What do climate change models tell us? Spain

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Introduction

- **Projections of runoff**
  - Studies made by Cedex
- **Projections of water availability**
  - WAAPA model, global for Europe and specific for Spain
  - Analysis of factors determining water availability
- **Role of adaptation**
  - Effect of policy on water availability

Studies of Cedex (2010, 2017) Methodology

Study of 2010
6 projections SRES A2
6 projections SRES B2

Study of 2017
6 projections RCP4.5
6 projections RCP8.5

Climate forcing

Precipitation

Potential ET

Hydrologic model

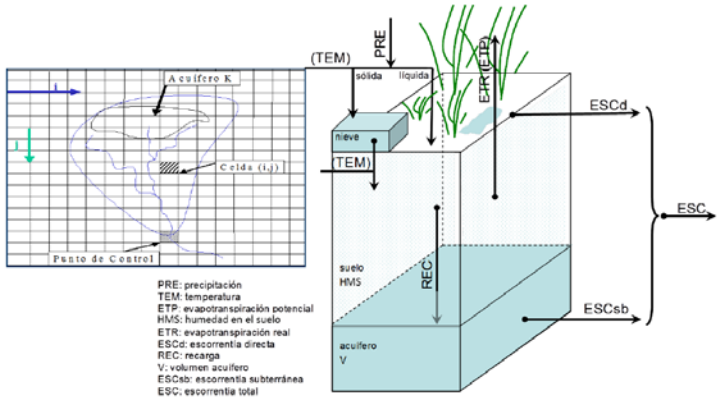
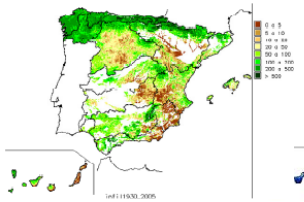


Figura 77. Esquema conceptual del módulo de evaluación de RRHH de SIMPA.

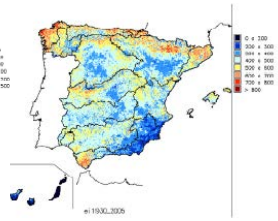
Hydrologic projections

Runoff

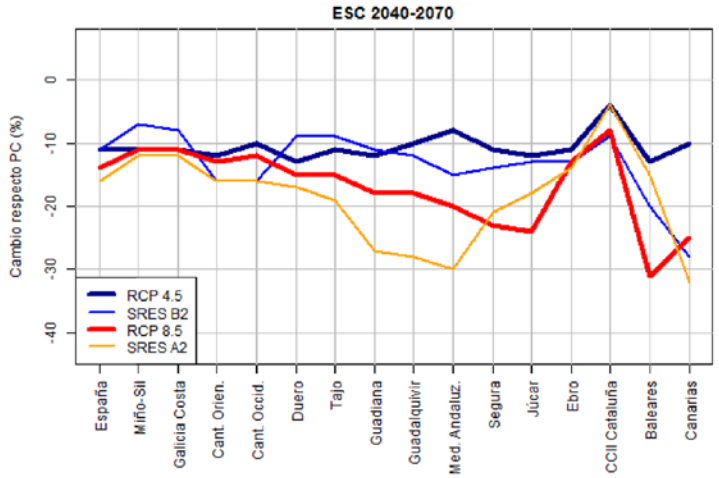
Recharge



Actual ET



Results by basin



Comparison of studies by Cedex (2010-2017)

Tabla 27. Rango y media de Δ en las variables hidroclimáticas en España en cada PI y escenario de emisiones según el presente estudio y comparación con el de CEDEX 2010.

	ESPAÑA		Presente Estudio						CEDEX 2010					
			RCP 4.5			RCP 8.5			SRES B2			SRES A2		
			Mx	Med	Mn	Mx	Med	Mn	Max	Med	Min	Max	Med	Min
Precipitation	PRE (%)	2010-2040	9	**-2**	-8	1	**-4**	-8	-3	**-6**	-10	0	**-5**	-11
		2040-2070	-1	**-6**	-13	3	**-8**	-16	-3	**-8**	-12	-4	**-9**	-16
		2070-2100	1	**-7**	-17	-2	**-14**	-24	-2	**-9**	-14	2	**-17**	-28
Temperature	TEM (ºC)	2010-2040	1.5	**0.9**	0.4	1.6	**1.0**	0.5	1.9	**1.6**	1.4	1.8	**1.5**	1.2
		2040-2070	2.6	**1.6**	0.9	3.4	**2.3**	1.7	3.0	**2.5**	2.0	3.4	**2.9**	2.5
		2070-2100	3.2	**2.0**	1.5	5.6	**3.9**	2.8	4.4	**3.6**	2.7	5.8	**4.8**	4.0
Potential ET	ETP (%)	2010-2040	6	**3**	1	7	**4**	2	8	**7**	6	6	**6**	6
		2040-2070	11	**7**	4	14	**10**	8	14	**12**	10	14	**13**	12
		2070-2100	14	**9**	6	24	**17**	12	19	**15**	13	28	**21**	19
Actual ET	ETR (%)	2010-2040	4	**-1**	-3	0	**-3**	-3	-3	**-5**	-8	1	**-3**	-7
		2040-2070	-2	**-3**	-5	0	**-4**	-7	-1	**-6**	-10	-2	**-6**	-10
		2070-2100	0	**-3**	-5	-2	**-6**	-11	0	**-7**	-12	2	**-12**	-24
Runoff	ESC (%)	2010-2040	20	**-3**	-13	4	**-7**	-14	1	**-8**	-18	-2	**-8**	-22
		2040-2070	-1	**-11**	-23	9	**-14**	-29	-5	**-11**	-21	-8	**-16**	-34
		2070-2100	4	**-13**	-31	-1	**-24**	-43	-1	**-14**	-28	0	**-28**	-40

Similar results, slightly less reduction in runoff

Results of Cedex 2017

Projected reduction of runoff (%)

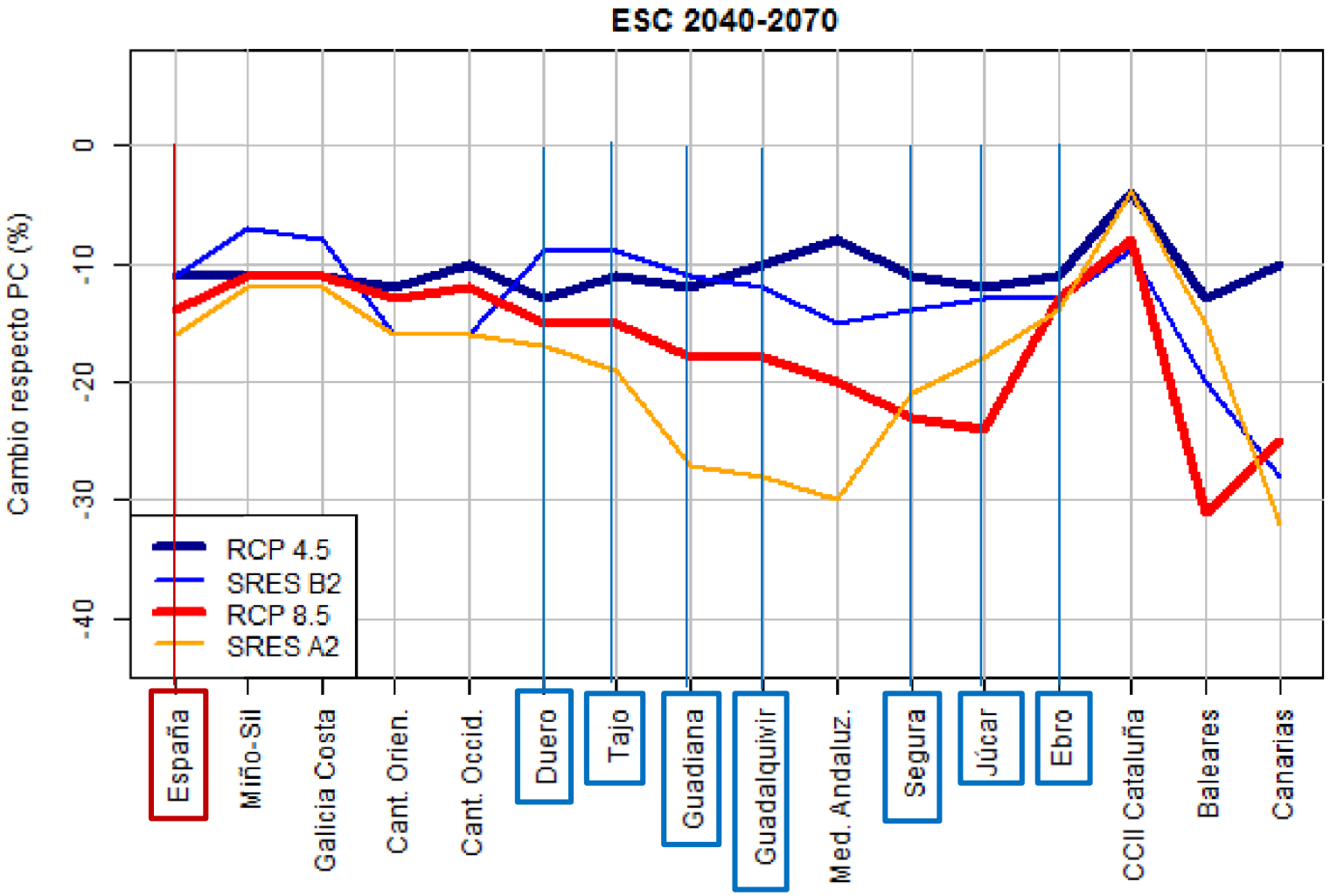
Tabla 24. Δ (%) ESC en cada DH y PI según cada proyección. Se indican los valores máximo (Mx), mínimo (Mn) y el promedio (Med) para cada RCP. Los colores reflejan la gradación del cambio.

ESC Δ Anual (%)		RCP 4.5									RCP 8.5								
		F4A	M4A	N4A	Q4A	R4A	U4A	Mx	Med	Mn	F8A	M8A	N8A	Q8A	R8A	U8A	Mx	Med	Mn
Duero	2010-2040	2	-7	-15	-12	-14	25	25	**-3**	-15	6	-5	-17	-19	-11	-5	6	**-9**	-19
	2040-2070	-10	-8	-14	-17	-27	1	1	**-13**	-27	-12	-20	-23	-19	-31	15	15	**-15**	-31
	2070-2100	-6	-21	-18	-13	-36	9	9	**-14**	-36	-23	-28	-15	-40	-46	3	3	**-25**	-46
Tajo	2010-2040	5	-4	-22	-10	-17	31	31	**-3**	-22	12	-5	-20	-20	-13	-4	12	**-8**	-20
	2040-2070	-6	-3	-14	-13	-29	3	3	**-11**	-29	-8	-19	-31	-16	-34	19	19	**-15**	-34
	2070-2100	-2	-20	-23	-13	-40	12	12	**-14**	-40	-23	-23	-18	-41	-51	7	7	**-25**	-51
Guadiana	2010-2040	9	-5	-35	-12	-23	46	46	**-3**	-35	18	-8	-30	-22	-20	5	18	**-9**	-30
	2040-2070	-6	-3	-21	-13	-36	9	9	**-12**	-36	-9	-23	-45	-19	-45	33	33	**-18**	-45
	2070-2100	1	-25	-37	-15	-50	22	22	**-17**	-50	-27	-26	-27	-50	-63	15	15	**-30**	-63
Guadalquivir	2010-2040	10	-4	-38	-11	-24	52	52	**-2**	-38	18	-10	-30	-22	-21	8	18	**-10**	-30
	2040-2070	-3	-2	-22	-10	-37	15	15	**-10**	-37	-6	-24	-51	-17	-48	35	35	**-18**	-51
	2070-2100	2	-22	-43	-16	-51	18	18	**-19**	-51	-30	-27	-32	-49	-67	13	13	**-32**	-67
Segura	2010-2040	6	-4	-21	-13	-22	15	15	**-7**	-22	12	-13	-19	-23	-19	7	12	**-9**	-23
	2040-2070	-1	-7	-10	-18	-32	-1	-1	**-11**	-32	-10	-17	-37	-23	-48	-3	-3	**-23**	-48
	2070-2100	-6	-19	-28	-17	-43	-9	-6	**-20**	-43	-36	-30	-34	-44	-63	-17	-17	**-38**	-63
Júcar	2010-2040	5	1	-17	-7	-26	21	21	**-4**	-26	15	-12	-20	-20	-25	-4	15	**-11**	-25
	2040-2070	-6	-4	-7	-11	-34	-8	-4	**-12**	-34	-12	-21	-34	-22	-49	-7	-7	**-24**	-49
	2070-2100	-7	-16	-26	-18	-46	-11	-7	**-21**	-46	-36	-28	-26	-41	-62	-20	-20	**-36**	-62
Ebro	2010-2040	0	-6	-3	-7	-12	15	15	**-2**	-12	-3	-9	-7	-9	-10	-2	-2	**-7**	-10
	2040-2070	-9	-12	-10	-13	-19	-5	-5	**-11**	-19	-9	-19	-14	-16	-25	4	4	**-13**	-25
	2070-2100	-7	-16	-12	-10	-25	-3	-3	**-12**	-25	-25	-33	-14	-32	-40	-10	-10	**-26**	-40

Large variability, strong reduction of runoff

Results of Cedex 2010-2017

Projected reduction of runoff (%)



Large variability, strong reduction of runoff (10% for RCP4-5)

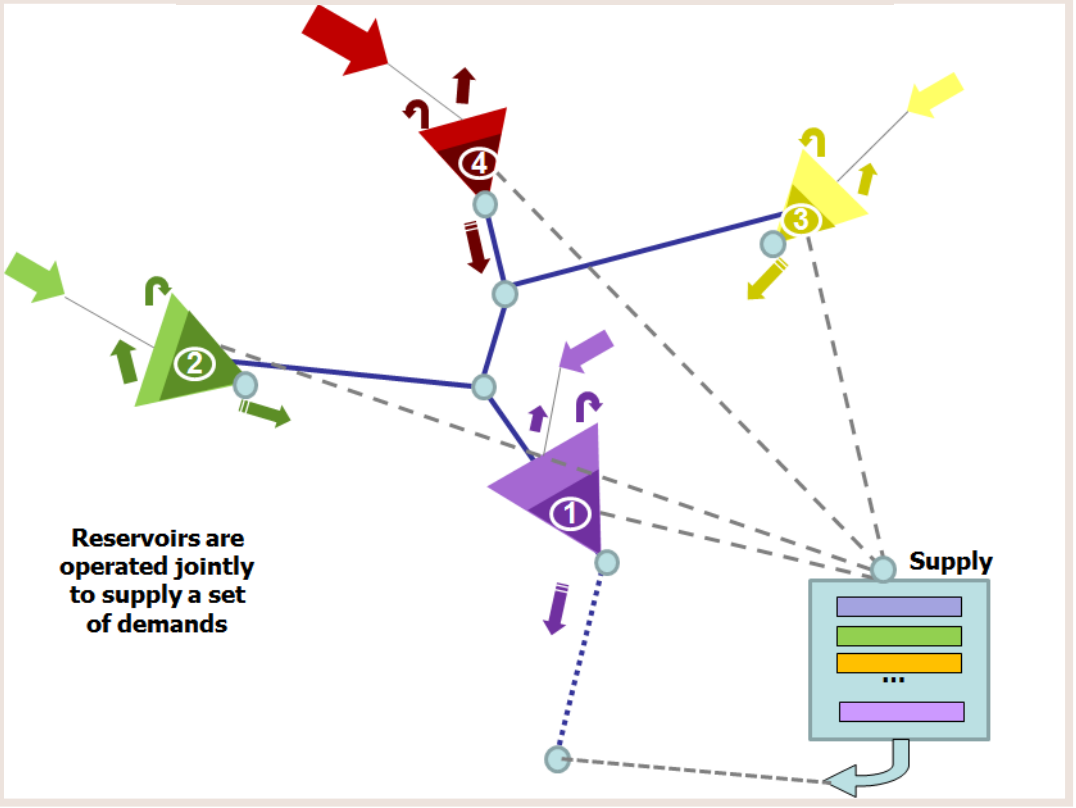
Water availability

- **Runoff is a proxy for changes in water availability**
- **But there are other factors…**
  - Changes in variability
  - Water management: reliability, environmental flows, storage
- **Simple model to estimate water availability**
  - Streamflow, storage, demands and environmental flows
  - Analysis under climate change scenarios

