

Beyond Streamflow: A Comprehensive Inventory of Renewable Water Resources in the Nile River Basin

Mekdelawit M. Deribe^{1*}, Belete B. Kindanewold², Assefa M. Melesse¹

¹Institute of Environment, Department of Earth and Environment Florida International University,
Miami, FL 33199, USA

²School of Civil and Environmental Engineering, Addis Ababa University, Addis Ababa, Ethiopia

* mekdelawitmessay@gmail.com / mderi017@fiu.edu

Supplementary Materials

Supplementary Tables

ST 1 Summary of datasets used in the study along with timeframe, resolution and source

Data	Parameters	Period	Resolution	Source
Landcover	Landcover classes	2009-2020	100m, annual	WaPOR datasets (https://data.apps.fao.org/wapor/?lang=en&share=f-be3aa021-58bc-4a75-a2e0-062ea826f5b0)
Climate data	Precipitation	1981-2020	0.05 degrees, monthly	Climate Hazards Center (CHIRPS) data (https://doi.org/10.15780/G2JQ0P)
	Temperature	1981-2020	0.5 degrees, monthly	Climate Research Unit (CRU) datasets (https://crudata.uea.ac.uk/cru/data/hrg/)
	Humidity	1981-2020	0.25 degrees, monthly	Climate Data Store (ERA5) datasets (https://cds.climate.copernicus.eu/datasets/reanalysis-era5-pressure-levels-monthly-means?tab=download)
	Wind speed	1981-2020	0.25 degrees, monthly	Climate Data Store (ERA5) datasets

				(https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels-monthly-means?tab=download)
	Cloudiness fraction	1981-2020	0.5 degrees, monthly	Climate Research Unit (CRU) datasets (https://crudata.uea.ac.uk/cru/data/hrg/)
Hydrological data	Observed flow data	1981-2002	Monthly timeseries Monthly average	ENTRO-NBI (obtained upon request; direct communication) Riverware Eastern Nile model, (obtained upon request; direct communication) Sutcliffe and parks, 2000
	Reservoir data: Storage capacity, Volume elevation data, reservoir evaporation and operating levels			Riverware Eastern Nile model (obtained upon request; direct communication) Global Reservoir Geometry Database (ReGEOM) (https://zenodo.org/records/1322884)
Shape files	Basin countries, basin boundaries, rivers, lakes			NBI, (obtained upon request; direct communication) Global lakes bathymetry dataset (GLOBathy) (https://gee-community-catalog.org/projects/globathy/) Hydrolakes (https://www.hydrosheds.org/products/hydrolakes)
Population data	Gridded population data	2020	1 km	Wang et al., 2022 (https://zenodo.org/records/5880037)
Economic data	Gross domestic product (GDP)	2000-2020		World Bank dataset (https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=1W)
Water demand data	Domestic, industrial and irrigation water demand	2000-2020		NBI, (obtained upon request; direct communication)

				AQUASTAT (https://www.fao.org/aquastat/en/) Worldometer (https://www.worldometers.info/water/)
	Irrigation efficiency	2000-2020		NBI, (obtained upon request; direct communication) FAO (https://www.fao.org/4/t7202e/t7202e08.htm)
	Actual ET SSEBop ET	2013-2020	Annual, 1 km	USGS FEWSNET (https://earlywarning.usgs.gov/fews/search/?geography=16)
	Veg ET	2013-2020	Annual, 1 km	USGS VegET (https://data.usgs.gov/datacatalog/data/USGS%3A64baa500d34e70357a2c91cd)
	GLEAM V4	1980-2023	Daily, 0.1 degrees	https://www.gleam.eu/

ST 2 WEAP Soil Moisture Method calibration parameters: allowable ranges, default values, and final calibrated ranges.

Calibrating parameters	Range	WEAP default value	Final calibrated ranges
Kc	0 to ∞	1	0.1 to 1.2
RRF	0 to 1000	2	1 to 10
Soil water capacity	0 to ∞	1000 mm	1000 to 3000 mm
Root zone conductivity	0.1 to ∞	20 mm/month	10-50mm/month (four catchments at 5, 8,100, 200 mm/month)
Deep water capacity	0 to ∞	1000 mm	500-5000 mm (two catchments at 100 and 300 mm)
Deep conductivity	0.1 to ∞	20 mm/month	5-50 mm/month (two catchments at 100 and 130 mm/month)
Preferred flow direction	0 to 1	0.15	0 to 1

