INCLUSIÓN DE LA ADAPTACIÓN AL CAMBIO CLIMÁTICO EN LA PLANIFICACIÓN HIDROLÓGICA: APROXIMACIÓN METODOLÓGICA Y APLICACIÓN A CASOS DE ESTUDIO EN EL MEDITERRÁNEO.

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INCLUSIÓN DE LA ADAPTACIÓN AL CAMBIO CLIMÁTICO EN LA PLANIFICACIÓN HIDROLÓGICA: APROXIMACIÓN METODOLÓGICA Y APLICACIÓN A CASOS DE ESTUDIO EN EL MEDITERRÁNEO.

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A la memoria de mi padre, Luis Sánchez Muñoz

Que quería que su hija fuera "doctora"

Agradecimientos

Al final del camino me dirán:
– ¿Has vivido? ¿Has amado?
Y yo, sin decir nada,
abriré el corazón lleno de nombres.

Pere Casaldàliga

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Resumen

Los impactos del cambio climático y otros cambios de origen antropogénico ponen en riesgo la disponibilidad del agua para la sociedad y para los ecosistemas, especialmente en regiones vulnerables como la región Mediterránea. Incorporar elementos y principios de adaptación en la gestión del agua y la planificación hidrológica de manera adecuada es un gran reto que no se ha enfrentado suficientemente hasta el momento, aunque las políticas relacionadas con la gestión de recursos naturales ofrecen la oportunidad para hacerlo. Es también urgente dotarse de herramientas que permitan evaluar la manera en que se incluye la adaptación al cambio climático en planes y programas.

Esta tesis desarrolla una aproximación participativa para identificar, evaluar y priorizar retos y opciones de gestión del agua como base para una planificación que incorpore elementos de adaptación al cambio climático en cuencas hidrográficas. La metodología se ha aplicado en cuatro cuencas, en los puntos cardinales del Mediterráneo (Vipava en Eslovenia, Rmel en Túnez, Pedieos en Chipre y Tordera en España), en las que se ha analizado y comparado los resultados obtenidos para cada caso de estudio. Por último, hemos construido un marco analítico que permite evaluar la coherencia de planes y programas de gestión del agua con los principios de adaptación al cambio climático y que ha sido testado en el plan de adaptación desarrollado para la cuenca de la Tordera.

Por un lado, la aproximación participativa ha asegurado que los actores locales, sus conocimientos, comprensión sobre las cuencas y preferencias, tuvieran un papel activo y determinante en definir los retos más importantes para sus cuencas en el contexto de cambio climático, así como en proponer y evaluar las soluciones para enfrentar dichos retos, aumentar la adaptación y reducir la vulnerabilidad socio-ambiental. De manera mayoritaria, las personas que han participado en el proceso lo han valorado muy positivamente y han considerado que la metodología era un buen ejemplo de cómo mejorar los procesos de toma de decisiones en materia de gestión del agua y que ha representado un avance en el diálogo entre ciencia, política y diferentes actores sociales. Por otro lado, el marco analítico desarrollado ha demostrado ser fácil de utilizar y proporciona información clara y detallada sobre criterios clave de adaptación incluidos en él. Se considera, por tanto, un buen punto de partida para futuras elaboraciones de herramientas más robustas de análisis y evaluación sobre la inclusión de la adaptación al cambio climático en la gestión del agua.

La adaptación al cambio climático necesita de una sociedad activa y consciente de los riesgos a los que se enfrenta y que participe en la toma de decisiones sobre la gestión y planificación hidrológica. Asimismo, sería imprescindible llevar a cabo cambios dentro de las instituciones que superen los actuales compartimentos y límites administrativos rígidos, que resuelva la fragmentación de responsabilidades y la falta de visión común entre diferentes áreas, que promueva una gestión integrada y a largo plazo y que, además, legitime los espacios intersectoriales, transversales y multiactor. Por último, es necesario incorporar herramientas para el seguimiento, medición y evaluación de la consecución de los objetivos de adaptación para conseguir, de manera efectiva, mejorar la planificación e implementación de las medidas de gestión para la adaptación.

Resum

Els impactes del canvi climàtic i altres canvis d'origen antropogènic posen en risc la disponibilitat d'aigua per a la societat i per als ecosistemes, especialment en regions vulnerables com la regió Mediterrània. Incorporar elements i principis d'adaptació en la gestió de l'aigua i la planificació hidrològica de manera adequada és un gran repte que no s'ha afrontat prou fins ara, tot i que les polítiques relacionades amb la gestió de recursos naturals ofereixen l'oportunitat per fer-ho. És també urgent dotar-se d'eines que permetin avaluar la manera de considerar l'adaptació al canvi climàtic en plans i programes.

Aquesta tesi desenvolupa una aproximació participativa per identificar, avaluar i prioritzar reptes i opcions de gestió de l'aigua com a base per a una planificació que incorpori elements d'adaptació al canvi climàtic en conques hidrogràfiques. La metodologia s'ha aplicat en quatre conques, en els punts cardinals de la Mediterrània (Vipava a Eslovènia, Rmel a Tunísia, Pedieos a Xipre i Tordera a Espanya), a les que s'ha analitzat i comparat els resultats obtinguts en cada cas d'estudi. Finalment, hem construït un marc analític que permet avaluar la coherència de plans i programes de gestió de l'aigua amb els principis d'adaptació al canvi climàtic i que ha estat testat en el pla d'adaptació desenvolupat per a la conca de la Tordera.

D'una banda, l'aproximació participativa ha assegurat que els actors locals, els seus coneixements, comprensió sobre les conques i preferències, tinguessin un paper actiu i determinant en definir els reptes més importants per les seves conques en el context de canvi climàtic, així com en proposar i avaluar les solucions per enfrontar aquests reptes, augmentar l'adaptació i reduir la vulnerabilitat socioambiental. De manera majoritària, les persones que han participat en el procés l'han valorat molt positivament i han considerat que la metodologia era un bon exemple de com millorar els processos de presa de decisions en matèria de gestió de l'aigua i que ha representat un avenç en el diàleg entre ciència, política i diferents actors socials. D'altra banda, el marc analític desenvolupat ha demostrat ser fàcil d'utilitzar i proporciona informació clara i detallada sobre els criteris clau d'adaptació inclosos en ell. Es considera, per tant, un bon punt de partida per a futures elaboracions d'eines més robustes d'anàlisi i avaluació sobre la inclusió de l'adaptació al canvi climàtic en la gestió de l'aigua.

L'adaptació al canvi climàtic necessita d'una societat activa i conscient dels riscos als quals s'enfronta i que participi en la presa de decisions sobre la gestió i planificació hidrològica. Així mateix, seria imprescindible dur a terme canvis dins de les institucions que superin els actuals compartiments i límits administratius rígids, que resolgui la fragmentació de

responsabilitats i la manca de visió comú entre diferents àrees, que promogui una gestió integrada i a llarg termini i que, a més, legitimi els espais intersectorials, transversals i multiactor. Finalment, cal incorporar eines per al seguiment, mesura i avaluació de l'assoliment dels objectius d'adaptació per a aconseguir, de manera efectiva, millorar la planificació i implementació de les mesures de gestió per a l'adaptació.

Summary

The impacts of climate change and other changes of anthropogenic origin put at risk the availability of water for society and for ecosystems, especially in vulnerable regions such as the Mediterranean region. Incorporating elements and principles of adaptation into water management and planning in an appropriate way is a great challenge that has not been sufficiently addressed so far, although policies related to natural resource management offer the opportunity to do so. It is also urgent to use tools that allow evaluating how adaptation to climate change is being considered in plans and programs.

This thesis develops a participatory approach to identify, evaluate and prioritize challenges and options for water management as a basis for a strategic planning that incorporates elements of adaptation to climate change in river basins. The methodology has been applied in four basins, in the cardinal points of the Mediterranean (Vipava in Slovenia, Rmel in Tunisia, Pedieos in Cyprus and Tordera in Spain), in which the results obtained in each case study have been analyzed and compared. Lastly, we have built an analytical framework that allows us to evaluate the coherence of water management plans and programs with the principles of adaptation to climate change and that has been tested in the adaptation plan developed for the Tordera river basin.

On the one hand, the participatory approach has ensured that local actors, their knowledge, understanding of basins and preferences, had an active and determining role in defining the most important challenges for their basins in the context of climate change, as well as in proposing and evaluating solutions to face these challenges, increasing adaptation and reducing socio-environmental vulnerability. Most of the people who have participated in the process have valued it very positively and have considered that the methodology was a good example of how to improve decision-making processes in water management and that it has represented an advance in the dialogue between science, policy and different social actors. On the other hand, the analytical framework developed has proven to be easy to use and provides clear and detailed information on key adaptation criteria included in it. It is therefore considered a good starting point for future development of more robust analysis and evaluation tools on the inclusion of adaptation to climate change in water management.

Adaptation to climate change requires a society that is active and aware of the risks it faces and that participates in decision-making on water management and planning. Likewise, it would be essential to carry out changes within the institutions that overcome the current silos and rigid administrative limits that resolve the fragmentation of responsibilities and the lack of common vision between different areas, that promote an integrated and long-term

management and that, in addition, legitimize intersectoral, transversal and multi-stakeholder spaces. Finally, it is necessary to incorporate tools for monitoring, measuring and evaluating the achievement of adaptation objectives in order to effectively improve the planning and implementation of management measures for adaptation.

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CAPÍTULO 1. Introducción

1.1 Contexto

1.1.1 Cambio climático en la cuenca mediterránea

La cuenca mediterránea es una región con alta heterogeneidad y está considerada una de las zonas del mundo con excepcional concentración de biodiversidad. Es, así mismo, una de las áreas más vulnerables a los impactos del cambio climático (MedECC 2019). Las proyecciones climáticas indican un incremento de la temperatura de 2,2 grados para mediados de siglo y una reducción de la precipitación superior al 8%, con la consecuente disminución de la disponibilidad de agua para los diferentes usos del recurso de hasta un 15% (MedECC 2019). Esta reducción de la disponibilidad de agua variará espacialmente de manera importante y se esperan limitaciones críticas en el sur y el este de la cuenca mediterránea (Cramer et al. 2018, MedECC 2020). Asimismo, diferentes estudios indican un cambio en el patrón temporal y la intensidad de precipitación en el litoral mediterráneo (De Luis et al. 2010) con importantes incrementos en la duración e intensidad de las sequías (Tramblay et al. 2020), que podrían causar periodos de extrema escasez de los recursos hídricos. Se espera que el efecto combinado de calentamiento y sequía lleve a un incremento generalizado de la aridez y, en consecuencia, a una tendencia a la desertificación en muchos de los ecosistemas terrestres de la cuenca. (MedECC 2019).

Además de las consecuencias directas del cambio climático, hay que considerar otras consecuencias combinadas de diferentes cambios ambientales derivados de las presiones humanas, tales como la contaminación del aire, el agua y los suelos, y la degradación de los ecosistemas terrestres y acuáticos debido a las actividades industriales, la urbanización, el transporte y el uso no sostenible de los recursos. Todos estos cambios globales afectan a la seguridad en el acceso a los recursos naturales, el estado saludable de los ecosistemas, la salud humana y la vulnerabilidad respecto a los riesgos naturales (MedECC 2019).

Por tanto, el contexto de cambio global y sus impactos en cuanto a reducción de los recursos hídricos disponibles, en una zona ya especialmente vulnerable como es la cuenca mediterránea, pone en grave riesgo la disponibilidad de agua para el adecuado funcionamiento de las sociedades y los ecosistemas y representa un reto muy importante para la gestión y planificación del agua.

1.1.2 Adaptación al cambio climático y gestión del agua

Debido a la inercia de los sistemas climáticos, aunque las emisiones de gases de efecto invernadero se detuvieran inmediatamente, muchos impactos asociados al cambio climático continuarán durante siglos (IPCC 2014a). Estos impactos ya se están observando en la actualidad y no harán sino incrementarse en el futuro afectando tanto a la población y a las actividades socioeconómicas como a los ecosistemas naturales (IPCC 2014b). Adaptarse al cambio climático es, por tanto, un reto social urgente e inaplazable, que debe avanzar en paralelo a los esfuerzos de mitigación, para conseguir ajustarnos a estos cambios y disminuir sus efectos negativos. En relación con el uso de los recursos naturales, implica asegurarnos de que se gestionan de manera que se preserve y recupere la funcionalidad de los ecosistemas y se promueva la mejora de su resiliencia (O'Higgins 2020). Es decir, la adaptación al cambio climático implica anticipar los efectos adversos, diseñar las acciones apropiadas para enfrentarlos y minimizar así sus consecuencias (IPCC 2014b). Para avanzar de manera efectiva en estrategias y acciones de adaptación, y más allá del ámbito internacional o europeo, el papel de los gobiernos nacionales, regionales y locales es fundamental (EU 2013).

La adaptación al cambio climático representa afrontar la complejidad intrínseca de los sistemas socio-ecológicos (Ladyman 2013), en un contexto de incertidumbre sobre la severidad y localización concreta de los impactos. En relación con la gestión del agua, esto implica que el diseño de políticas y de prácticas de gestión incorporen cada vez más aproximaciones flexibles, transversales y dinámicas que puedan responder a los cambios e incertidumbres presentes y futuras y proporcionen respuestas sistémicas (Lee 1999, Polansky 2011, Sterling 2013). En este sentido y, para asegurar que las estrategias y políticas de adaptación en la gestión del agua sean creíbles, fundamentadas y factibles, deben de ser desarrolladas a través de procesos abiertos y transparentes con la participación activa y real de diversos actores; y, además, deben considerar los marcos de gestión de recursos naturales que se promueven a nivel europeo y nacional en los cuales se reconoce cada vez más la importancia de involucrar a la sociedad en los procesos de toma de decisiones (Pahl-Wostl 2007, Pahl-Wostl et al. 2007). Se considera (UNDP 2010, Newig 2018) que la participación activa de actores en la gestión y planificación del agua contribuye a:

i) la aceptabilidad, sostenibilidad y resiliencia de los proyectos y políticas sobre el agua;

ii) el fortalecimiento de la formación, el aprendizaje mutuo y el empoderamiento de los participantes y la oportunidad de que sus perspectivas, conocimientos y prioridades sean tenidas en cuenta;

iii) la garantía de equidad y democracia en la toma de decisiones;

iv) la mejora de la definición y el conocimiento sobre las causas de los problemas, así como de las soluciones, especialmente en situaciones de conflicto; y

v) la eficiencia económica de las soluciones y a su efectividad e impacto.

La participación de actores representantes de diferentes sectores y ámbitos que puedan aportar sus visiones y conocimientos es clave ya que las estrategias y políticas de gestión del agua y de adaptación al cambio climático están interconectadas de manera muy importante con las de otros sectores (MedECC 2020) y los *trade-offs* entre ellos en términos de impactos sociales y ambientales deben ser considerados conjuntamente.

Sin embargo, la principal legislación europea sobre agua, la Directiva Marco de Agua (DMA) (Directiva 2000/60/EC), no especifica la manera en la que los estados miembros deben operacionalizar la participación pública, que puede quedar en mera consulta, ni considera explícitamente el cambio climático. Aunque posteriormente se han desarrollado documentos guía de implementación de la DMA (EC 2009) con el objetivo de mejorar la consideración del cambio climático y de la adaptación en la gestión del agua, su adopción por parte de los estados miembros ha sido limitada hasta la fecha y continúa siendo una cuestión pendiente (EC 2015). El marco que proporciona la DMA sigue siendo válido tanto para la mejora en la calidad de la participación y la inclusión de la adaptación al cambio climático como para la consecución del buen estado de las masas de agua. La reciente evaluación de la legislación del agua europea así lo indica, concluyendo que es adecuada para la consecución de sus objetivos, pero que su implementación debe mejorar y acelerarse (EU 2019).

1.1.3 Gestión y gobernanza adaptativa

Como ya se ha comentado previamente, la adaptación al cambio global supone modificar la manera en que se toman las decisiones sobre la gestión del territorio, incorporando marcos transversales, flexibles y dinámicos que puedan dar respuesta a los cambios (Lee 1999). Ello implica considerar nuevas maneras de gestión y de gobernanza de los recursos naturales, como las conceptualizadas en los enfoques de la gestión y gobernanza adaptativa.

La gestión adaptativa reconoce que nuestra habilidad para predecir el comportamiento futuro de los motores, las dinámicas y las respuestas de un ecosistema son limitados. Por lo tanto, desde esta perspectiva la gestión debe ser flexible y rentabilizar lo aprendido de las experiencias pasadas e incluir estos aprendizajes en las prácticas de gestión posteriores para su continua mejora (Pahl-Wostl 2009, Pahl-Wostl et al. 2012). Por esta razón se requiere que, en el ciclo iterativo de gestión, todos los pasos sean participativos: desde la definición del problema al diseño de políticas, incluyendo el análisis de escenarios, los estudios sobre los efectos de la interacción con otras políticas e incluso los programas de monitoreo para evaluar su efectividad (Rist 2013). La involucración de los actores sociales es un aspecto clave en esta aproximación de la gestión. Estas dos dimensiones, el aprendizaje basado en la experiencia y la interrelación entre actores, están en la base del concepto de gestión adaptativa representado como un ciclo de gestión-evaluación-aprendizaje que se va repitiendo (Huitema 2009).

La gobernanza adaptativa es un marco conceptual que pretende promover prácticas adecuadas en el ámbito de la gestión de los riesgos, la incertidumbre y la complejidad determinadas por el contexto de cambios globales (Djalante 2012). La gobernanza adaptativa representa el contexto institucional que permite la implementación de sistemas de gestión adaptativa (Huntjens et al. 2012, Wyborn 2015) y engloba los cambios institucionales necesarios en relación con:

- el incremento de perspectivas incluidas en los procesos de toma de decisiones,
- el incremento de coordinación entre diferentes instituciones y departamentos de la administración pública,
- el incremento de coordinación entre diferentes niveles institucionales (de local a estatal) y
- el incremento de coordinación entre diferentes actores de la sociedad y la administración.

La gobernanza adaptativa requiere armonización e intersectorialidad de las políticas y la construcción de una visión común y objetivos estratégicos compartidos entre diferentes sectores, requisitos que las estructuras y prácticas actuales no facilitan. Debido a ello, es necesario instituir y promover nuevos espacios de gobernanza para la adaptación que permitan la colaboración entre órganos de gestión y la participación de todos los actores implicados de manera efectiva. Si bien se ha avanzado en este sentido en algunos estados europeos, existen todavía dificultades importantes para conseguir reestructurar las jerarquías institucionales y los canales y mecanismos de decisión existentes (Russel 2020).

En concreto para el ámbito de la gestión del agua, la combinación del contexto teórico relacionado con la gobernanza adaptativa, y su concreción en la práctica mediante protocolos de gestión adaptativa, se consideran aproximaciones muy válidas para dar respuesta a los retos que plantea el cambio global (IPCC 2014a) y al enfoque holístico e iterativo promovido por la DMA.

1.1.4 Metodologías participativas para la adaptación en la gestión del agua

Dada la necesidad de abordar los *trade-offs* y construir compromisos entre los diferentes intereses creados sobre el uso del agua y para preservar el buen estado ecológico de las masas de agua, la DMA promueve un enfoque holístico para proteger las cuencas hidrográficas, incluido el objetivo central de involucrar a los actores sociales para que participen en las diferentes etapas del ciclo de planificación (Giakoumis and Voulvoulis 2018). La participación activa y real alimenta el proceso de diseño de políticas con información actualizada y relevante sobre presiones e impactos, incluye perspectivas sociales y económicas y sugiere soluciones que podrían necesitar una amplia aceptación por parte de los actores locales (Jager et al. 2016). Esta implicación social mejora la calidad de los procesos de toma de decisiones (Tompkins and Adger 2004, Lemos 2015) al combinar diferentes habilidades, marcos teóricos y experiencias necesarias para ofrecer respuestas más adecuadas en un contexto caracterizado por un alto grado de incertidumbre de los problemas tratados (Amaru and Chhetr 2013). Desde la perspectiva de la DMA, la participación pública se considera, por tanto, como una herramienta imprescindible para conseguir los objetivos ambientales.

Esta participación activa requiere de metodologías específicas tanto para promover y dinamizar la participación de los actores de un territorio, como para permitir la integración de diferentes tipos de información en los procesos promovidos y así lograr una comprensión más completa del funcionamiento de los sistemas complejos: conocimiento basado en la ciencia, conocimiento basado en la experiencia, información del contexto socioeconómico, entre otros (Voinov and Bousquet 2010, Voinov et al. 2016).

Se han desarrollado diversas técnicas y herramientas para facilitar la incorporación de los actores en el análisis de los impactos del cambio climático, co-diseñar soluciones, comparar y priorizar dichas soluciones, así como monitorizar y evaluar el proceso de implementación de estas. Por su relevancia para esta tesis doctoral, introduciremos algunas de estas metodologías en los siguientes sub-apartados: la metodología *STIR* (*Stakeholder Integrated Research*)

(Gramberger 2015), el mapeo cognitivo (Jetter 2014, Gray 2015, Martínez et al. 2018) y el análisis multicriterio (Huang 2011).

Metodología STIR

El enfoque STIR (*Stakeholder Integrated Research*) (Fig. 1), ha sido desarrollado por Gramberger et al. (2015) como un enfoque estructurado para la participación de los actores en la adaptación al cambio climático. El enfoque STIR consta de una serie de pasos, incluidos la identificación y selección de los actores, y su involucración en un proceso cuidadosamente diseñado y facilitado profesionalmente, basándose en métodos científicos.

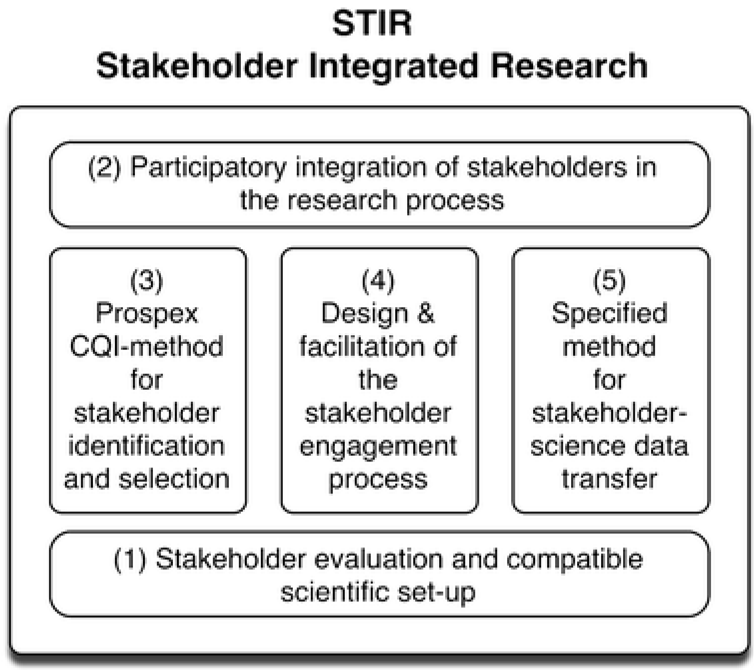

Figura 1. Esquema de la metodología *Stakeholder Integrated Research* STIR. Fuente: pág. 203 en Gramberger, M. et al. (2015).

Este enfoque proporciona un marco general para la participación de los actores, aunque no prescribe metodologías individuales para ser utilizadas en cada uno de los pasos.

El paso inicial de identificación de los actores es clave y determinará qué perspectivas se recogen. Este paso tiene como objetivo detectar quién podría estar interesado o afectado por los resultados del proceso, quién podría realizar aportaciones al proceso y quien podría utilizar la información obtenida. En este paso es común construir un mapa de actores para recoger estructuradamente los contactos de las personas que participarán en el proceso, pudiéndose utilizar diversas herramientas para su construcción. Posteriormente se utilizan distintos criterios de selección que permiten la composición equilibrada del grupo de participantes y se definen los eventos e interacciones que permitirán cumplir los objetivos definidos.

Mapeo Cognitivo

Dentro de las metodologías participativas para la gestión de recursos naturales encontramos el mapeo cognitivo (Fig. 2). Esta metodología de modelización participativa permite aumentar el conocimiento y la comprensión de un sistema (por ejemplo, una cuenca hidrográfica) y sus dinámicas por parte de los participantes, así como analizar el impacto de políticas y estrategias de gestión (Vasslides et al. 2016). De esta manera, los mapas cognitivos son representaciones del sistema tal y como lo perciben los individuos (Bosma et al. 2017). Es una metodología adecuada para capturar el conocimiento y facilitar la comunicación entre actores, de diversos sectores y orígenes, y expertos. Los mapas cognitivos se han utilizado de forma amplia para representar el funcionamiento de los sistemas naturales y, más específicamente, para representar el uso y la gestión de los recursos hídricos y los impactos relacionados con el cambio climático (Reckien et al. 2017, Olazabal et al. 2018).