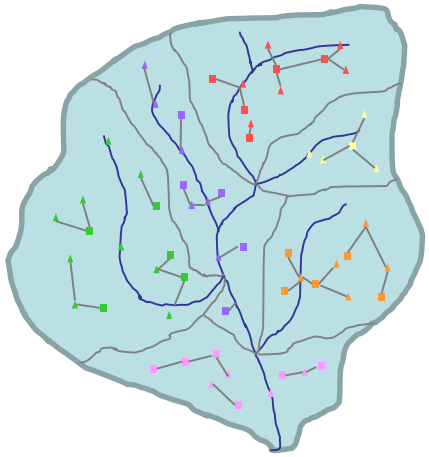
WAAPA Model

WAAPA : Water Availability and Adaptation Policy Analysis

WAAPA MODEL ALGORITHM

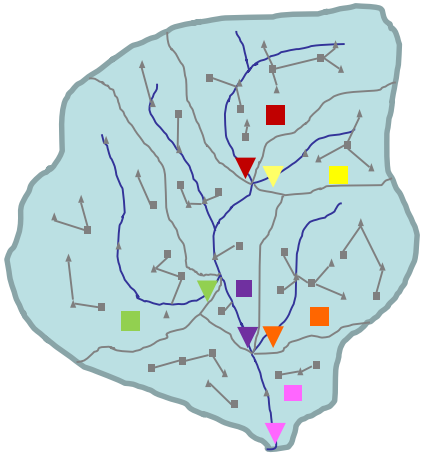


GEOGRAPHICAL DATA



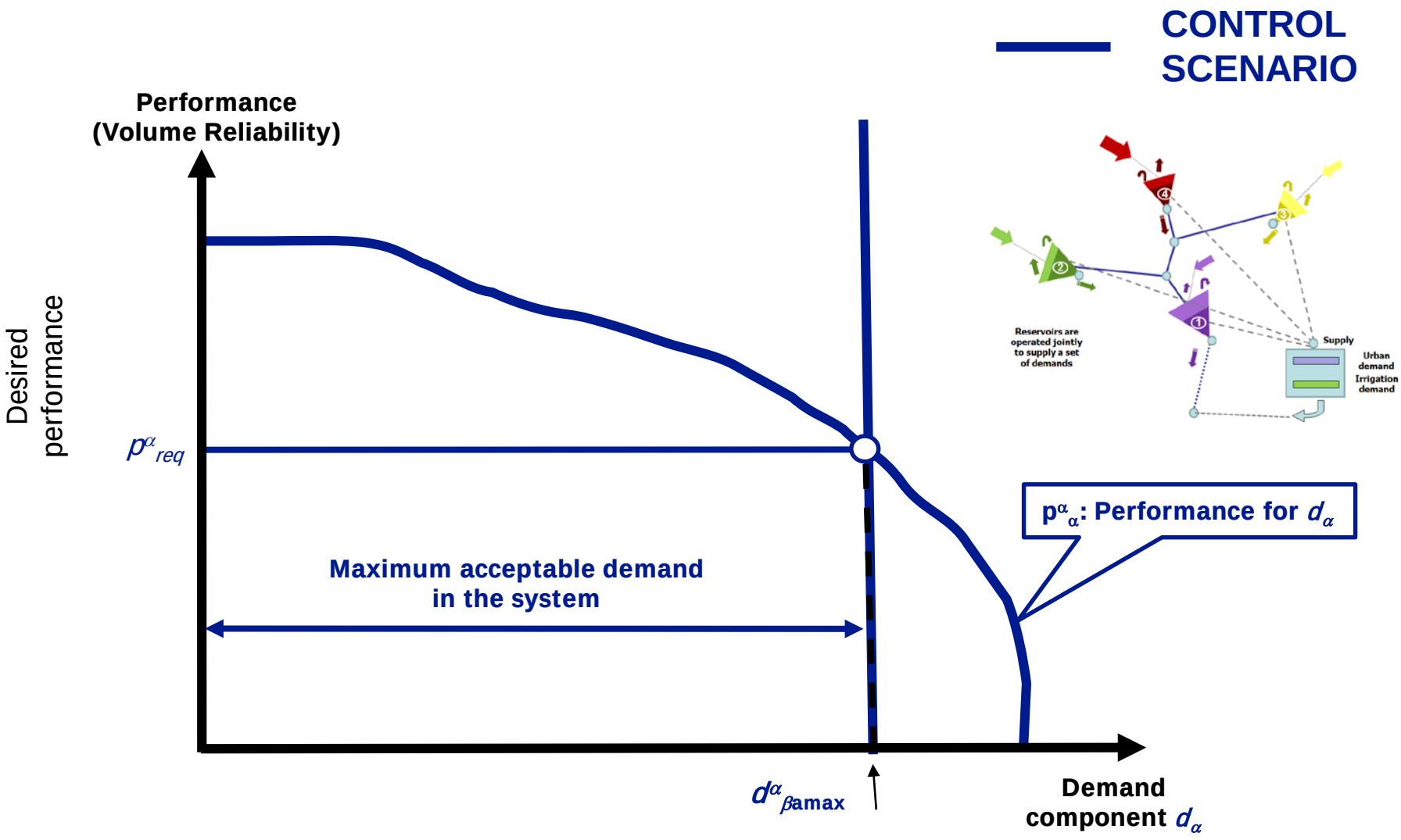
Reservoirs and demands distributed in subbasin

WAAPA MODEL DATA



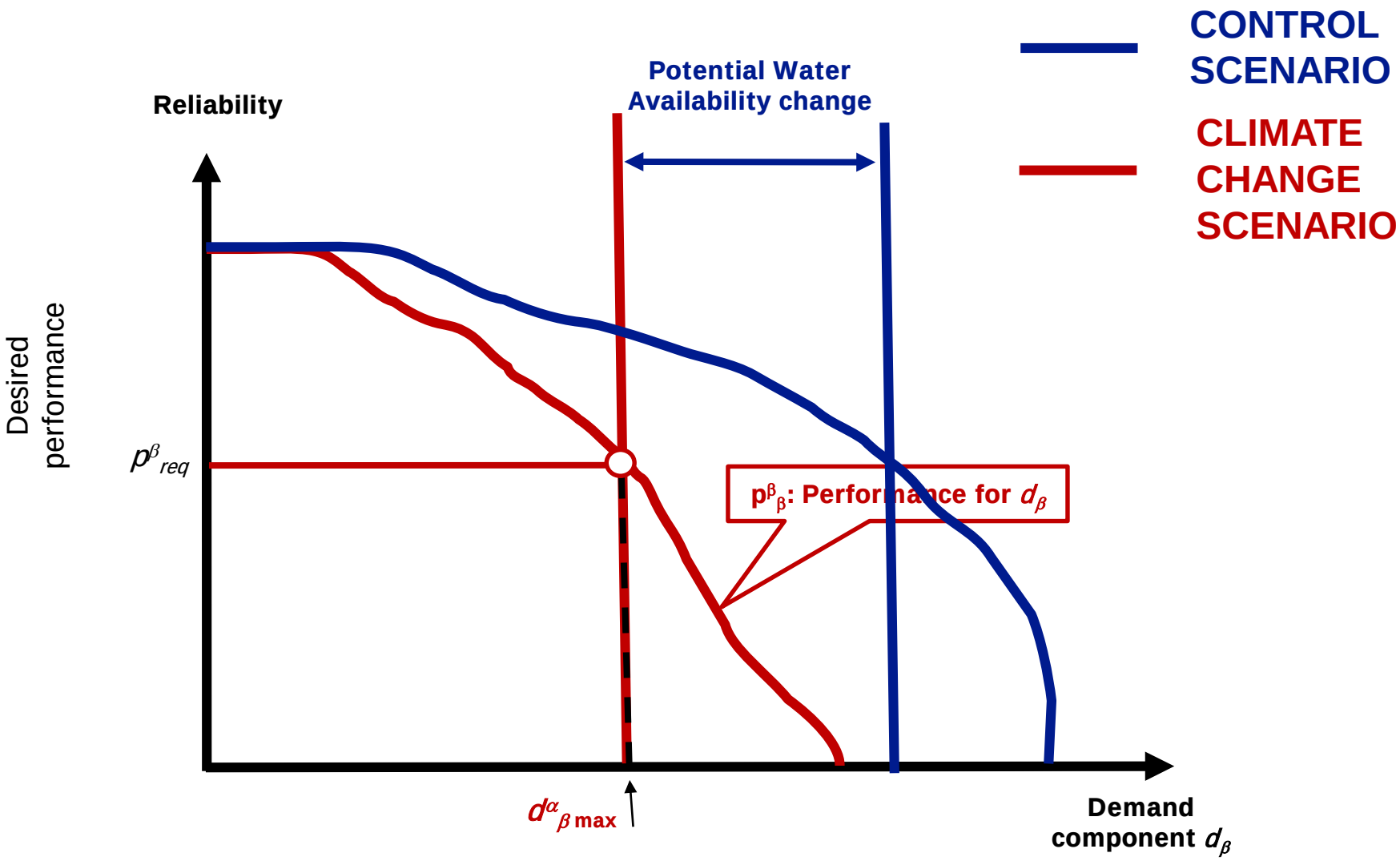
One reservoir and one demand per subbasin

Potential Water Availability analysis



DEMAND-RELIABILITY CURVE

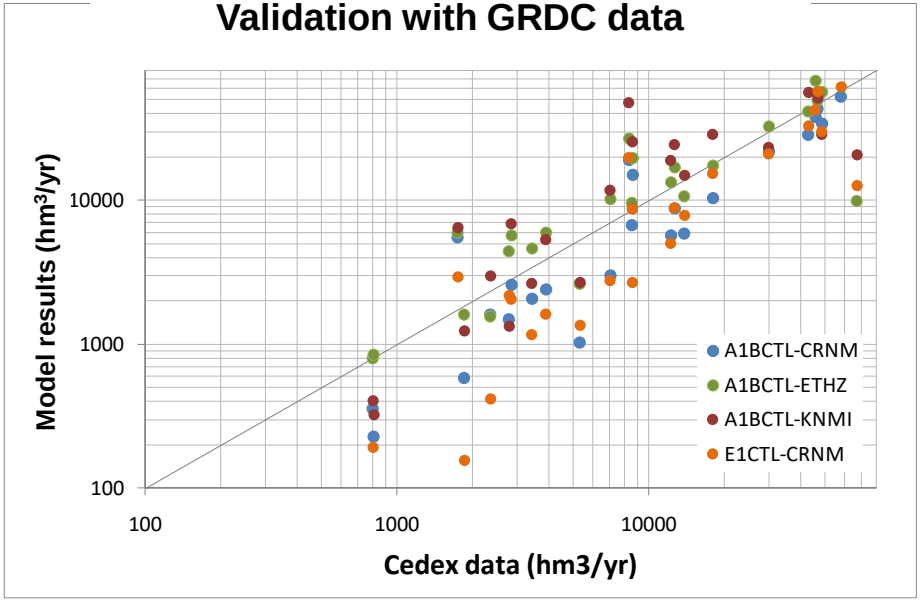
PWA analysis under climate change

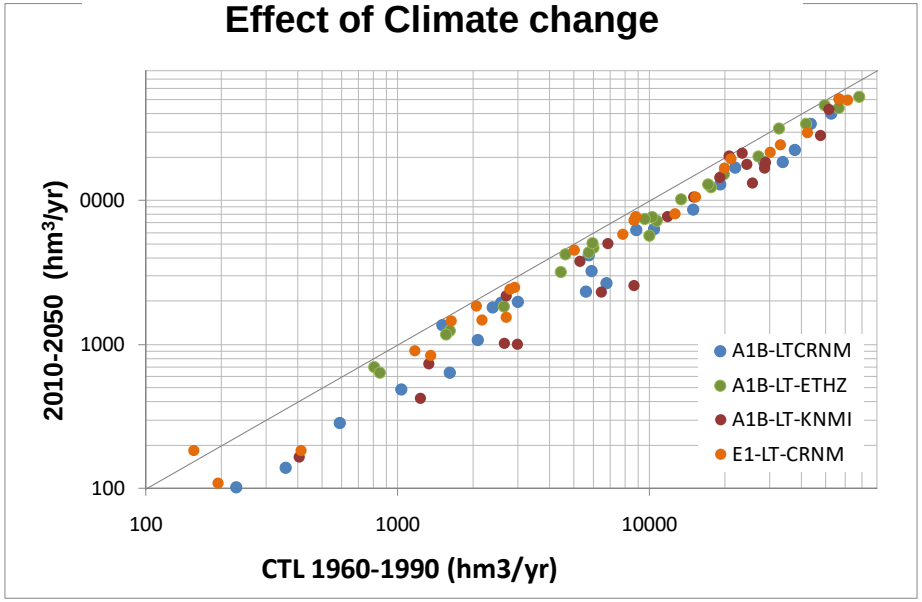


DEMAND-RELIABILITY CURVE

Climate scenarios

- Climate scenarios were taken from regional models in different projects: PRUDENCE, ENSEMBLES and CORDEX
  - 8 **A2**, 4 **B2**, 3 **A1B**, 5 **RCP2**, 5 **RCP4**, 5 **RCP6**, 5 **RCP8**
  - Time slices CTL: **1960-2000** FUTURE: **2070-2100**



