Managing climate risks: New evidence from integrated analysis at the basin scale

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Managing climate risks: New evidence from integrated analysis at the basin scale

Safa Baccour

Water for all

Futures and solutions

Towards Innovative Solutions and Efficient Water Allocation
through Integrative Water Analysis (WEFE nexus)

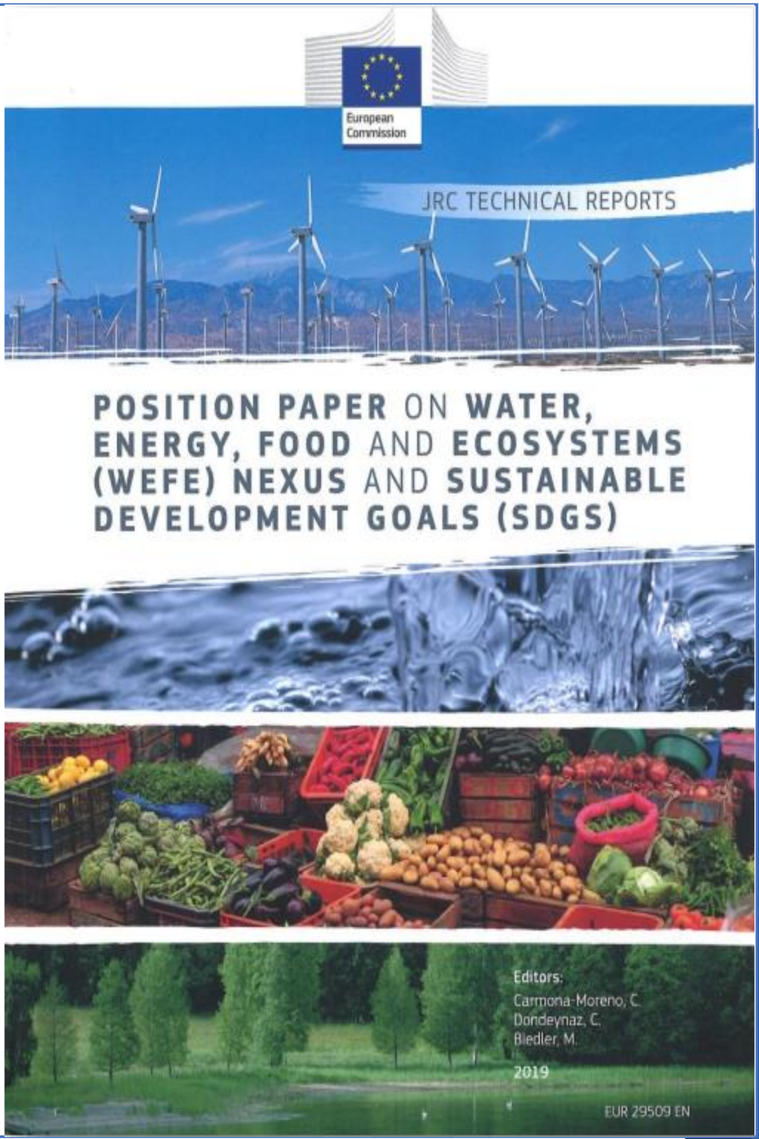
IIASA, WAT seminar , 23 May 2023

WEFE nexus: Integrated Water Resources Management and Planning

The WEFE NEXUS DEFINED

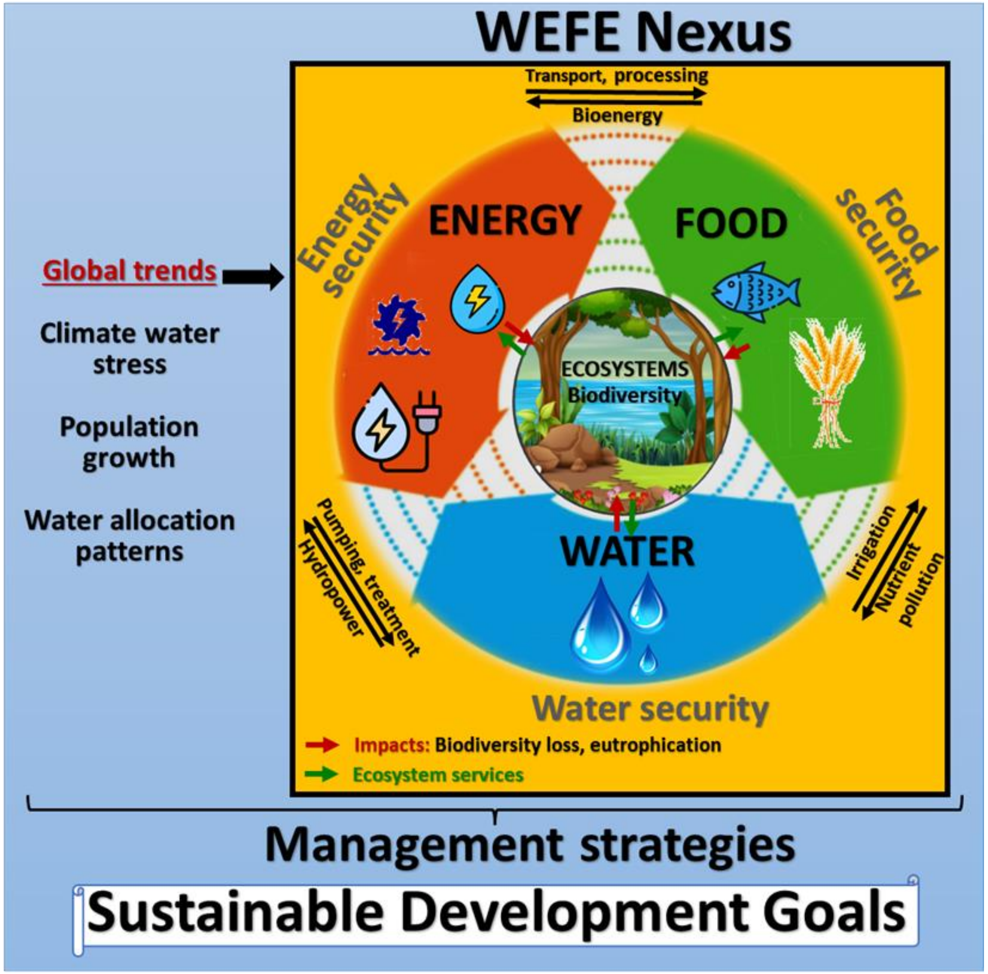
- **WEFE NEXUS** is an **approach** that integrates management and governance across the multiple sectors of food, energy, water and ecosystems.

