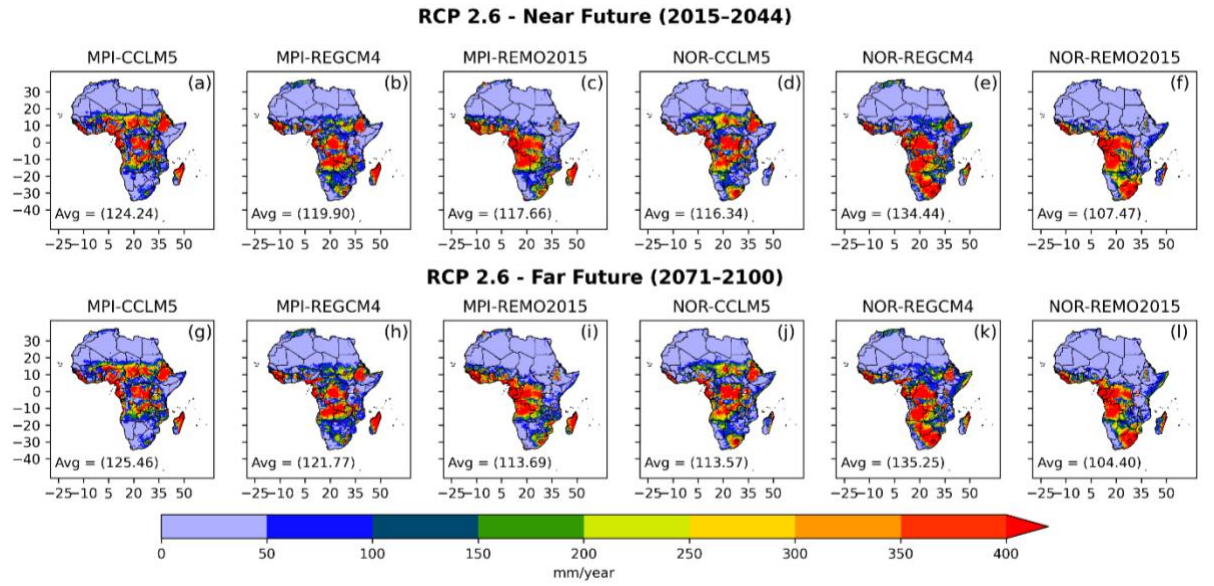


Figure S1: Projected 30-year continental PGWR average over Africa for the near future (2015–2044 a-f) and far future (2071–2100 g-l) under the RCP2.6 scenario. PGWR estimates are presented for six CLM5 simulations using outputs from different GCM-RCM combinations: MPI-CCLM5 (a, g), MPI-REGCM4 (b, h), MPI-REMO2015 (c, i), NOR-CCLM5 (d, j), NOR-REGCM4 (e, k), and NOR-REMO2015 (f, l).

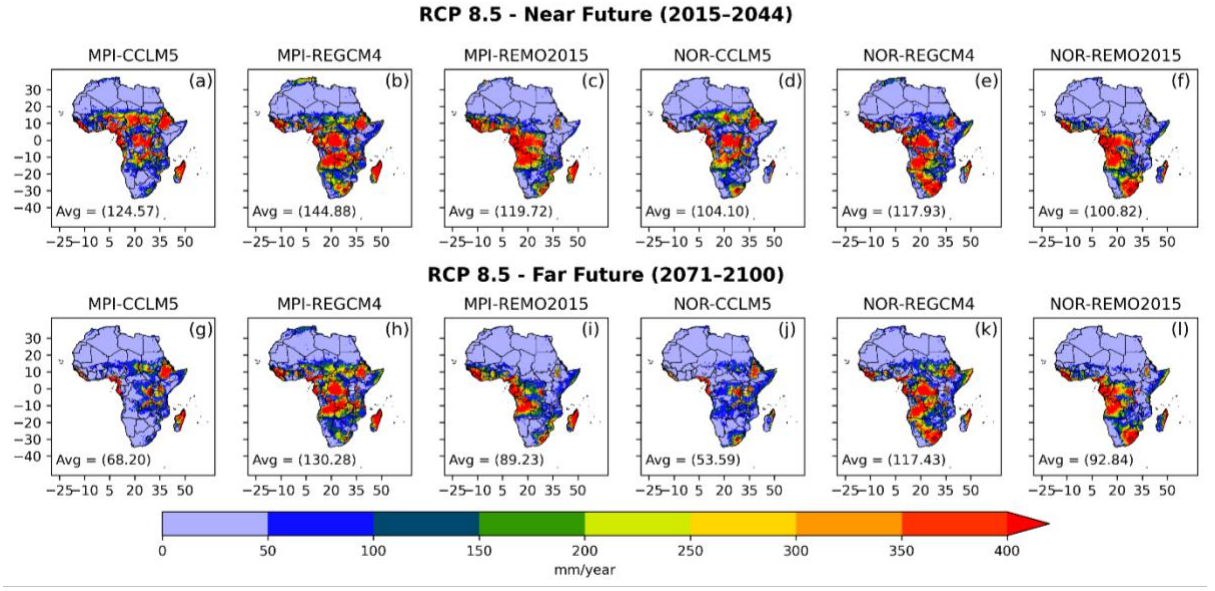


Figure S2: Projected 30-year continental PGWR average over Africa for the near future (2015–2044 a-f) and far future (2071–2100 g-l) under the RCP8.5 scenario. PGWR estimates are presented for six CLM5 simulations using outputs from different GCM-RCM combinations: MPI-CCLM5 (a, g), MPI-REGCM4 (b, h), MPI-REMO2015 (c, i), NOR-CCLM5 (d, j), NOR-REGCM4 (e, k), and NOR-REMO2015 (f, l).

