellent
		R^2	0.95	Excellent	0.93	Excellent
	Khartoum Gage	MEP	−0.20	Excellent	−20.69	Good
		NSE	0.91	Excellent	0.87	Excellent
		R^2	0.91	Excellent	0.91	Excellent
	Tamaniat Gage	MEP	4.68	Excellent	−0.70	Excellent
		NSE	0.92	Excellent	0.87	Excellent
		R^2	0.93	Excellent	0.90	Excellent
	Hassanab Gage	MEP	12.86	Very good	—	—
		NSE	0.86	Excellent	—	—
		R^2	0.86	Excellent	—	—
	Khashm Elgirba Dam	MEP	34.23	Poor	28.74	Fair
		NSE	0.79	Very good	0.79	Very good
		R^2	0.80	Very good	0.83	Very good
	Dongola Gage	MEP	13.04	Very good	26.55	Fair
		NSE	0.92	Excellent	0.75	Very good
		R^2	0.93	Excellent	0.80	Very good
Water level	Jebel Aulia Dam	MEP	0.01	Excellent	−0.02	Excellent
		NSE	0.94	Excellent	0.93	Excellent
		R^2	0.94	Excellent	0.94	Excellent
	High Aswan Dam	MEP	−0.88	Excellent	0.37	Excellent
		NSE	0.76	Very good	0.66	Good
		R^2	0.98	Excellent	0.65	Good

Stern, M., Flint, L., Minear, J., Flint, A., & Wright, S. (2016). Characterizing changes in streamflow and sediment supply in the Sacramento River Basin, California, using hydrological simulation program—FORTRAN (HSPF). Water, 432(8), 1–21. https://doi.org/10.3390/w8100432

