Christian-Albrechts-Universität zu Kiel

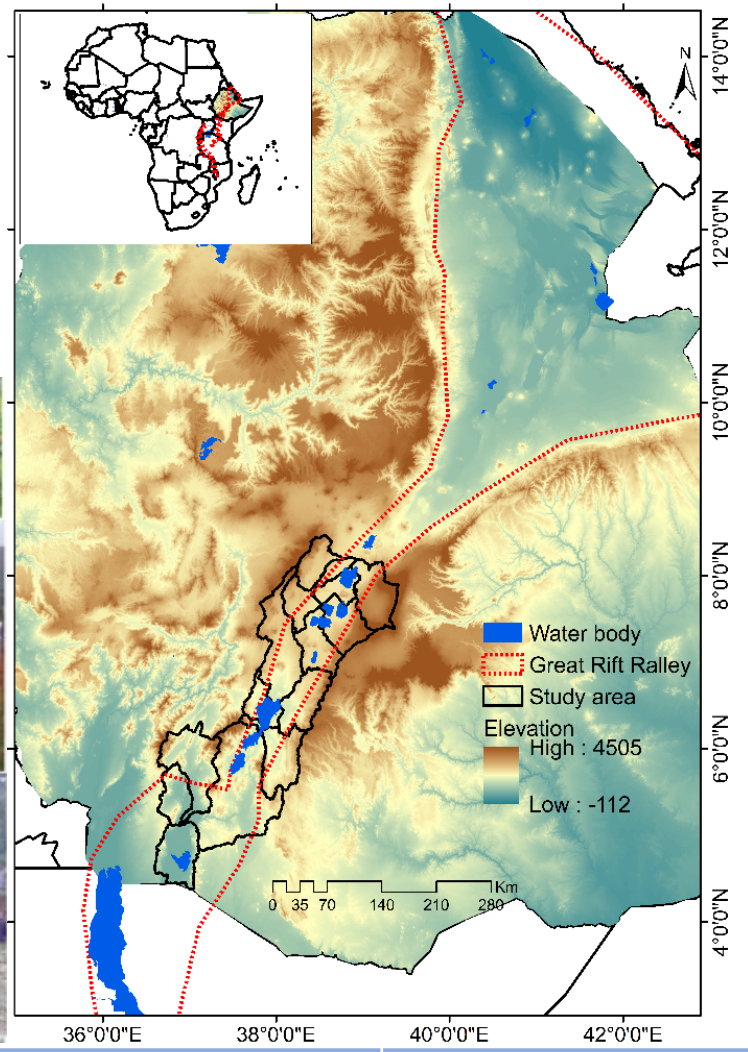
Unveiling Hydrological Dynamics in Data-Scarce Regions: A Comprehensive Integrated Approach

Ayenew Desalegn, Paul Wagner, Dejene Sahlu, and Nicola Fohrer

Department of Hydrology and Water Resources Management

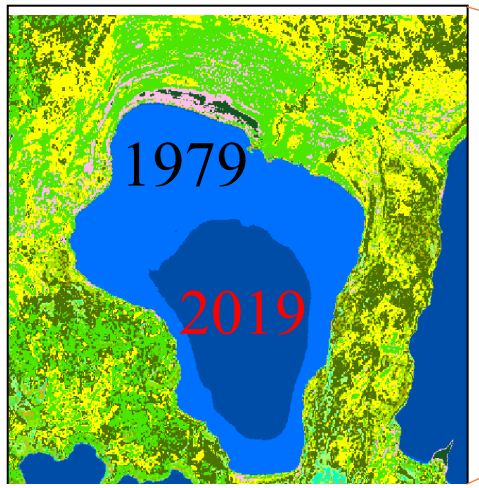
Ethiopian Rift Valley Lakes Basin

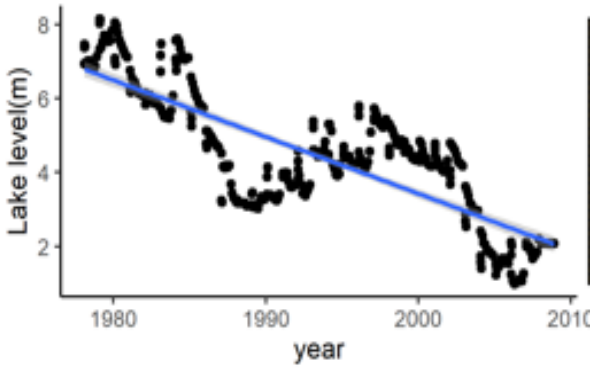
- It is part of the Great Rift Valley and located in the central part of Ethiopia
- Contains 80% of Ethiopian lakes
- Characterized by diverse landscapes
- The climate varies from semi-arid to temperate

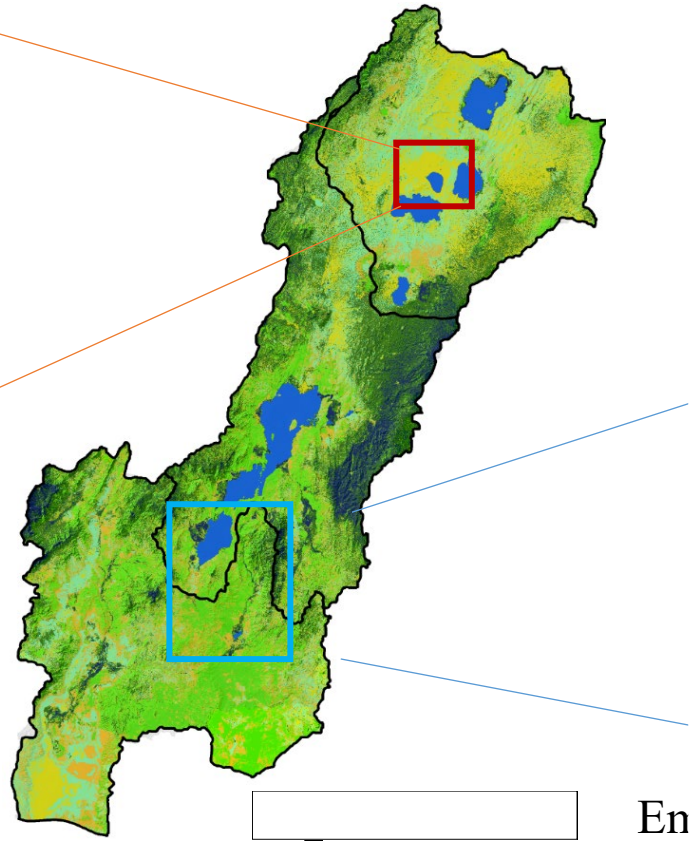


The hydrological system is changing (losing & **gaining water**)

Area decline (68%)







En

Water resources are under pressure

- The ever **increasing water demand** for irrigation, industrial use and domestic purpose
  (TA Hulluka et al. 2023).

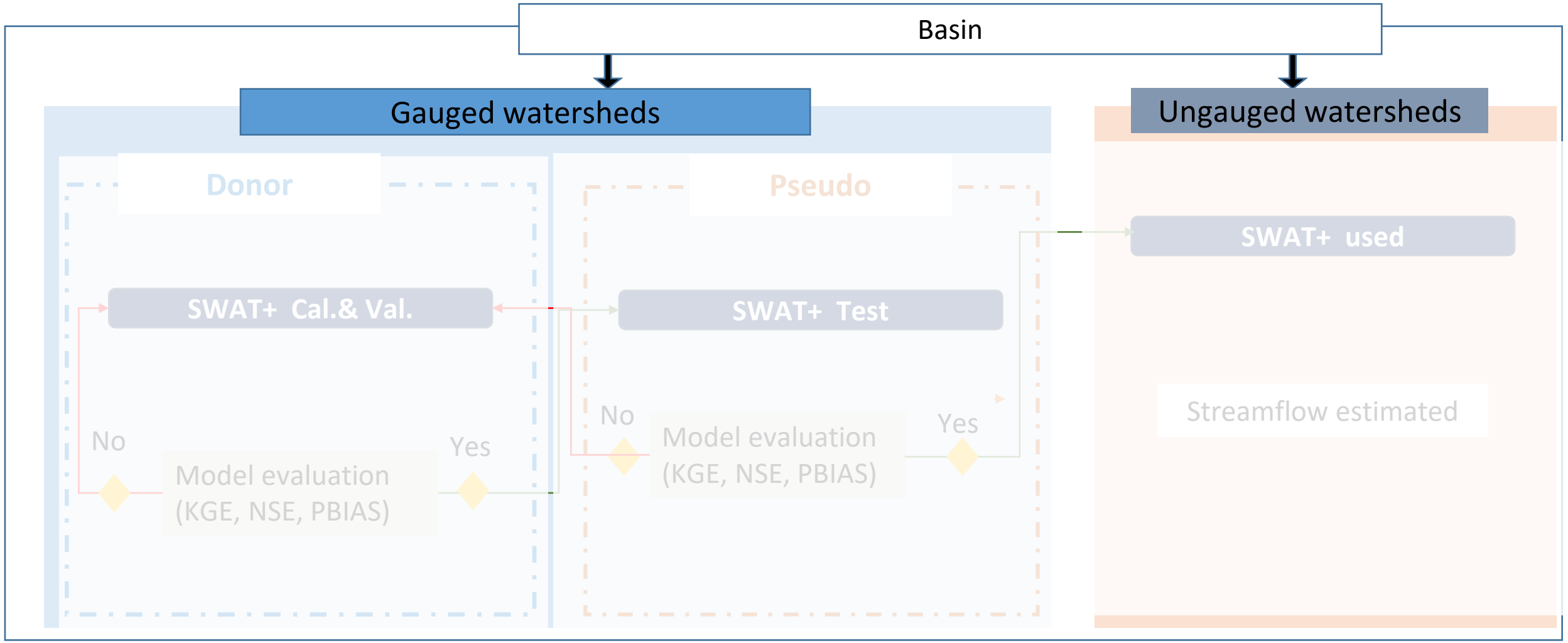
- Critical knowledge gaps about the hydrological system

- Emerging water management and governance problems

Objectives

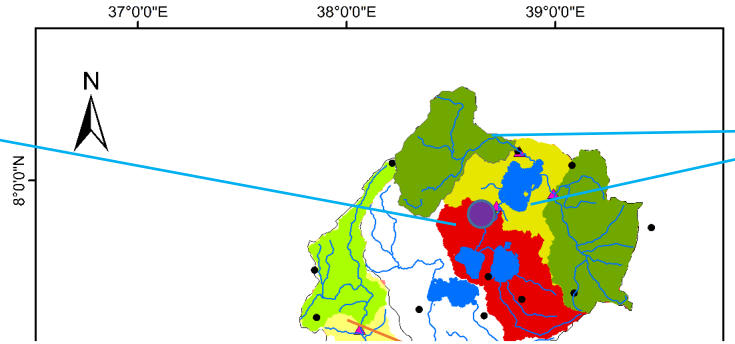
- Quantify and assess the dynamics of main water balance components
- Analyze the spatial and temporal patterns of hydrological change
- Identify the primary drivers of hydrological changes