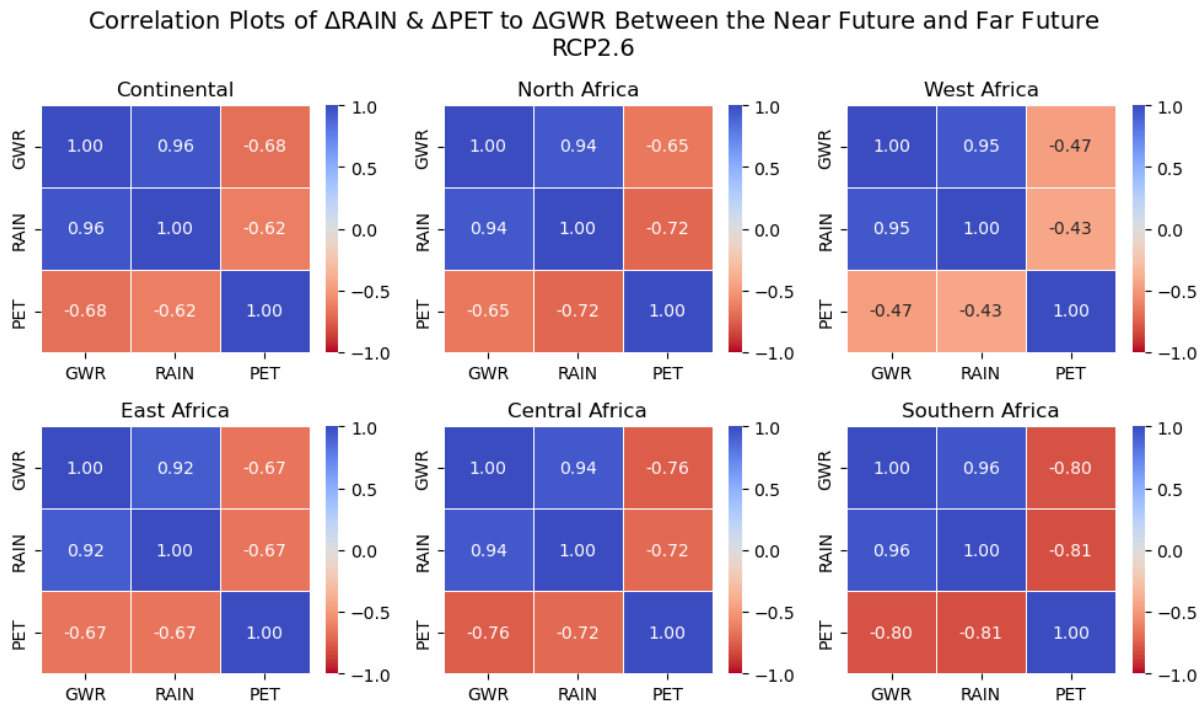


Figure S3: Correlation heatmaps of changes in rainfall (ΔRAIN) and potential evapotranspiration (ΔPET) to changes in groundwater recharge (ΔGWR) between near future and far future under RCP2.6. The correlation matrices for the continental average and five African regions (North Africa, West Africa, East Africa, Central Africa, and Southern Africa) show the strength and direction of the relationships between ΔGWR, ΔRAIN, and ΔPET.

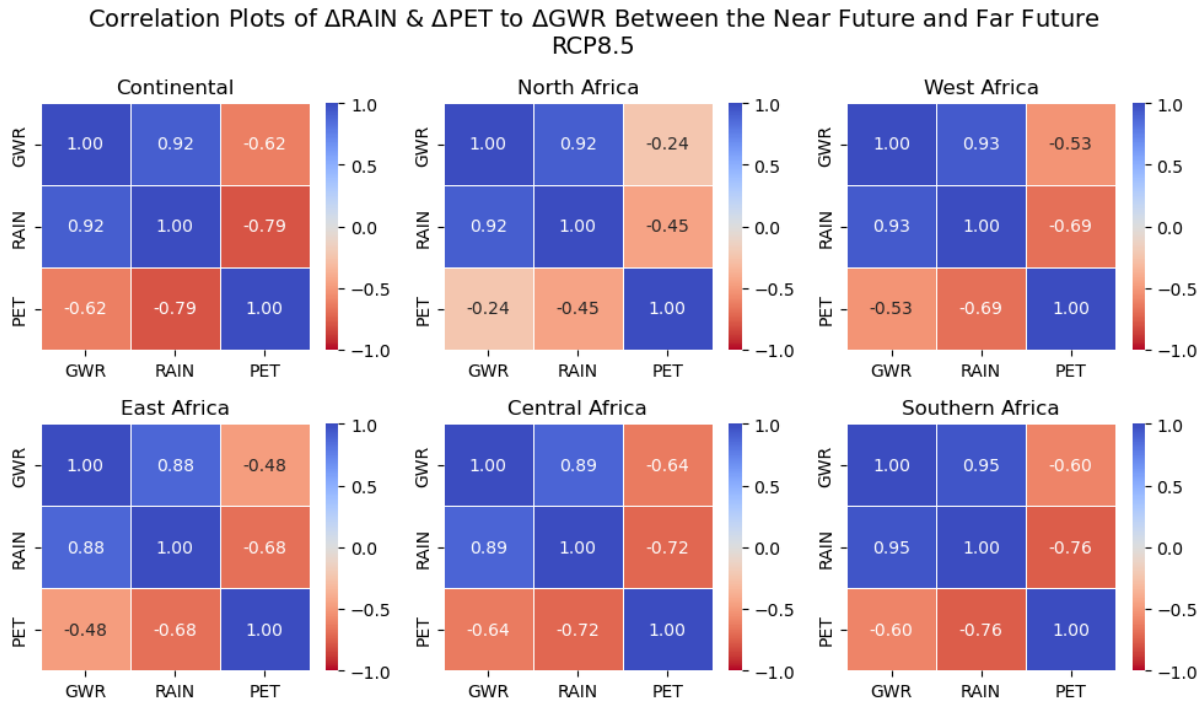


Figure S4: Correlation heatmaps of changes in rainfall (ΔRAIN) and potential evapotranspiration (ΔPET) to changes in groundwater recharge (ΔGWR) between near future and far future under RCP8.5. The correlation matrices for the continental average and five African regions (North Africa, West Africa, East Africa, Central Africa, and Southern Africa) show the strength and direction of the relationships between ΔGWR, ΔRAIN, and ΔPET.