- **WEFE NEXUS approach** is a way of ensuring more integrated and sustainable use of resources that both reaches beyond the traditional silos and can be applied at all scales.

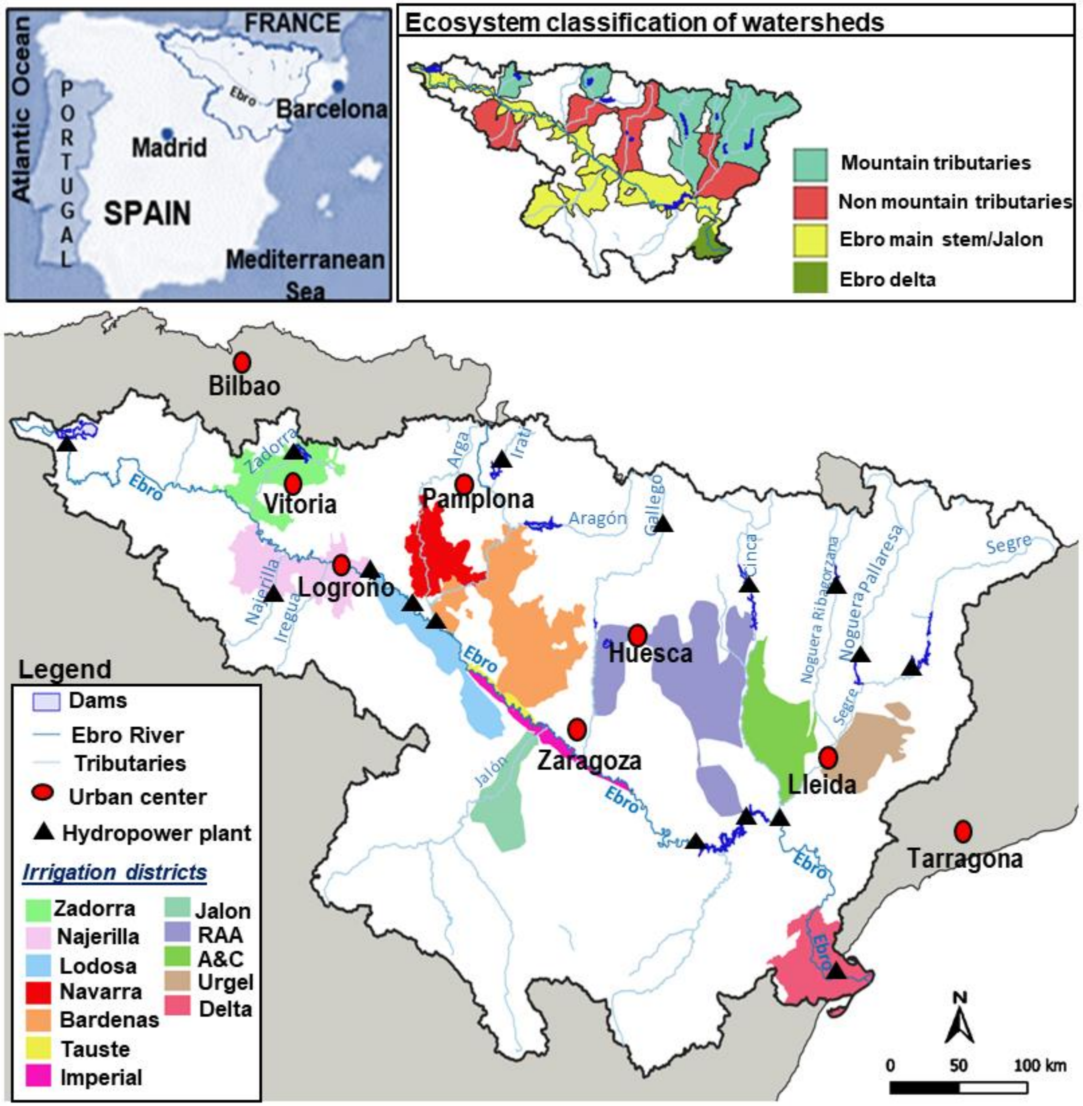


Keys principals

- Recognize the interdependence between water, energy, food and ecosystems.
- Understand the Interdependence of resources within a system across space and time.
- Identify integrated policy solutions to optimize trade-offs and maximize synergies across sectors.
- Value the natural capital of land, water, energy sources and ecosystems.