Regionalization



Regionalization

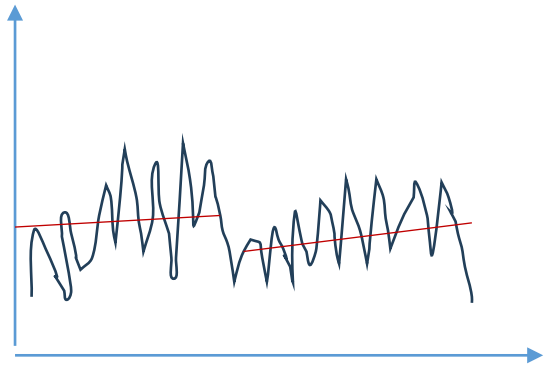
Donor
watershed



Pseudo
watersheds

Change detection and sedimentation

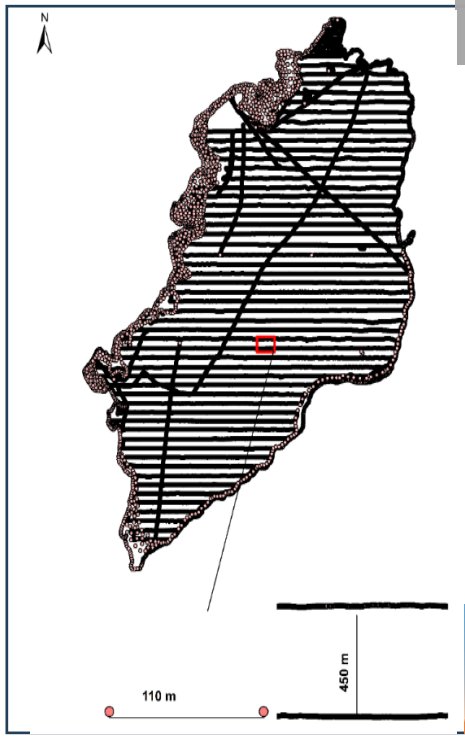
Change detection



- Climate
- Streamflow
- Lake level

Statistical method

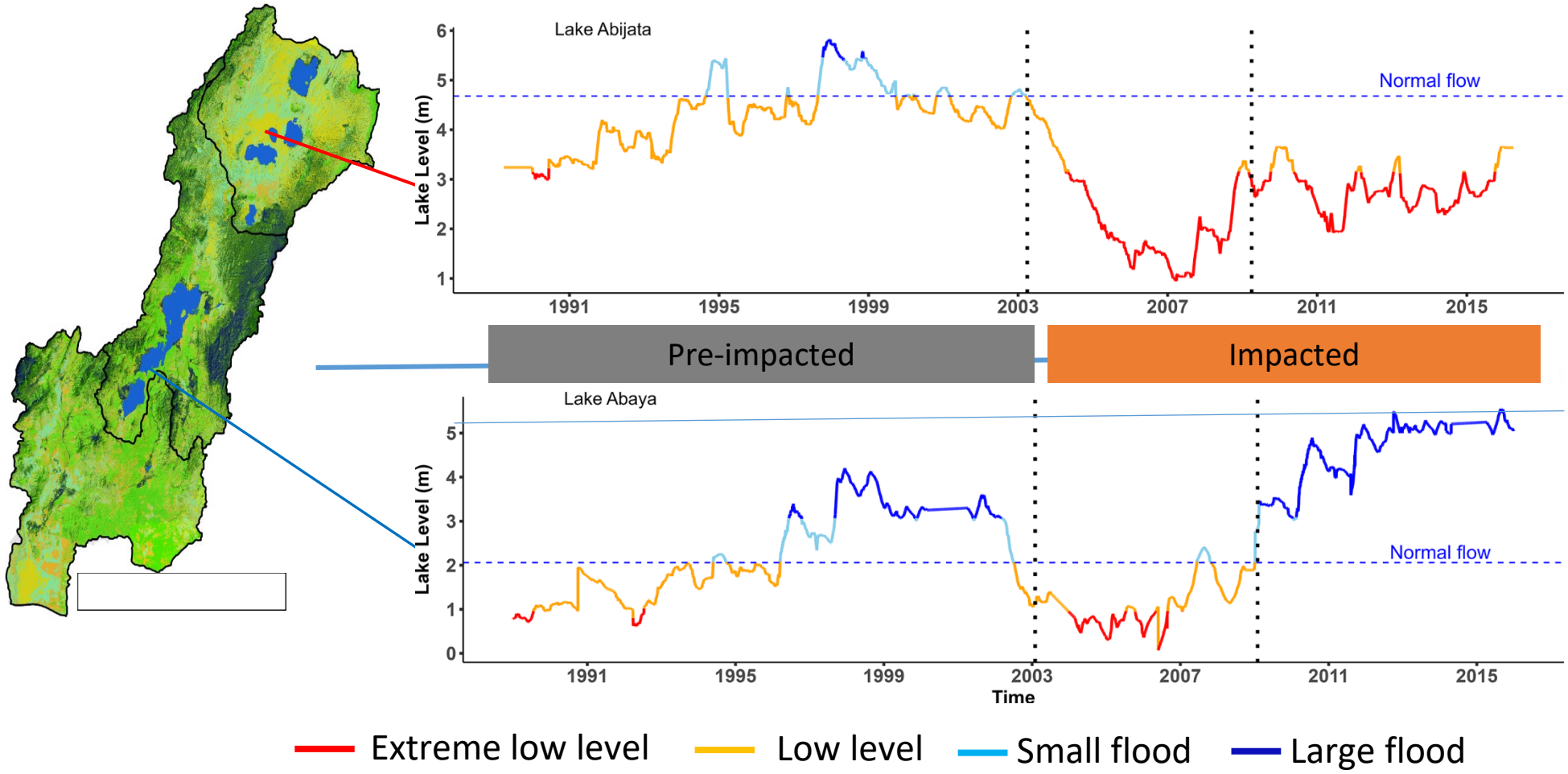
Sedimentation



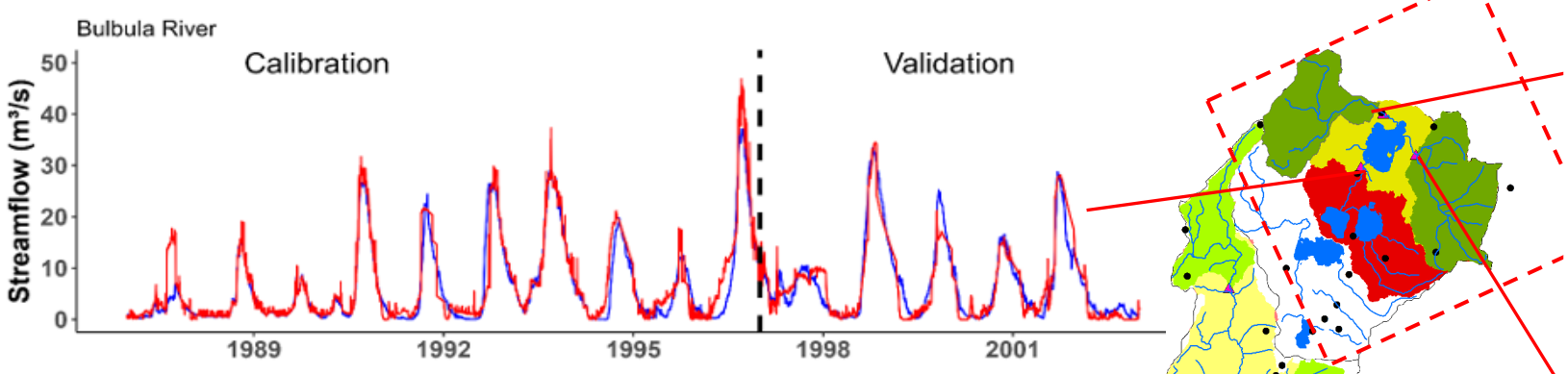
Bathymetry survey

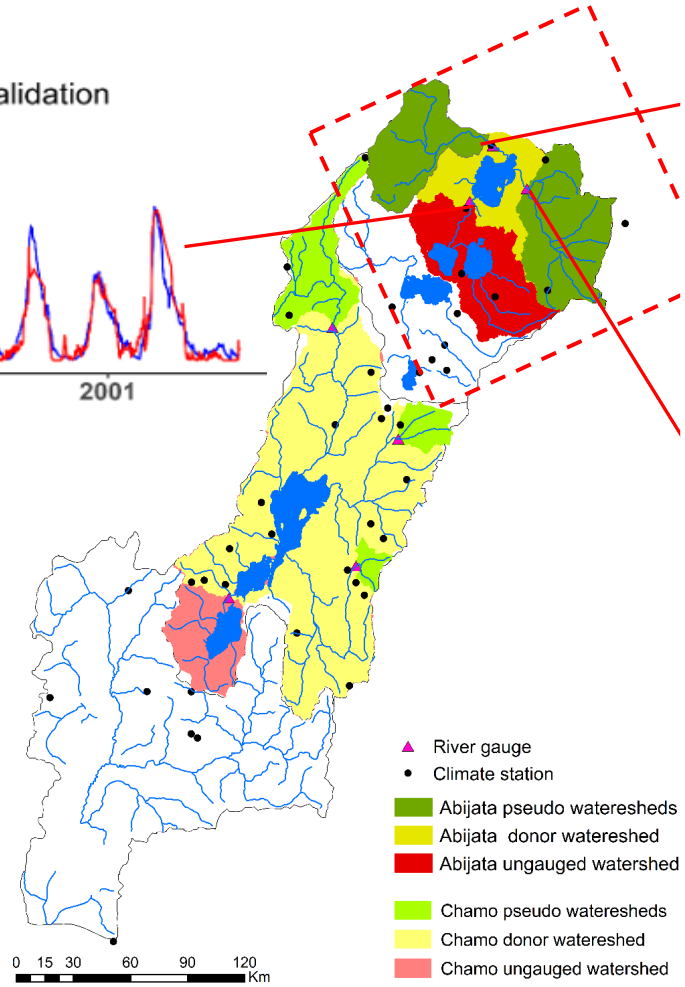
Results

Spatio-temporal patterns of hydrological change

