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Hydrological responses to LULC and climate dynamics in the Rift Valley Lakes Basin, Ethiopia

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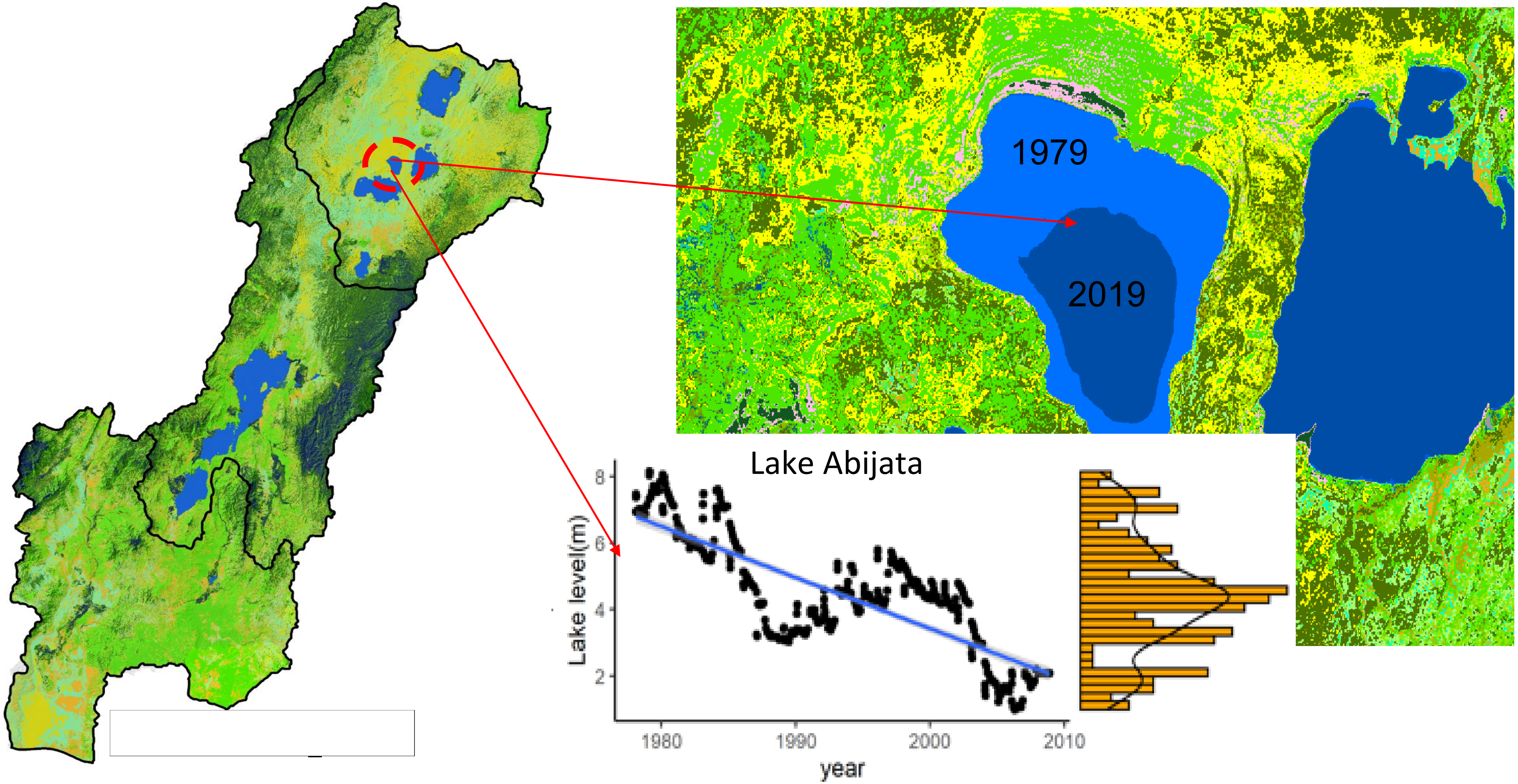
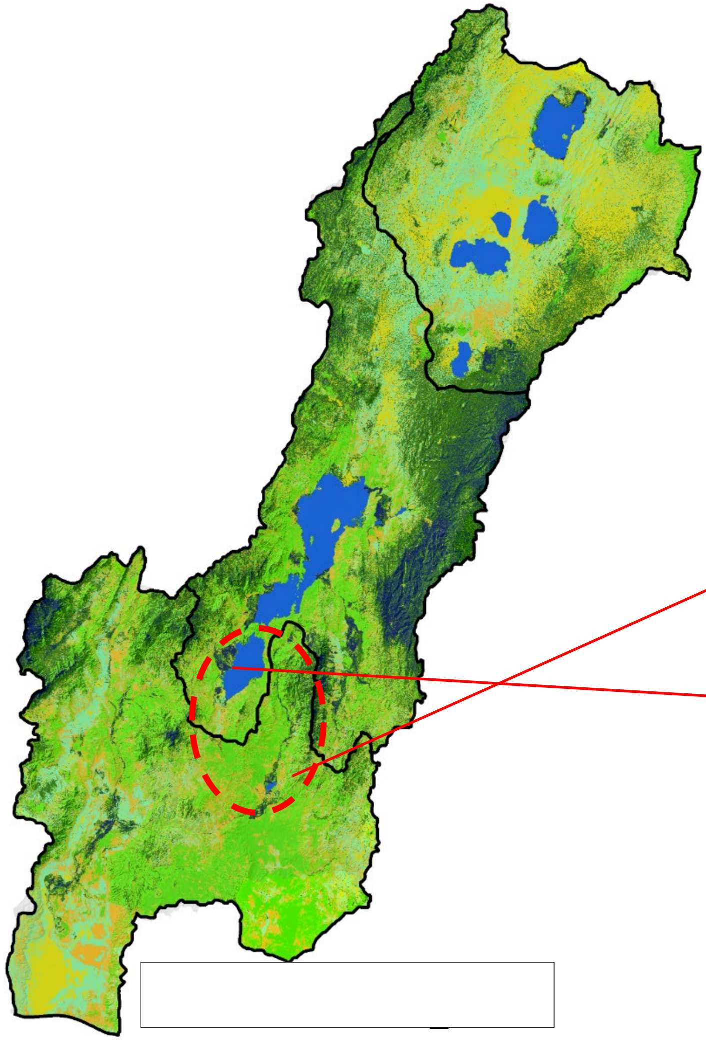
Deutscher Akademischer Austauschdienst
German Academic Exchange Service

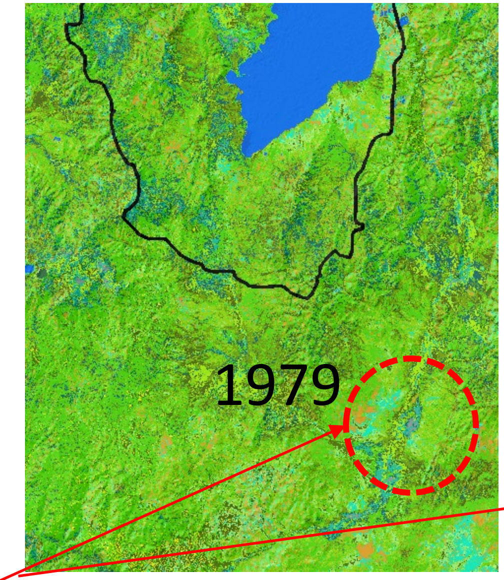
Department of Hydrology and Water Resources Management

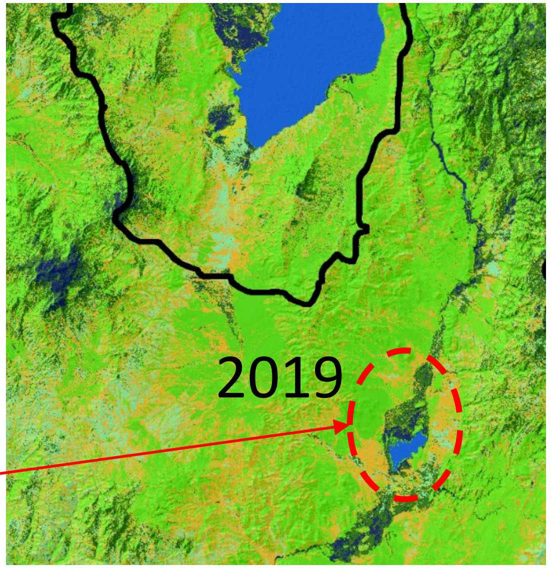
Rationale - Hydrological system is changing(losing water)