Model application: the case of the Ebro Basin



Ebro Basin surface:
85.000 km^2

Involve:
9 autonomous communities
18 provinces
1717 municipalities

Population:
3.2 million inhabitants

Model application: the case of the Ebro Basin

Sector	Agriculture	Urban	Industrial	Total
Available renewable water				14,600
Surface water withdrawals	7,420	590	100	8,110
Groundwater withdrawals	260	40	50	350
Used in the basin	7,680	360	150	8,190
Exported to other basins		270		270
Total withdrawals	7,680	630	150	8,460

High Uses of Water, Irrigation

Water scarcity

Model application: the case of the Ebro Basin

El Ebro se seca a su paso por Zaragoza: su caudal registra una de los peores datos de los "últimos 34 años" por la sequía

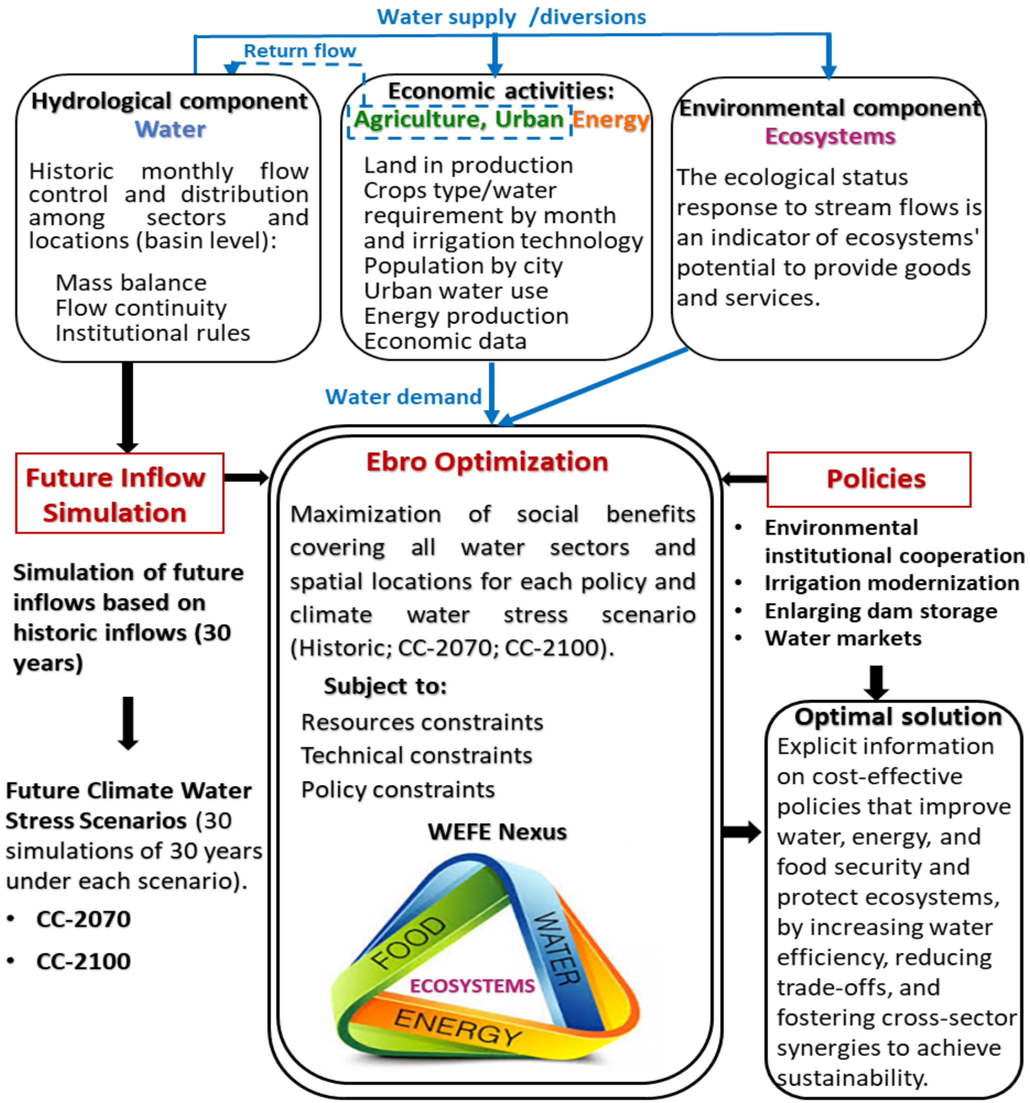
20MINUTOS / NOTICIA / 11.05.2023 - 19:50H

- Zonas de este río, que está al 51% de su capacidad, se pueden atravesar andando.
- La situación de los embalses en España se agrava: bajan del 50% de capacidad y tienen menos agua que hace un año.

Reservoir capacity
1530 Mm^3

Embalse de Mequinenza (abril 2023)

Hydro-economic modeling framework



Key features represented in the model:

