Niger River Basin
Strategic Development Action Plan

Climate Risk Assessment for Water Resources Development in the Niger River Basin

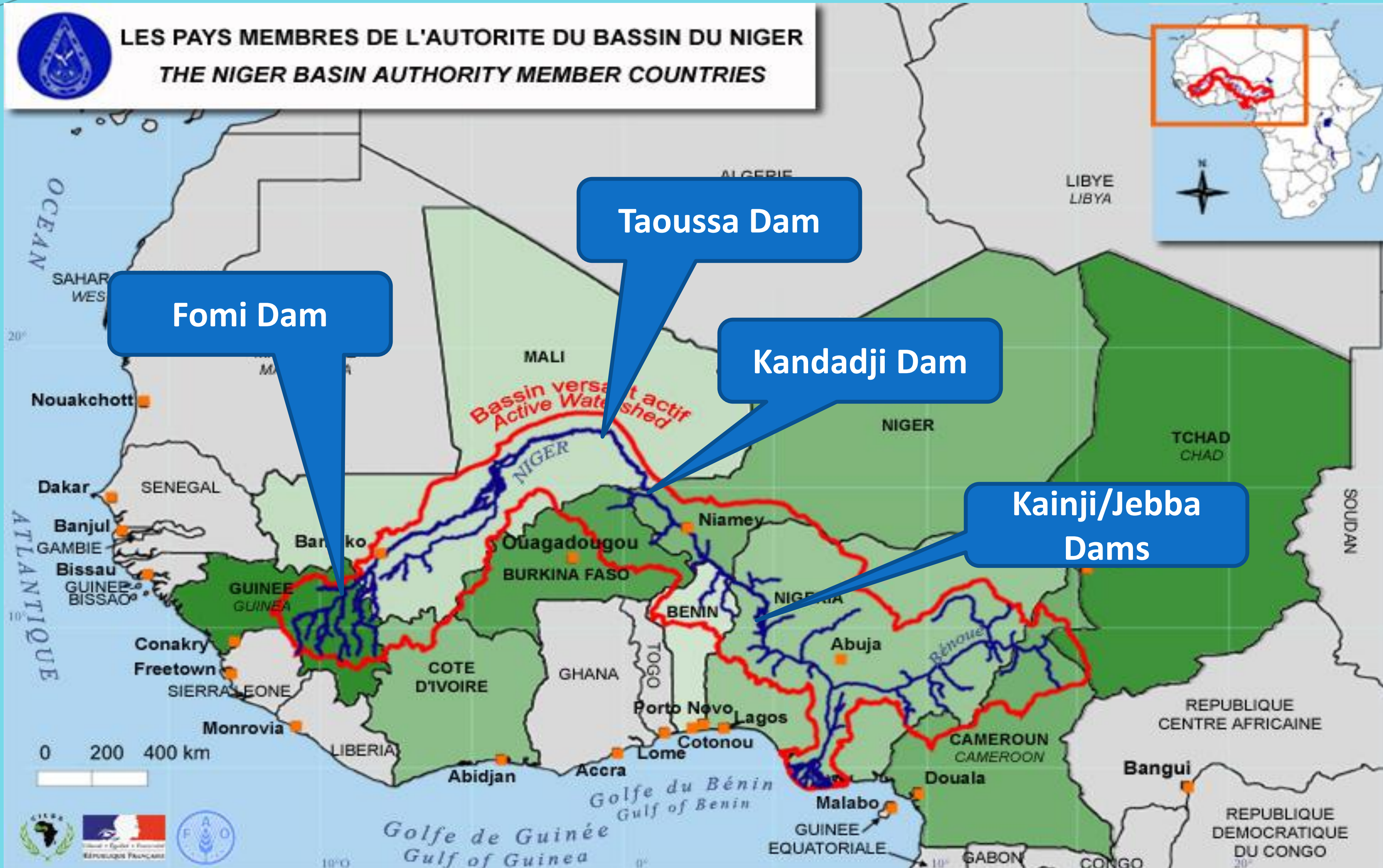
Johan Grijsen, C. Brown (UMass), A. Tarhule (UOK), Y. Ghile (Stanford), U. Taner (UMass)

HydroPredict, Special Session 3: Choosing Models for Resilient WRM
Water Partnership Program (WPP)/TWIWA, The World Bank
Vienna, September 2012

Outline

1. The SDAP
2. Objective and Methodology
3. Impacts of future changes in the Niger's runoff regime on key performance indicators (vulnerability analysis)
4. Climate change projections for the Niger River Basin
5. Runoff response to projected climate change
6. Quantitative climate risks for key water related sectors
7. Sensitivity of selected sectors to climate change
8. Rapid Assessment Methodology for project analysis

SDAP development of the Niger River Basin



Strategic Development Action Plan

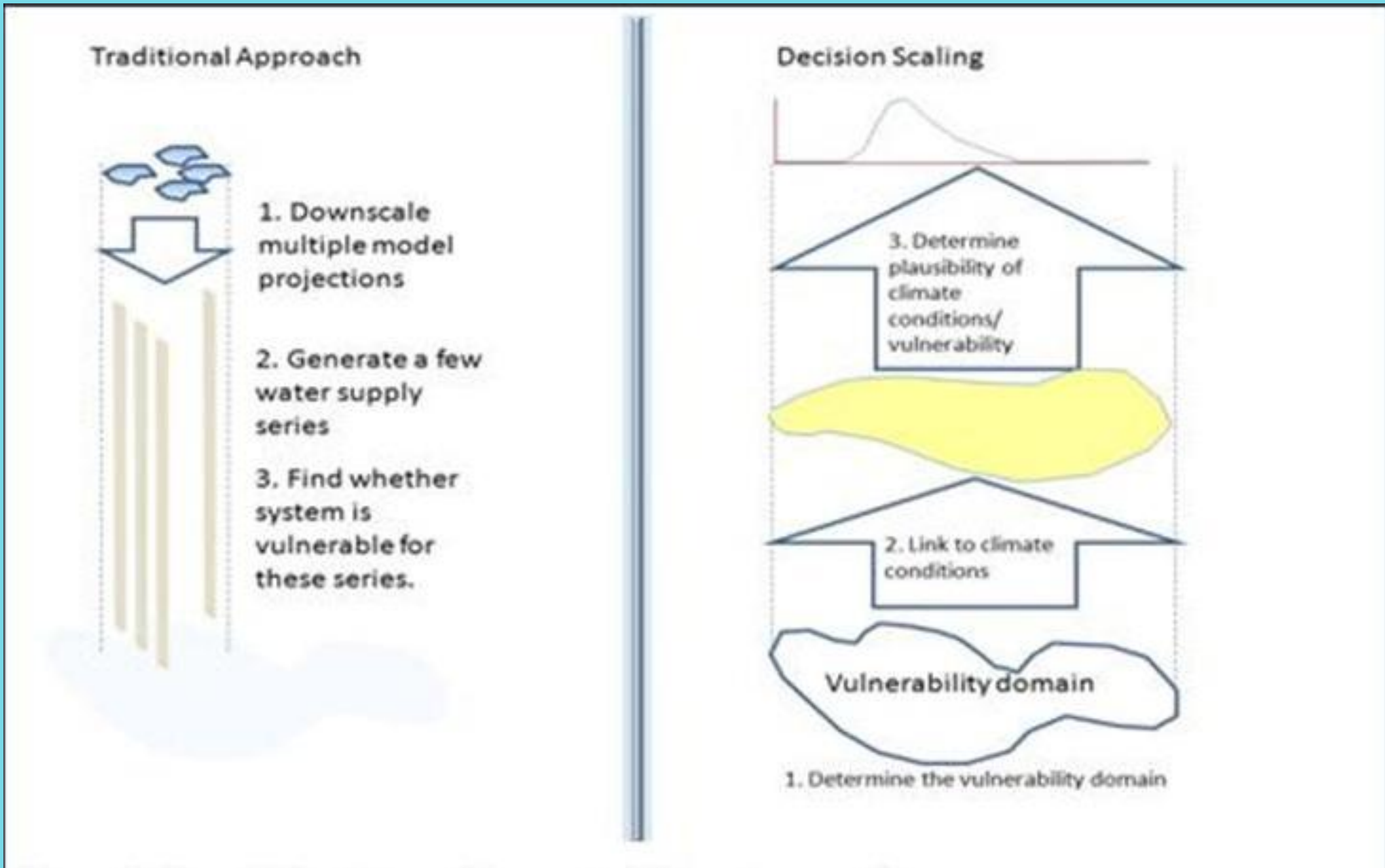
The Strategic Development Action Plan (SDAP) is an $8 billion, 20 year investment program that includes investments in:

- *Socio-economic infrastructure* (80%) including
  - water storage (3 new main stem dams and two major rehabilitations),
  - New irrigation development (about 1.5 Mha),
  - Hydroelectric power generation (900 GWh/yr)
  - Navigation, transport, water supply, fisheries & livestock
- *Ecosystem conservation and resource protection* (15%) including biodiversity protection, erosion and sediment control, and prevention of water pollution
- *Capacity Building* (5%) including a strengthened legal and regulatory framework

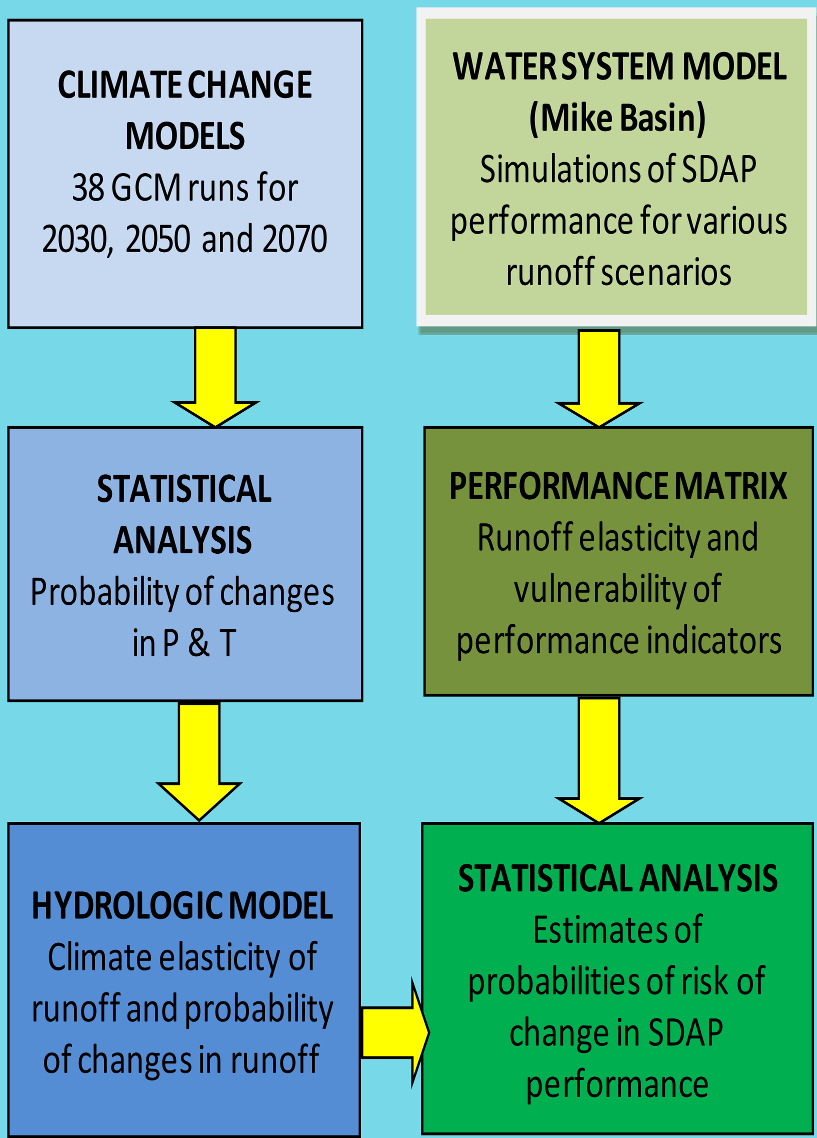
Objective of NRB CC Risk Assessment

- The 8th Heads of State meeting in 2008 asked: What are CC risks to goals of the SDAP?
- NBA requested the Bank to undertake a joint initiative to assess the climate risks
- Objective of CRA: assess risks of climate change to the water resources and associated development sectors of the Niger Basin in the near (2030), mid (2050), and distant future (2070).

