

Supplementary Materials

Table S1. Descriptors and their classes used to characterize WMOs grouped by typology 1) Climate change adaptation potential, 2) Costs and timing, 3) Features of the basin targeted and 4) Uses targeted.

1) Climate Change Adaptation Potential	
Descriptor	Classes
Character	Demand Supply Support Environmental conservation
Approach to adaptation	Green Grey Soft
Feasibility	No major obstacles Minor obstacles Serious obstacles
Acceptability (a priori)	High Low
Effectiveness	High Medium Low
Nature of approach	Bear the loss Share the loss Modify the threat Prevent effects Change use Research Educate, inform and encourage change
Potential to address climate change	Robustness Flexibility
2) Costs and timing	
Descriptor	Classes
Implementation time horizon	Short (< 5 yrs) Medium (5-20 yrs) Long (> 20 yrs)
Expected lifetime	Short (< 5 yrs) Medium (5-20 yrs) Long (> 20 yrs)
Time lag between implementation and effectiveness	Short (< 5 yrs) Medium (5-20 yrs) Long (> 20 yrs)
Implementation costs	< 10,000 € 10,000 - 100,000 €

Operational costs	100,000 - 1,000,000 €
	> 1,000,000 €
	< 10,000 €/yr
	10,000 - 100,000 €/yr
	100,000 - 1,000,000 €/yr
> 1,000,000 €/yr	

3) Features of the basin targeted	
Descriptor	Classes
Water status	Quantity
	Chemical quality
	Ecological quality
	Hydrogeomorphological quality
Water bodies	Surface water
	Groundwater
River section	Up
	Middle
	Down
	River as a whole
Extreme events	Drought
	Flooding
	Storms
	Wildfires
	Not related
Implementation scale	National
	Regional
	Municipal
	Basin

4) Uses targeted		
Descriptor	Classes	
Target water use sector	Local population	
	Tourism	
	Industry	
	Agriculture	
	Forestry	
	Energy	
	Water management	
	Others	
	Target land use	Arable land (rainfed)
		Arable land (irrigated)
Permanent crops (rainfed)		
Permanent crops (irrigated)		
Grassland		
Forests		
Built-up		
Wetlands & deltas		
Beaches & salines		
Others		

Table S2. WMOs descriptors included in the MCA as selected criteria per river basin.

WMOs descriptors included in the MCA	Pedieos	Vipava	Tordera	Rmel
Character	✓	✓	✓	
Average annual cost over 10 y.	✓			
Effectiveness	✓		✓	✓
Feasibility	✓		✓	✓
Acceptability	✓		✓	✓
Approach to adaptation		✓		
Timelag		✓	✓	✓
Implementation costs		✓		✓
Potential to address climate change				✓
Implementation and running costs			✓	
Operational costs		✓		

Table S3. Factors from the WMOs impact assessment (FCM) included in the MCA as selected criteria per river basin.

Factors from FCM included in the MCA	Pedieos	Vipava	Tordera	Rmel
Forest ecosystem services	✓			
Dam waterbody ecosystem services	✓			
Riverbed and riparian area ecosystem services	✓			
Rainfed cropland	✓	✓		✓
Irrigated cropland	✓	✓		✓
Livestock	✓			
Domestic water demand	✓			
Groundwater	✓			
Urban runoff	✓			
Floods	✓	✓		
Surface water and groundwater				✓
Soil degradation				✓
Water availability in reservoirs				✓
Water quality		✓	✓	✓
Job creation				✓
Forest Fire			✓	✓
Population livelihood and settlements				✓
Water quantity		✓	✓	
Water uses			✓	
External water			✓	
Hydro-geo-morphological quality			✓	
Wind damages		✓		
Status of water infrastructure		✓		
Economic wealth		✓		

Table S4. Overview of the water management options (WMO) for the Tordera River Basin. Challenges A: Increase water quantity, B: Health of forests and water ecosystems, C: Increase water quality and D: Integrated water management. MCA results: (0: least preferable; 100: most preferable) Costs: (€: low (<200,000 eur), €€: medium (200,000-1,000,000 eur), €€€: high >1,000,000 eur)).