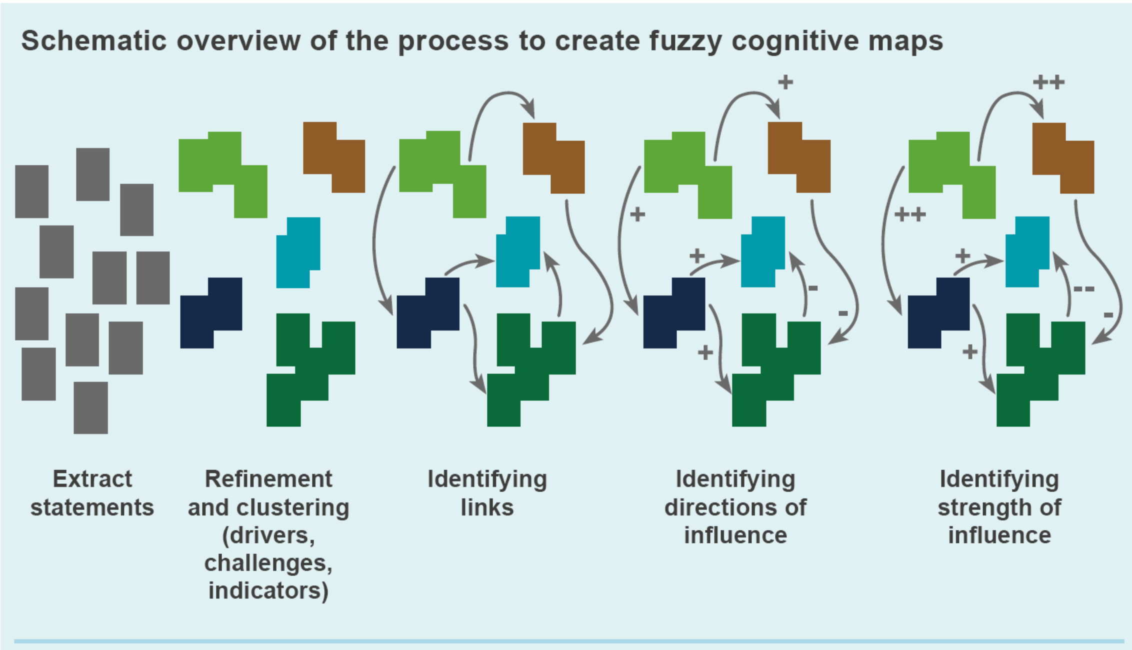

Figura 2. Esquema que ejemplifica el proceso de creación de un mapa cognitivo. Fuente: BeWater Project EU.

Análisis multicriterio

Las técnicas de análisis multicriterio se utilizan para comparar, clasificar y priorizar alternativas a través de un conjunto de criterios de evaluación (Dodgson 2009). El análisis multicriterio ha sido ampliamente utilizado y recomendado tanto en la gestión del agua (Hajkowicz 2006) como en la adaptación al cambio climático (Janssen 2006, De Brun 2009), incorporando en la definición y valoración de alternativas de gestión las propuestas y los criterios acordados por los actores en un proceso participativo (Fig. 3).

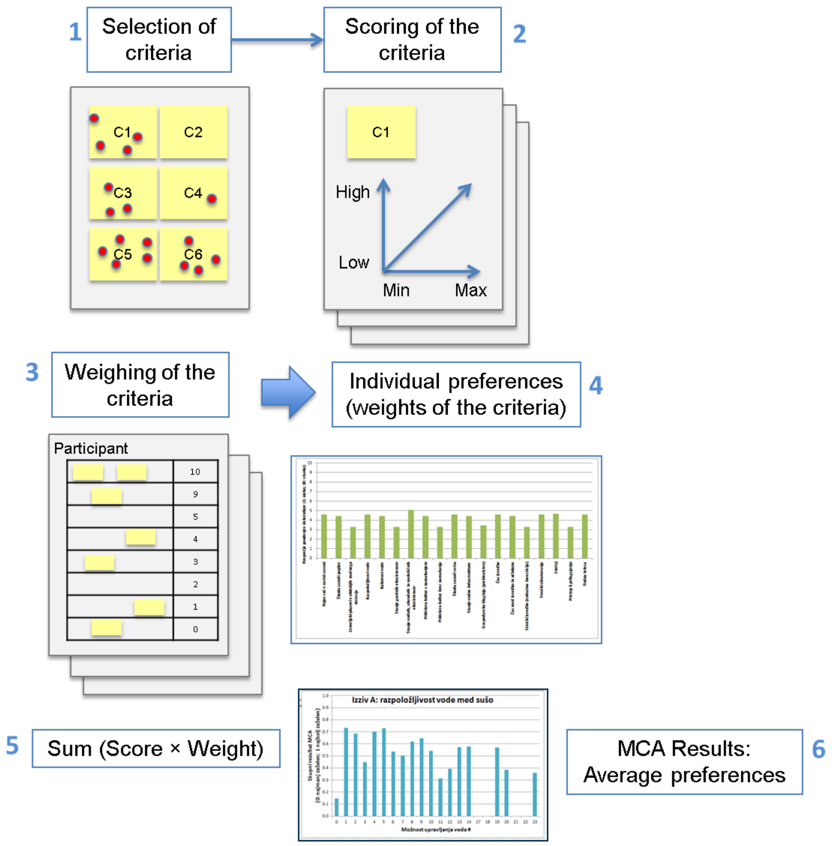

Figura 3. Esquema del proceso de análisis multicriterio y pasos desarrollados de manera participativa por los actores de una cuenca hidrográfica para definir preferencias y priorizar medidas de gestión del agua. Fuente: BeWater Project EU.

1.1.5 Evaluación de la incorporación de la adaptación en la gestión y planificación del agua

La integración del cambio climático en la gestión de los recursos hídricos es una prioridad en Europa y aunque esta prioridad está ya ampliamente recogida en las estrategias y políticas a todos los niveles, hay todavía poca experiencia y una insuficiente, y en muchos casos inadecuada, inclusión de este aspecto clave en políticas y prácticas de gestión del agua.

La evaluación de planes, programas y prácticas que es imprescindible para cualquier ámbito de gestión, es un aspecto especialmente delicado y relevante en la adaptación al cambio climático. La adaptación al cambio climático requiere de transformaciones profundas en la manera tradicional de planificar y gestionar los recursos naturales. Por un lado, requiere cambiar los procesos de planificación lineales y rígidos en procesos circulares y flexibles. Por otro lado, precisa cambios en la estructura institucional que permitan pasar de una mentalidad compartimentada y sectorizada a otra integrada, que tenga en cuenta las implicaciones transectoriales de la gestión y evite la maladaptación (OECD 2009, Barnett 2010, Feliu 2014, UNEP 2019, Schipper 2020, MITECO 2020). Estas transformaciones no son fáciles de llevar a la práctica y por ello es clave implementar un adecuado sistema de evaluación que incluya indicadores específicos para la misma. Sería, por tanto, de gran importancia avanzar en la evaluación rigurosa y en el desarrollo y la adopción de metodologías de evaluación crítica de los planes y estrategias que pretendan incluir la adaptación al cambio climático en la gestión del agua.

1.2 Justificación

Una parte importante de esta tesis doctoral es el resultado de tres años y medio de trabajo desarrollados en el marco del proyecto europeo *BeWater: Society Adapting to Global Change*, 2013-2017 (http://www.bewaterproject.eu), financiado por el 7° Programa Marco de la Unión Europea. El resto de la tesis se basa en análisis posteriores de dichos resultados o en la utilización de los mismos para otros desarrollos. En concreto, la elección de los casos de estudio, cuatro cuencas hidrográficas —Pedieos (Chipre), Vipava (Eslovenia), Rmel (Túnez) y Tordera (España) — y de la metodología participativa para adaptar cuencas hidrográficas al cambio climático, se contextualiza en algunas de las decisiones tomadas en el proyecto. Este hecho ha facilitado la difusión y el interés generado sobre los resultados. Los contenidos y temáticas de investigación presentados, se enmarcan en líneas de trabajo más amplias que preceden y continúan el trabajo desarrollado (ver Curriculum Vitae, Anexo 2).

Ya hemos mencionado que la adaptación al cambio climático en la gestión del agua especialmente en zonas con alta vulnerabilidad ambiental y social es un reto para toda la sociedad. Enfrentar este reto requiere, por un lado, implementar enfoques que permitan dar respuestas integradas y transversales y además considerar conjuntamente informaciones, conocimientos y saberes de diversa naturaleza. Y, por otro lado, requiere involucrar a todos los actores interesados tanto en la detección compartida de los problemas de una cuenca como en el desarrollo, y priorización de medidas de gestión para la adaptación y la reducción de la vulnerabilidad.

Por tanto, el trabajo que se presenta en esta tesis surge de la inquietud de combinar y aplicar metodologías de participación activa para incorporar criterios y enfoques de adaptación al cambio global en planes y programas de gestión del agua en cuencas hidrográficas, basándonos en el conocimiento científico más actualizado sobre impactos y vulnerabilidades presentes y futuras de dichas cuencas e integrando el conocimiento de poblaciones y territorios. Se fundamenta también en la necesidad de testar la aplicación de esta metodología en varias cuencas hidrográficas con realidades ecológicas y socioeconómicas diversas para analizar las diferencias y asegurar así su validez en diferentes contextos.

Por último, este trabajo surge del convencimiento de que es necesario avanzar mucho más de lo que se ha hecho hasta el momento en cuanto a la incorporación de la adaptación al cambio climático en la gestión y planificación del agua y que, no todo lo que se hace pasar por adaptativo, lo es en realidad. Por ello, creemos que es necesario desarrollar metodologías que contribuyan a entender mejor los elementos clave necesarios para adaptarnos, así como proporcionar marcos de análisis para evaluar la manera en que planes y programas de gestión del agua incluyen dichos elementos. Todo ello ayudaría a entender mejor de qué manera se está abordando la incorporación de la adaptación en la gestión del agua y qué aspectos son los que más están dificultando o favoreciendo el avance hacia unas políticas y prácticas realmente adaptativas.

La presente tesis doctoral representa una oportunidad para aportar metodologías útiles para el diseño, implementación y evaluación de políticas y prácticas de adaptación basadas en experiencias concretas y colaborativas, que puedan ser extrapolables a otras cuencas y a otros sectores. Estos desarrollos metodológicos y aproximaciones se concretan en:

- una combinación innovadora de herramientas para la modelización participativa (aplicación de mapeo cognitivo y análisis multicriterio).
- una propuesta metodológica de análisis y evaluación de la inclusión de la adaptación en planes y programas (*check-list* para la adaptación).

Con esta tesis doctoral se pretende contribuir en los siguientes aspectos:

- generar experiencias que sirvan como ejemplo de cómo ir transformando los enfoques tradicionales, de carácter lineal, sectorial y tecnocrático, en nuevos modelos que promuevan la resiliencia de la sociedad frente al cambio climático.
- acercar ciencia y sociedad, poniendo a disposición de la ciudadanía resultados de investigaciones previas disponibles, útiles y muy relevantes a nivel de cuenca hidrográfica, así como metodologías científicas que faciliten la incorporación del conocimiento de los actores de las cuencas en el proceso de investigación.
- construir de manera colaborativa entre los actores de una cuenca hidrográfica, propuestas que puedan ayudar a mejorar la base científica y la participación de la sociedad en la toma de decisiones para enfrentar el cambio climático.
- realizar una reflexión detallada sobre la propia investigación desarrollada en el marco del proyecto europeo en la que se gestó, incorporando así elementos de autoevaluación que resulten en conclusiones constructivas y mejoras del diseño de investigaciones posteriores.

1.3 Objetivos

Esta tesis tiene como objetivo general contribuir al avance de la inclusión de la adaptación al cambio climático en la gestión y planificación hidrológica, tanto desde el desarrollo de enfoques metodológicos, como a través de su aplicación en cuencas de estudio en el Mediterráneo.

Este objetivo general se ha estructurado en los siguientes objetivos específicos:

- Desarrollar una metodología participativa para identificar y evaluar medidas de gestión del agua para la adaptación al cambio climático y aplicarla en cuatro cuencas hidrográficas del Mediterráneo.

- Analizar y comparar las medidas de gestión del agua preferidas por los actores participantes para enfrentar los retos relacionados con el cambio climático y promover la adaptación en cuatro cuencas hidrográficas del Mediterráneo.

- Desarrollar un marco de análisis crítico para evaluar la inclusión de la adaptación al cambio climático en planes y programas. Testar su aplicabilidad en el Plan de adaptación de la cuenca de la Tordera.

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CAPÍTULO 2. Artículos

2.1 Resumen de los artículos

El trabajo de investigación recogido en esta tesis se ha concretado en la realización de los siguientes artículos científicos:

Artículo 1: Desarrollo de una metodología participativa para adaptar la gestión de cuencas hidrográficas al cambio climático.

Verkerk P. J., Sánchez-Plaza A., Libbrecht S., Broekman A., Bruggeman A., Daly-Hassen H, Giannakis E., Jebari S., Kok K, Krivograd Klemenčič A., Magjar M., Martinez de Arano I., Robert N., Smolar-Žvanut N., Varela E., Zoumides C. (2017) A Participatory Approach for Adapting River Basins to Climate Change. *Water* 9(12): 958. https://doi.org/10.3390/w9120958

Artículo 2: Aplicación de la metodología desarrollada en el artículo 1 y comparación de resultados en cuatro cuencas del Mediterráneo.

Sánchez-Plaza A., Broekman A., Retana J., Bruggeman A., Giannakis E., Jebari S., Krivograd-Klemenčič A., Libbrecht S., Magjar M., Robert N., Verkerk Pieter J. (2021) Participatory evaluation of water management options for climate change adaptation in river basins. *Environments* 8(9):93. https://doi.org/10.3390/environments8090093

Artículo 3: Desarrollo de un marco de análisis sobre la incorporación de la adaptación al cambio climático en la gestión del agua y test de su aplicabilidad en el Plan de adaptación de la cuenca de la Tordera, producido usando las metodologías participativas expuestas en el Artículo 1 y 2.

Sánchez-Plaza A., Broekman A., Paneque P. (2019). Analytical Framework to Assess the Incorporation of Climate Change adaptation in Water Management: Application to the Tordera River basin Adaptation Plan. *Sustainability* 11(3): 762. https://doi.org/10.3390/su11030762

La Tabla 1 recoge un resumen del planteamiento y elementos más destacables de cada uno de los artículos.

Tabla 1. Resumen de los artículos científicos que forman parte de la tesis.

	Artículo 1	**Artículo 2**	**Artículo 3**
Tema central	Aproximación participativa para adaptar cuencas hidrográficas al cambio climático.	Evaluación participativa de medidas de gestión del agua para la adaptación al cambio climático en cuencas hidrográficas.	Evaluación de la inclusión de la adaptación al cambio climático en la gestión del agua.
Objetivos	Desarrollar una metodología participativa para identificar y evaluar medidas de gestión del agua para la adaptación al cambio climático y aplicarla en cuatro cuencas hidrográficas del Mediterráneo.	Analizar y comparar las medidas de gestión del agua preferidas por los actores participantes para enfrentar los retos relacionados con el cambio climático y promover la adaptación en cuatro cuencas hidrográficas del Mediterráneo.	Desarrollar un marco de análisis crítico para evaluar la inclusión de la adaptación al cambio climático en planes y programas. Testar su aplicabilidad en el Plan de adaptación de la cuenca de la Tordera (ver Anexo 3, publicación A3.1 https://doi.org/10.5281/zenodo.439491).
***Gap* al que pretende responder**	Necesidad de desarrollar aproximaciones participativas para mejorar la adaptación al cambio climático en cuencas hidrográficas.	Necesidad de implementar metodologías participativas para la definición de retos, desarrollo de propuestas y modelización del impacto de las mismas para la adaptación en la gestión del agua en diferentes contextos socioeconómicos y ambientales.	Falta de herramientas para evaluar la calidad de la incorporación de la adaptación al cambio climático en planes y programas de gestión del agua.
Contexto de aplicación	4 cuencas hidrográficas: Pedieos (Chipre), Vipava (Eslovenia), Rmel (Túnez) y Tordera (España)	4 cuencas hidrográficas: Pedieos (Chipre), Vipava (Eslovenia), Rmel (Túnez) y Tordera (España)	1 cuenca hidrográfica: Tordera (España)
Materiales y métodos	4 casos de estudio que cubren condiciones contrastadas en el Mediterráneo (Túnez, Eslovenia, Chipre y España). Metodologías participativas para la adaptación (STIR). Mapeo cognitivo (FCM) y Análisis multicriterio (MCA).	4 casos de estudio que cubren condiciones contrastadas en el Mediterráneo (Túnez, Eslovenia, Chipre y España).Metodologías participativas para la adaptación (STIR). Mapeo cognitivo (FCM) y Análisis multicriterio (MCA). Definición y comparación de retos y medidas de gestión del agua.	Desarrollo de un marco analítico basado en la identificación de elementos clave que caracterizan la adaptación al cambio climático, la gestión adaptativa y la gobernanza adaptativa. El marco analítico está estructurado en siete áreas de análisis con diversas preguntas clave estructuradas en forma de *check-list* para la evaluación.

Resultados	Retos y medidas de gestión del agua desarrolladas con los actores locales. Desarrollo de mapas cognitivos y análisis multicriterio. Evaluación del proceso por parte de los actores.	Análisis comparativo de los retos y medidas entre las 4 cuencas hidrográficas. Evaluación participativa de las medidas y comparación entre cuencas.	Propuesta de un marco d análisis trasladable a otros contextos y aplicación práctica a un caso de estudio: el Plan de adaptación de la cuenca de la Tordera.
Discusión	Las aproximaciones utilizadas han asegurado una adecuada representación de actores locales y una implicación activa de los mismos en todo el proceso metodológico. Evaluación muy positiva de todo el proceso por parte de los actores participantes.	La metodología participativa ha sido útil para detectar y evaluar prioridades, retos y medidas de gestión que son, en gran parte, específicos de cada cuenca hidrográfica debido a los distintos contextos socioeconómicos y ecológicos, así como a la tipología de actores participantes. Las preferencias mostradas por dichos actores han sido recogidas en mayor o menor grado dependiendo del caso de estudio.	El marco analítico desarrollado permite evaluar la coherencia respecto a los criterios y elementos de la adaptación al cambio climático de planes y programas. Se ha demostrado fácil de utilizar y proporciona información clara y detallada sobre los criterios clave incluidos. El plan utilizado para testar la aplicabilidad del marco analítico muestra una coherencia elevada con los elementos clave de adaptación evaluados.
Innovación	Combinación de metodologías para la participación de actores en la adaptación al cambio climático en cuencas hidrográficas (STIR, FCM, MCA). (Detalles en la Guía metodológica Anexo 3, publicación A3.2 https://doi.org/10.5281/zenodo.439522)	Combinación de conocimientos de diversa naturaleza (científico y local) e inclusión de las preferencias de los actores en el desarrollo de medidas de adaptación.	Desarrollo de una herramienta para evaluar la inclusión de la adaptación al cambio climático en planes y programas.
Contribución propia	Contribución principal (segunda autora, tras coordinación del proyecto) al diseño del estudio, a la elección de metodologías, al análisis de resultados y a la redacción del artículo. Coordinación de la implementación en los cuatro casos de estudio. Implementación en la cuenca de la Tordera.	Diseño del estudio, realización de los análisis y comparaciones (primera autora). Contribución a la implementación de las metodologías. Redacción del artículo.	Conceptualización de la investigación y desarrollo y aplicación de la metodología (primera autora). Realización de los análisis. Redacción del artículo.

2.2. Artículo 1. A Participatory Approach for Adapting River Basins to Climate Change.

Verkerk P. J., Sánchez A., Libbrecht S., Broekman A., Bruggeman A., Daly-Hassen H, Giannakis E., Jebari S., Kok K, Krivograd Klemenčič A., Magjar M., Martinez de Arano I., Robert N., Smolar-Žvanut N., Varela E., Zoumides C. (2017) A Participatory Approach for Adapting River Basins to Climate Change. *Water* 9(12): 958. https://doi.org/10.3390/w9120958

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A Participatory Approach for Adapting River Basins to Climate Change

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Abstract: Climate change is expected to reduce water availability in the Mediterranean region and water management needs to adapt to future conditions. The aims of this study were (1) to develop a participatory approach for identifying and evaluating management options for river basin climate adaptation and (2) to apply and evaluate the approach in four case-study river basins across the Mediterranean. As part of the approach, a diverse group of stakeholders joined a series of workshops and consultations in four river basins located in Cyprus, Slovenia, Spain and Tunisia. In each river basin, stakeholders expressed their views on challenges in their river basins, as well as options to tackle these challenges. We used the information on challenges, as well as the factors contributing to these challenges to develop a fuzzy cognitive map for each basin. These maps were converted into mathematical models and were used to assess the impact of a total of 102 suggested management options for the four river basins. We linked the options and their estimated impacts with a multi-criteria analysis to identify the most preferred options. The approach was positively evaluated by the participating stakeholders and allowed the link of stakeholders' knowledge and perceptions about their river basin with their preferences for options to adapt the management of their river basins to future conditions.

Keywords: adaptation; fuzzy cognitive mapping; climate change; multi-criteria analysis; participation; river basin; water management

1. Introduction

Society crucially depends on access to high quality water resources. Unfortunately, water resources are limited and climate change is expected to exacerbate water scarcity [1,2], particularly affecting drier regions such as the Mediterranean. Temperatures are expected to increase, seasonal precipitation patterns are expected to shift and extreme events (heatwaves, droughts, heavy rain) are projected to become more frequent and intense [3]. Despite the uncertainties in climate model simulations, the projections for the Mediterranean area indicate a strong consistency in reduced future availability of water [4].

Climate change impacts should be analyzed together with other factors that influence water resources. The population in the Mediterranean has been growing significantly in recent decades and this trend is expected to continue during the next decades, especially in the Southern part of the Mediterranean [5]. Furthermore, land cover and land use influence both the amount and the quality of available water [6,7]. Humans have modified Mediterranean landscapes for millennia [8] and the area has experienced urban expansion in coastal areas and contraction of croplands during recent decades, followed by an expansion of the forest area [9,10]. Water is already under high demand due to agriculture, urbanization and tourism with negative consequences on water quality [11–13]. The demand for water is estimated to increase in the future and may lead to further pressure on water availability and quality [14,15]. Altogether, these constraints indicate the need to develop water management strategies to adapt to future conditions.

To ensure that adaptation strategies for water management are credible, informed and achievable, they need to be developed through an open and transparent process with the active participation of diverse stakeholders, representing different sectors and policy areas in the river basin [13,16,17]. Stakeholder participation in water management planning is thought to (i) contribute to acceptability, sustainability and resilience in water projects and policies; (ii) strengthen capacity building and empowerment; (iii) guarantee equity and democracy in decision making; (iv) provide solutions for conflict situations; and (v) contribute to economic efficiency [18–20]. The importance of involving stakeholders in decision-making is increasingly acknowledged at the policy level. For example, the European Union's Water Framework Directive (Directive 2000/60/EC) requires public consultation in the water management planning process. However, this directive neither prescribes how public participation should be operationalized [21], nor does it explicitly consider climate change [22].

Numerous studies have developed and applied participatory approaches for climate change adaptation [23–25], including for the management of water resources under climate change [26,27]. Quantitative simulation models are frequently used to provide detailed and important insights in the effects of water management under climate change [28–30]. The use of such quantitative and often complex models in participatory processes is not straightforward, as such models may be perceived by stakeholders as black-boxes. Furthermore, data to feed quantitative models may not always be available, and semi or non-quantitative, participatory modelling methods may be a suitable approach to deal with data gaps. Participatory modelling methods have been developed and used to enhance stakeholders' knowledge and understanding of a system (e.g., a river basin) and its dynamics and to assess impacts of policies or management strategies [31]. In this study, we applied such a participatory modelling method and combined it with a multi-criteria analysis in an attempt to involve stakeholders from four river basins across the Mediterranean to plan for the adaptation of the management of their river basins. The aims of this study were (1) to develop a participatory approach for identifying and evaluating management options for river basin adaptation planning and (2) to apply and evaluate the approach in four case-study river basins across the Mediterranean.

2. Materials and Methods

2.1. Case-Study Approach

To formulate and evaluate water management options, we focused on four Mediterranean case study river basins, which are located across the Mediterranean area: the Pedieos river basin (Cyprus) in the east, the Rmel river basin (Tunisia) in the south, the Tordera river basin (Spain) in the west, and the Vipava river basin (Slovenia) in the north. The four river basins cover different Mediterranean conditions with regard to climate, land use and socio-economic conditions (Table 1).

Table 1. Characteristics of the Pedieos, Rmel, Tordera and Vipava river basins.