3- GERD role in 2020 Nile floods



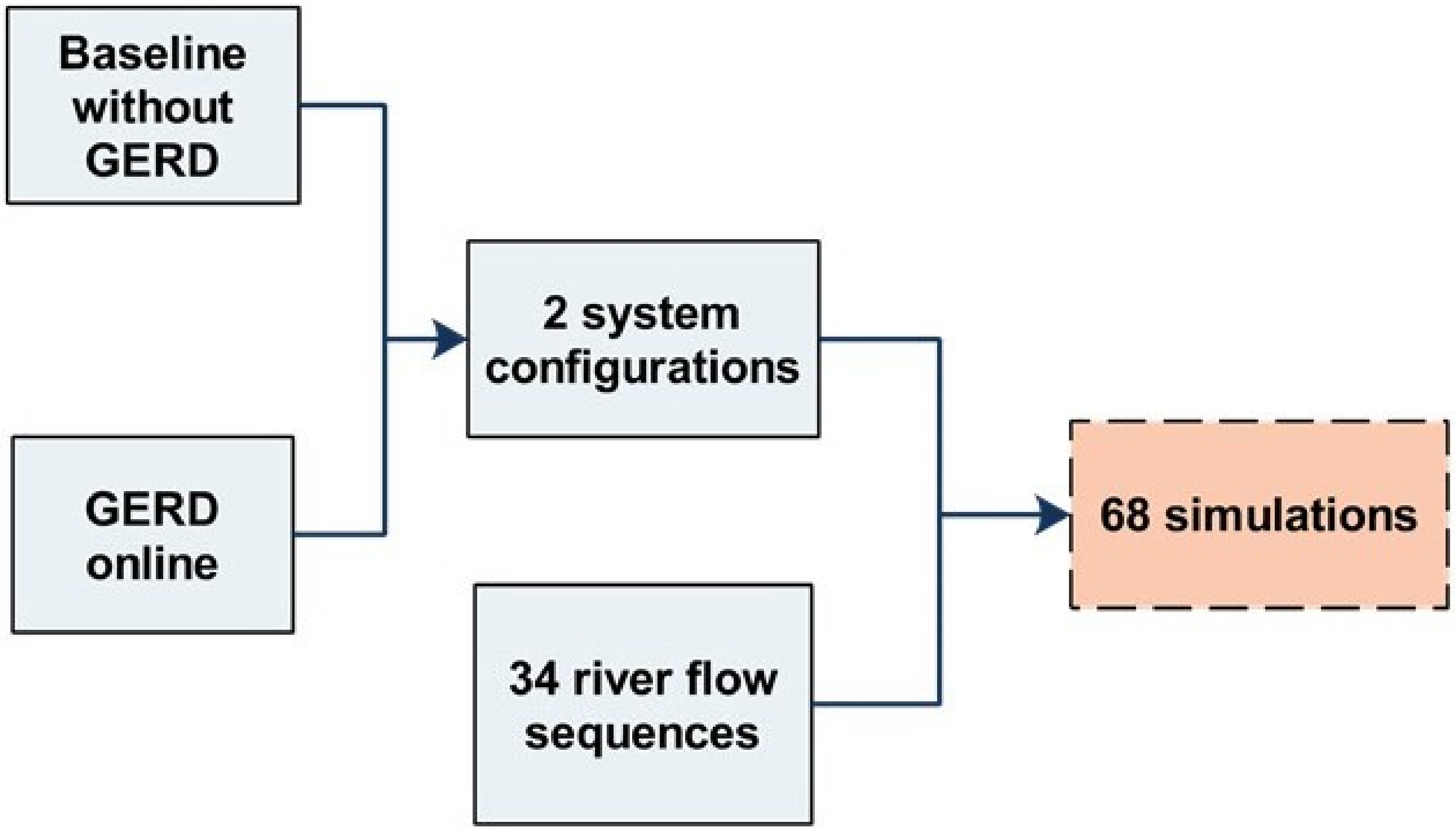


4- GERD potential long-term impacts on riverine floods

- ❑ Index-sequential method used to generate 34 river flow sequences, each 34 years long

- ❑ The GERD is operated to target 38.4 GWh/day (Wheeler et al., 2018)

- ❑ Perfect downstream knowledge on GERD releases is assumed



4- GERD potential long-term impacts on riverine floods

❑ Simulation assumptions

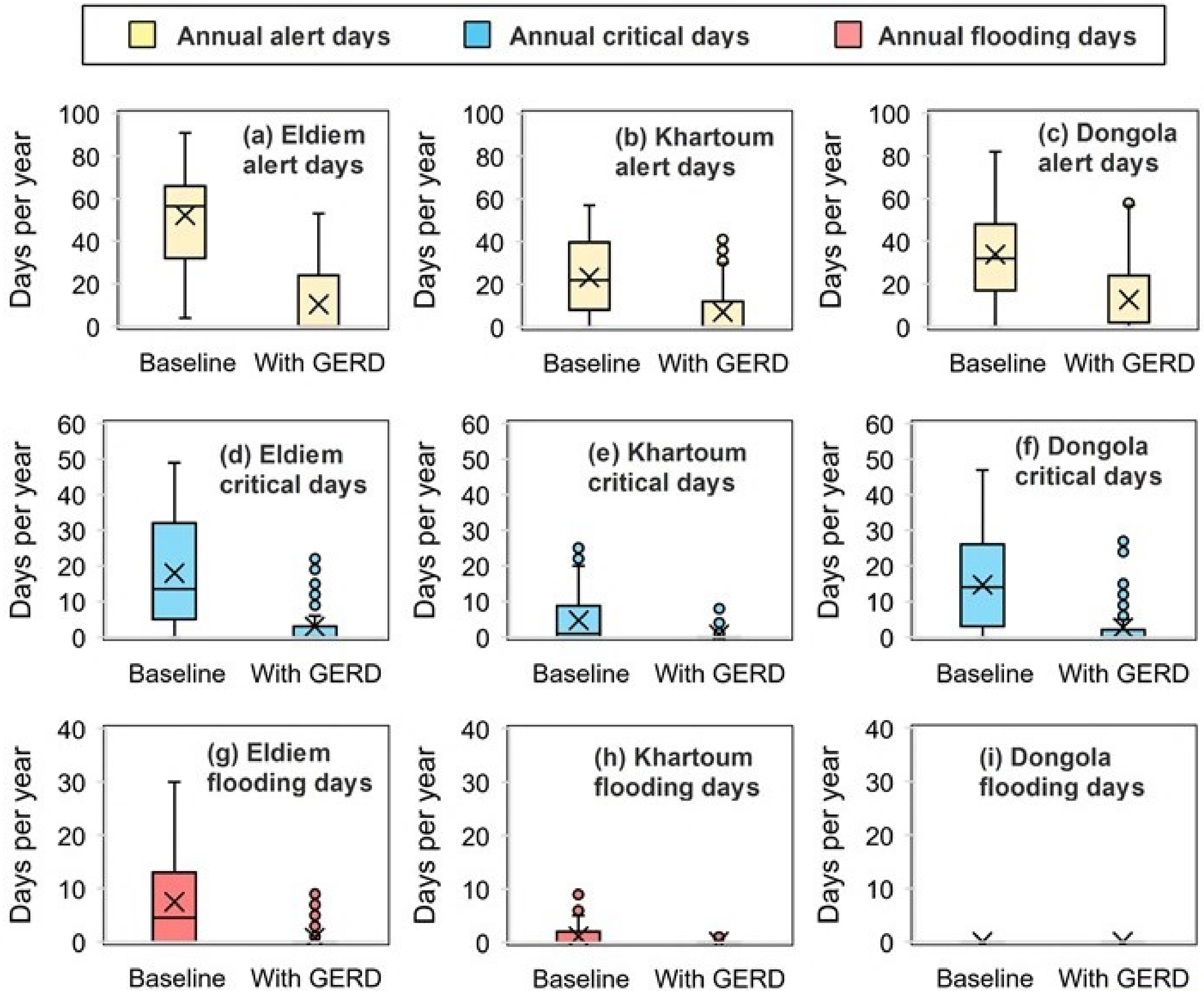
- GERD's long-term operation starts with reservoir storage of 49.3 bcm