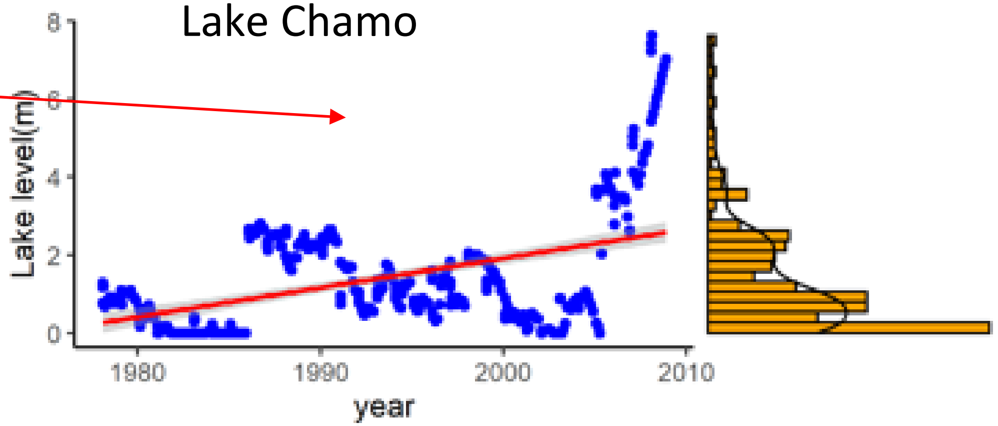
Rationale - Hydrological system is changing (gaining water)







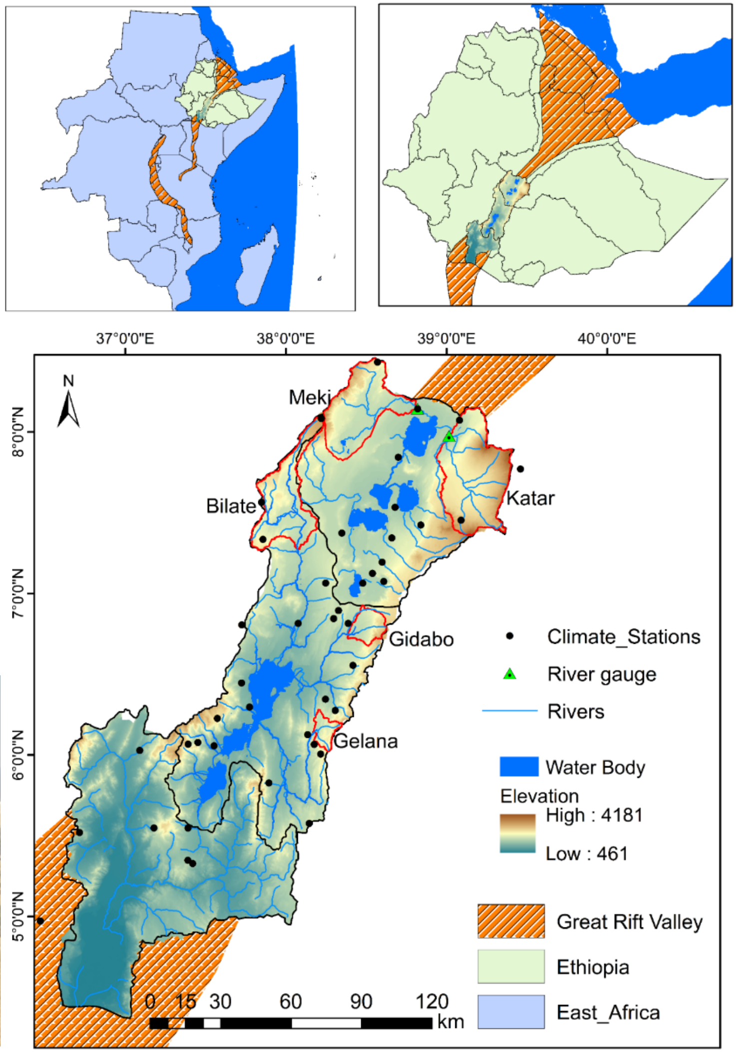
13.35Km2



How does the hydrological system of Rift Valley respond to a changing LULC and climate?

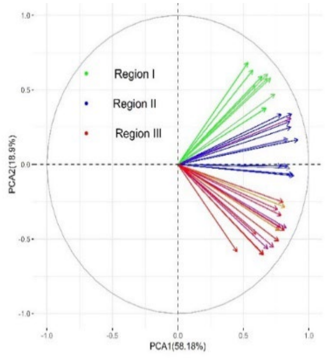
Study Area - Rift Valley Lakes Basin

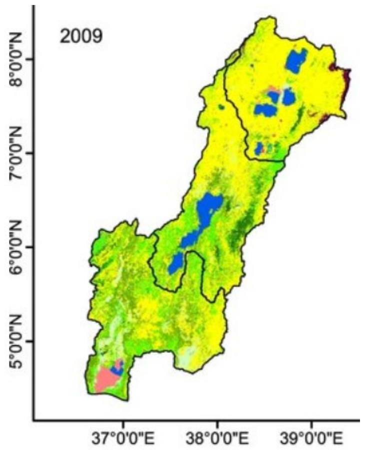
- Part of Great Rift Valley, located in the central part of Ethiopia (Area: 55,050 km²)
- Characterized by its unique geological features and diverse landscapes features
- Encompasses numerous lakes, springs, wetlands and rivers
- The region experiences both seasonal and spatial variations in climate patterns
- Five watersheds are selected