Characteristic	Pedieos	Rmel	Tordera	Vipava
Country	Cyprus	Tunisia	Spain	Slovenia
Area (km^2)	120	860	865	589
Inhabitants (number)	192,000	40,000	157,500	52,000
European Union member state	Yes	No	Yes	Yes
Mean annual temperature (°C) *	19	18.5	14	12.1
Mean annual precipitation (mm) *	320 (downstream) to 670 (upstream)	350 to 600	748	1500 (downstream) to 2000 (upstream)
Dominant land uses	Forest (42%), agriculture (31%), urban (27%)	Forest (20%), agriculture (75%)	Forest (81%), agriculture (10%)	Forest (61%), agriculture (33%)
Dominant water uses	Agriculture (90%), urban (10%)	Agriculture (60%); urban (18%); other (22%)	Urban (39%), industry (35%), agriculture (26%)	Urban (43%), industry (34%), agriculture (20%)

Note: * Reference period: 1981–2010 for Pedieos, Rmel and Vipava; 1984–2008 for Tordera.

2.2. Stakeholder Participation

Stakeholders played a central role in the approach to identify and evaluate management options for each of the four river basins. To involve them, we built on the Stakeholder Integrated Research (STIR) approach [32], which was developed as a structured approach for stakeholder engagement in climate change adaptation. The STIR approach consists of a number of steps, including stakeholder identification and selection, and engages them in a carefully designed and professionally facilitated process, building on scientific methods. While the STIR approach provides a general framework for stakeholder participation, the approach does not prescribe individual methods to be used in all these steps. We identified and applied specific methods for each step in the STIR approach as shown in Table 2.

Table 2. Steps in the approach to involve society in the formulation and evaluation of river basin management options.

Number	Step	Method(s)
1	Identify who is affected by or can affect the transition towards a more sustainable, resilient and adaptive river basin management	Stakeholder identification
2	Elicit expectations with regards to water management for the future	Workshops, interviews, narratives
3	Develop a model for the river basin to portray the complexity of the river basin information	Fuzzy Cognitive Mapping
4	Formulate management options to overcome the challenges	Workshops, interviews
5	Assess the impacts of the options on the river basin through the model	Impact assessment, Fuzzy Cognitive Map application
6	Evaluate the options to identify which options have desirable impacts on the river basin	Combination of Fuzzy Cognitive Map application and Multi-criteria analysis, workshops

We identified stakeholders as any group or individual who is affected by or can affect the preparation of water adaptation options in each of the four case study river basins (adapted from [33]). We identified stakeholders for each river basin by following the Criteria–Quota–Individuals method [32] to ensure diversity and representativeness in the group of workshop participants. In practice, stakeholder groups were identified, starting from broad categories (academia, civil society, media, environment, business, policy) and gradually refining to sectors (e.g., water, energy, textile, tourism) relevant for each of the river basins. Subsequently, we identified individuals belonging to these categories and sectors to create a pool of candidate participants to the stakeholder workshops and consultations. Next, multiple criteria were stated together with quota to guide the selection of participants to be invited for a stakeholder workshop, out of the pool of candidate participants. As an example, gender would be a criterion and the quotum would be 30%, implying that the aim would be to achieve a participant group composition with at least 30% of either gender. In reality, it was not always possible to achieve the pre-defined group composition due to late cancellations or replacements of individuals.

To integrate these stakeholders in the process, we invited them to two major participatory workshops in each river basin, complemented with additional consultations or events to ensure their engagement throughout the process (Table 3). All workshops and consultations were held in the local language (i.e., Greek, Arabic, Catalan and Slovenian). The interactions took place at key stages of the process (as outlined in Sections 2.3–2.5) to ensure the provision of the required information for each step in our approach.

Table 3. Type of stakeholder interactions and number of stakeholders involved in the Pedieos, Rmel, Tordera and Vipava river basins.

Type of Interaction	Pedieos	Rmel	Tordera	Vipava
Stakeholder workshop I (May–June 2014)	20	30	24	32
Stakeholder interviews (September–November 2014)	10	10	11	14
Stakeholder consultation I (December 2014–March 2015)	12	42	22	19
Stakeholder workshop II (May–June 2015)	19	18	16	12
Stakeholder consultation II (October 2015)	-	30	15	16

2.3. Eliciting Expectations

To identify the issues to be tackled in each river basin, we elicited stakeholders' expectations for river basin management during Stakeholder workshop I. Stakeholders that could not participate in the workshops were interviewed. During these workshops and interviews, we presented and discussed the results of previous (quantitative) studies on the potential future impacts of climate change and other relevant factors (e.g., population development, land use change, etc.) on their river basins. In a next step, we asked participants "From your perspective, what are the biggest challenges in the medium-long term for this river basin?" and "If you are allowed to dream, and looking from your perspective, what should water management have achieved by 2030, in this river basin?" Workshop participants addressed these questions during group discussions and we captured their responses by taking notes and photographs of the post-its they filled-in and placed on flip-charts during the discussions. The interviewed stakeholders responded to the same set of questions and their answers were captured by taking notes.

All the information obtained during the workshops and interviews was organized and synthesized by the researchers into narratives for each basin. These narratives described stakeholders' beliefs and expectations for management of each river basin along a common storyline. Each narrative consisted of a text and a graphic. The text described the context, the status and the challenges of water management in the river basins verbally. The graphic consisted of a Fuzzy Cognitive Map (FCM) [34–38]. A FCM is a graphical representation of the dynamics in a system—a river basin in this case—based on the understanding of individuals and can include local and expert knowledge. The components (factors) are represented as boxes and relationships as arrows. The arrows reflect the sign and strength of the relationships between the factors. FCMs can be converted into simple mathematical models to assess the impact of management options on river basins.

We constructed FCMs using Mental Modeler (http://www.mentalmodeler.org/), based on statements provided by the participants in the stakeholder workshops and interviews. Factors in the FCMs could be challenges, drivers, or other aspects that describe the river basin system. Challenges represented issues that require attention in the years to come, as indicated by stakeholders in their responses to the abovementioned questions. Next, we identified drivers, which are factors that exert influence on the system, but are not affected by other factors in the system. We systematically included water quality and water quantity among the challenges in each basin, as our study intended to contribute to the development of adaptation plans for each river basin, but we did not prescribe any other factors. After identifying all relevant factors, we connected these factors with arrows and qualified the relationships as being positive or negative. A positive relationship indicates a positive causality, i.e., a factor that receives a positive arrow changes in the same direction as the factor sending the arrow, while a negative arrow indicates a negative causality. Finally, we assigned strengths to these relationships. To facilitate interaction with stakeholders, relationships were expressed in seven classes: strong (+++ or ——), medium (++ or —-), weak (+ or –) or no relationship.

On the basis of the first versions of the FCMs, we consulted the stakeholders in the Rmel, Tordera and Vipava river basins and expert stakeholders and researchers in the Pedieos river basin (stakeholder consultation I; Table 3). This consultation was done in the form of interviews in the Vipava river basin and in a workshop setting in the three other basins. Stakeholders commented on the FCMs and suggested factors and relationships to be added, removed or modified. After the consultations in each of the four river basins, we refined the FCMs [39]. These refinement steps resulted in a final version of a FCM, as well as the narrative, for each basin, which we presented to stakeholders in Stakeholder workshop II.

2.4. Formulating Management Options

To address the challenges specified by the participants of Stakeholder workshop I and the subsequently interviewed stakeholders, they also were asked to respond to the question: "What options do you see to help achieve that desired state by 2030?" Suggestions made by stakeholders were formulated as options. Each option was characterized using a set of pre-defined descriptors (Table S1 in the Supplementary Materials). Using this characterization, we checked for gaps and redundancies in the identified options, such that each challenge was addressed by multiple options and that options represented different types of solutions (e.g., options addressing water demand and options addressing water supply). After these checks, we prepared a first list of synthesized options and discussed it with participants of Stakeholder workshop II. In this workshop, participants discussed the descriptions of the options. In several cases, they asked for refining, improving or correcting the formulation of the options. These comments were recorded and used to develop a second version of the options list. This revised list was presented and discussed during stakeholder consultation II. This iterative approach resulted in a final set of options for each basin.

2.5. Evaluating Management Options

2.5.1. Impact Assessment

We used the FCMs to assess how the management options would affect each river basin. To do this, the FCMs were converted to mathematical models [36,37] in Excel (Microsoft Corporation, 2016, Redmond, WA, USA). The models for Rmel, Tordera and Vipava were implemented as linear models. We assigned an initial value of 1 to drivers that were expected to increase in the future (e.g., temperature), an initial value of -1 to drivers that were expected to decrease in the future (e.g., precipitation) and an initial value of 0 to all other factors (i.e., non drivers) in the map. Whether a driver was expected to increase or decrease was determined based on the literature. The strength of the relationships between factors was converted to semi-quantitative values; we assigned the values 0.3, 0.6 and 0.9 to indicate weak, medium, and strong relationships, respectively. By iteratively multiplying the initial values of all factors with the strength of the relationships, we investigated how the change in drivers would affect the dynamics in each basin. The models converged generally within 30 iterations. For Pedieos, a non-linear model was developed; a sigmoid (logistic) function (see e.g., [40]) was used to normalize all factors before each multiplication. This was done to prevent oscillations caused by the multiplication of negative relations with negative values and resulted in a physically expected behavior of the map. A starting value of 0.659 was taken for the drivers and 0.5 for all other factors (these values are the transformation of 1 and 0, respectively, with the sigmoid function). The values of all factors stabilized within eight iterations.

For all basins, we assessed the impacts of the options by (i) changing existing relationships between factors; (ii) introducing new relationships; (iii) introducing new factors and relationships, or by a combination of these three possibilities. The decision on how to implement an option was based on the description of each option separately. For example, an option suggesting the reconstruction of an existing irrigation system was introduced by modifying arrows already included in a FCM, while an option suggesting the construction of a new irrigation system was introduced by adding a new factor and arrow. To avoid the loss of relationships in case of reduced intensity of "weak" relationships (i.e., one + or one −) we added a "very weak" category (+0.1 for positive relationships and −0.1 for negative relationships). By comparing the new equilibrium from the modified model for each option with the baseline model, we were able to assess the impacts of all options for each basin separately.

2.5.2. Multi-Criteria Analysis

Following the impact assessment, we conducted a multi-criteria analysis to be able to compare and prioritize the identified options, based on their characteristics and impacts on the basin. We prepared a list of criteria composed of the set of descriptors that characterize the options (e.g., cost, efficiency, feasibility, acceptability), as well as the factors from the FCMs (excluding drivers) as potential criteria to be considered in the analysis. From this list, the participants of Stakeholder workshop II selected the criteria that should be considered in the evaluation of the options. They also indicated what values of each criterion would represent the most and least preferred outcome. Finally, participants assigned individually a weight to each criterion on an ascending scale of 1 to 10, depending on their preferences. To evaluate the management options we combined (i) the scores and weights of the criteria given by the stakeholders; (ii) the characterization of the management options and (iii) the normalized (based on the minimum and maximum values of the data range for each factor over all options) outcomes of the impact assessment. We averaged the evaluation of the management options over all workshop participants and presented the outcome of the multi-criteria analysis to the stakeholders at the end of Stakeholder workshop II. Taking into account their feedback, we made corrections to the formulation of some of the management options. Final versions of the options were presented to and discussed with stakeholders in Stakeholder consultation II.

2.6. Evaluating the Approach

To evaluate our approach, most participants of Stakeholder workshops I and II—with the exception of a few that left before the end of the workshop—completed an evaluation questionnaire. The questionnaire included questions including: (1) do you believe that basin stakeholders have the necessary knowledge and the skills to influence local policies in issues regarding climate change and adaptation; (2) do you consider the involvement of stakeholders in the process of developing climate change adaptation plans useful; (3) are you satisfied with how the workshops included your opinions and views; and (4) how do you rate the workshops in general?

3. Results

3.1. Challenges and Options for River Basin Management

Stakeholders highlighted three to five challenges in each of the four river basin. For a complete description of these challenges, we refer to [41–44]. These challenges included water quantity and water quality in all four river basins. Flooding-related challenges were identified in both the Pedieos and Vipava river basins, while the status of forests represented challenges in Rmel and Tordera. Awareness of civil society and Integrated Water Management were specific challenges for the Rmel and Tordera river basins, resp. Multiple factors affected these challenges and such factors included climate variables, population development, but also various land use sectors (Figure 1, Figures S1–S4 and Tables S2–S9 of the Supplementary Materials).

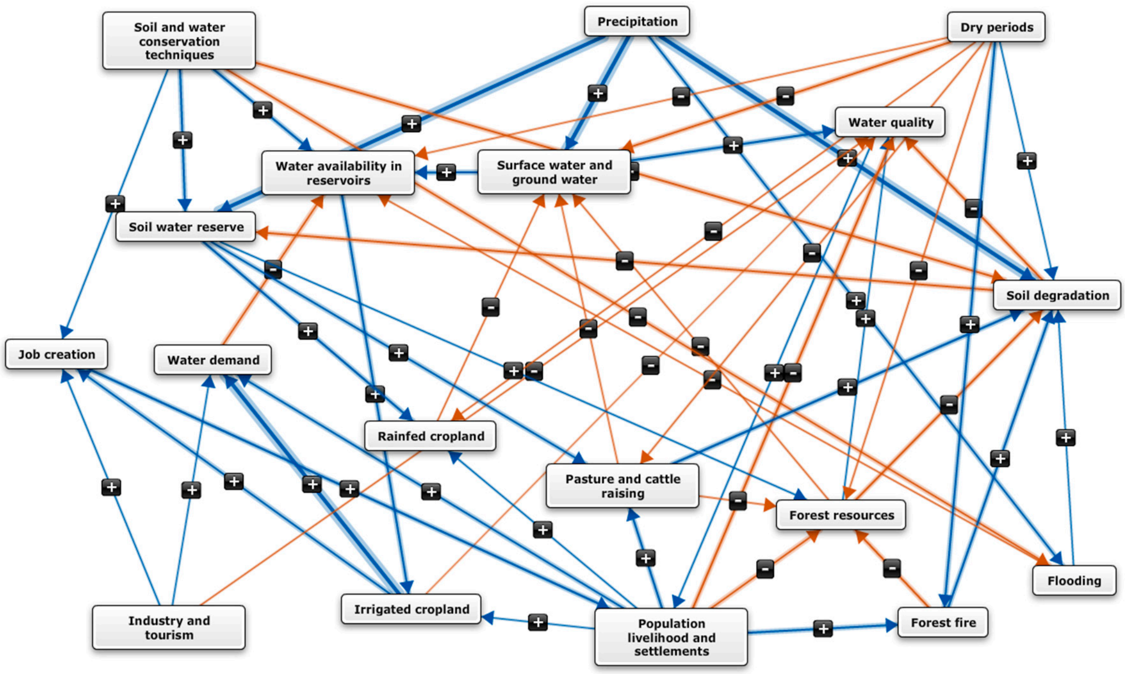

Figure 1. Fuzzy cognitive map developed for the Rmel river basin. Blue lines indicate positive relationships and red lines indicate negative relationships. Line thickness indicates to the strength of the relationships (e.g., a thick line corresponds to a strong relationship).

Agriculture and forestry were included in all four FCMs as land use sectors influencing the river basins' dynamics. In the Pedieos, Rmel and Vipava river basins, a separation was made between rainfed crop production and irrigated crop production. In the Tordera river basin, irrigation was also considered, but embedded into different land exploitation regimes: extensive and intensive agriculture. In the Pedieos and Rmel basins, livestock was considered as a third agricultural land use sector. In the Pedieos river basin, irrigated agriculture was considered to have a negative effect on water quantity and quality, whereas rain-fed agriculture had no impact on water resources. In the other three basins, agriculture negatively affected water quantity and water quality. In all four maps, forests affected water availability and the relationship was considered positive in three out of the four basins. Stakeholders in the Rmel river basin considered that forests affect water availability negatively, because trees consume water from aquifers. In the case of the Pedieos, Rmel, and Vipava basins, forests positively affect water quality by protecting soil from degradation and minimizing soil erosion on site, and through trapping or filtering other water pollutants. In the Tordera river basin, the relation between water quality and forests was considered indirectly, i.e., the relationship was included through linkages with other factors in the map.

A total of 102 management options were identified and formulated to address the challenges in the Pedieos (30 options), Rmel (19 options), Tordera (33 options), and Vipava (20 options) river basins. The definition and evaluation of all these options are documented in detail in [41–44]. Here we focus on the three highest-ranked options for each basin. In Figure 2, the outcomes of the impact assessment with the FCMs and the characterization of management options are shown as heatmaps. The results of the impact assessment indicate that management options can improve the overall dynamics in each river basin, compared to their baseline conditions (i.e., a situation where no management options are assumed). For example, the highest-ranked option for Tordera was the option Adaptive Forest Management, which aimed to foster pilot cases for specific adaptive forest management agreements between forest landowners and the local administration. By reducing uncontrolled biomass accumulation, stakeholders considered this option could help to reduce forest evapotranspiration and wildfire risk, as well as improving forest health. The impact assessment with the FCM supported this assertion and also indicated this option could have positive impacts on biodiversity and would increase water quantity in rivers and aquifers. Results of the impact assessment for this option, as well as other options in other basins, indicate that due to feedbacks in the river basin systems not all options have a positive impact on all factors. For example, improved water quantity in the Tordera river basin was considered to stimulate water uses and this was considered an undesirable development according to the outcomes of the multi-criteria analysis. In fact, none of the 102 options that were proposed and analyzed were fully in agreement with the preferences stated by workshop participants with regards to the characteristics and impacts of the options. Moreover, the results suggest that the preference for particular options is to a larger extent determined by their characteristics, rather than by their impacts on the river basin systems.

3.2. Stakeholder Evaluation of the Process

Results of the evaluations carried out at the end of Stakeholder workshops I and II are shown in Figure 3. Across all basins and workshops, 83% of the participants indicated that stakeholders have (to some extent) the necessary knowledge and the skills to influence local policies on issues regarding climate change and adaptation (Figure 3A). Only 12% of the respondents answered no to the question whether stakeholders would be able to influence local policies on issues regarding climate change and adaptation, indicating some scepticism towards the uptake of their contribution in possible decision-making processes. Yet, the majority of the respondents indicated they considered their involvement in the process very useful (45%) or somewhat useful (50%) and no respondent considered participation not useful (Figure 3B). This outcome reflects the endorsement given by the stakeholders to the participatory approach, which is a condition for successful stakeholder engagement. With regards to our approach, 68% of the respondents were highly satisfied, 24% were medium satisfied and 3% were not satisfied with the way the workshops allowed them to express their perspectives and the extent to which their arguments were taken into account. A similar pattern in responses can be seen for the response on the evaluation of the workshop (irrespective of their rating of the facilitators, content supporters, reporters, venue, etc.). In general, the participants positively evaluated the workshops; 87% of the respondents rated the workshops as good or very good, sometimes even going up to 100% (second workshops in the Rmel and Tordera basins). For none of the workshops did participants rate the workshop as very bad and only one participant of the first workshop in Tordera gave a bad rating (Figure 3D).

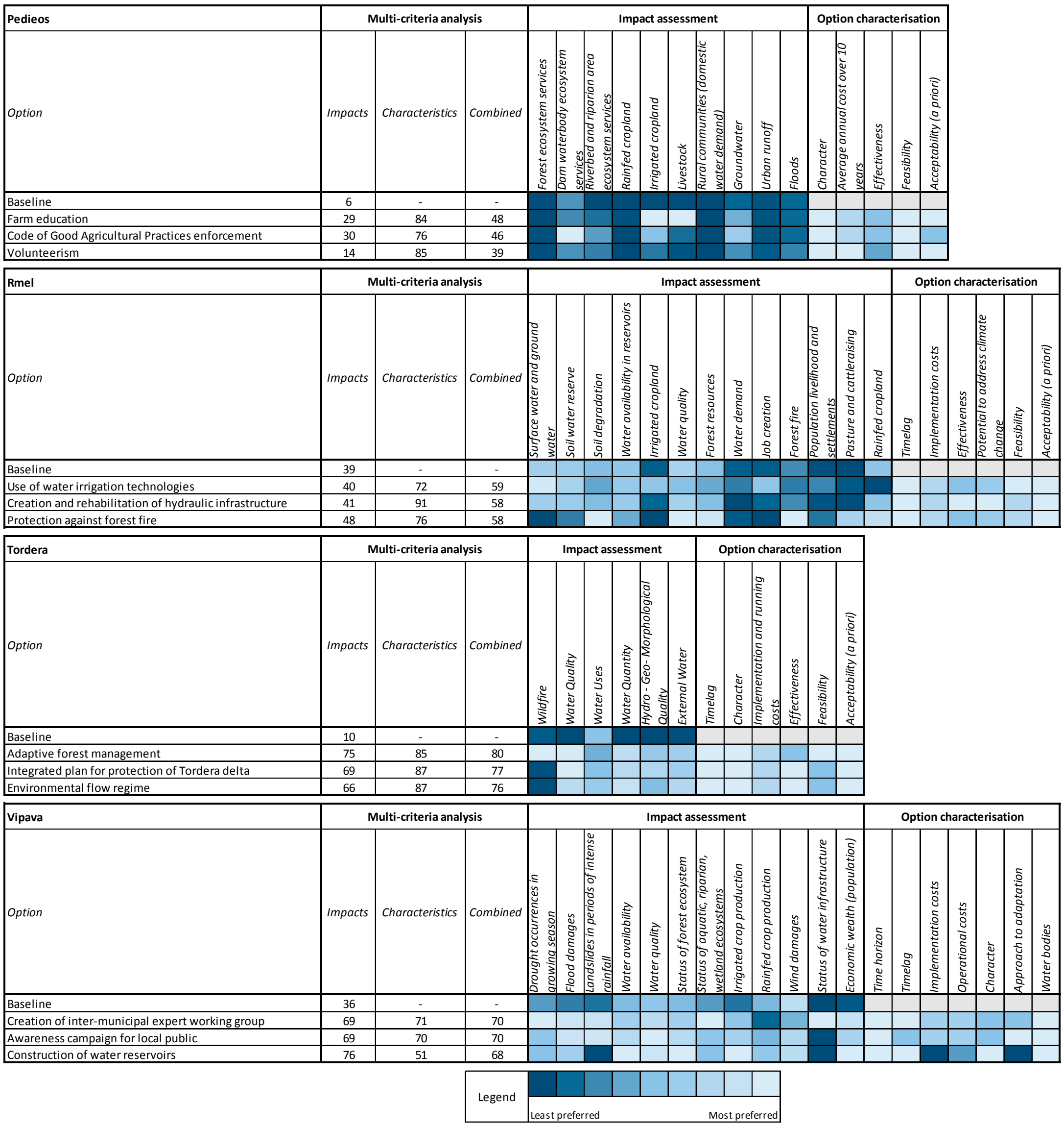

Figure 2. Illustration of the results obtained for the top three management options in the Pedieos, Rmel, Tordera and Vipava river basins. Results are shown as heatmaps in which the impacts and characterization of management options are displayed, which served as input to the multi-criteria analysis.

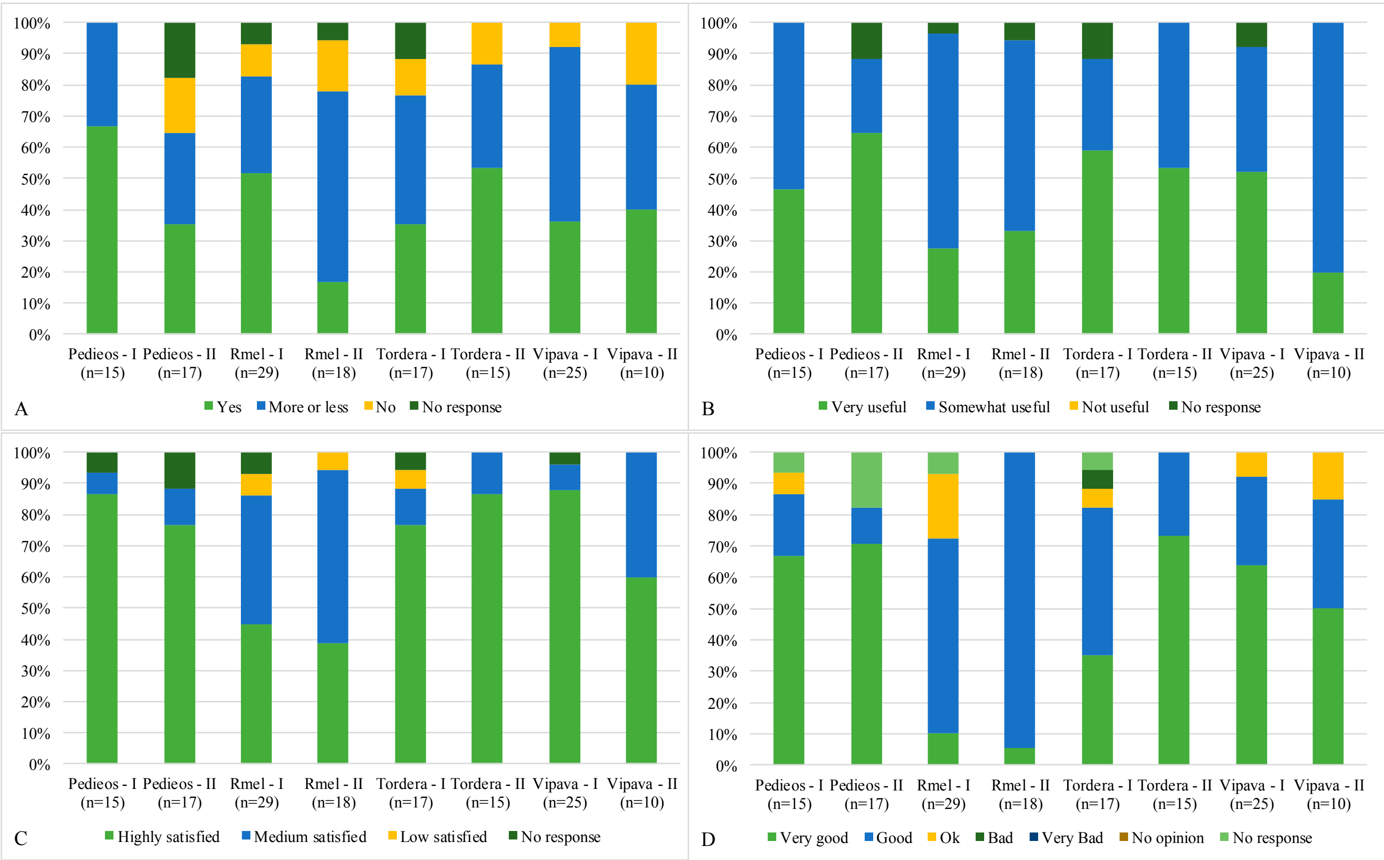

Figure 3. Response to evaluation questions: (**A**) Do you believe that basin stakeholders have the necessary knowledge and the skills to influence local policies in issues regarding climate change and adaptation?; (**B**) Do you think that your involvement in the process of developing climate change adaptation plans is useful?; (**C**) Are you satisfied how this workshop included your opinions and views?; and (**D**) How do you rate the workshop in general? Responses are shown per basin for Stakeholder workshops I and II separately.