ST 3 Water balance at the subbasin-country level

	Inflow	Outflow				Soil moisture storage			Balance
	RF	ET	SR	BF	IF	SMI	SMD	Δ SM	
BUR_LV	16.61	13.27	2.4	0.95	0	4.16	4.17	-0.01	0.00
RWN_LV	29.42	21.92	5.75	1.68	0.01	4.53	4.46	0.07	-0.01
TAN_LV	88.98	82.32	5.13	1.19	0.32	23.01	22.99	0.02	0.00
UG_LV	40.49	36.3	3.37	0.63	0.19	7.4	7.4	0	0.00
KEN_LV	63.22	52	9.45	1.45	0.34	9.24	9.25	-0.01	-0.01
KEN_VN	1.92	1.4	0.44	0.07	0.01	0.3	0.3	0	0.00
UG_VN	105.4	94.65	7.78	2.63	0.29	19.02	18.97	0.05	0.00
UG_LA	63.95	58.67	1.74	3.12	0.38	11.5	11.48	0.02	0.02
DRC_LA	21.41	19.34	0.75	1.21	0.14	2.96	2.99	-0.03	0.00
SSUD_BEG	326.4	307.63	8.43	3.88	6.36	139.33	139.85	-0.52	0.62
SUD_BEG	163.49	158.92	0.97	1.31	2.36	92.1	92.19	-0.09	0.02
UG_BEJ	42.89	37.39	3.89	1.13	0.45	11.53	11.5	0.03	0.00
SSUD_BEJ	152.75	137.81	12.03	2.88	0.01	52.02	52	0.02	0.00
SUD_BEJ	8.45	8.16	0.37	0.09	0	4.33	4.5	-0.17	0.00
ET_BAS	100.57	78.03	13.37	6.76	2.48	26.35	26.41	-0.06	-0.01
UG_BAS	3.22	3.16	0.01	0.04	0	0.98	0.98	0	0.01
SSUD_BAS	125.14	121.92	0	3.31	0	45.43	45.52	-0.09	0.00
SSUD_WN	50.16	47.78	0.04	0.92	1.38	20.88	20.83	0.05	-0.01
ET_WN	9.04	8.07	0.78	0.1	0.1	3.17	3.18	-0.01	0.00
SUD_WN	83.17	80.01	0.72	1.35	0.97	38.56	38.44	0.12	0.00
ET_BN	264.64	198.3	51.34	14.26	0.68	81.25	81.14	0.11	-0.05
SUD_BN	58.94	36.98	18.44	0.61	2.97	23.58	23.63	-0.05	-0.01
ET_TEK	87.03	68.83	14.4	3.59	0	33.64	33.4	0.24	-0.03
ERI_TEK	14.14	12.42	1.39	0.28	0.03	6.3	6.27	0.03	-0.01
SUD_TEK	25.6	23.36	1.89	0.49	0.03	12.28	12.45	-0.17	0.00
SUD_MN	41.69	39.53	0.16	2.11	0.27	23.51	23.88	-0.37	-0.01
EGY_MN	5.14	4.57	0.16	0.37	0.09	2.68	2.73	-0.05	0.00

Basin total	2109.54	1856.79	168.06	62.53	22.51	726.23	726.52	-0.29	-0.06
-------------	---------	---------	--------	-------	-------	--------	--------	-------	-------

ST 4 Stream level water balance at the subbasin-country level

	Rainfall- Evapotrans piration RF-ET	Upstream inflows	Total inflow into subbasin	Subbasin outflow	Contribution to subsurface system (GW)	Retained open Water (OW)	Total release from subbasin
BUR_LV	3.34	0	3.34	3.33	0.01	0.00	3.34
RWN_LV	7.50	3.33	10.83	8.54	1.75	0.54	10.83
TAN_LV	6.66	8.54	15.20	15.17	0.03	0.00	15.20
UG_LV	4.19	15.17	19.36	15.88	0.82	2.66	19.36
KEN_LV	11.22	15.88	27.10	22.97	1.77	2.36	27.10
KEN_VN	0.52	32.75	33.27	30.61	0.08	2.58	33.27
UG_VN	10.75	30.61	41.36	33.35	2.97	5.04	41.36
UG_LA	5.28	0	5.28	5.25	0.03	0.00	5.28
DRC_LA	2.07	5.25	7.32	7.22	0.10	0.00	7.32
SSUD_BEG	18.77	0	18.77	7.46	10.34	0.97	18.77
SUD_BEG	4.57	7.46	12.03	0.3	3.60	8.13	12.03
UG_BEJ	5.50	0	5.50	2.74	1.61	1.15	5.50
SSUD_BEJ	14.94	43.31	58.25	18	2.91	37.34	58.25
SUD_BEJ	0.29	18.3	18.59	18.47	0.00	0.12	18.59
ET_BAS	22.54	0	22.54	9.06	9.17	4.31	22.54
UG_BAS	0.06	0	0.06	0.05	0.01	0.00	0.06
SSUD_BAS	3.22	9.06	12.28	12.28	0.00	0.00	12.28
SSUD_WN	2.38	30.75	33.13	31.75	1.38	0.00	33.13
ET_WN	0.97	31.75	32.72	32.42	0.19	0.11	32.72
SUD_WN	3.16	32.42	35.58	24.83	2.44	8.31	35.58
ET_BN	66.34	0	66.34	46.78	15.00	4.56	66.34
SUD_BN	21.96	46.78	68.74	50.31	3.52	14.91	68.74
ET_TEK	18.20	0	18.20	12.62	3.80	1.78	18.20
ERI_TEK	1.72	12.62	14.34	14.11	0.23	0.00	14.34
SUD_TEK	2.24	14.11	16.35	10.22	0.35	5.78	16.35
SUD_MN	2.16	85.36	87.52	85.35	2.00	0.17	87.52
EGY_MN	0.57	85.35	85.92	12.05	0.41	73.46	85.92

Basin total	252.75		804.58	12.05	66.43	174.28	804.58
-------------	--------	--	--------	-------	-------	--------	--------

ST 5 Inventory of agricultural, municipal and industrial water demand of Nile River Basin countries from various sources in Billion Cubic Metres (BCM)

	Country	Burundi	DRC	Egypt	Eritrea	Ethiopia	Kenya	Rwanda	Sudan	South Sudan	Tanzania	Uganda	Total
Worldometer (2000-2017)	Agricultural water demand	0.22	0.07	61.35	0.55	9.69	3.23	0.10	25.91	0.24	4.63	0.26	106.26
	Municipal water demand	0.04	0.46	10.75	0.03	0.81	0.50	0.06	0.95	0.19	0.53	0.33	14.65
	Industrial water demand	0.02	0.15	5.40	0.06	-	0.30	0.02	-	0.23	-	0.05	6.22
	Year	2005	2005	2017	2004	2005	2016	2005	2011	2011	2002	2008	
AQUASTAT	Agricultural water demand	0.22	0.07	68.01	0.55	9.69	3.23	0.36	25.91	0.24	4.63	0.26	113.17
	Municipal water demand	0.04	0.46	10.75	0.03	0.81	0.49	0.23	0.95	0.19	0.53	0.33	14.81
	Industrial water demand	0.01	0.15	5.4	-	0.05	0.30	0.01	0.07	0.23	0.03	0.05	6.30
NBI SWRA (2015)	Irrigation water demand	0.03	-	57.42	-	1.5	0.31	0.06	13.3	0	0.06	0.26	72.94
	Municipal plus industrial water demand	-	-	12.5	-	0	0.01	0.01	0.29	0.01	0.02	0.08	12.92
NBI personal communication	Irrigation water demand	0.03	-	57.06	-	2.02	0.37	0.06	13.96	-	0.1	0.26	73.86