General Approach: Decision scaling



Methodology for Climate Risk Assessment



- Mike Basin modeling to determine runoff elasticity and indicator vulnerabilities (Performance Matrix)
- Hydrological analyses and modeling (VIC and GeoSFM) to assess climate elasticity of runoff
- Downscaling of 38 GCM projections for 21st Century and translate P and T projections into runoff (Q) projections.
- Combine 38 projected runoff series with Performance Matrix to assess likelihood of significant impacts on key performance indicators

Key Performance Indicators

The CRA study focuses on five sectors/domains :

Sector/Domain	Indicator	Baseline
Agriculture/irrigation	Incremental Net Irrigated area	1.5 Mha
Energy production	Total annual energy production	8,250 GWh/yr
Navigation	Annual number of days	5 months/yr
Inner Delta Flooding	Reduction annual flooded area	11,000 km^2
Environmental Flow s (at Markala, Mali-Niger border, Niamey, Malanville)	Minimum flow in m^3/s	40, 75, 125, 80 m^3/s

The *baselines* for estimating the changes are SDAP targets

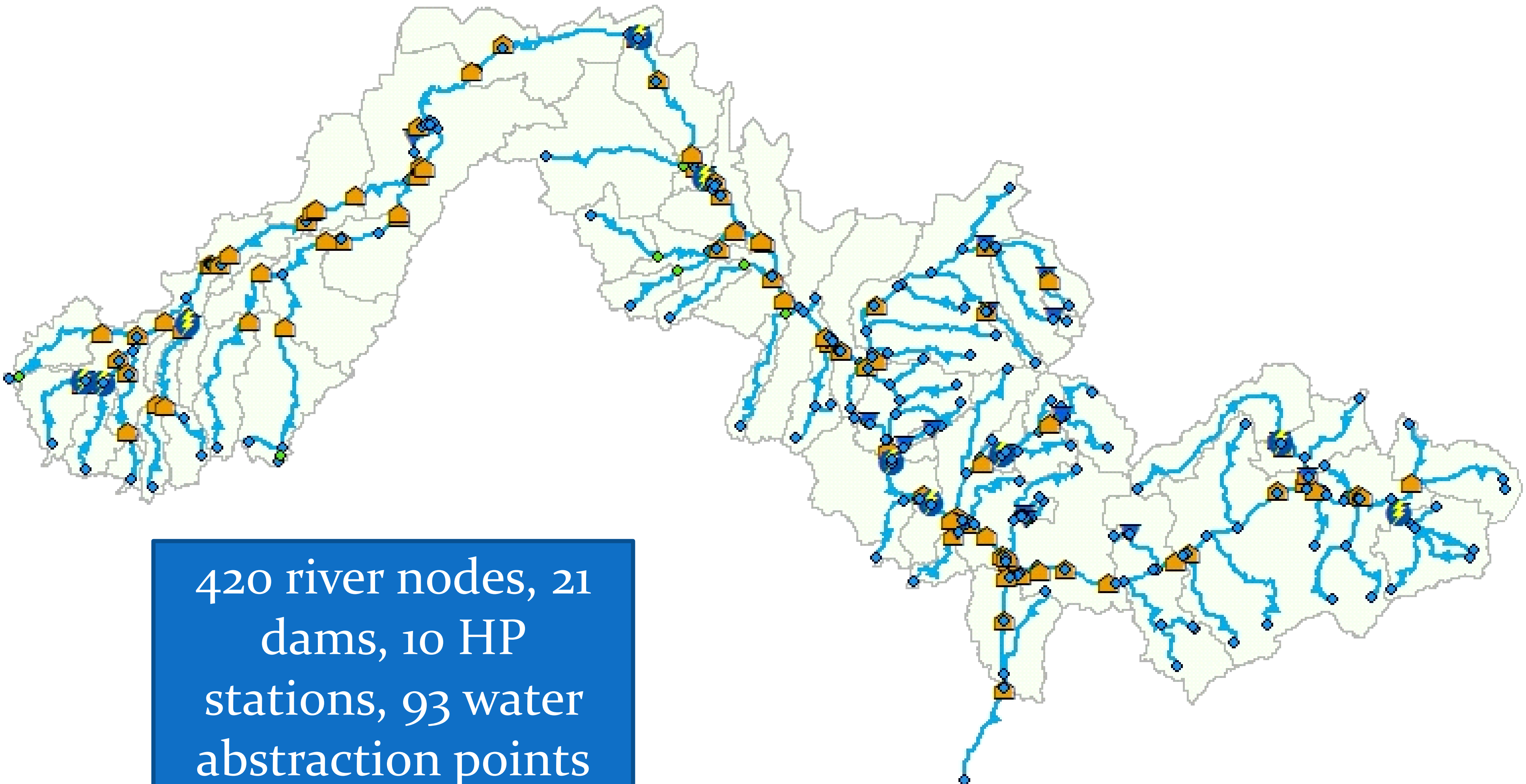
Risk levels

Risk Level	Change in Vulnerability Indicator or metric
Mild	0% to -10%
Moderate	-10% to -20%
Significant	-20% to -40%
Severe	-40% to -60%
Extreme	Greater than -60%

Ouagadougou Stakeholder Workshop Threshold

Different risk levels and categories can be chosen, and these could differ in different parts of the basin, for major projects and for different users

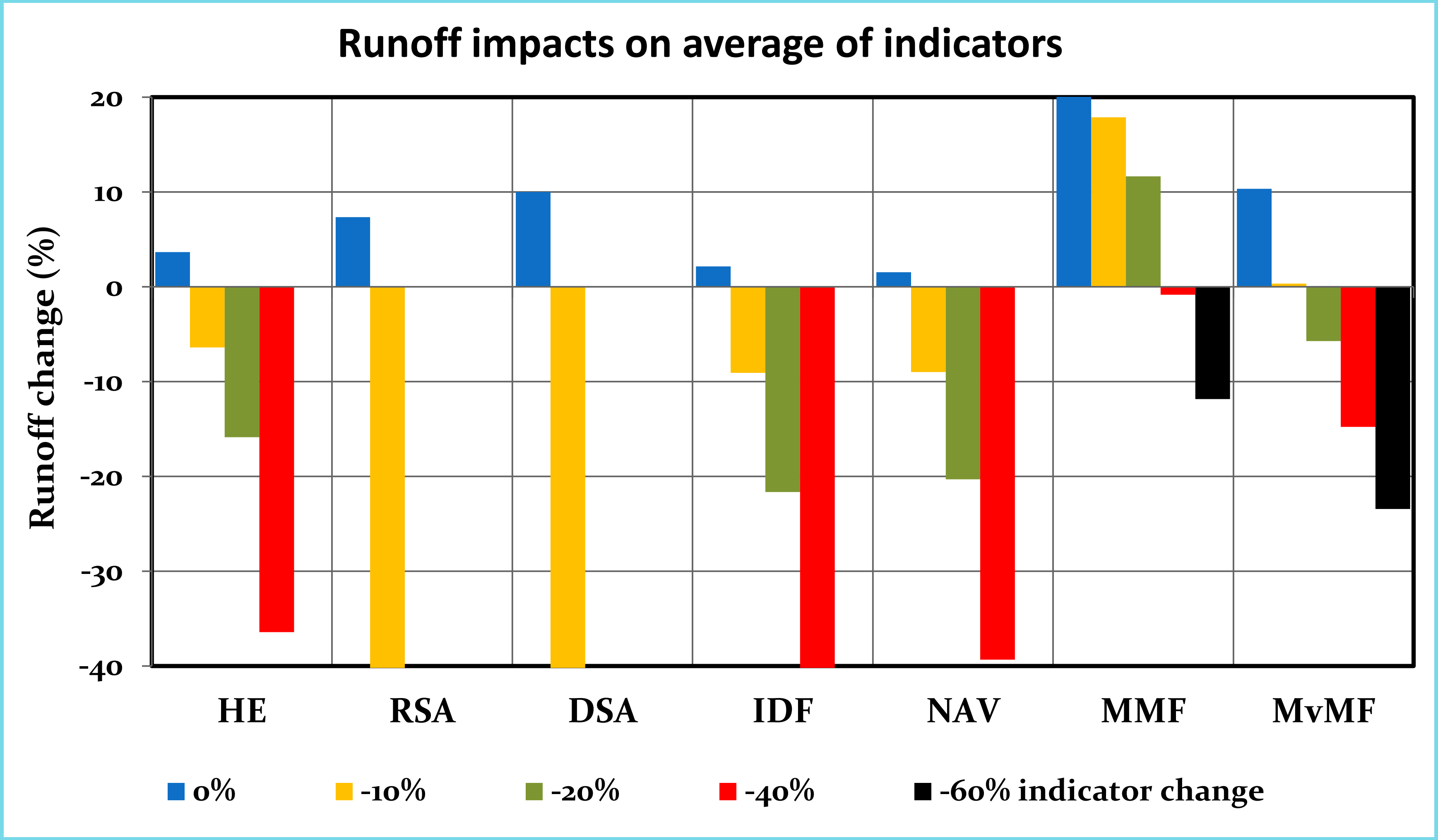
Mike Basin WR model schematization



420 river nodes, 21 dams, 10 HP stations, 93 water abstraction points

Runoff impact on indicator performance

HE = Hydro-energy, RSA/DSA=agriculture, IDF=Inland Delta Flooding, NAV = Navigation, MMF and MvMF= minimum flows at Markala and Malanville