- Roseires, Sennar, and Merowe dams are operated at high levels and are allowed to drop only to meet the water or energy demands

4- GERD potential long-term impacts on riverine floods

- GERD would reduce the annual number of days in each of the three flood alarm categories

- There remains a riverine flood hazard, especially at Khartoum

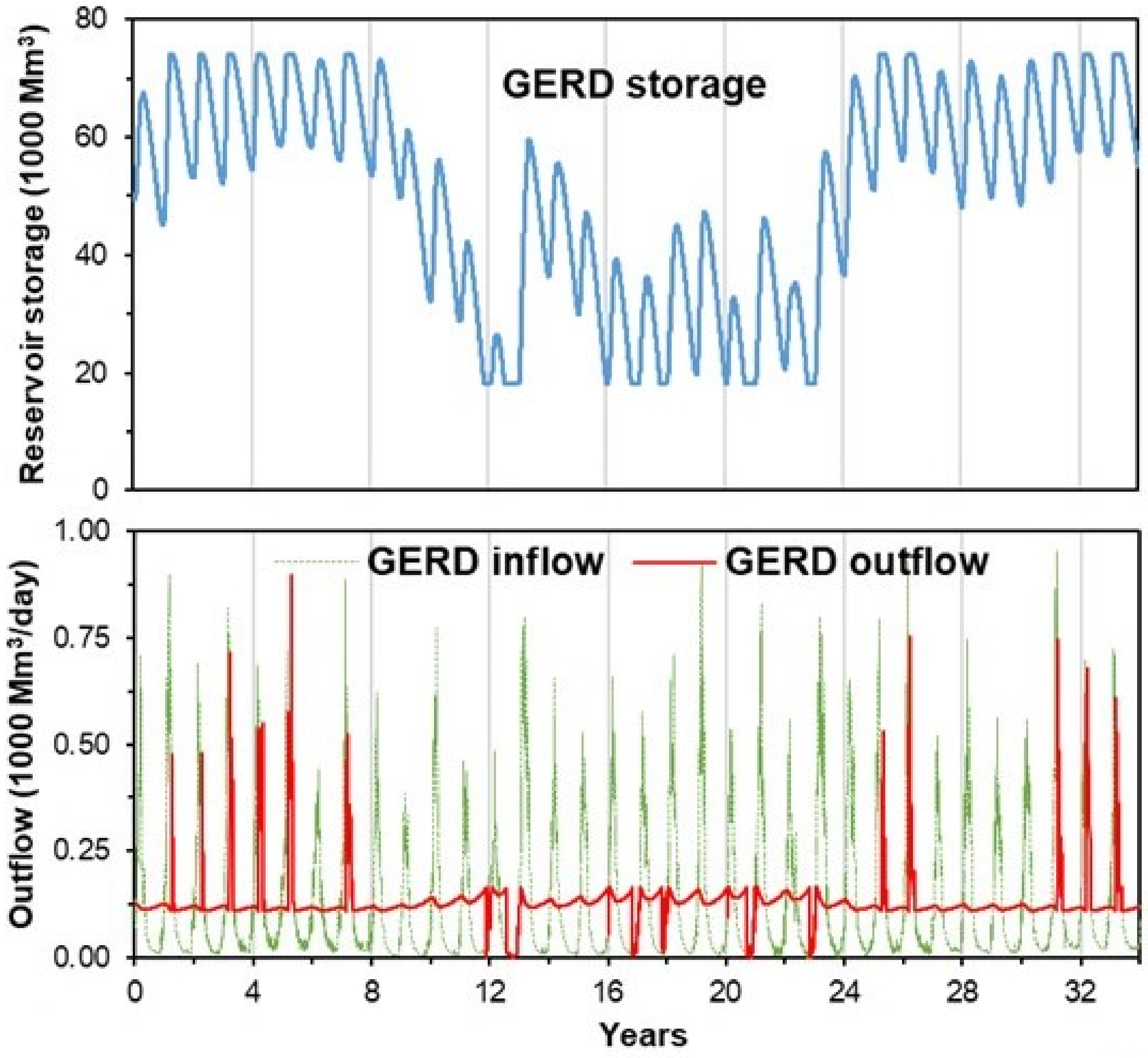