4. Discussion

To plan the adaptation of river basin management to future climate conditions, we presented a bottom-up approach to ensure that stakeholders from local societies can play an active role and become engaged in selecting suitable options to manage river basins. Our approach is a variant of the STIR approach [32] and we elaborated this approach by focusing on methods to capture the stakeholders' knowledge and understanding of a river basin, as well as their preferences for management options to address issues at hand. Specifically, we adapted the STIR approach to the context in four Mediterranean river basins and applied it to guide the overall participatory process. As an innovation, we applied this approach by using and linking a participatory modelling method to assess impacts of management options with a multi-criteria analysis. The outcomes of the analyses contributed to the development of four river basin adaptation plans (see [41–44]).

FCMs have been applied in previous water management studies to gain a shared understanding of the dynamics of their study object or to assess impacts of (few) management options [21,45,46], but it has, to our knowledge, not been combined before with a multi-criteria analysis. The combination of these methods, however, was a valuable step to evaluate the impacts of 102 options in total, taking into account the stakeholder preferences in the evaluation of the options. Combining these two methods revealed that while the four river basins faced similar challenges, stakeholders in these basins had different preferences to address these challenges. Stakeholders in the Pedieos and Vipava basins generally preferred options that target or involve society through awareness campaigns or education and for options to improve the knowledge basis of water management through improved monitoring or hydrological studies. Stakeholders in the Tordera basin preferred mostly green options that addressed important ecosystems in the basin (i.e., forests, water, wetlands) and soft approaches to better prevent over-exploitation of water resources. The most preferred option in this forested basin targeted adaptive forest management, as stakeholders considered forest management as a key issue to address climate change impacts. Finding optimal integrated forest and water management interventions [47] are needed to benefit both forest and water ecosystems. In general, the suggested water management options for the Pedieos, Tordera and Vipava could be characterized by requiring minor or moderate investment or operational costs and give limited space for potential conflicts. Strikingly, technological solutions, such as irrigation, were mentioned by stakeholders but were not amongst the most preferred options in these three basins. Giannakis et al. [48] suggested that one reason for the limited uptake of irrigation could be related to the aging and less trained farm population, the small farm size, the low level of farm investments and the low water price elasticities. Increased support for farm training schemes, including issues such as agro-ecological innovation, water conservation and climate change mitigation and adaptation, could improve the knowledge and skills of farmers and foster the adoption of new technologies [49]. Stakeholders in the Rmel basin had different preferences for water management options as compared to the other three basins, which may be explained by different socio-economic conditions. Important options were those that improved or developed water infrastructures or options that aim to generate income and jobs. Altogether, these results indicate that while river basins can have similar challenges, (preferred) solutions to these challenges may be different.

Our approach provided the tools to understand the dynamics of a river basin and to evaluate identified management options. For example, some stakeholders in the first workshop proposed the demolition of the dam in the Pedieos river basin as an adaptation option. The creation and application of the FCM brought a more general understanding about the potential effects of this option, such as flooding in the downstream urban areas. The FCM application also showed that another proposed option (dynamic dam management) could maintain the ecosystems services of the dam reservoir, release surface water for biodiversity downstream of the dam, and improve groundwater recharge of the alluvial river aquifer downstream. In general, our approach provided a neutral and objective framework to guide the stakeholder discussions. Stakeholders actively participated and highly appreciated the approach and their involvement, as demonstrated by the positive evaluations of the events.

We elaborated and tested our approach to identify management options for four river basins across the Mediterranean. To facilitate the application of our approach in other settings, we here document lessons learned during the process. First, through a specified stakeholder identification procedure [32], we attempted to include a broad range of views on water management in each of these river basins. Obviously, we could only include views and preferences of the stakeholders that participated in the different workshops and consultations, although an effort was made in the Pedieos river basin to involve also the general public [50]. The incorporation of only the perceptions and preferences of stakeholders that participated in the process may have affected the outcomes of the FCMs and multi-criteria analysis. To avoid the exclusion of important views and perceptions, we discussed all analyses with stakeholders in multiple events. Each of these events included stakeholders new to the process and they generally did not disagree when we presented results from previous workshops. The inclusion of new stakeholders during the process, in addition to stakeholders participating in all events, helped to verify the results obtained throughout the process.

Second, a careful balance is needed between providing stakeholders with relevant information and directing the workshops to particular outcomes. We tried to avoid introducing bias by carefully planning each stakeholder workshop through a clear process design and by defining the roles of scientists (focusing on the scientific methodology) and facilitators (focusing on the participatory approach) that were guiding the process. Yet, some steering of the process is unavoidable. For example, participants of Stakeholder workshop I were informed about the potential impacts of global change, including climate change, based on the existing scientific knowledge. Providing such information could have influenced the specification of the challenges in each basin. Furthermore, stakeholders provided many suggestions for water management options and researchers processed these suggestions and prepared a list of synthesized options. This processing may have influenced the formulation of the options in each basin. However, in subsequent events, stakeholders new to the process did not question the challenges or the suggested options. Hence, we believe that the information provided and the processing of information did not influence the identification of challenges to a considerable extent.

Third, the outcomes of our analyses of management options are largely based on the FCMs. We constructed the FCMs on the basis of statements by stakeholders expressed during Stakeholder workshop I and the subsequent interviews, and then discussed the FCMs during workshops and interviews with (expert) stakeholders who could propose modifications. FCMs can, however, be constructed with different levels of stakeholder involvement, ranging from desk research [37], interviews [21] to workshops [38,40,51]. While we did not develop the FCMs in a workshop setting, we believe that such a setting could enhance the involvement of the stakeholders and enable them to better understand the role of the maps in our analyses. Developing FCMs is possible within a one- to two-day workshop [51], but in our experience a refinement of the map would be needed before its use as a tool for assessing impacts of management options.

Altogether, our approach allows identifying locally-relevant challenges for the management and adaptation of river basins, understanding how these challenges are interrelated and how they could be tackled through river basin management. However, our approach captures uncertainty associated with future changes in climate, land use, population development, etc. only to a limited extent and quantitative methods and approaches are more appropriate to assess the effectiveness of management options in uncertain future conditions [28–30]. A combination of quantitative and qualitative methods could be pursued to better integrate stakeholders in the process for adaptation planning. Quantitative (modeling) methods could help to assess the impact of climate change and other relevant factors on water resources and its adaptive management over a range of climate projections, while locally-relevant adaptation measures could be identified through a participatory process with the relevant stakeholders and experts [52]. This scoping of relevant options would narrow down the total number of options that could be subject to a detailed quantitative analysis in a next step.

Thus, combining qualitative stakeholder-based approaches, such as ours, with more quantitative approaches is a promising avenue to better integrate stakeholders in adaptation planning, while considering uncertain future conditions [25,52].

5. Conclusions

To address sustainable water management and adaptation to global change, we developed an approach to ensure that stakeholders from local societies can play an active role and become engaged in determining appropriate strategies to manage their river basins. While we relied on the STIR approach to guide the overall participatory process, we applied it using state-of-the-art methods, including FCMs and multiple criteria analysis, to capture the stakeholders' knowledge and understanding of a river basin and to evaluate their preferences for management options to address the basin challenges. Our approach can represent a useful contribution to existing, quantitative approaches for identifying and evaluating management options. Our approach contributes to these existing methodologies by explicitly harnessing stakeholders' knowledge, perceptions and preferences. We tested this approach to identify and evaluate management options in four river basins across the Mediterranean region, covering entirely different contexts from a geographical, environmental, socio-economic, cultural and political perspective. This shows that the approach has the potential to be applied in a wide range of river basins across the Mediterranean area and potentially beyond. The approach was met with enthusiasm by the individuals participating in the process, which provides the basis to enhance the shared understanding of the challenges and solutions for managing river basins.

Supplementary Materials: The following are available online at www.mdpi.com/2073-4441/9/12/958/s1, Table S1: descriptors used to characterize water management options; Figures S2–S5: Fuzzy Cognitive Maps developed for the four river basins; Tables S2–S9: documentation of the factors and relationships in the Fuzzy Cognitive Maps for the four river basins.

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Author Contributions: Pieter Johannes Verkerk and Steven Libbrecht coordinated the design of study. Annelies Broekman, Adriana Bruggeman, Hamed Daly-Hassen, Elias Giannakis, Sihem Jebari, Aleksandra Krivograd Klemenčič, Manca Magjar, Anabel Sánchez, Nataša Smolar-Žvanut and Christos Zoumides contributed to the design of the study, carried out the workshops and analysed results for the four river basins. Inazio Martinez de Arano, Kasper Kok and Elsa Varela assisted in the analysis. Pieter Johannes Verkerk analysed the results across all river basins and wrote the paper, with support from all co-authors.

Conflicts of Interest: The authors declare no conflict of interest.

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2.3. Artículo 2. Participatory Evaluation of Water Management Options for Climate Change Adaptation in River Basins.

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Participatory Evaluation of Water Management Options for Climate Change Adaptation in River Basins

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Abstract: Climate and other human-induced changes will increase water scarcity in world areas such as in the Mediterranean. Adaptation principles need to be urgently incorporated into water management and stakeholder engagement needs to be strengthened at all steps of the management cycle. This study aimed to analyse and compare stakeholder-preferred water management options (WMOs) to face climate change related challenges and to foster adaptation in four Mediterranean river basins. The challenges and WMOs of the four river basins identified by stakeholders were analysed examining to what extent the WMOs tackled the identified challenges. The impact of the WMOs resulting from a participatory modelling method was included in a comparative analysis of the stakeholders' WMOs preferences. The results indicate the participatory approach that was applied allowed local priorities and real-world challenges to be defined with adequate detail as well as the definition of tailored responses. The participatory impact analysis provided an integrated view of the river basin as an interrelated system. The participatory evaluation of the WMOs was able to consider a wide range of elements and was able reflect the combined preferences of the stakeholders. Moreover, it allowed groups of basin actors with highly diverse profiles and concerns to further promote sets of these WMOs as input into decision making processes.

Keywords: adaptation; climate change; stakeholder engagement; participatory evaluation; river basin; water management

1. Introduction

Adequate water availability is of the utmost importance for the sustainability of social and ecological systems [1]. Depending on the region, the impacts of climate change on water resources will have adverse consequences on the availability of water resources to a different extent. The Mediterranean region is expected to be intensively affected by drier conditions [2], an increase in annual average temperature (hence higher evapotranspiration), a decrease in annual rainfall with changes in its seasonal distribution, higher inter-annual rainfall variability, and an increase in the occurrence of extreme events (droughts and floods) [3]. This complex picture is exacerbated if we consider other human-induced changes affecting water resources [4], such as land cover and land use changes, urban sprawl, and changes in population. These conditions are expected to negatively affect water quantity and quality and result in different impacts (e.g., increased concentration of pollutants, increased salinity, groundwater depletion, loss of connectivity), putting e the already precarious water balance in the region more at risk and threatening water availability for multiple uses, including for the environment.

In this context of increased water scarcity and increased rainfall extremes, there is a pressing need to incorporate adaptation principles into water management at all policy and governing levels to guarantee sustainability. Different policies tackling natural resource management at both the European and national levels offer a useful framework to develop concrete adaptation strategies, aiming to meet the threats and challenges imposed by climate and other anthropic-related changes. Thus, regarding water, a set of norms and principles are included in the Water Framework Directive (WFD) [5] and the Floods Directive [6] and are mainstreamed through the implementation of river basin management plans (RBMPs) in subsequent management cycles, including in specific action plans tackling extreme climatic events such as floods and droughts [7]. This policy framework offers an adequate instrument to makes advances in the consideration of climate change-related adaptations in water management [8]; however, success has been limited in previous management cycles [9], and further advances are needed to incorporate the likely impact of climate change and to consider national climate change strategies and to develop coordinated adaptation measures [10]. Furthermore, the main objective of WFD is to protect and enhance aquatic ecosystems, and it is grounded in the promotion of the sustainable use of water in the European member states [11]. This European legislation puts the absolute necessity of achieving sustainability to meet present and future water use needs at the center of water management, as it related to the UN Sustainable Development Goals (SDGs), many of which have targets directly or indirectly related to water [12].

Given the need to tackle tradeoffs and to build compromises between different sectoral vested interests on natural resource use and to preserve common sources, the WFD promotes a holistic approach to protect river basins, including a strong call for engaging stakeholders to participate in the different stages of the planning cycle [13]. Participation feeds the policy design process with updated and relevant information on pressures and impacts, includes social and economic perspectives, and suggests solutions that might rely on wide acceptance from local actors [14]. The importance of stakeholder engagement when considering adaptation to climate change more globally claims similar collective contributions to face the huge and urgent challenges ahead [15,16]. This engagement increases the quality of decision-making processes [17,18] by combining the different skills, theoretical backgrounds, and experiences required to deliver better answers in a context characterized by a high degree of uncertainty regarding the issues at stake [19].

Participation calls for the ability to integrate different types of information: science-based knowledge, experience-based knowledge, socio-economic context information, amongst others. Different methods and tools are available to promote the involvement of stakeholders in the analysis of climate change impacts, in the co-design solutions as well as in the monitoring and evaluation of the implementation process of these solutions. Over the last few years, different participatory modelling methodologies [20,21], such as fuzzy cognitive mapping or agent-based modelling, have been applied in natural resource management to incorporate knowledge of different natural environments together and thus achieve a more complete understanding of the functioning and interdependencies of complex systems [22,23].

In this study, we show how a participatory approach can be implemented in real cases. In particular, we highlight how this technique can be used to prepare river basin management plans that take climate change as well as socioeconomic challenges into account. The novelty of the study lies in the practical experience and the lessons learnt from engaging stakeholders in different basins facing climate change issues, following a single approach in all cases. It shows the practicability of the methodology and its usefulness in different contexts, with a diverse composition of the stakeholders involved.

Complementing and building on the methodological description of the participatory approach developed in Verkerk et al. [24], the overall aim of our study was to further analyse and compare stakeholder-preferred water management options (WMOs) to face climate change-related challenges and to foster adaptation in four river basins in the Mediterranean: Pedieos in Cyprus, Tordera in Spain, Rmel in Tunisia, and Vipava in Slovenia. These basins represent a wide range of social and environmental characteristics in the Mediterranean region, with all of them having water resources that are vulnerable to climate change impacts; thus, the study could be relevant for any vulnerable river basin in the region and beyond. We have undertaken this study in order to answer various research questions: Are the challenges and WMOs similar or different between river basins? Do WMOs adequately respond to all of the challenges detected? Which WMOs are preferred by stakeholders in each river basin? To do this, the objectives of the study are to (i) define and compare the challenges and WMOs of the four river basins, (ii) analyse how the identified WMOs tackle the challenges of each river basin, (iii) analyse the impact of WMOs on the river basin through a participatory modelling method, and (iv) evaluate the stakeholder's preferences regarding WMOs through a multi-criteria analysis. Our research hypothesis is that a fully participatory approach, similar to the one that we present, allows for the adequate incorporation of water management adaptation strategies and that its application is valid in diverse contexts.

2. Materials and Methods

2.1. Case Study River Basins: Characteristics and Stakeholders

The participatory evaluation of the WMOs was conducted in four river basins across the Mediterranean: the Vipava river basin (Slovenia), the Tordera river basin (Spain), Rmel river basin (Tunisia), and the Pedieos river basin (Cyprus), which are located in the four cardinal points of the Mediterranean (Figure 1).

Figure 1. Location of the four case study river basins.

The four case study river basins (CSRB) are characterised by contrasting climates, natural ecosystems, land uses, and socio-economic aspects (Table 1), which represent part of the diversity in the Mediterranean.

Table 1. Characteristics of the four case study river basins.

CSRB (Country)	Pedieos (Cyprus)	Rmel (Tunisia)	Tordera (Spain)	Vipava (Slovenia)
Area (km^2)	120 km^2	870 km^2	865 km^2	589 km^2
Inhabitants	192,000	135,500	157,500	52,000
Mean annual temperature (°C) [1]	19.0	18.5	14.0	12.1
Mean annual precipitation (mm) [1]	320 to 670	350 to 600	650 to 1050	1500 to 2000
Main land uses	Forest (23%) Agriculture (65%) Urban (12%)	Forest (24%), Agriculture (75%), Urban (1%)	Forest (81%), Agriculture (10%) Urban (9%)	Forest (61%), Agriculture (33%) Urban (5%)
Key issues	High pressure on rivers by agriculture, industry, settlements, and river regulation.	High pressure on water resources by multiple users	Flooding, groundwater over-use, water quality	Limited resources and increasing tensions

[1] reference period: 1984 to 2008 for Tordera and 1981 to 2010 for Rmel, Pedieos, and Vipava. Range shown stands for elevation.

In each CSRB, dialogue and collaboration with local communities was promoted through an iterative process of mutual learning, participatory techniques, and a bottom-up approach integrated in a science-based methodology; a detailed description of this approach is described in Verkerk et al. [24]. The objective was to ensure that stakeholders could play an active role in determining appropriate strategies for the management of the river basins and could contribute to the key steps of the formulation and evaluation of the WMOs to meet climate change-related challenges [25–28]. Different types of interaction with stakeholders were performed during the co-design process, such as interviews, consultations, and workshops. Stakeholder involvement, from identification to selection and engagement, was structured following the Stakeholder Integrated Research (STIR) Approach [29].

The stakeholders were identified and selected following the Criteria, Quota, and Individuals method (CQI) of the STIR Approach, which aims to create a diverse and balanced group of participating stakeholders [29]. At first, each CSRB had to build its map of actors to be engaged in the process by interviewing key stakeholders and by conducting public meetings. The participants represented the main interest groups of the basin, including participants who were involved in activities such as agriculture, forestry, tourism, education, entrepreneurial endeavours, environmental and social associations as well as participants who were public authorities at the municipal and regional levels, researchers, experts, and lay people. Diverse criteria were applied together with the quota to guide the selection of participants (more details in Verkerk et al. [24]). In each basin, the composition of the groups of participants was different in accordance with the main local challenges and conditions. In Vipava, 93 people participated in the co-design process, and agriculture was the main sector represented, and we found high interest from the local administration, even though strong difficulties arose at engaging national level administrations. In Rmel, 130 people participated in the co-design process, and the process engaged a broad variety of actors who were interested and active. Notably, the education sector was strongly engaged, and due to the importance of the water sector in this region, engineers and researchers also actively participated. In Pedieos, 145 people participated in the co-design process, and the group of actors engaged was composed of community leaders, agricultural and environmental researchers, farmers, educators, consultants and officials working with the river basin, and people working in the agriculture and urban planning sectors. In Tordera, 88 people participated in the co-design process, and the group of participants covered different relevant sectors, but given that forests occupy 80% of land, the forestry sector was strongly represented.

2.2. Challenges and Water Management Options in Each Basin

A first series of workshops and interviews with local key stakeholders was held with the aim of presenting the project and to introduce the work. The stakeholders were asked to share interests and concerns regarding the river basin's current and desired state, its social and economic context, and how they the perceived risks and expected impacts of climate change. The results of the workshops were presented in the form of narratives for each river basin. These first conversations allowed the identification of the main challenges to be addressed in each basin, in other words, specific issues that require the development of concrete actions.

In all four river basins, 'water quality' and 'water quantity' were deliberatively included as challenges to ensure that the central elements of current river basin water planning in line with the WFD [5] as well as the basin's key vulnerabilities to climate change were tackled in an integrated manner. Furthermore, in each river basin, other challenges were formulated in accordance with specific issues that were at stake locally. For Vipava, 'water availability during droughts in growing season', and 'flood risk reduction' were highlighted as key challenges. In Rmel, the range of identified challenges also included 'agriculture', 'forestry and biodiversity management', and 'awareness of society' as well as 'human resources and employment'. In Pedieos, 'water quality' and 'water quantity' were tackled separately for groundwater and surface water, and the list of identified challenges also included 'flood risk'. In Tordera, special concerns were raised about the 'health of forests and water ecosystems' as well as the challenge of implementing 'integrated water management principles'.

Aiming to tackle the identified challenges, stakeholders contributed with potential WMOs during a specific workshop in each basin. WMOs are understood as concrete actions to be undertaken to change the pressures on the status of a water basin while taking global changes into account. According to our methodology, these WMOs had to address at least one of the specified challenges, and each challenge had to be tackled by several WMOs [24].

The WMOs that were developed were characterised using a set of 19 pre-defined descriptors (Table S1 in the Supplementary Materials) covering a wide range of elements that can be grouped into four typologies: (1) climate change adaptation potential, described by character, effectiveness, approach to adaptation, nature of the approach, potential to address climate change, feasibility, and acceptability; (2) costs and timing, described by implementation time horizon, expected lifetime, time lag between implementation and effectiveness, implementation costs, and operational costs; (3) features of the targeted basin, described by water status, water bodies, river section, extreme events, and implementation scale; (4) targeted uses, described by the water use sector and land use.

From the total 19 descriptors used, we selected four from the climate change adaptation potential typology to analyse relevant differences and to compare the characteristics of the WMOs defined in each river basin (see Table 2). The character of a WMO describes how to face water needs. The approach used to adapt a WMO describes the technical design of a solution and the means by which it reduces vulnerability to climate change and creates resilience. The feasibility of a WMO describes the degree of eventual obstacles to implementation. The acceptability of a WMO describes if there are any reasons a priori to reject an option.

The list of WMOs and their characteristics were contrasted and agreed upon among the stakeholders in specific participatory events for each of the four river basins. Once the WMOs were defined and characterised, it was possible to analyse to what extent these solutions could contribute to tackling the challenges and to decreasing the pressures on the water basin while taking climate change impacts into account.

Table 2. Classes of each of the selected descriptors for the comparison of water management option (WMOs) characteristics in the four river basins.

Descriptor	Classes	Explanation
Character	Demand	Option targeting the need for water
	Supply	Option targeting the availability of water
	Support	Option targeting improved governance (including awareness raising, monitoring, and stakeholder involvement)
Approach to adaptation [1]	Environmental conservation	Option targeting the recovery of the ecological status
	Green	Ecosystem-based approaches
	Grey	Technological and engineering solutions
	Soft	Managerial, legal, and policy approaches that change human behaviour and styles of governance
Feasibility	No major obstacles	The implementation could be initiated straightaway, e.g., missing information or technical details or no obstacles at all
	Minor obstacles	Some interventions are needed, but the implementation can be planned, e.g., costs and timing, responsibilities, political context
	Serious obstacles	The implementation will not happen until the obstacle is removed, e.g., legal barriers, serious cost or timing mismatches, and administrative hindrances
Acceptability	High	There are no significant reasons a priori for anyone to reject the option
	Low	There are significant reasons a priori for someone to reject the option

[1] From Adaptation in Europe [30].

2.3. *Fuzzy Cognitive Maps*

The stakeholder-based approach undertaken in this study incorporated the use of participatory modelling methodologies, specifically Fuzzy cognitive mapping [31–33], which is representations of a system as perceived by individuals. This methodology was chosen because it can be used to capture knowledge and to facilitate communication between stakeholders from various sectors and backgrounds as well as experts, ensuring that models of the studied system are being constructed in an understandable way [34–36]. Fuzzy Cognitive Maps (FCMs) have been widely used to depict the functioning of natural systems [37–42] and more specifically water resources use and management and climate change related impacts [43,44]. We used FCMs to represent the functioning of the river basins as they had been described by the stakeholders in an initial workshop and later written as narratives. The FCMs incorporated the basic elements of the functioning of the river basins as factors including, when possible, the challenges identified in each basin. Furthermore, climate change (changes in precipitation and temperature) was added into the map as an external driver affecting the system. The relationships between the factors were depicted as arrows with a determinate sign (positive or negative) and strength (strong, medium, and weak).