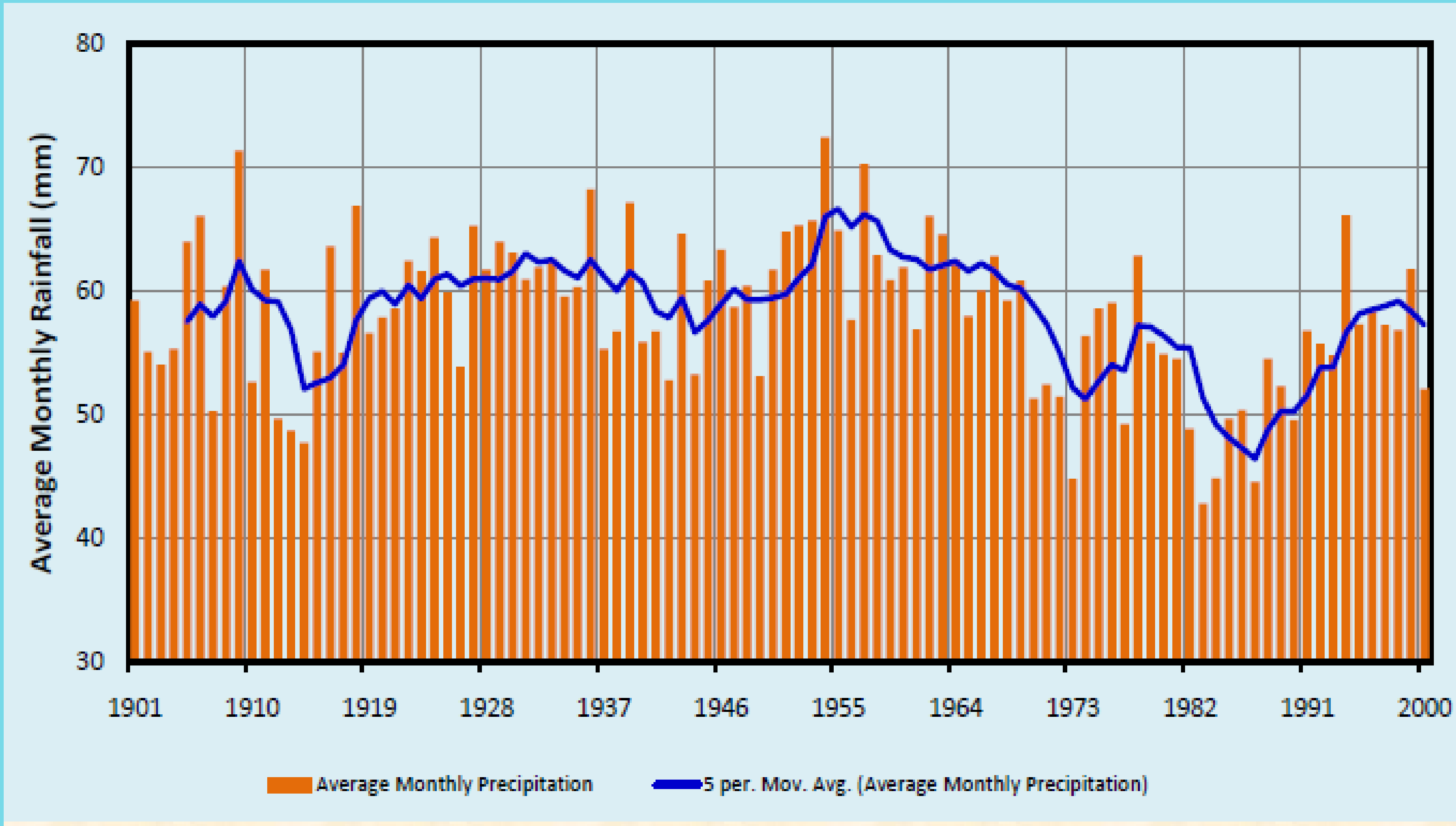


Performance Indicator Matrix for FO – TA –KD development scenario

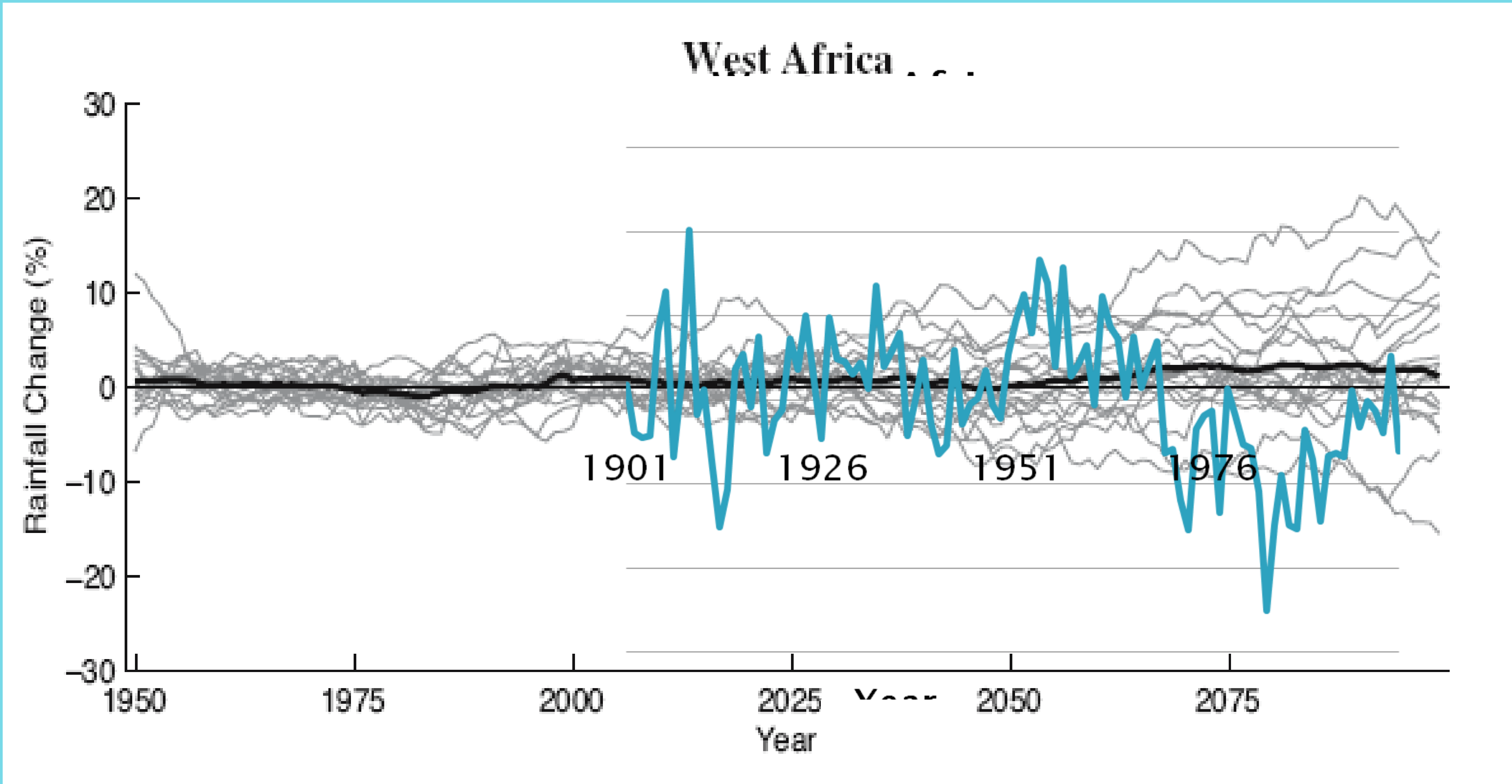
Performance Metrics	Probability of non-exceedance	Reference 2005 (SA)	Impacts FO-TA-KD	20thC + 5% water demands; FO-TA-KD						Average runoff elasticity
				20thC-R	+10% R	0% R	-10% R	-20% R	-30% R	
		Value	% change	Value	Percentage changes (%)					
Hydro-energy										
Basin energy	1/2(50%)	9,152	-10.0	8,241	5.2	-3.0	-13.9	-24.3	-33.8	1.1
(GWh)	1/5(20%)	7,224	-21.0	5,709	8.9	-3.5	-16.0	-28.5	-38.7	1.3
Kainji/Jebba	1/2(50%)	4,484	-33.3	2,990	11.1	-5.8	-23.0	-37.3	-48.2	1.5
	1/5(20%)	3,715	-40.8	2,200	9.8	-5.1	-21.3	-38.0	-50.3	1.6
Irrigated Agriculture										
Total irrigation	mean	228,138	435	1,220,591	0.1	-0.3	-0.9	-1.8	-3.6	0.1
RS (ha)	1/5(20%)	228,138	424	1,194,537	-0.1	-0.5	-2.1	-4.2	-8.1	0.2
Total irrigation	mean	111,744	471	637,537	-0.4	-0.8	-1.2	-1.5	-2.2	0.1
DS (ha)	1/5(20%)	105,130	500	630,890	-0.7	-0.9	-1.4	-5.5	-15.7	0.5
Navigation for various reaches (average number of days)										
Average	Large boats	171	-20.9	135	7.9	-1.4	-10.9	-19.7	-30.2	1.0
Flooding (km^2)	mean	12,117	-9.7	10,940	5.4	-1.5	-10.9	-18.7	-28.6	1.0
Inland Delta	1/5(20%)	10,342	-14.1	8,887	7.1	-1.6	-13.9	-24.8	-37.3	1.2
Sustenance of 10-day average minimum flows (m^3/s)										
Markala	1/2(50%)	70	-13	61	-25.0	-38.6	-54.7	-83.5	-100.0	3.5
	1/5(20%)	51	-2	50	-31.1	-40.6	-69.8	-99.6	-100.0	5.0
Malanville	1/2(50%)	68	35	91	-0.3	-10.3	-27.2	-53.9	-71.6	2.0
	1/5(20%)	4	2,035	77	-2.1	-21.9	-55.8	-83.5	-98.2	3.0

Projections of P and T for 21st Century

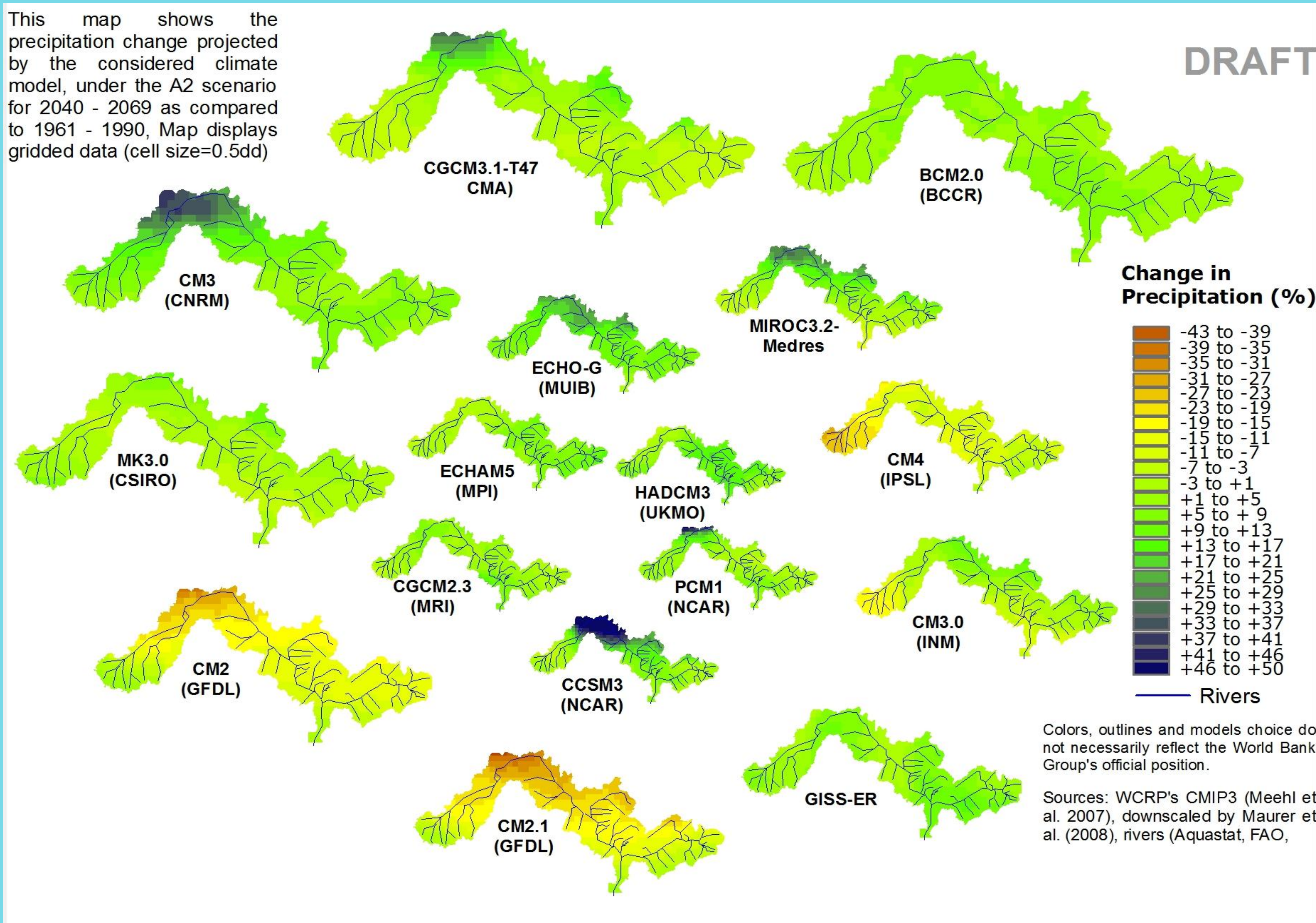
Long-term variability of rainfall in the Niger Basin



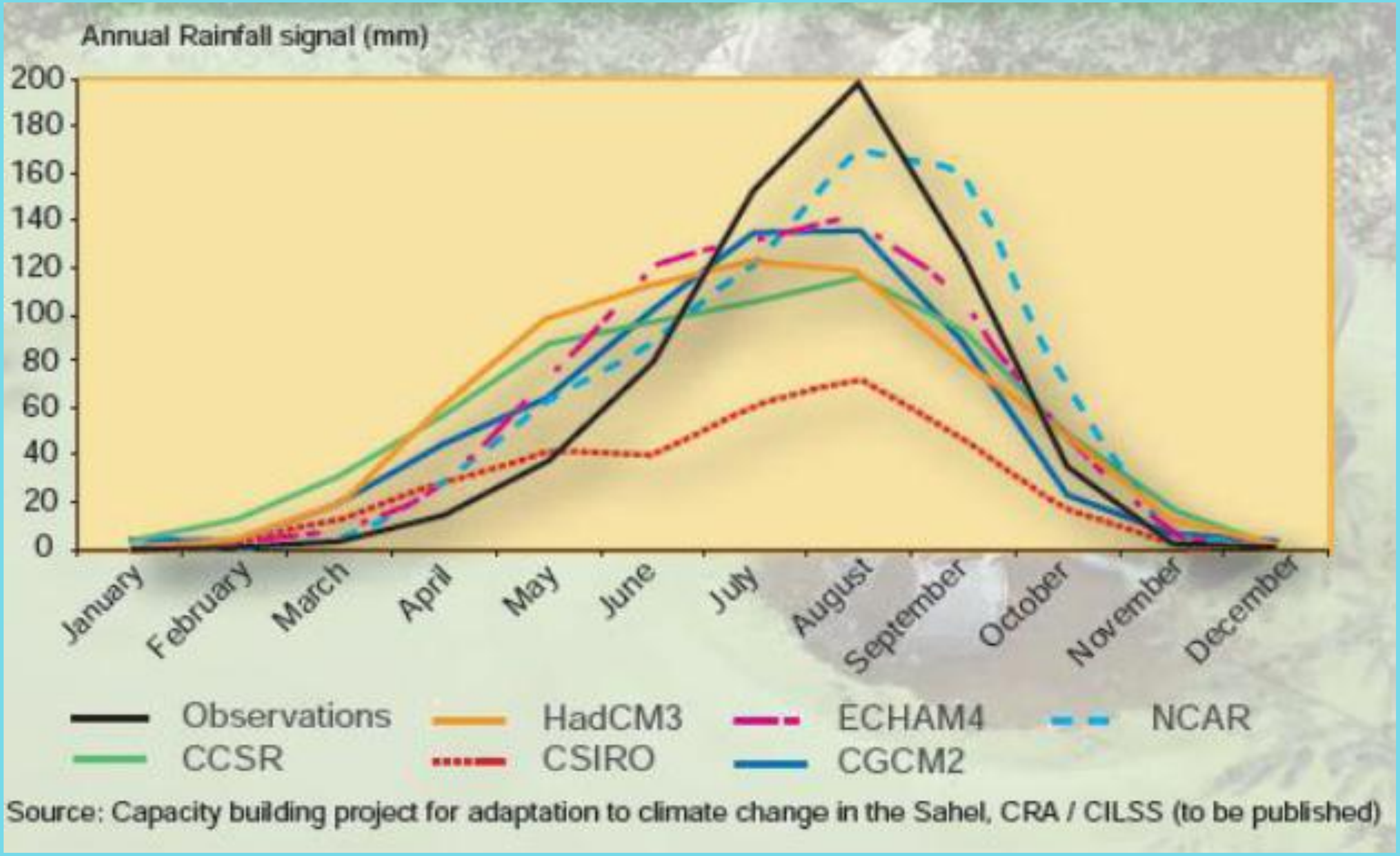
Historic variability is as important as variability in climate projections for the Niger Basin