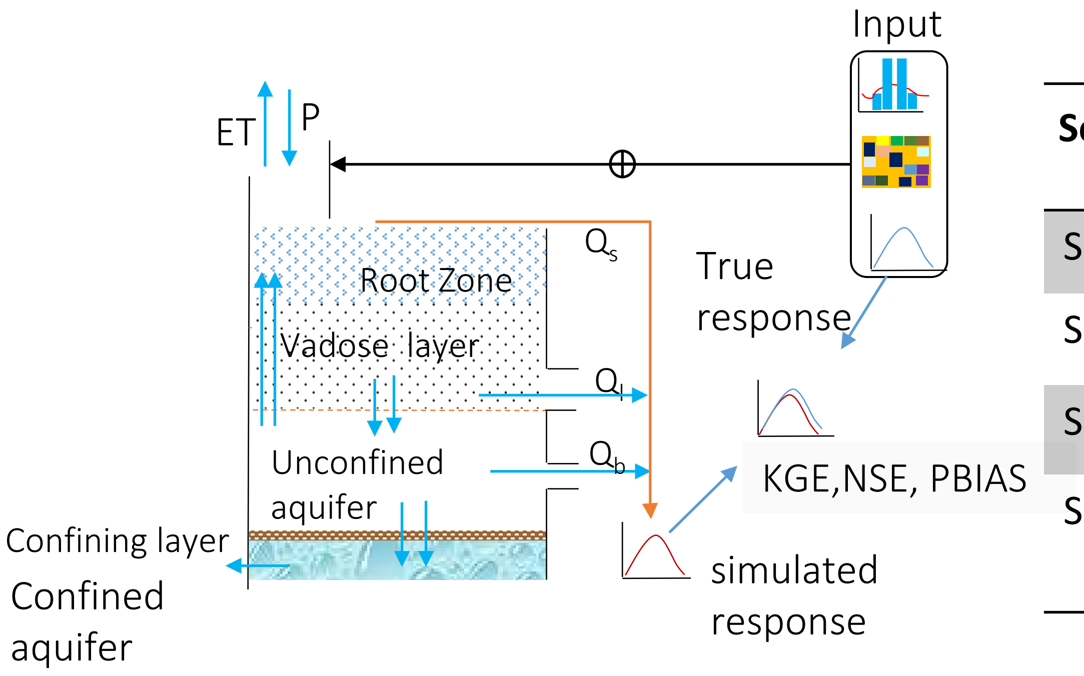
Methodology

Basin characterization





Hydrological modelling

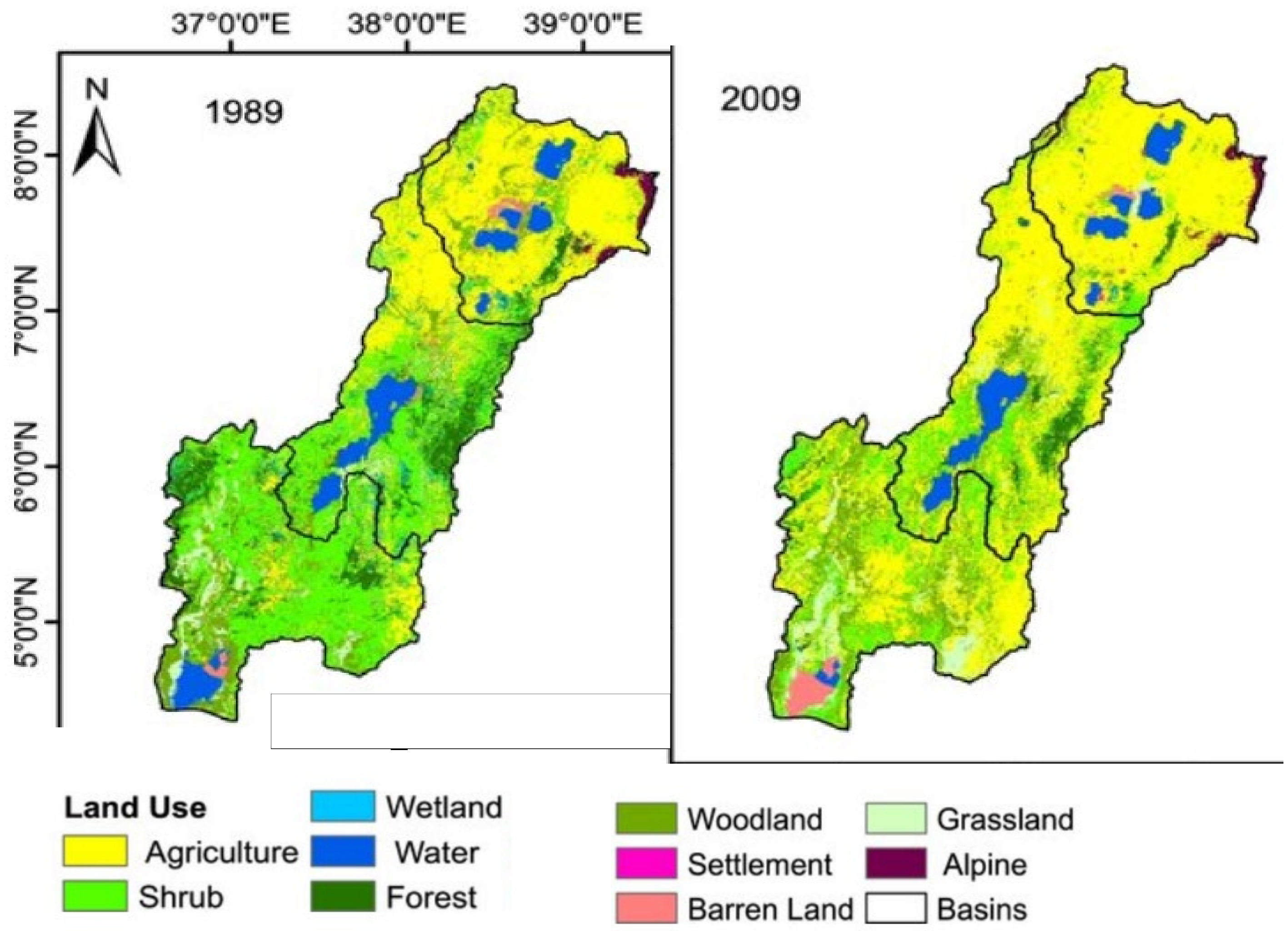


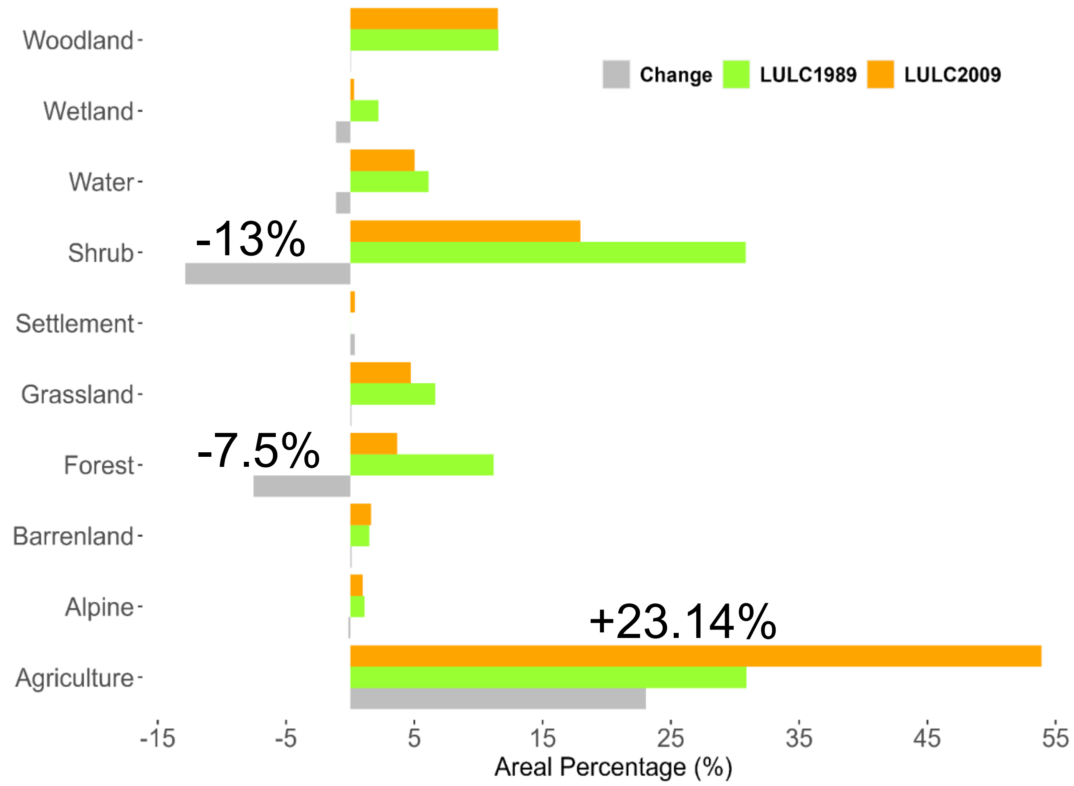
Attribution analysis(LULC & CC)

Scenario	LULC	Climate data	Objective
S1	1989	1980-2000	Baseline
S2	1989	2001-2018	CC
S3	2009	1980-2000	LULC
S4	2009	2001-2018	CC & LULC