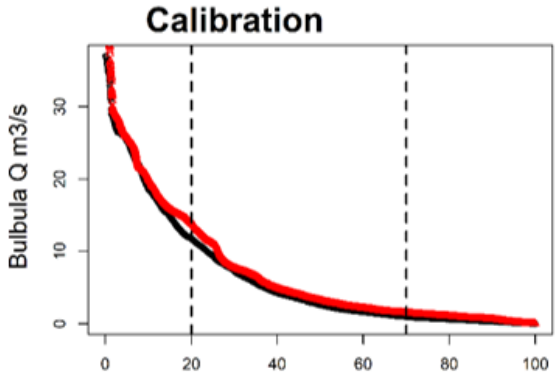


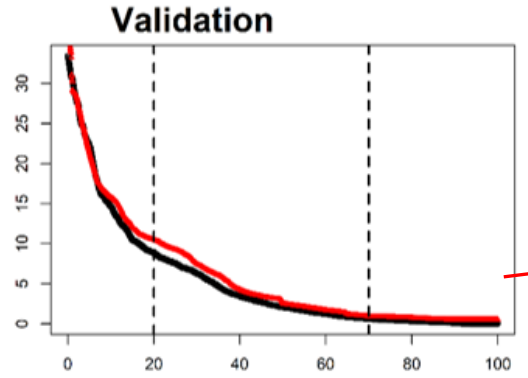
Water-losing basin: regionalization





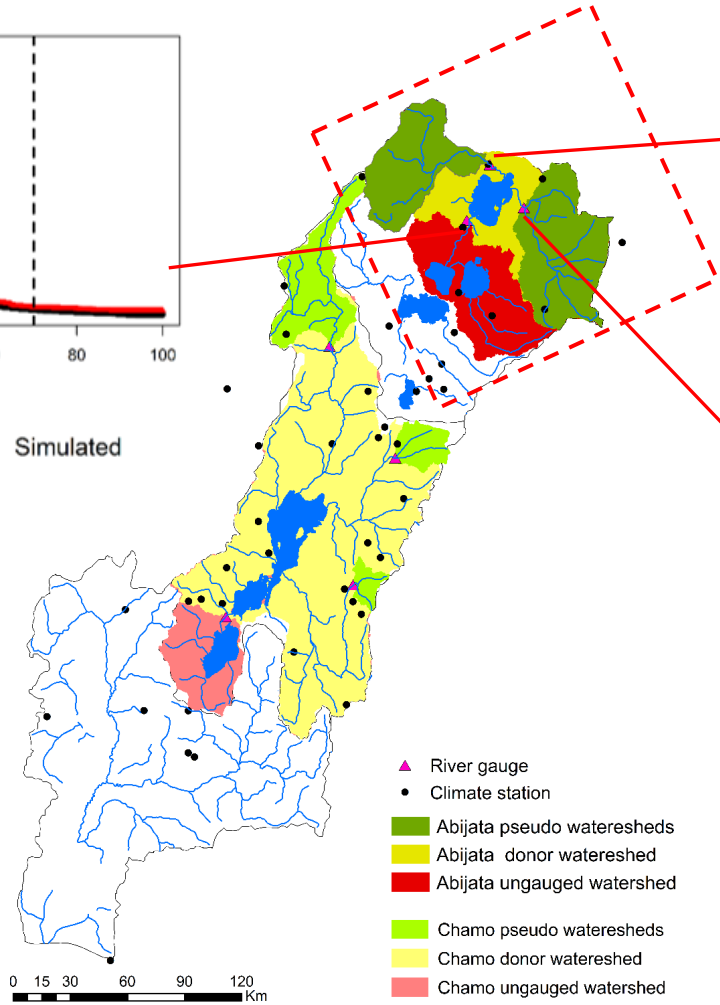
Water-losing basin: regionalization

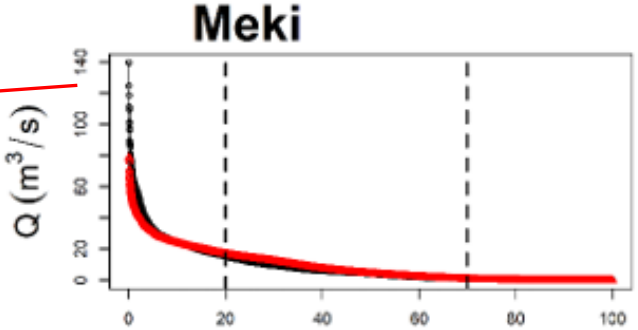


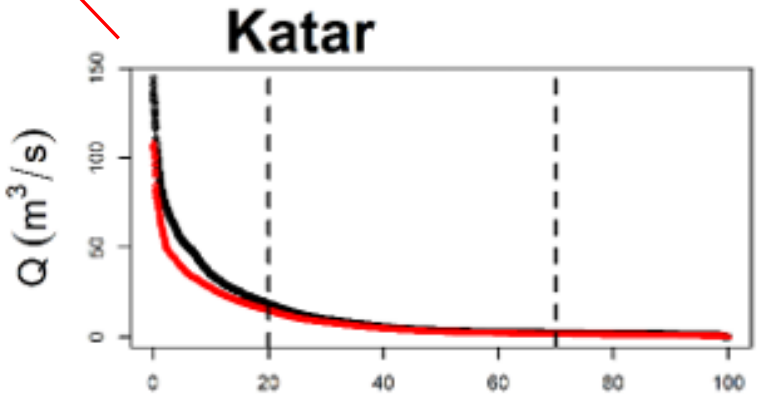


Observed Simulated

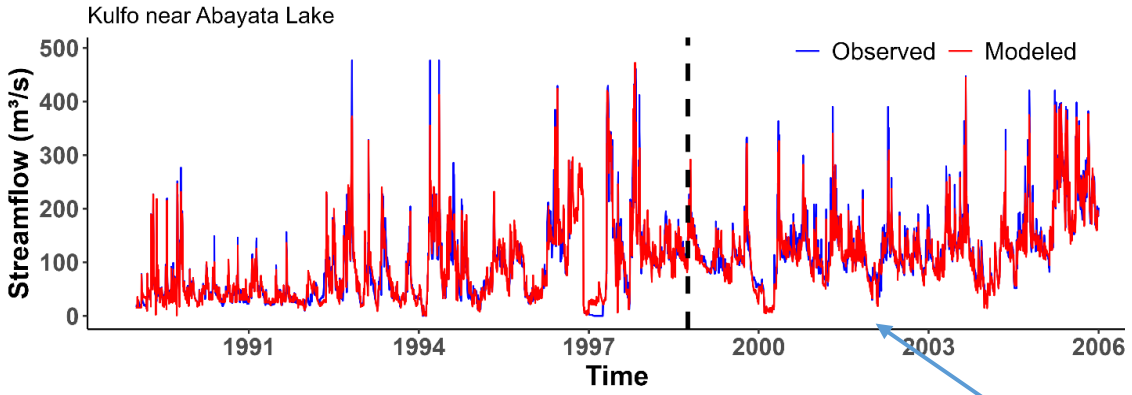
Watershed	Method	KGE
Bulbula (Donor)	Cal.	0.84
	Val.	0.80
Meki (Pseudo)	Test	0.71
Katar (Pseudo)	Test	0.75