4- GERD potential long-term impacts on riverine floods

- ❑ Inter-annual variability of the Blue Nile flow results in fluctuation in GERD storage

- ❑ When the GERD level is close to the full supply level the likelihood of too intense downstream releases increase.

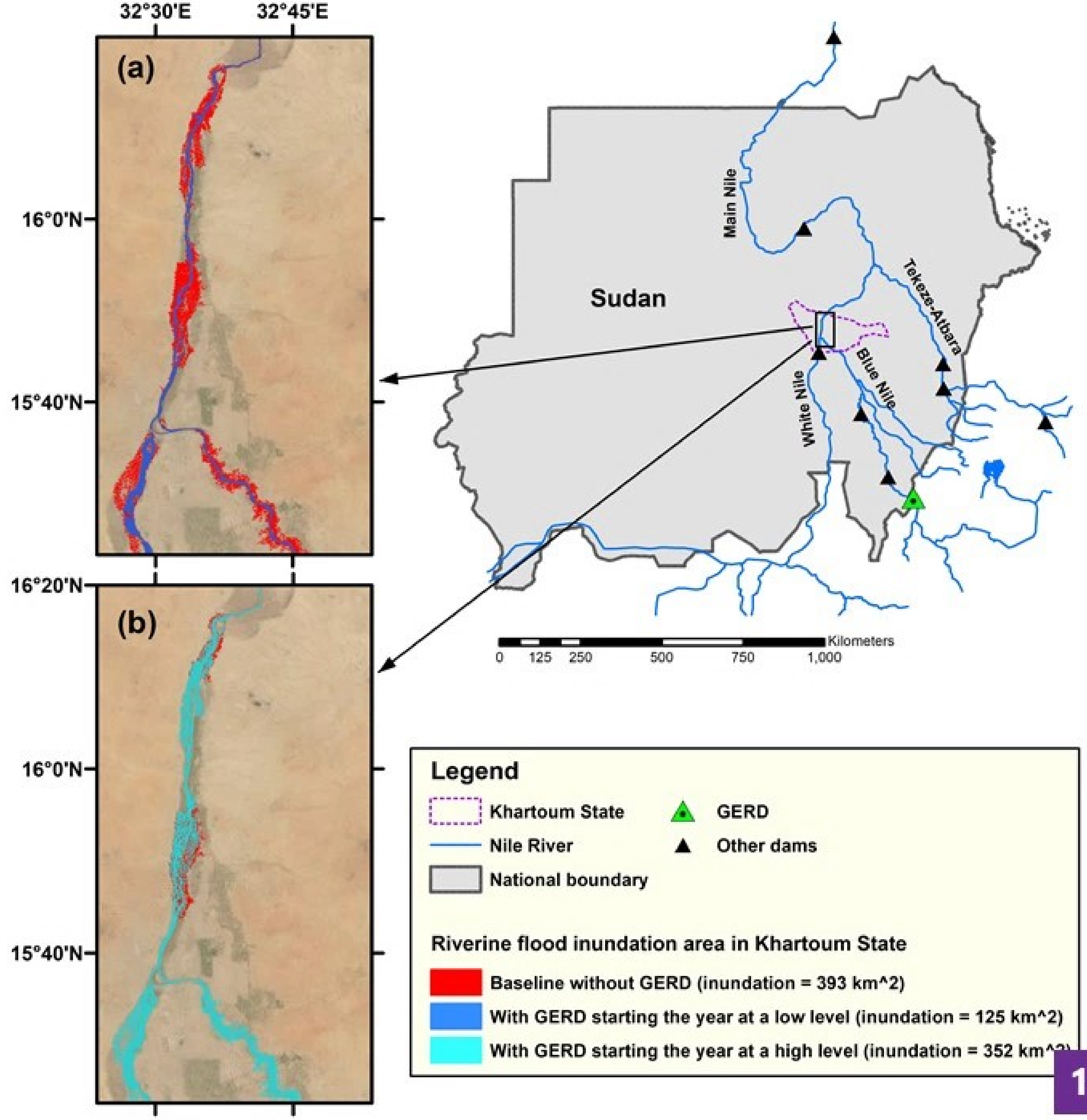
Results of one of the 34 simulated river flow sequences