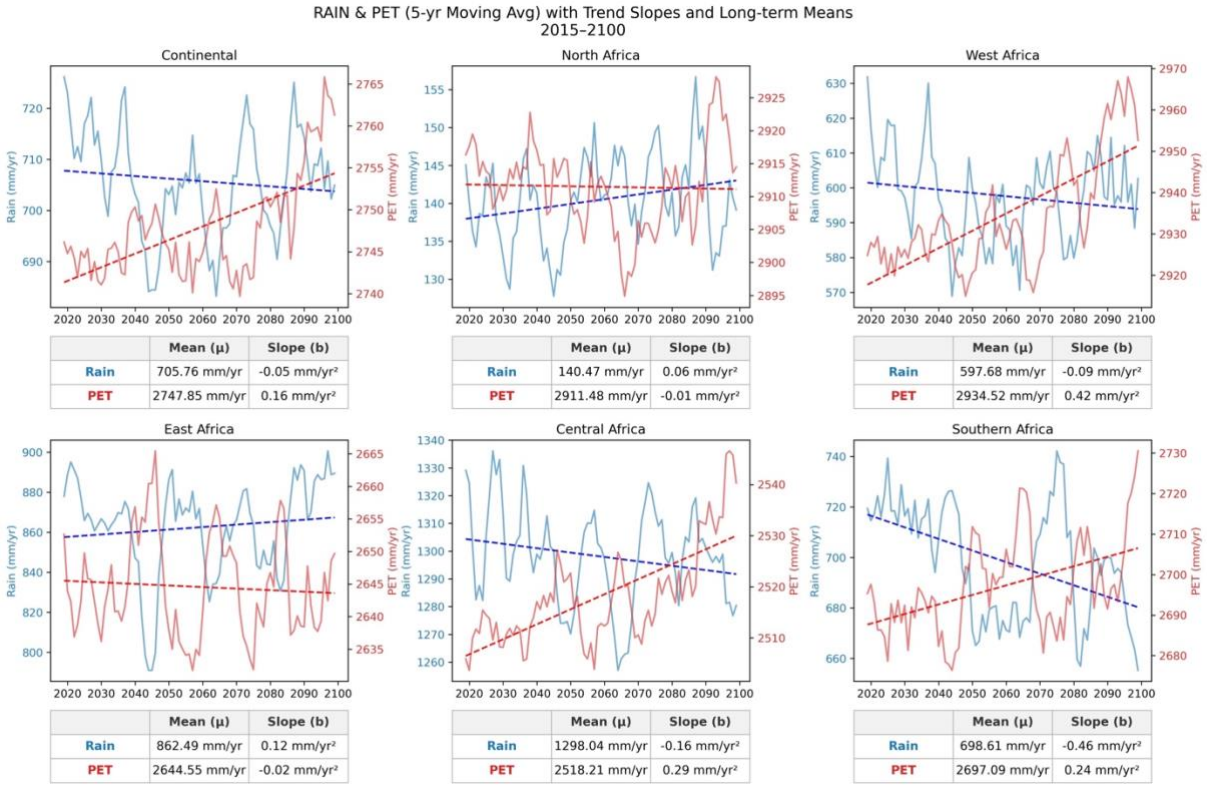
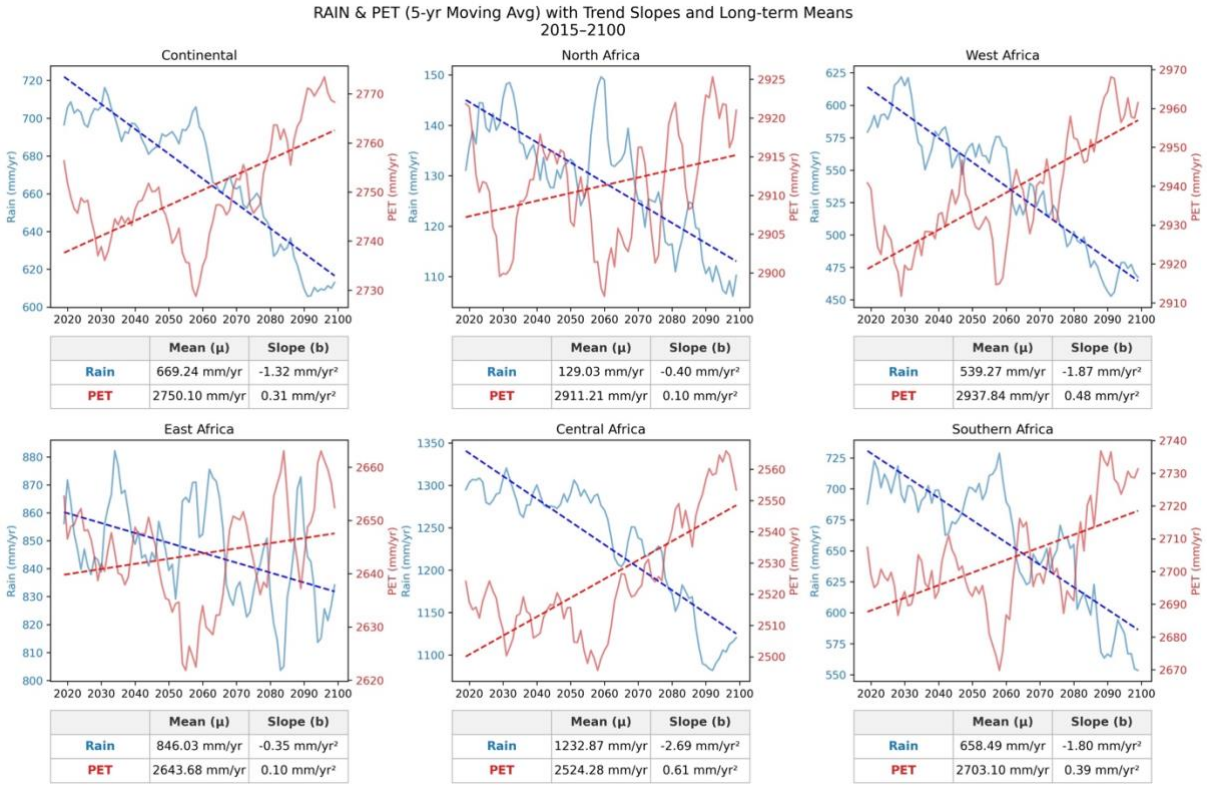


Figure S5: Time series plots showing trends in rainfall (RAIN) and potential evapotranspiration (PET) from 2015 to 2100 under RCP2.6. The plots illustrate annual rainfall (blue, primary axis) and PET (red, secondary axis) trends for the continental average and five African regions (North Africa, West Africa, East Africa, Central Africa, and Southern Africa). The dashed lines represent linear trends. Table also shows annotated slope and time series average values (). Positive slopes indicate increasing trends, while negative slopes indicate decreasing trends.