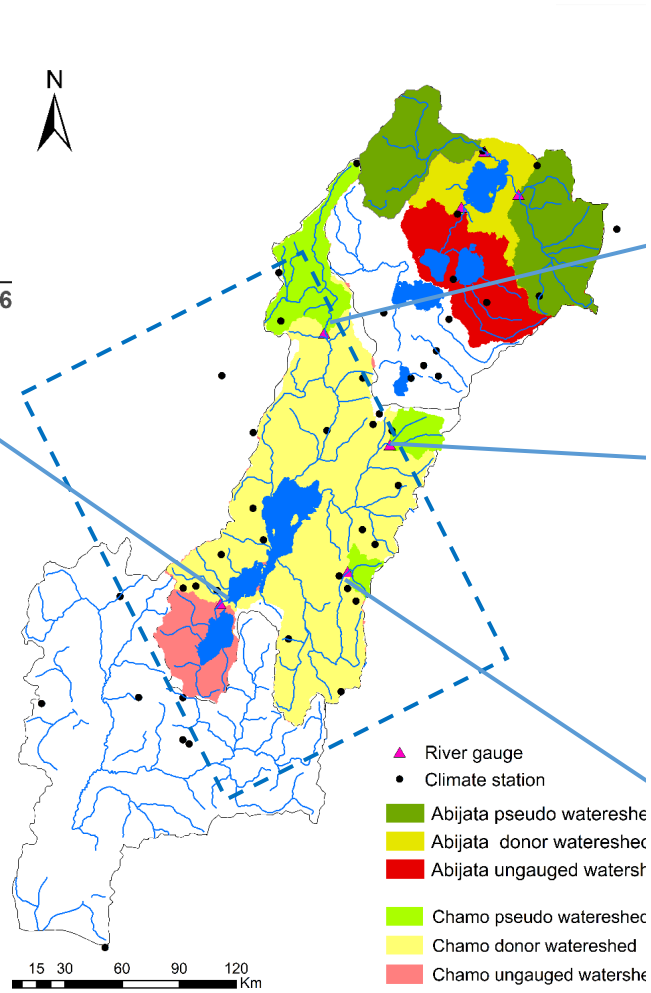




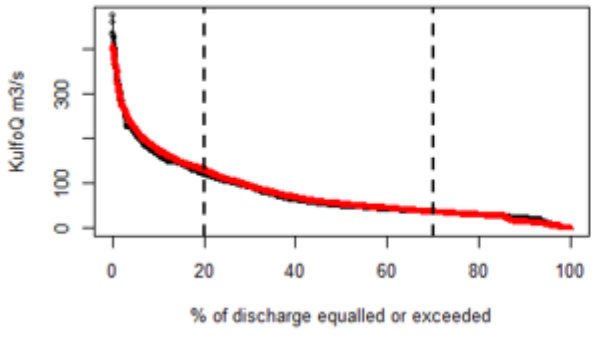


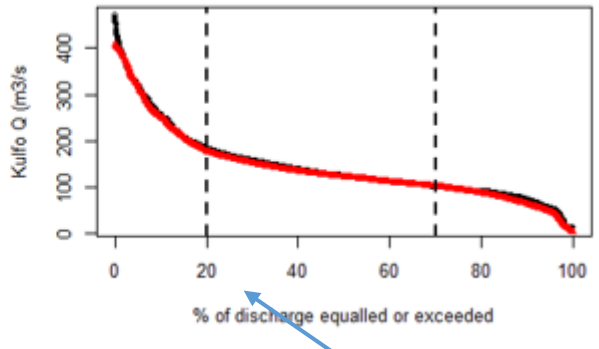
Water-gaining basin: regionalization



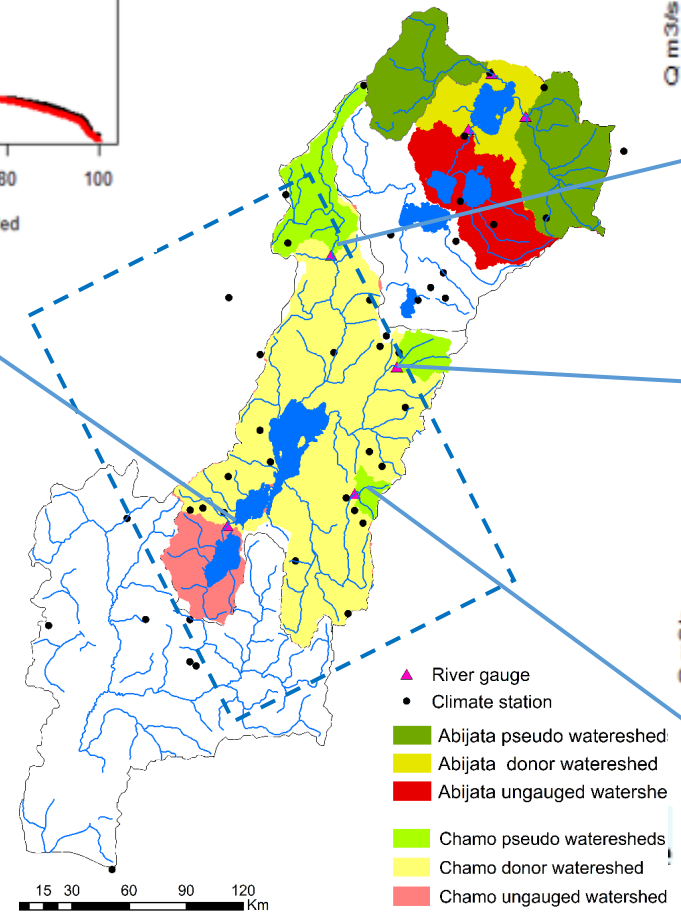


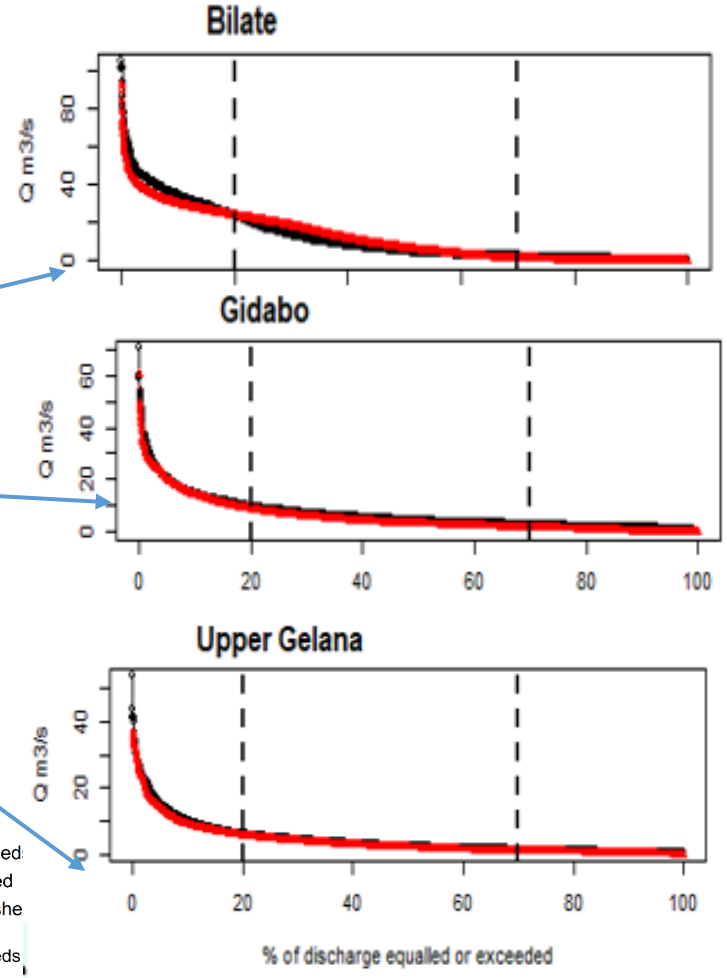
Water-gaining basin: regionalization



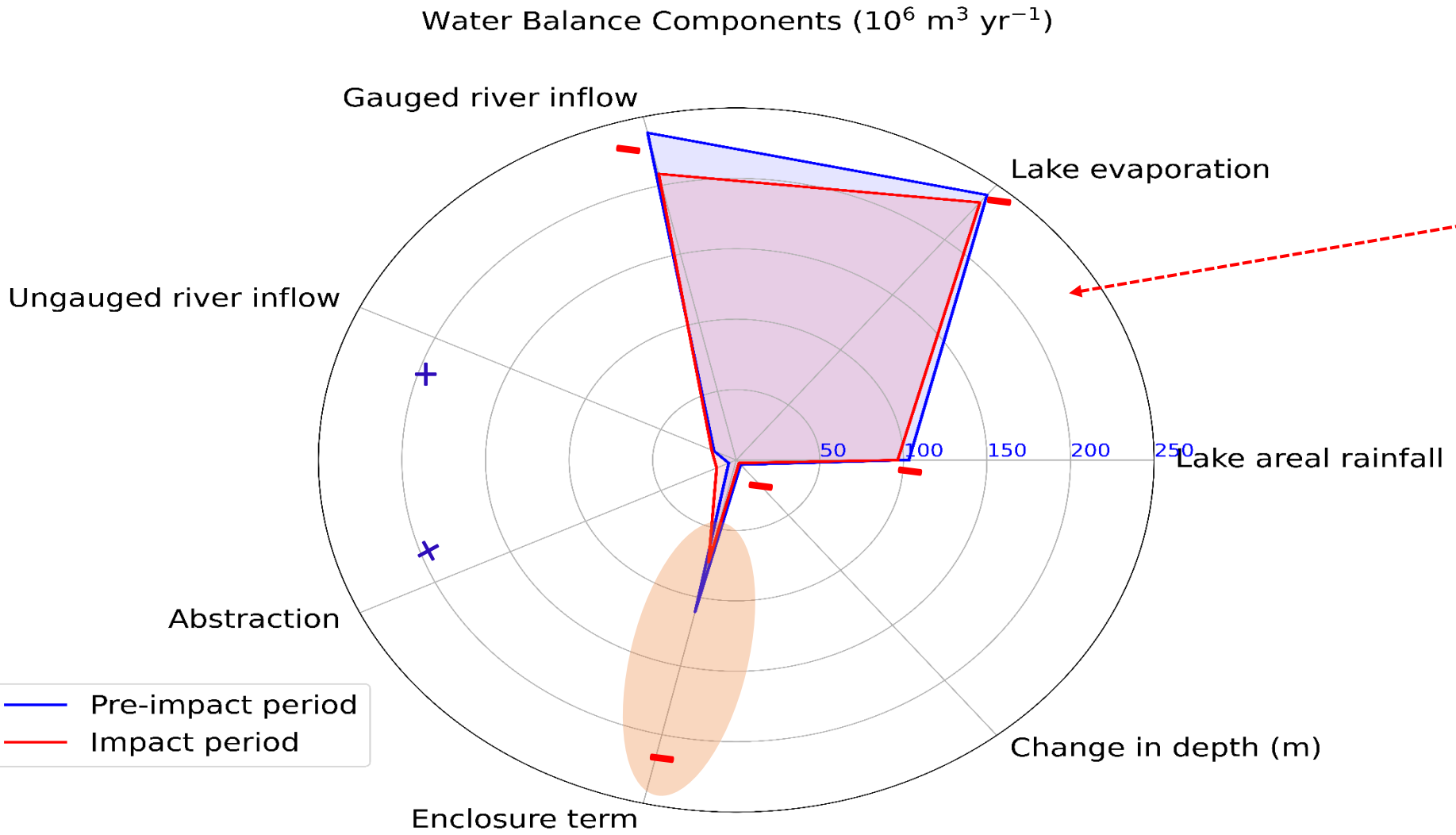


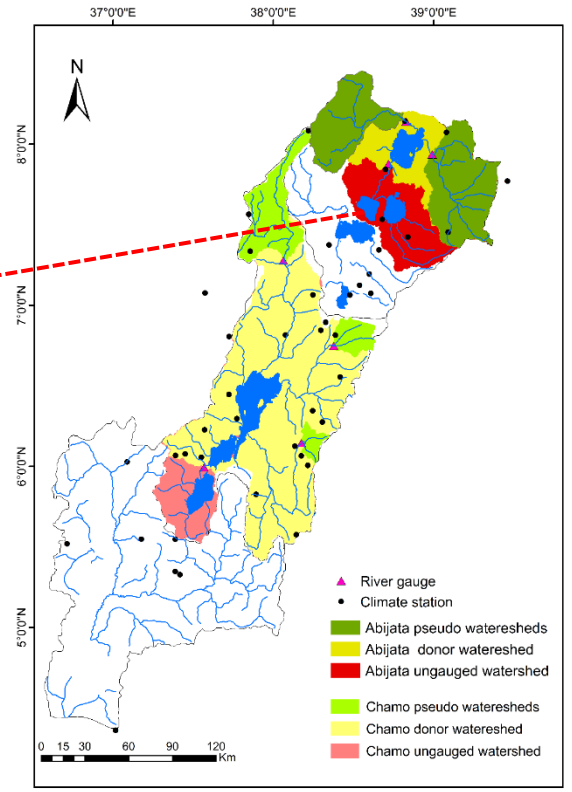
Watershed	Method	KGE
Kulfo (Donor)	Cal.	0.81
	Val.	0.78
Gidabo (Pseudo)	Test	0.70
Gelana (Pseudo)	Test	0.67
Bilate (Pseudo)	Test	0.59