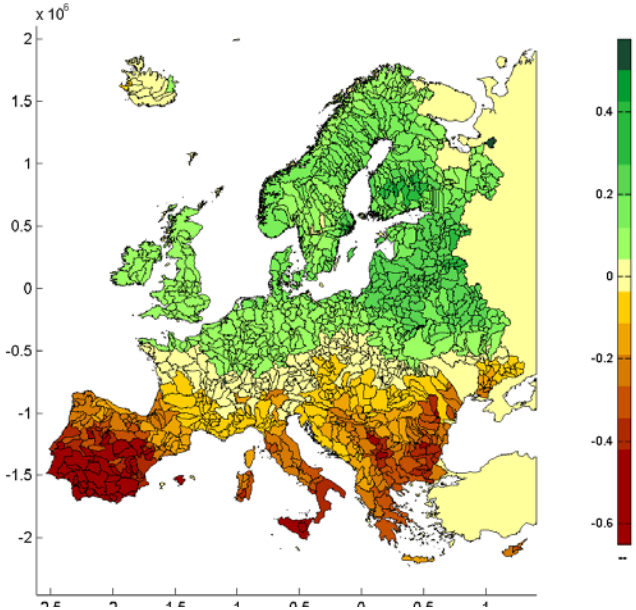


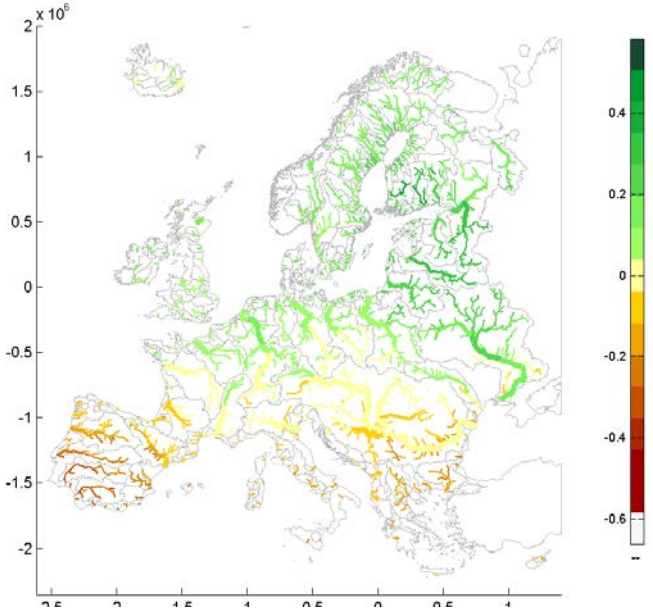
- Streamflow data were corrected for **bias**