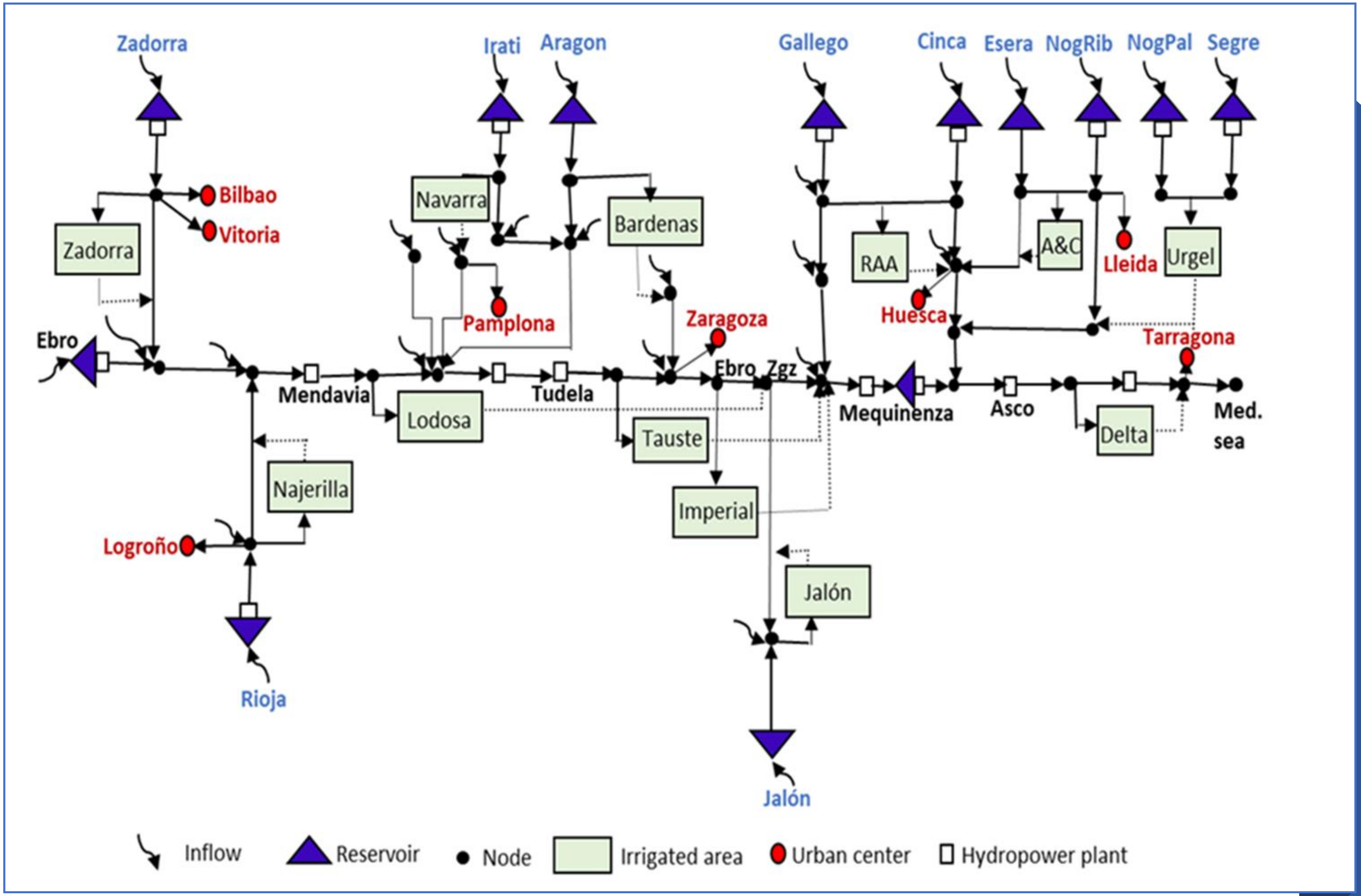
Drivers: Resource availability; Climate change; Population growth; etc.

Processes: Reservoir management; Irrigation use; Energy generation; Ecosystems protection; etc.

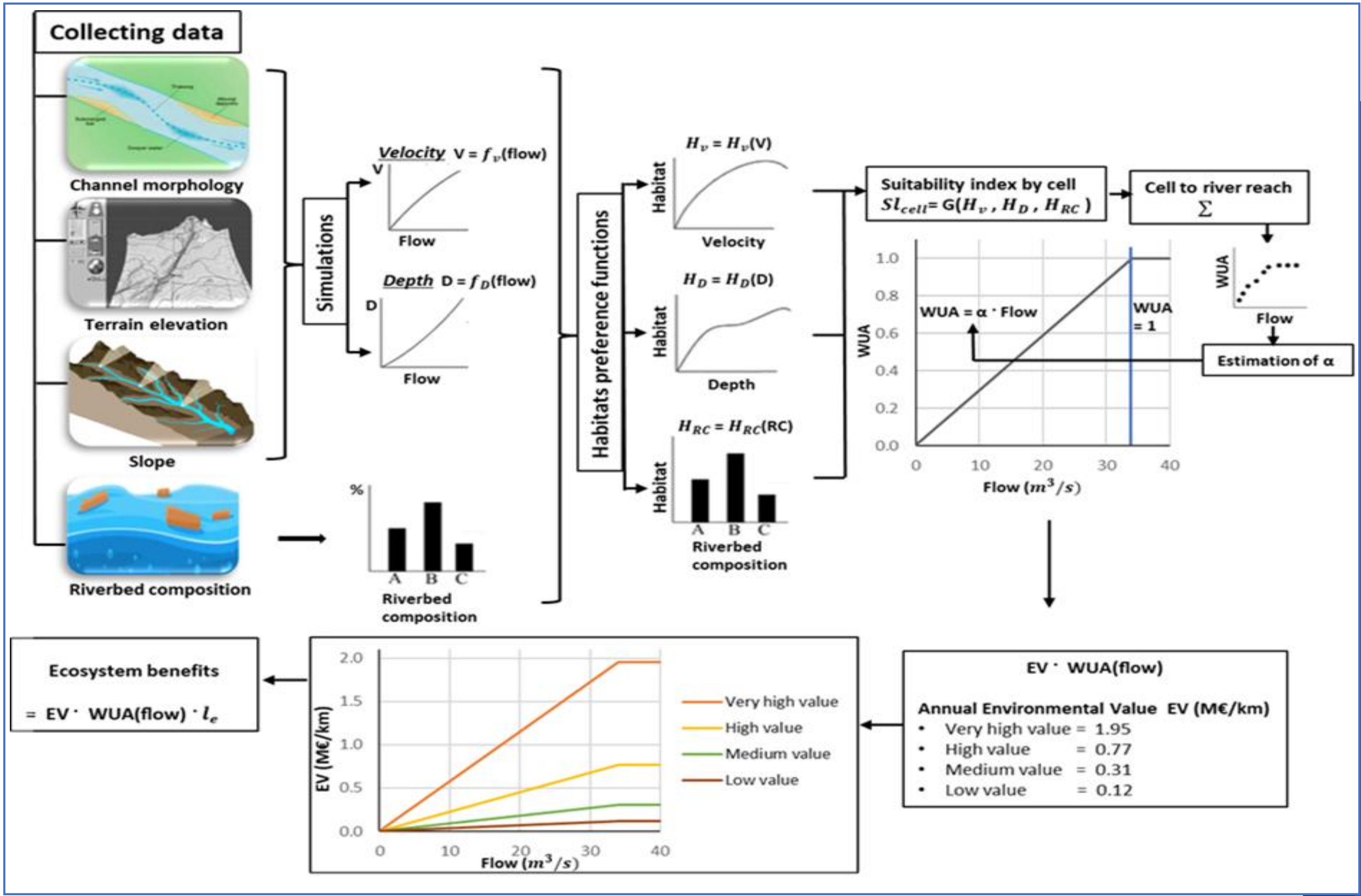
Impacts: Demands; Environmental flow; Resource security; etc.