The maps included a selection of a maximum of 20 main biophysical, social, and economic factors relevant in the basin, which were able to describe the dynamics of the basins and the interlinkages between the factors in qualitative terms. The FCM representation was converted into simple mathematical models and was used to assess the impact of the WMOs on each of the four river basins. An in-depth description of the FCM elaboration and application used in our study is given in Verkerk et al. [24]. Linear models were used for Rmel, Tordera, and Vipava, while a non-linear approach was developed in Pedieos. The FCMs were used as semi-quantitative models to assess how WMOs would affect the dynamics of each river basin.

2.4. *Impact of the Water Management Options on the River Basin*

The next step undertaken was oriented at evaluating the impacts of the WMOs for all basins using the FCMs. The developed WMOs are solutions that act on the river basin system, increasing its adaptation capacity by modifying the interactions between water uses and the water body. There were several possible ways to determine the effect of the WMOs in the map dynamics, such as by (i) modifying the initial relationships between factors, (ii) defining new relationships, (iii) introducing new factors and relationships, or by (iv) combining the above-mentioned possibilities. After implementing each WMO in the map and running the model, a new equilibrium was reached. The impact analysis of each WMO on the river basins was conducted by calculating and comparing the difference between the baseline scenario and the alternative scenario resulting from the implementation of the WMO in the map. Most of the challenges defined for the case studies were included as factors in the FCMs; therefore, the impact of the different WMOs on the challenges that had been initially identified could be assessed. A detailed description of this methodology is described in Verkerk et al. [24].

2.5. Multi-Criteria Analysis

Multi-criteria analysis techniques, which are used to compare and rank alternatives through a set of evaluation criteria, are widely applied in water management [45]. After performing the impact analysis of the WMOs on the basin using the FCM and after taking into their characteristics into consideration, a stakeholder-driven Multi-Criteria Analysis (MCA) was conducted to make it possible to compare WMOs. In each river basin, we presented a list of evaluation criteria, the descriptors that characterized WMOs (Table S2 in the Supplementary Materials), and all of the factors from the FCMs except for drivers (Table S3 in Supplementary Materials) to the stakeholders in specific workshops. The workshop participants were asked to select the criteria that—according to their experience and opinions—needed to be used in the MCA of the WMOs. Then, for each of the selected criteria, the stakeholders indicated the values that represented the most and least preferred outcome for them.

Successively, the stakeholders were invited to develop an individual exercise as way to weigh each criterion based on their preferred importance on a scale 1 to 10. The MCA incorporated all of the stakeholders' answers. The results were calculated as the average of the FCM scores (obtained in the modelling) weighted by the preferences. These results were presented on a scale of 0 to 100, with 0 being the lowest preference possible and being 100 the highest. In order to easily compare the MCA results between the river basins, scores indicating stakeholder preferences for WMOs were structured into preference categories. WMOs scoring below 40 were considered as having low stakeholder preference, scores between 40 and 70 were considered as having medium preference, and scores over 70 were considered as having high preference. A chi-square test was then performed with the categorised data to make comparisons between the MCA results for each river basin and to differentiate the degree of stakeholder preference that the WMOs from the studied river basins had achieved.

During the stakeholder session when the MCA was conducted, a first preliminary averaged outcome of the MCA was presented, and the participants' feedback was incorporated. Moreover, as a result validation procedure, the stakeholders were asked to review the formulation of the WMOs to better include the perspectives of the participants.

3. Results

3.1. Definition and Comparison of Challenges in the Four River Basins

The stakeholders from each river basin identified a variety of challenges, ranging from three in Vipava to six in Rmel (see Table 3). All four river basins included challenges related to 'water quality and quantity' due to the importance of these factors in the state of the water bodies and their management needs. In Pedieos and Vipava, 'flood risk' reduction was considered a key challenge because of the frequency and intensity of flood damage on human activities occurring in those basins. In Rmel, the challenges covered broad aspects such as 'forest and biodiversity management', 'agriculture', and 'awareness of civil society' as well as 'human resources and employment' because the role of resource management was highly stressed in this basin. In the case of Tordera, stakeholders defined 'health of forests and water ecosystems' as well as 'integrated water management' as challenges given that they were very much aware of the importance of preserving ecosystem functionality and the connection between different water bodies.

Table 3. Climate change related challenges per river basin.

	Pedieos	Rmel	Tordera	Vipava
Water quality	√ [1]	√	√	√
Water quantity	√ [1]	√	√	√
Flood risk reduction	√			√
Health of forest and water ecosystems			√	
Forest and biodiversity management		√		
Agriculture		√		
Integrated water management			√	
Awareness of civil society		√		
Human resource and employment		√		

[1] For Pedieos, the water quality and water quantity challenges are differentiated between groundwater and surface water bodies.

3.2. Comparison of Water Management Options Characteristics

As a result of the interactions with stakeholders in all of the river basins, a final list of 102 specific WMOs were defined (Tables S4–S7 in the Supplementary Materials). The descriptors characterising these WMOs allow for their comparison within and among the case study river basins. The analysis of the four chosen descriptors (Table 4) shows the clear differences and diversity of the solutions proposed in the four river basins.

Table 4. Percentage of WMOs per river basin corresponding to each descriptor class for character, approach, feasibility, and acceptability. For some descriptors, more than one class could be chosen per water management option; thus, the total % may exceed 100% (these cases are marked with * in the Table).

WMO Descriptor	Classes	Pedieos	Rmel	Tordera	Vipava
Character	Demand	20	5 *	24 *	10
	Supply	7	32 *	6 *	30
	Support	36	32 *	24 *	30
	Environmental conservation	37	42 *	48 *	30
Approach to adaptation	Green	40 *	11	12	25
	Grey	33 *	63	15	35
	Soft	50 *	26	73	40
Feasibility	No obstacles	27	26	30	10
	Minor obstacles	63	48	55	80
	Major obstacles	10	26	15	10
Acceptability	High	67	42	82	85
	Low	33 [1]	58	18	15

[1] For Pedieos, the water quality and water quantity challenges are differentiated between groundwater and surface water bodies.

(a) Character: Pedieos and Tordera had the highest percentage of water demand-oriented WMOs, while Vipava and Rmel had the highest percentage of water supply-oriented ones. Pedieos had the highest support-oriented percentage, and Tordera the highest with environmental conservation character.
(b) Approach to adaptation: Pedieos had the highest percentage of WMOs adopting a green approach, while Rmel had the highest percentage of WMOs adopting a grey approach. Tordera was, by far, the basic with the most WMOs adopting a soft approach.

(c) Feasibility: Vipava had the lowest percentage of WMOs with no obstacles for their implementation. The least number of WMOs with major obstacles was found in Pedieos and Vipava, while Tordera and Rmel had a higher rate of major obstacles to overcome regarding WMO implementation.
(d) Acceptability: In all of the river basins except Rmel, most of the WMOs were considered to have high acceptability.

3.3. Analysis of How the Water Management Options Tackle the River Basin's Challenges

The WMOs were formulated to face the specific challenges that were detected (Tables S4–S7 in the Supplementary Materials). The way that this was done differed in each river basin:

1. For Pedieos (see Table S6 in the Supplementary Materials), 30 WMOs were identified. A total of ten of then tackled 'flood risk reduction', ten tackled 'quality and quantity of groundwater', and ten tackled 'quality and quantity of surface water' bodies. Although most of the WMOs tackled more than one challenge, each WMO was assigned to the challenge that it addressed the most.
2. In Rmel (see Table S7 in the Supplementary Materials), each of the 19 WMOs that were identified tackled one specific challenge. There were three WMOs that simultaneously tackled 'water quantity' and 'water quality'. There were four WMOs that addressed 'forest and biodiversity management', four that addressed 'agriculture', and three that addressed 'awareness of civil society'.
3. In Tordera (see Table S4 in the Supplementary Materials), most of the 33 WMOs that were identified tackled one specific challenge. There were five that addressed 'water quality', ten that addressed 'water quantity', eleven that addressed the 'health of forest and water ecosystems', and ten that addressed 'integrated water management'.
4. For Vipava (see Table S5 in the Supplementary Materials), from a total of 20 WMOs, six addressed all of the challenges, as they were related to raising awareness, governance, and environmental restoration as a strategy to reduce vulnerability. The other WMOs addressed at least two challenges. There were sixteen WMOs that addressed 'water quantity', ten that addressed 'flood risk reduction', and thirteen that addressed 'water quality'.

3.4. Analysis of the Impact of Water Management Options on the River Basin

We used Fuzzy Cognitive Maps (FCM) to analyse the impact of WMOs on the dynamics of the basins and on the challenges to be addressed (see the maps in Figures S1–S4 in the Supplementary Materials). The changes induced in each challenge by the implementation of each WMO for the Tordera river basin are shown in Figure 2, and those for the other three river basins are shown in Figures S5–S7 in the Supplementary Materials.

1. For the Pedieos river basin (Figure S7 in the Supplementary Materials), the smallest improvements were observed for the 'water quantity and quality of surface water' challenge for all WMOs compared to the baseline, and the highest were observed for 'flood risk reduction'. The 'water quantity and quality of groundwater' challenge had the highest number of WMOs contributing to a positive impact.
2. For the Rmel river basin (Figure S5 in the Supplementary Materials), the impact of the WMOs determined both positive and negative changes in the challenges compared to the baseline situation. The challenge achieving a larger improvement and less negative effects resulting from the WMOs implemented in the map was 'agriculture', followed by 'human resources and employment'. On the other hand, the challenges of 'water quality' and 'forest and biodiversity management' showed the highest negative impact from some of the WMOs considered.
3. In the Tordera river basin (Figure 2), the analysed WMOs had an overall positive impact, improving the state of the challenges compared to the baseline situation. The highest positive impacts were in the 'health of water ecosystems' challenge. It is interesting to note that the case for the 'water quality' challenge, where most of the

best performing WMOs were, were initially designed to tackle the 'health of forests and water ecosystems' challenge.

4. For the Vipava river basin (Figure S6 in the Supplementary Materials), the majority of WMOs had a very limited impact on the basin's challenges compared to the baseline. Few WMOs were able to provide improvement. Several WMOs induced worsening baseline conditions: reducing 'water quality' and 'water quantity' and producing decreases on 'flood risk reduction'.

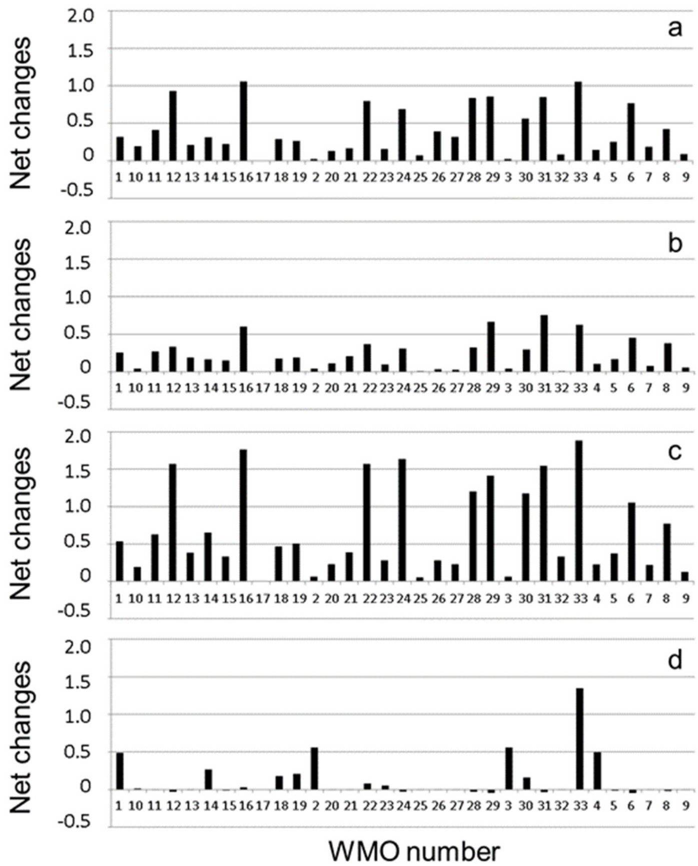

Figure 2. Impact assessment of WMOs on the Tordera river basin challenges included in the Fuzzy Cognitive Map (FCM) as factors: impacts on (**a**) 'water quality', (**b**) 'water quantity', (**c**) 'health of water ecosystems', and (**d**) 'health of forests'. The bars represent net changes from the baseline situation and show how each WMO (1 to 33) affects the river basin dynamics of the FCM model. Positive values correspond to the improvement of the challenge and negative values correspond to deterioration.

3.5. Evaluation of Stakeholder's Preferences Regarding Water Management Options

The resulting MCA scores indicating the stakeholder preferences for WMOs structured into preference categories ('low': below 40, 'medium': between 40 and 70, and 'high': above 70) are shown in Figure 3.

In order to compare the resulting MCA preferences obtained by the WMOs in the four river basins, a chi-square test was performed with the categorized data. The test showed clear differences among the four river basins ($\chi2 = 57.8$ $p < 0.005$); thus, we can say that the set of WMOs developed per river basin was able to meet different degrees of stakeholder preferences. Pedieos had the most cases of low scoring WMOs; in Rmel, all of the WMOs had medium preference scores, while Tordera and Vipava had similar results, with WMOs scoring in all preference categories but with slightly more high preference values. Multi-Criteria Analysis results for each WMO in all four case study river basins are shown in Figure 4. Each WMO is associated with the challenge it tried to address.

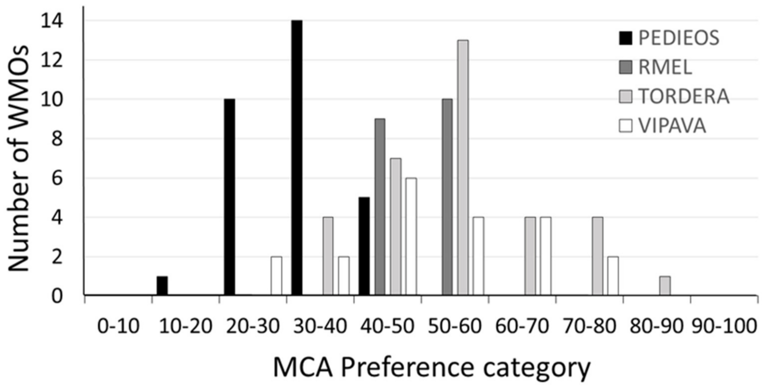

Figure 3. Number of WMOs per preference category taking the characterization and impact assessment criteria of the four river basins into account (classes of 10 units, from 0 to 100 of increased preference).

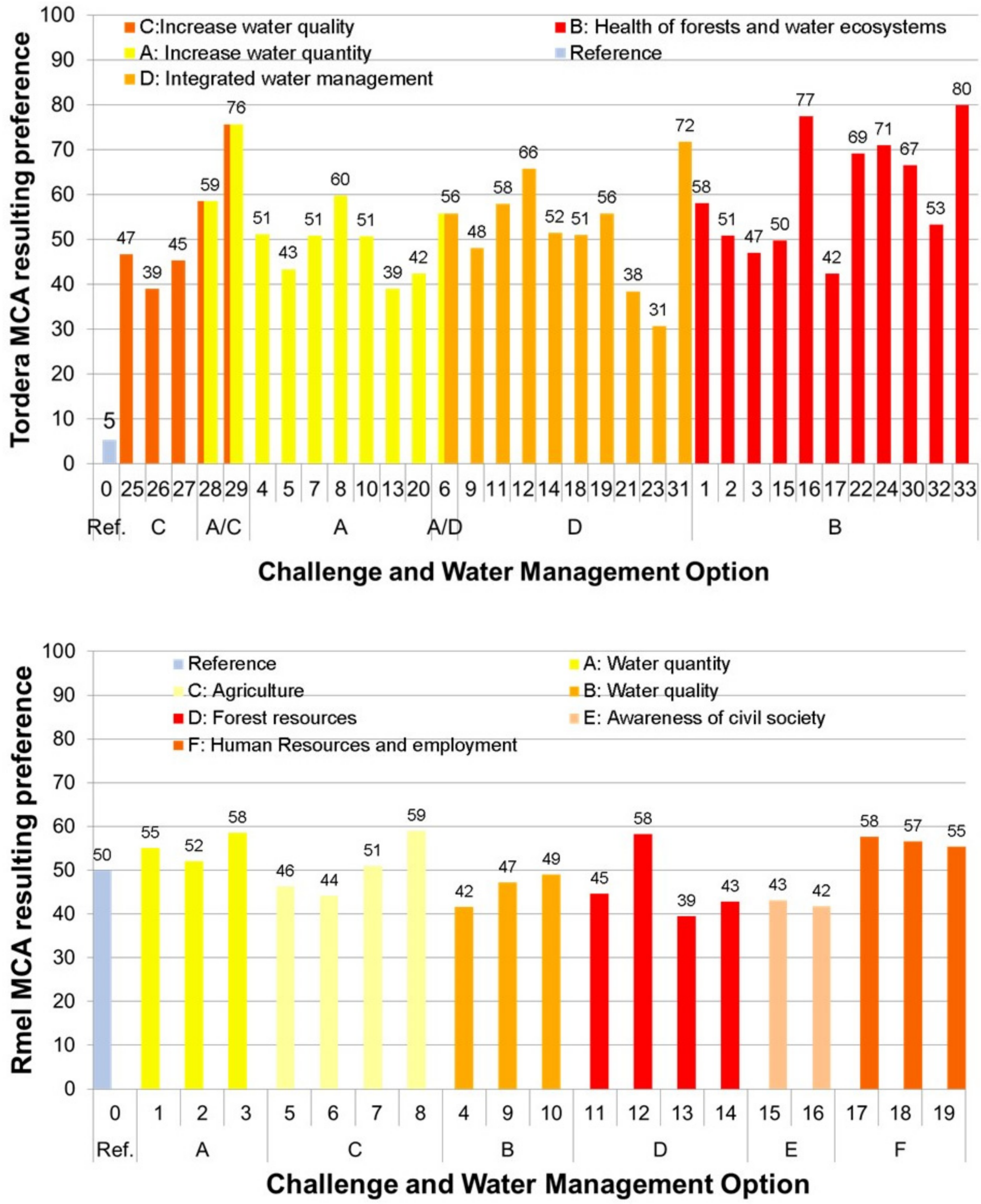

Figure 4. *Cont*.

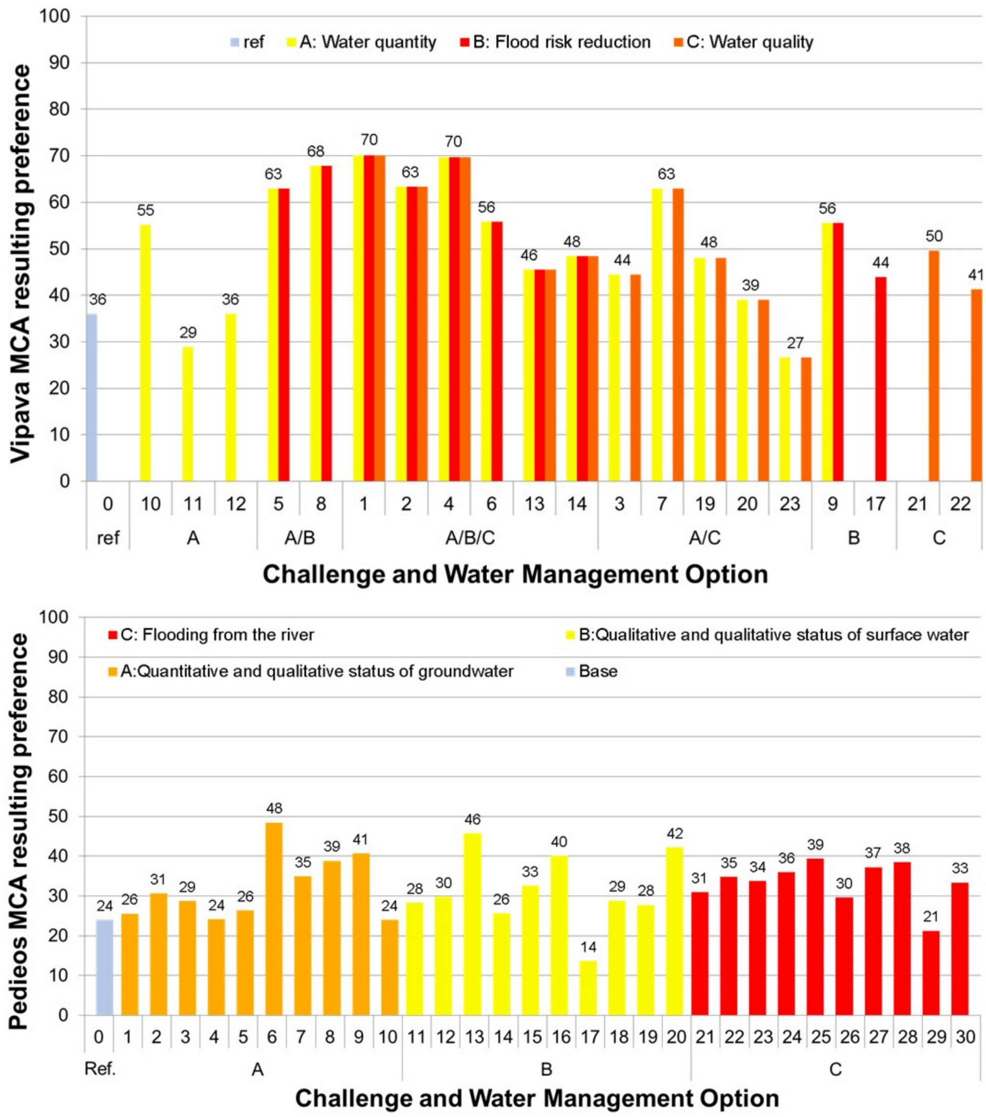

Figure 4. Multi-Criteria Analysis results based on the criteria derived from the impact assessment with the Fuzzy Cognitive Map and the characterization of the WMOs. Numbers on the x-axis refer to the WMOs for each river basin found in Tables S4–S7 in the Supplementary Materials. On the y-axis, preference values range from 0: least preferable to 100: most preferable. Bar colors represent the different challenges the WMOs were designed to tackle, which are also represented by letters in the x-axis.

In the case of the Tordera river basin, there were WMOs representing each preference score that addressed all changes, and there was at least one highly preferred WMO tacking each of the four challenges. For the Rmel river basin, all of the challenges were tackled by WMOs with medium preference scores. WMOs tackling the challenges 'water quality' and 'awareness of civil society' all scored below 50, while all the rest of the challenges were tackled by WMOs scoring slightly above 50. In Pedieos, two out of three challenges were tackled by at least one WMO with medium-ranked preference values. In Vipava, all of the challenges were tackled by at least one highly preferred WMO.

4. Discussion

Different studies identify common patterns regarding the challenges that need to be overcome in order to adapt to the impacts of climate change in the Mediterranean region [46]. Methodologies involving stakeholders, including representatives from the public authorities, allow these challenges to be pinned down specifically at the local level and invite water managers to consider the outcomes of science-based participatory practices that are able to deliver more in-depth assessments of stakeholder perceptions on management priorities. Such practices can mobilise transformative dynamics promoting sustainability across sectors to contribute to meeting SDG targets [47]. In this study, we aimed to analyse and compare the challenges and WMOs of four Mediterranean river basins. The challenges that were identified clearly reflect common stakeholder concerns regarding climate change impacts, human activities, and aspects related to natural ecosystems. The participatory approach that was applied was useful to define local features and key challenges with adequate detail, as expected from multi-institutional and multi-stakeholder frameworks [48]. Noticeable differences were identified between basins. Because of its concrete socio-economical context, Rmel is the only river basin where the stakeholders included some aspects directly linked to perceived societal vulnerability such as 'human resources and employment' and 'awareness of civil society' and economic sector performance such as 'agriculture' as challenges. In Tordera, the 'health of forest and water ecosystems' and 'integrated water management' challenges reveal strong concerns regarding environmental sustainability and the restoration of ecosystems. In this river basin, many stakeholders had intensively been involved in previous participatory processes, such as the ones linked to the WFD, and might have been especially aware of current environmental issues in the area. Pedieos and Vipava are the only river basins that specified 'flood risk' as a challenge because in these basins, flash floods are common.