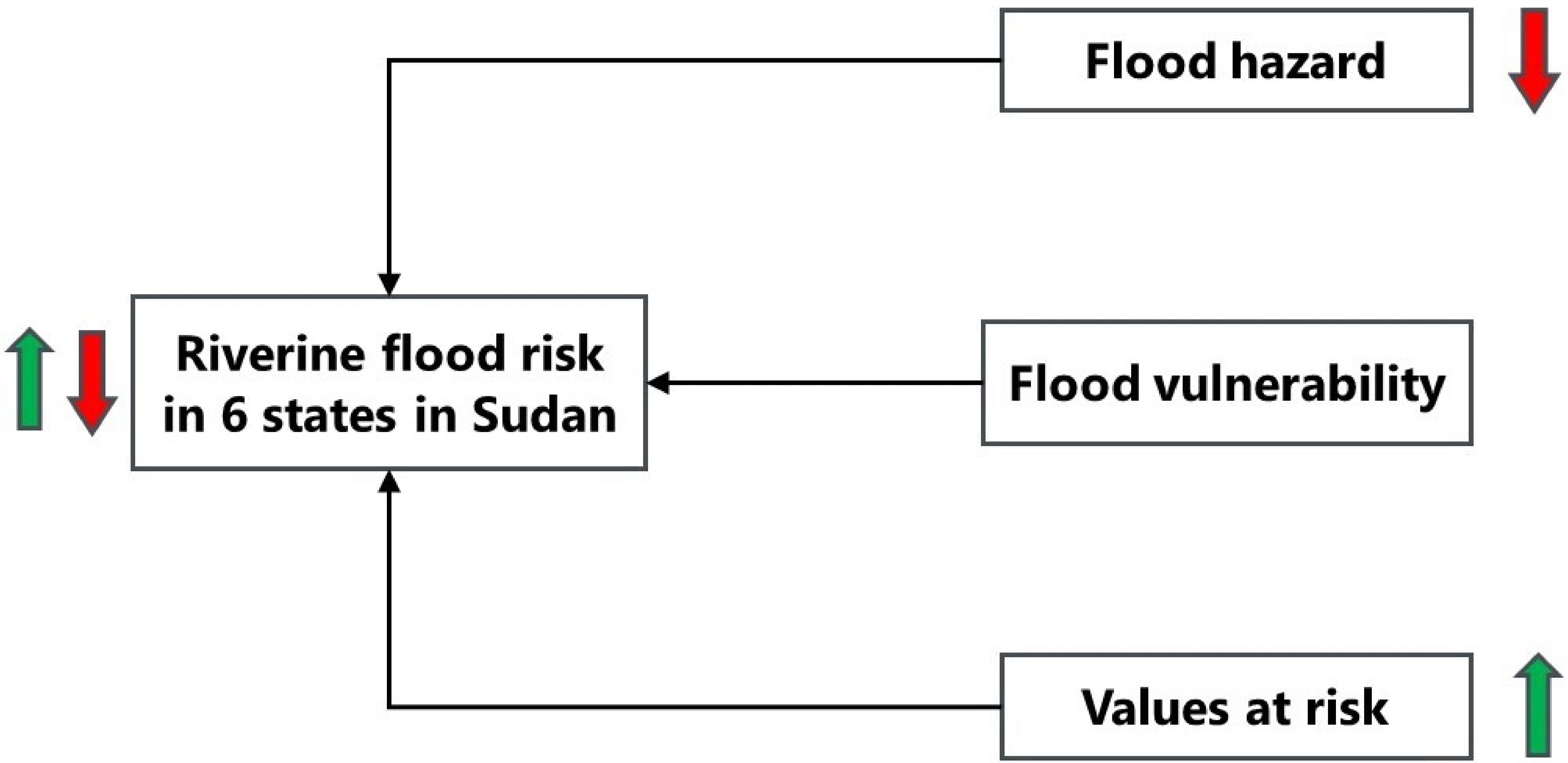
4- GERD potential long-term impacts on riverine floods