	Name of WMO (Tordera river basin)	Challenges Addressed	MCA score	Cost range
1	Develop and refurbish facilities to consolidate and extend livestock grazing in the forest.	B	59	€€
2	Create specific branding for the commercialization of extensive livestock products.	B	54	€
3	Expand the Catalan School for Shepherds in the Tordera basin area.	B	48	€€
4	Promote rainfed crop production.	A	45	€€
5	Revise the Extractions Master Plan.	A	44	€€
6	Establish water use entitlement conditions.	A/D	49	€
7	Promote knowledge transfer on irrigation with reclaimed water.	A	47	€
8	Integrate water-saving solutions in construction protocols.	A	58	€€
9	Promote the use of renewable energy to power water management infrastructure in small towns and scattered houses.	D	37	€€
10	Promote water recycling in production processes.	A	44	€
11	Create “Water User Associations” (WUA).	D	61	€€
12	Create a “Permanent Participation Centre”(PPC)	D	59	€€
13	Develop a water traceability label for agricultural products.	A	46	€€
14	Create a Municipal Adaptation Coordination Board (MACB).	D	54	€
15	Enhance phyto-treatment plants in small municipalities and scattered houses.	B	45	€€€
16	Create an “Integrated Plan for the Protection of the Tordera Delta” (IPPTD).	B	70	€
17	Foster selective fishing.	B	52	€
18	Foster local use of adaptation-to-global-change indicators.	D	53	€
19	Raise awareness.	D	57	€€
20	Modernize irrigation techniques.	A	45	€€€
21	Integrate adaptation principles into water service provider contracts.	D	40	€
22	Enhance environmental protected areas.	B	69	€
23	Water provision guarantee as a precondition for urban expansion.	D	41	€

24	Recover wetlands and their connectivity.	B	64	€€
25	Eliminate toxic substances used in municipal parks and gardening practices.	C	40	€
26	Create a catchment agreement to reduce diffuse pollution.	C	46	€€
27	Centralize and facilitate access to relevant data on the basin water bodies' status and uses.	C	38	€
28	Protect groundwater recharge areas.	A/C	53	€
29	Implement an environmental flow regime.	A/C	69	€€
30	Recover and protect river space.	B	60	€
31	Revise and update water entitlements.	D	69	€€
32	Develop River custody agreements.	B	48	€€
33	Conclude adaptive forest management agreements.	B	81	€€

Table S5. Overview of the water management options for the Vipava River Basin. Challenges A: Water availability, B: Flood risk reduction, C: Appropriate water quality. MCA results: (0: least preferable; 100: most preferable) Costs: (€: low (<200,000 eur), €€: medium (200,000-1,000,000 eur), €€€: high >1,000,000 eur)).

	Name of WMO (Vipava river basin)	Challenges Addressed	MCA score	Cost range
1	Establish an inter-municipal expert working group for the Vipava river basin	A, B, C	70	€
2	Awareness campaign focused on educating experts involved in surface water management for sustainable water management	A, B, C	63	€€
3	Awareness campaign focused on optimizing water use for farmers, for proper irrigation and minimize impacts on water quality through proper agricultural practices	A, C	44	€€
4	Awareness campaign for local public on impact of their activities on the river	A, B, C	70	€
5	Improve the financing system for water infrastructure	A, B	63	€
6	Upgrade and update the existing network for monitoring the status of water environment	A, B, C	56	€€
7	Setting up monitoring to reduce pressures on aquatic ecosystems resulting from water abstraction and water storage	A, C	63	€
8	Construction of water reservoirs on the watercourses in the upper part of the river basin	A, B	68	€€€
9	Construction of dry reservoirs	B	56	€€€
10	Reconstruction of existing water reservoir Vogršček	A	55	€€€
11	Development of new irrigation systems	A	29	€€€
12	Reconstruction of existing irrigation system	A	36	€€€
13	Restoration of Vipava river and its tributaries	A, B, C	46	€€€
14	Restoration of old meanders and oxbows of Vipava river and its tributaries	A, B, C	48	€€€
17	Reconstruction of stabilizing and transverse constructions from natural stone in the smaller tributaries of Vipava river	B	44	€
19	Improving the system of payment for water used for irrigation	A, C	48	€

20	Preservation of existing and introduction of new shelterbelts	A, C	39	€€€
21	Removal of invasive non-native species	C	50	€
22	Construction of municipal wastewater treatment plants and sewage systems	C	41	€€€
23	The cultivation of crops that are resistant to climate changes (drought, pests and diseases)	A, C	27	€€€

Table S6. Overview of the water management options for the Pedieos River Basin. Challenges A Quantitative and qualitative status of groundwater, B Quantitative and qualitative status of surface water, C Flooding from the river. MCA results: (0: least preferable; 100: most preferable) Costs: (€: low (<200,000 eur), €€: medium (200,000-1,000,000 eur), €€€: high >1,000,000 eur)).

	Name of WMO (Pedieos river basin)	Challenges Addressed	Key Challenge Addressed	MCA score	Cost range
1	Improved irrigation technologies	A-B	A	26	€€
2	Borehole licences and water meters	A	A	31	€€€
3	Water pricing enforcement	A-B	A	29	€€
4	Use of treated sewage water for irrigation and green infrastructure	A-B	A	24	€€€
5	Water desalination	A-B	A	26	€€€
6	Farm education	A-B	A	48	€€
7	Improve plant genetic resources bank and use of drought tolerant agricultural crops	A-B	A	35	€
8	Dynamic dam water management	A-B-C	A	39	€€
9	Awareness campaign for local society	A-B	A	41	€€
10	Agrotourism development	A-B-C	A	24	€€€
11	Domestic water saving equipment	A-B	B	28	€€€
12	Maintenance and repair of water distribution networks	A-B	B	30	€€€
13	Code of Good Agricultural Practices enforcement	A-B	B	46	€€
14	Grazing control	A-B	B	26	€€
15	Improve plant genetic resources bank and use of drought tolerant forest species	A-B	B	33	€€
16	Hydrological studies	A-B	B	40	€€
17	Dam demolition	A-B-C	B	14	€€€
18	Integrated waste management	A-B	B	29	€€€