FigureS6: Time series plots showing trends in rainfall (RAIN) and potential evapotranspiration (PET) from 2015 to 2100 under RCP8.5. The plots illustrate annual rainfall (blue, primary axis) and PET (red, secondary axis) trends for the continental average and five African regions (North Africa, West Africa, East Africa, Central Africa, and Southern Africa). The dashed lines represent linear trends. Table also shows annotated slope and time series average values. Positive slopes indicate increasing trends, while negative slopes indicate decreasing trends

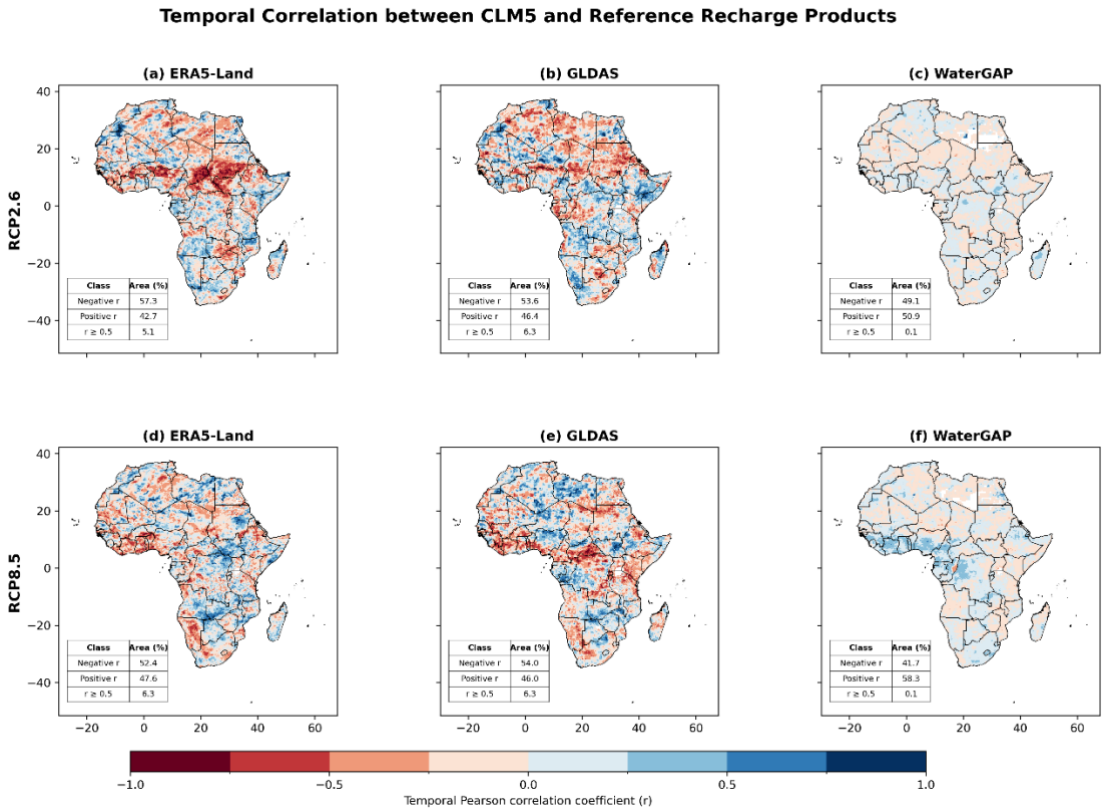


Figure S7: Spatial distribution of temporal correlation between CLM5-simulated groundwater recharge and three reference datasets (ERA5-Land, GLDAS, and WaterGAP) across Africa for RCP2.6 (top row) and RCP8.5 (bottom row). The maps show the Pearson correlation coefficient (r) computed at each grid cell over the overlapping period. Positive values (red) indicate agreement in interannual variability, while negative values (blue) indicate opposing temporal behavior. Insets summarize the percentage of grid cells exhibiting negative correlation, positive correlation, and strong positive correlation (r ≥ 0.5).