Differences between GCMs; annual precipitation projections for 2050

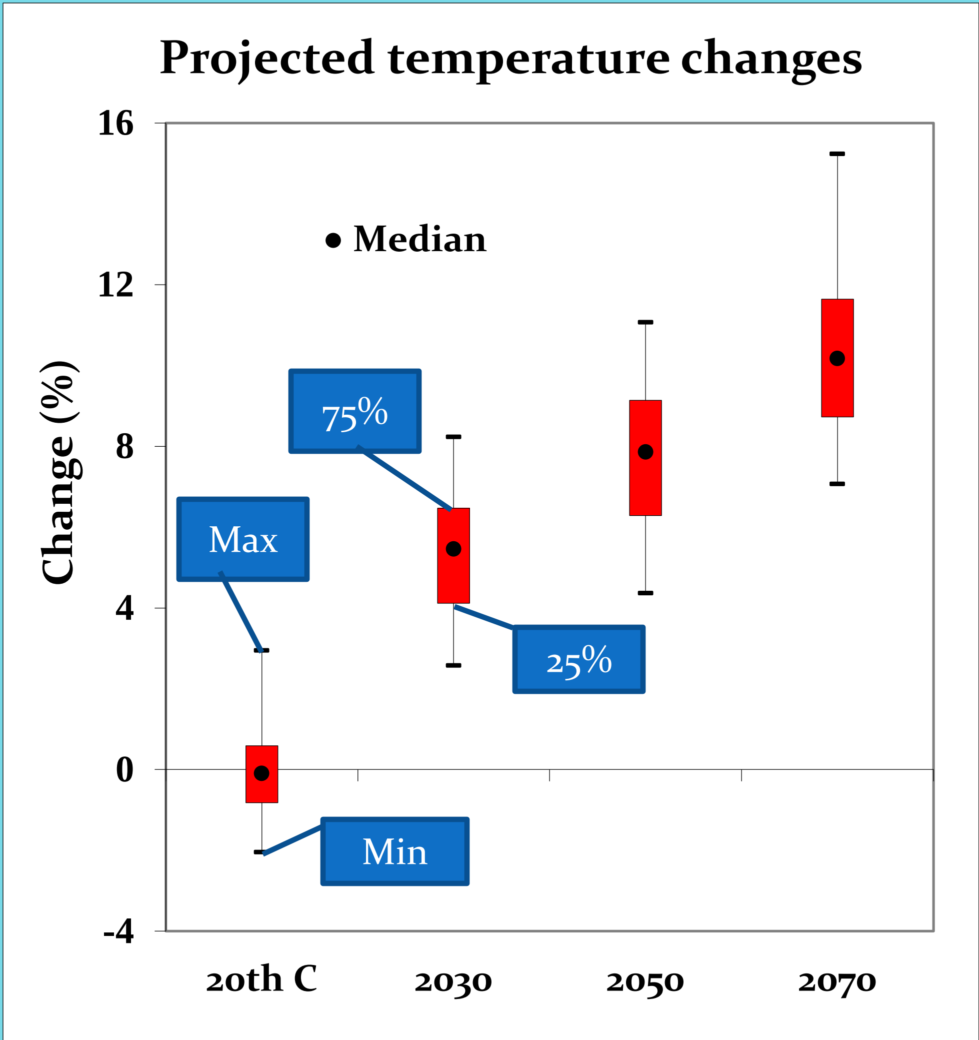


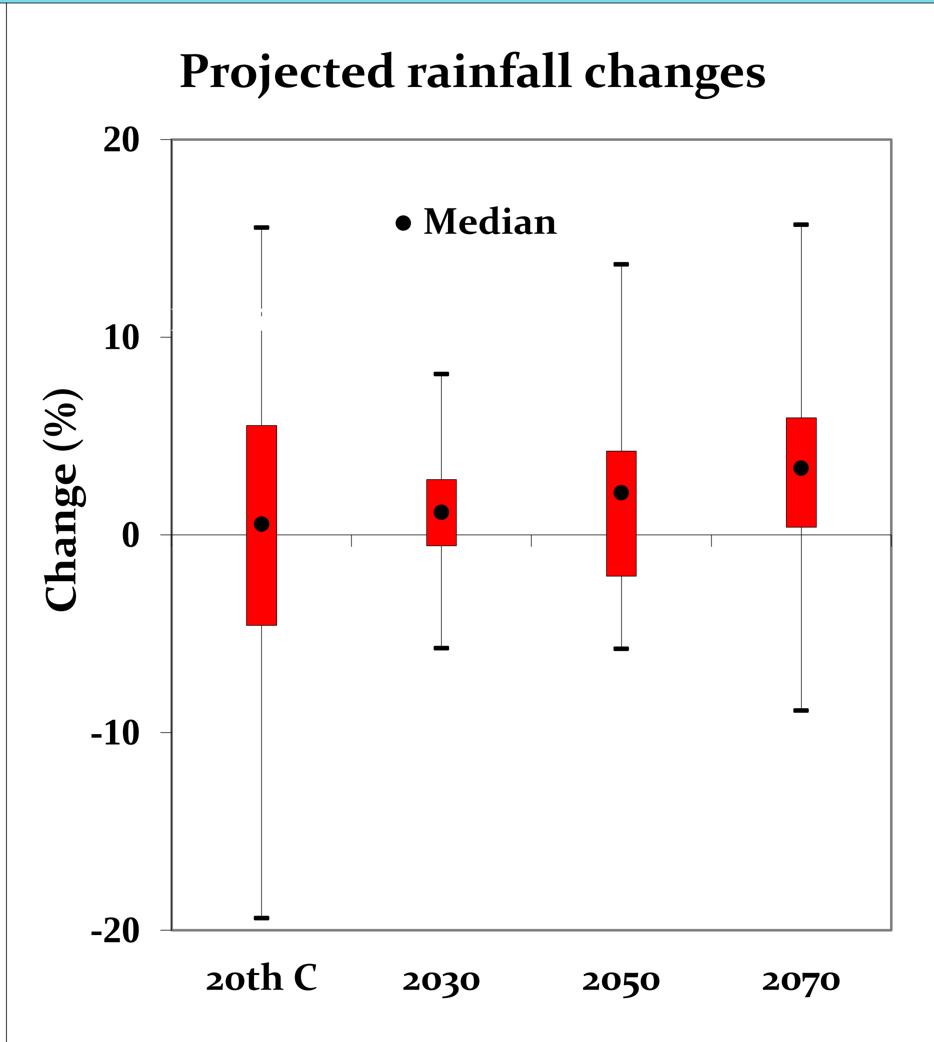
Poor performance of climate models in West Africa



Climate Change Projections for T & P

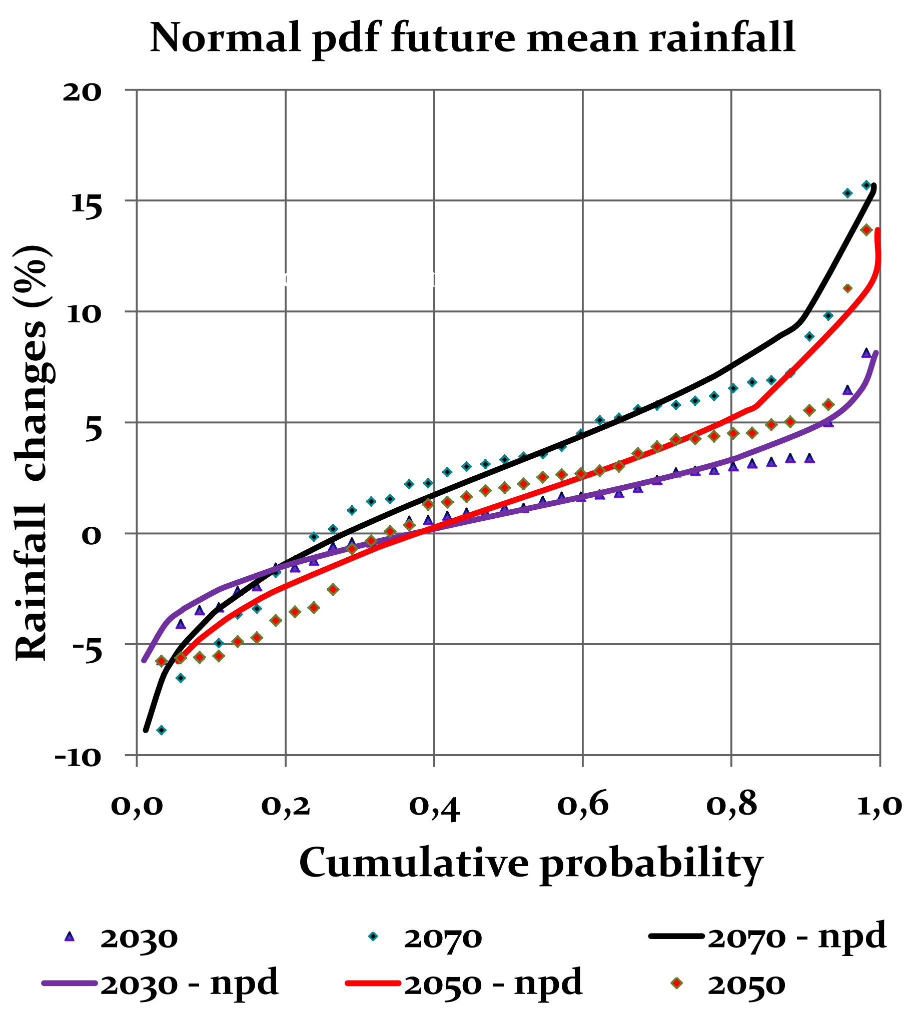
Quartiles of 38 GCM simulations for 21st Century; 30-year averages centered around 2030, 2050 and 2070