- Significant **reduction** in most basins

Analysis of European basins

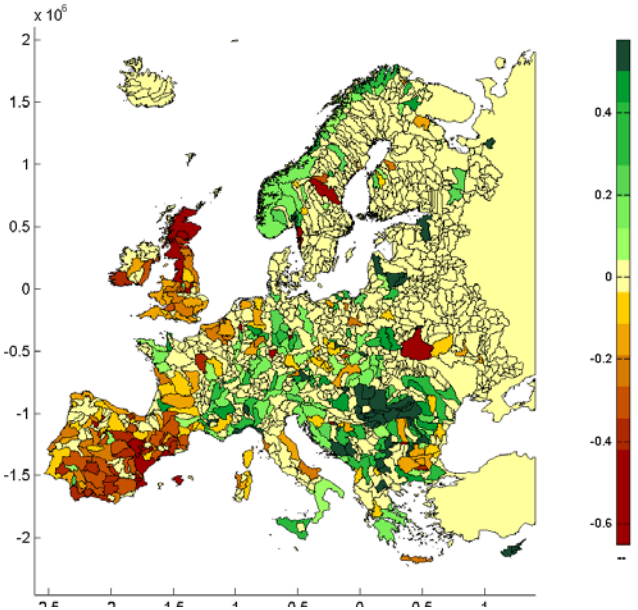
CHANGE in RUNOFF

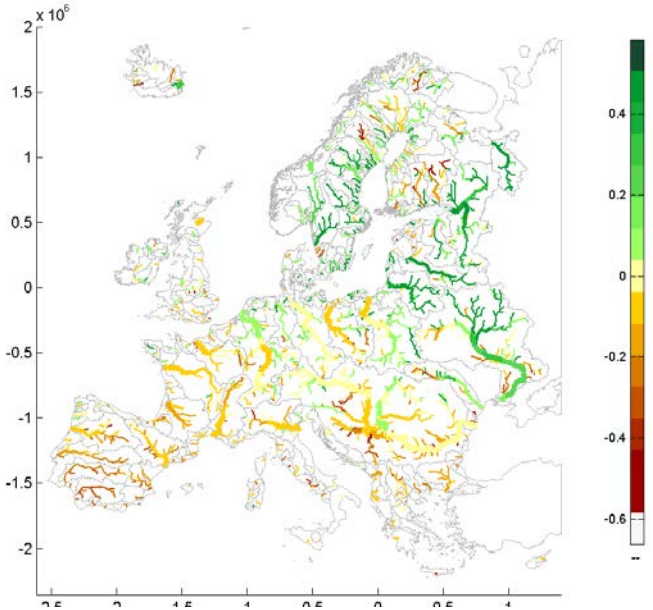




Scenario RCP4.5

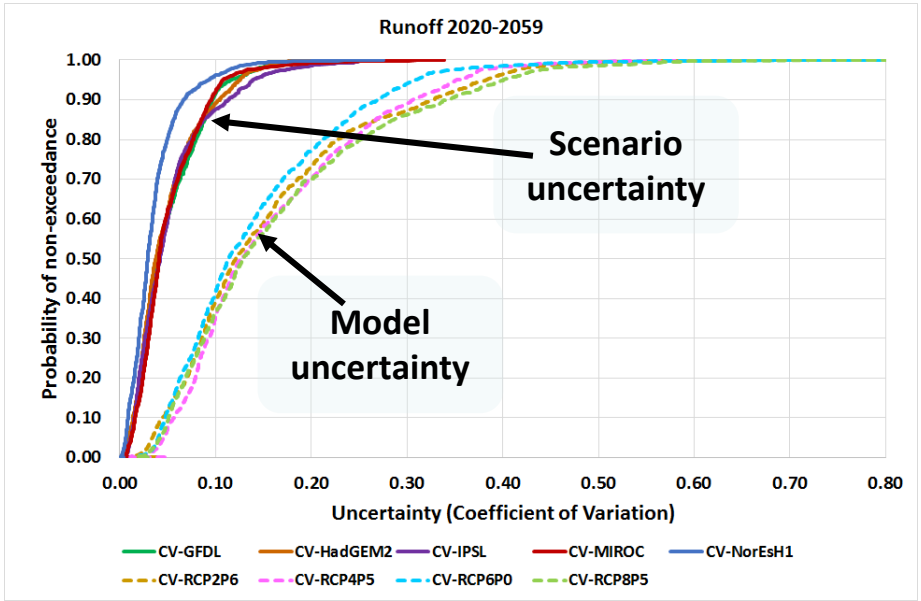
CHANGE in AVAILABILITY

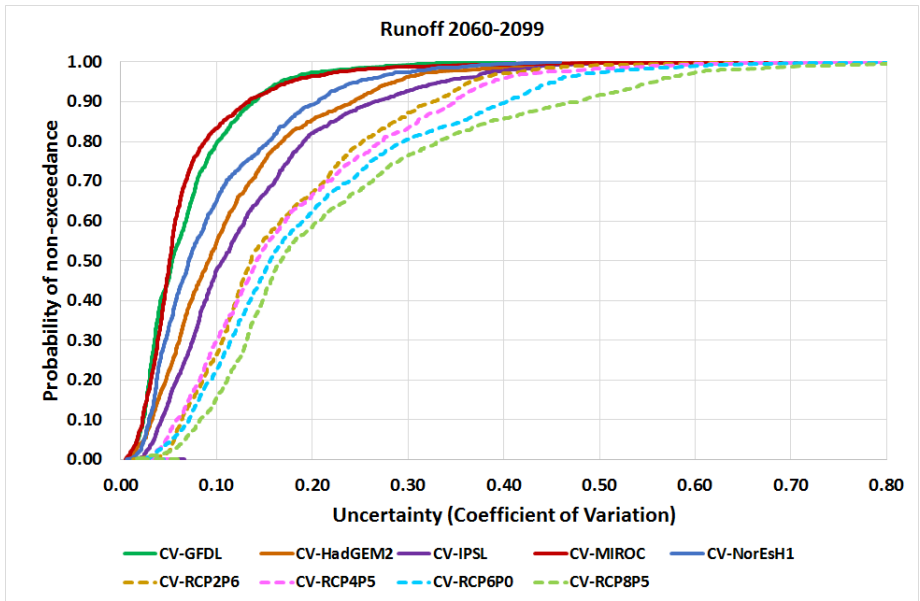


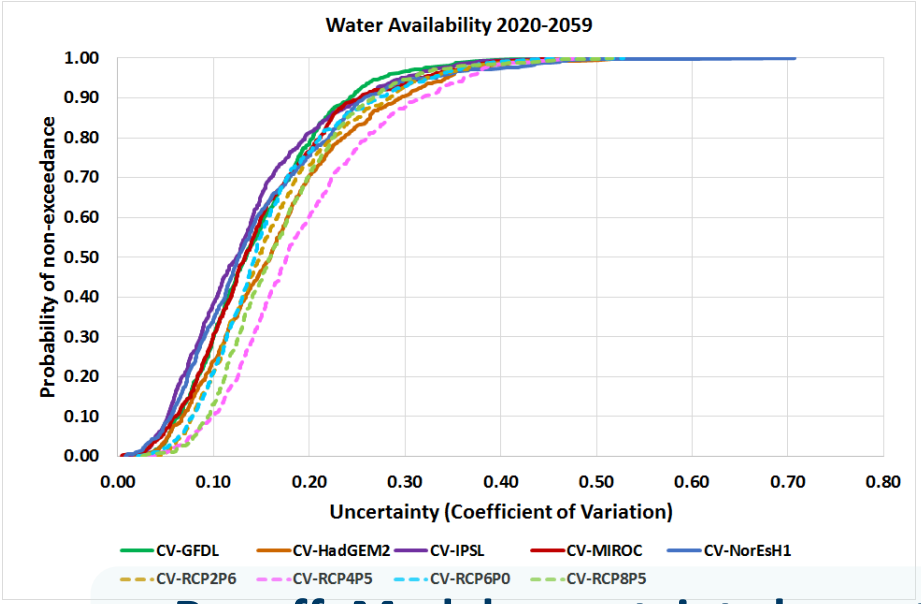


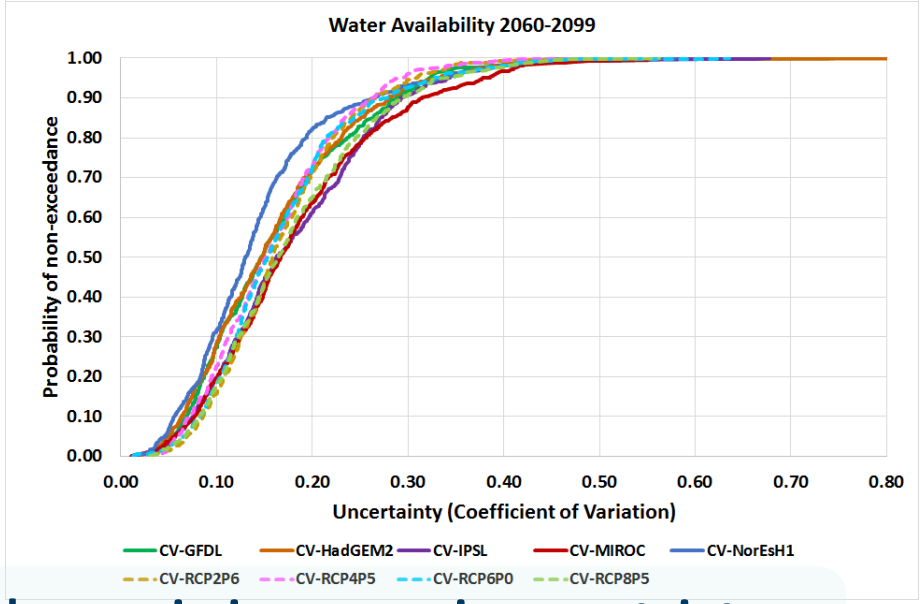
Loop over 5 models

Analysis of Uncertainty





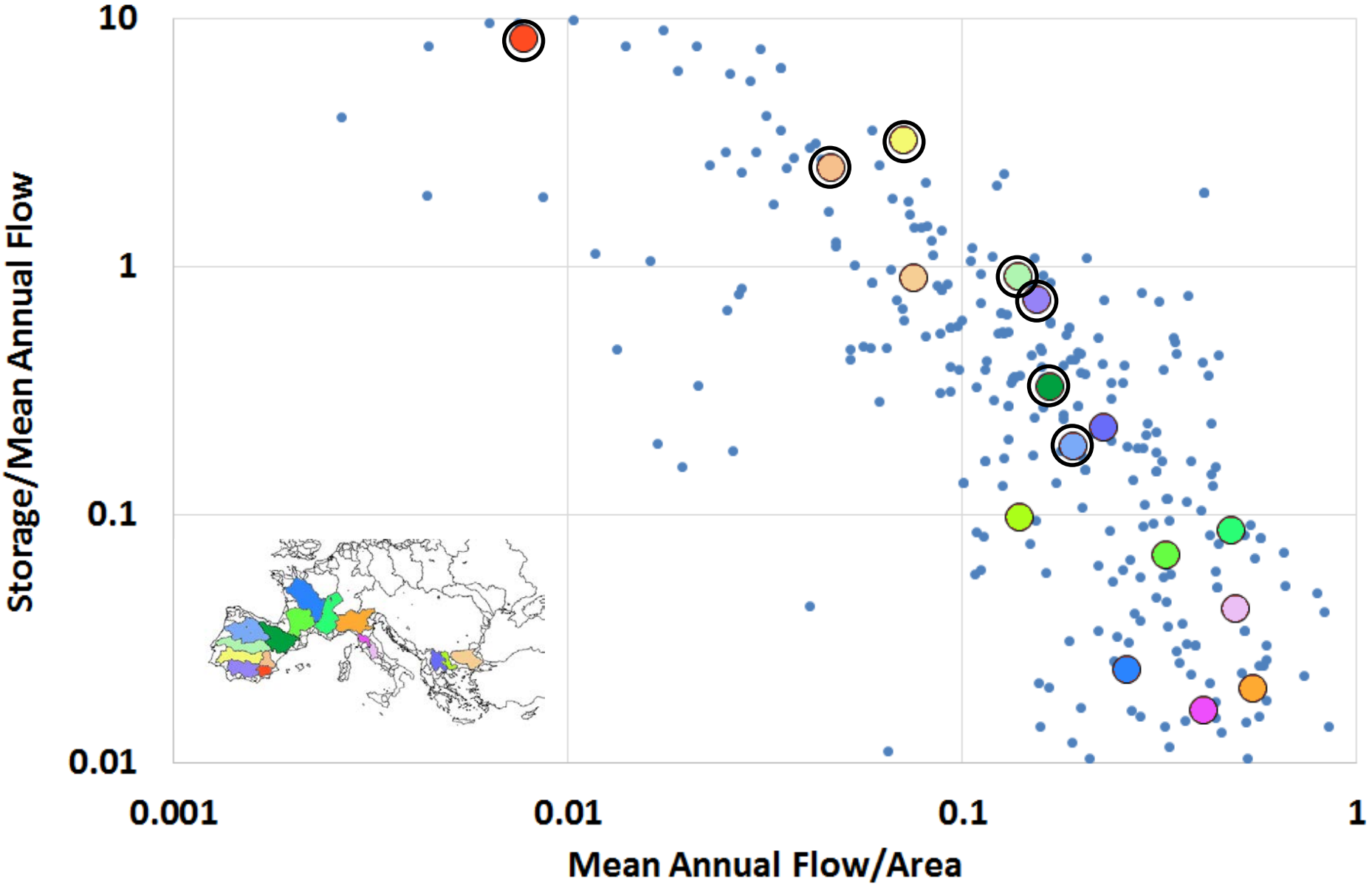




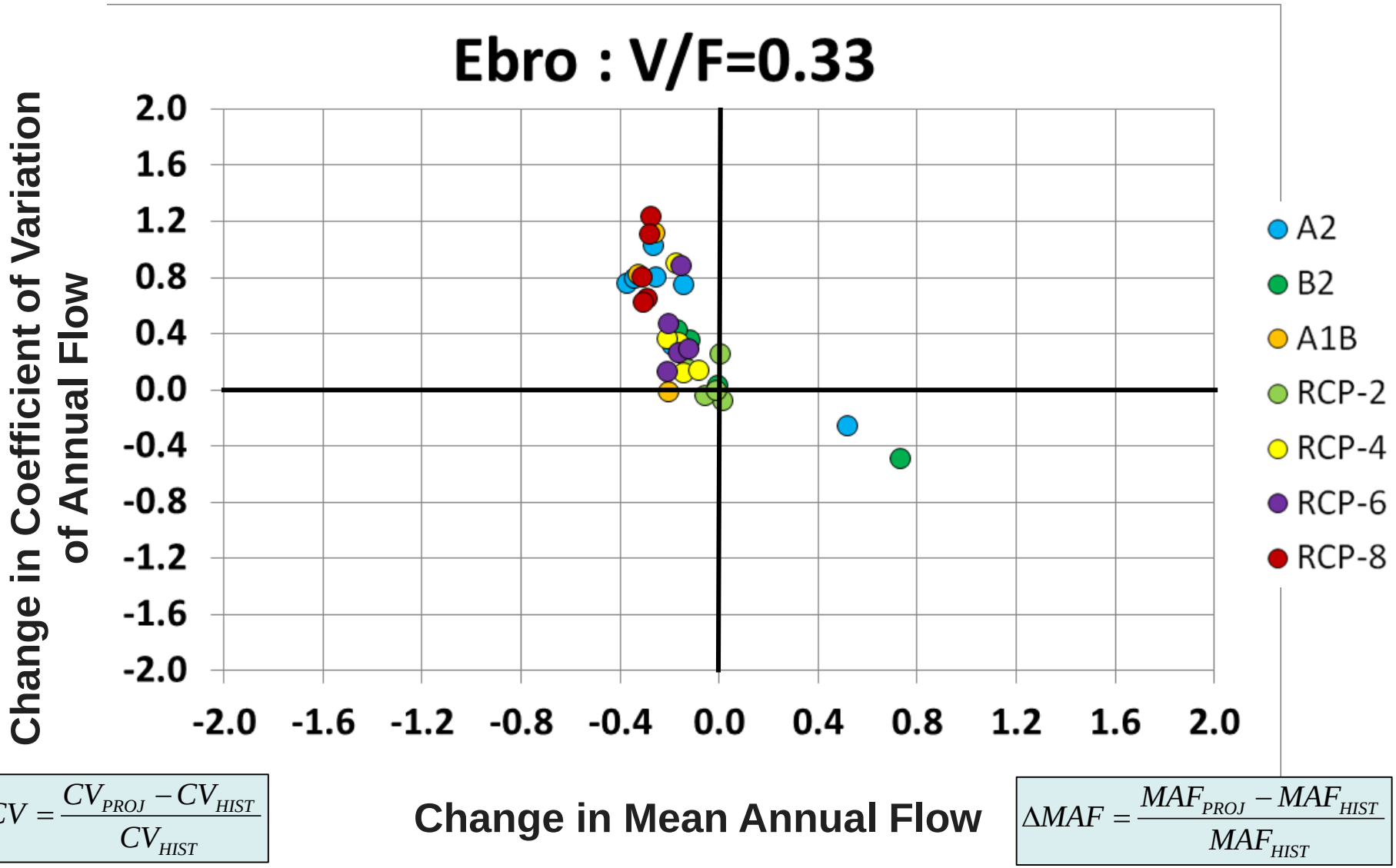
Runoff: Model uncertainty larger than emission scenario uncertainty

Availability: same level of uncertainty (storage)

Specific study of Mediterranean basins



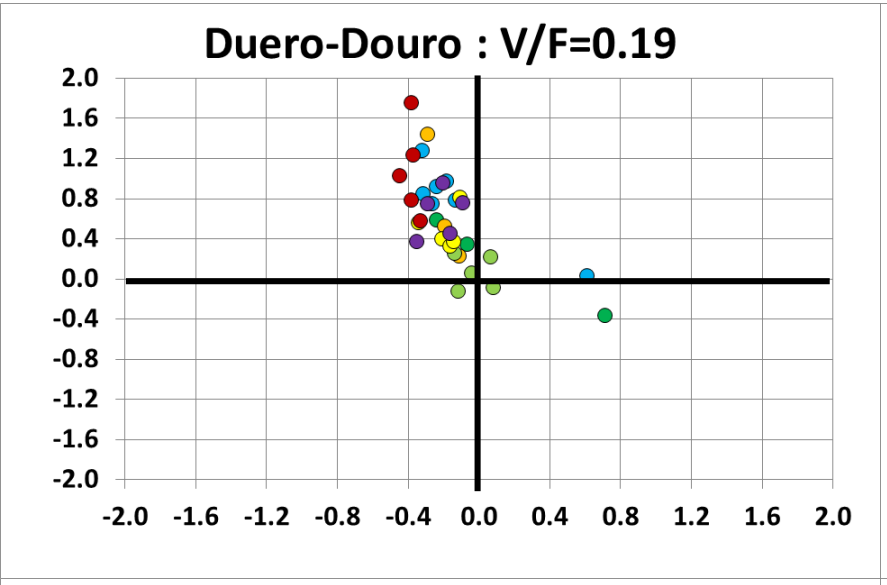
Climate projections

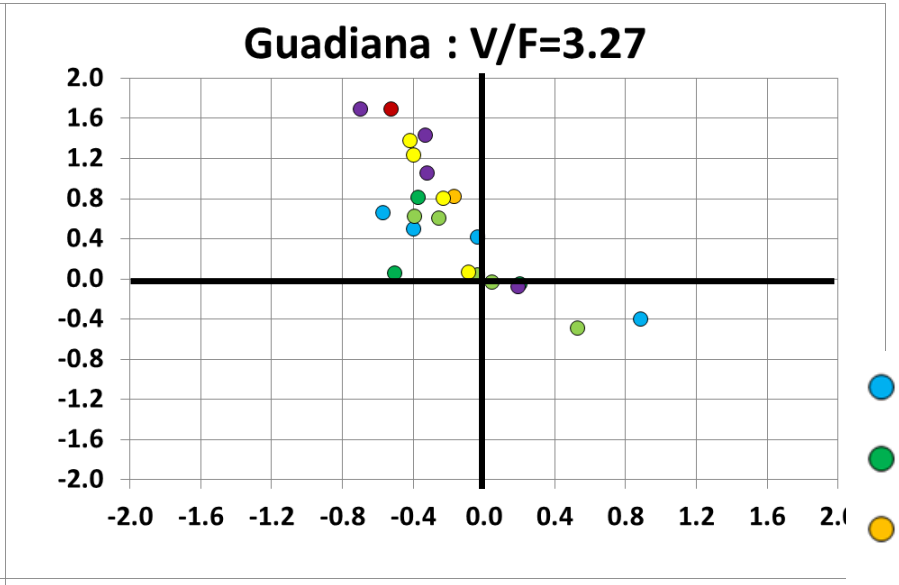


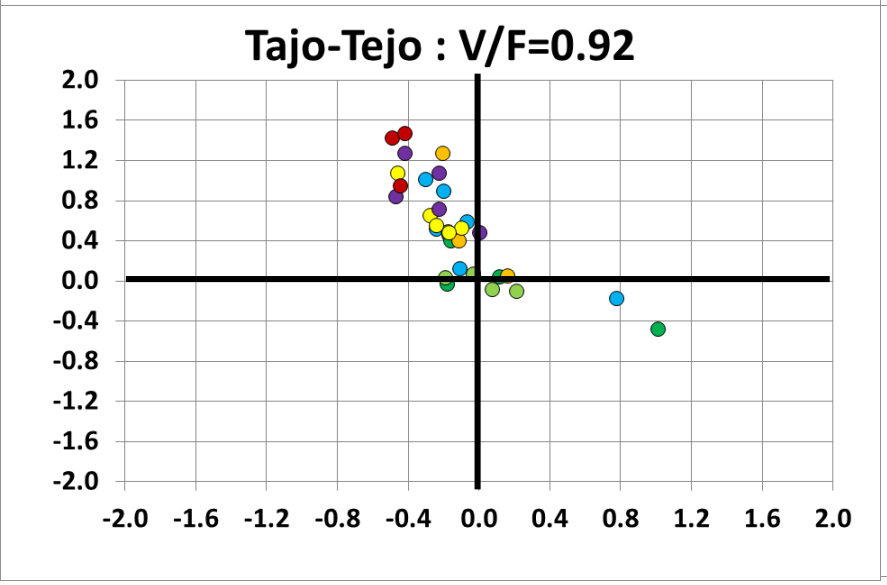
$$\Delta CV = \frac{CV_{PROJ} - CV_{HIST}}{CV_{HIST}}$$

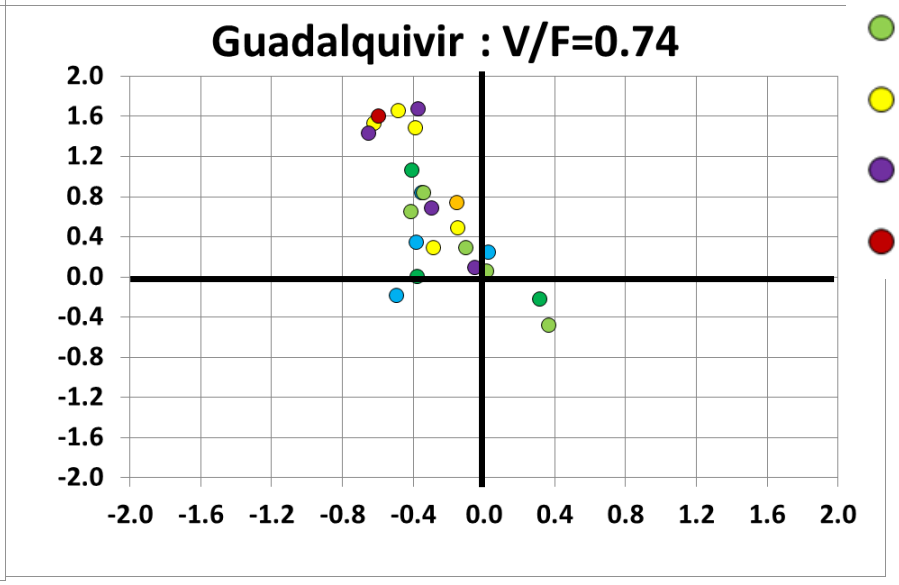
$$\Delta MAF = \frac{MAF_{PROJ} - MAF_{HIST}}{MAF_{HIST}}$$

Climate projections





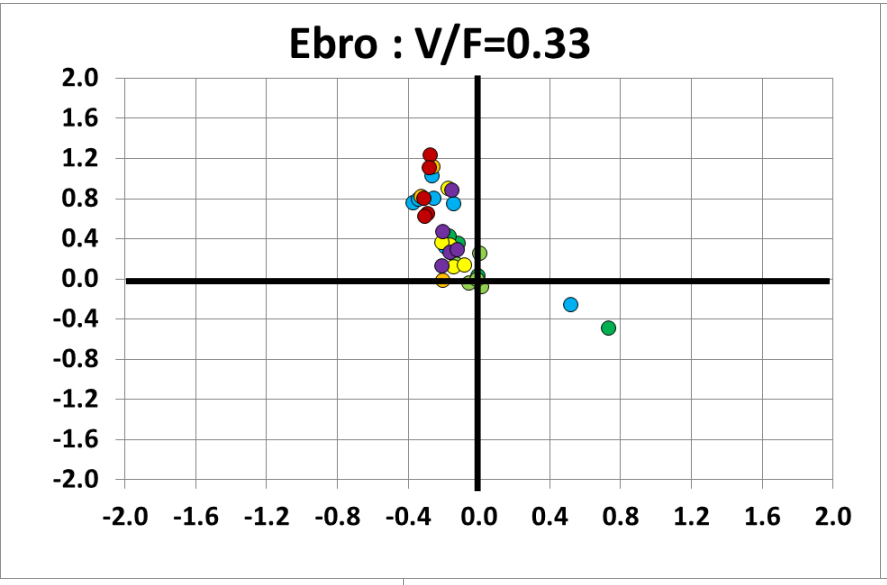


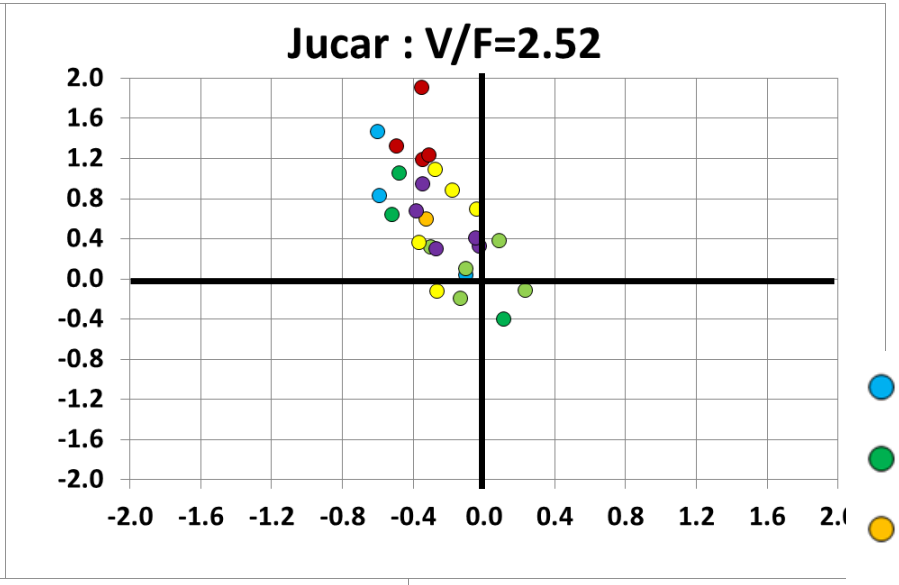


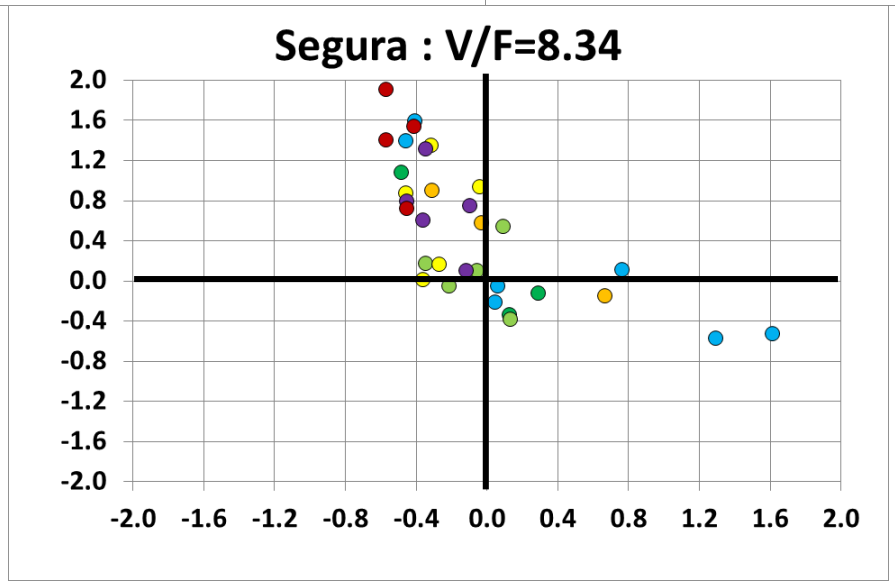
Reduction in MAF and larger increase in CV