Decisions: Extract resources; Expand infrastructure; Irrigation efficiency; Trade resources

Network of the Ebro Basin



Ecosystems valuation



Mathematical formulation

Objective function: The discounted net present value of social benefits

$$\textbf{Max} \quad \frac{\sum_{k,t} B_{k,t}^{Irr} + \sum_{u,t} B_{u,t}^{Urb} + \sum_{HPplant,t} B_{HPplant,t}^{HP} + \sum_{e,t} B_{e,t}^{ecos}}{(1+r)^{t}}$$

Subject to

$$Q_{d,t,m}^{in} - Q_{d,t,m}^{out} - E_{d,t,m} + P_{d,t,m} = Z_{d,t,m} - Z_{d,t,m-1}$$

Mass balance

$$r_{d,t,m}^{IR} \cdot \left(Div_{d,t,m}^{IR}\right) + r_{d,t,m}^{URB} \cdot \left(Div_{d,t,m}^{URB}\right) \leq Q_{d,t,m}^{out}$$

Supply- demand balance

$$Z_{d,t,m} \leq C_{max} \, ; Z_{d,t,m} \geq C_{min}$$

Reservoir capacity

$$\sum_{i} X_{ijkt}^{IR} \leq Tland_{kj}$$

Land constraint

$$Q_{HPplant,t,m} \leq C_{HPplant,t,m}$$

Hydropower plants capacity

$$Q_{d,t,m}^{out} \geq E_{d,t,m}^{min}$$

Environmental flows

Model calibration - validation

Hydrologic calibration

The hydrologic calibration entails adjusting model parameters to replicate observable system states such as monthly streamflow and reservoir storage under baseline conditions.

Economic calibration: Positive Mathematical Programming PMP

We use the PMP procedure developed by Dagnino and Ward (2012), where the parameters for a crop yield function are calculated based on "first order necessary conditions" for optimal resource use (decreasing yield with additional land).

The PMP calibration method is developed for consumer surplus of the urban sector entails to replicate the observed water use behavior in each city.

In this study, the predicted water use in each city for the first year replicates the observed water use behavior. For later years, the predicted water use increases with population growth in each city.

Description of water management options

Institutional cooperation (IC): Is the current water management by the Ebro basin authority. The allocation and distribution of water resources among different users or entities based on a proportionate or equitable basis.

Demand management options

- **Better allocation rules**

Environmental institutional cooperation (EIC): is the IC policy is combined with a stronger protection of ecosystems.

Water markets (WM): The total water supply is allocated among all water users, creating market-motivated trading to efficiently move water to where it could minimize economic losses caused by climate water stress.

- **Efficient irrigation technologies**

Irrigation modernization (IM): Investments in modernization involve upgrading irrigation technologies, which enhance the efficiency of water use.

Description of water management options

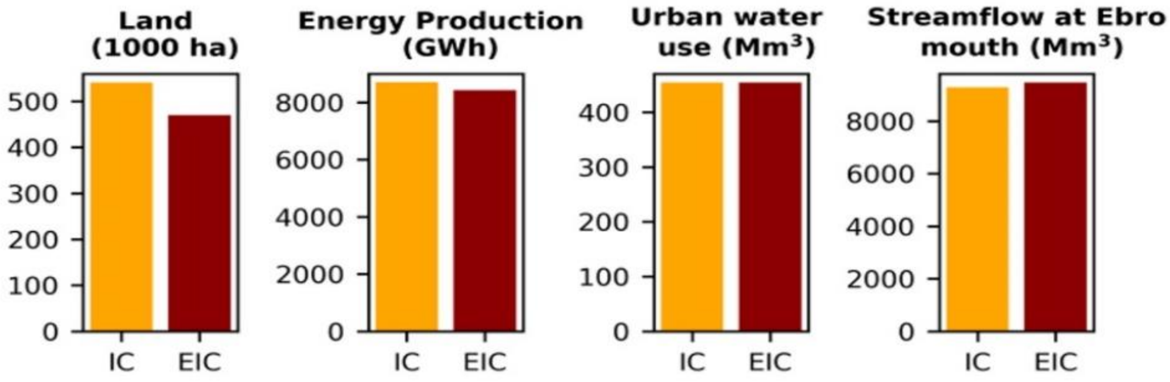
Supply management option

Enlarging dam storage capacity (EDS)