(based on 2015 data)	Municipal water demand	0.01	0.01	12.26	-	0.07	0.91	0.15	0.26	0.07	0.01	0.17	13.92
	Industrial water demand	-	-	0.59	-	0.02	0.24	0.04	0.07	0.02	-	0.04	1.02
Updated demand data for 2020 for the Nile River Basin extent	Irrigation water demand	0.00	0.18	51.13	0.34	0.78	0.03	0.02	15.5	0.98	0.03	0.43	69.42
	Municipal water demand	0.04	0.03	10.72	0.01	0.5	0.2	0.28	1.1	0.2	0.16	0.47	13.71
	Industrial water demand	0.02	0.00	6.78	0.00	0.01	0.13	0.02	0.04	0.00	0.01	0.04	7.06

ST 6 Disaggregated irrigation, domestic and industrial water demand across the Nile River Basin by subbasin-country.

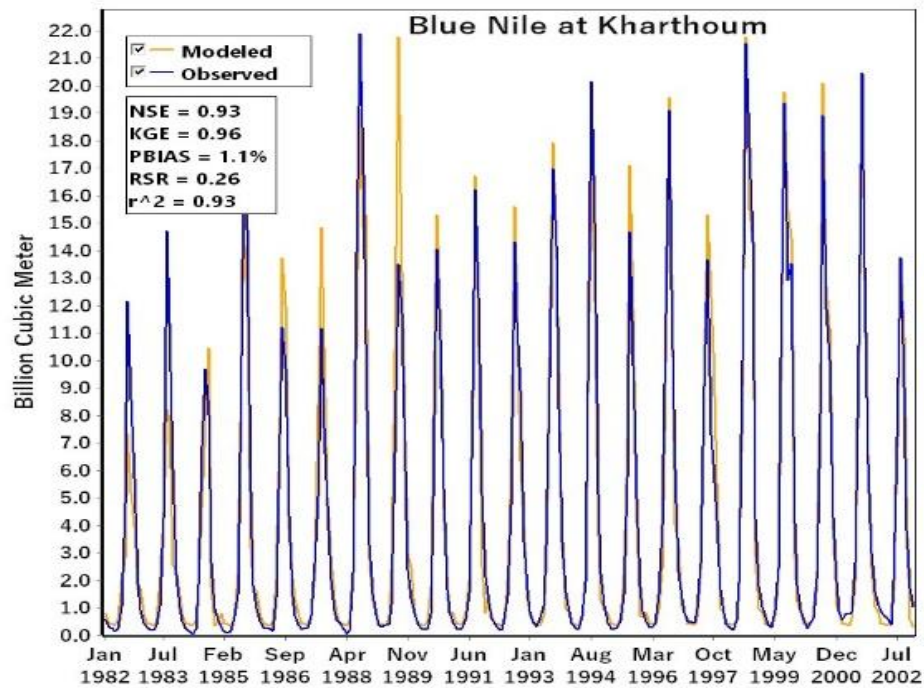
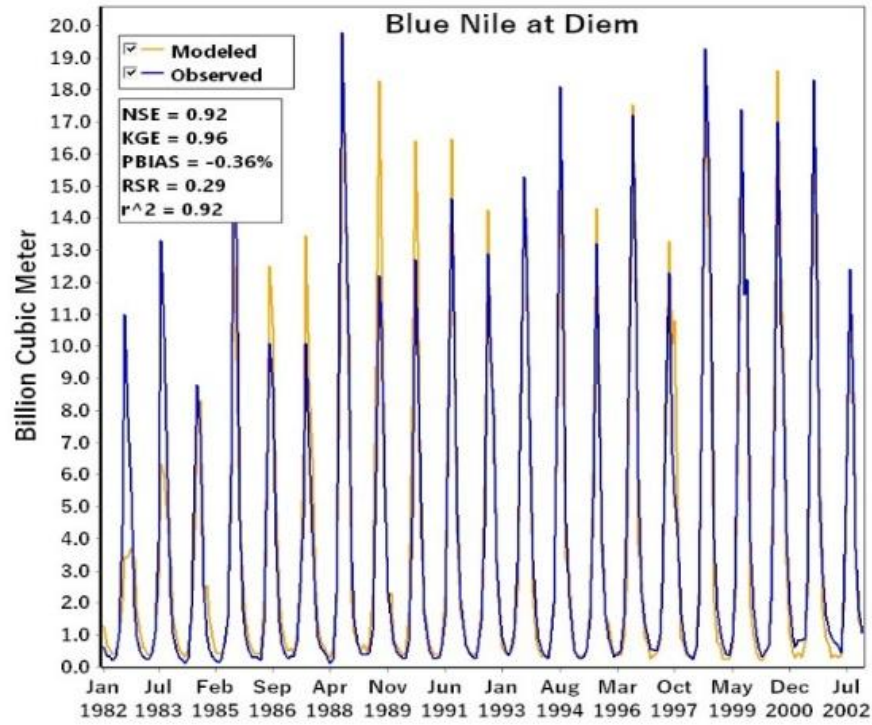
Country	Subbasin-country	% population	% irrigation area	Domestic and industrial water withdrawal from the Nile in BCM	Irrigation water withdrawal from Nile in BCM
Burundi	BUR_LV	100.0%	100.0%	0.060	0.003
DRC	DRC_LA	99.9%	100.0%	0.030	0.180
Egypt	EG_MN	100.0%	100.0%	17.510	51.130
Eritrea	ERI_TE_AT	100.0%	100.0%	0.010	0.340
Ethiopia	ET_BAS	11.0%	3.2%	0.057	0.025
	ET_BN	68.7%	76.5%	0.357	0.597
	ET_TK_AT	19.9%	20.3%	0.103	0.158
	ET_WN	0.5%	0.0%	0.003	0.000
Kenya	KEN_LV	97.4%	100.0%	0.321	0.030
	KEN_VN	2.6%	0.0%	0.009	0.000
Rwanda	RWN_LV	99.8%	100.0%	0.290	0.020
South Sudan	SSD_BAS	12.4%	14.2%	0.025	0.139
	SSD_BEG	43.6%	9.0%	0.087	0.088
	SSD_BEJ	35.0%	37.2%	0.070	0.365