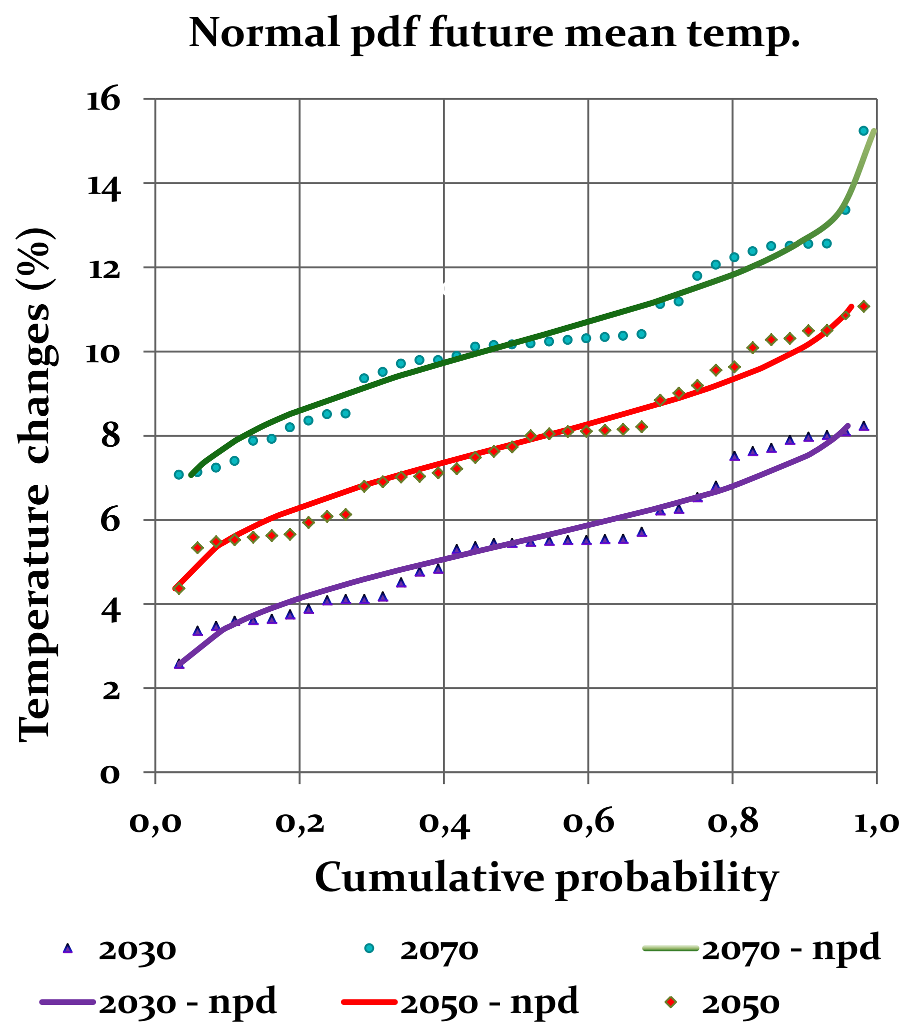




Climate Change Projections for T & P

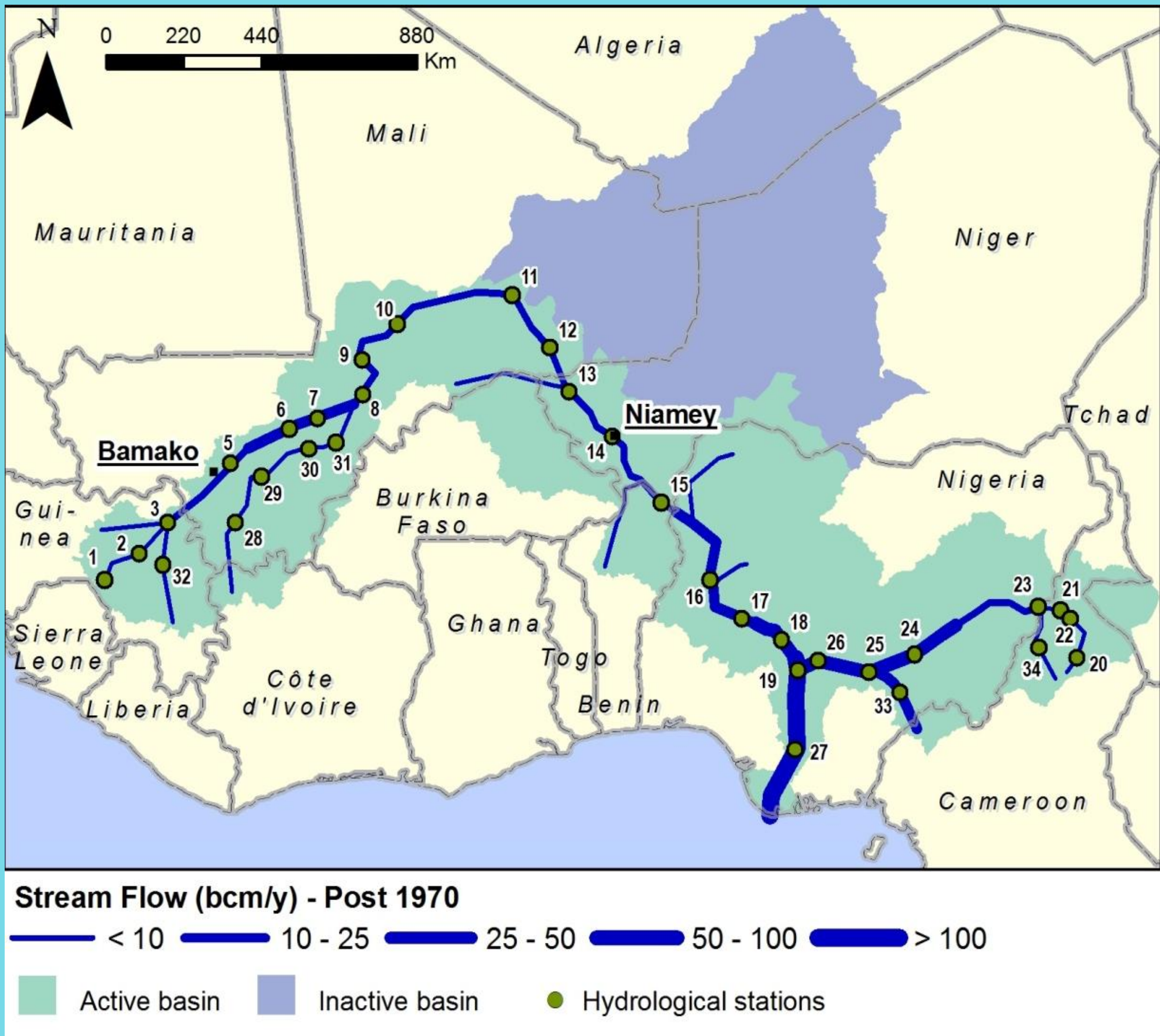
Normal probability distributions of 30-yr average projections





Runoff response to climate change:

Network of hydrometric stations in the Niger Basin

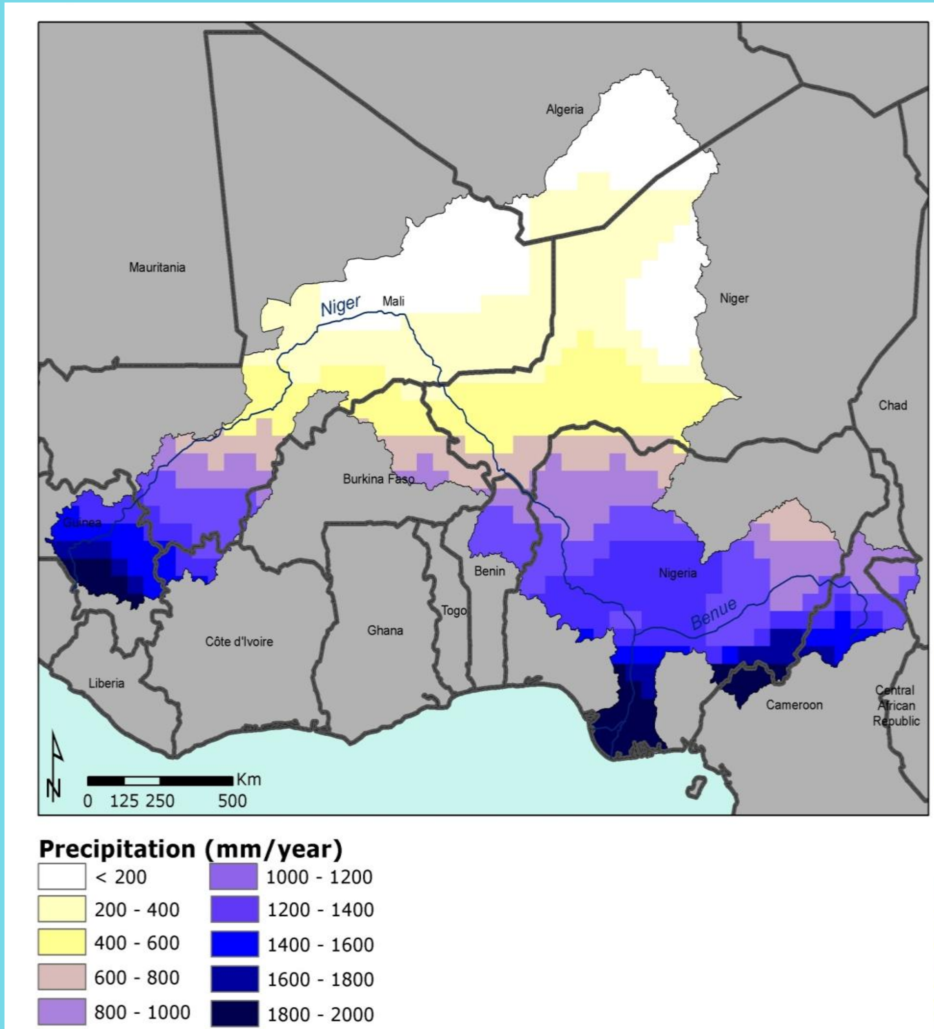


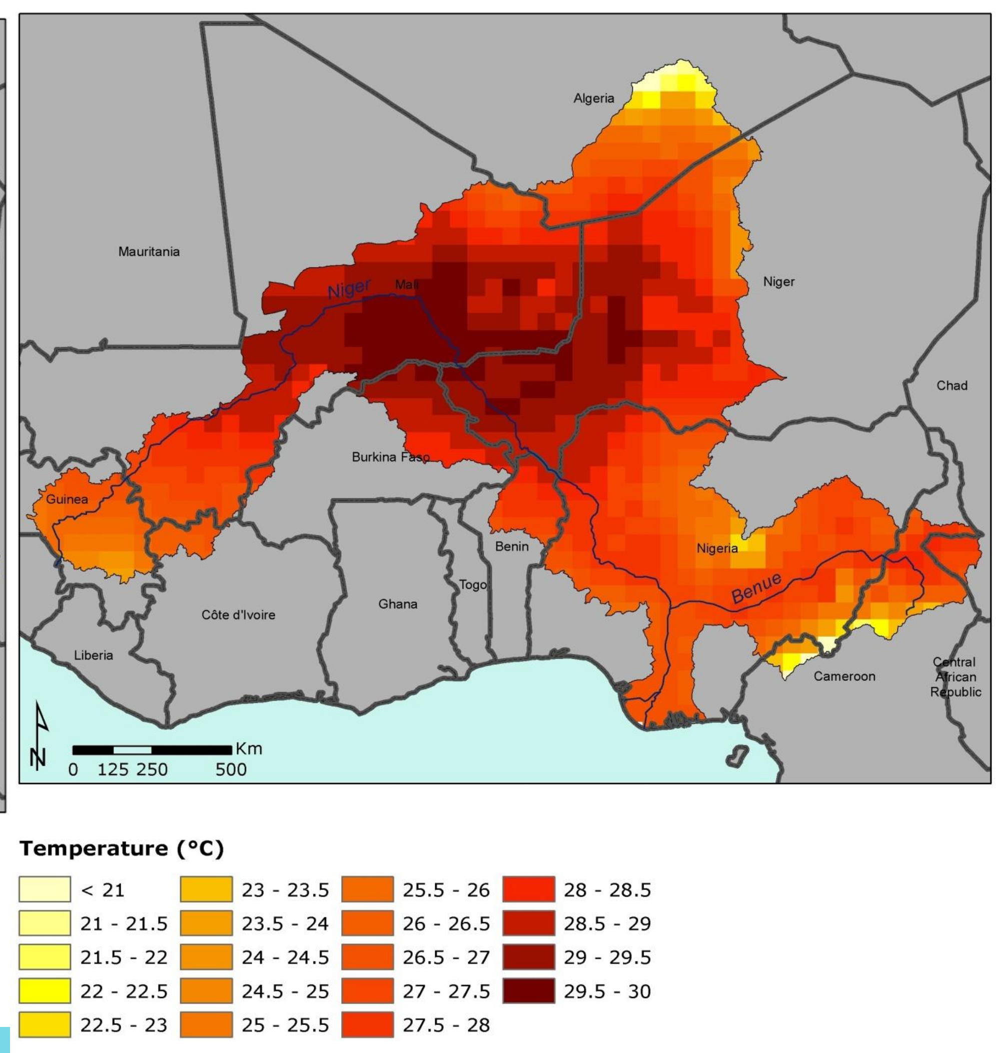
#	Station Name	Pre-1970 Flow	Post-1970 Flow
1	Faranah	2.5	1.7
2	Kouroussa	8.1	5.2
3	Siguiri	39.0	23.6
5	Koulikouro	48.9	32.9
6	Kirango aval	50.9	26.1
7	Ké-Macina	50.6	30.4
8	Mopti	42.9	23.3
9	Akka	-	24.5
10	Diré	36.6	24.5
11	Taoussa (Tossaye)	-	20.5
12	Ansongo	34.3	20.4
13	Kandadji	-	22.3
14	Niamey (Nigelec)	32.3	24.4
15	Malanville	40.1	24.4
16	Kainji amont	-	32.2
17	Jebba Bridge	54.8	33.5
18	Baro	77.4	50.7
19	Lokoja	191.7	150.8
20	Buffle noir	1.6	1.2
21	Riao	8.3	5.5
22	Garoua	12.3	7.5
23	Wuro Boki	22.4	16.9
24	Ibi	69.3	52.9
25	Makurdi	117.2	93.1
26	Umaisha	117.9	91.6
27	Onitsha	206.8	165.1
28	Bougouni	4.3	2.2
29	Dioila	7.2	2.9
30	Douna	23.6	7.7
31	Beneny Kegny	20.3	7.2
32	Kankan	6.5	4.8
33	Katsina Alla	23.3	25.1
34	Jellepo	9.9	8.0

Flow data in bcm/y

Historic P and T distribution (1948-2002)

(source Hirabayashi, 2008)