19	Construction of multi-purpose cycling/ walking paths across the river	A-B	B	28	€€€
20	Volunteerism	A-B-C	B	42	€
21	Rainwater harvesting systems	A-B-C	C	31	€€€
22	Improve plant genetic resources bank and use of drought tolerant plants in green infrastructures	A-B-C	C	35	€€
23	Fire safety measures	A-B-C	C	34	€€
24	Improving land zonation	A-B-C	C	36	€€
25	Improve stakeholders' cooperation	A-B-C	C	39	€
26	Restoration and maintenance of riverbed	C	C	30	€€
27	River runoff retention and groundwater recharge systems	C	C	37	€€
28	Sustainable urban drainage systems	C	C	38	€€€
29	Construction of flood protection works	C	C	21	€€€
30	Cooperation for storm water drainage system	C	C	33	€€

Table S7. Overview of the water management options for the Rmel River Basin: Challenges A water quantity, B water quality, C Agriculture, D Forest resources, E civil society awareness, F resources and employment. MCA results: (0: least preferable; 100: most preferable) Costs: (€: low (<200,000 eur), €€: medium (200,000-1,000,000 eur), €€€: high >1,000,000 eur)).

	Name of WMO	Challenges Addressed	MCA score	Cost range
1	Promote new water and soil conservation techniques.	A	51	€€€
2	Consolidation of existing water and soil conservation techniques.	A	40	€€€
3	Creation and rehabilitation of hydraulic infrastructure	A	41	€€€
4	Application of taxes.	B	47	€
5	Developing agricultural cooperatives.	C	42	€€
6	Good use of agriculture land.	C	37	€€
7	Developing financial awareness tools.	C	39	€€€
8	Use of water irrigation technologies	C	40	€€€
9	Improvement of the treatment of waste water.	B	46	€€€
10	Water discharge control.	B	42	€€€
11	Reduction of society pressure on forests	D	39	€€
12	Protection against forest fire	D	48	€€€
13	Introduction of new agro forestry species and enrichment of existing forest.	D	37	€€€
14	Better governance of forest resources	D	42	€€
15	Awareness campaign and learning	E	40	€
16	Improved decision making	E	38	€
17	Promote projects that generate more income.	F	45	€€€
18	Encourage investments	F	41	€€€
19	Developing skills for young people	F	44	€€