Yesa reservoir

Results

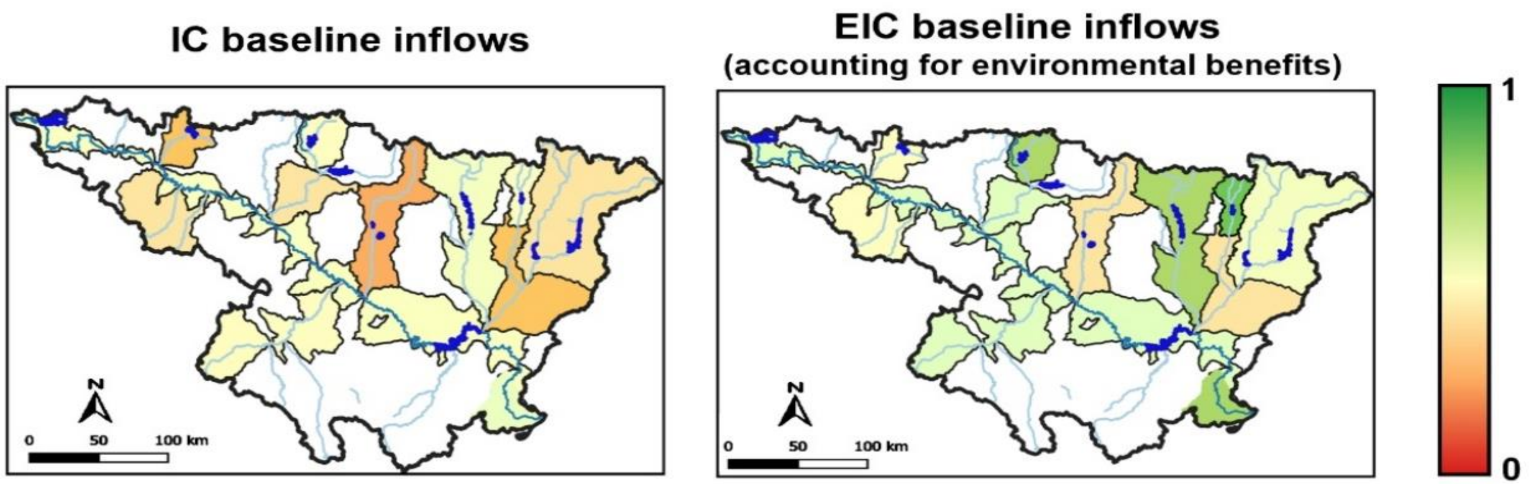
(a) Land, Energy production, Urban water use, and Streamflow at Ebro mouth



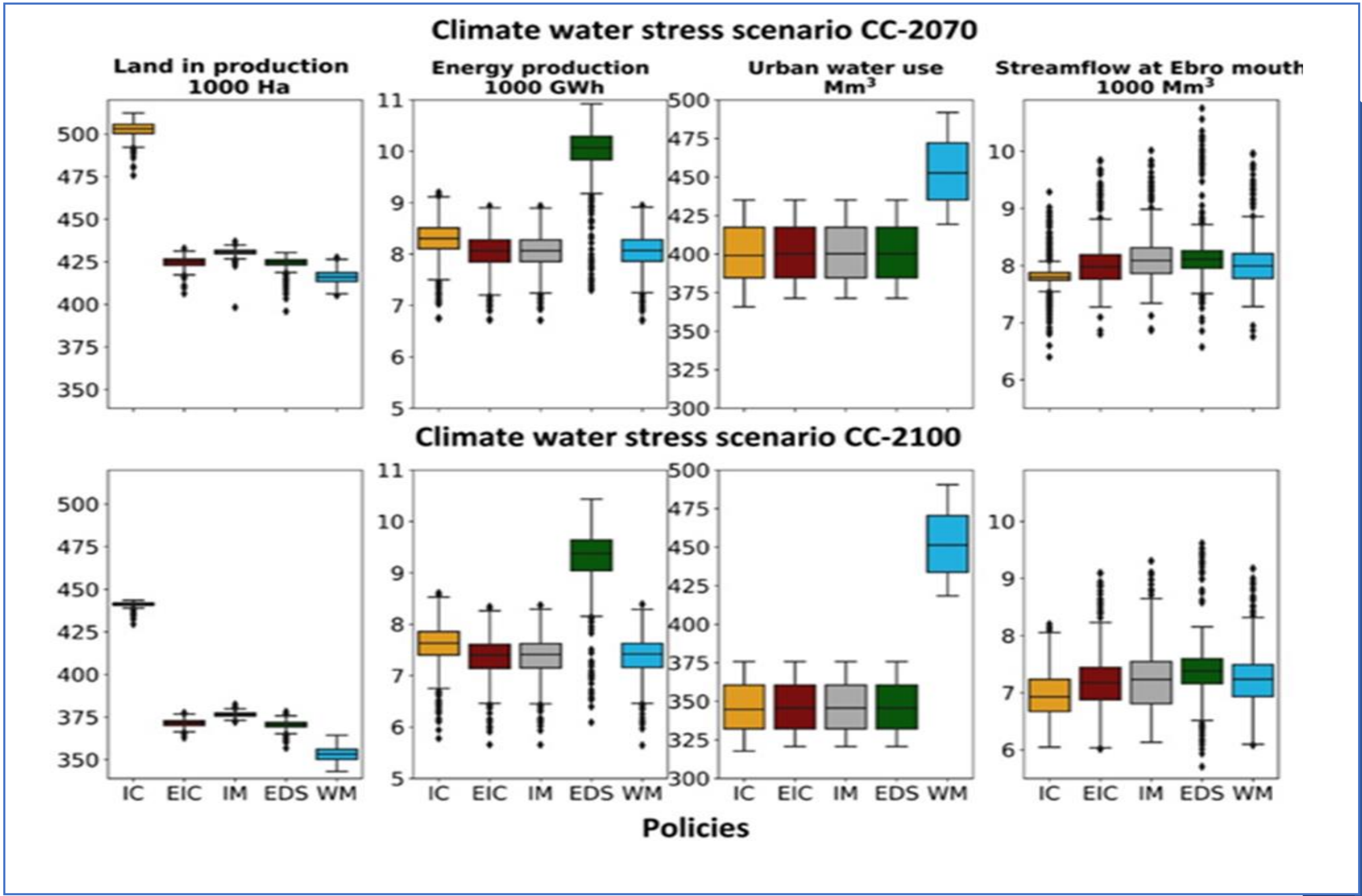
(b) Benefits (M€)