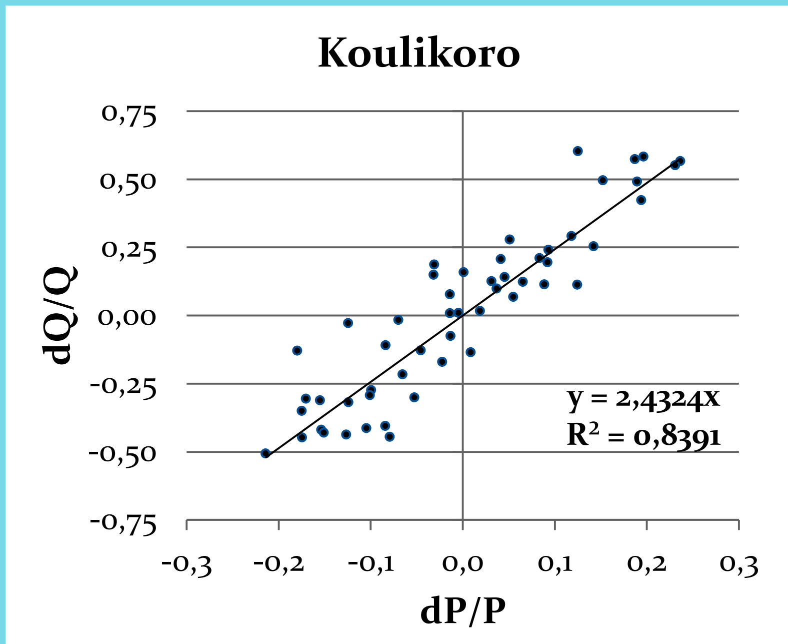


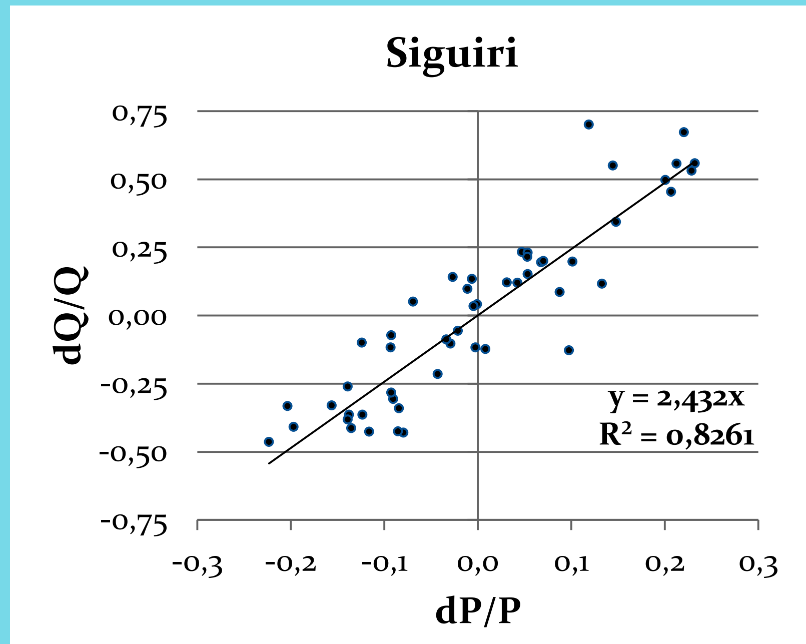


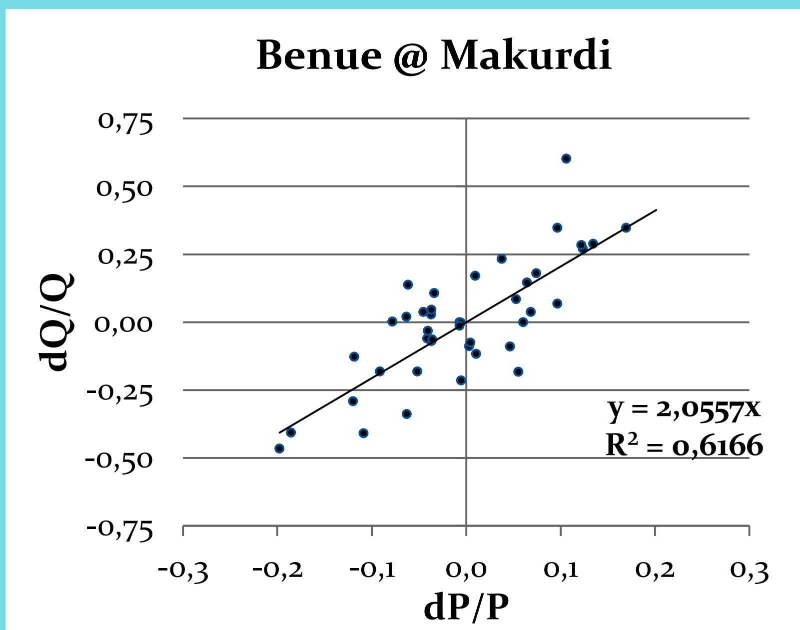
Runoff response to climate change

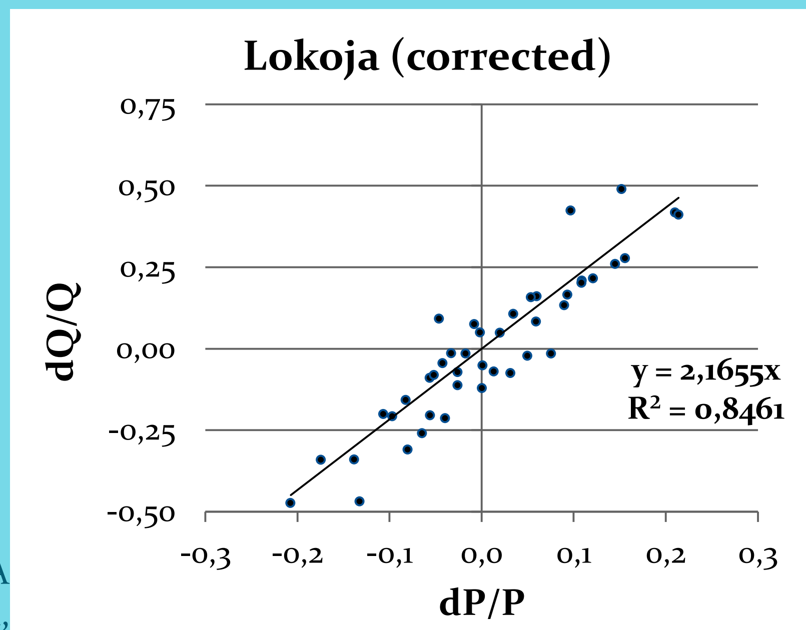
- Precipitation (ε_P) and temperature (ε_T) elasticity or sensitivity (S_T) of runoff determined based on literature research, hydrological modeling and theoretical approaches (Arora, 2002)
- Linear and non-linear regression analysis for multiple sub-catchments of Niger Basin
- Log-linear models not suitable for assessing ε_T due to small contribution of temp to runoff signal (CV-P=0.09; CV-T=0.013); CV-Q = 0.23
- Hydrological modeling was not conclusive regarding ε_T; ε_P derived from R-R model equal to results from hist. data
- We have adopted $\varepsilon_P = +2.5$ and $\varepsilon_T = -0.75$ ($S_T = -3\%$ per ^oC increase); sensitivity analysis for $\varepsilon_T = -1.25$ ($-5\%/^oC$)
- 10% increase of temperature and 3% increase of precipitation yield no change in runoff