Adaptation processes are complex [49] and so are the variety of responses that might be promoted to reduce the vulnerability to eventual impacts, triggering the broadening of the scope of conventional river basin assessments, thus motivating policy harmonisation and collaboration between different public authorities. The potential water management options that could contribute to meeting the challenges identified reveal the water management approach and principles of the stakeholders, at the same time revealing the strong interlinkages between territorial management and anthropogenic resource use and climate change-related vulnerability. This is quite clear when analyzing the portfolio of the WMOs that were identified in each of the river basins. For example, in Vipava and Rmel, the highest percentage of WMOs are water-supply oriented. Indeed, in these basins, the agricultural sector was very much involved and motivated to reduce the water supply risks that significantly affect the profitability of agricultural land use [50]. On the other hand, in Tordera, participant consensus on the management principles of the WFD aiming to achieve good ecological status induced the design of soft options with an environmental conservation character. During the participatory meetings, with the exception of those in Rmel, the participants strongly indicated the need for better normative frameworks, management decisions, and implementation to face the challenges ahead. This highlights the importance of political and social aspects in adaptation [51], especially considering decisions on land use and economic development that determine the status of water bodies (quantity and quality), often in a higher degree than climate change impacts alone. A high level of soft options shows that the participants see social and ecological tensions as opportunities for thinking and acting differently rather than as mere technical problems to be solved [52]. In Rmel, the stakeholders had a different perception, likely because they are not used to participating in management and because they are not familiar with European innovation in governance principles and practices. Nevertheless, stakeholders in all of the river basins acknowledged the important role of education, capacity building, and knowledge transfer, expressing that the participatory experience was positively contributing to improving water management, as shown in Verkerk et al. [24].

In terms of finding solutions to meet local challenges, all of the river basins produced WMOs tackling all of the challenges more or less specifically. Results show that some challenges were addressed by a higher number of WMOs than others. Given the fact that the challenges were broad and interrelated, the stakeholders found it difficult to define WMOs that would tackle each challenge on its own. Thus, in the Tordera, there were few WMOs exclusively targeting the 'water quality' challenge because the WMOs dealing with the 'health of forest and water ecosystems' were considered to have a big impact on the qualitative status of the water bodies due to the dynamics of the river basin.

Regarding the objective of analysing the impact of WMOs on the river basins through a participatory modelling method, indeed, the FCM impact analysis methodology allowed going beyond classical impact analysis and provided an integrated view of the river basins as systems. It made it possible to characterise the impact of WMOs on the whole system, including the indirect effects of changes oriented at one specific factor. Interestingly some of the WMOs designed specifically to address one challenge did not always have the most positive impact on that challenge. For example, in Tordera, some WMOs would positively impact the challenge of the 'health of water ecosystems' even though they were not initially designed to address this specific challenge. The reasons behind differences regarding the impact performance between case studies are determined by how the FCMs were structured, including the meaning behind the factors and how the relationship between the factors were established together with stakeholders as well as the choices made on how to interrelate the WMOs with the FCM. In Vipava, the modeling exercise shows that some WMOs are unlikely to achieve the desired impacts and, in some cases, may result in a worsening situation compared to the baseline conditions due to adverse interactions with other factors. When designing a WMO and the way it impacts the dynamics of the basin, assumptions are made about the effects on the different factors it addresses. These results underpin the idea that systemic analysis with FCMs allows the integration of the interaction between social, economic and environmental factors and can reveal potential weaknesses in the WMOs. However, one should remain cautious in the interpretation of the results. When designing a WMO and the way it impacts the dynamics of a basin, assumptions are made about the effects on the different factors it addresses. These assumptions are critical for the results of the FCM analysis.

Related to the aim of evaluating stakeholder preferences regarding WMOs through a multi-criteria analysis, the MCA methodology was used to find preferable solutions for adapting the river basins to global change but also to compare the performance of the WMOs. This methodology proves that it is able to consider a wide range of elements that are diverse in nature and that it is able to consider combined stakeholder preferences for different criteria, including elements from both the descriptors characterizing WMOs (purely qualitative) and the FCM-simulated impacts of the WMOs (semi-quantitative). The characteristics of the WMOS, for example, time spent between the implementation and the effectiveness of the WMO, the degree of its acceptability, or economic aspects, have high relevance in most results because they are highly preferred by stakeholders. Moreover, this high relevance is also due to the more direct effects of criteria linked to WMO characteristics, unlike the criteria linked to the impact assessment developed through the FCM that have a more nuanced and uncertain effects.

In Tordera and Vipava, the WMOs with high preference scores could be identified, while in Pedieos and Rmel, this was not the case. In fact, in Pedieos, most WMOs had low preference scores, while in Rmel, all of the WMOs had medium preference scores, not allowing differences to be shown between them effectively. Nevertheless, the results of the MCA can be used since they are meant to support complex choices where knowing the least attractive WMOs is as interesting as knowing the most attractive ones. Moreover, a water basin management plan usually includes several WMOs to tackle different aspects of the river basin's dynamics. If single WMO MCA scores are low in Pedieos—due to the fact that WMOs are highly challenge specific, i.e., WMOs have limited impacts on attributes not related to the challenge that they target—a collection of the best WMOs for each challenge would likely meet stakeholders' expectations. As the MCA results depict the combined preferences of a group of actors with highly diverse profiles and concerns, they can be used in the decision-making processes to develop management plans that will likely reach a high degree of acceptance. Moreover, in most cases, MCA results are in line with the presumed outcome of a WMO at the design stage, and in rare cases, they contrast. The details of the MCA scores can be then used to understand the source of the discrepancy between the MCA score and the presumed outcome and can explain the phenomenon to decision makers.

5. Conclusions

The participatory evaluation of WMOs for climate change adaptation in river basins provided results that could support public decisions. However, additional efforts are required to improve the participatory formulation of the WMOs. Moreover, a more detailed process of their characterisation could improve the responsiveness of the approach. Thus, diving more in depth and further modulating WMO characteristics could provide a refined analysis of stakeholder preferences. On the other hand, it is crucial to design the river basin dynamics so as to represent their specificities through the formulation of the FCM as close to actual reality as possible, as this will also determine if the impact of the WMOs is more or less adequate with respect to the initial aims and objectives that they were designed for.

It is important to remark that the efforts and approach adopted to identify and engage stakeholders in the process are crucial. The composition of the profiles included in the stakeholder databases need to be as broad as possible, and the approach to engage the actors identified needs to include the objectives to consolidate a balanced group of stakeholders who are available to assist throughout the different stages and moments of interaction required by the methodology. The importance of sound scientific and technical information being available to the participants is fundamental so as to ensure the quality and pertinence of contributions. The application of the combined methodology of co-designing the WMOs, FCM, and MCA in the four basins has been revealed to be an effective approach to obtain results at a low cost and over short time span. Moreover, it could allow groups of basin actors with highly diverse profiles and concerns to further promote sets of these WMOs as input into decision-making processes.

This study demonstrates that a fully participatory approach is able to adequately incorporate climate change adaptation in water management through the definition and evaluation of WMOs aimed at tackling climate change related challenges. It also proves that the application of the participatory approach is valid in diverse contexts and allows the consideration and comparison of basin features and stakeholder perceptions.

Further research opportunities would, for example, include broadening the focus and integrating water–energy–land nexus approaches with climate services in stakeholder led processes to improve policymaking and to provide elements to avoid maladaptation and at the same time search for synergies and co-benefits and to manage trade-offs among different sectors.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/environments8090093/s1, Table S1: Descriptors and their classes used to characterize WMOs, Table S2: WMO descriptors included in the MCA as selected criteria per river basin, Table S3: Factors from the WMOs impact assessment (FCM) included in the MCA as selected criteria per river basin, Tables S4–S7: Overview of the water management options per river basin, Figure S1–S4: Fuzzy Cognitive Map developed per river basin, Figure S5–S7: Graphs showing how river basin challenges are impacted by all WMOs.

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Analytical Framework to Assess the Incorporation of Climate Change Adaptation in Water Management: Application to the Tordera River Basin Adaptation Plan

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Abstract: Projections indicate that the Mediterranean region is an area where drastic changes in climate will occur, which will significantly affect water resources. In a context of increasing pressure on water resources as a result of the reduction in water availability, it is essential and urgent to structure water management in a way that allows for adaptation to the challenges that the changing climate will bring to an already water scarce region. It is necessary to generate experiences and methodologies that are based on real case studies that will lay the foundations for the generalisation of practices of climate change adaptation in water management. In this study, we have developed a ready to use analytical framework to evaluate the coherence of water management plans and programs with climate change adaptation principles. We have tested the applicability of the framework that was developed on the Tordera River Basin Adaptation Plan (TRBAP). The analytical framework has proven to be easy to apply and to allow for identifying the inclusion or exclusion of key climate change adaptation features appropriately. We have structured this analytical framework as a starting point contributing to further assessments of how climate change adaptation is incorporated in water management.

Keywords: adaptation; climate change; water management; adaptive management; adaptive governance; river basin

1. Introduction

Climate change projections predict that the Mediterranean will be one of the most affected regions [1], with annual average temperature increases that are higher than those of the rest of the world. These projections indicate a decrease in annual rainfall and changes in its seasonal distribution, together with greater inter-annual rainfall variability and an increase of extreme events occurrence [2–5].

The impact of these projections on water resources is expected to be very high [6–10], and pressure on water bodies will increase as a consequence of the reduction in water availability and the increase in the frequency and duration of extreme events (droughts and floods) [11–13]. The effects on water bodies will, in turn, have an impact on different ecological processes and systems, as well as on human activities, leading to an increase in the vulnerability of both social and natural systems.

These scenarios represent a great challenge for water management; but there are still few initiatives that adequately address the impacts of climate change in this field [14,15]. For example, the current main European water regulation, the Water Framework Directive (WFD) [16] does not include climate change explicitly. Therefore, further specific implementation guidelines were developed with the aim to improve the consideration of climate change adaptation in water management [17]. Successful adoption of these guidelines is limited to date [18] and it still remains a key challenge that few initiatives and experiences have addressed satisfactorily.

Moreover, the present context of global changes brings considerable uncertainty that is related both to the predictions of climate change itself, and to the intrinsic complexity of social-environmental systems [19–22]. Referring specifically to water resource management, this implies that policy design and management practices increasingly require taking into consideration flexible and dynamic frameworks that are able to respond to those changes and uncertainties [23,24].

The pathway towards a sound integration of climate change in water management, both in practise and in legislation, is an ongoing process and, due to an overall lack of rigorous evaluation exercises, little information exists on the extent to which relevant factors are currently being integrated. The knowledge gap this study wants to address is the lack of tools for evaluating the incorporation of climate change adaptation in water management plans.

Despite potential barriers that need to be overcome [25], adaptation policies and practices provide an opportunity to reduce the impacts and manage the risks that are associated with climate change, especially in highly vulnerable regions, while paving the way for social and institutional change through the fundamental increase in coordination and trans-sectoral approaches that the adaptation frameworks bring in.

The combination of the theoretical context related to adaptive governance [26–28], and its concretion into praxis through adaptive management protocols, allow for managing new and complex situations flexibly, as well as to take up experience based knowledge for continuously improved management performance [29,30]. This offers a valid approach to respond to the challenges that climate change poses in water management [31].

Promoting new forms of water management that are able to fully integrate climate change related features is crucial, as well as defining methodologies allowing the evaluation as to what extent these elements are adequately incorporated. Therefore, the objectives of this study are: (1) to develop an analytical framework ready for implementation that allows for assessing the coherence of water management plans and programs with climate change adaptation principles; and, (2) to test this analytical framework on a specific river basin plan, the Tordera River Basin Adaptation Plan (TRBAP).

2. Materials and Methods

2.1. Methodological Approach

According to Coral and Bokelmann [32], analytical frameworks provide the basic vocabulary of concepts and terms that may be used to construct the kinds of causal explanations that are expected of a theory. In addition, analytical frameworks help to organize research and provide a general list of variables to be used in any type of analysis, and they are applied as a way of dealing with complexity. A decade ago, Ostrom [33] proposed that the construction of general frameworks could help in identifying the elements to take into consideration, as well as the relationship between these elements [32,34].

The analytical framework that was developed in the present study intends to gather and structure those key elements of climate change adaptation that should be included in water management policies and principles, as well as to contribute in generating methodologies that are functional to improving applied and concrete adaptation actions in river basins.

In order to illustrate the applicability of the analytical framework resulting from the present study, it is tested by the authors using the Tordera River Basin Adaptation Plan (TRBAP) as an example. This particular case was chosen because, on the one hand, the Tordera River Basin is a well-studied area located in the Mediterranean basin, a region that is highly affected by climate change and related impacts on water and other resources [13,35]. In addition, multiple sectors compete for water [36] and high water abstractions [37] induce intense pressure on the river basin's rich ecosystems and their functionality, a situation that is projected to increase in the future. On the other hand, the case was chosen because the Tordera River Basin Adaptation Plan was specifically developed in the framework of the EC FP7-SIS BeWater project aiming at explicitly tackling climate change adaptation in water management in four case study river basins [38], thus allowing for testing all of the elements included in the analytical framework of the present study.

To feed the construction of the analytical framework, a variety of theoretical and methodological literature sources, as well as specific case studies, were analysed (see Table S1 in the Supplementary Material for the list of literature sources analysed). These literature sources allowed for characterising climate change adaptation elements in water management and policy design, thus identifying pivotal features that should be included in any sound adaptive water management plan. These pivotal features were structured into a framework (see Figure 1), allowing for obtaining a checklist to easily identify the different key elements in the plan that is to be evaluated. Key elements may refer to concepts/themes/contents/results of the theoretical and methodological literature sources consulted.

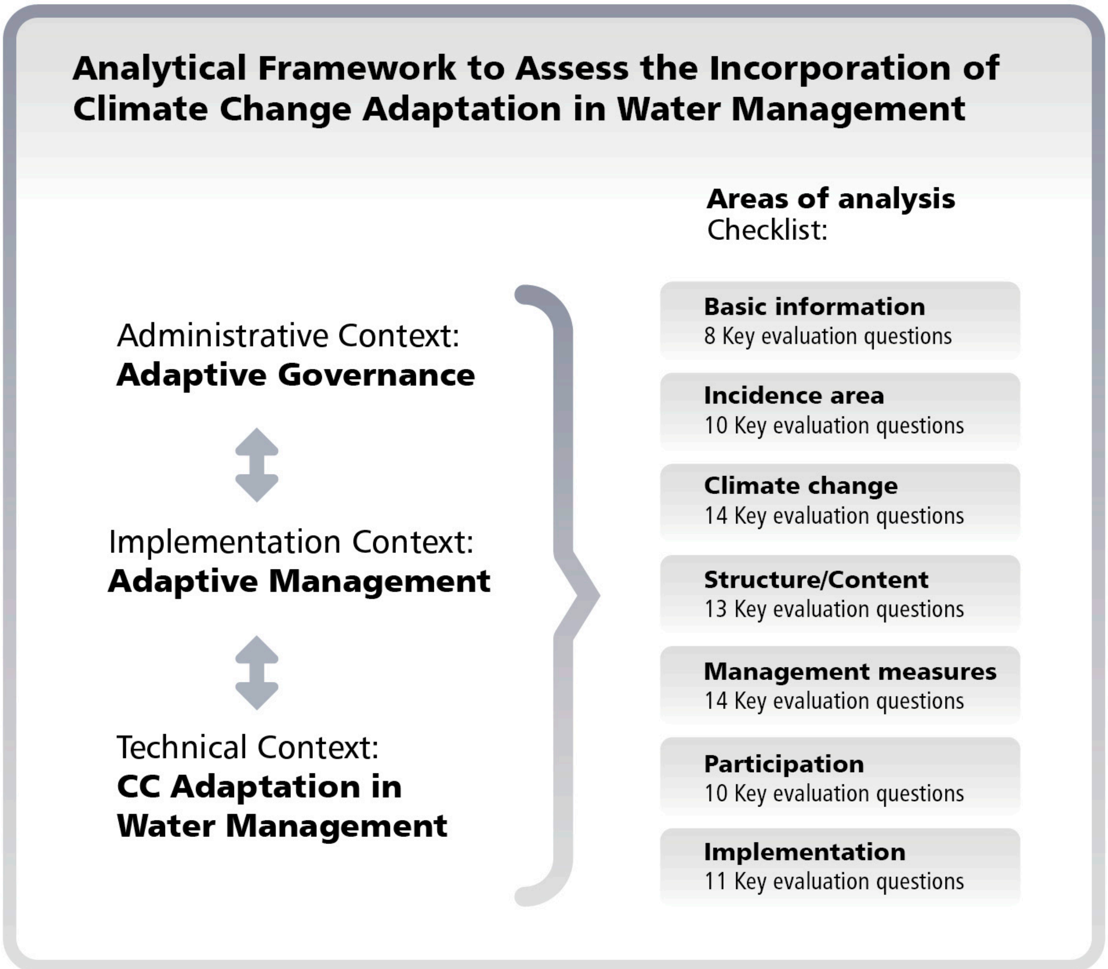

Figure 1. Analytical framework built within this study to assess the degree in which climate change adaptation is taken into account in water management. On the left, criteria and references regarding administrative, implementation and technical context retrieved from the theoretical and methodological references used to build the analytical framework. On the right, the resulting basic structure of the analytical framework, including the key evaluation questions for each area of analysis. Source: Own elaboration.

The sources of information consulted and analysed include references that are especially relevant in the field of water management and adaptive governance, [39,40], such as the works that were developed by the Research Institute of Environmental Systems of the University of Osnabrück, Germany. This research group has decisively contributed to the development of New Approaches to Adaptive Water Management under Uncertainty [27,41–43] providing innovative approaches that help to understand and facilitate the change towards adaptive and integrated water management strategies in different river basins. Furthermore, this research group has brought forth general knowledge with high political relevance for developing adaptive water governance in the context of climate change [30,44], which are taken up in this study's analytical framework. Moreover, we give particular relevance to the methodological proposals that are linked to WFD deployment within the framework of the Common Implementation Strategy, published by means of specific guidance documents for all the member states of the European Union. More concretely, the climate change related guidance document [17] highlights, for example, that the cyclical approach of the river basin management process promoted by the WFD implementation agenda is adequate to apply adaptive management to face the impacts of climate change. In addition, it states that a way to face the uncertainty that is related to climate projections and their impacts on aquatic ecosystems could be to incorporate management strategies that are beneficial, regardless of climate perspectives.

Despite its clear usefulness for water management practitioners who want to know how to include adaptation principles in water management, the guidance document still does not face some key challenges: the role of active citizen participation and multi-stakeholder platforms [45,46] that are considered in adaptive management protocols, the importance of a cross-sectoral approach, and the need to tackle coordination between public administrations.

2.2. Methodological Proposal: Analytical Framework

The elements that were identified from literature, as described in Section 2.1, were taken up in the analytical framework structured and grouped into seven areas of analysis, as shown in Table 1. For each area of analysis, a cluster of related key evaluation questions is put together and compiled as a checklist (see Table S2 in the Supplementary Material for the complete analytical framework, including the whole list of key evaluation questions for each area of analysis).

Table 1. Description of the seven areas of analysis from the analytical framework. For each area of analysis, the theoretical and/or methodological justification together with examples of key evaluation questions are included.

Area of Analysis	Description	Theoretical/Methodological Justification	Example of Key Evaluation Question
1: Basic information	Basic references of the document and areas of incidence.	To define the context in which the plan was developed.	What is the time horizon of the plan?
2: Incidence area characterisation	Diagnosis of the current state of ecosystems, socio-economy, legal and political framework.	To clarify if and how the plan includes a characterization of the area considering all relevant aspects.	Is there a diagnosis of the current state of the Plans' area of incidence and, if so, does it include a description of the methodologies used?
3: Incorporation of climate change	Level of incorporation of climate change related information: climate projections, vulnerability and impacts.	To consider if climate projections and related impacts are properly taken into account to anticipate adverse effects and minimize consequences.	Have the vulnerability of ecosystems and society in the Plans' area of incidence been evaluated and, if so, how?
4: Structure and general content	Scope of the plan: a) challenges and objectives, b) uncertainty and complexity, c) monitoring and evaluation.	To clarify a) the specific objectives and challenges the plan addresses, b) how it takes into account uncertainty and complexity and c) if it promotes experience based learning.	Does the Plan address the complexity associated with its challenges and objectives?

Table 1. *Cont.*

Area of Analysis	Description	Theoretical/Methodological Justification	Example of Key Evaluation Question
5: Management measures	Specific information on adaptation measures: characterization, description, and synergies.	To clarify if measures included have the appropriate characteristics to advance in the adaptation of water management.	Does the Plan include a categorization of the measures proposed according to adaptation criteria?
6: Participation	Participatory character of the plan.	To clarify if the quality of multi-stakeholder participation is appropriate to advance in the adaptation of water management.	Has multi-stakeholder participation been included in the preparation of the Plan and, if so, how?
7: Implementation	Implementation context: barriers and opportunities, commitments, synergies, available budget, evaluation and review of the plan.	To clarify if the roadmap for implementation includes commitments and synergies with other sectors, reviews governance structures and management practices to advance in the adaptation of water management.	Are barriers and opportunities for plan implementation indicated?

The checklist is categorised as to assess the inclusion, partial inclusion or exclusion of the different elements in the plan being evaluated, as shown in Table 2.

Table 2. Categorisation of the answers for each key evaluation question.

Yes (+)	Properly considered in the plan
Partially (±)	Partially considered in the plan
No (-)	Not considered in the plan

2.3. Case Study

The authors have chosen to test this analytical framework in the Tordera River Basin Adaptation Plan (TRBAP). The Tordera river basin is located in the northern half of Catalonia (Figure 2), as characterised by globally Mediterranean climatic conditions. Projections indicate that the impacts of climate change could be very intense in this area [13]. The Tordera basin is a small river basin that is rich in natural heritage and of great geostrategic importance for the socioeconomic development of Catalonia. The impacts of global change in this territory could have special relevance, as its effects could extend beyond the local level. Indeed, the basin plays a crucial role in the connection between North and South Catalonia and the area hosts prosper economic activities, such as tourism and logistic industry.

The Tordera River is 55 km long and it flows along the Catalan Pre-coastal Mountain Range, its basin comprises 894 km^2, with 81% forest area. Its rich biodiversity is protected by different environmental regulations: some areas are part of the Catalan Network of Natural Protected Areas, others have been declared Sites of Community Importance, and the basin also has two natural parks, the Montnegre Park and the Montseny Park, with the latter designated in 1978 by the United Nations Educational Scientific and Cultural Organization (UNESCO) as a Biosphere Reserve.

This area typically encompasses Mediterranean climate related impacts and vulnerabilities, together with high human induced pressures on water and associated ecosystems. During the last 10 years, the Tordera basin has been part of several national and European projects to identify and address these vulnerabilities by creating adaptation plans at the river basin level through the collaboration between scientists and local society [47,48]. In particular, the Tordera River Basin Adaptation Plan (TRBAP) was developed within the framework of the European Commission Framework Program 7 Science in Society (EC FP7- SiS) BeWater project as one of four case study river basins applying a joint methodology. The TRBAP was co-created in a participatory manner involving stakeholders of the basins' main economic sectors as well as the responsible administrations from the local to regional level [47]. Together with the Plan, a handbook of lessons learned was published explaining this innovative participatory methodology [49].

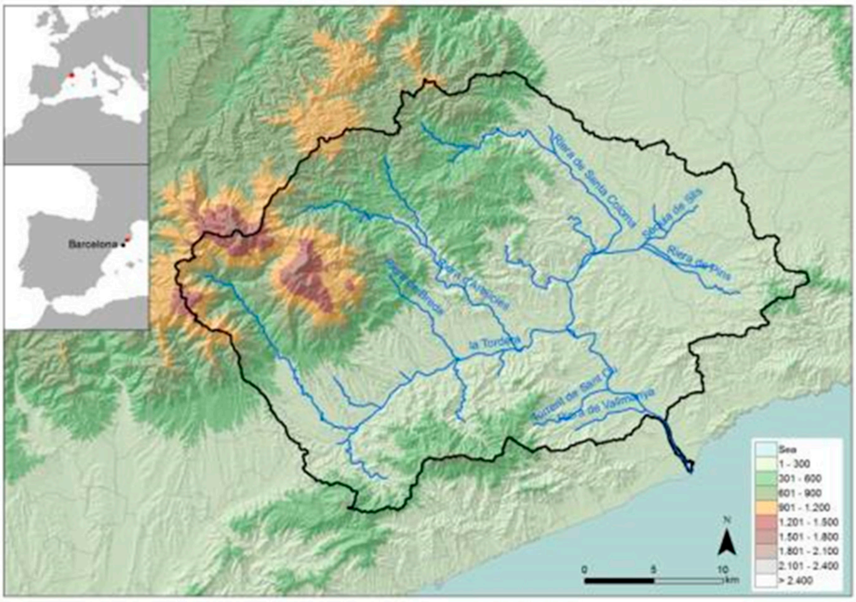

Figure 2. Location of the Tordera river basin.

There are few concrete experiences of participatory adaptation plans at the river basin level based on sufficiently detailed scientific information [50]. We consider, therefore, that the TRBAP brings together the necessary conditions to adequately serve for testing the analytical framework to assess the incorporation of climate change adaptation in water management we have developed.