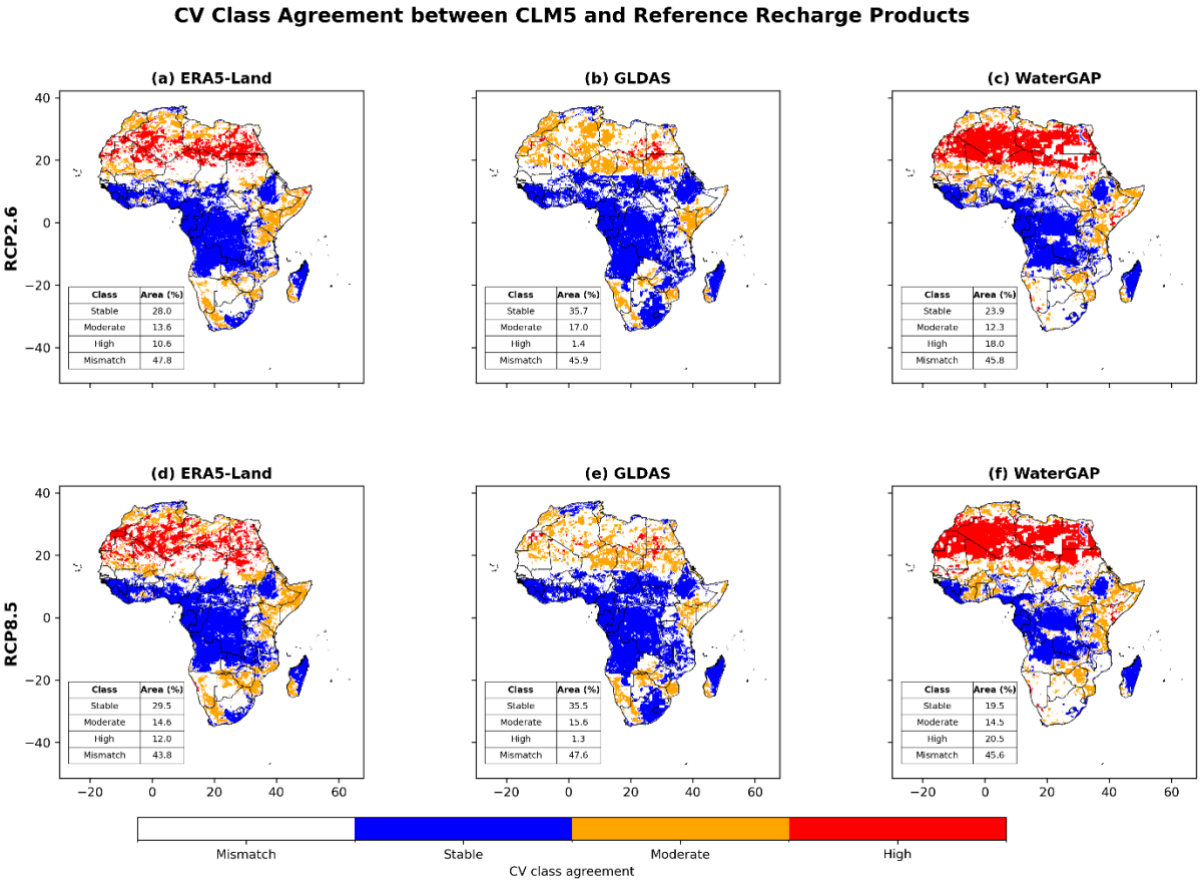


Figure S8: Spatial agreement in groundwater recharge variability regimes between CLM5 and reference datasets based on coefficient of variation (CV) classification across Africa for RCP2.6 (top row) and RCP8.5 (bottom row). Recharge variability is classified into four categories: Stable (<50%), Moderate (50–100%), High (≥100%), and Mismatch (disagreement between datasets). Insets indicate the percentage of continental area in each category.

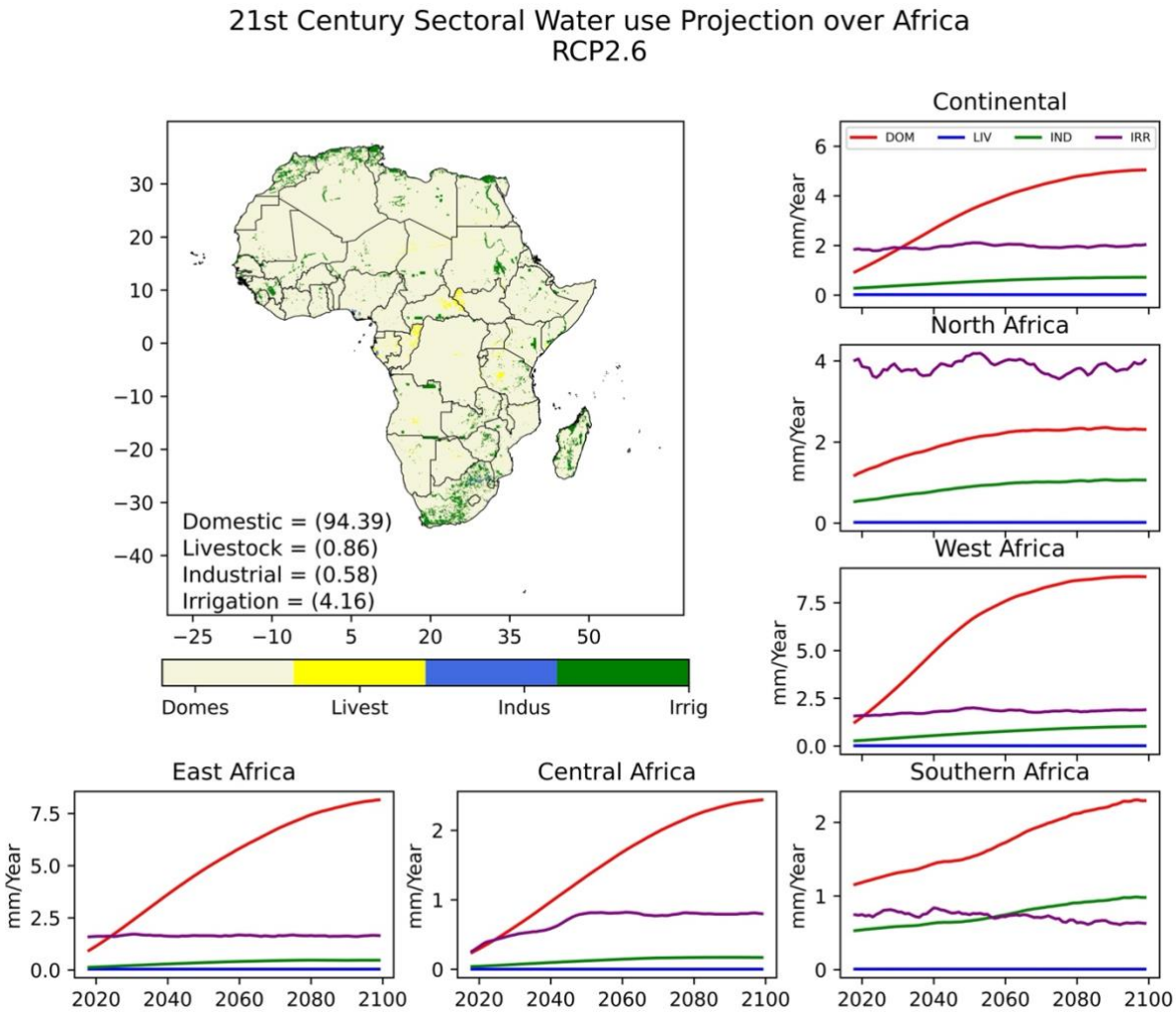


Figure S9: Projected sectoral water use across Africa during the 21st century under the RCP2.6 climate scenarios. The map shows the dominant water use sector per grid cell, categorized into domestic (DOM), livestock (LIV), industrial (IND), and irrigation (IRR) based on average consumption from 2015 to 2100. The time series plots illustrate the evolution of annual water consumption for each sector at both continental and regional scales.