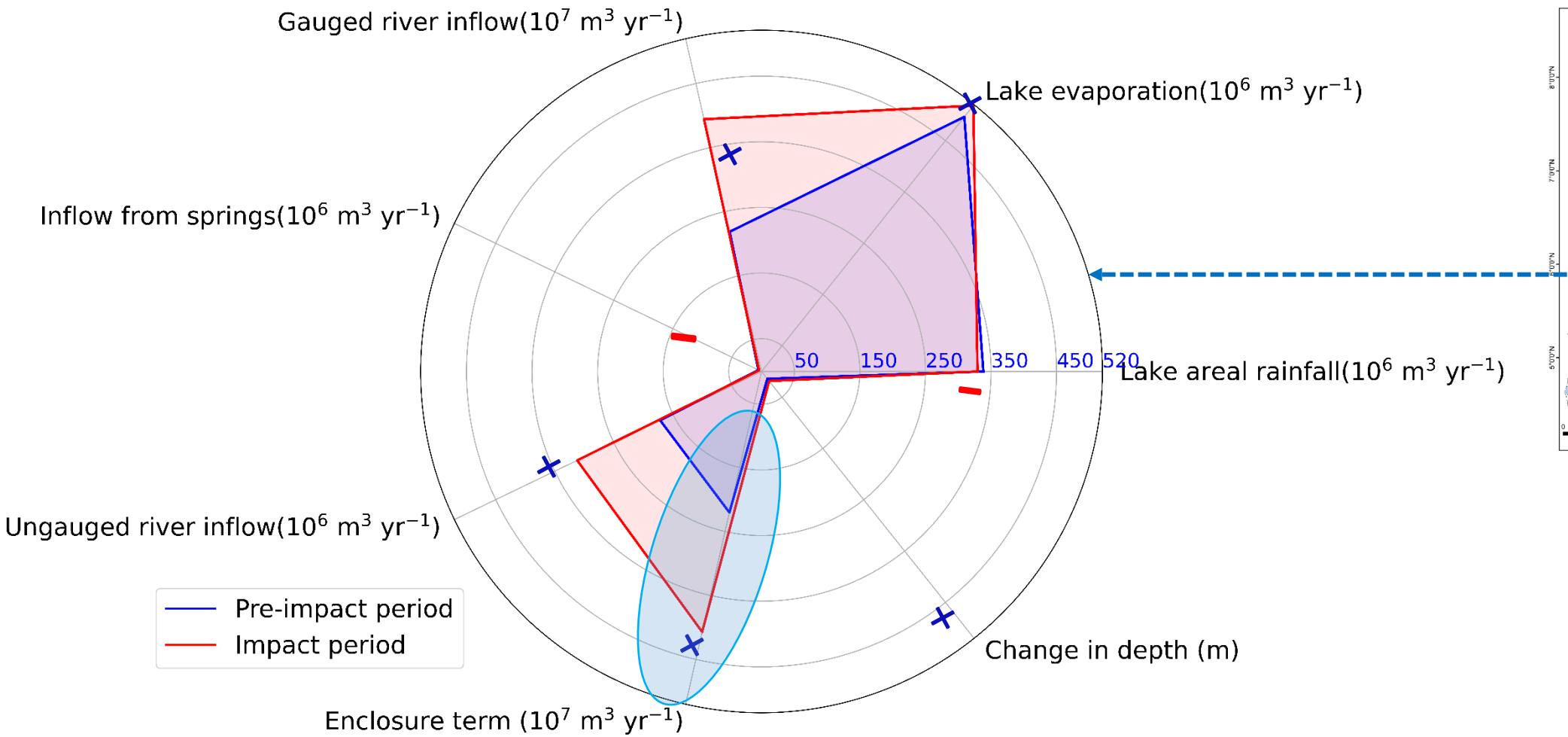


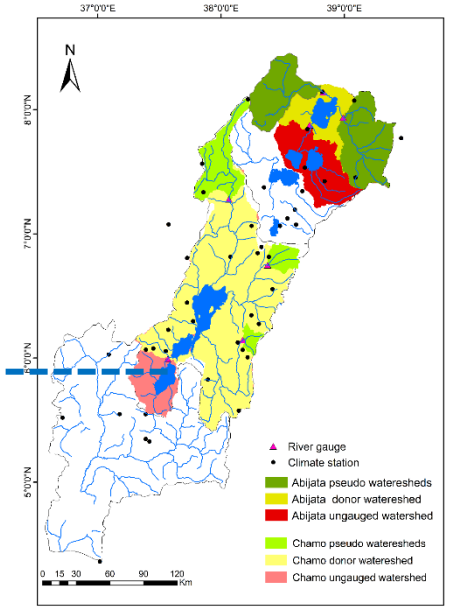
Water-losing basin



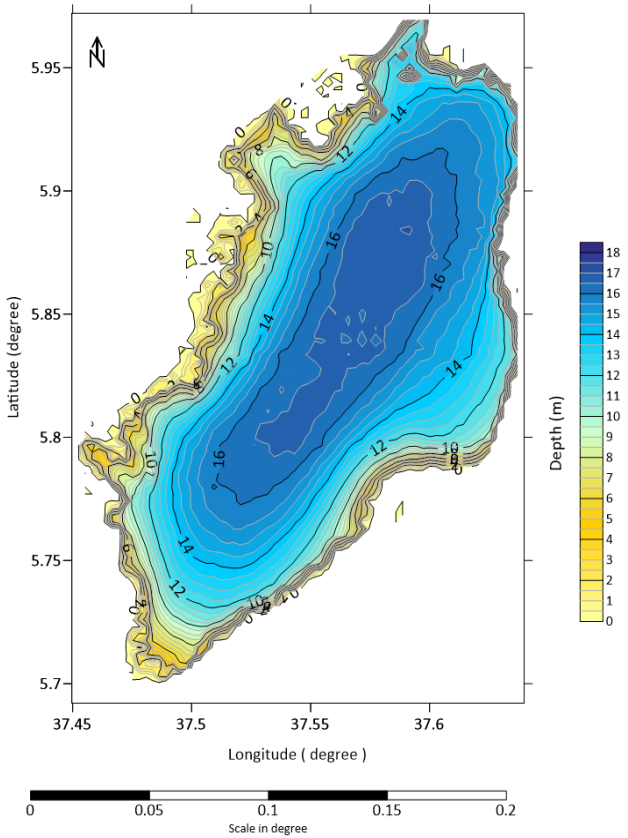


Water-gaining basin

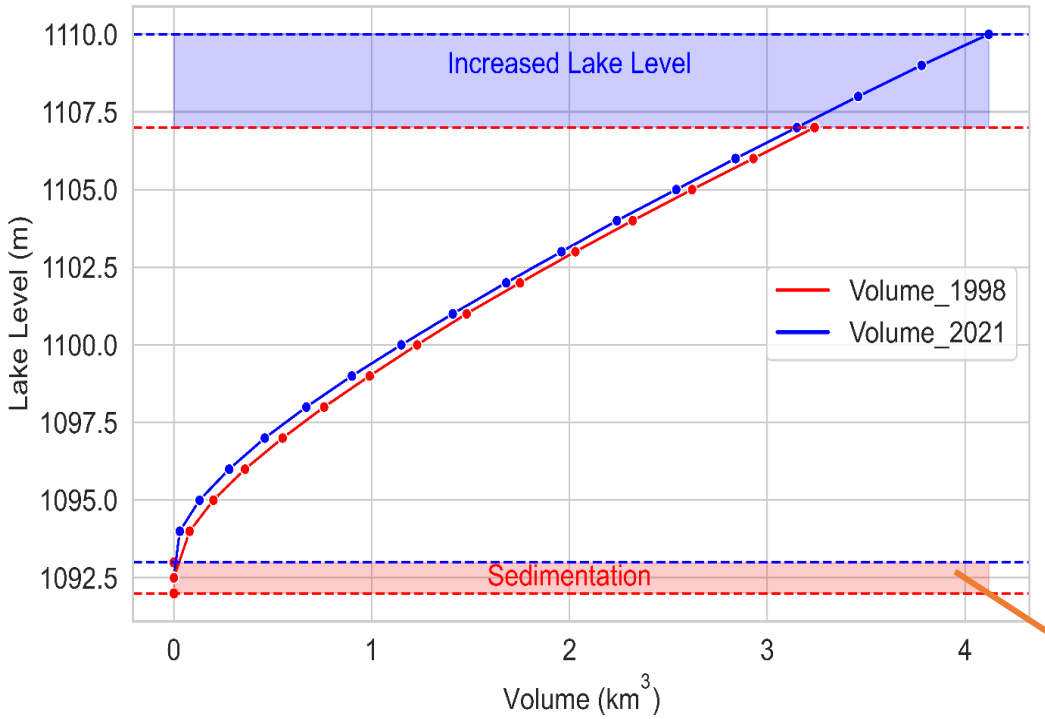




Water-gaining lake: Bathymetry analysis



Lake Chamo



Lake surface area 30 km^2

Lake depth 3 m

Bed elevation 0.6 m

Sedimentation

Conclusions

- The main water balance components are significantly changed.
  - ↑ Surface runoff, ET and Abstraction
  - ↓ Precipitation, Lateral flow and Percolation

- Increasing evaporation and abstraction are the main causes for the changing lake hydrology of water losing lakes.

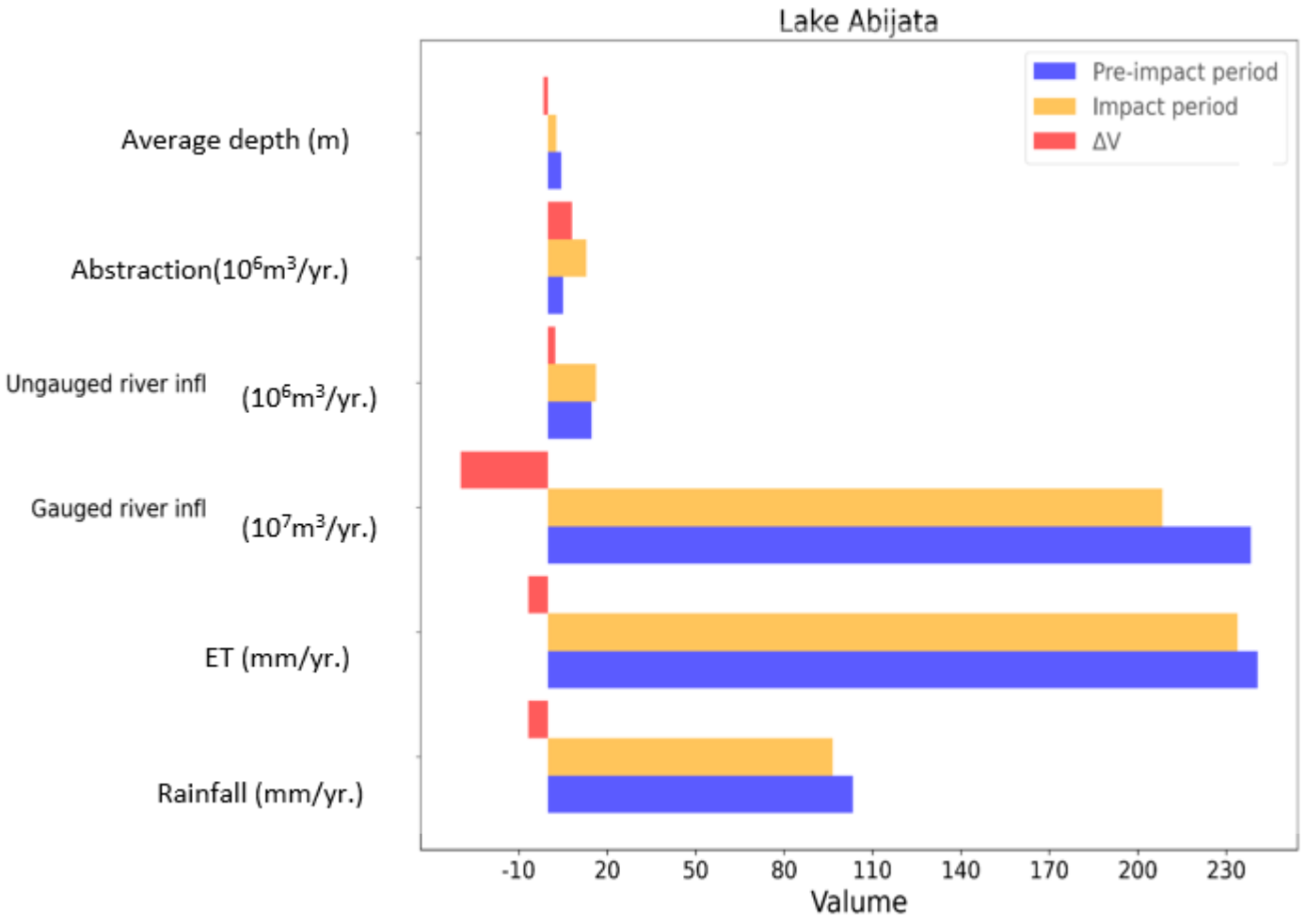
- Increasing surface runoff and sedimentation are the main causes for the changing lake hydrology of water gaining lakes.

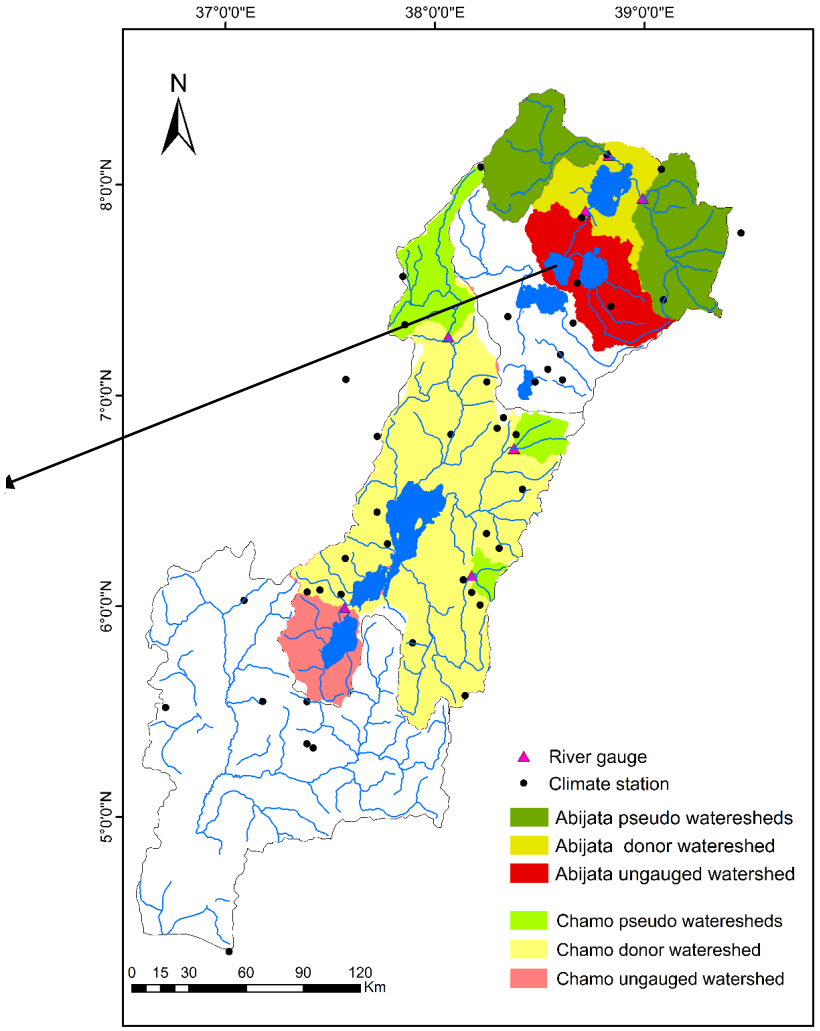

Thank you for your attention!