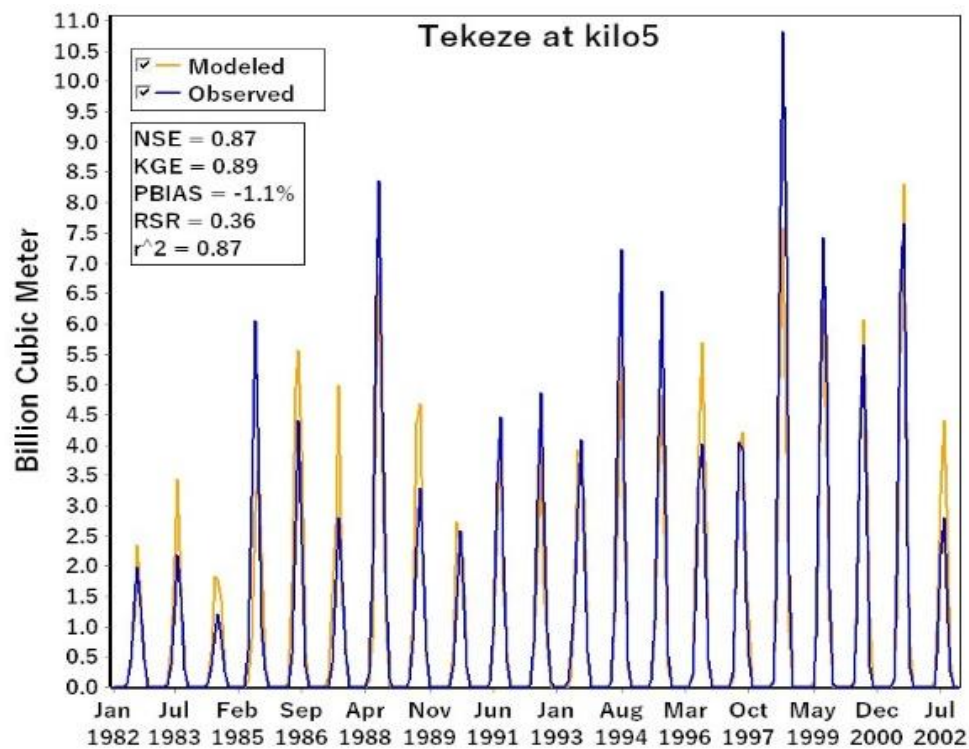
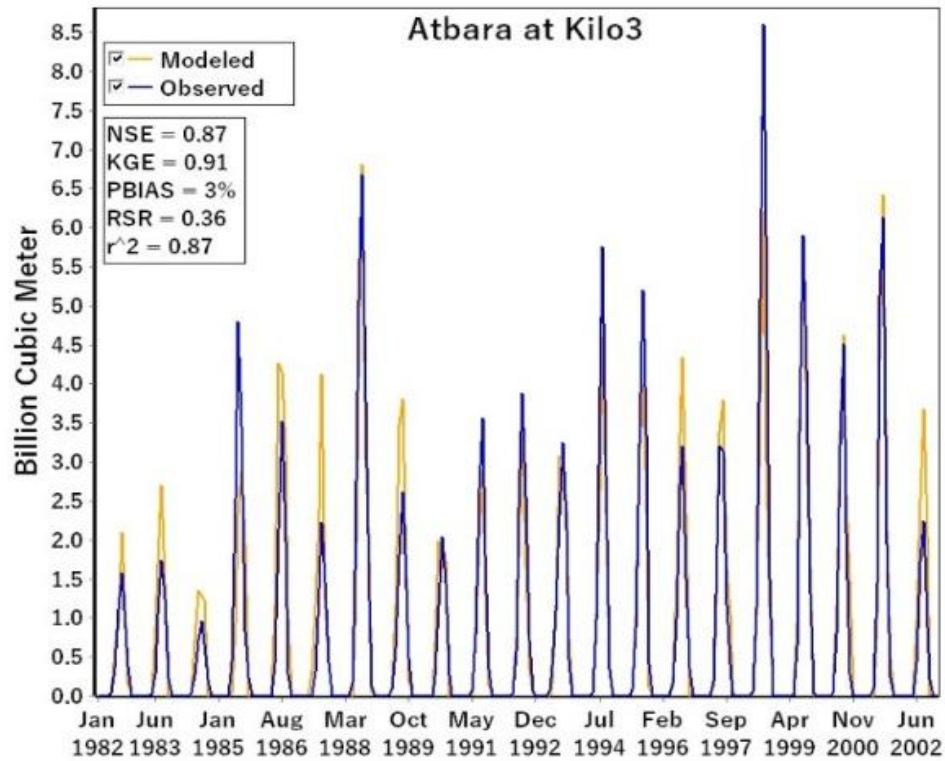
	SSD_WN	8.7%	39.6%	0.018	0.388
Sudan	SUD_BEG	26.2%	1.2%	0.299	0.186
	SUD_BEJ	0.3%	0.0%	0.003	0.001
	SUD_BN	21.1%	26.8%	0.240	4.154
	SUD_MN	15.6%	10.4%	0.178	1.611
	SUD_TE_AT	8.9%	13.0%	0.101	2.017
	SUD_WN	28.0%	48.6%	0.319	7.532
Tanzania	TAN_LV	100.0%	100.0%	0.170	0.030
Uganda	UG_BAS	0.1%	1.3%	0.000	0.006
	UG_BEJ	6.1%	7.9%	0.031	0.034
	UG_LV	22.2%	4.4%	0.113	0.019
	UG_VN	47.0%	18.1%	0.240	0.078
	UG_LA	24.6%	68.2%	0.126	0.294
Basin total				20.77	69.42