Sectors	IC	EIC
Agriculture	1008	989
Urban	2655	2655
Energy	400	382
Ecosystems	888	1056
Expense by CHE		-3
Total	4951	5079

(c) Ecosystem status (unitless)



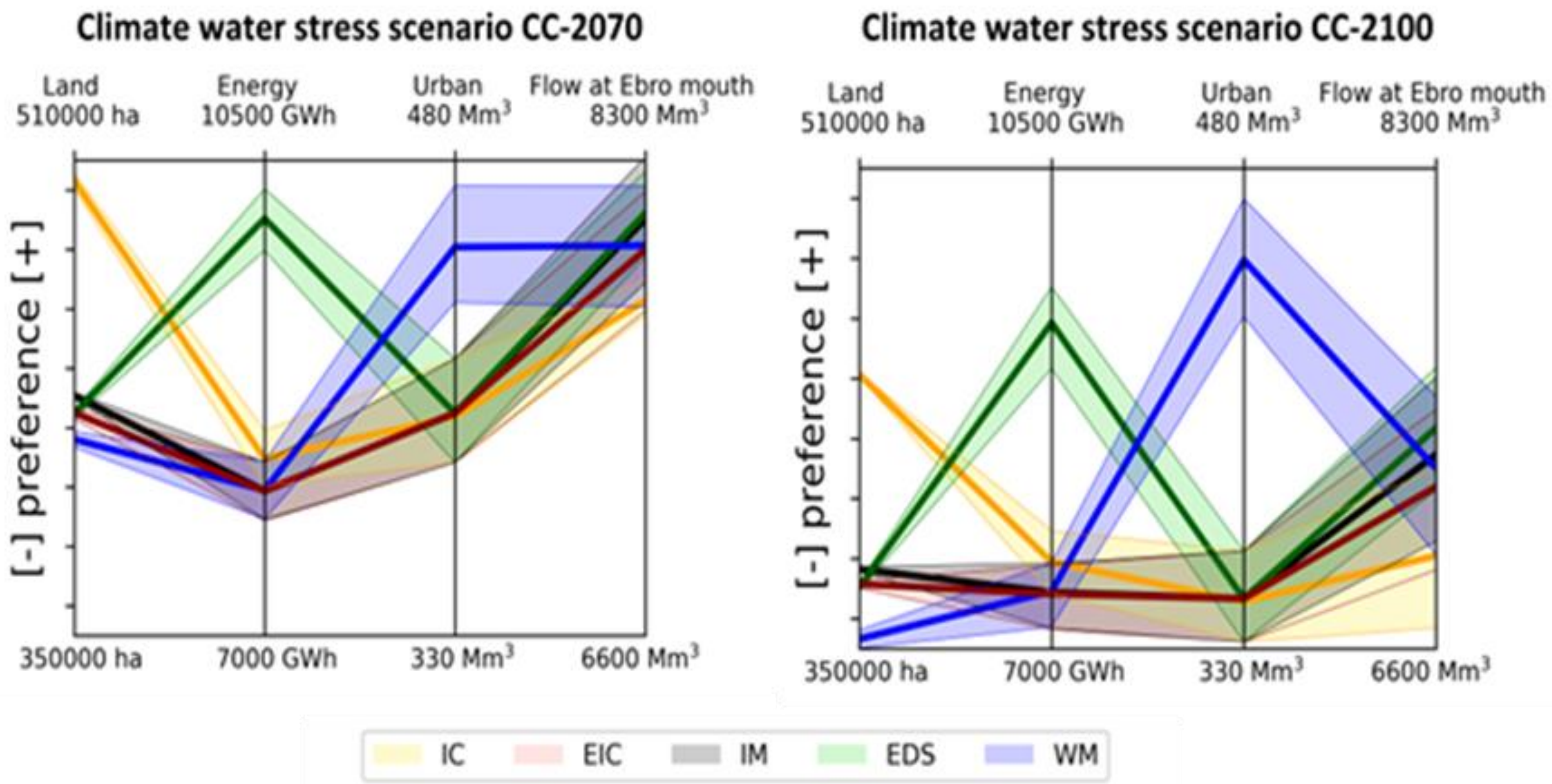
Results



Climate water stress scenario CC-2070
Land in production 1000 Ha
Energy production 1000 GWh
Urban water use Mm³
Streamflow at Ebro mouth 1000 Mm³
Climate water stress scenario CC-2100
IC EIC IM EDS WM
Policies