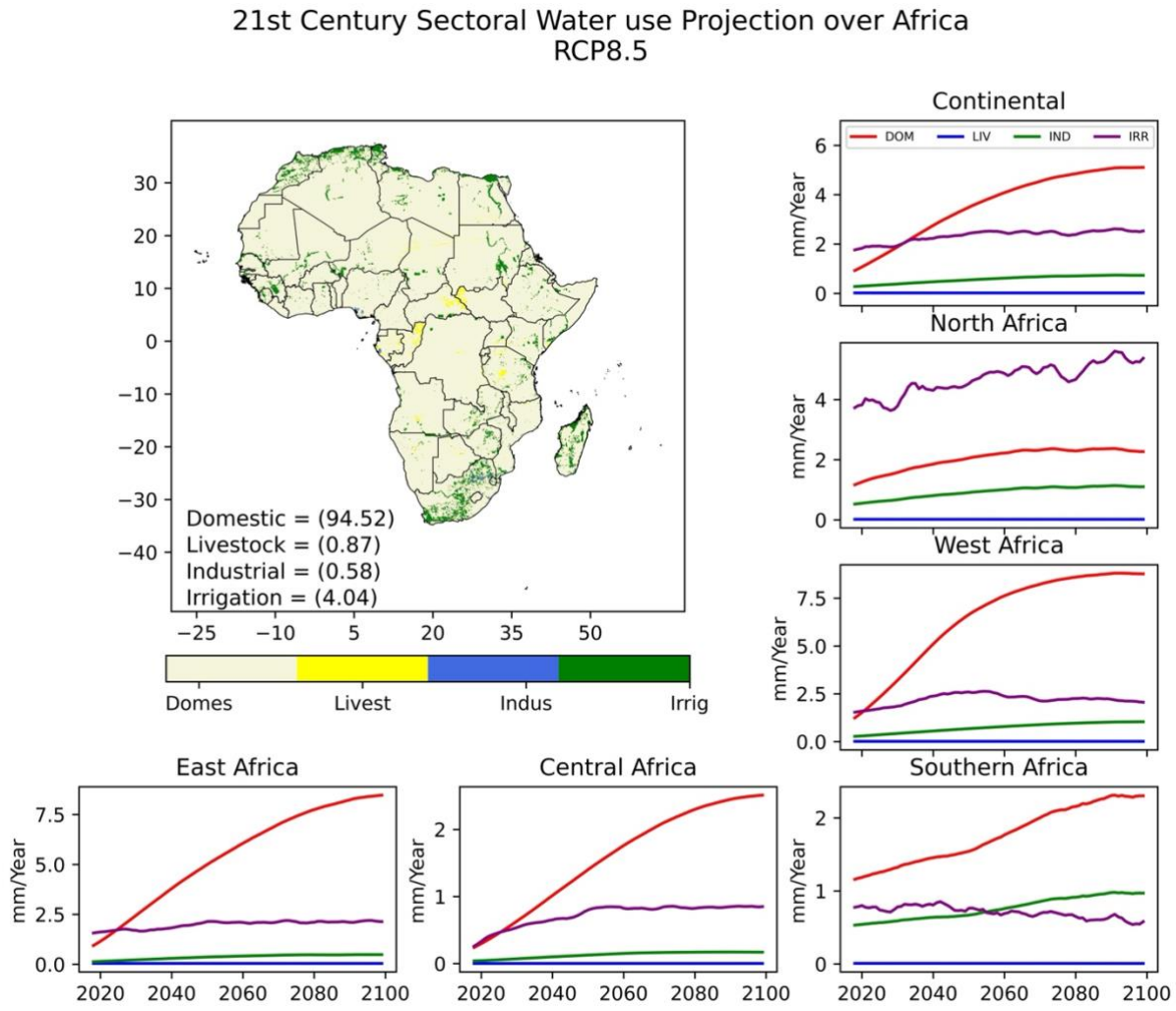


Figure S10: Projected sectoral water use across Africa during the 21st century under the RCP8.5 climate scenarios. The map shows the dominant water use sector per grid cell, categorized into domestic (DOM), livestock (LIV), industrial (IND), and irrigation (IRR) based on average consumption from 2015 to 2100. The time series plots illustrate the evolution of annual water consumption for each sector at both continental and regional scales.

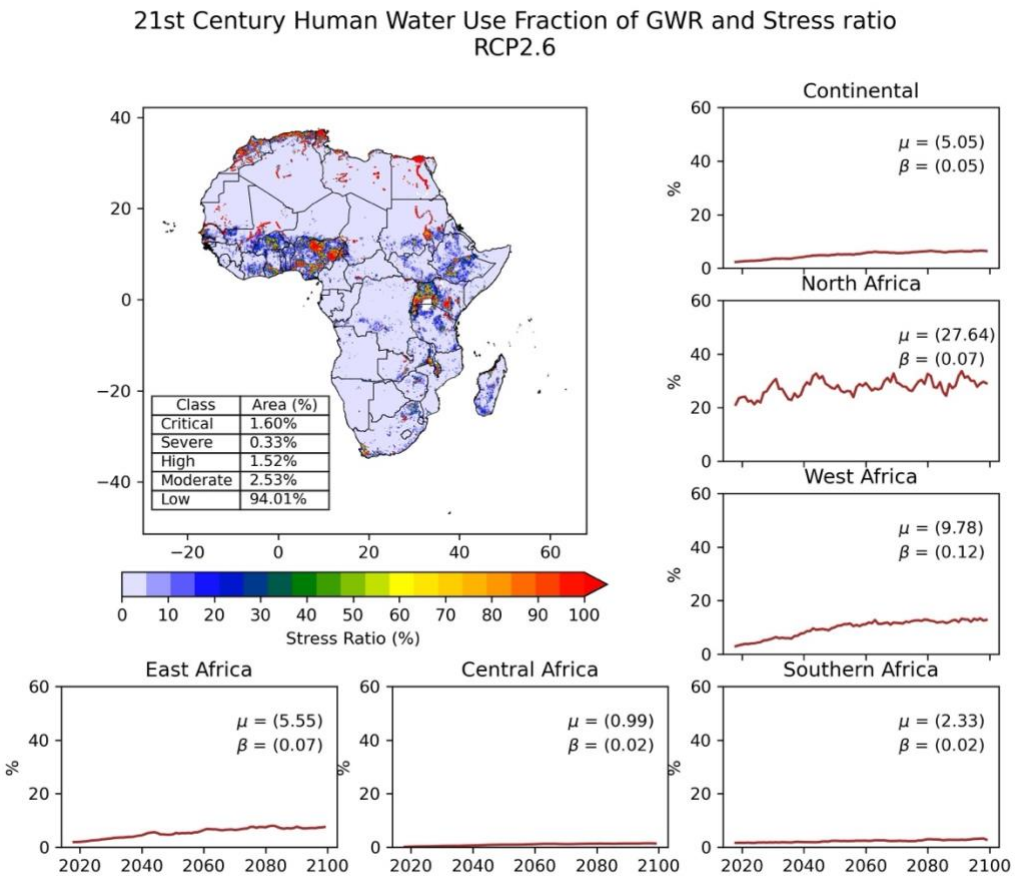


Figure S11: RCP2.6 Human Water Use and Stress Ratio. The map displays the time-mean stress ratio in %, i.e., HWU/GWR×100. Stress Ratio classes are Low (<20%), Moderate (20–40%), High (40–80%), Severe (80–100%), and Critical (>100%, meaning human water use exceeds simulated recharge). The inset table reports the share of African continent (%) in each class. To the right and bottom of each map, regional time-series (5-year running mean) summarize the stress ratio for Continental, North, West, Southern Africa, East, and Central; annotations show the mean (μ, %) and the linear trend (β, %/yr2).