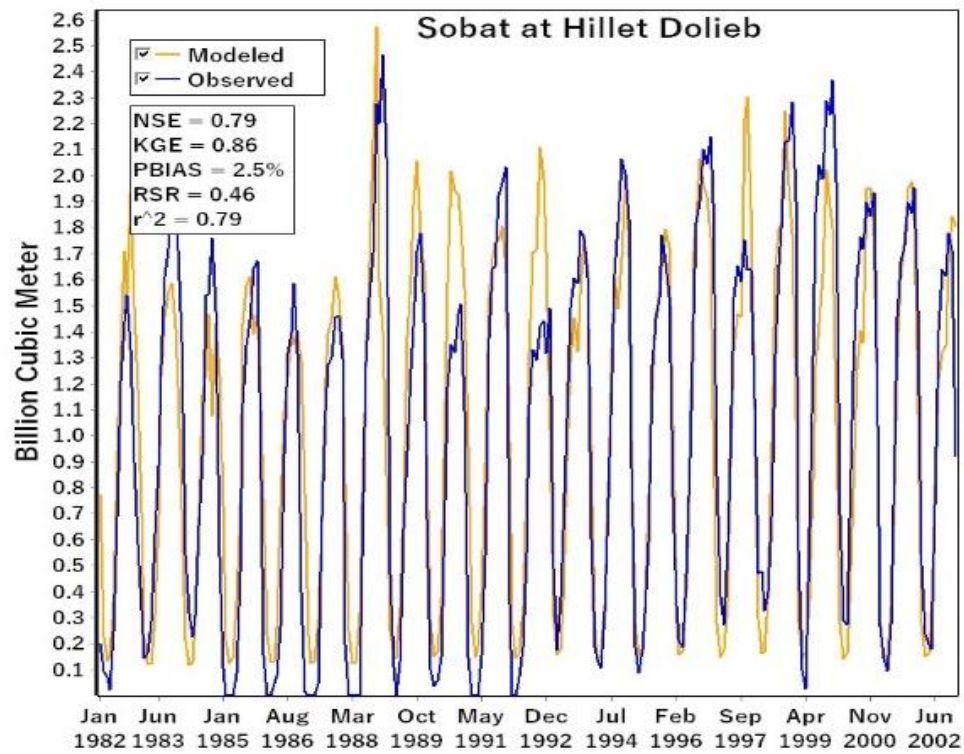
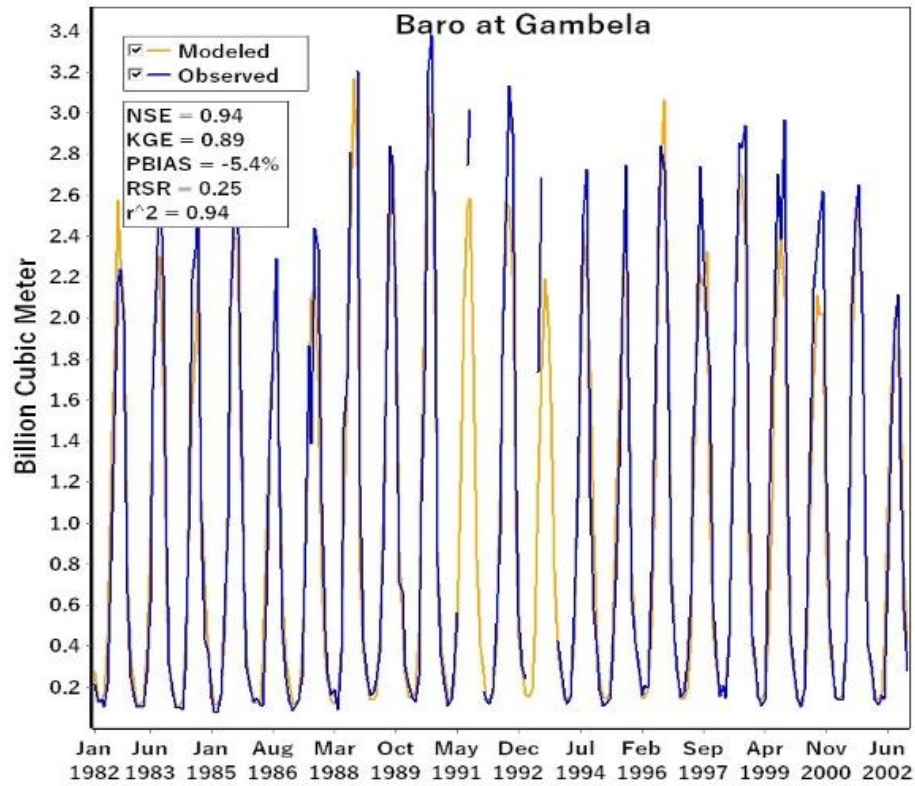
ST 7 Summary of retained open water and contribution to subsurface systems by subbasins