Results

Sectoral response and competition

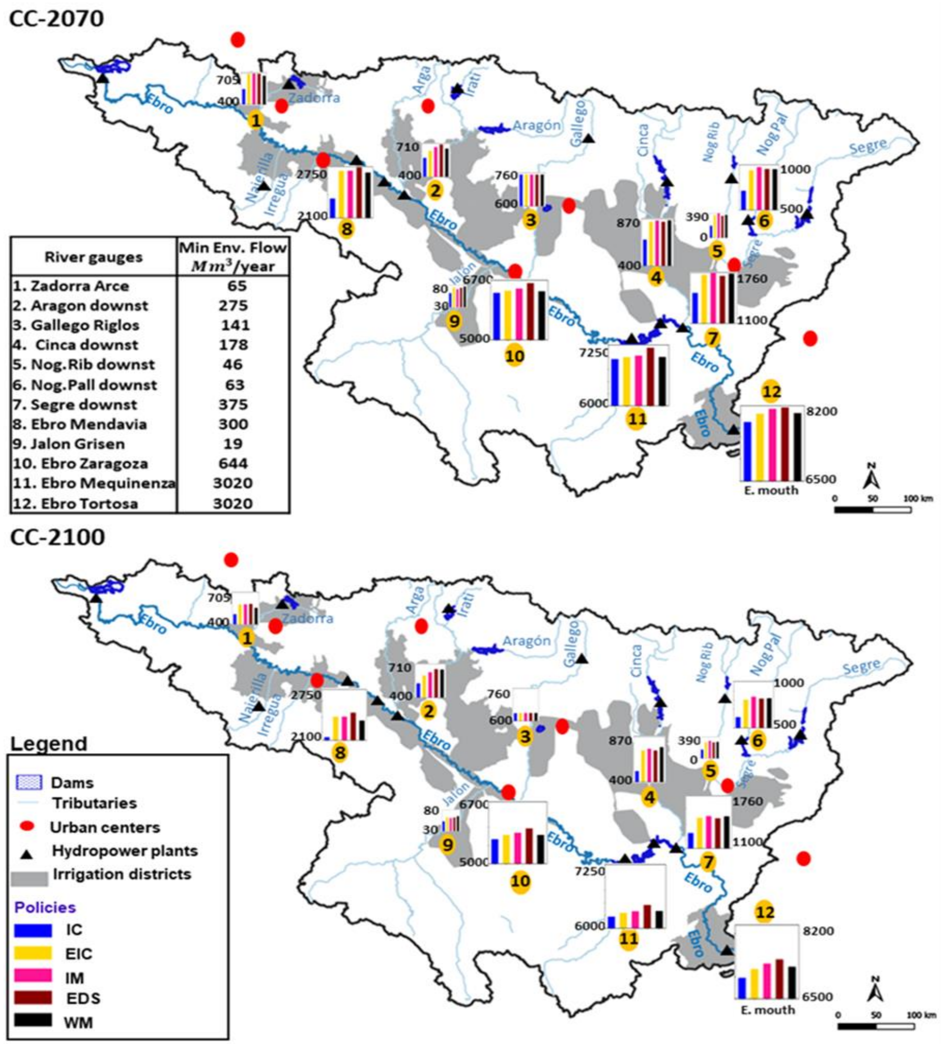


Results

Climate scenarios	Baseline	CC-2070					CC-2100				
Policies	**IC**	**IC**	**EIC**	**IM**	**EDS**	**WM**	**IC**	**EIC**	**IM**	**EDS**	**WM**
Land (1000 ha)	**541**	**503**	**425**	**431**	**424**	**416**	**441**	**371**	**377**	**371**	**353**
Field crops	384	351	277	282	276	268	299	229	233	228	211
Fruits trees	121	116	115	115	115	115	109	111	112	111	111
Vegetables	36	35	33	34	33	33	33	31	32	32	31
Flood	293	265	214	17	213	208	225	180	14	180	168
Sprinkler	158	151	125	268	125	122	133	107	222	107	101
Drip	90	87	86	146	86	86	83	84	141	84	84
Hydropower (GWh)	**8710**	**8288**	**8060**	**8064**	**9975**	**8068**	**7553**	**7361**	**7373**	**9263**	**7384**
Reservoir	6401	5987	5835	5837	7130	5840	5425	5286	5296	6574	5298
Run-of-river	2309	2301	2225	2227	2845	2228	2128	2075	2077	2689	2086
Water use (Mm^3)											
Agriculture[1]	4248	3948	3282	2953	3285	3206	3459	2831	2539	2830	2665
Urban	454	401	401	401	401	454	346	346	346	346	452
Energy	32082	30935	32437	32487	31930	32465	28905	29980	30017	29610	30028
Streamflow at Ebro mouth (Mm^3)	**9287**	**7827**	**8014**	**8124**	**8156**	**8028**	**6983**	**7183**	**7312**	**7406**	**7238**
Social benefits (M€)	**4951**	**4772**	**4896**	**4923**	**5002**	**4931**	**4494**	**4596**	**4615**	**4697**	**4741**
Agriculture	1008	1006	980	1027	981	980	981	956	1005	957	963
Urban	2655	2617	2617	2617	2617	2654	2502	2502	2502	2502	2647
Energy	400	382	368	369	463	368	349	337	338	429	338
Ecosystems	888	767	944	951	955	948	662	826	834	835	834
Expenses by CHE			-13	-41	-14	-19		-25	-65	-26	-42

Results

Climate risks: resilience and adaptation



All the evaluated management options have demonstrated the ability to increase streamflow in the river, thereby promoting climate resilience and facilitating adaptation efforts.

Identify the most suitable policies to be implemented in specific spatial locations. This information can inform decision-making processes by providing valuable insights into the optimal policy choices.

Baccour, S., Albiac, J., Ward, F., Kahil, T., Esteban, E., Uche, J., Calvo, E., Crespo, D., 2023. Managing climate risks: New evidence from integrated analysis at the basin scale. (Submitted).

Spanish Ministry of Science and Innovation

Sustainability of Land and Water Use in Agricultural Activities and Protection of Ecosystems against Droughts and Climate Change.

Related publications

Baccour, S., Ward,F., Albiac,J., 2022. Climate Adaptation Guidance: New Roles for hydroeconomic Analysis. Journal of Science of the Total Environment, 155518. https://doi.org/10.1016/j.scitotenv.2022.155518

Baccour, S., Albiac, J., Kahil, T., Esteban, E., Crespo, D., Dinar, A., 2021. Hydroeconomic modeling for assessing water scarcity and agricultural pollution abatement policies in the Ebro River Basin, Spain. Journal of Cleaner Production, 129459. https://doi.org/10.1016/j.jclepro.2021.129459

Crespo, D., Albiac, J., Kahil, T., Esteban, E., **Baccour, S.**, 2019. Tradeoffs between water uses and environmental flows: a hydroeconomic analysis in the Ebro basin. Water Resources Management, 33(7), 2301-2317. http://doi.org/10.1007/s11269-019-02254-3

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Thank you !