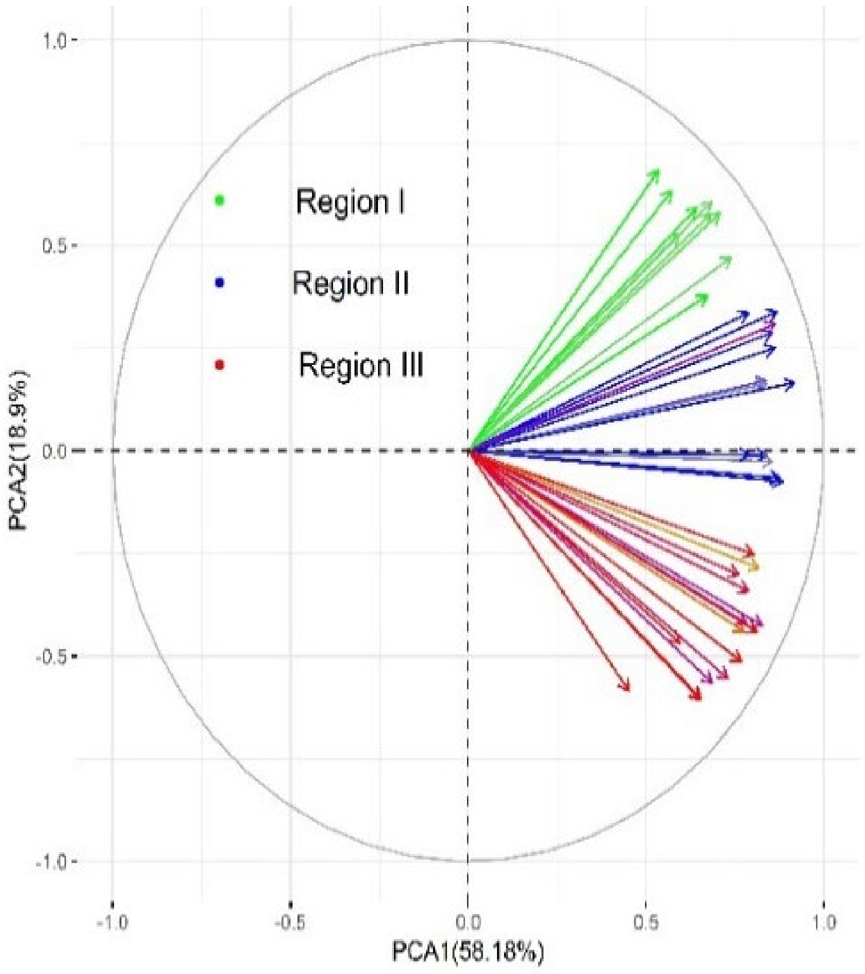
PCA/RF/cpt → SWAT+ → SWAT+

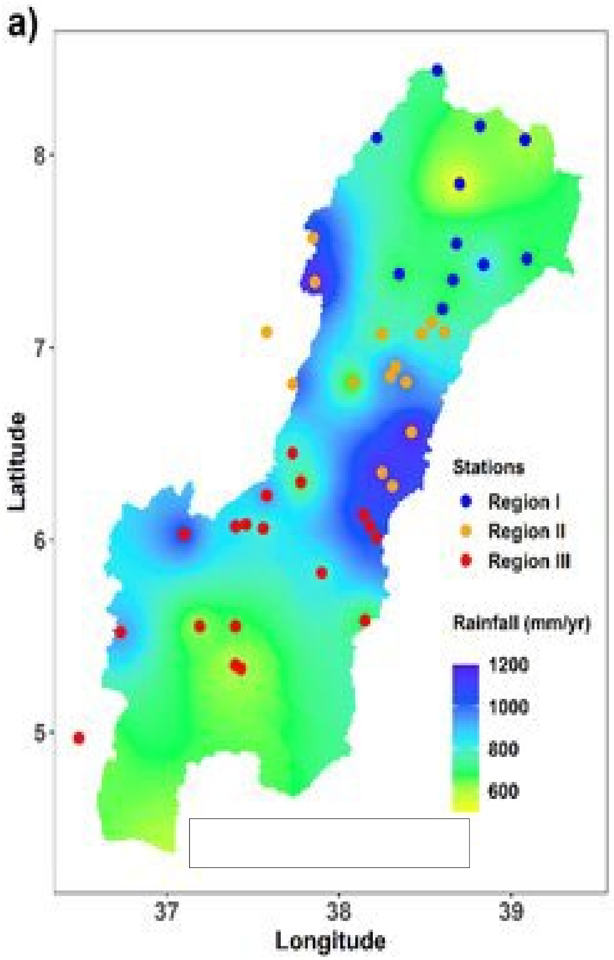
Results - LULC change

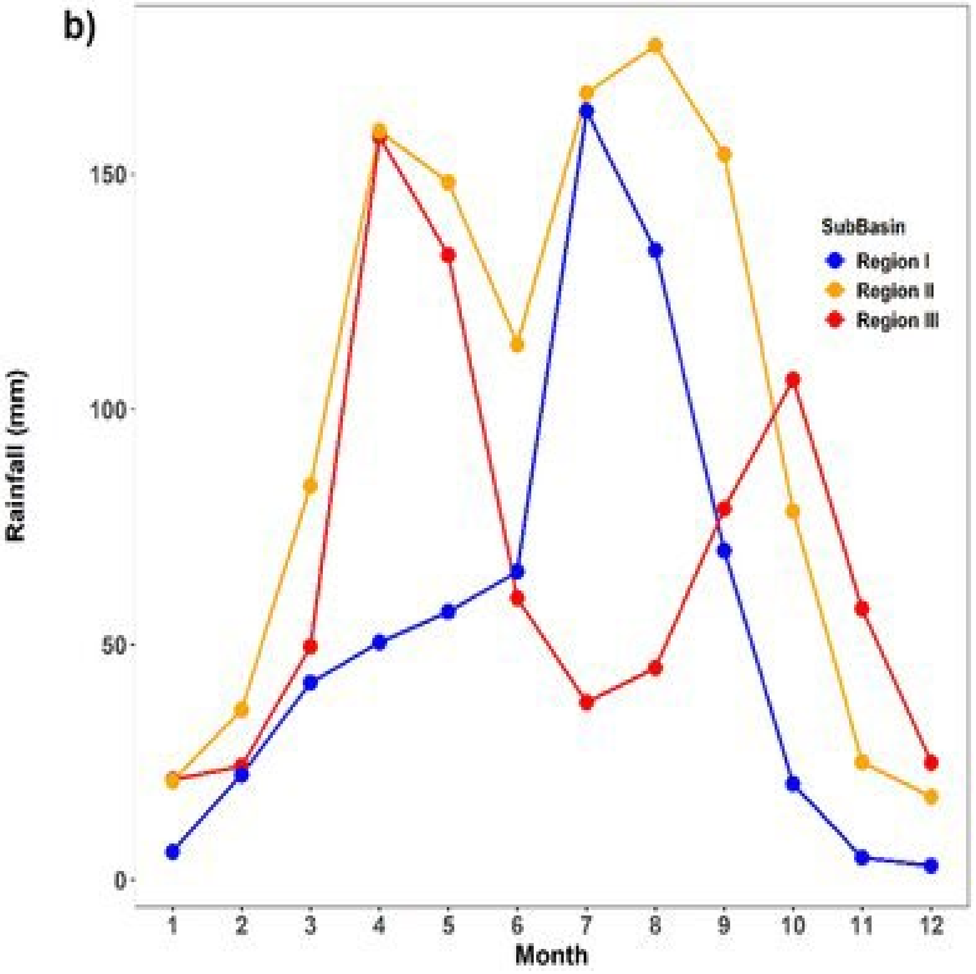




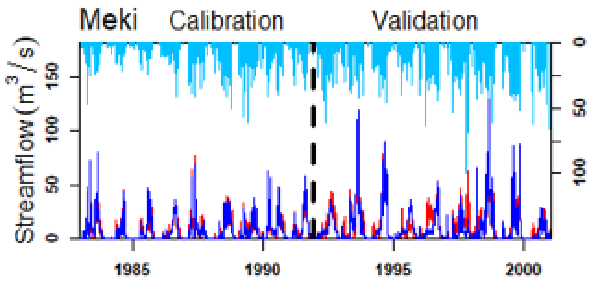
Results - Climate pattern



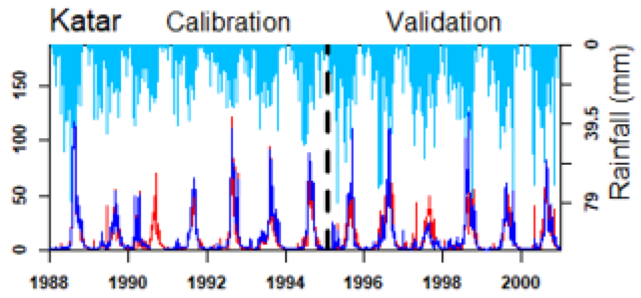




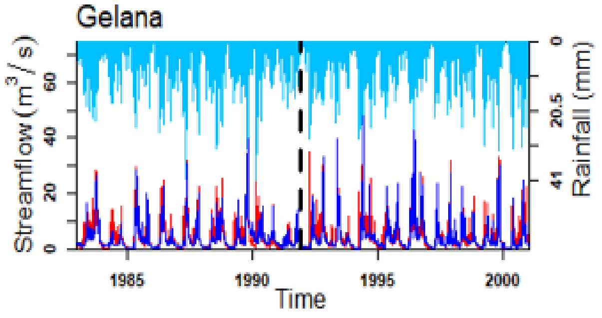
SWAT+ model calibration and validation - Hydrograph