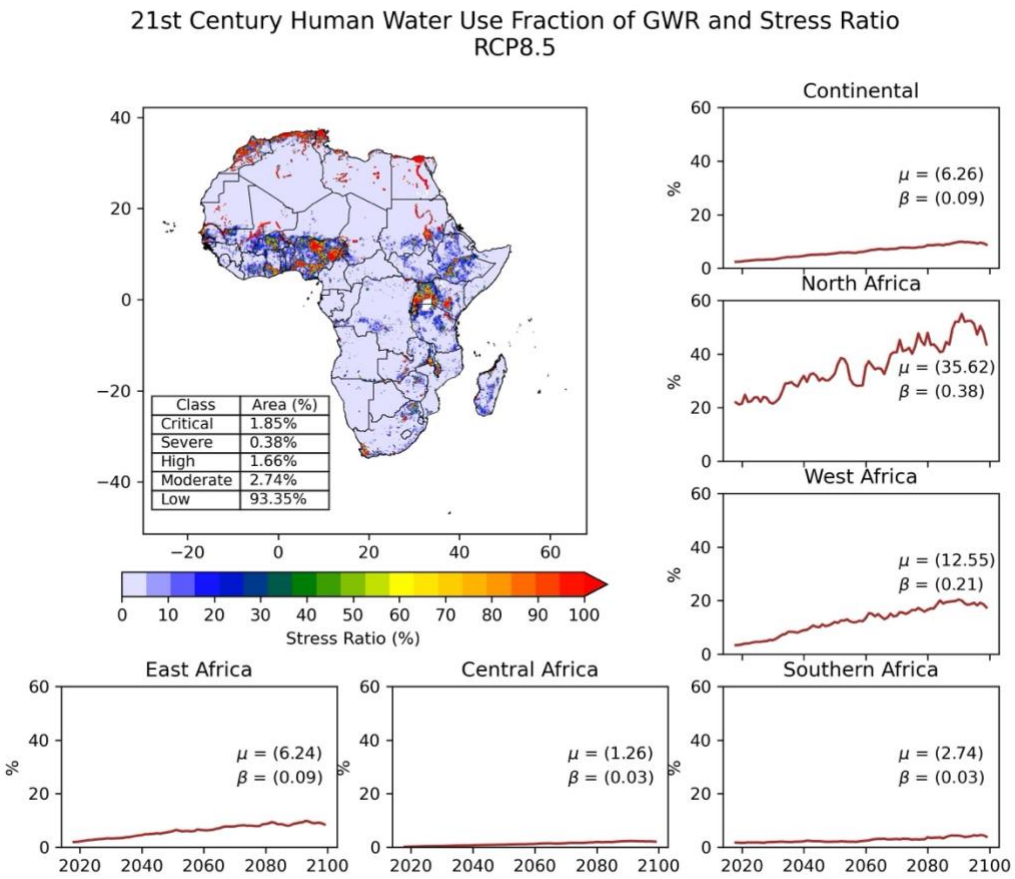


Figure S12: RCP8.5 Human Water Use and Stress Ratio. The map displays the time-mean stress ratio in %, i.e., HWU/GWR×100. Stress Ratio classes are Low (<20%), Moderate (20–40%), High (40–80%), Severe (80–100%), and Critical (>100%, meaning human water use exceeds simulated recharge). The inset table reports the share of African continent (%) in each class. To the right and bottom of each map, regional time-series (5-year running mean) summarize the stress ratio for Continental, North, West, Southern Africa, East, and Central; annotations show the mean (μ, %) and the linear trend (β, %/yr2).

Table S1: Projected National Groundwater recharge stress ratios (Columns 3-6) and population (Columns 7-10) under climate scenarios across African countries.

Country	ISO3	RCP2.6 (2015–2044) (%) Stress Ratio	RCP2.6 (2071–2100) (%) Stress Ratio	RCP8.5 (2015–2044) (%) Stress Ratio	RCP8.5 (2071–2100) (%) Stress Ratio	SSP1-2.6 2045 (million people)	SSP1-2.6 2100 (million people)	SSP5-8.5 2045 (million people)	SSP5-8.5 2100 (million people)
Angola	AGO	1.48	2.18	1.28	6.96	41.15	56.89	36.85	42.11
Burundi	BDI	28.56	58.35	18.42	64.79	15.97	18.92	16.06	16.74
Benin	BEN	19.39	83.20	20.23	213.65	18.08	24.39	16.63	18.71
Burkina Faso	BFA	131.61	188.20	71.26	707.13	35.93	55.33	30.02	34.27
Botswana	BWA	0.33	0.42	0.66	1.25	2.66	2.76	2.64	2.32
Cen. Afr. Rep'lic	CAF	1.73	5.82	0.92	8.85	7.15	7.89	6.52	5.99
Côte d'Ivoire	CIV	8.44	18.67	8.79	165.30	29.77	32.66	24.82	20.24
Cameroon	CMR	54.77	51.81	43.74	125.45	31.98	35.93	29.44	27.98
D.R Congo	COD	9.46	4.66	2.07	14.13	136.79	187.02	123.91	142.16
Congo	COG	0.09	0.31	0.09	0.69	7.45	9.15	7.05	7.28
Comoros	COM	0.00	0.01	0.00	0.01	1.24	1.41	0.98	0.73
Djibouti	DJI	0.10	0.16	0.21	0.12	1.34	1.40	1.26	1.11
Algeria	DZA	34.23	46.19	31.18	122.63	48.64	45.60	44.76	33.58
Egypt	EGY	627.46	1093.87	1514.35	857.77	121.20	131.24	109.75	93.58
Eritrea	ERI	1.92	7.16	1.89	76.33	10.95	14.39	9.96	10.71
Ethiopia	ETH	30.71	77.73	73.52	59.63	151.07	191.01	133.20	132.90
Gabon	GAB	0.11	0.16	0.11	0.25	2.23	2.30	2.11	1.85
Ghana	GHA	26.99	142.68	24.88	627.74	44.06	57.60	38.21	38.00
Guinea	GIN	2.64	10.70	5.67	14.75	15.10	16.58	11.84	8.38
Gambia	GMB	86.32	455.02	90.95	973.11	3.14	3.84	2.67	2.44
Guinea-Bissau	GNB	4.95	25.93	48.92	94.91	2.41	2.65	2.14	1.95
Equatorial Guinea	GNQ	0.38	0.50	0.39	0.75	1.37	1.77	1.34	1.49