- ❑ The inundated area in Khartoum State decline by 68% when the GERD reservoir starts the year at 595 masl

- ❑ The inundated area in Khartoum State decline by 10% when the GERD reservoir starts the year at 625 masl



4- GERD potential long-term impacts on riverine floods



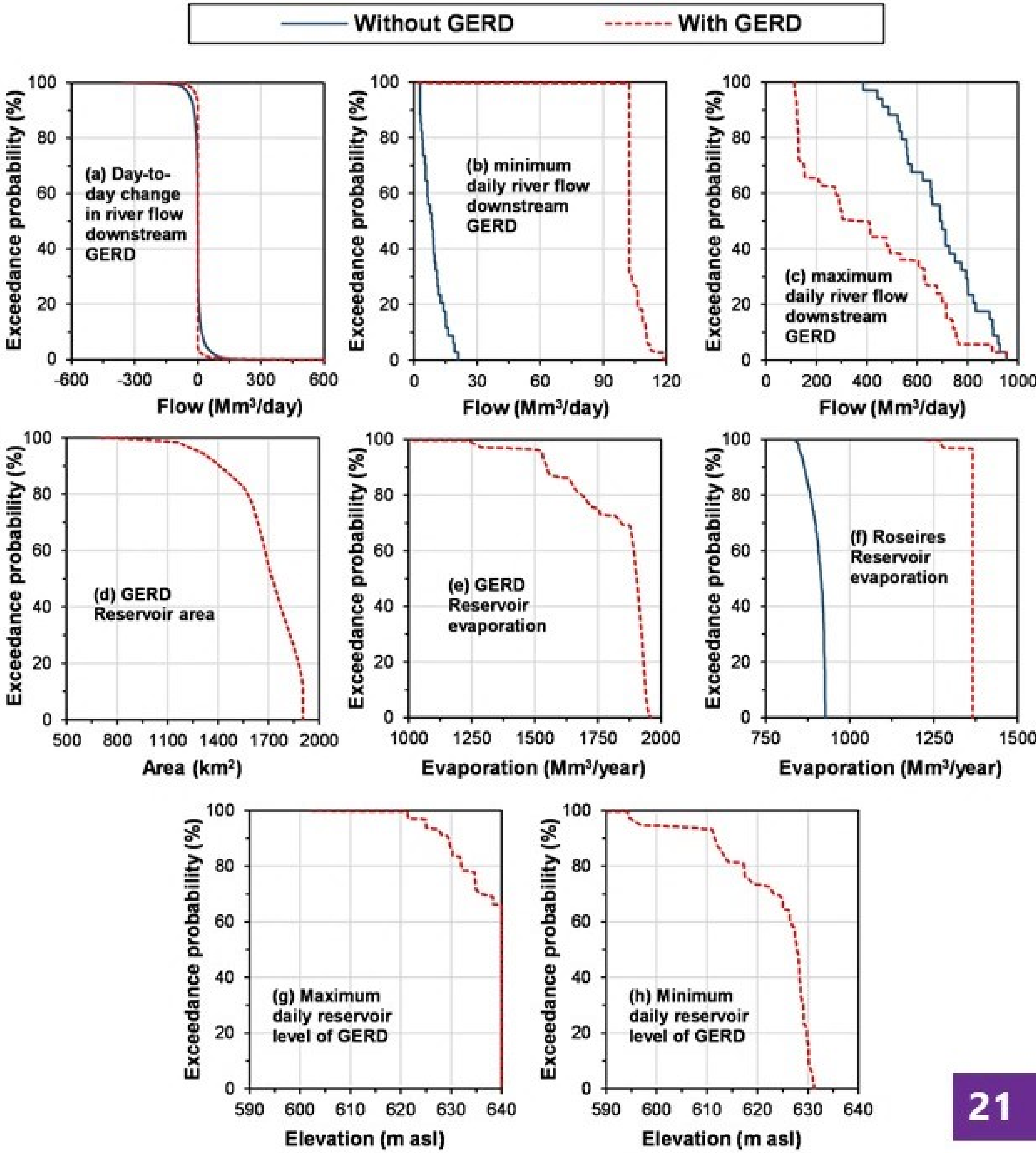
Kron, W. (2005). Flood risk = hazard • values • vulnerability. Water International, 30(1), 58–68. https://doi.org/10.1080/0250806050869 1837