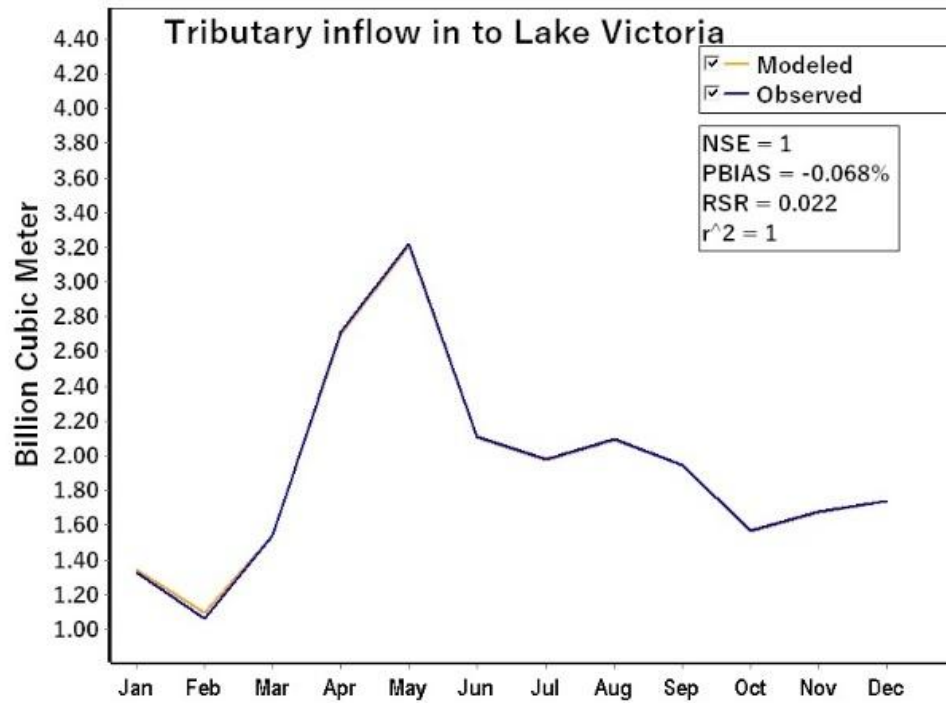
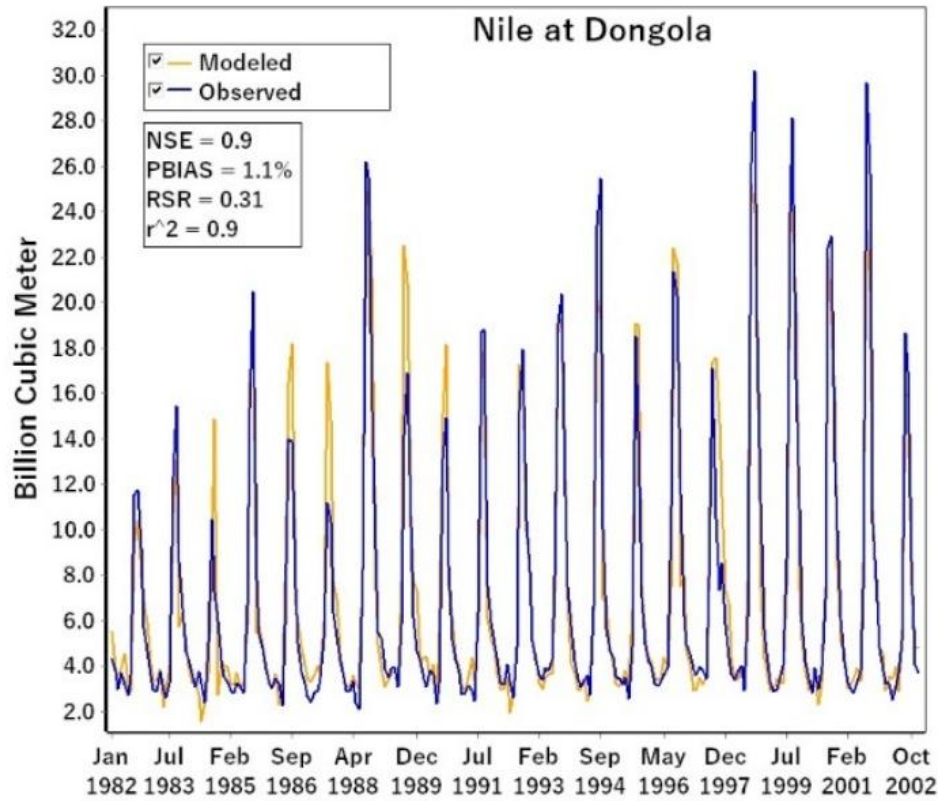
Subbasins	Open water storage	Groundwater recharge	Main water bodies
Equatorial lakes	13.18	9.42	Lake Victoria, Lake Kyoga, Lake Albert, Lake George, Swamps
Bahr el Ghazal	9.1	13.94	Swamps and flood planes
Bhar el Jebel	38.61	4.52	Swamps (Sudd)
Baro-Akobo-Sobat	4.31	9.23	Swamps (Machar)
White Nile	8.42	4.01	Swamps and reservoir (Jebel Aulia dam)
Blue Nile	19.47	18.52	swamps around Lake Tana, Lake Tana, Reservoirs (GERD, Fincha, Ribb dam, Koga dam, Megech dam)
Tekeze-Atbara	7.56	4.38	Reservoirs (Tekeze dam, Khashim el Gerba dam, Upper Atbara and Setit dam)
Main Nile	73.63	2.41	Reservoirs (Merowe and High Aswan dam)