Kenya	KEN	98.14	138.42	163.93	72.17	74.28	95.54	66.33	67.29
Liberia	LBR	0.49	1.72	0.55	2.42	10.27	14.86	10.03	12.06
Libya	LBY	76.92	65.01	195.75	115.41	9.41	9.78	8.60	7.07
Lesotho	LSO	0.68	1.06	0.66	1.10	2.64	2.45	2.47	1.87
Morocco	MAR	183.82	234.67	246.42	406.71	37.20	30.88	31.88	18.73
Madagascar	MDG	9.10	57.10	8.38	39.67	42.41	59.05	36.02	36.47
Mali	MLI	264.71	105.58	175.25	4667.04	33.61	48.14	28.30	31.30
Mozambique	MOZ	5.39	7.11	2.73	10.33	40.49	50.19	36.29	35.96
Mauritania	MRT	563.89	37.36	42.57	93.44	6.01	7.32	5.36	5.05
Malawi	MWI	68.31	97.97	119.52	106.10	36.92	66.73	31.09	41.09
Namibia	NAM	0.83	0.76	1.16	1.70	3.27	3.31	3.12	2.67
Niger	NER	4.36	7.03	11.95	25.36	45.19	97.91	35.54	50.19
Nigeria	NGA	125.26	258.25	123.55	748.49	340.95	582.38	305.94	424.04
Rwanda	RWA	54.85	194.07	59.91	107.46	21.52	30.88	19.01	21.33
Sudan	SDN	54.53	97.56	46.66	114.35	85.07	127.37	73.45	84.11
Senegal	SEN	423.97	530.17	2062.24	9790.38	23.08	31.15	18.23	16.07
Sierra Leone	SLE	1.02	2.09	1.15	2.59	10.73	13.15	10.07	10.37
Somalia	SOM	7.68	8.01	16.26	6.99	15.60	19.23	11.36	7.67
Sao Tome and Principe	STP	0.00	0.00	0.00	0.00	0.21	0.20	0.16	0.08
Swaziland	SWZ	3.34	4.23	3.31	15.41	1.52	1.52	1.48	1.24
Chad	TCD	7.36	12.99	7.24	45.27	23.62	34.20	20.44	23.03
Togo	TGO	21.80	51.21	15.01	384.83	9.96	11.42	9.27	8.90
Tunisia	TUN	1424.82	202.19	133.71	506.37	12.70	10.65	12.03	8.36
Tanzania	TZA	295.23	36.64	22.68	34.87	95.35	143.79	79.49	86.84
Uganda	UGA	71.81	508.37	101.24	419.50	84.80	155.66	70.37	94.58
South Africa	ZAF	7.31	9.64	11.24	16.45	62.25	58.48	64.39	52.37
Zambia	ZMB	6.49	36.84	5.87	17.92	28.05	43.43	23.71	28.02
Zimbabwe	ZWE	16.60	15.32	13.54	48.53	13.24	11.48	10.22	5.49

Table S2: Summary of groundwater recharge dynamics, human water use projections, and groundwater stress indicators across African regions under the RCP2.6 climate scenario.

Domain	NF GWR (mm/yr)	FF GWR (mm/yr)	Change in GWR between NF and FF (%)	Slope of GWR in 21st Century (mm/yr^2)	NF HWU (mm/yr)	FF HWU (mm/yr)	Change in HWU between NF and FF (%)	Slope of Human Water Use increase (mm/yr^2)	NF SR (%)	FF SR (%)	Change in Stress Ratio between NF and FF (%)	Slope of the fraction of GWR used by Humans (%/yr)
AFR	123.89	121.00	2.33	-0.05	4.21	7.51	78.30	0.06	3.45	6.20	79.95	0.05
NAF	23.99	24.75	-3.17	0.00	6.09	7.16	17.52	0.02	25.65	29.02	13.10	0.07
WAF	96.93	94.23	2.79	-0.04	5.48	11.53	110.43	0.08	5.85	12.45	112.74	0.12
SAF	154.74	143.20	7.46	-0.19	2.69	3.75	39.63	0.02	1.81	2.76	52.04	0.02
CAF	245.78	237.53	3.36	-0.14	1.22	3.24	164.97	0.04	0.50	1.36	170.79	0.02
EAF	131.62	133.70	-1.58	0.03	4.40	9.76	121.82	0.10	3.45	7.30	111.79	0.07

Table S3: Summary of groundwater recharge dynamics, human water use projections, and groundwater stress indicators across African regions under the RCP8.5 climate scenario.

Domain	NF GWR (mm/yr)	FF GWR (mm/yr)	Change in GWR between NF and FF (%)	Slope of GWR in 21st Century (mm/yr^2)	NF HWU (mm/yr)	FF HWU (mm/yr)	Change in HWU between NF and FF (%)	Slope of Human Water Use increase (mm/yr^2)	NF SR (%)	FF SR (%)	Change in Stress Ratio between NF and FF (%)	Slope of the fraction of GWR used by Humans (%/yr)
AFR	123.34	92.40	25.09	-0.52	4.43	8.16	84.04	0.07	3.66	8.75	139.09	0.09
NAF	25.04	19.00	24.12	-0.11	6.41	8.59	34.12	0.04	25.89	46.27	78.72	0.38
WAF	93.73	64.93	30.73	-0.48	5.87	11.84	101.60	0.08	6.46	17.96	177.90	0.21
SAF	142.85	105.98	25.81	-0.71	2.72	3.78	38.83	0.02	1.97	3.70	88.07	0.03
CAF	244.02	166.27	31.86	-1.32	1.28	3.37	161.99	0.04	0.54	2.00	271.66	0.03
EAF	135.71	125.87	7.25	-0.18	4.59	10.57	130.38	0.11	3.46	8.66	150.54	0.09