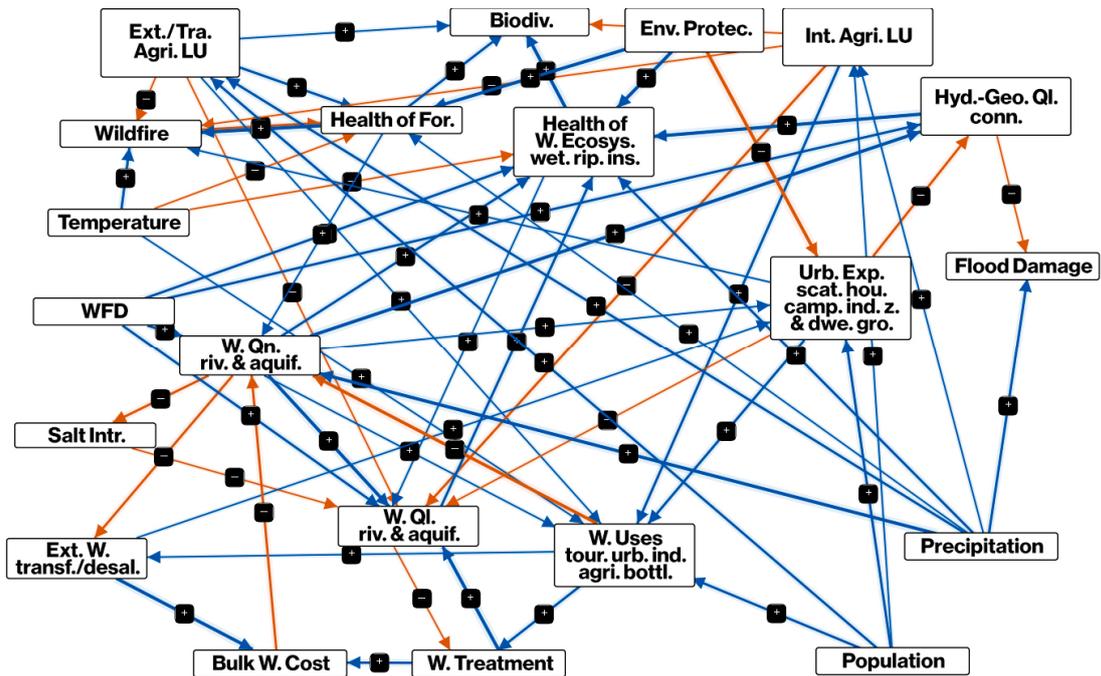


Figure S1. Fuzzy Cognitive Map developed for the Tordera river basin. Line thickness indicates the strength of the relationship (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships. Factors abbreviations (from left-up to right and downwards): Extensive/Traditional agriculture land use, Biodiversity, Environmental protection, Extensive agriculture land use, Wildfire, Health of forests, Health of water ecosystems, wetland, riparian, instream, Hydro-geomorphological quality connectivity, Temperature, Water Framework Directive, Urban expansion scattered houses, camping, industrial zones and dwelling growth, Flood damage, Water quantity rivers and aquifers, Salt