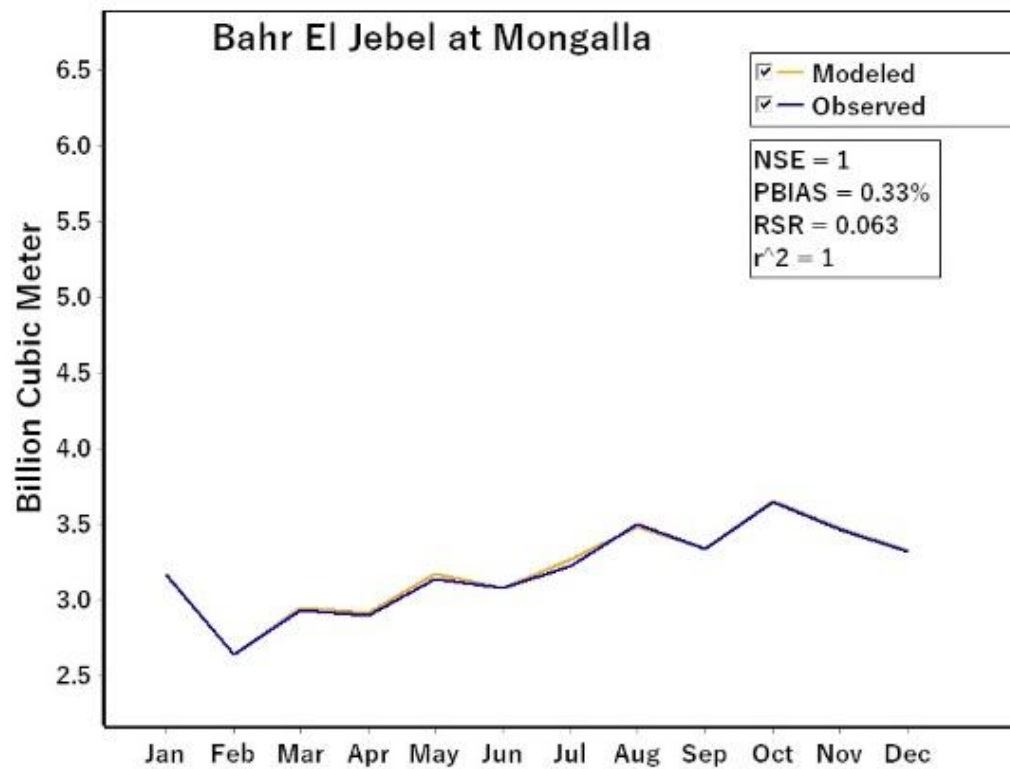
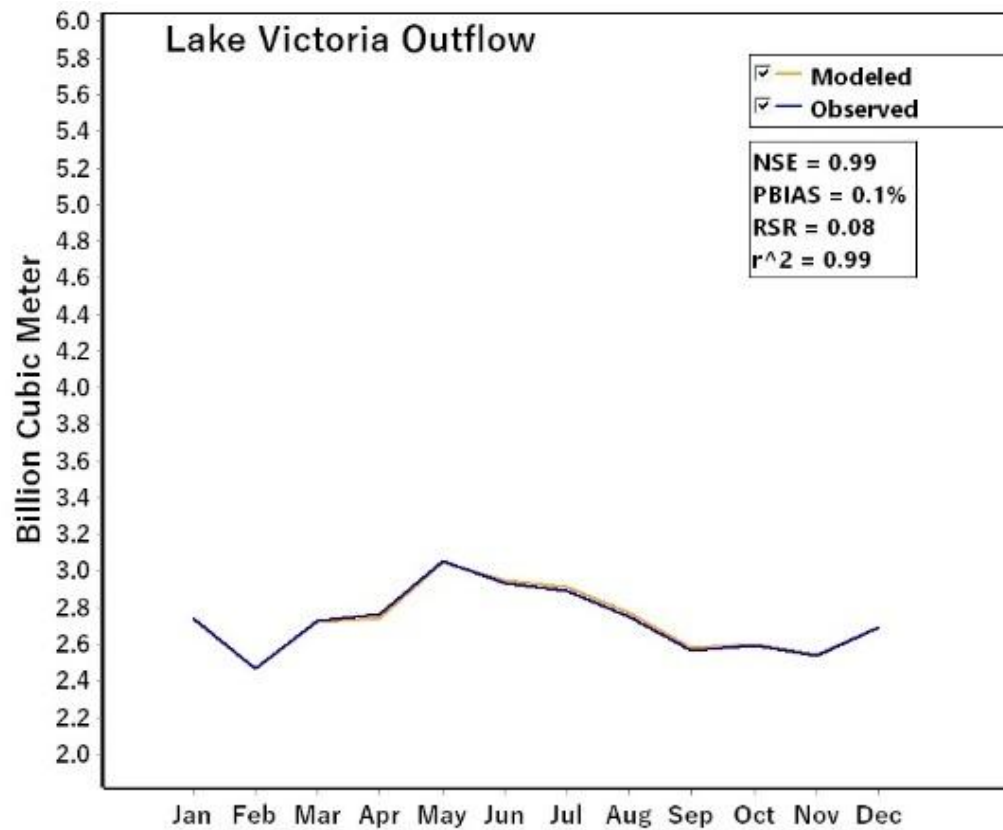
Supplementary Figures