Runoff response to climate change

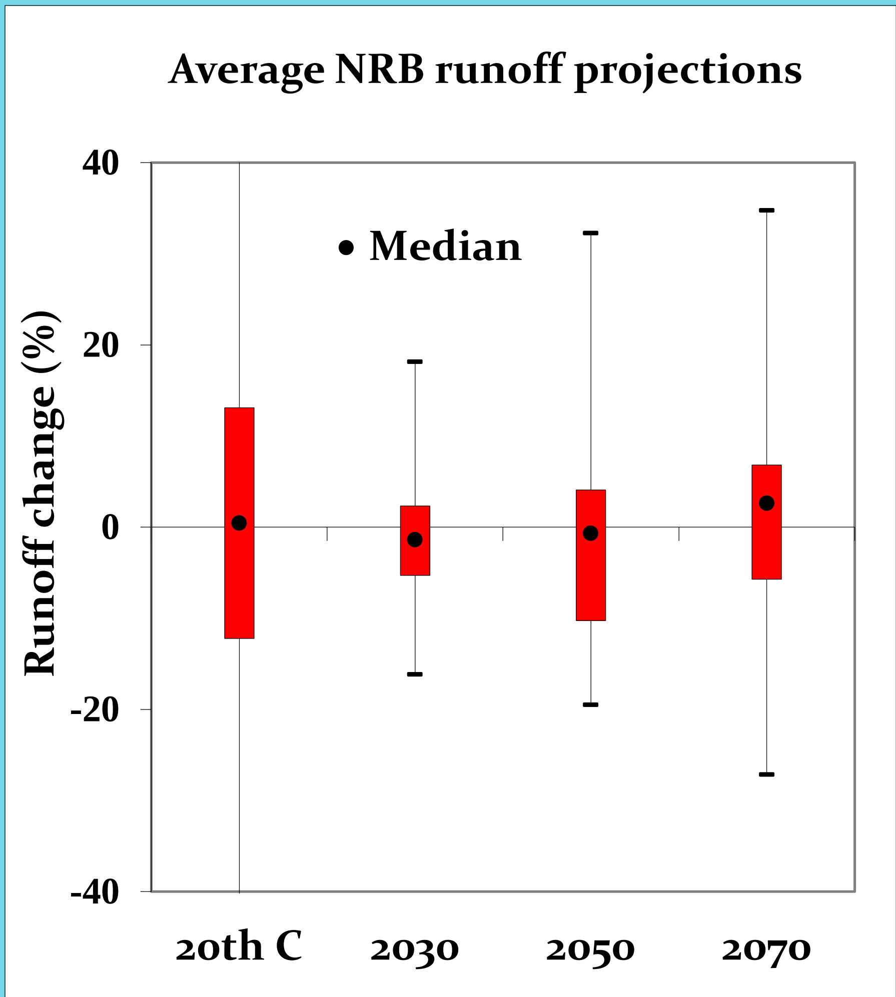


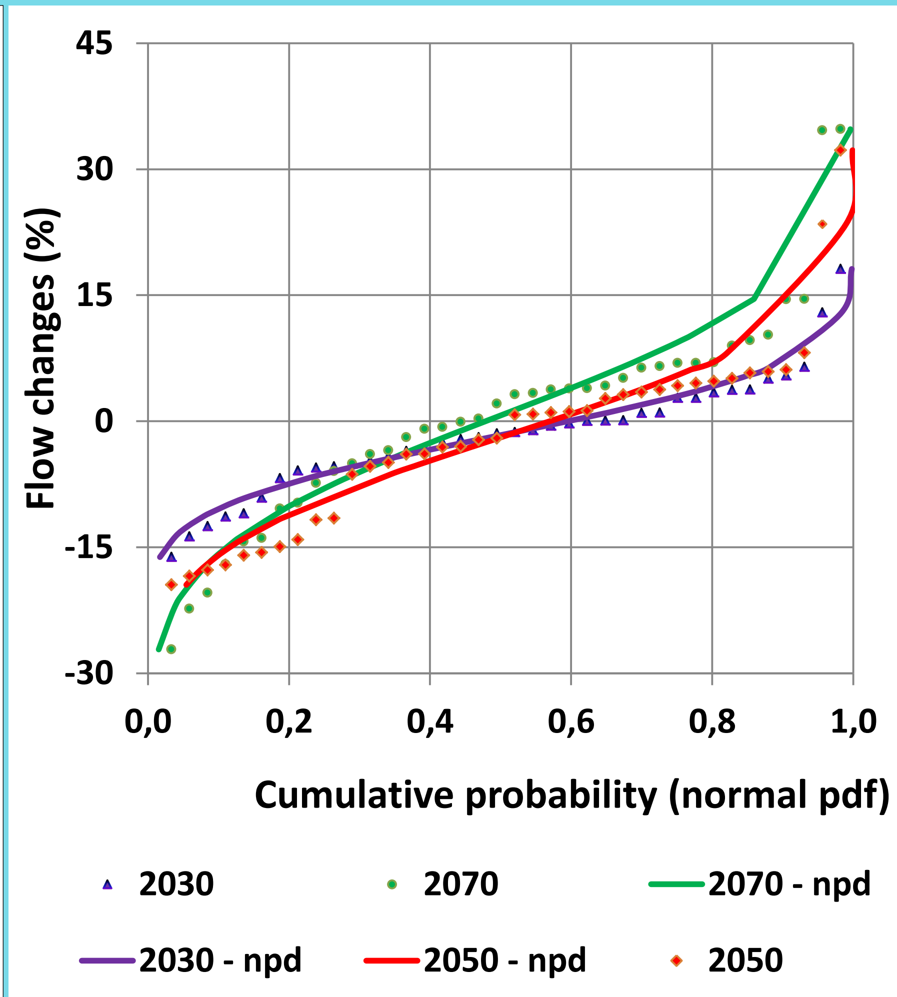






Quartiles and cumulative pdf of projected runoff changes





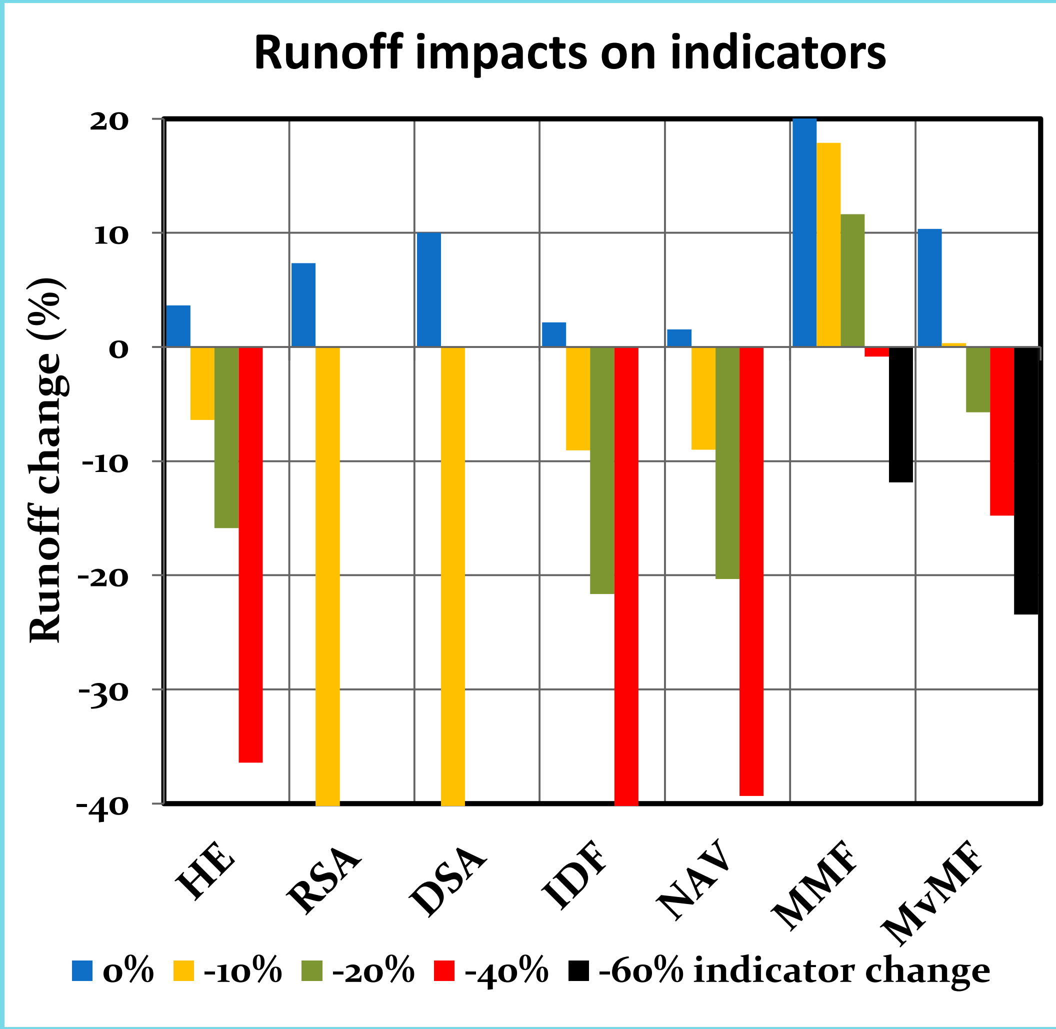
Results from various sources

- Climate Wizard: 16 GCMs
- Climate Portal WBG: 22 GCMs + CLIRUN-II (WatBal) modeling
- Niger CRA study: 38 runs for 15 GCMs + log-linear Q-P regression
- Similar results for precip, temp and runoff projections
- Worst case scenario: -20% to -25% runoff by 2050

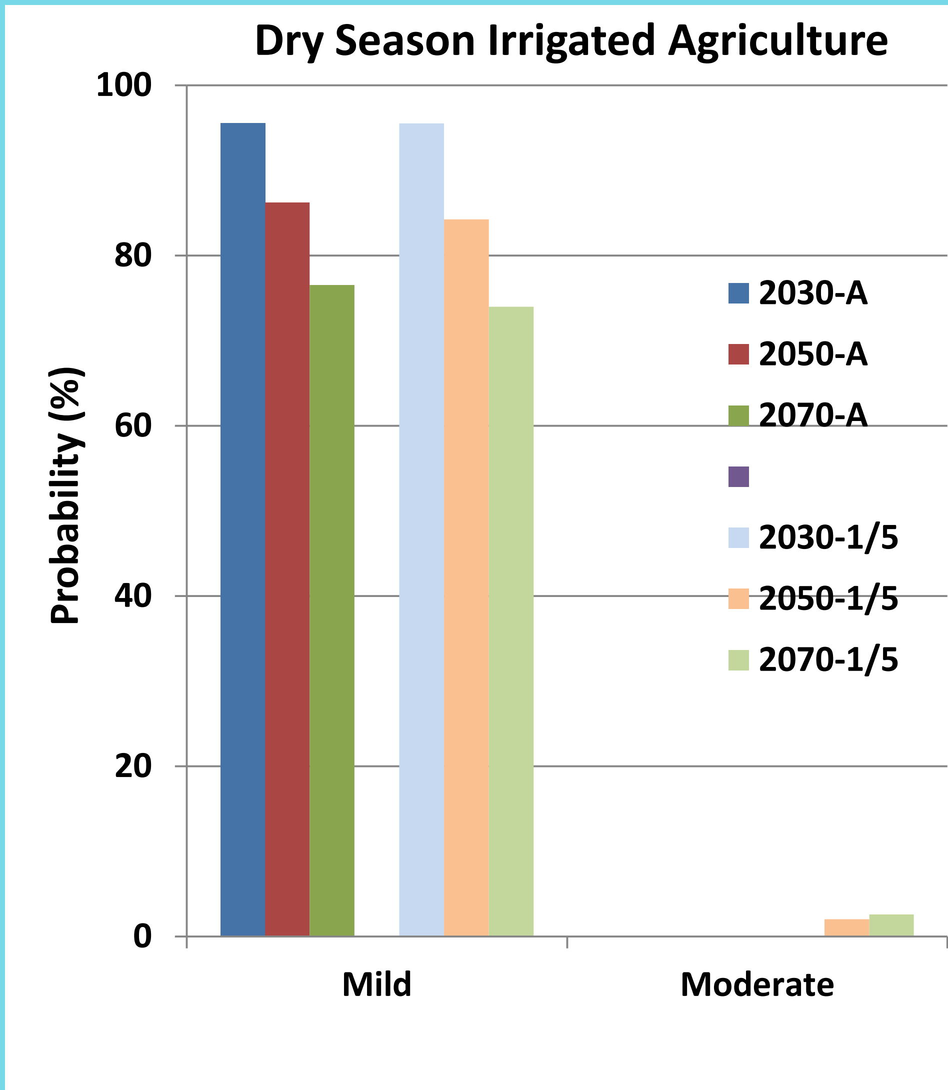
Variable	Min	20%	Mean	80%	Max	St. dev.
Climatewizard.org						
Guinea						
Temperature (^{0}C)	1.8	2.0	2.3	2.8	3.0	
Precipitation (%)	-20.0	-6.0	0.0	6.0	10.0	
Nigeria						
Temperature (^{0}C)	1.5	1.8	2.1	2.5	2.8	
Precipitation (%)	-15.0	-4.0	2.0	10.0	15.0	
WB Climate Change Knowledge Portal						
Guinea						
Temperature (^{0}C)	1.2	1.8	2.1	2.6	3.0	0.5
Precipitation (%)	-12.2	-5.2	0.5	5.6	12.9	6.8
Annual runoff (%)	-23.8	-13.5	-0.3	12.0	38.7	16.5
Annual PET (%)	0.7	3.9	5.0	6.7	8.1	1.7
Nigeria						
Temperature (^{0}C)	1.2	1.6	2.0	2.4	2.7	0.4
Precipitation (%)	-13.4	-4.4	1.2	7.0	10.9	6.4
Annual runoff (%)	-31.0	-11.3	-0.2	15.1	29.9	17.0
Annual PET (%)	1.5	3.7	4.6	6.1	7.4	1.4
Projections 38 GCM model runs for Niger River Basin						
Temperature (^{0}C)	1.2	1.6	2.1	2.6	2.9	0.5
Precipitation (%)	-5.8	-3.5	1.4	4.5	13.7	4.5
Annual runoff (%)	-19.5	-13.2	-1.9	4.7	32.3	10.9
Annual PET (%)	2.6	3.6	4.7	5.8	6.7	1.1

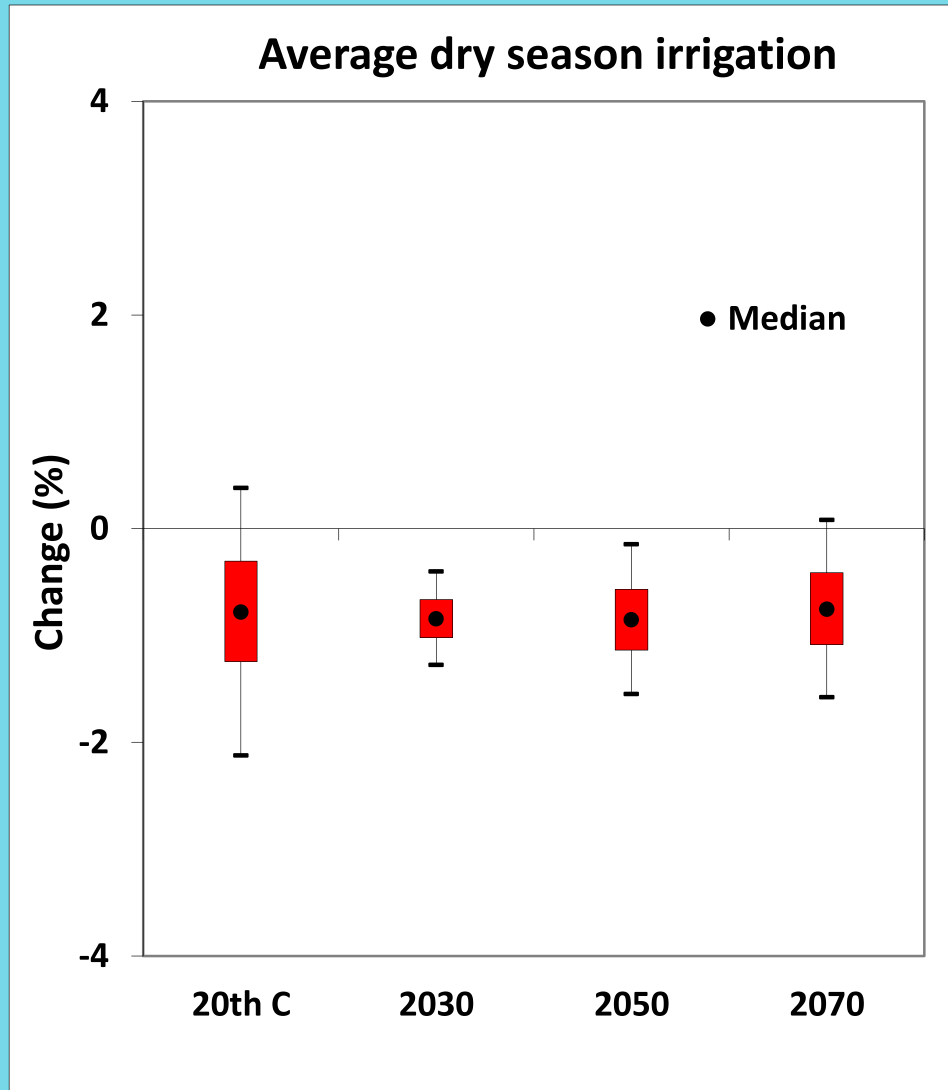
Quantitative climate risks for key water related sectors

- ❖ Impacts of runoff changes on performance indicators are combined with pdf of future average runoff changes, to produce pdf of performance indicators
- ❖ Runoff elasticities of key performance indicators:
- Irrigated agric: 0.1-0.2
- Hydro, Navigation, Flooding of Inner Delta: 1.0 – 1.2
- Minimum flows: 2 - 5