4- GERD potential long-term impacts on riverine floods

- ❑ Coordinated operation and planning are necessary to mitigate the remaining riverine flood hazard.
- ❑ Tough trade-offs on flood management lay ahead, requiring to in advance agreement.
- ❑ Raising public awareness on the remaining riverine flood hazard.

5- GERD potential downstream environmental impacts

- ❑ **Floods provide social, economic, and environmental benefits.**
- ❑ **GERD-induced alterations would:**
  - ❑ Reduction in oxygen content
  - ❑ Increase in water salinity
  - ❑ Alteration to water temperature
  - ❑ Loss of floodplains



6 - Conclusions

- GERD operation aiming to achieve a 90% power reliability **reduces** the riverine flood **hazard** in 6 states in Sudan.

- How to mitigate the remaining riverine flood **risk**?

  - Seasonal coordination and planning on GERD operation
  - Raising public awareness on the remaining riverine flood hazard

- Floods provide social, economic, and environmental **benefits**.

Publications on GERD

Basheer, M. (2021). **Cooperative operation of the Grand Ethiopian Renaissance Dam reduces Nile riverine floods**. River Research and Applications, https://doi.org/10.1002/rra.3799

Basheer, M., Wheeler, K. G., Elagib, N. A., Etichia, M., Zagona, E. A., Abdo, G. M., & Harou, J. J. (2020). **Filling Africa's largest hydropower dam should consider engineering realities**. One Earth, 3(3), 277–281. https://doi.org/10.1016/j.oneear.2020.08.015

Basheer, M., Wheeler, K. G., Ribbe, L., Majdalawi, M., Abdo, G., & Zagona, E. A. (2018). **Quantifying and evaluating the impacts of cooperation in transboundary river basins on the water-energy-food nexus: The Blue Nile Basin**. Science of the Total Environment, 630, 1309–1323. https://doi.org/10.1016/j.scitotenv.2018.02.249

Elagib, N. A., & Basheer, M. (2021). **Would Africa's largest hydropower dam have profound environmental impacts?** Environmental Science and Pollution Research, 28(7), 8936–8944. https://doi.org/10.1007/s11356-020-11746-4

Siddig, K., Basheer, M., & Luckmann, J. (2021). **Economy-wide assessment of potential long-term impacts of the Grand Ethiopian Renaissance Dam on Sudan**. Water International. https://doi.org/10.1080/02508060.2021.1885126

Wheeler, K. G., Basheer, M., Mekonnen, Z., Eltoum, S., Mersha, A., Abdo, G., … Dadson, S. (2016). **Cooperative filling approaches for the Grand Ethiopian Renaissance Dam**. Water International, 41(4), 611–634. https://doi.org/10.1080/02508060.2016.1177698

Thank you
for your attention!