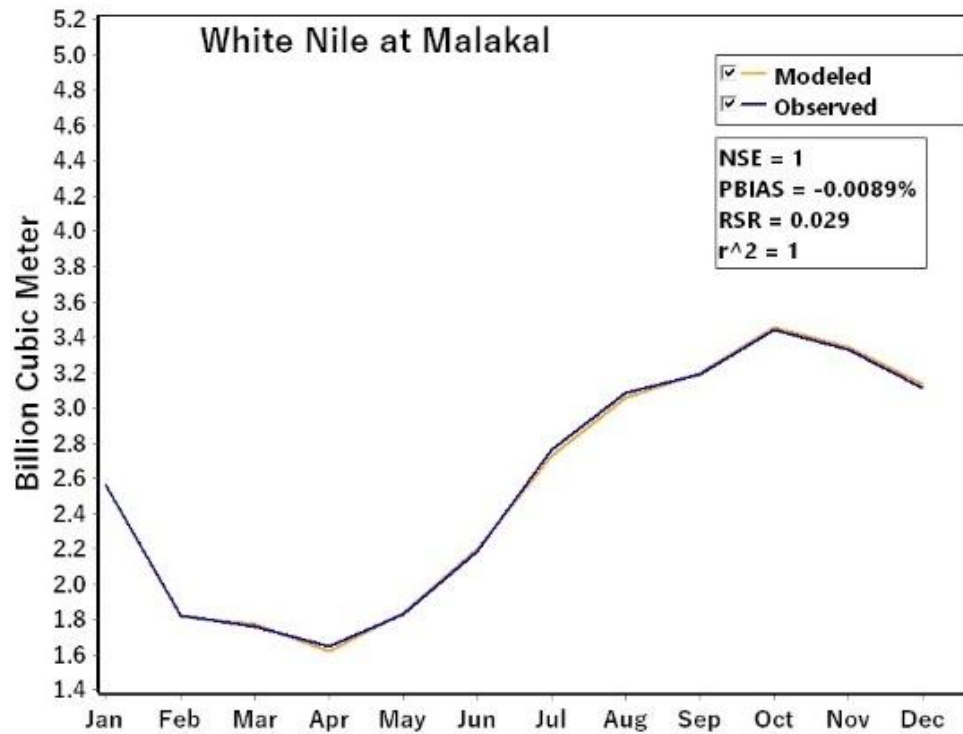




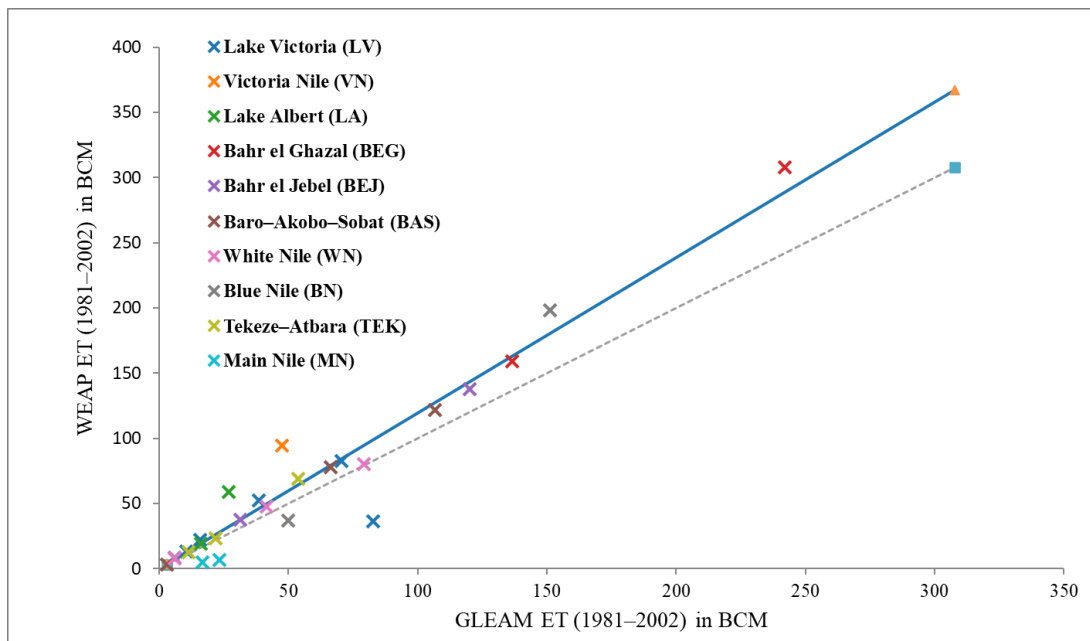




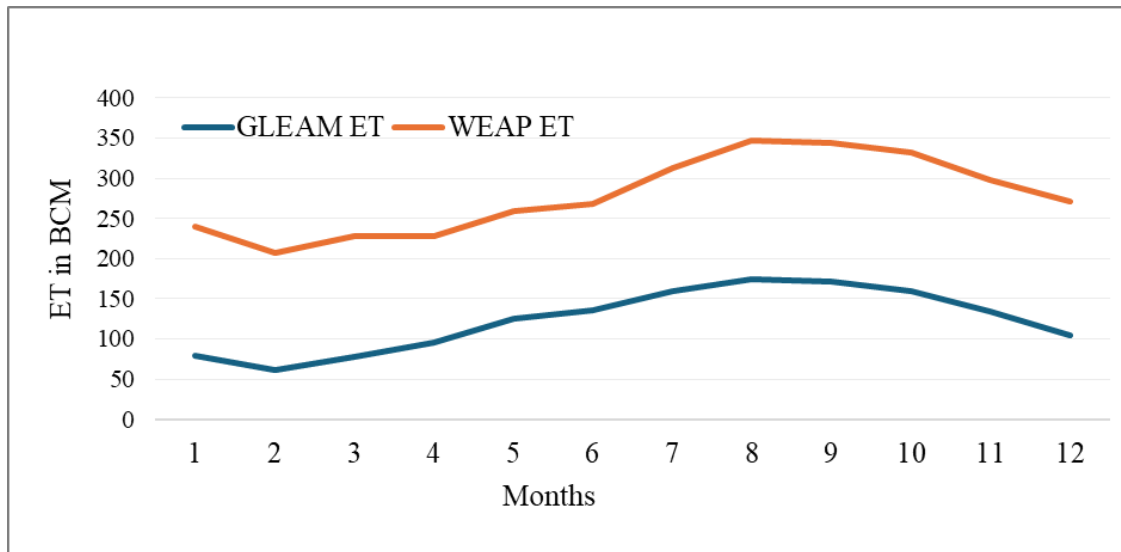




SF1 Calibration and validation results of streamflow for various gauging stations along the Nile River



SF2 Spatial fidelity of WEAP-simulated evapotranspiration (ET) relative to GLEAM. Mean annual ET (1981–2002) aggregated at the subbasin-by-country scale is shown for WEAP (y-axis) against GLEAM actual evaporation (x-axis). Points are colored by subbasin group. The dashed line denotes the 1:1 relationship and the solid line show the best-fit linear relationship constrained through the origin. Model–data agreement is summarized using r , R^2 , RMSE, mean bias error (MBE), and unbiased RMSE (ubRMSE).



SF3 Comparison of the seasonal cycle of basin evapotranspiration (ET) from WEAP and GLEAM. Mean monthly ET climatology for 1981–2002 are shown for WEAP-simulated ET and GLEAM actual evaporation aggregated over the Nile Basin. Both datasets exhibit consistent seasonal timing, with minimum ET during late winter and maximum ET during late boreal summer (Aug–Sep), while WEAP estimates are systematically higher in magnitude.