intrusion, External water transferred or desalted, Water quality rivers and aquifers, Water uses tourism, urban, industrial, agriculture, bottling, Precipitation, Bulk water cost, water treatment, Population.

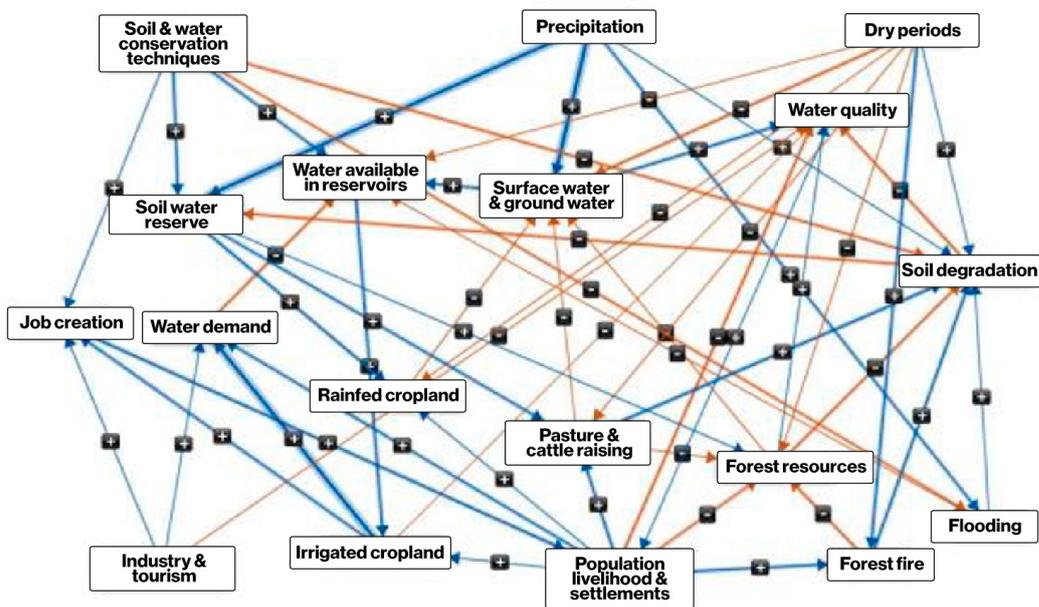


Figure S2. Fuzzy Cognitive Map developed for the Rmel river basin. Line thickness indicates the strength of the relationship between factors (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships.

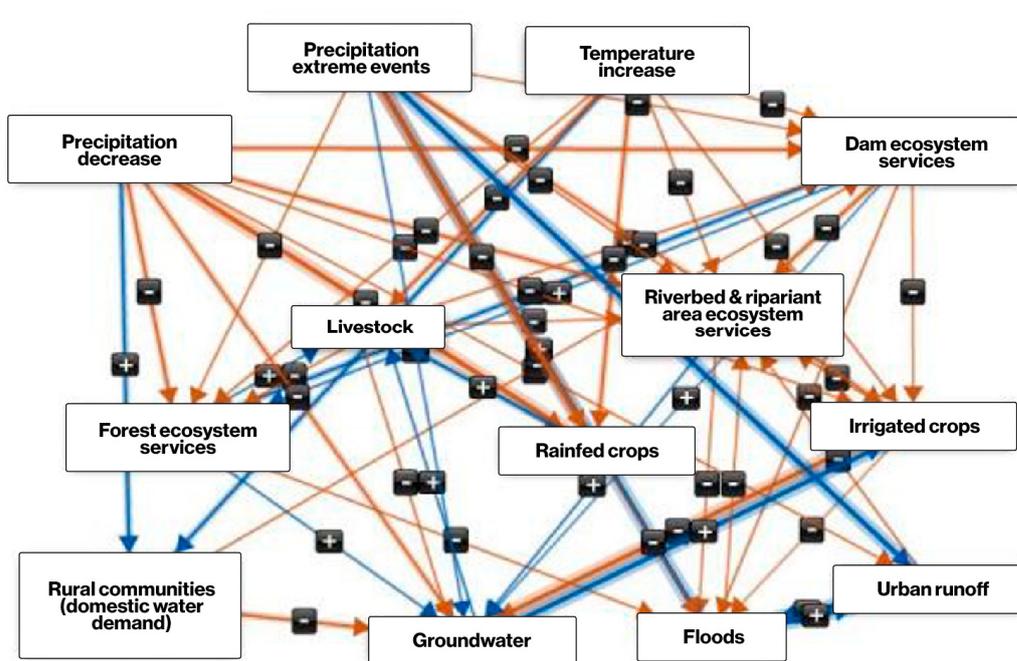


Figure S3. Fuzzy Cognitive Map developed for the Pedieos river basin. Line thickness indicates the strength of the relationship between factors (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships.