SWAT+ Parameters

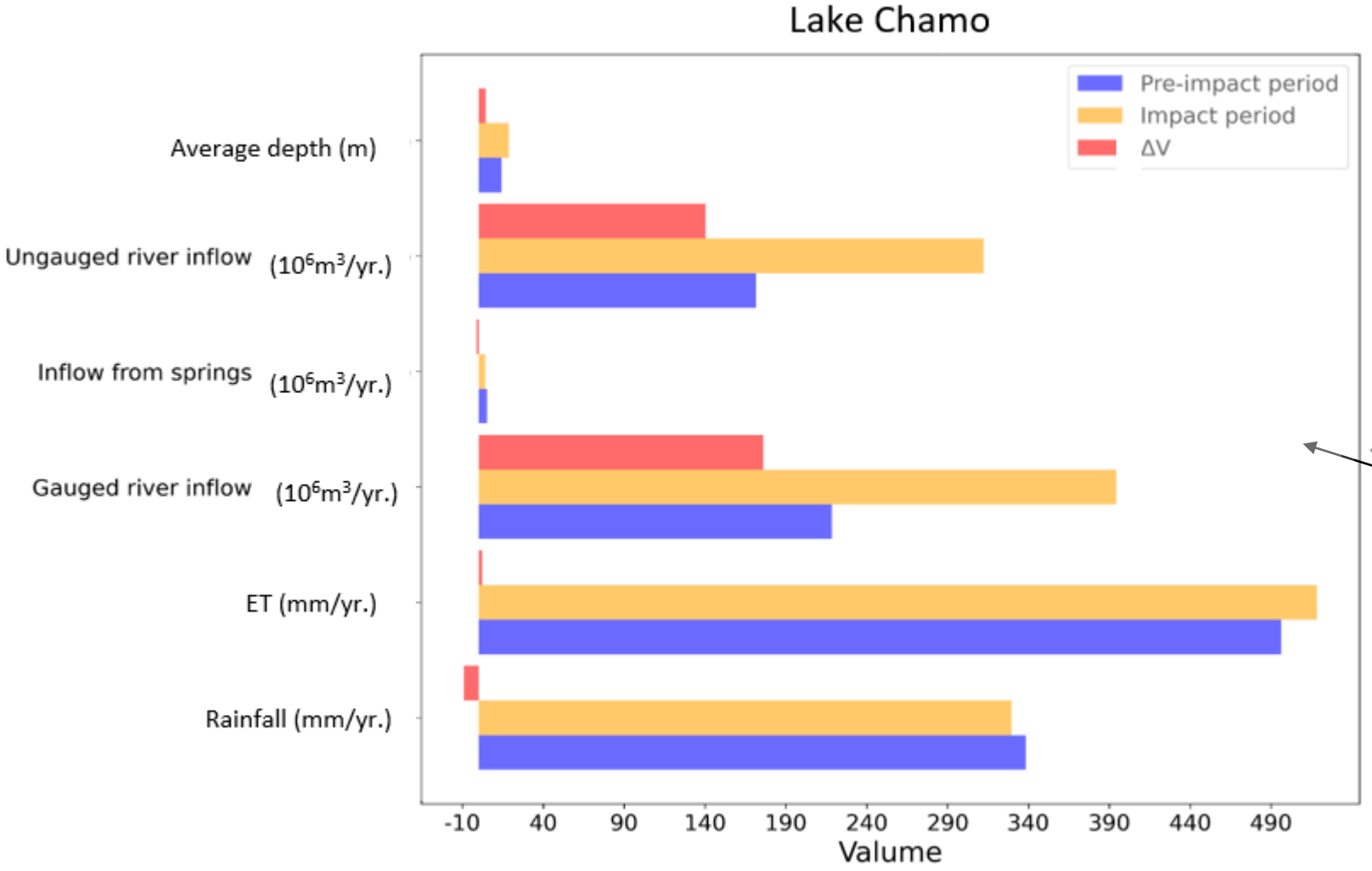
Parameters	Description	Limit		Change	Fitted range and value					
		Min	Max		Lake Abijata			Lake Chamo		
					Min	Max	Value	Min	Max	Value
CN2	Condition-II curve number	−15	+15	abschg[a]	−15	−5	−1.8	−15	−10	−11.8
Sol-Awc	Available water capacity of the soil layer (mm H_2O per mm soil)	−0.25	+0.25	abschg	−0.16	+0.15	−0.05	−0.16	+0.15	−0.12
ESCO	Soil evaporation compensation coefficient	0	1	absval[b]	0.01	0.5	0.34	0.01	0.5	0.21
SURLAG	Surface runoff lag coefficient (d)	0	24	absval	0.1	10	6.7	0.1	10	8.4
PERCO	Percolation coefficient (mm H_2O)	0	1	absval	0.01	0.95	0.91	0.01	0.3	0.17
LATQ_CO	Lateral flow contribution to reach (mm H_2O)	0	1	absval	0.01	0.95	0.63	0.01	0.3	0.10
ALPHA_BF	Base flow recession constant fast aquifer (d)	0	1	absval	0.01	0.6	0.27	0.01	0.3	0.07
k	Saturated hydraulic conductivity (mm h^{-1})	−45	+45	pctchg[c]	−10	+15	1.86	−10	+15	−3.7
EPCO	Plant uptake compensation factor	0	1	absval	0.6	0.9	0.8	0.6	0.9	0.85
z	Soil depth (mm)	−45	+45	pctchg	−15	+0	−3.7	−15	+0	−7.5
Lake depth	Average depth of a lake (m)	10 (default)		absval	2.5	9	5.5	5	13	9.7

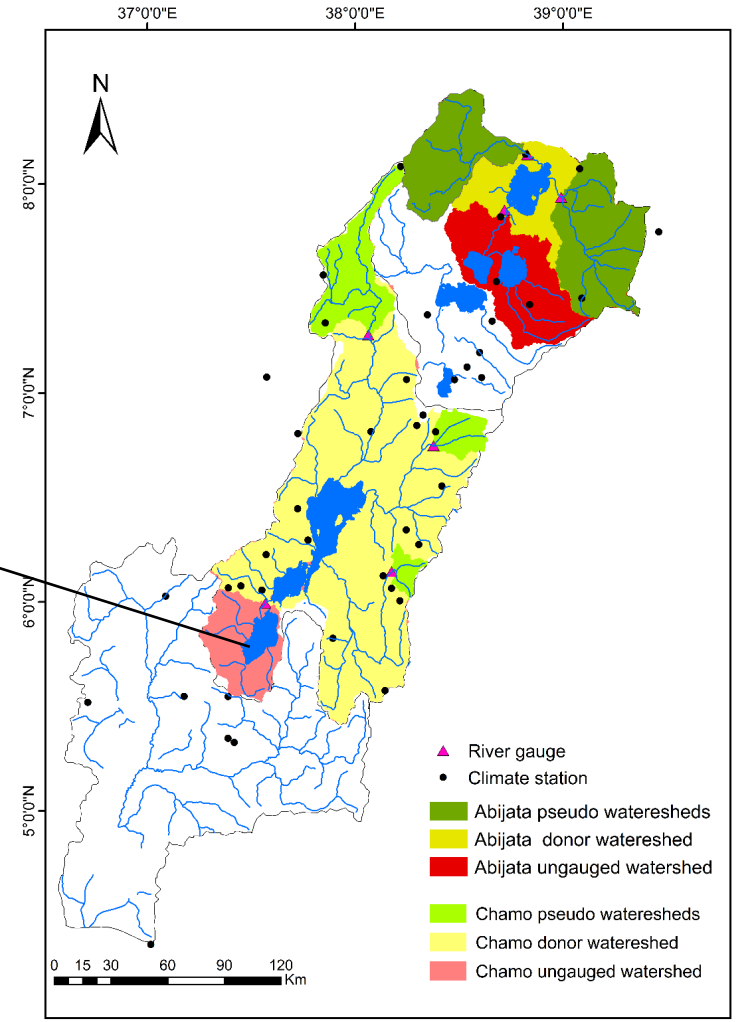
Water-losing basin: Water balance change analysis

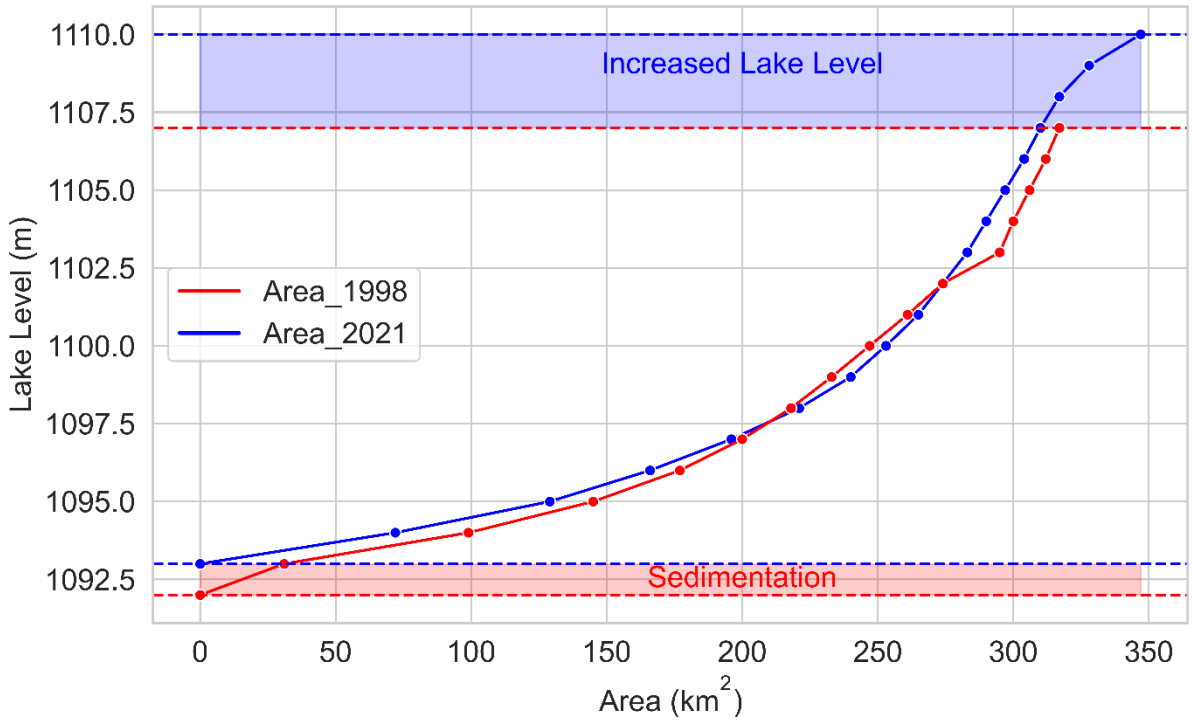




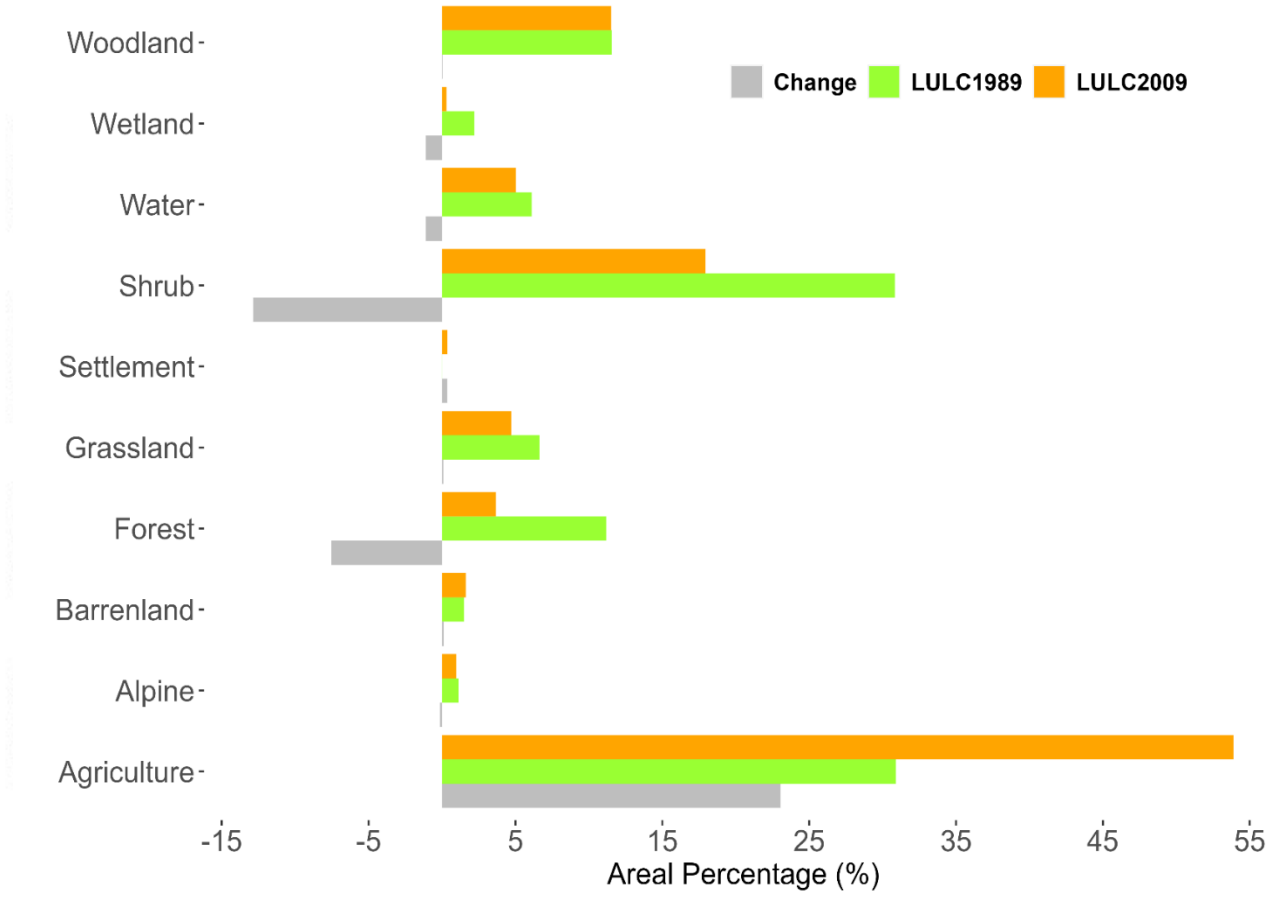
Water-gaining basin: Water balance change analysis