Stronger forcing in areas already exposed to water scarcity

Climate projections





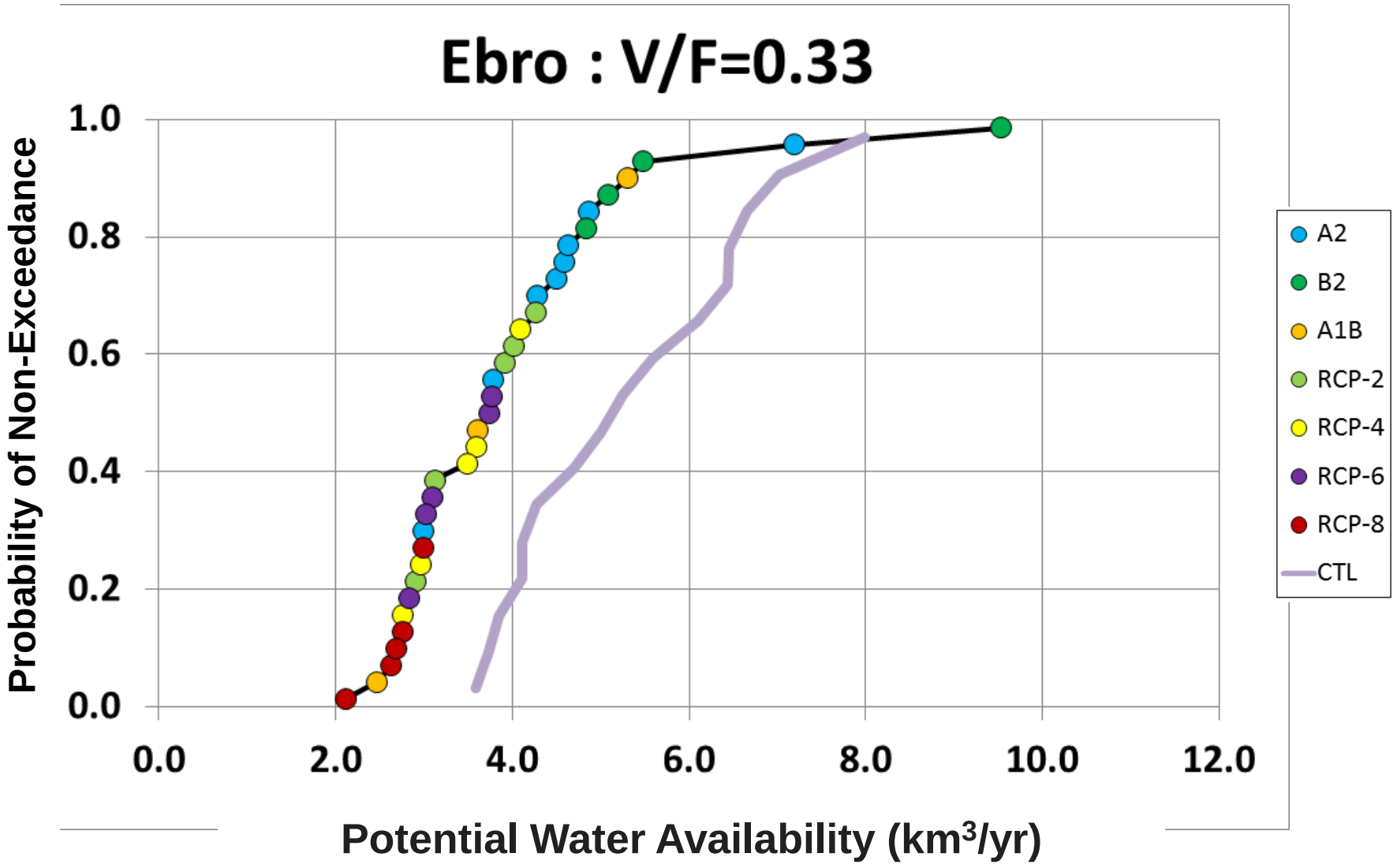


A2
B2
A1B
RCP-2
RCP-4
RCP-6
RCP-8

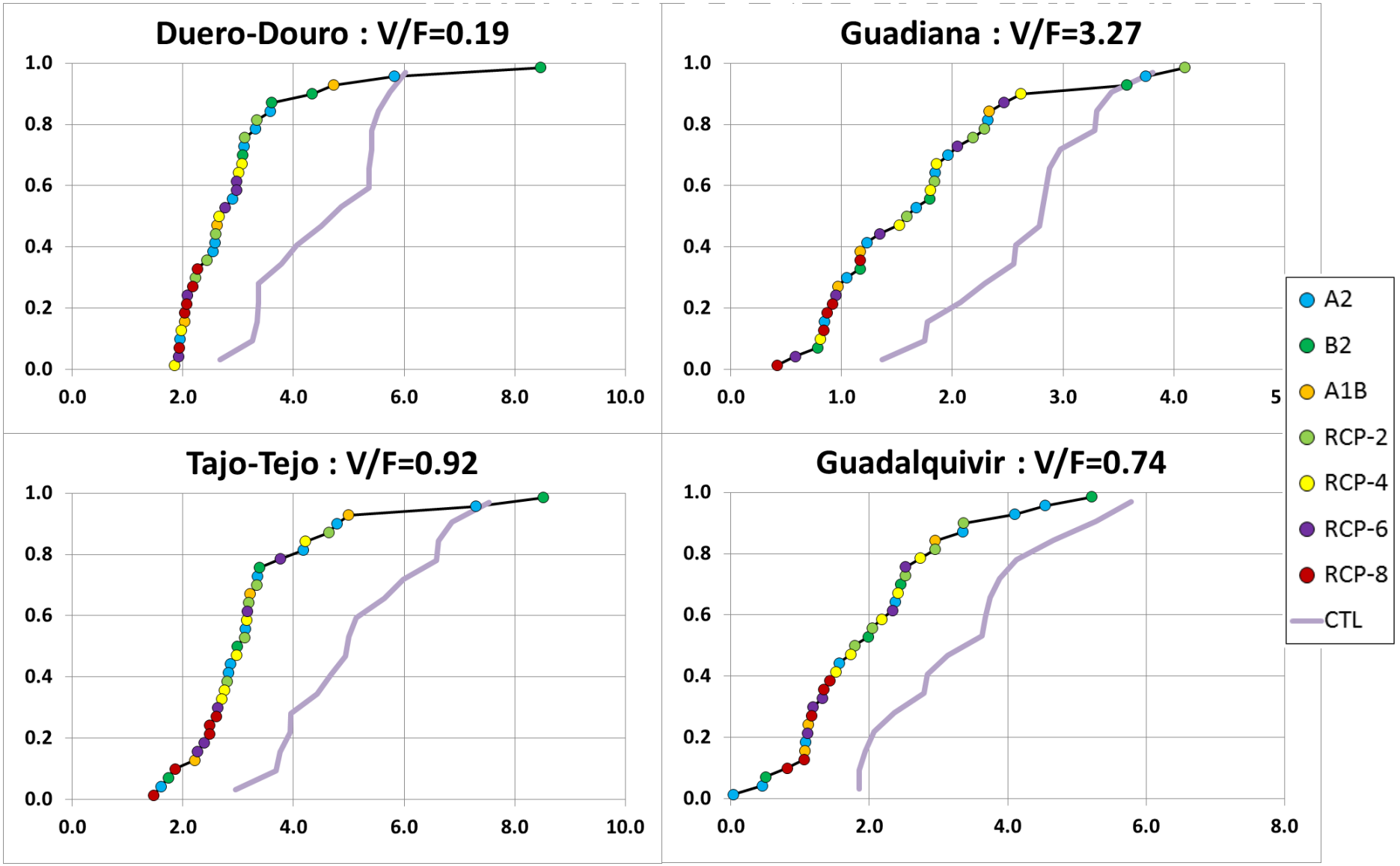
Reduction in MAF and larger increase in CV

Stronger forcing in areas already exposed to water scarcity

Potential Water Availability



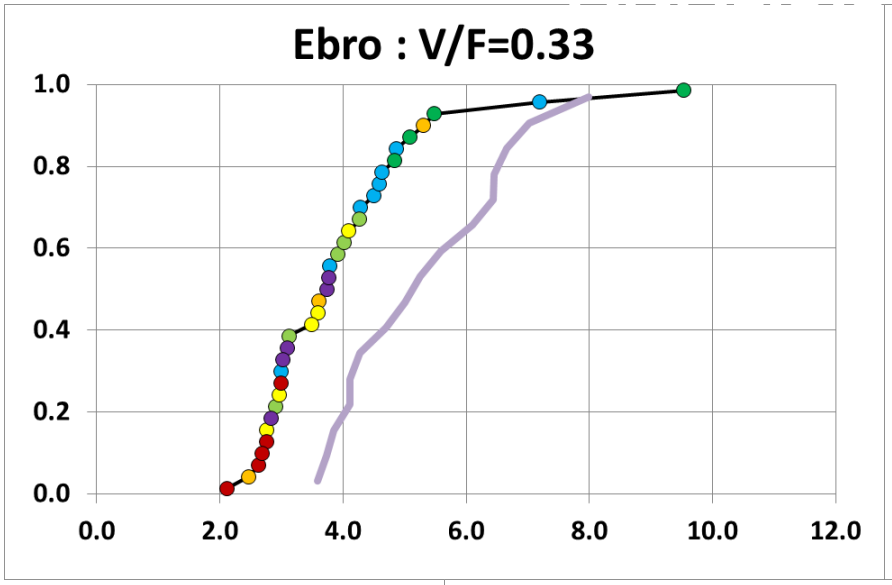
Potential Water Availability

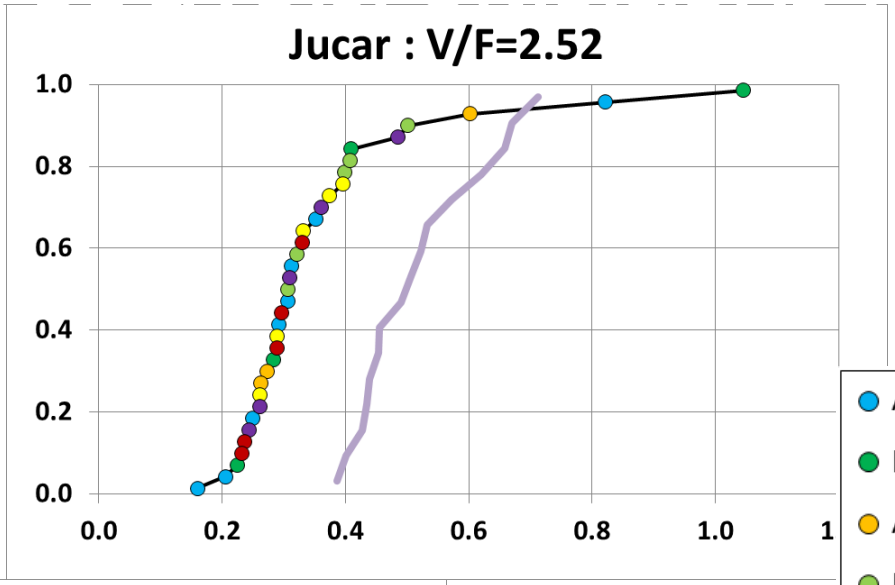


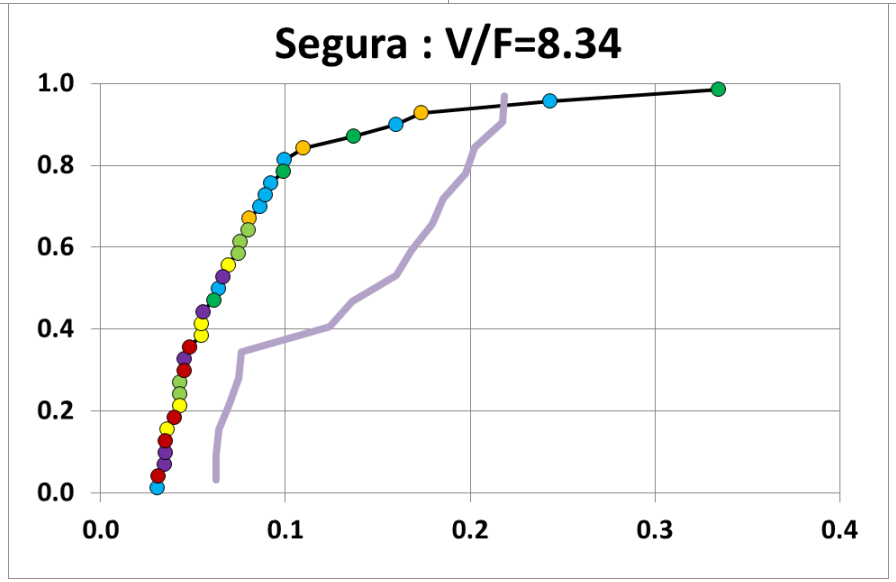
Large uncertainty and significant reduction of PWA

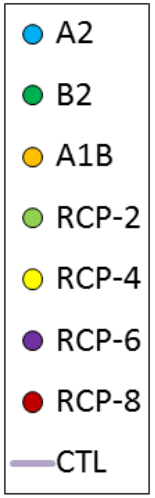
Model uncertainty larger than emission scenario uncertainty