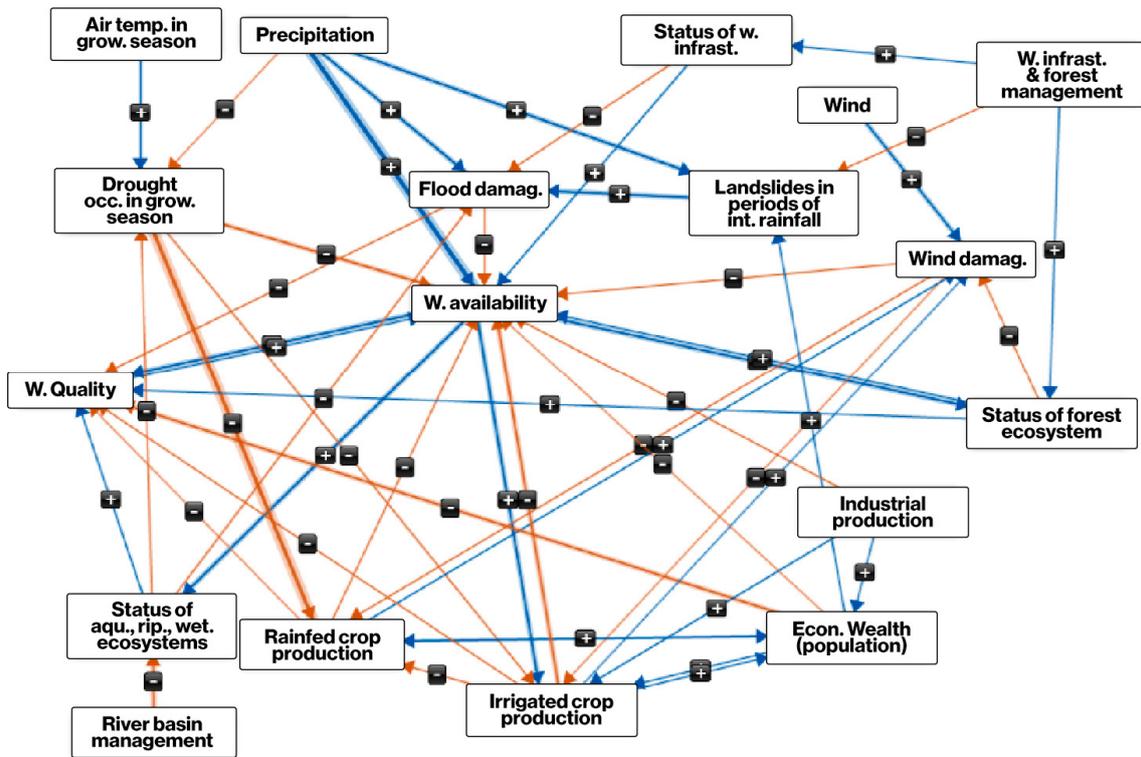
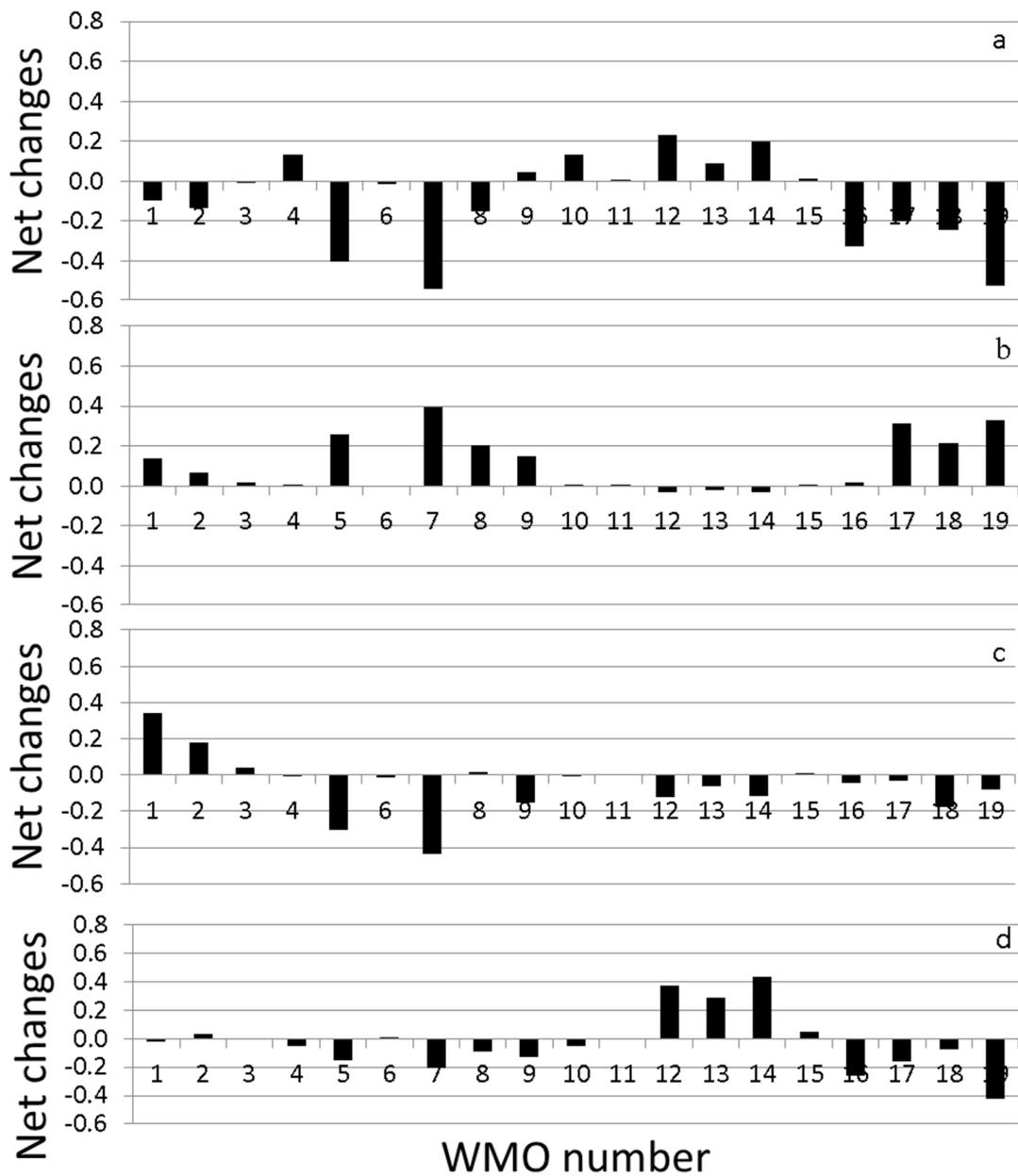