	KGE	NSE	PBIAS	RSR
Cal.	0.81	0.70	-1.6	0.54
Val.	0.73	0.64	-2.4	0.68

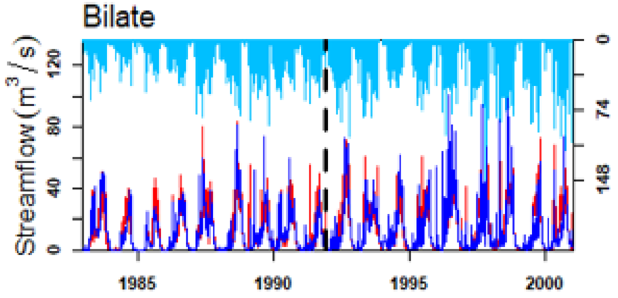


	KGE	NSE	PBIAS	RSR
Cal.	0.83	0.72	1.0	0.52
Val.	0.72	0.66	1.4	0.65



	KGE	NSE	PBIAS	RSR
Cal.	0.81	0.71	-1.8	0.62
Val.	0.76	0.65	-3.4	0.68

Rainfall (mm) Qobs (m³/s) Qsim (m³/s)



	KGE	NSE	PBIAS	RSR
Cal.	0.81	0.71	-1.8	0.62
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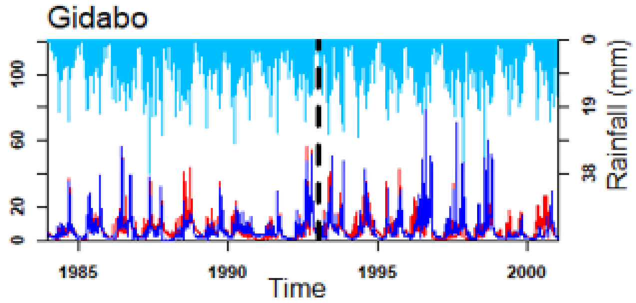
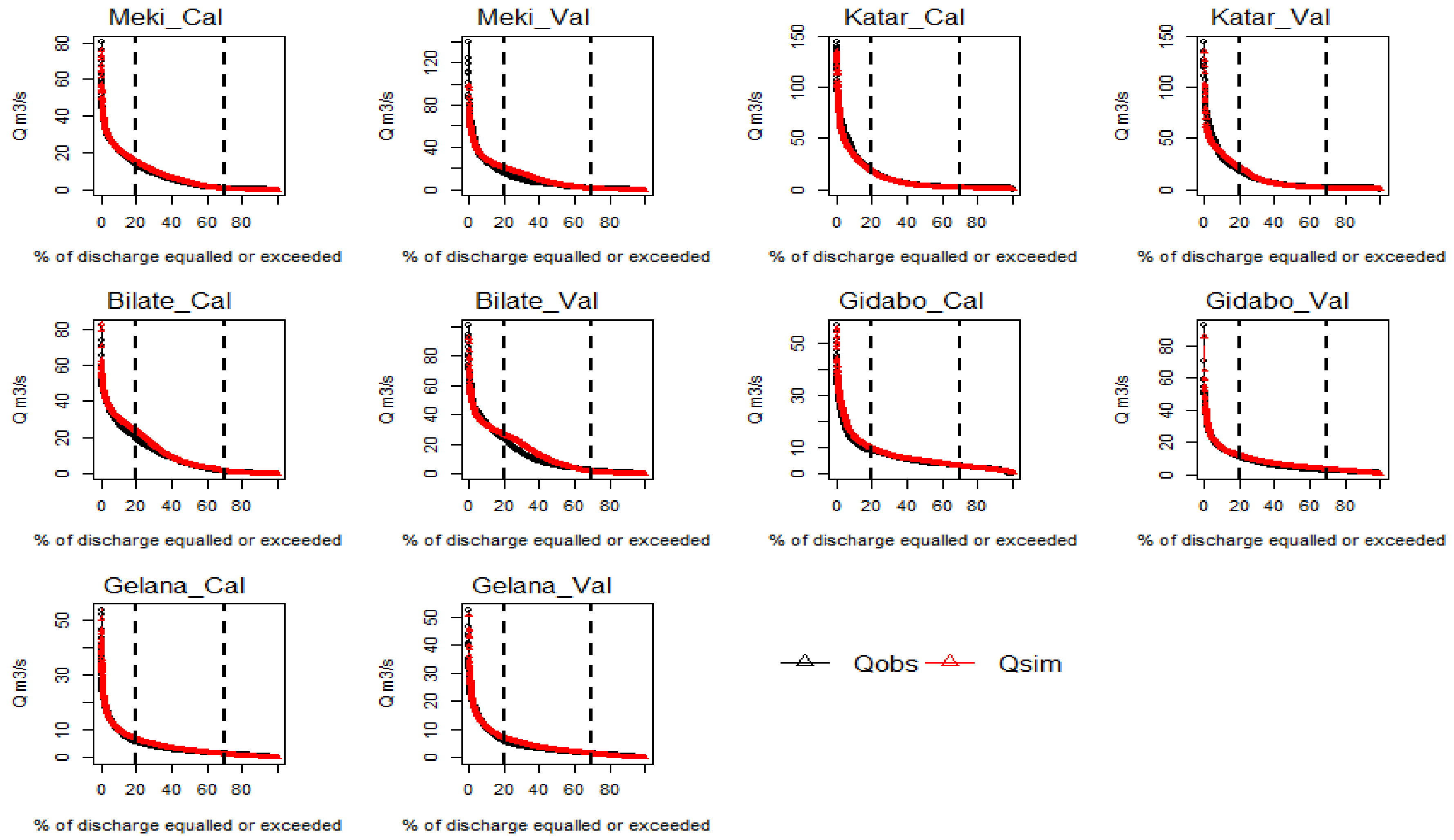


	KGE	NSE	PBIAS	RSR
Cal.	0.79	0.65	-0.6	0.56
Val.	0.68	0.61	-1.2	0.69

Using R packages

- FME for Latin Hypercube Sampling(Soetaert and Petzoldt, 2010)
- hydroGOF for model evaluation (Zambrano-Bigiarini, 2014),

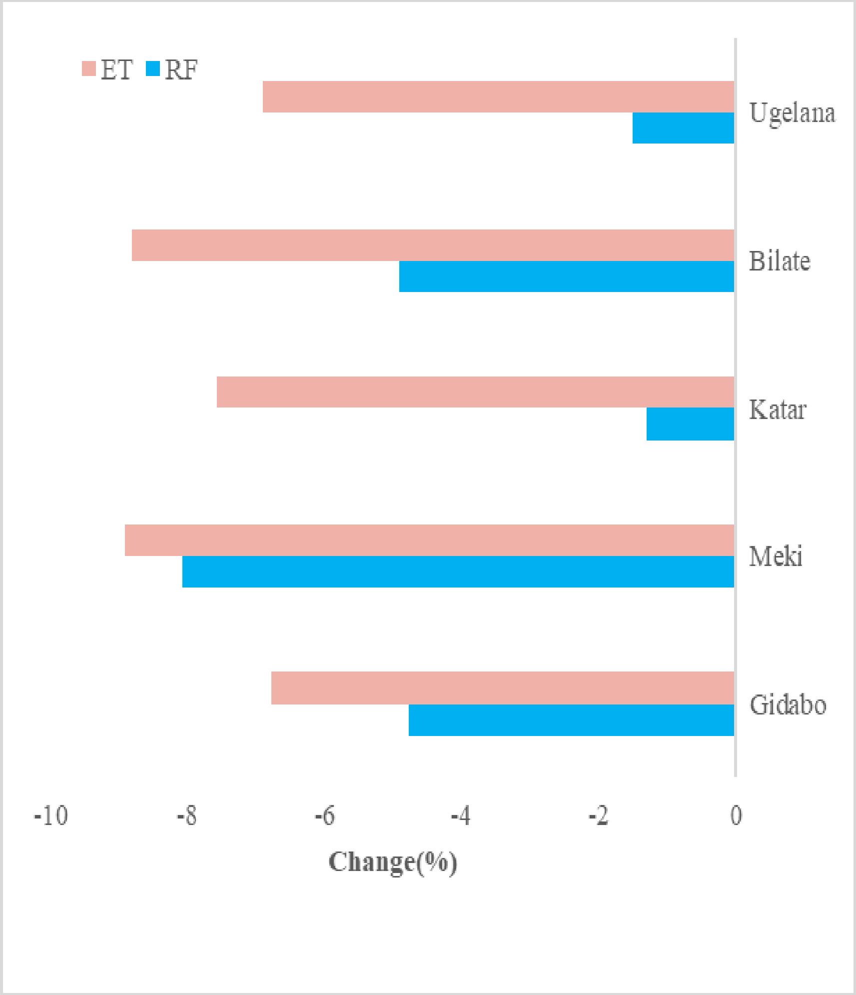
SWAT+ model calibration and validation - FDC