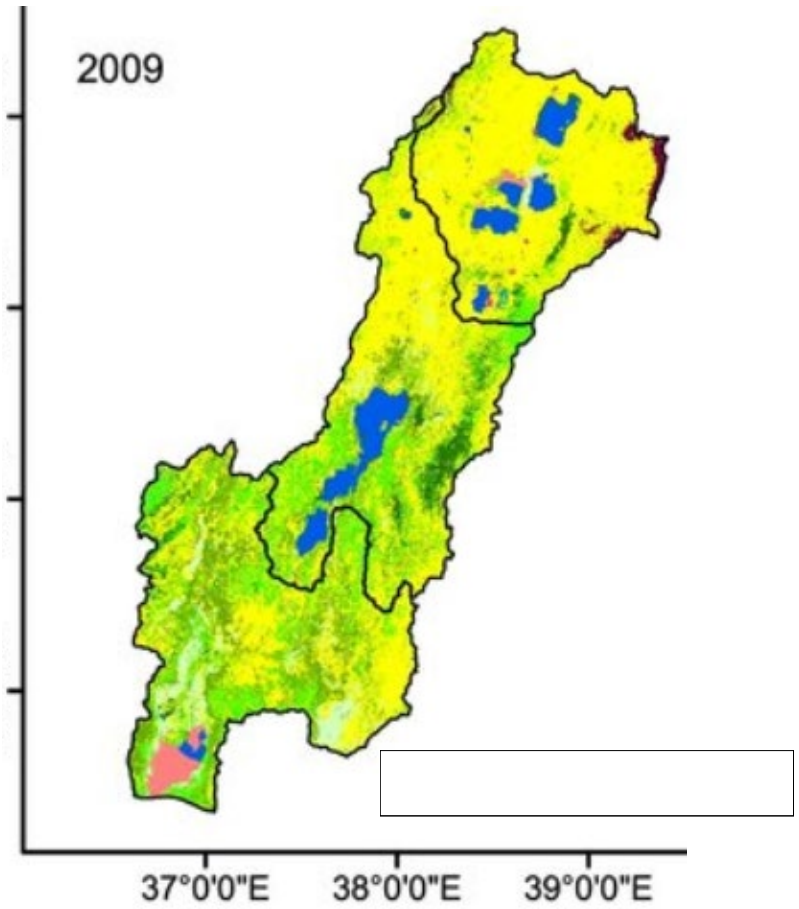





Increased Lake Level
Sedimentation
Area_1998
Area_2021
Lake Level (m)
1110.0
1107.5
1105.0
1102.5
1100.0
1097.5
1095.0
1092.5
0
50
100
150
200
250
300
350
Area (km^2)

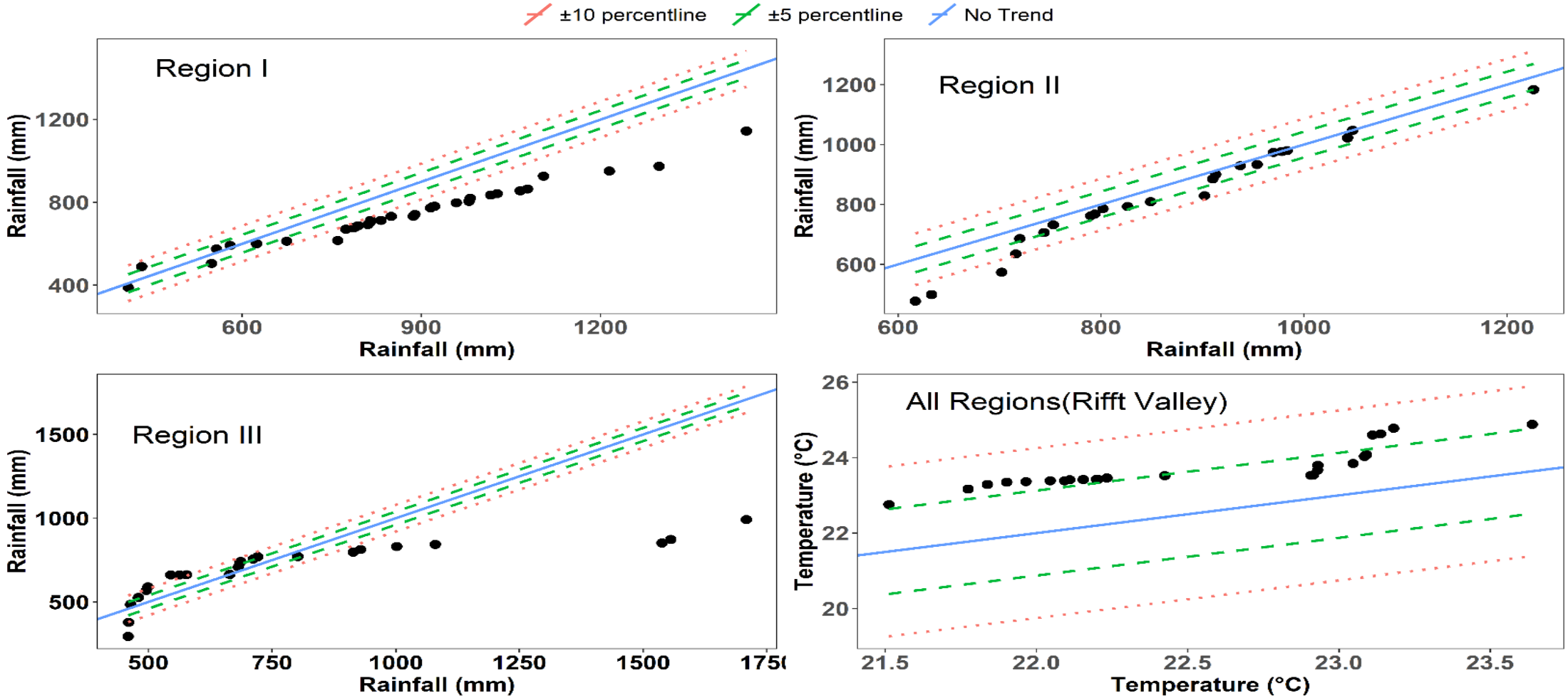
Results - LULC change



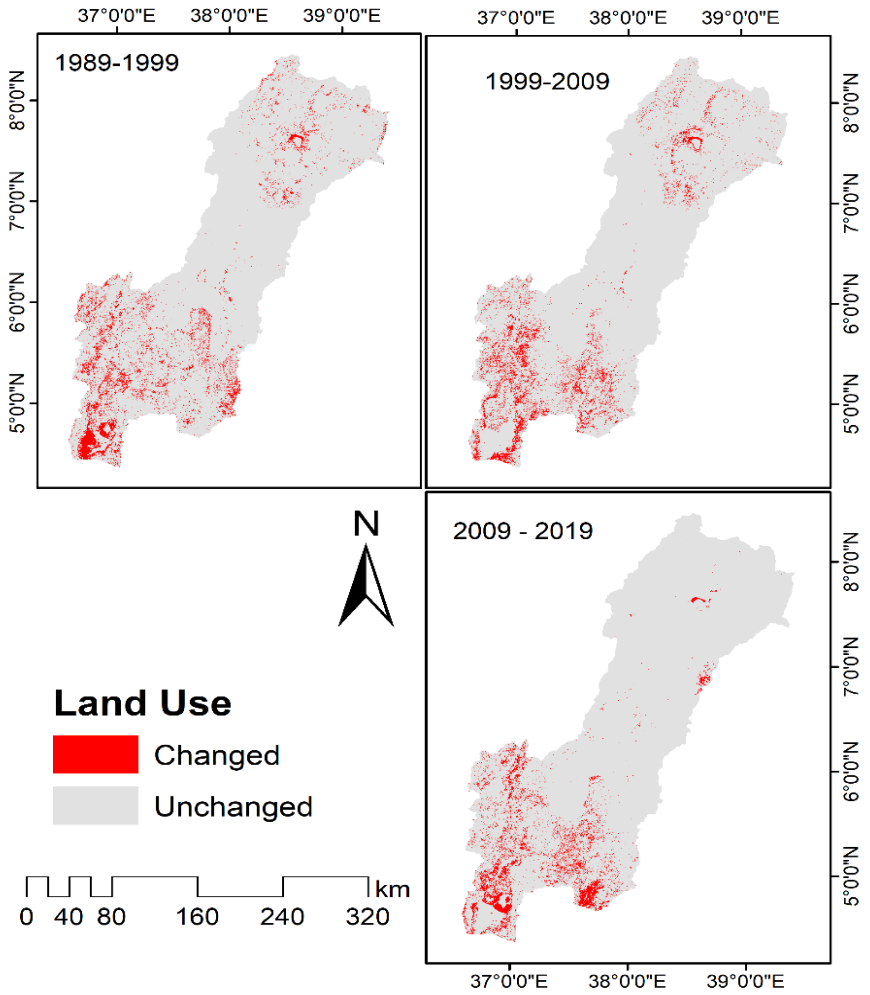


	Agriculture	Alpine	Barren	Forest	Grass	Settlement	Shrub	Water	Wetland	Wood
Net loss/gain	23.14	-0.14	0.12	-7.52	0.10	0.32	-13.0	-1.08	-1.92	-0.04