Potential Water Availability





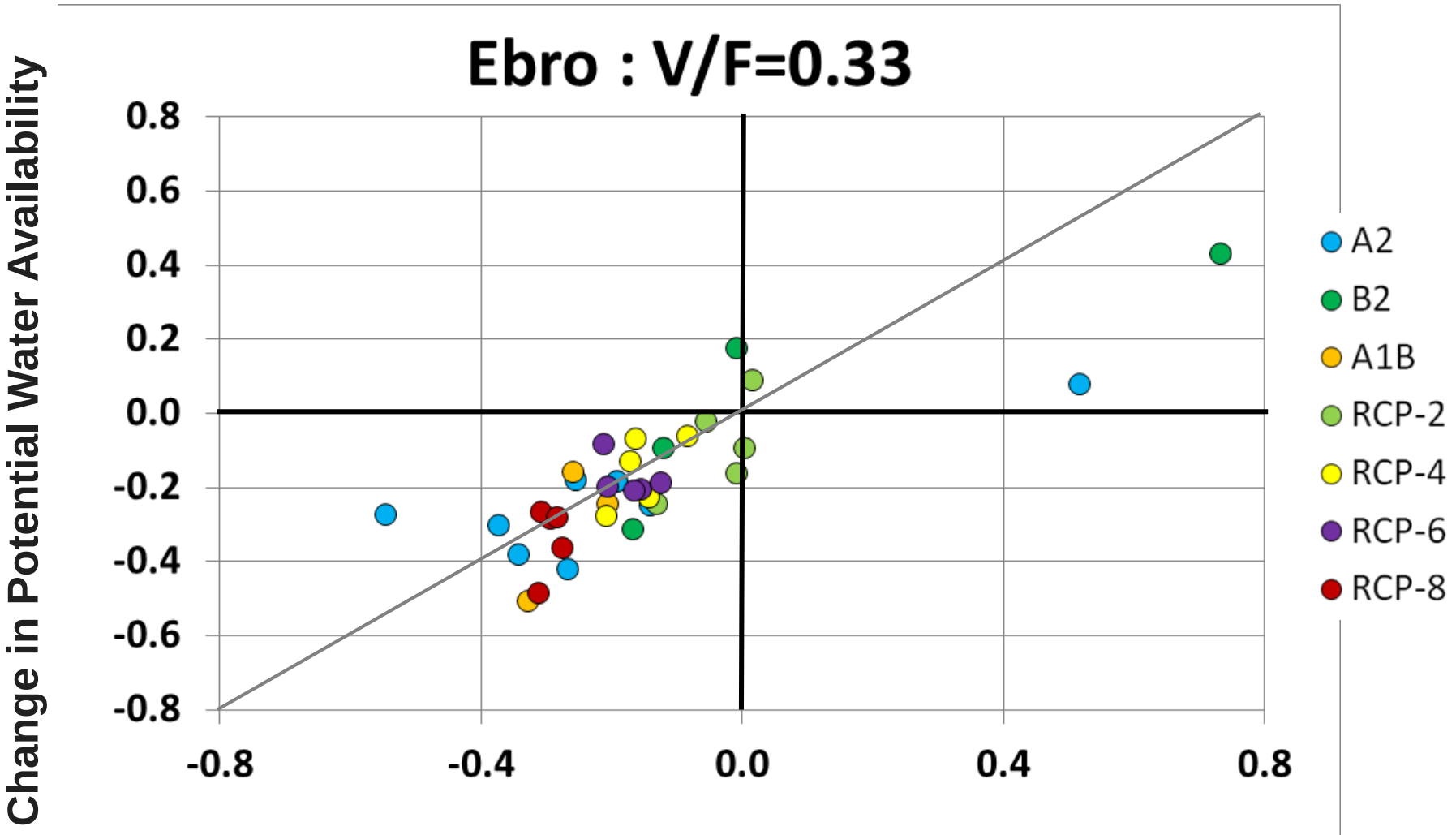




Large uncertainty and significant reduction of PWA

Model uncertainty larger than emission scenario uncertainty

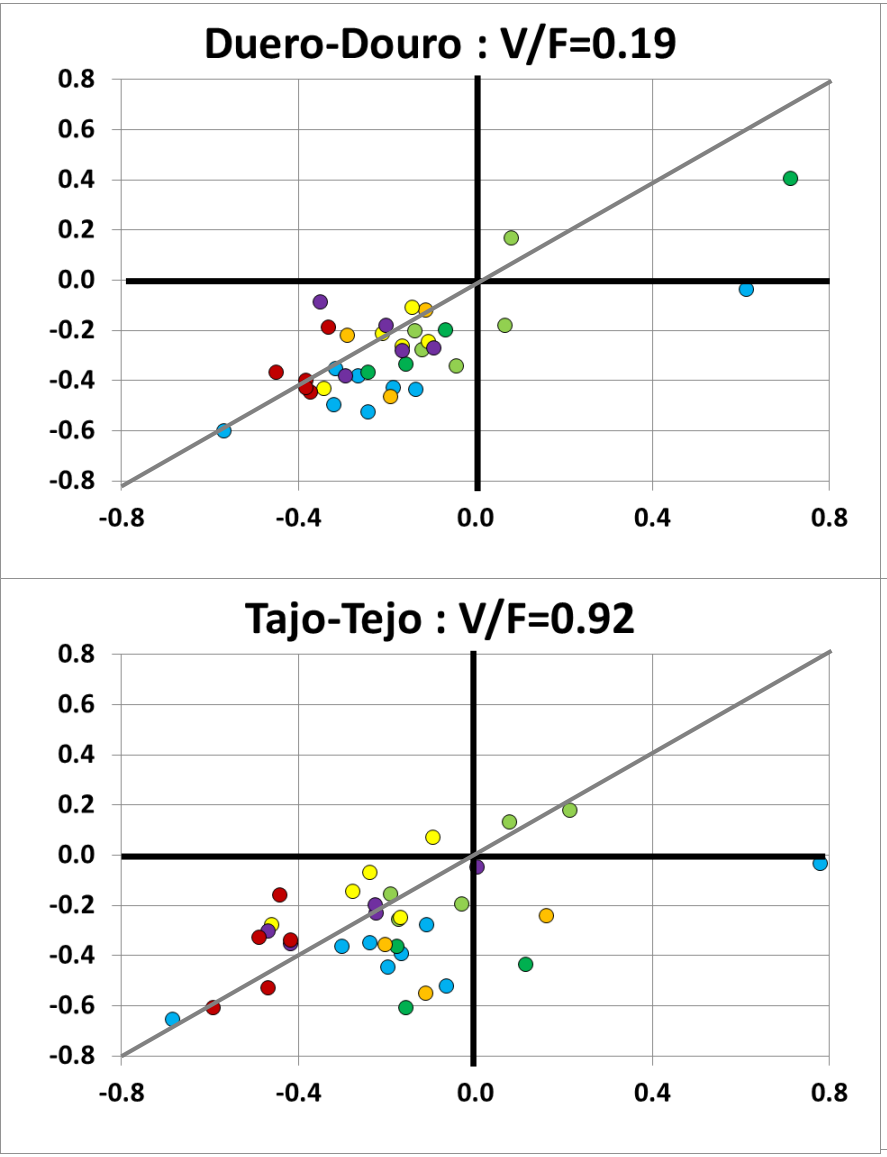
Projected changes of MAF vs. PWA

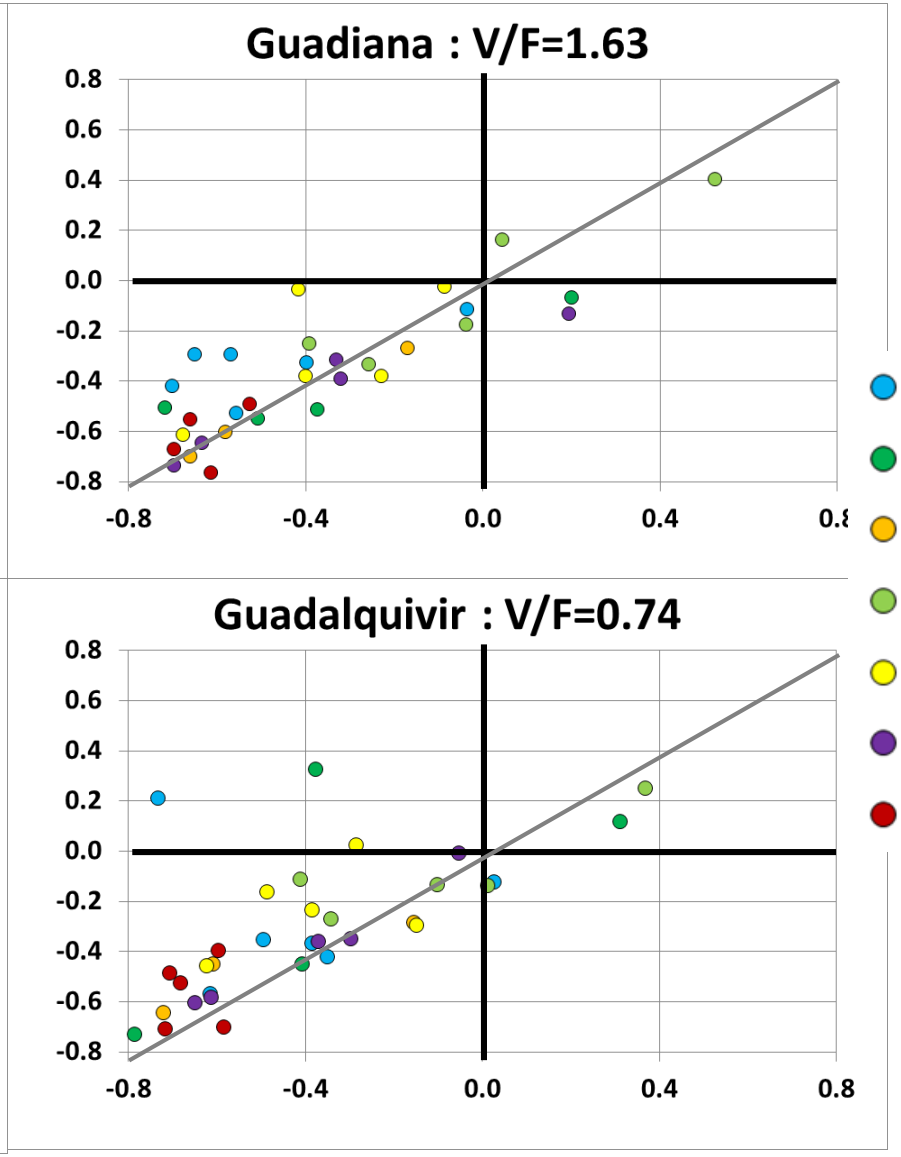


$$\Delta PWA = \frac{PWA_{PROJ} - PWA_{HIST}}{PWA_{HIST}}$$

$$\Delta MAF = \frac{MAF_{PROJ} - MAF_{HIST}}{MAF_{HIST}}$$

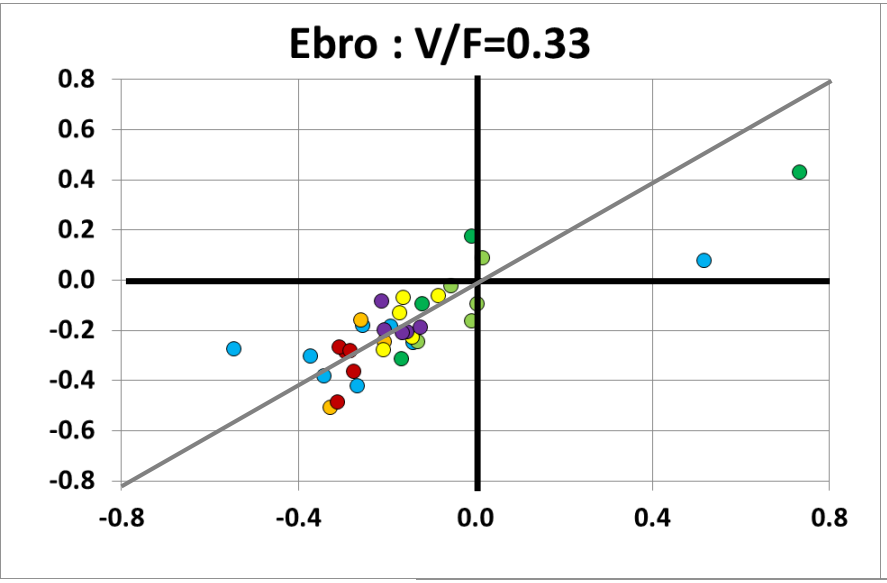
Projected changes of MAF vs. PWA

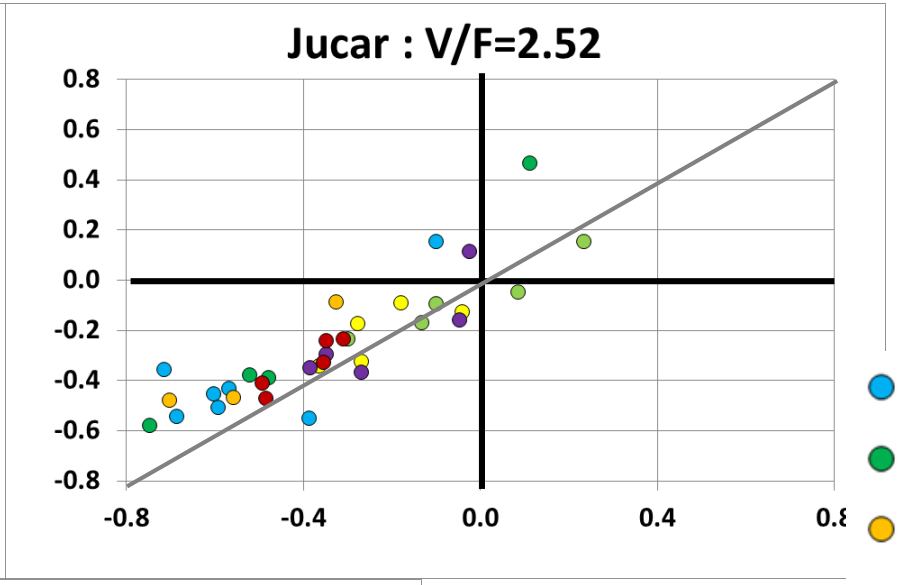


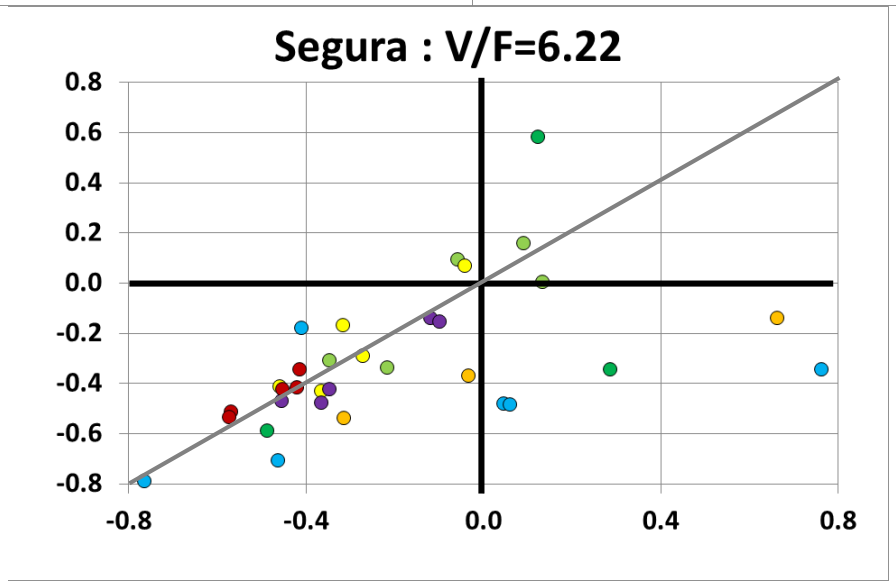


Changes in MAF are a good proxy for changes in PWA
We found stronger dispersion in areas with high variability