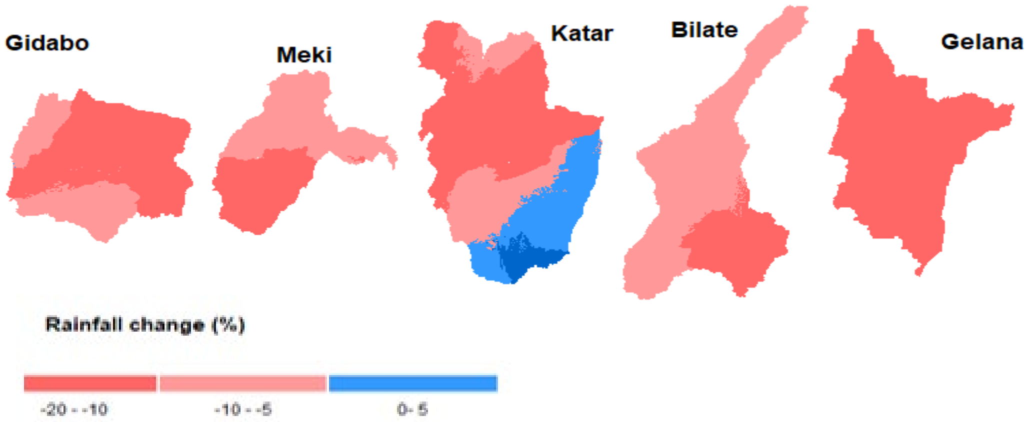
Model performance for d/f flow regimes

- High flow
- Mid flow
- Low flow

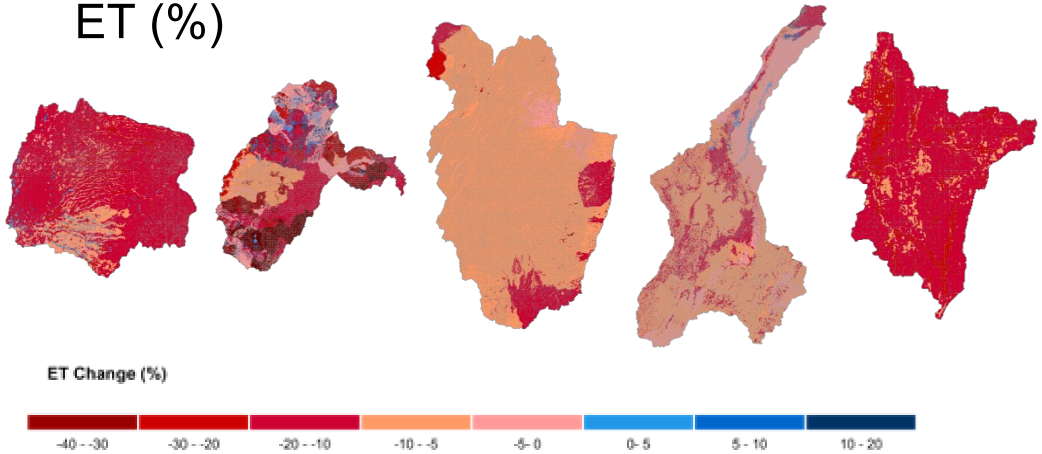
Results - Water balance change (1980-2000/2001-2018)



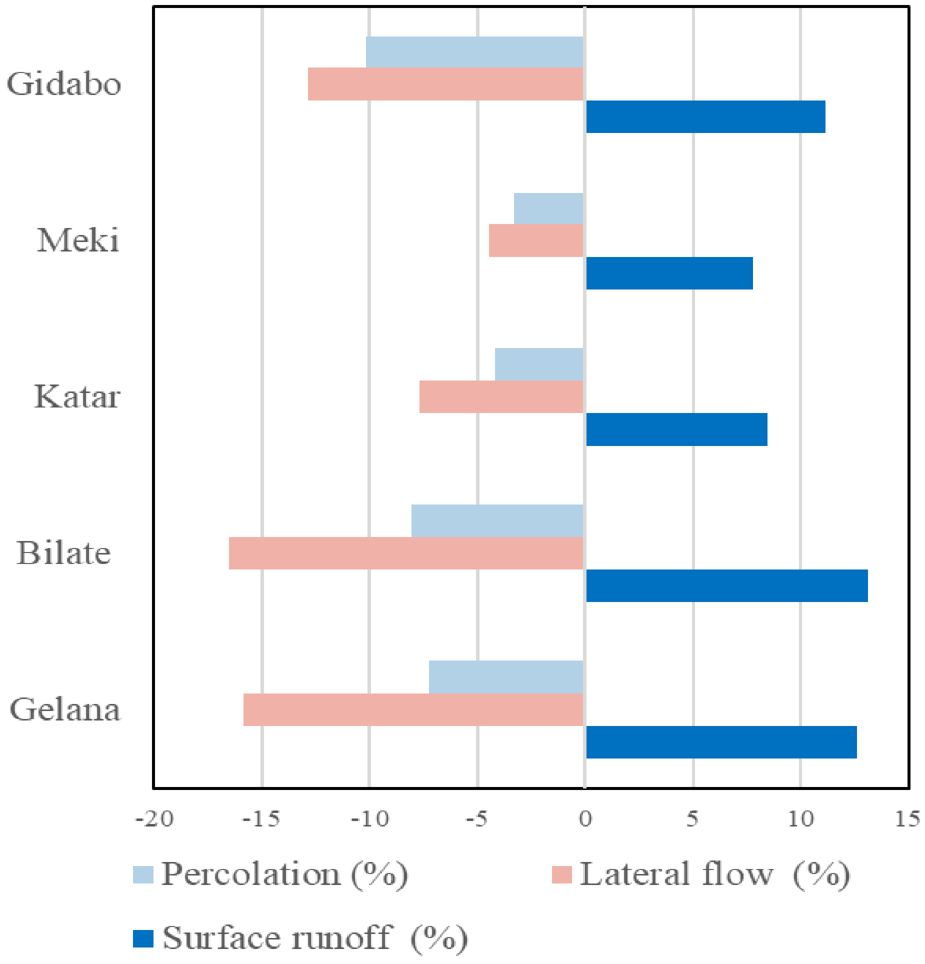
Rainfall change (%)