Figure S4. Fuzzy Cognitive Map developed for the Vipava river basin. Line thickness indicates the strength of the relationship (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships. Factors abbreviations (from left-up to right and downwards): Air temperature in growing season, Precipitation, Status of water infrastructures, Water infrastructures and forest management, Wind, Drought occurrences in growing season, Flood damage, landslides in periods of intense rainfall, Wind damage, Water availability, Water Quality, Status of forest ecosystems, Industrial production, Status of aquatic, riparian, wetland ecosystems, Rainfed crop production, Economic wealth (population), River basin management, Irrigated crop production.



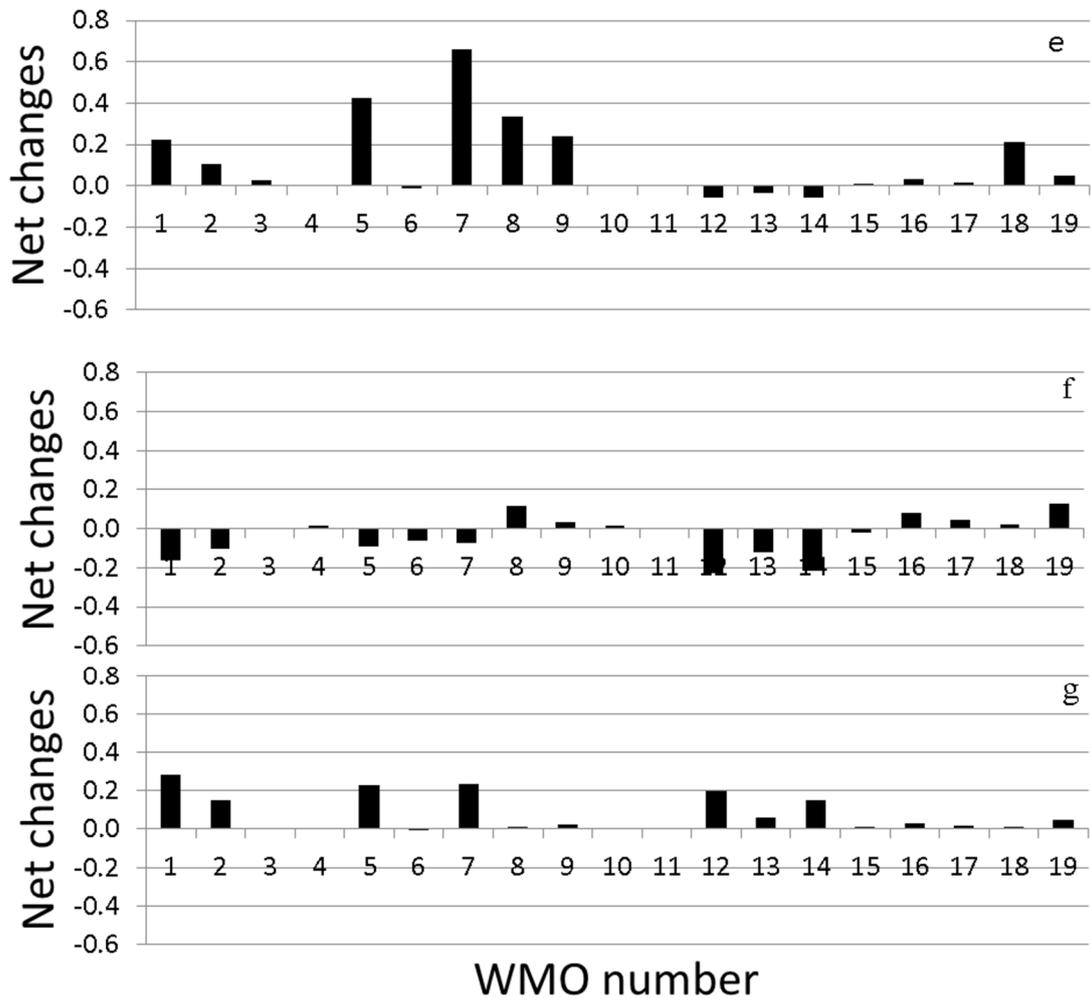


Figure S5. Graph showing how Rmel river basin challenges are impacted by all WMOs as net changes from baseline situation estimated with the FCM. Impacts on challenges: a) Water quality, b) Job creation, c) Water availability in reservoirs, d) Forest resources, e) Irrigated cropland, f) Surface water and ground water and g) Pasture and cattle raising.