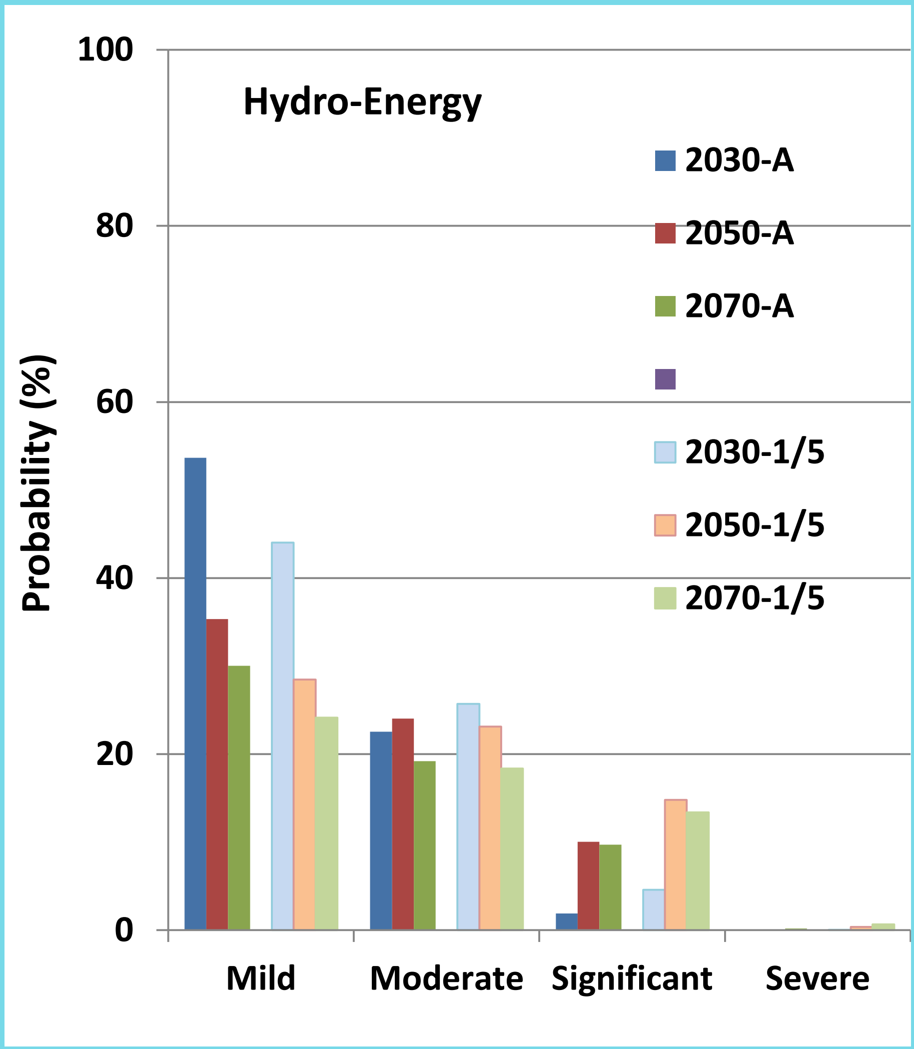


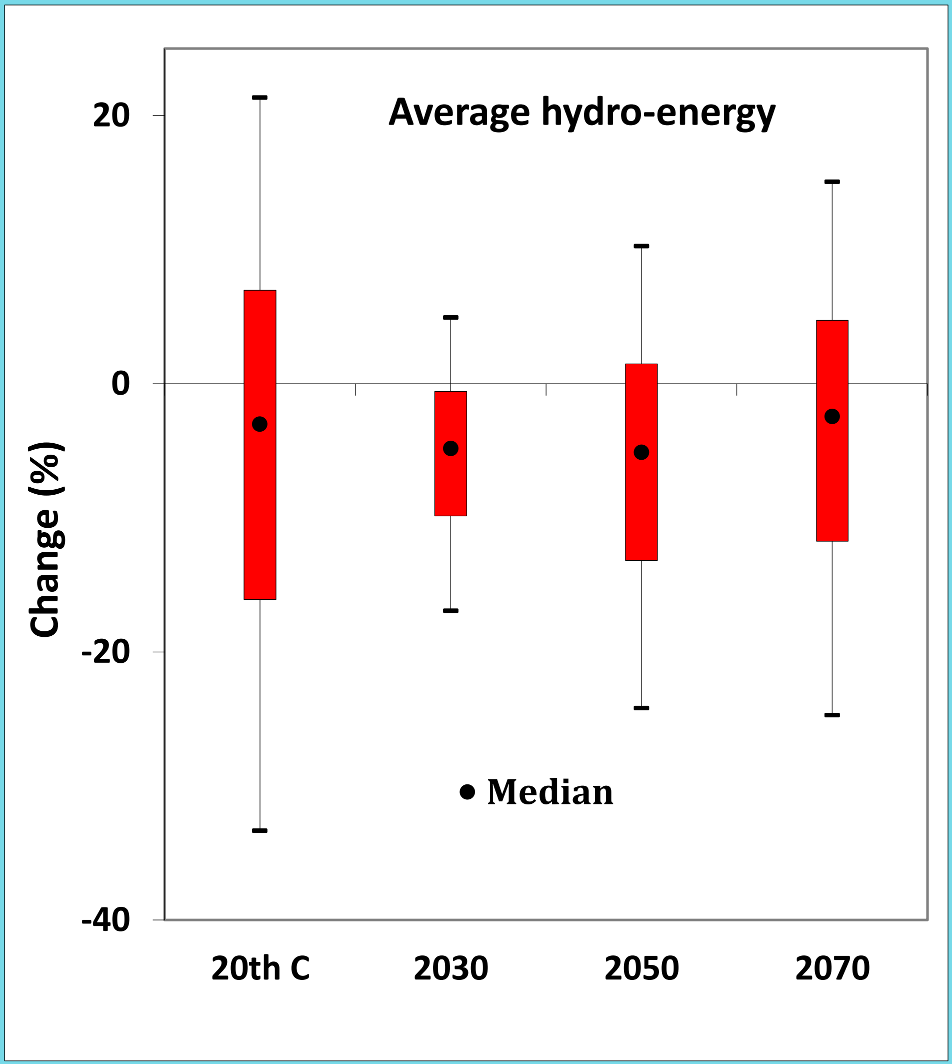
Probabilities of climate risks for dry season irrigated agriculture in the NRB



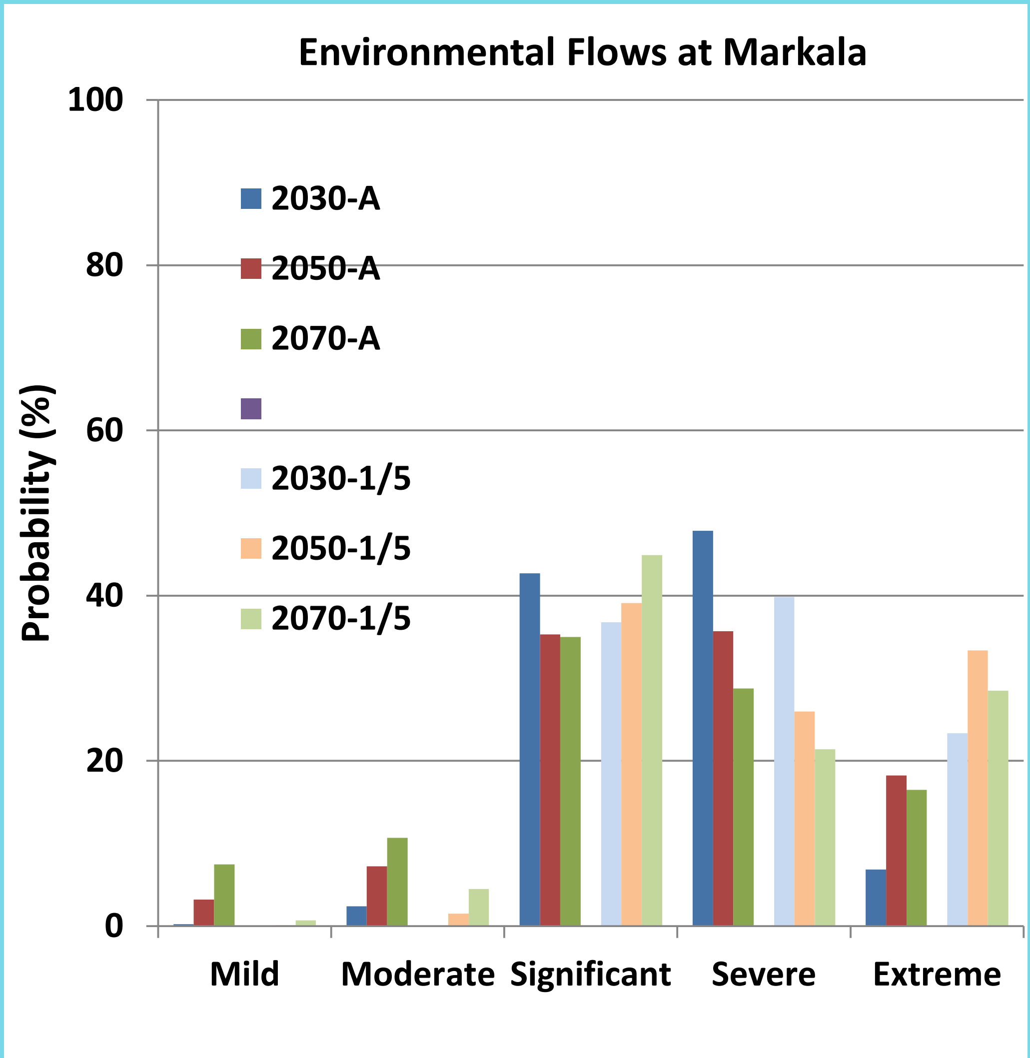


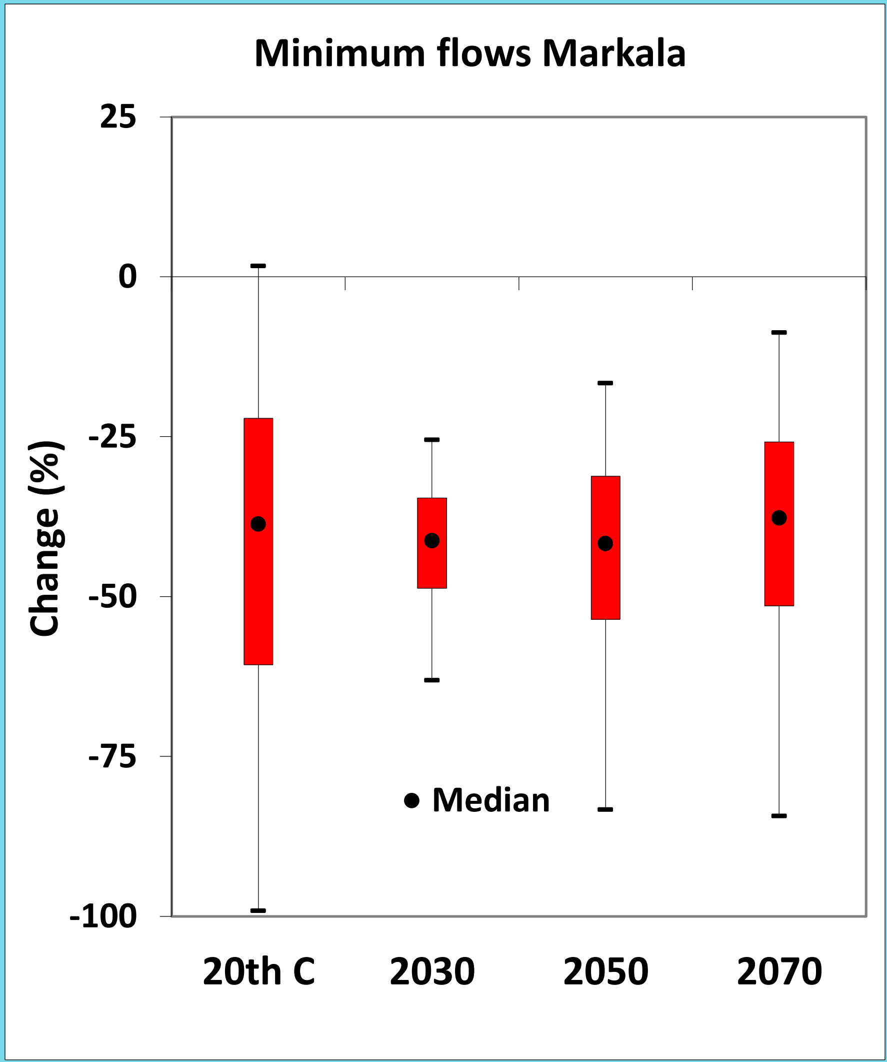
Probabilities of climate risks for Hydro-energy in the NRB





Probabilities of climate risks for minimum flows at Markala





Summary

- Irrigated agriculture is insensitive to projected climate changes; SDAP and particularly the construction of Fomi dam in Guinea is an effective adaptation measure.
- Climate change impacts on hydro-energy, navigation, and Inner Delta Flooding are projected to be mild (<10% decrease) to moderate (<20% decrease); more reservoirs with HP in Guinea and Nigeria as adaptation measures would help to augment energy production and minimum flows.
- Climate change impacts on minimum flows can be severe and require adaptations for enhancing minimum Niger River flows:
  - Implementation of SDAP
  - Improved reservoir management and seasonal planning
  - Increased irrigation efficiencies at Office du Niger in Mali
  - Shift to less water demanding non-rice dry season crops

Rapid Assessment of CC impacts

Rapid Assessment Method for CC impacts as a reliable tool under conditions of limited technical and institutional capacities and data deficiencies:

- Derive P, T and Q projections from WBG Climate Portal and Climate Wizard websites; estimate pdf of P and T changes
- Based on historical runoff and hydromet data and gridded data sets (P and T), estimate climate elasticities of runoff and derive pdf of future runoff changes from projected P and T changes
- Estimate shift in annual Q: $dQ/Q=\varepsilon_P\, E\{dP/P\}+\varepsilon_T\, E\{dT/T\}$; $Cv_Q=\varepsilon_P Cv_P$; Q, P and T denote long-term averages
- Estimate runoff elasticity of key performance indicators through WR modeling, regression analysis, etc.
- Include CC impacts on runoff in project economics analysis, for worst case scenarios: 25% runoff reduction would reduce EIRR for Kandadji dam in Niger from 13.5% to 12.1%.

Thank you!