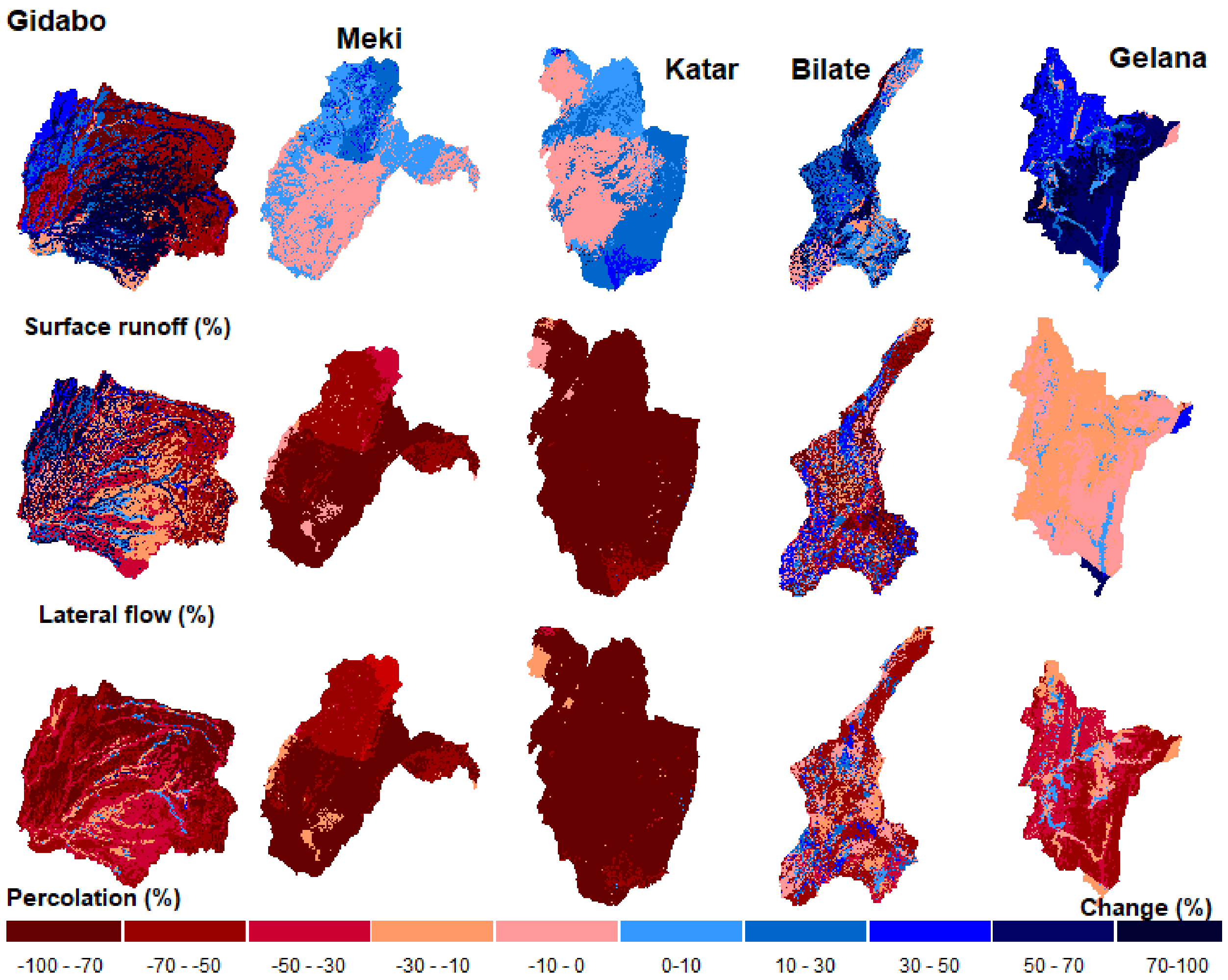


ET (%)

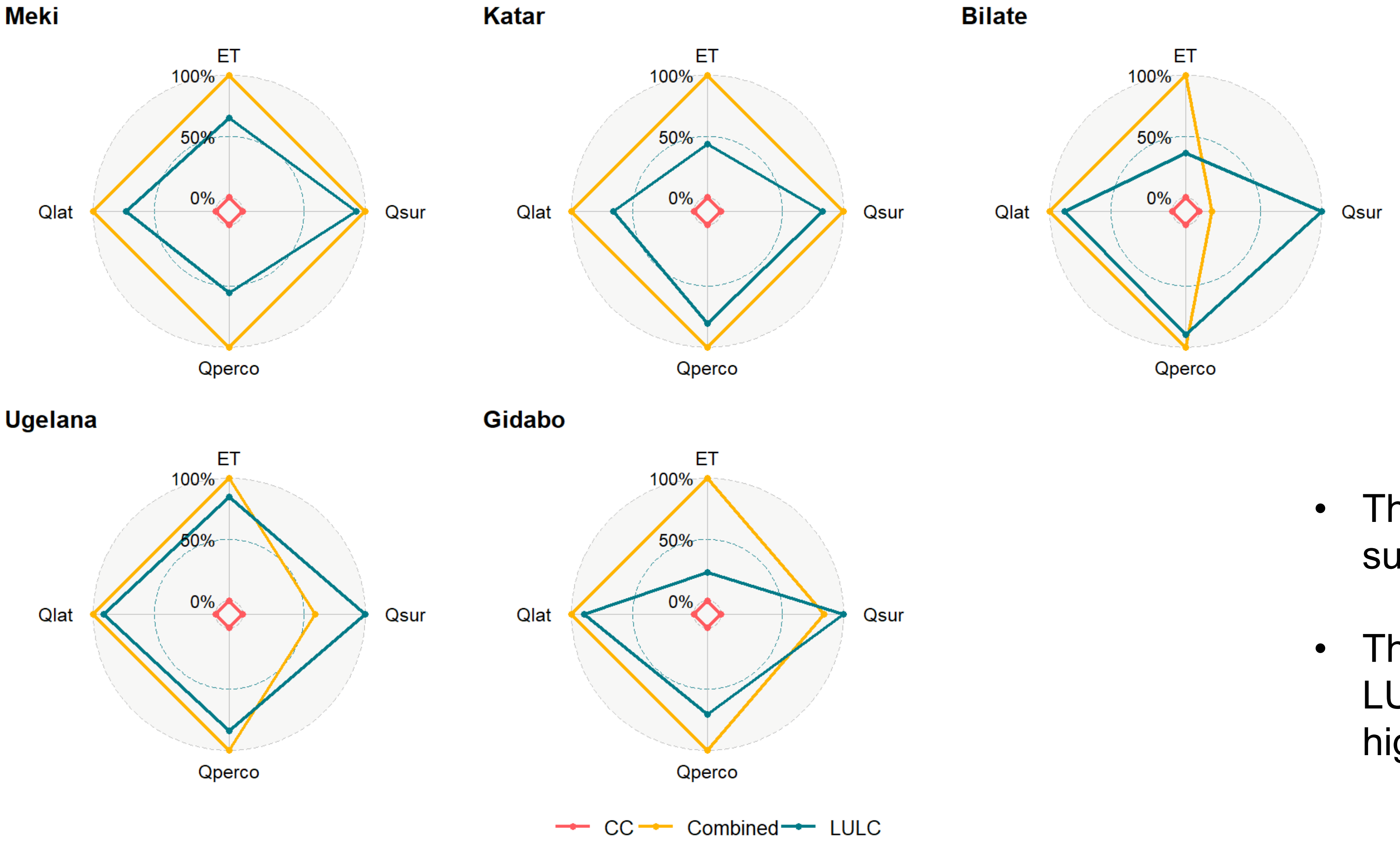


Results - Water balance change





Attribution of LULC and climate change on WBC



- The attribution of LULC on surface runoff is higher
- The attribution of combined CC & LULC on regional hydrology is higher

Summary and conclusion

- The hydrological system responds significantly to LULC changes and climate dynamics.

- The isolated impact of LULC change increased surface runoff and decreased infiltration and ET.

- The isolated impact of climate dynamics decreased all water balance components.

- LULC change had a greater impact on regional hydrological change compared to climate change.

Acknowledgments:

- German Academic Exchange Service (DAAD)
- Ethiopian Ministry of Education
- Ethiopian Ministry of Water Resources
- Ethiopian Meteorology Agency

Thank you very much for your attention!

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		2009										
	Class	Agriculture	Alpine	Barren	Forest	Grass	Settlement	Shrub	Water	Wetland	Wood	**Total**
1989	Agriculture	27.36	0.11	0.05	0.12	0.48	0.13	1.82	0.04	0.04	0.74	30.88
	Alpine	0.34	0.66	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	1.10
	Barren	0.49	0.00	0.23	0.01	0.03	0.02	0.31	0.19	0.00	0.20	1.48
	Forest	4.43	0.10	0.02	2.44	0.10	0.03	2.95	0.05	0.08	0.99	11.19
	Grass	1.88	0.00	0.04	0.02	1.45	0.01	0.55	0.00	0.00	0.67	4.62
	Settlement	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	Shrub	12.79	0.08	0.05	0.78	1.06	0.09	9.13	0.08	0.07	6.77	30.89
	Water	0.02	0.00	1.17	0.02	0.14	0.00	0.09	4.63	0.00	0.03	6.11
	Wetland	1.11	0.01	0.00	0.20	0.01	0.01	0.68	0.02	0.05	0.08	2.17
	Wood	5.59	0.00	0.05	0.07	1.45	0.05	2.26	0.04	0.01	1.99	11.53
Total		54.02	0.97	1.60	3.67	4.72	0.37	17.89	5.04	0.25	11.48	100.0
Net loss/gain		23.14	-0.14	0.12	-7.52	0.10	0.32	-13.0	-1.08	-1.92	-0.04	