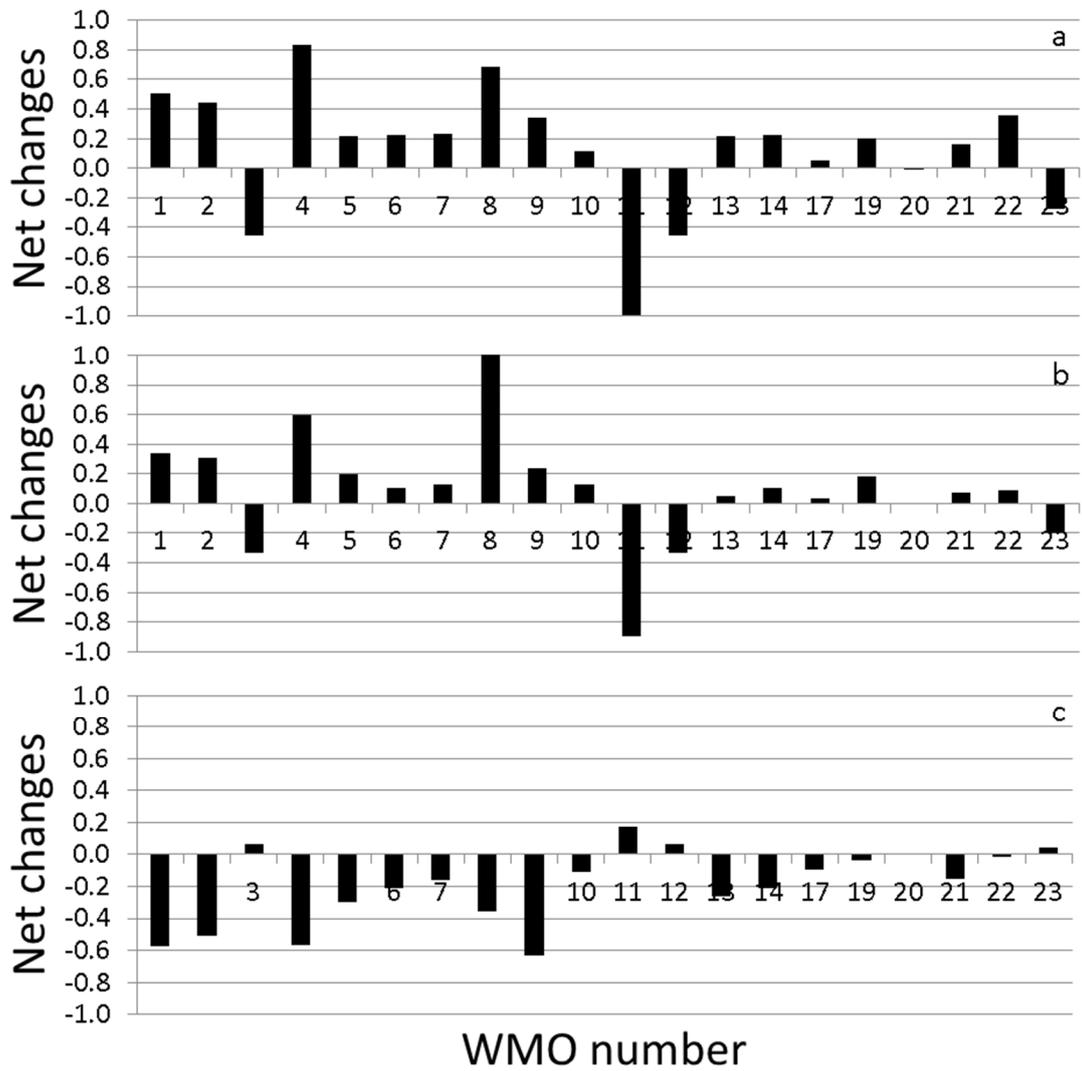


Figure S6. Graph showing how Vipava river basin challenges are impacted by all WMOs as net changes from baseline situation estimated with the FCM. Impacts on challenges: a) Water quality, b) Water availability and c) Flood damages.

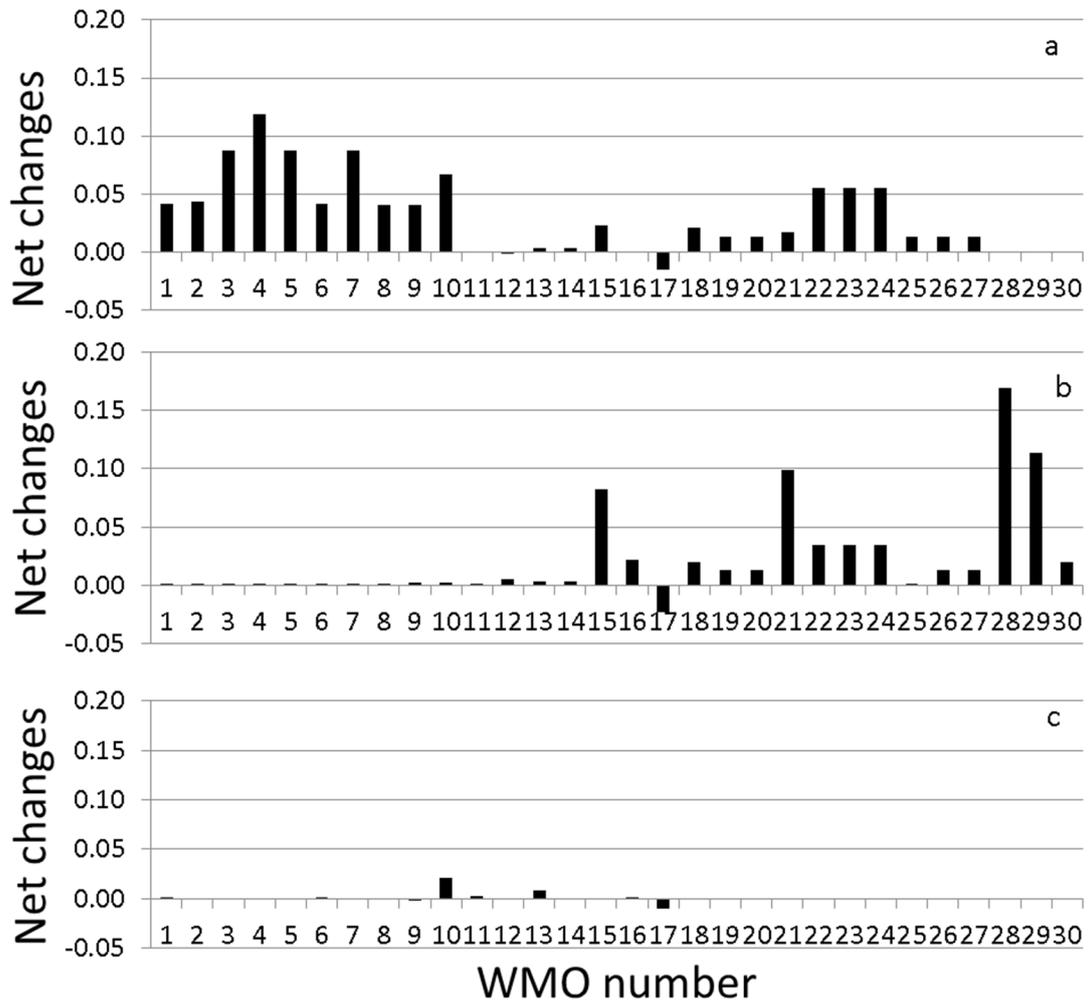


Figure S7. Graph showing how Pedieos river basin challenges are impacted by all WMOs as net changes from baseline situation estimated with the FCM. Impacts on challenges: a) Groundwater, b) Flood, and c) Dam ecosystem services (proxy of surface water status).