Projected changes of MAF vs. PWA



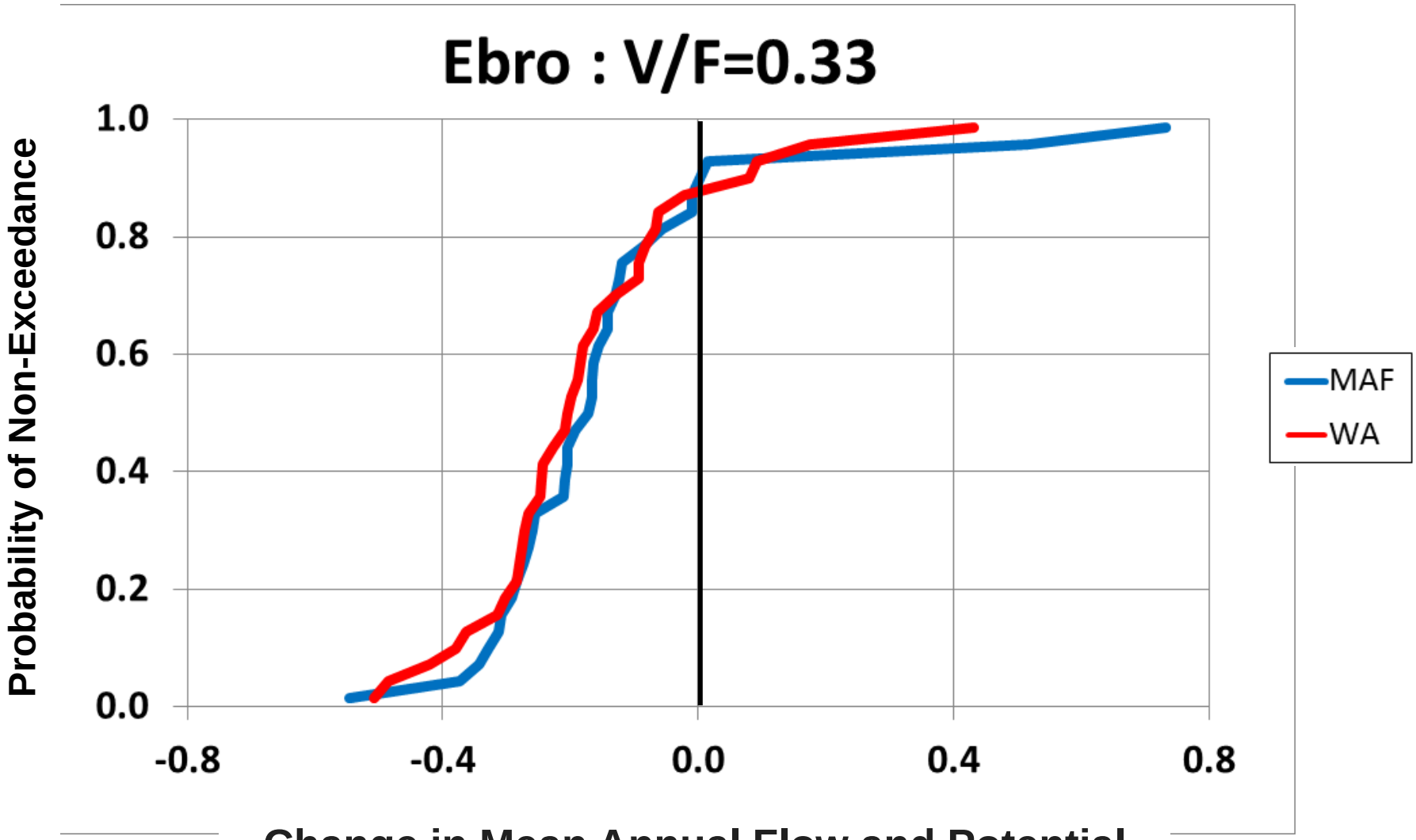




A2
B2
A1B
RCP-2
RCP-4
RCP-6
RCP-8

Changes in MAF are a good proxy for changes in PWA
We found stronger dispersion in areas with high variability

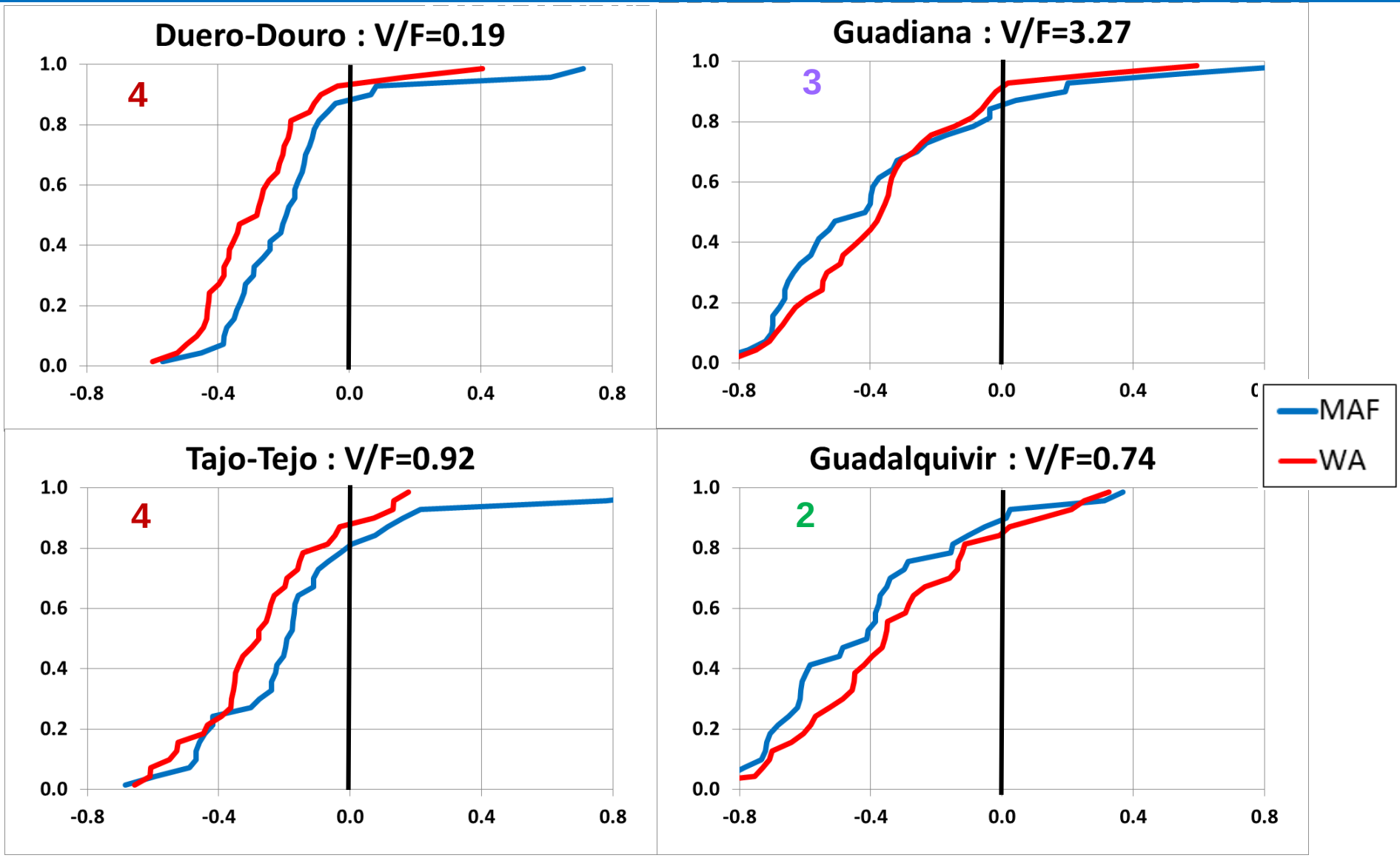
Changes in MAF vs PWA



$$\Delta MAF = \frac{MAF_{PROJ} - MAF_{HIST}}{MAF_{HIST}}$$

$$\Delta PWA = \frac{PWA_{PROJ} - PWA_{HIST}}{PWA_{HIST}}$$

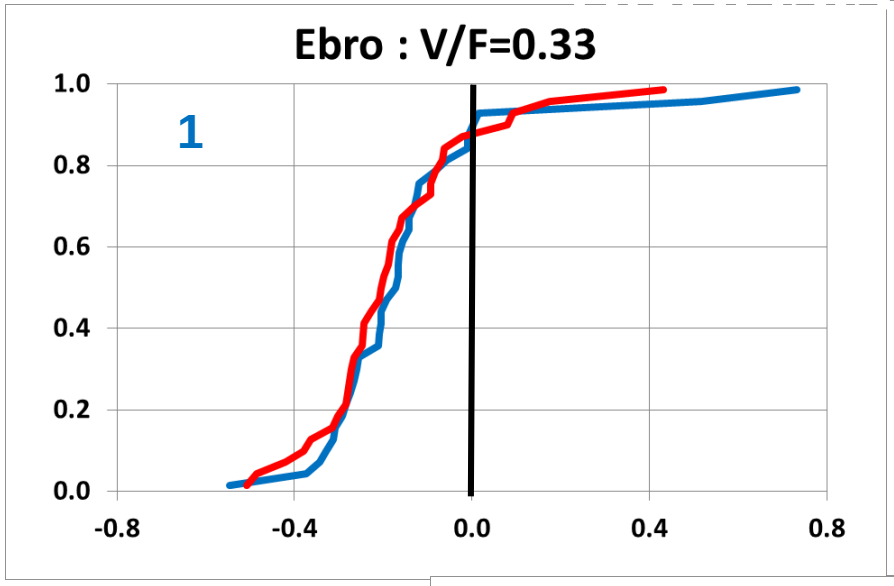
Changes in MAF vs PWA

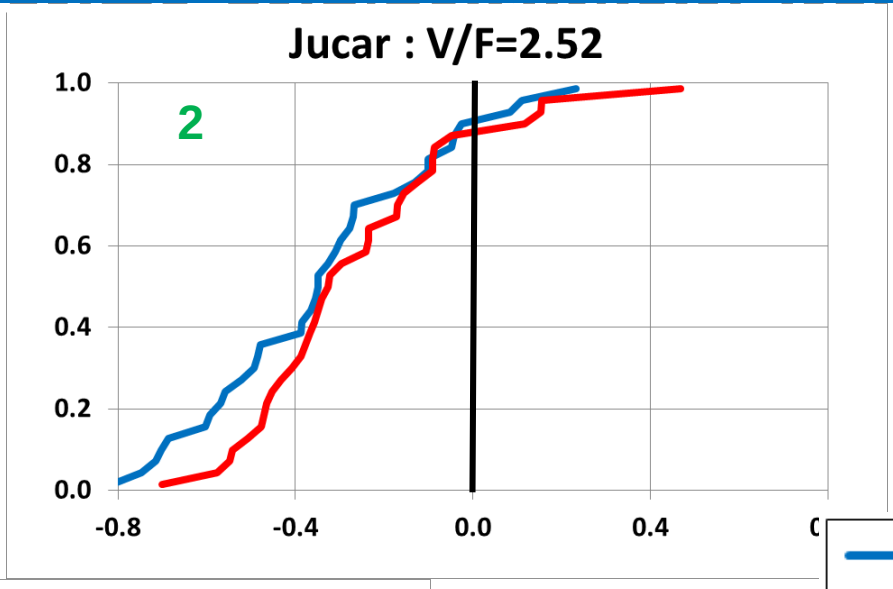


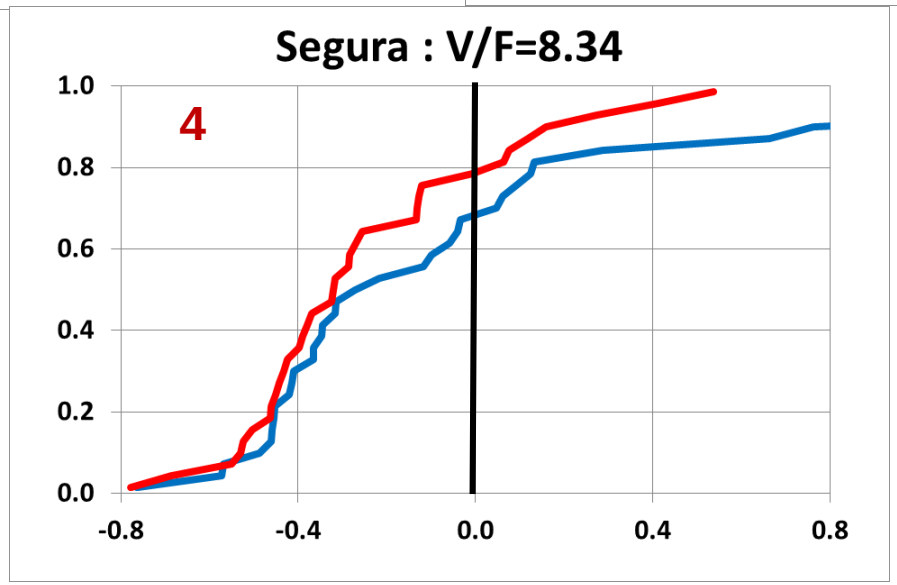
We found a range of behaviors:

1 similar reduction; 2 less reduction PWA; 3 cross; 4 more reduction PWA

Changes in MAF vs PWA







MAF
WA

We found a range of behaviors:

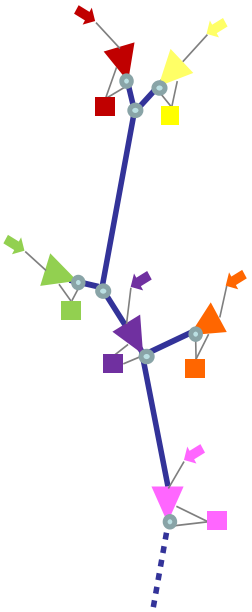
1 similar reduction; 2 less reduction PWA; 3 cross; 4 more reduction PWA

The role of adaptation

- **Strong reductions of runoff and water availability**
- **Policy and management may modify availability**
  - Water allocation to environmental flows
  - Investment in infrastructure or improved management
  - Governance: social arrangements to accept less reliability
- **What is the impact of policy on water availability?**
  - Simple analysis based on modelling framework