Climate pattern and trend

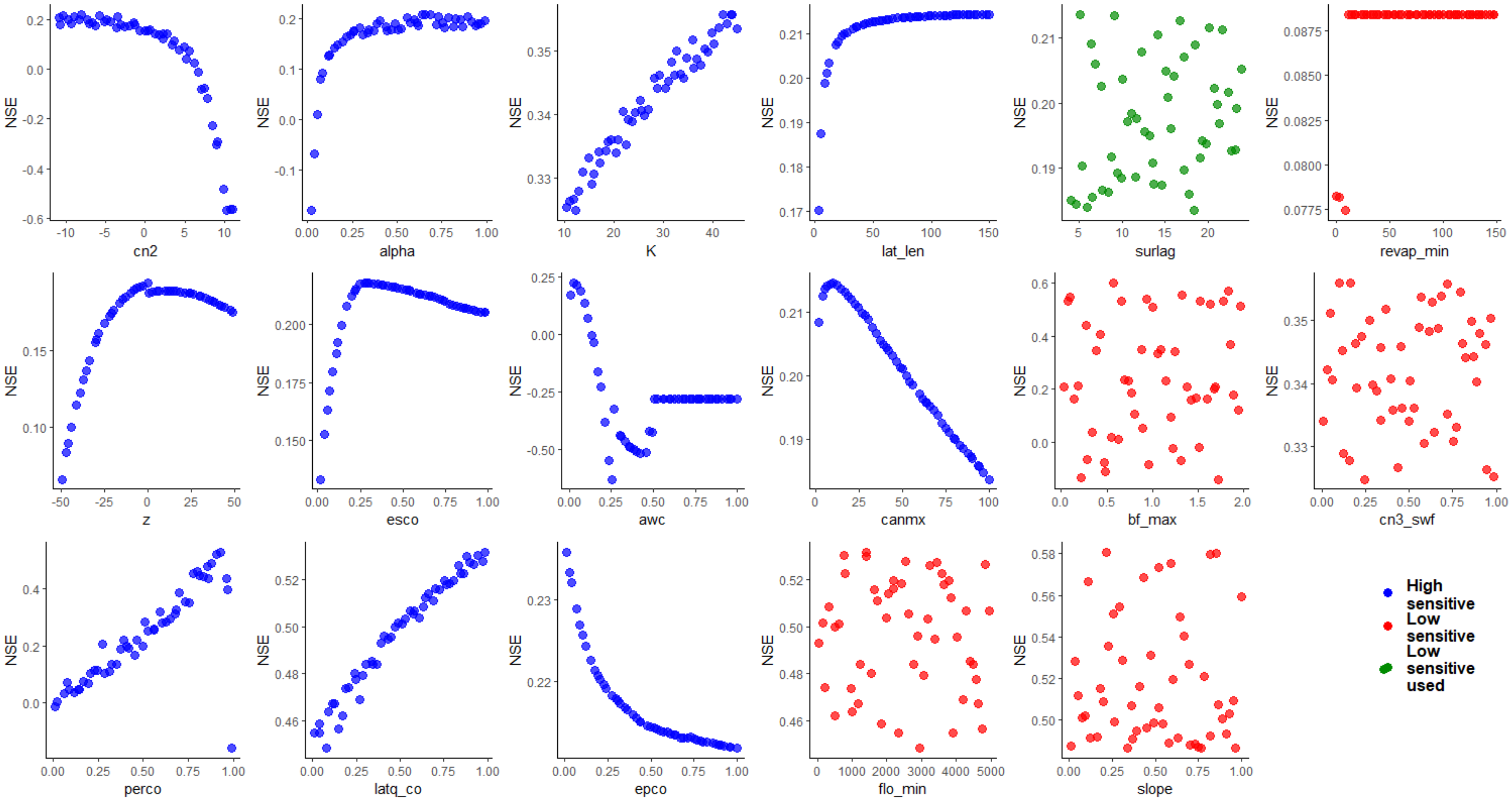
Climate change significancies

	R1		R2		R3		Temp	
	Base line	Interference	Base line	Interference	Base line	Interference	Base line	Interference
Tau	-0.147	-0.094	-0.0667	-0.123	-0.133	0.157	0.39	0.6
P	0.38	0.5995	0.695	0.48411	0.415	0.3833	0.0144	0.000359

SWAT+ model - Calibrated parameters

Parameters	Description	Limit		Change	Fitted range			
		Min	Max		R I		R II	
					Min	Max	Min	Max
CN2	Condition II curve number	-15	+15	abschg [a]	-5	+5	-15	-10
Sol-Awc	Available water capacity of the soil layer (mm H2O/mm soil)	-0.25	+0.25	abschg	-0.16	+0.15	-0.16	+0.15
ESCO	Soil evaporation compensation coefficient	0	1	absval [b]	0.01	0.3	0.01	0.15
SURLAG	Surface runoff lag Coefficient (days)	0	24	absval	0.1	10	0.1	10
PERCO	Percolation coefficient (mm H2O)	0	1	absval	0.01	0.5	0.01	0.3
LATQ_CO	Lateral flow contribution to reach (mm H2O)	0	1	absval	0.01	0.3	0.01	0.3
ALPHA_BF	Baseflow recession constant fast aquifer (days)	0	1	absval	0.01	0.6	0.01	0.3
k	Saturated hydraulic conductivity (mm/h)	-45	+45	pctchg[c]	-10	+15	-10	+15
EPCO	Plant uptake compensation factor	0	1	absval	0.6	0.9	0.6	0.9
z	Soil depth (mm)	-45	+45	pctchg	-15	+0	-15	+0

SWAT+ Model parameterization - Sensitivity Analysis



- Morris' screening (one factor at a time [OAT])

Attribution of LULC and climate change on WBC

		ET		Qsur		Qlat		Perco	
	Scenario	Change(%)	RC (%)	Change(%)	RC (%)	Change(%)	RC (%)	Change(%)	RC (%)
Ugelana	cc	1.89	37.61	-4.29	-58.83	-0.39	-6.67	-0.35	-2.86
	lulc	-4.53	-90.44	3.38	128.76	-5.41	-92.00	-10.38	-84.87
	combined	-5.01	-100.00	2.63	100.00	-5.88	-100.00	-12.24	-100.00
Bilate	cc	2.00	37.30	-7.19	- 88.32	-2.31	-13.97	-1.72	-21.23
	lulc	-3.24	-60.28	16.44	202.05	-17.22	-104.29	-7.44	-92.05
	combined	-5.37	-100	8.14	100.00	-16.51	-100.00	-100.00	-100.00
Gidabo	cc	0.405	3.35	-11.65	- 41.39	-2.026	-19.53	-0.41	-7.98
	lulc	-3.12	-25.712	31.29	111.14	-19.562	-188.51	-3.80	-73.22
	combined	-12.08	-100.00	28.15	100.00	-10.377	-100.00	-100.00	-100.00
Katar	cc	1.39	12.80	-6.84	-30.20	-0.84	-2.57	-0.83	-26.33
	lulc	-5.49	-50.64	13.13	57.99	-32.32	-98.93	-2.70	-85.68
	combined	-12.05	-100.00	31.65	100	-32.10	-100.00	-100.00	-100.00
Meki	cc	0.58	32.28	-15.96	-76.21	-10.22	-21.99	-9.22	-23.47
	lulc	-2.45	-135.52	16.47	94.35	-50.20	-91.02	-29.92	-76.16
	combined	-5.27	-100.00	28.28	100.00	-40.38	-100.00	-33.12	-100.00

Sensitive method

$$\alpha_l = \frac{Q_2 - Q_1}{|Q_1 - Q_4|}$$

$$\alpha_c = \frac{Q_3 - Q_1}{|Q_1 - Q_4|}$$

$$\alpha_{com} = \frac{Q_4 - Q_1}{|Q_1 - Q_4|}$$

Where Q1, Q2, Q3, and Q4 are the mean annual simulated surface runoff under S1, S2, S3, and S4 scenarios; and α_l , α_c and α_{com} denote the relative contributions of LUCC, climate variability and combined effect on the water balance components, respectively.