3. Results

To test the analytical framework's applicability, it was used on the Tordera River Basin Adaptation Plan (TRBAP). To do so, we went through each one of the seven areas of analysis defined in the analytical framework (Table 1) and took into consideration all of the information and data included in the TRBAP regarding these seven areas of analysis. All of this content of the TRBAP related to each area of analysis was then used to answer the key evaluation questions that constitute the analytical framework that was developed in the present study (see Table S2 in the Supplementary Material for the complete analytical framework, including the whole list of key evaluation questions for each area of analysis).

In the following sections, we present a summary of the results of this analytical framework applicability test on the TRBAP (complete responses for all key evaluation questions can be found in Table S3 in the Supplementary Material). In this summary of results, we include two different elements as outcomes of the TRBAP plan evaluation per area of analysis. On the one hand, we highlight some relevant FEATURES of the plan content that exemplify the information and data included, and, on the other hand, we present the RESULTS of answering the key evaluation questions using the categorisation that is shown in Table 2 so as to assess the inclusion, partial inclusion, or exclusion of the different elements in the plan being evaluated. The complete results of the Analytical Framework application to the Tordera River Basin Adaptation Plan is shown as answers to all key evaluation questions per area of analysis in Table S3 of the Supplementary Materials.

When presenting the RESULTS, we have considered that a determinate area of analysis was adequately characterised within the plan that was analysed if at least two-thirds of the key evaluation questions for that area had a positive or partially positive response.

3.1. Area of Analysis 1: Basic Information

Main Features: The promoter of the TRBAP was the European Commission through the financing of an EC FP7- SiS project, BeWater (project no. 612385). It was carried out by a research centre and published in September 2016. The time horizon of the plan is 2018–2030 and its geographical scale is the Tordera river basin. The TRBAP includes complementary documents that go in abundant detail into the information and methodologies that were used for its development.

Results: Clear information and references can be found on the context of the TRBAP development. No quantification of results is included for this area of analysis as it only aims at gathering context information.

3.2. Area of Analysis 2: Characterisation of the Incidence Area

Main Features: the main diagnosis of reference, concerning the local water cycle in the TRBAP, is based on the Analysis of Pressures and Impacts (named IMPRESS) included in the River Management Plan for the Catalan internal river basins [51]. This document relates the current status of the basin's water bodies detailing the pressures and impacts that are exerted on them. Moreover, for elaborating the TRBAP, several additional sources of information were used, such as biophysical and socioeconomic studies [52]. All of this information was integrated with contributions that were collected directly from local stakeholders on: economic sectors, legal and political aspects, historical information, power balances between stakeholders, extreme climatic events, etc. The developers of the TRBAP tried to take the uncertainty and complexity of characterising a river basin into consideration by combining scientific information with local knowledge, capable of capturing elements that are associated with social, economic, and political uncertainties.

Results: 100% of the key evaluation questions for this area of analysis had a total (90%) or partially positive response (10%); therefore, we conclude that the TRBAP has included an adequate characterisation of the incidence area (see Figure 3).

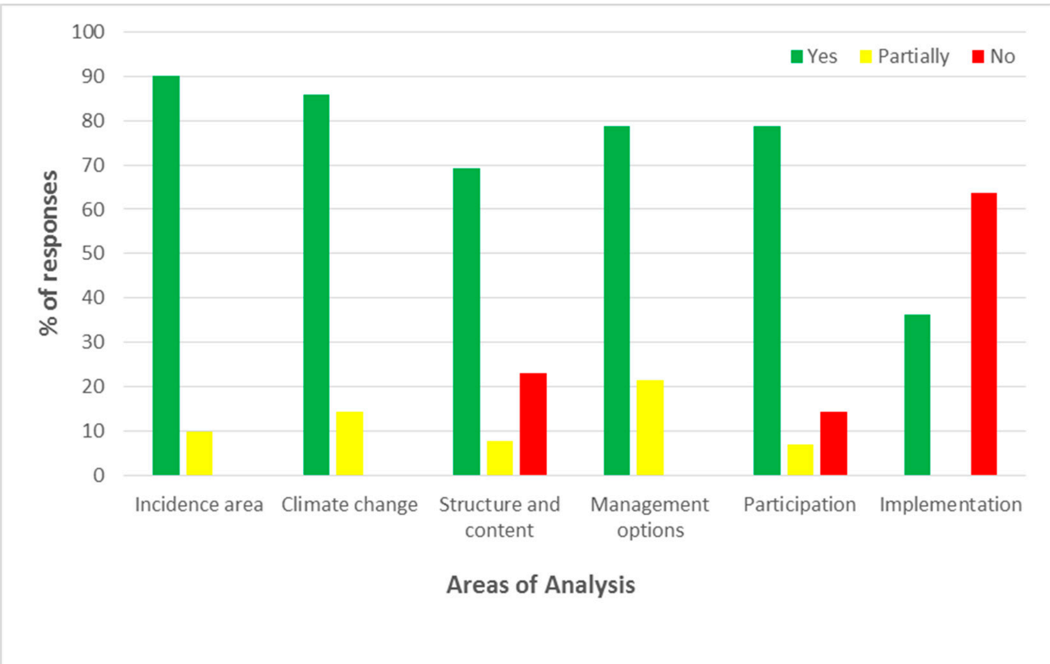

Figure 3. Percentage of responses to key questions of each area of analysis after applying the analytical framework to the Tordera River Basin Adaptation Plan. Categories: *Yes*- The question is properly considered in the plan; *Partially*- The question is partially considered in the plan; and, *No*- The question is not considered in the plan.

3.3. Area of Analysis 3: Inclusion of Climate Change

Main features: climate projections were those of the European Centre Hamburg climate Model 5 (ECHAM5) downscaled to the area of interest for A2 and B1 Intergovernmental Panel of Climate Change (IPCC) scenarios [53] with a 2030 time horizon. These also allowed for obtaining information on vulnerabilities and impacts of climate change on crops, forests, and water bodies in the basin. Moreover, the TRBAP integrated this information with perspectives of local stakeholders through different participatory activities and methodologies. Participants built a cognitive map for the basin [47], in which climate change was a driver whose influence reflected on the dynamics of the map. It is interesting to highlight that the climate projections are not the latest available [1] and that only two future scenarios have been used. In a quite innovative way, the TRBAP uses a combination of impact and vulnerability assessments of different nature (quantitative through modelling and qualitative through participatory exercises). By integrating different types of knowledge the TRBAP aims at increasing the understanding of both natural and social systems and their future evolution [47].

Results: 100% of the key evaluation questions for this area of analysis had a total (85%) or partially positive response (15%), so we conclude that there has been an adequate inclusion of climate change in the TRBAP (Figure 3).

3.4. Area of Analysis 4: Structure and General Content

Main features: The challenges and objectives of the TRBAP are to: (i) analyse and identify with stakeholders from different sectors, as well as the general public, the main water-related challenges in the basin, (ii) identify key leverage points to improve social resilience, and (iii) promote the transfer of knowledge as well as the elaboration of innovative proposals to deal with the impacts of climate and global change based on a grassroots participatory approach. The plan clearly presents limitations that are related with the nature of the context in which the plan was developed, given that neither the promoter nor the authors have the authority to implement the plan of measures included.

Results: 77% of the key evaluation questions included in this area of analysis had a total (70%) or partially positive (7%) response and 23% negative (Figure 3), we conclude that the TRBAP includes an adequate scope of plan challenges and objectives within its structure and general content.

3.5. Area of Analysis 5: Management Measures

Main features: the TRBAP focuses its development outlining, formulating, categorising, evaluating, prioritising and grouping all measures. The measures were categorised in a very comprehensive and complete manner, including aspects that are related to implementation viability. Different pre-defined descriptors allowed for assessing the level of coherence of the measures with the framework of adaptation to climate change. A simplified estimation of costs for the measures was performed, as well as an impact analysis of single measures and a participatory evaluation through a multi-criteria analysis [47]. An assessment of synergies and conflicts between measures was also performed to consider possible benefits of implementing measures together.

Results: 100% of the key evaluation questions for this area of analysis had a total (80%) or partially positive (20%) response, therefore it can be concluded that the TRBAP guaranteed the appropriate development of management measures (Figure 3).

3.6. Area of Analysis 6: Participation

Main features: The participation of relevant local stakeholders in the preparation of the TRBAP is the main focus of the approach and methodologies undertaken. Participants could, on the one hand, provide information to feed the whole process and, on the other, discuss, and validate the results at key moments of its development through workshops, interviews, meetings, and specific events. The participatory approach permeates the Plan and its importance is stressed by the fact that different measures included actually aim at improving and increasing participatory practices in the basin, and advancing on institutional changes and political will to implement them.

The TRBAP has intended to foster social learning [54], through an iterative process of regular meetings and workshops, a cumulative construction of interactions and relationships, and the generation of common visions and shared understandings among all the participants in the process.

Results: 79% of the key evaluation questions for this area of analysis had a positive response and 7% had a partially positive response. Therefore, it can be concluded that the TRBAP guaranteed an adequate Participation (Figure 3).

3.7. Area of Analysis 7: Implementation

Main features: The scope of the implementation roadmap included in the TRBAP does not ensure effective adaptation to climate change, as it lacks the needed features to detect the responsible organisms for its implementation, define a concrete calendar for its review, and define a full budget to fund its development. This is, in fact, the most important limitation of the TRBAP, which has been developed within the framework of a research project, and therefore it lacks an implementation strategy that would be necessary to ensure the effective implementation of the measures.

Results: Only 36% of the key evaluation questions for this area of analysis had a positive response due to the limitations of the plan exposed previously. Thus, we conclude that the TRBAP does not guarantee adequate implementation (Figure 3).

4. Discussion

Even though current visions and experiences on adaptation to climate change, adaptive management and adaptive governance is quite large by now and is well documented in literature, advances need to be made to adequately incorporate adaptation to climate change in water management practices and policy design. A necessary element to guarantee the proper inclusion of adaptation that is not sufficiently developed at present is the existence of clear and ready to use analytical frameworks that are able to assess how adaptation to climate change is considered in water management and policy design. This is the knowledge gap that this study aims at contributing to.

Therefore, we developed a ready to use analytical framework to allow for evaluating the coherence of different water management plans and programs with climate change adaptation features. The analytical framework that was created by this study has been tested by the authors through its application for the evaluation of the Tordera River Basin Adaptation Plan (TRBAP). The framework developed proved to be easy to apply and it was useful for critically examining and evaluating the TRBAP. Structured in seven areas of analysis, the framework allows for examining the different sections of the plan under evaluation in an organized manner and ensuring that the evaluation considers all important elements. The checklist of key evaluation questions for each area of analysis is clear and pertinent, allowing for revealing the inclusion or exclusion of relevant elements in a comprehensive manner.

The results of the evaluation of the TRBAP using the analytical framework indicate a high degree of coherence of this plan with the principles of adaptation to climate change, as it incorporates most of the relevant features. The application of the analytical framework highlighted that the main limitation of the TRBAP is the lack of an implementation strategy, due to the fact that not the promotors (European Commission) or the project leader (a research center) have any responsibility regarding the implementation of the measures proposed. Consequently, the Implementation area of analysis is the one where the TRBAP shows most deficiencies.

The analytical framework we have developed aims to be a starting point for more advanced elaboration of evaluation tools. Further testing of its applicability to other plans or programs would be useful to better evaluate its limitations and the needed improvements. Other applications of the framework developed could also be explored, for example, as a tool for the comparison between different water management plans according to their degree of coherence with the theoretical framework of adaptation to climate change.

The present study represents a creative exercise of structuring relevant existing knowledge on adaptation to climate change, adaptive management, and adaptive governance into a practical and ready-to use tool (analytical framework). It is thus a step forward in the advancement of methodologies that are able to assess how climate change adaptation is being incorporated in current water management and policy design.

Adaptation requires new ways of formulating policies, fostering an integrated approach that tackles key challenges. Despite existing efforts, synergic integration of policies into water management planning and practises is, at present, not adequately realised. This is evident when looking at the implementation of the water framework directive, where the incorporation of climate change in the second management cycle has been very superficial or absent in the Member States, as indicated by the 2015 Water Framework Directive implementation assessment report [18]. The present study could add up to the attempts of effectively integrating adaptation to climate change in subsequent management cycles by helping to evaluate to what extent adaptation principles are currently incorporated.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/11/3/762/s1, Table S1: List of literature sources analysed. Table S2: Complete Analytical Framework including all areas of analysis and all key evaluation questions. Table S3. Results of the Analytical Framework application to the Tordera River Basin Adaptation Plan.

Author Contributions: A.S.-P. and A.B. conceptualized the research and outlined the methodology. P.P. contributed to the methodological development of the study. A.S.-P. carried out the analysis and A.B. assisted in the analysis. A.S.-P. wrote the paper while the review and editing was completed by A.B. and P.P.

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Conflicts of Interest: The authors declare no conflict of interest.

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CAPÍTULO 3. Conclusiones

En este capítulo recogemos las conclusiones más relevantes que se extraen del trabajo desarrollado en la presente tesis doctoral con la intención de aportar un análisis más reflexivo e integrado que el de las conclusiones específicas de los artículos que forman parte del capítulo 2. Al final incluimos propuestas de posibles líneas de investigación futuras.

3.1 Conclusiones generales

Dado que el cambio climático supone un conjunto de riesgos y retos complejos que afectan a todos los sectores de la sociedad, el proceso de adaptación necesita que ésta sea una sociedad activa y consciente de los riesgos a los que se enfrenta y que se involucre a un amplio abanico de actores en la toma de decisiones sobre la gestión del territorio y concretamente sobre la gestión del agua. Por tanto, para avanzar en la adaptación sería fundamental fomentar la participación social, más allá de la consulta puntual vinculada a los ciclos de planificación, mediante la creación de espacios permanentes que permitan a la ciudadanía compartir su conocimiento del territorio, su visión histórica y las dinámicas socioeconómicas que se dan, así como que se incorporen prácticas y enfoques metodológicos adecuados para ello.

Por otro lado, se necesita que las administraciones públicas responsables de la gestión del agua, pero también de los espacios naturales y de los diferentes sectores productivos, puedan incrementar el nivel de coordinación para armonizar las políticas que se promueven en el territorio. Del mismo modo, la mejora en la coordinación se debe fomentar entre administraciones de diferentes ámbitos territoriales: nacionales, regionales, comarcales y locales. Este enfoque necesario requiere de cambios en la manera de funcionar de las administraciones y, de hecho, constituye uno de los mayores retos para la adaptación. Dichos cambios se englobarían en promover un enfoque innovador en la gobernanza para la adaptación que:

- Supere los compartimentos y los límites administrativos de las instituciones.

- Resuelva la fragmentación de responsabilidades y la falta de visión común entre diferentes áreas (p.ej. coordinación entre políticas sectoriales y la DMA).
- Promueva una gestión integrada de los territorios priorizando el buen estado de los ecosistemas.
- Acepte la incertidumbre y promueva estrategias y visiones a largo plazo.
- Legitime los espacios intersectoriales, transversales y multiactor.
- Incorpore la información científico-técnica y el conocimiento local y basado en la experiencia en todos los pasos de los procesos de toma de decisiones y el diseño de políticas.

Este enfoque innovador contribuiría de manera efectiva a la reducción de la vulnerabilidad socio-ecológica y a una mayor resiliencia, en general, y frente a momentos críticos o probables emergencias, en particular.

Por último, otro de los aspectos que presenta más dificultades a la hora de avanzar en la adaptación es, precisamente, el seguimiento, medición y evaluación de la consecución de los objetivos de adaptación. Esta dificultad y deficiencia abarca desde la evaluación de planes, programas y políticas hasta el seguimiento de indicadores específicos para sectores socioeconómicos y ecosistemas, incluyendo el establecimiento y desarrollo de criterios, herramientas y metodologías específicas para tal fin.

3.2 Conclusiones sobre la metodología

3.2.1 Metodología participativa para la adaptación en la gestión del agua

Para abordar la gestión sostenible del agua y la adaptación al cambio global, hemos desarrollado un enfoque *bottom-up* que garantizara la participación activa y real de los actores locales en la determinación de estrategias adecuadas de gestión de sus cuencas hidrográficas para la adaptación. Hemos utilizado el enfoque *STIR* para guiar el proceso participativo general aplicándolo junto a una combinación innovadora de técnicas, como el mapeo cognitivo y el análisis multicriterio, que nos han permitido capturar el conocimiento de los actores y su comprensión de las cuencas hidrográficas además de evaluar sus preferencias en cuanto a medidas de gestión para abordar los desafíos de las cuencas frente al cambio global (Capítulo 2, Artículo 2.1). Podemos concluir que esta metodología:

- Permite identificar retos relevantes a nivel local para la gestión y adaptación de las cuencas hidrográficas, teniendo en cuenta cómo estos retos están interrelacionados entre sí y cómo podrían abordarse mediante la gestión de cuencas hidrográficas.
- Representa una contribución útil a enfoques existentes para definir y evaluar medidas de gestión como experiencia en la que se han recogido explícitamente los conocimientos, las percepciones y las preferencias de los actores de las cuencas.
- Tiene el potencial de aplicarse a cualquier cuenca hidrográfica y presumiblemente a otros sectores, ya que se ha aplicado satisfactoriamente en cuatro cuencas hidrográficas con contextos diferentes en cuanto a su ámbito geográfico, ambiental, perspectiva socioeconómica, cultural y política. Para facilitar la aplicación de este enfoque en otros contextos, hemos desarrollado una guía metodológica que recoge las lecciones aprendidas de cada uno de los pasos del mismo (Anexo 3, publicación A3.2).
- Ejemplifica experiencias prácticas de co-creación entre ciencia y sociedad y algunas metodologías válidas para llevarlas a cabo.
- Promueve el intercambio de conocimientos y el aprendizaje común entre científicos, expertos, responsables del desarrollo de políticas y sociedad local y proporciona una base sólida para la formación de capacidades, la concienciación y el incremento de la percepción de los retos y riesgos asociados al cambio climático por parte de la sociedad.
- Permite la co-creación de medidas de adaptación en la gestión del agua con un alto grado de aceptación social, relevancia política e interés técnico a la hora de abordar las incertidumbres y la naturaleza compleja del cambio global.
- Fue recibido con entusiasmo y aceptación por parte de las personas que participaron en el proceso, que lo valoraron como una buena contribución para mejorar la comprensión compartida sobre retos y soluciones para la gestión de cuencas hidrográficas en un contexto de cambio global.

Contribuir con metodologías para mejorar los procesos de toma de decisiones en materia de gestión del agua es un elemento clave para avanzar en el diálogo entre ciencia, política y sociedad.

Recogemos también algunas limitaciones de la metodología aplicada.

- En primer lugar, limitaciones relacionadas con la tipología de actores que han participado en el proceso cuyas percepciones y preferencias propias, podrían haber afectado los resultados de los mapas cognitivos y del análisis multicriterio. Para minimizar la posible exclusión de puntos de vista y percepciones importantes, se realizaron múltiples eventos cada uno de los cuales incorporaba nuevos actores en el proceso a los cuales se les pedía que verificaran los resultados obtenidos previamente.

- En segundo lugar, las que tienen que ver con los posibles sesgos introducidos por los propios investigadores en los procesos participativos al presentar la información relevante, facilitar las interacciones y procesar los datos obtenidos en ellos. Para minimizar este sesgo, se han planificado cuidadosamente los talleres, se ha contado con expertos para su facilitación y se han proporcionado informes detallados de todos los pasos del proceso para su validación por parte de los participantes.

- En tercer lugar, las relacionadas con las limitaciones temporales para la participación impuestas por el proyecto europeo en el que se circunscribe la investigación. Algunos pasos del proceso de implementación de la metodología se hubieran beneficiado de eventos participativos adicionales para profundizar en algunos elementos clave como son:

  - El desarrollo de los mapas cognitivos en los que se basan en gran medida los resultados de nuestros análisis. Construimos los mapas cognitivos sobre la base de las declaraciones expresadas por los actores en uno de los talleres y algunas entrevistas y, posteriormente, fueron presentados, modificados y finalmente validados por los participantes. Creemos que si los mapas cognitivos se hubieran desarrollado totalmente por los actores en el marco de talleres específicos esto hubiera contribuido a convertirlos en mejores herramientas para el análisis de los impactos de las medidas de gestión del agua.

  - El desarrollo técnico y la definición específica de las medidas de gestión del agua que se definieron sobre la base de propuestas bastante generales hechas por los actores en un taller específico y que posteriormente los participantes validaron. Consideramos que un taller extra que hubiera tenido como único objetivo el desarrollo conjunto y la caracterización de las medidas hubiera contribuido a una mejor definición de las mismas para su incorporación en planes y programas específicos.

Por último, nuestro enfoque captura de manera limitada la incertidumbre asociada con cambios futuros en el clima, el uso del territorio, la dinámica de la población, etc. En este sentido, el alcance y los métodos y enfoques cuantitativos serían más apropiados para evaluar la eficacia de opciones de gestión en condiciones futuras inciertas. Por tanto, propondríamos una combinación de métodos cuantitativos (modelización) y cualitativos (integración de conocimiento no experto) en los procesos de planificación para la adaptación.

3.2.2 Metodología para la evaluación de la incorporación de la adaptación en la gestión y planificación del agua

Para abordar la necesidad de evaluar la coherencia de planes y programas de gestión del agua con los aspectos clave sobre adaptación, se ha desarrollado una propuesta metodológica en forma de marco de análisis crítico listo para su aplicación (Capítulo 2, Artículo 2.3).

El marco analítico desarrollado ha demostrado ser útil para examinar y evaluar planes de adaptación al cambio climático en la gestión del agua, habiendo sido testado mediante su utilización en el análisis crítico del Plan de adaptación de la cuenca de la Tordera (Anexo 3, publicación A3.1). Su estructuración en ámbitos de análisis permite llevar a cabo, de una manera organizada, el análisis lógico de los diferentes contenidos de los planes y cubre todas las temáticas relevantes. Las preguntas de evaluación para cada ámbito son claras y permiten chequear fácilmente la inclusión o exclusión de los diferentes elementos clave en el plan objeto de análisis y dar una breve descripción sobre la forma en que se incluyen. Es de fácil aplicabilidad y permite detectar visualmente los ámbitos en los que el plan incluye mayores limitaciones.

Esta propuesta metodológica pretende ser un punto de partida para futuras elaboraciones de herramientas más robustas de análisis y evaluación sobre la inclusión de la adaptación al cambio climático en la gestión del agua. Eventualmente, podría permitir la comparación entre diferentes planes de gestión del agua según su mayor o menor adecuación y coherencia con el marco analítico de adaptación al cambio climático. Esta metodología de análisis es una aportación a la generación de conocimientos relacionados con la adaptación y su inclusión concreta y efectiva en la planificación hidrológica.

Como ideas para avanzar en la mejora de la herramienta, se sugiere:

- Realizar diversas pruebas de su aplicabilidad utilizando otros planes o programas que permitan recoger en detalle limitaciones y mejoras necesarias.
- Promover su uso por grupos de investigación diversos que puedan aportar perspectivas complementarias para su perfeccionamiento.

- Elaborar índices sintéticos, calculados a partir de la información recogida en su aplicación, que permitan evaluar de manera más sólida la incorporación de la adaptación en planes y programas y faciliten la comparación entre aplicaciones de la herramienta.

3.3 Conclusiones sobre los resultados.

Son necesarios ejemplos prácticos de que el trabajo deliberativo y colaborativo para avanzar en la adaptación al cambio climático es posible y ofrece resultados válidos. La adaptación en la gestión del agua no trata solo de generar soluciones técnicas desde las administraciones, la gestión del agua es más que calidad y cantidad, deben considerarse cuestiones e interacciones complejas de aspectos ambientales, sociales y políticos. Los resultados de esta tesis doctoral pretenden avanzar en esta línea demostrando que una metodología totalmente participativa es capaz de incorporar de manera adecuada la adaptación en la gestión del agua a través de la definición y evaluación de medidas destinadas a abordar los retos relacionados con el cambio climático. Los resultados indican que el enfoque es válido en diversos contextos y permite considerar y comparar las características de las cuencas y las diferentes percepciones de los actores (Capítulo 2, Artículo 2.2). La aplicación de la metodología combinada ha revelado ser un enfoque eficaz para obtener resultados diseñados específicamente para los retos y necesidades de las cuencas con un coste bajo, en un tiempo corto y con gran relevancia a nivel local y regional. Además, ha permitido construir comunidades de actores que, en conjunto, pueden influir en la gestión de las cuencas hidrográficas, teniendo en cuenta la información científica y aportando información sólida a los procesos de toma de decisiones.

El trabajo que hemos desarrollado en esta tesis doctoral nos ha servido para mucho más que desarrollar y testar metodologías y analizar resultados, también:

- Hemos reafirmado la importancia de entender y tener en cuenta las necesidades, motivaciones, valores y preferencias de los actores de un territorio tanto para mejorar la gestión de recursos naturales como la investigación en sí misma.
- Hemos experimentado la fuerza y potencialidad que tienen los procesos de participación activa y real que dan valor a todo tipo de conocimientos, combinando técnica, ciencia y cultura y que fomentan el aprendizaje mutuo y la colaboración para caminar hacia una adaptación transformadora.