climate pattern

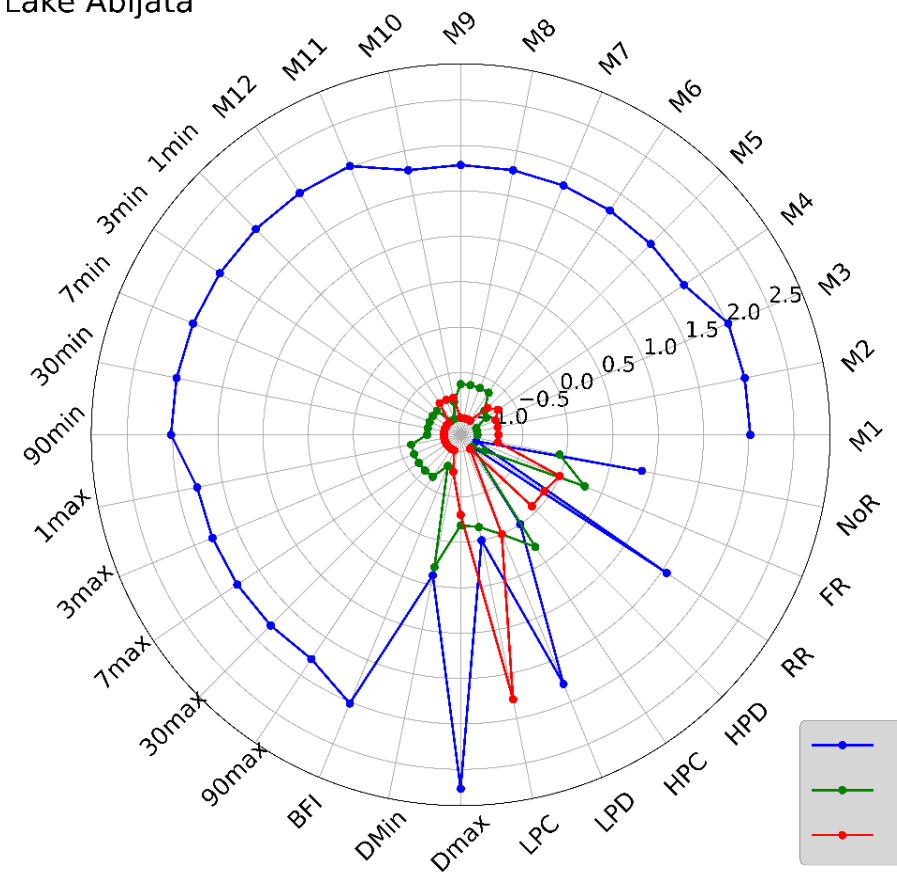


LULC

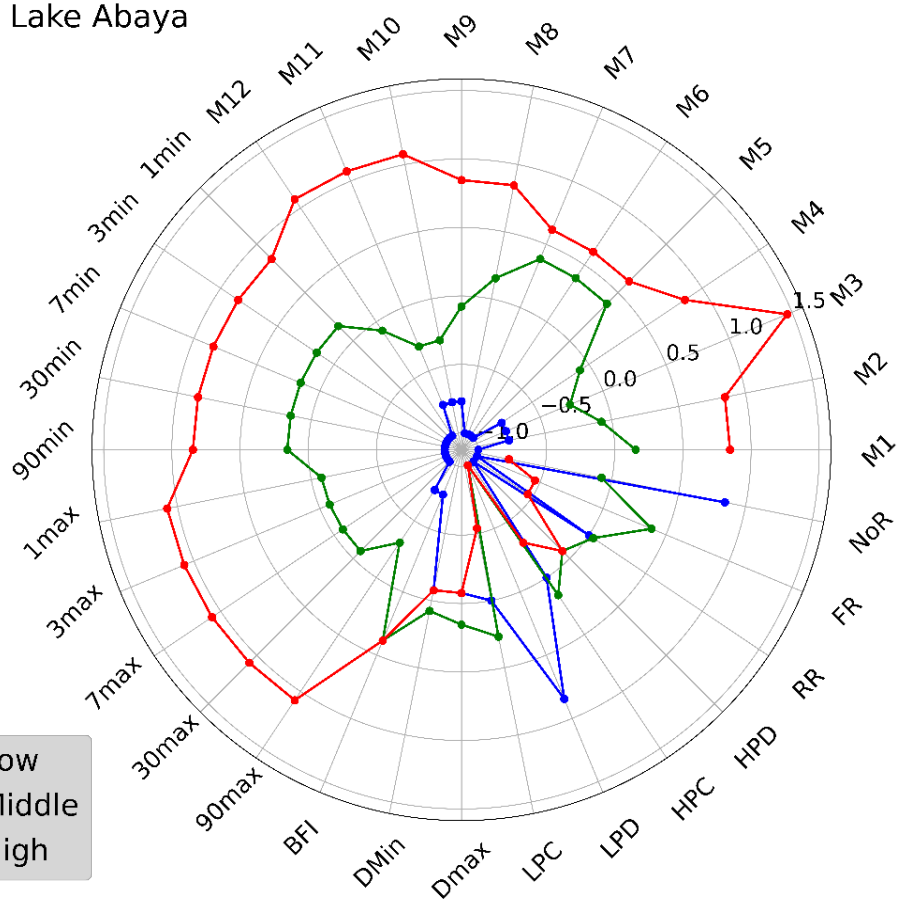

37°0'0"E
38°0'0"E
39°0'0"E
1989-1999
1999-2009
2009 - 2019
8°0'0"N
7°0'0"N
6°0'0"N
5°0'0"N
N
Land Use
Changed
Unchanged
0 40 80 160 240 320
km

Results - Hydrological alteration

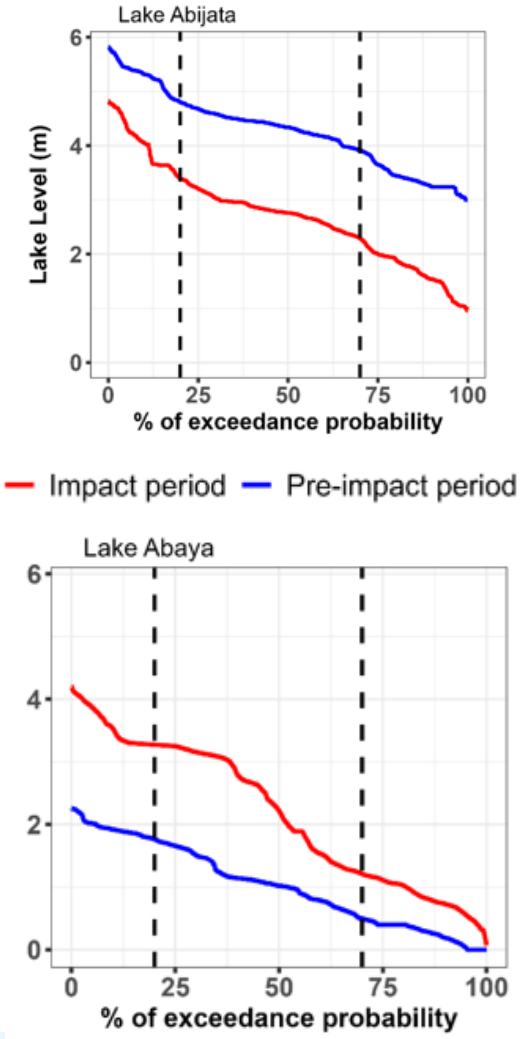
Lake Abijata



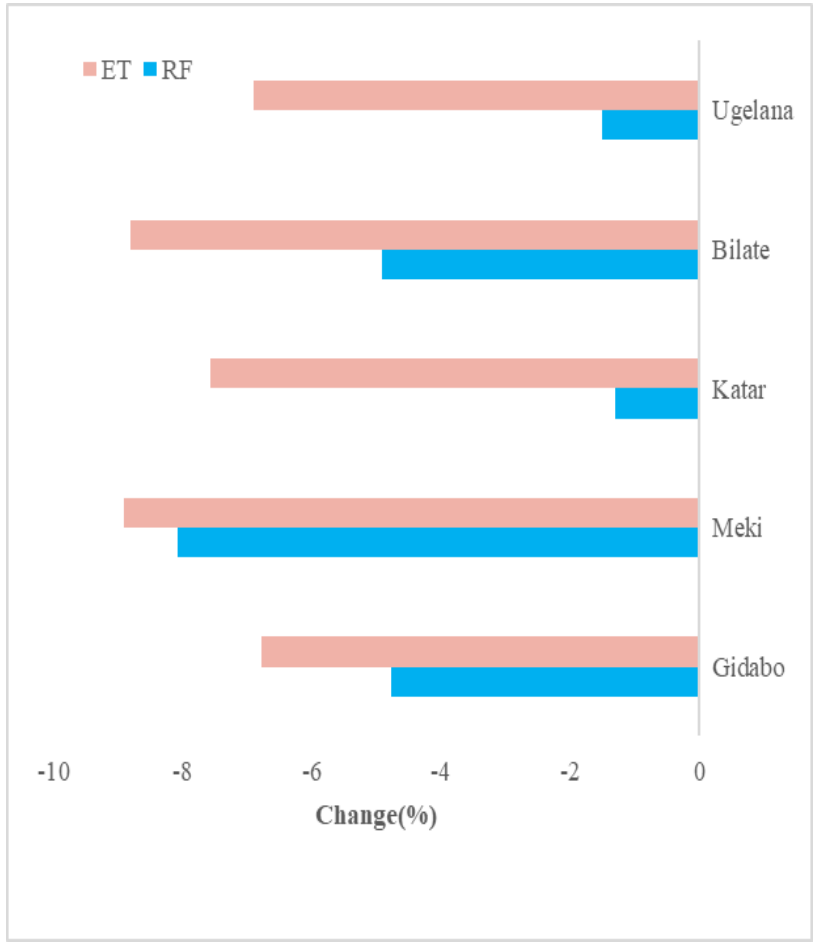
Lake Abaya



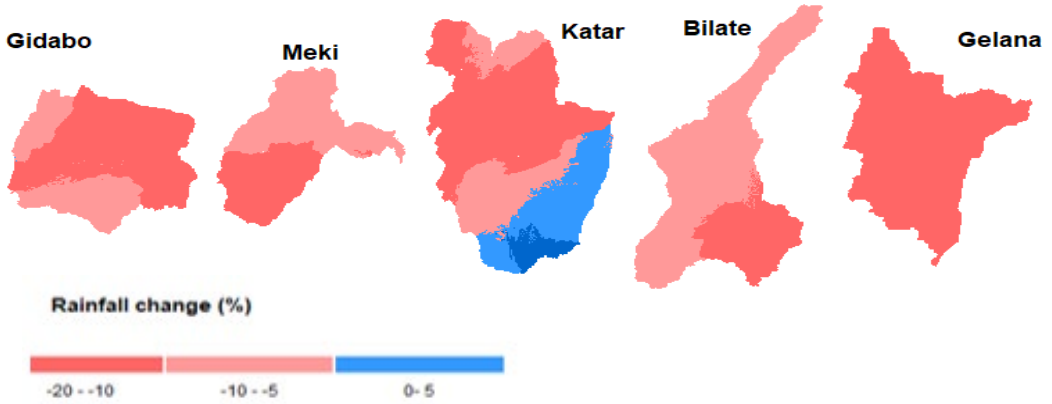
RVA_Low
RVA_Middle
RVA_High



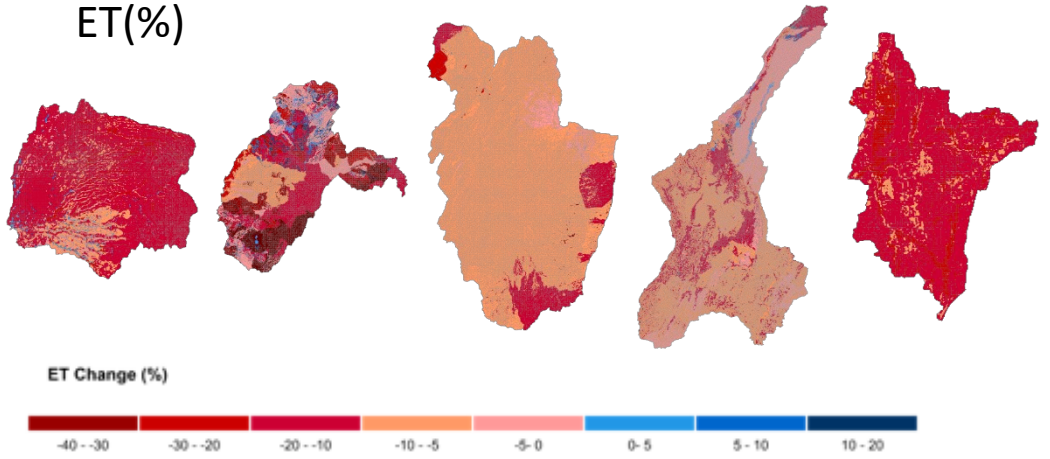
Results - Water balance change (1980-2000/2001-2018)



Rainfall change(%)



ET(%)



Results - Water balance change