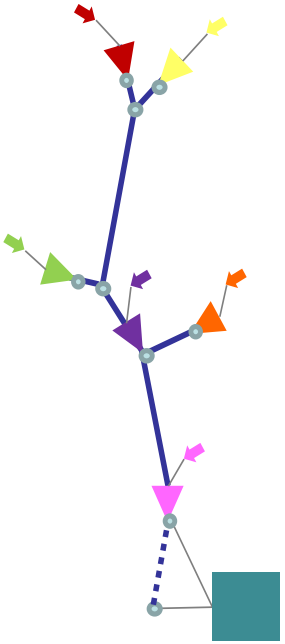
Adaptation options

Reference Management



Every reservoir supplies local demands only

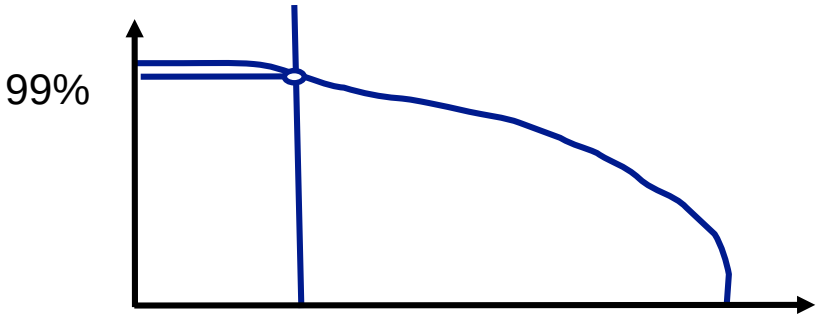
Improved Management



All reservoirs contribute to supply all demands

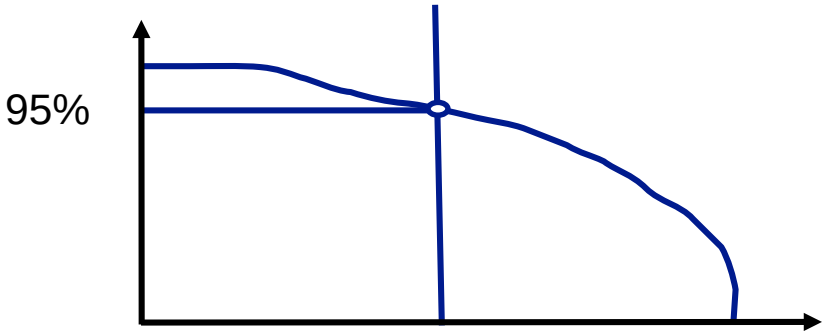
POLICY: densification of water transport and distribution networks; enhancement of management capacity

Reference Governance



Water users do not share resources

Improved Governance



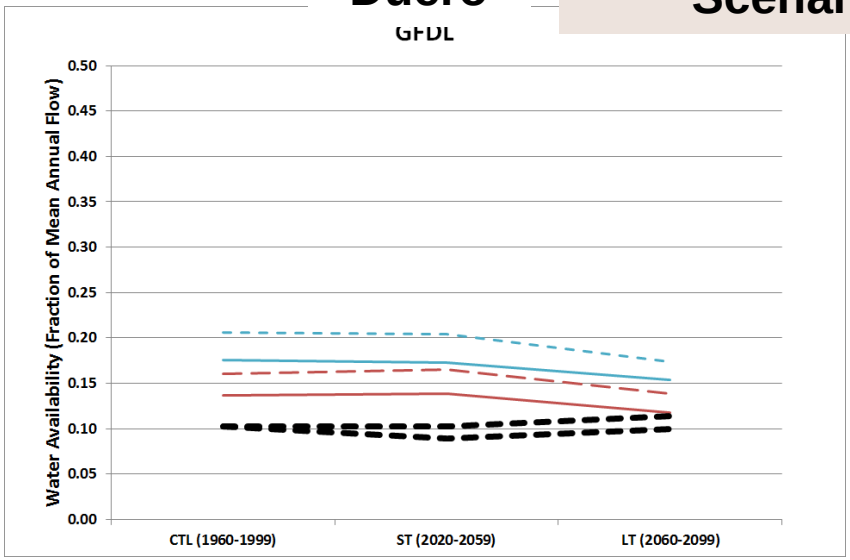
Water users cooperate and share resources

POLICY: enhancement of legal framework for water sharing; capacity building to improve education of water users

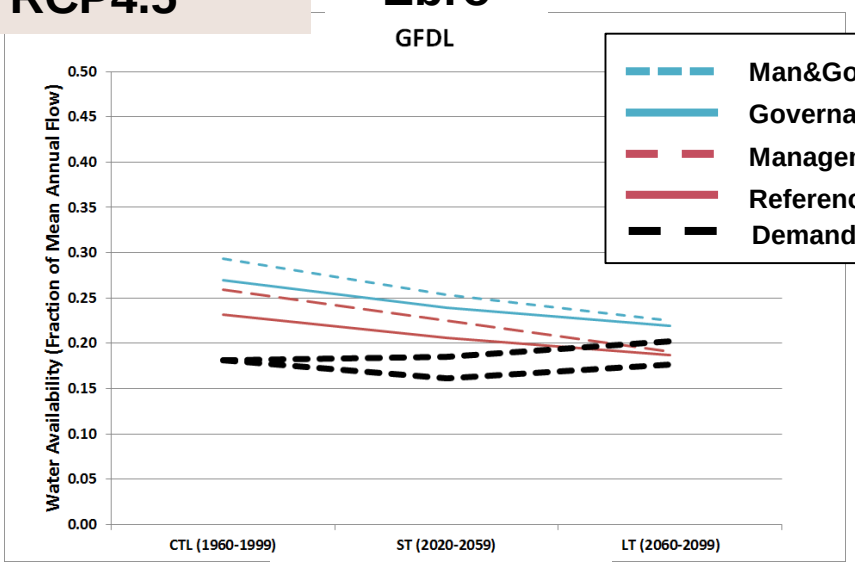
Effect of adaptation: management and governance

Scenario RCP4.5

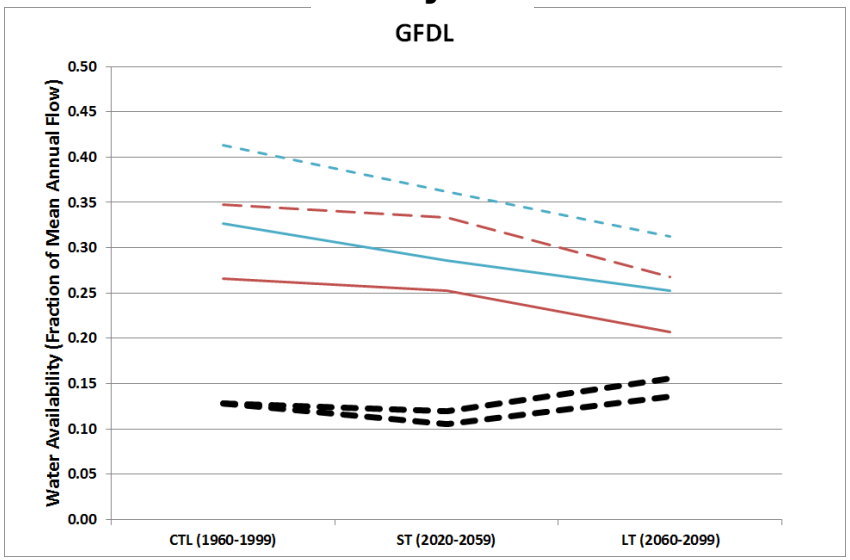
Duero



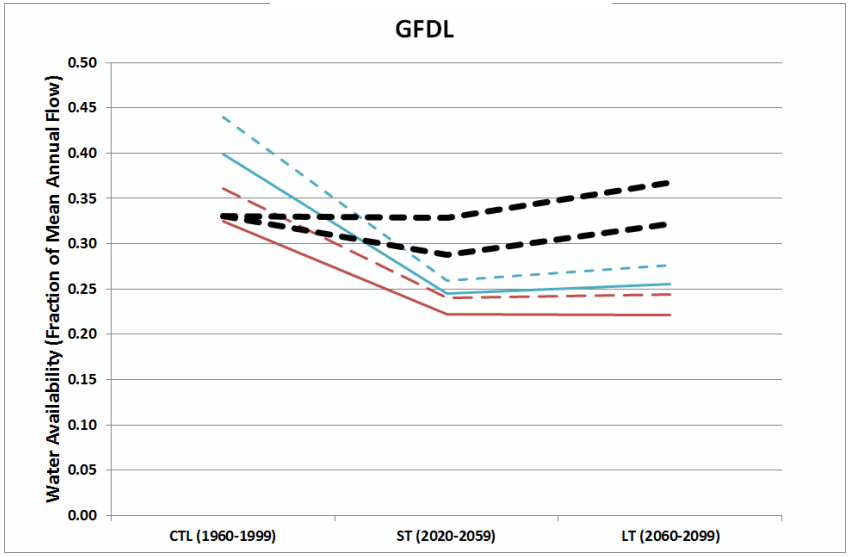
Ebro



Tajo



Guadalquivir

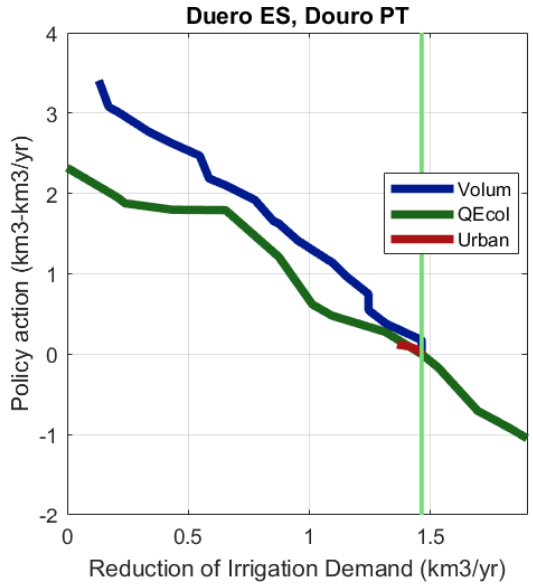


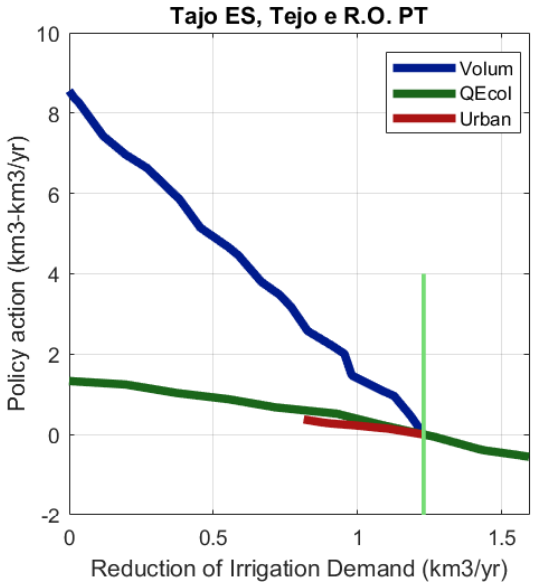
Adequate management and governance may compensate the reduction of availability

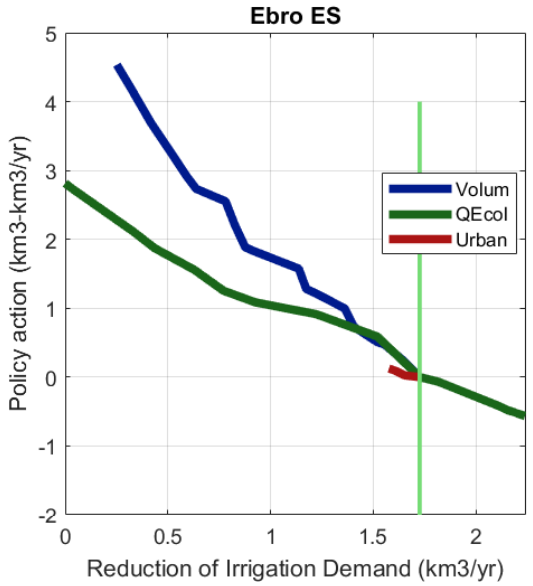
Effect of adaptation: Storage, Environmental Flow, Efficiency

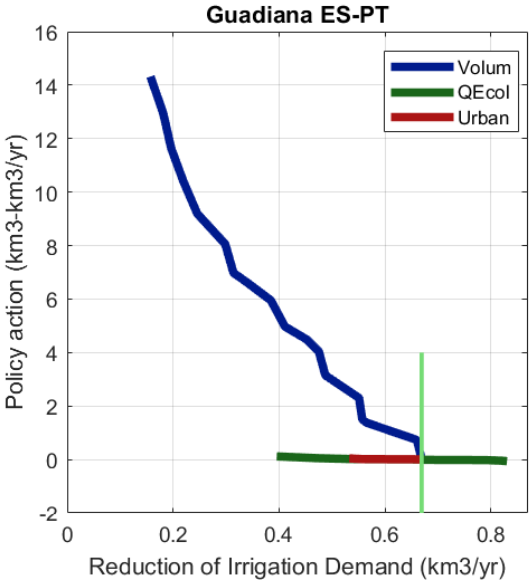
- **Policy target**
  - Maintain acceptable reliability under climate change scenarios
- **Main policy action**
  - Demand reduction to maintain reliability under climate change
- **Additional policy actions**
  - Supply enhancement through increased reservoir storage
  - Increase water efficiency in urban use
  - Modify environmental flow conditions

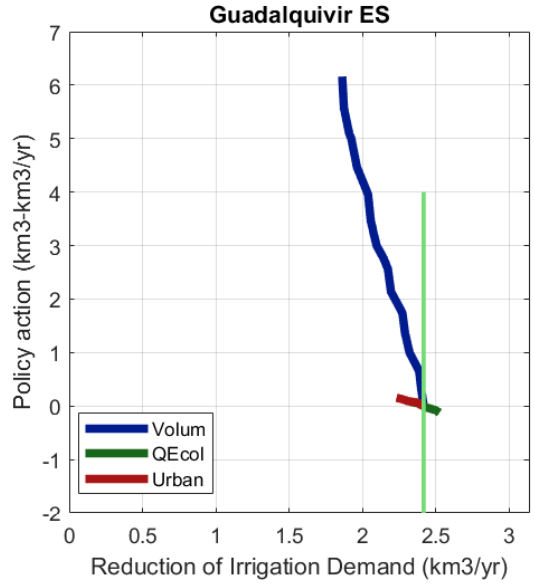
Effect of adaptation: Storage, Environmental Flow, Efficiency

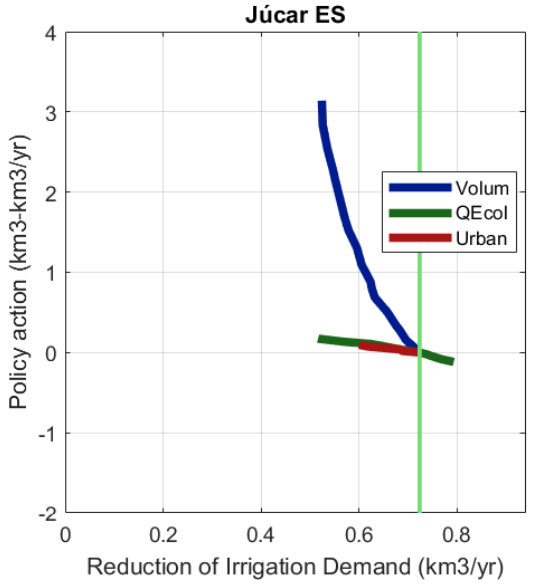












The range and effectivity of measures vary strongly across basins

Conclusions

- **Modeling tools**
  - Model performance is very poor while describing the currently observed features of hydrologic regime relevant for water availability
  - Model uncertainty is very wide, equal or greater than emission scenario uncertainty. Is this of any use?

- **Water availability projections**
  - Climate change impacts on water availability are uncertain and heterogeneous, but are expected to be strongly negative in Spain
  - Impacts are stronger in areas already affected by water scarcity

- **Role of adaptation policy**
  - Improved water management and water governance may compensate adverse effects of climate on water availability
  - Effectiveness varies across basins, requiring local analyses

What do climate change models tell us? Spain

L. Garrote

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