- Hemos constatado la necesidad, no satisfecha hoy en día, de incorporar el cambio climático y la adaptación en la planificación hidrológica de manera que modifique en esencia dicha planificación a nivel de:
    - incorporación de los impactos en planes de medidas,
    - implementación efectiva de dichos planes,
    - evaluación de la consecución de los objetivos ambientales y sociales y
    - vinculación y coordinación con el resto de las políticas sectoriales, para las que el agua es siempre el eje vertebrador, aprovechando los instrumentos y estrategias existentes a nivel europeo, nacional, regional y local.
- Nos ha permitido reflexionar sobre el propio trabajo de investigación al utilizar el Plan de adaptación de la cuenca de la Tordera (Anexo 3, publicación A3.1) elaborado previamente, como plan para testar la aplicabilidad de la metodología de evaluación de la inclusión de la adaptación en planes y programas (Capítulo 2, artículo 2.3), desarrollada posteriormente. Esta oportunidad no suele darse de manera frecuente y ha sido muy útil para incorporar mejoras en el diseño e implementación de investigaciones posteriores.

3.4 Conclusiones sobre el impacto de la investigación.

El hecho de que una parte importante de esta tesis doctoral sea el resultado del trabajo desarrollado en el marco del proyecto europeo *BeWater*, ha facilitado la difusión y el impacto de los resultados de esta investigación. Las actividades relacionadas con la investigación han representado involucrar a las sociedades locales (más de 700 participantes) de las cuatro cuencas hidrográficas de estudio en:

- 16 talleres de co-creación de los Planes de adaptación de las cuatro cuencas.

- 25 eventos complementarios a los talleres.

- 4 campañas de sensibilización, que han llevado exposiciones itinerantes y charlas informativas sobre los retos de las cuencas y la adaptación al cambio climático a museos, ayuntamientos, bibliotecas, centros culturales, escuelas, parques, etc.

Además de lo anterior, también se han difundido los resultados de la investigación relacionados con las medidas de adaptación en la gestión del agua co-diseñadas y los retos frente al cambio climático utilizando diversos medios (escrito, radio, televisión, redes sociales, gamificación) llegando así a un número muy amplio y diverso de públicos (26 438 visitas a la web de proyecto, 440 seguidores en Twitter, 500 seguidores en Facebook, 3 artículos en prensa local en Vipava distribuidos a 10 000 personas cada uno, cuestionario abierto al público respondido por 391 personas en el parque fluvial de Pedieos, juego de cartas del BeWater presentado en las escuelas en Rmel a 150 alumnos, 4 entrevistas en programas de radio local escuchados por una media de 6000 oyentes en Tordera, etc.).

Debido a esta alta interacción con los actores de las cuencas hidrográficas y a que el papel de las autoridades locales (p. ej. municipios) es crucial en el diseño, implementación y seguimiento de las medidas de adaptación, el mayor impacto de la investigación se ha dado precisamente a escala local. Podemos afirmar que se han obtenido diversos impactos de la investigación en relación con:

- **la ciudadanía en general**; el trabajo ha ayudado a aumentar el conocimiento de la población de las cuencas de estudio y su concienciación sobre la adaptación al cambio climático y los retos y riesgos a los que se enfrentan.

- **los actores participantes de talleres y eventos**; a pesar de partir de prioridades en conflicto y competencia en el uso del recurso, el trabajo desarrollado ha contribuido a construir una percepción de los riesgos e impactos compartida entre los participantes. De la misma forma, se ha establecido un diálogo entre ellos que ha permitido alcanzar una visión común sobre qué estado se desea conseguir en la cuenca y cómo llegar a él. Este proceso ha fortalecido la cooperación entre diferentes actores a nivel de cuenca y a nivel nacional/regional y se han establecido nuevos canales de comunicación entre ellos, además de empoderarles para participar en otros procesos de toma de decisiones.

- **los municipios**; el trabajo desarrollado ha propiciado la creación de organismos supramunicipales para la adaptación en la cuenca de Vipava (Eslovenia) y ha contribuido en los planes y políticas de adaptación local en la cuenca de la Tordera (España).

También se han producido impactos de la investigación a otros niveles:

- **regionales/nacionales**; por un lado, los resultados han contribuido a informar directamente al Comité de Medio Ambiente del Parlamento de Chipre y la metodología se ha adoptado en otros procesos de toma de decisiones (cuenca del Pedieos). Por otro lado, veinte medidas co-diseñadas de adaptación en la gestión del agua se incorporaron en el Plan de medidas incluido en el 2ª ciclo de planificación del distrito de Cuenca Fluvial de Cataluña (2016-2021) desarrollado por la Agencia Catalana del Agua (cuenca de la Tordera). Además, diversas medidas y resultados elaborados han contribuido en el proceso participativo vinculado a la Ley Catalana del Cambio Climático y al documento de seguimiento y evaluación de la Estrategia Catalana de Adaptación al Cambio Climático (ESCACC) en la cuenca de la Tordera.

- **investigaciones posteriores**; se ha conseguido financiamiento nacional y europeo (LIFE+) para implementar diversas medidas de adaptación resultantes de la investigación, tanto en la cuenca del Vipava (Eslovenia) como en la de la Tordera (España).

3.5 Futuras líneas de investigación

Como resultado de esta tesis y partiendo de las conclusiones extraídas, podemos apuntar futuras líneas de investigación que se fundamentan en algunos de los aspectos destacados como retos especialmente relevantes para avanzar en la adaptación al cambio climático en la gestión y planificación del agua.

- Promover y analizar procesos de innovación en la gobernanza para la adaptación, con especial énfasis en el agua como eje vertebrador de los territorios. Se trataría de impulsar y estudiar la evolución de espacios deliberativos permanentes que permitieran la participación activa y real de toda la sociedad utilizando metodologías y herramientas adecuadas. Estos espacios deberían incluir administraciones, sectores productivos y sociedad civil en un trabajo conjunto, continuado, transversal y coordinado que alimentara los procesos de planificación.

- Analizar el aprendizaje de los participantes en relación con impactos, retos y riesgos vinculados al cambio climático y a las estrategias y medidas de adaptación. Con el objetivo de evaluar el aprendizaje social y la mejora del conocimiento y comprensión de los contenidos y de la aproximación científica, diseñar y aplicar metodologías específicas que permitan recoger la información deseada, tales como encuestas y entrevistas, análisis de contenido y valores creados y aportados por los participantes, incidencia posterior en el territorio si se diera, etc.

- Desarrollar enfoques y metodologías capaces de incorporar diferentes sectores en una modelización cuantitativa para promover la sostenibilidad y la resiliencia frente al cambio climático que informe la toma de decisiones y las políticas. Esta línea de investigación ya se ha iniciado (ver Curriculum Vitae, Anexo 2) con el trabajo y la publicación de varios artículos, de los que soy co-autora, que trabajan la integración a través de escalas y sectores de los servicios climáticos en el nexo agua-energía-suelo (Cremades et al. 2019, Tudose N.C. et al 2021) con especial consideración de la vulnerabilidad de las ciudades frente a la sequía (Cremades et al. 2021).

- Profundizar en la evaluación de la consideración de los impactos y de la adaptación al cambio climático en la gestión y planificación hidrológica. Para ello debe:
    - aplicar y validar la metodología propuesta para otros planes y en otras demarcaciones hidrográficas,
    - explorar la utilización de la metodología propuesta para la comparación entre planes y para la aplicación a diferentes sectores y
    - profundizar en el desarrollo y mejora de metodologías de evaluación explorando indicadores e índices sintéticos de adaptación al cambio climático que permitieran evaluar de manera más robusta la planificación y las acciones de adaptación en la gestión del agua.

Anexos

Anexo 1: Material suplementario de los artículos

A1.1. Material suplementario: A Participatory Approach for Adapting River Basins to Climate Change.

Supplementary Materials

Contents

Documentation of the characterization of water management options

Table S1: Descriptors used to characterize water management options

Attribute	Classes	Description
Water status	Quantity	Option targets the availability of water
	Chemical quality	Option targets the chemical properties of water
	Ecological quality	Option targets biological quality of surface water
	Hydrogeomorphological quality	Option targets hydromorphological quality of the fluvial system
Water bodies	Surface water	Option targets surface water
	Groundwater	Option targets groundwater
River section	Up	Option targets the upper section of the river basin
	Middle	Option targets the middle section of the river basin
	Down	Option targets the down section of the river basin
	River as a whole	Option targets the whole river basin

Target water use sector	Local population	Option targets the water needed or used by residents within the basin
	Tourism	Option targets the water needed or used by the touristic/recreation sector within the basin
	Industry	Option targets the water needed or used by industry within the basin
	Agriculture	Option targets the water needed or used by farmers within the basin
	Forestry	Option targets the water needed or used by trees within the basin
	Energy	Option targets the water needed or used by the energy sector within the basin
	Water management	Option targets authorities responsible for water quantity and quality (e.g. waste treatment, issuing water permits)
	Others	Option targets water use sectors different from the previous *(please specify at the end of the row the specific sector)*
Target land use	Arable land (rainfed)	Land that is being farmed with crops that are sown and harvested within the same agricultural year, relying exclusively or rain water
	Arable land (irrigated)	Land that is being farmed with crops that are sown and harvested within the same agricultural year, relying exclusively irrigation water
	Permanent crops (rainfed)	Land that is being farmed with crops which last for many seasons, rather than being replanted after each harvest, relying exclusively or rain water
	Permanent crops (irrigated)	Land that is being farmed with crops which last for many seasons, rather than being replanted after each harvest, relying exclusively irrigation water
	Grassland	Land that is dominated by grasses or shrubs for grazing or fodder purposes
	Forests	Land that is predominantly covered by trees
	Built-up	Land that is used for housing, industry (incl urban fabric, industrial/commercial areas, transport networks, mineral extraction sites, dump sites, construction sites, etc.)
	Wetlands & deltas	Swamps and marshes, estuaries, deltas and tidal flats, near-shore marine areas and human-made sites such as reservoirs

	Beaches and dunes	Sands and muds from the coasts of the oceans not covered by sea water at low tide
	Other	Land that is used for other purposes
Extreme events	Drought	Option targets droughts
	Flooding	Option targets floodings
	Storm	Option targets storms
	Fire	Option targets wildfires
	Not related	Option does not target an extreme event
Implementation scale	National	Option is to be implemented at national level
	Regional	Option is to be implemented at regional level
	Basin	Option is to be implemented at basin level
	Municipal	Option is to be implemented at municipal level
Implementation time horizon	Short	Option can be functioning on short term (<5yrs)
	Medium	Option can be functioning on medium term (5-20 yrs)
	Long	Option can be functioning on long term (>20 yrs)
Expected lifetime	Short (< 5 years)	Expected time for which the option is operational without major rehabilitation is short (less than 5 years)
	Medium (5 -20 years)	Expected time for which the option is operational without major rehabilitation is medium (5 - 20 years)
	Long (> 20 years)	Expected time for which the option is operational without major rehabilitation is long (more than 20 years)
Timelag between implementation and effectiveness	Short (< 5 years)	Expected time since the option is implemented until it starts to have the desired effect is short (less than 5 years)
	Medium (5 -20 years)	Expected time since the option is implemented until it starts to have the desired effect is short (less than 5 years)
	Long (> 20 years)	Expected time since the option is implemented until it starts to have the desired effect is long (more than 20 years)
Character	Demand	Option targets the need for water
	Supply	Option targets the availability of water
	Support	Option targets improved governance (incl. awareness raising, monitoring, stakeholder involvement)
	Environmental conservation	Option targets the recovery of the ecological status
Implementation costs *(one-time set up cost of*	< 10,000 €	Direct capital costs of implementing the option are below 10,000 €
	10,000 - 100,000 €	Direct capital costs of implementing the option are in the range 10,000-100,000 €

implementing the measure, after which there will only be recurring operational or running costs)	100,000 - 1,000,000 €	Direct capital costs of implementing the option are in the range 100,000-1,000,000 €
	> 1,000,000 €	Direct capital costs of implementing the option are over 1,000,000 €
Operational costs *(costs incurred annually to maintain the measure operating)*	< 10,000 € / yr	Total annual running costs for this option are below 10,000 €
	10,000 - 100,000 € / yr	Total annual running costs for this option are in the range 10,000-100,000 €
	100,000 - 1,000,000 € / yr	Total annual running costs for this option are in the range 100,000-1,000,000 €
	> 1,000,000 € / yr	Total annual running costs for this option are over 1,000,000 €
Effectiveness (capacity to tackle the specified challenge)	High	Option is highly effective in tackling the specified challenge
	Medium	Option is medium effective in tackling the specified challenge
	Low	Option is low effective in tackling the specified challenge
	Uncertain	Uncertainty about how the option may tackle the specified challenge
Approach to adaptation	Green	Ecosystem-based approaches that use services of nature
	Grey	Technological and engineering solutions
	Soft	Managerial, legal and policy approaches that change human behaviour and styles of governance

Nature of approach	Bear the loss	Occurs when those affected have no capacity to respond in any other ways
	Share the loss	Occurs when the losses are shares among a wider community (either extended family or village-level in traditional societies or through public relief, rehabilitation and reconstruction or insurance)
	Modify the threat	Occurs when the measure exercises a degree of control over the environmental threat itself (e.g. flood control measures such as dikes)
	Prevent effects	Occurs when the option involves steps to prevent the effects of climate change and variability (e.g. modification in crop management practices)
	Change use	Occurs when the continuation of an economic activity is changed due to the difficulty of continuing it (e.g. agricultural use changed into forest use)
	Research	Occurs when the option means use of new technologies and new methods of adaptation
	Educate, inform and encourage behavioural change	Occurs when the option is based on dissemination of knowledge through education, public campaigns leading to behavioural change
Potential to address climate change	Robustness	An option is considered robust to uncertainties if it can maintain its effectiveness under different climatic and socioeconomic development scenarios.
	Flexibility	An option is considered flexible when it can be adjusted/ complemented or reversed when it turns out to be inadequate or inappropriate in practice.
Feasibility	No major obstacle	No barriers for the implementation
	Minor obstacles	Physical, technical or organizational obstacles that can easily be overcome
	Serious obstacles	Physical, technical, regulatory or organizational obstacles that would be difficult to overcome within the time horizon of the project
Acceptability (a priori)	High	There is not significant reason a priori for anyone to reject the option.
	Low	There are obvious signs that one or several actors of the RB will reject the option because of its design.

Documentation of the Fuzzy Cognitive Map for the Pedieos river basin

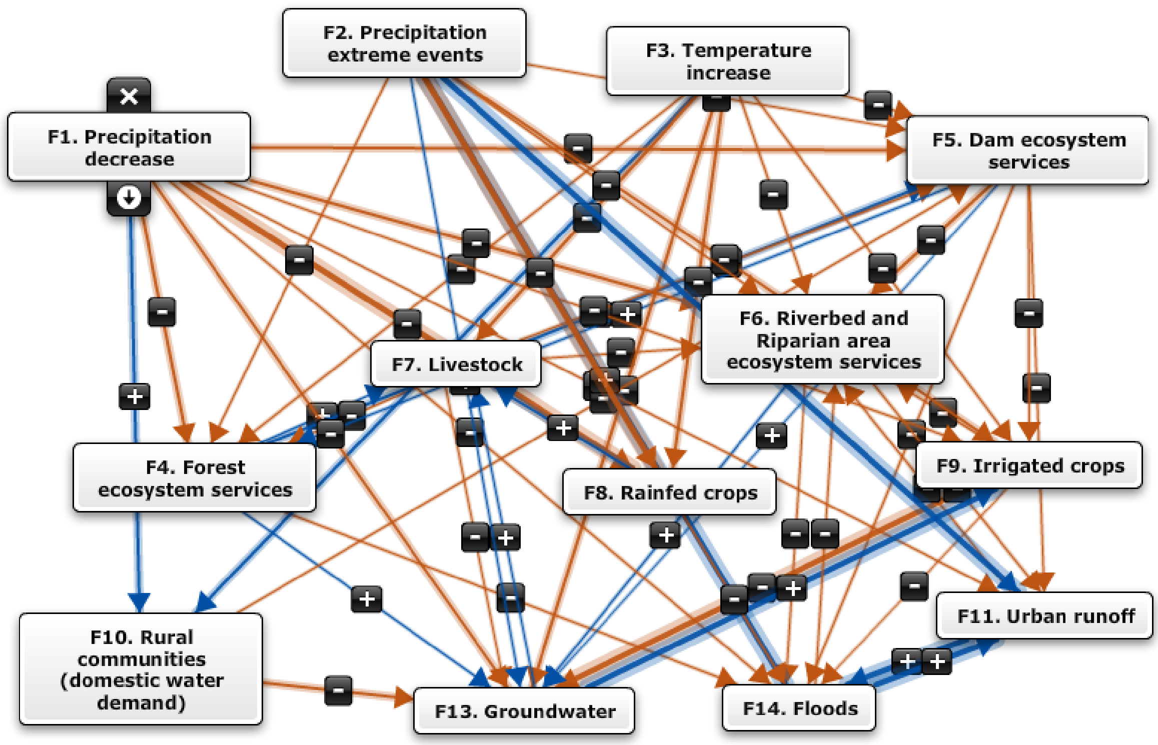


Figure S1: Fuzzy Cognitive Map developed for the Pedieos river basin.

Table S2: Definition of the factors for the Pedieos river basin

Number	Name of factor	Definition
F1	Temperature increase	Overall increase in temperature (1-2 ^{0}C), and more hot days (>35 ^{0}C) and tropical nights (>22.5 ^{0}C).
F2	Precipitation decrease	Reduction in the average annual rainfall (1-12%) and more very dry years.
F3	Precipitation extreme events	Increase in the number of extreme precipitation events (days with more than 50 mm rain).
F4	Forest ecosystem services	Ecosystem services provided by forests, namely, ecological, sociocultural, scenic and landscape services and values, including the regulation of water flows and reduction of erosion.
F5	Dam waterbody ecosystem services	Quantitative and qualitative status of surface water, related to the ecosystem services provided by the Tamassos dam reservoir, including flood control, water supply, provision of habitat for biodiversity and recreation.
F6	Riverbed and riparian area ecosystem services	Ecosystem services of the river and riparian zones, including sediment and nutrient filtering, water storage and release, aquifer recharge, bank stabilization and provision of habitat for biodiversity.
F7	Rainfed cropland	Land cultivated with crops that rely on rainfall for water, mainly barley grown during November-April and some olive orchards.

F8	Irrigated cropland	Land cultivated with irrigated crops such as vegetables, fruit trees and some olive orchards.
F9	Livestock	Intensive livestock farms, mainly with sheep, goats, chickens, but also cows and horses. Occasional grazing of natural vegetation by sheep and goats in the lower upstream and upper midstream areas.
F10	Rural communities (domestic water demand)	Water demand of rural households for drinking and gardens' watering purposes.
F11	Groundwater	Quantitative and qualitative status of groundwater.
F12	Urban runoff	Surface runoff of rainwater created by impervious surfaces (roofs, roads, sidewalks etc) and poor urban drainage systems.
F13	Floods	Flooding from the Pedieos river.

Table S3: Documentation of the relationships for the Pedieos river basin

From	To	Justification	Relationship
F1	F4	The increase in temperature negatively impacts on the ecosystem services provided by the forests	-0.2: weak negative relationship
F1	F5	The increase in temperature negatively impacts on the ecosystem services provided by the Tamassos dam reservoir, including mainly the water supply and the provision of habitat for biodiversity	-0.2: weak negative relationship
F1	F6	The increase in temperature negatively impacts on the ecosystem services of the river and the riparian zones including water storage and release and aquifer recharge.	-0.2: weak negative relationship
F1	F7	The increase in temperature creates strong negative impacts on the rainfed crops that rely on rainfall for water	-0.5: medium negative relationship
F1	F8	The increase in temperature negatively impacts on the irrigated crops	-0.2: weak negative relationship
F1	F9	The increase in temperature creates strong negative impacts on livestock	-0.5: medium negative relationship
F1	F10	The increase in temperature strongly increases the water demand of rural households for drinking and gardens' watering purposes	0.5: medium positive relationship
F2	F4	The reduction in the average annual rainfall creates strong negative impacts on the ecosystem services provided by the forests	-0.5: medium negative relationship
F2	F5	The reduction in the average annual rainfall creates strong negative impacts on the ecosystem services provided by the Tamassos dam reservoir, including mainly water supply.	-0.5: medium negative relationship
F2	F6	The reduction in the average annual rainfall creates strong negative impacts on the ecosystem services provided by the river and the riparian zones including mainly the water storage and release and the aquifer recharge.	-0.5: medium negative relationship

F2	F7	The reduction in the average annual rainfall creates very strong negative impacts on the rainfed crops that rely on rainfall for water	-1: very strong negative relationship
F2	F8	The reduction in the average annual rainfall negatively impacts on the irrigated crops	-0.2: weak negative relationship
F2	F10	The reduction in the average annual rainfall strongly increases the water demand of rural households for drinking and gardens' watering purposes	0.5: medium positive relationship
F2	F11	The reduction in the average annual rainfall creates strong negative impacts on the quantitative status of groundwater.	-0.5: medium negative relationship
F2	F12	The reduction in the average annual rainfall decreases the surface runoff of rainwater in urban areas	-0.2: weak negative relationship
F3	F4	An increase in the number of extreme precipitation events affects negatively the ecosystem services provided by the forests.	-0.2: weak negative relationship
F3	F5	An increase in the number of extreme precipitation events affects negatively the ecosystem services provided by the Tamassos dam, mainly the flood control.	-0.2: weak negative relationship
F3	F6	An increase in the number of extreme precipitation events affects negatively the ecosystem services provided by the river and the riparian zones, mainly the bank stabilization and the provision of habitat for biodiversity.	-0.2: weak negative relationship
F3	F7	An increase in the number of extreme precipitation events creates very strong negative impacts on rainfed crops.	-1: very strong negative relationship
F3	F8	An increase in the number of extreme precipitation events creates strong negative impacts on rainfed crops.	-0.5: medium negative relationship
F3	F11	An increase in the number of extreme precipitation events improves the quantitative and qualitative status of groundwater resources	0.2: weak positive relationship
F3	F12	An increase in the number of extreme precipitation events very strongly increases the surface urban runoff in urban areas	1: very strong positive relationship
F3	F13	An increase in the number of extreme precipitation events very strongly increases the flooding from the Pedieos river	1: very strong positive relationship
F4	F5	Forest ecosystem services including the regulation of water flows and the reduction of erosion strongly improve the ecosystem services provided by the Tamassos dam reservoir, namely, flood control and provision of habitat for biodiversity and recreation.	0.5: medium positive relationship
F4	F9	Forest ecosystem services improve livestock	0.2: weak positive relationship

F4	F11	Forest ecosystem services including the regulation of water flows and the reduction of erosion improve the qualitative and quantitative status of groundwater	0.2: weak positive relationship
F4	F13	Forest ecosystem services including the regulation of water flows and the reduction of erosion reduces the flooding from the Pedieos river.	-0.2: weak negative relationship
F5	F4	The ecosystem services provided by the Tamassos dam reservoir positively impact on the ecological, sociocultural, scenic and landscape services of the forests.	0.2: weak positive relationship
F5	F6	The improvement of the ecosystem services provided by the Tamassos dam reservoir create strong negative effects on the ecosystem services of the river and riparian zones, including sediment and nutrient filtering, water storage and release, aquifer recharge, bank stabilization and provision of habitat for biodiversity.	-0.5: medium negative relationship
F5	F8	The improvement of the ecosystem services provided by the Tamassos dam reservoir negatively impacts on the irrigated crops since less water is diverted for irrigation	-0.2: weak negative relationship
F5	F11	The improvement of the ecosystem services provided by the Tamassos dam reservoir increases the groundwater recharge.	0.2: weak positive relationship
F5	F13	The improvement of the ecosystem services provided by the Tamassos dam reservoir reduces the flooding from the Pedieos river.	-0.2: weak negative relationship
F6	F11	The improvement of the ecosystem services of the river and riparian zones improves the aquifer recharge	0.2: weak positive relationship
F6	F13	The improvement of the ecosystem services of the river and riparian zones reduces the flooding from the Pedieos river.	-0.2: weak negative relationship
F7	F9	Better management of rainfed crops creates strong positive effects on the livestock	0.5: medium positive relationship
F7	F13	Rainfed crops reduce the flooding from the Pedieos river through the land cover.	-0.2: weak negative relationship
F8	F6	Irrigated crops negatively impacts on the ecosystem services of the river and riparian zones since less water flows in the riverbed	-0.2: weak negative relationship
F8	F11	Irrigated agriculture creates very strong negative impacts on the groundwater resources both in quantitative and qualitative terms	-1: very strong negative relationship
F8	F13	Irrigated crops reduce the flooding from the Pedieos river through the land cover.	-0.2: weak negative relationship
F9	F4	The expansion of livestock negatively impacts on the ecosystem services provided by the forests	-0.2: weak negative relationship
F9	F5	The expansion of livestock negatively impacts on the ecosystem services provided by the Tamassos dam reservoir	-0.2: weak negative relationship

F9	F6	The expansion of livestock negatively impacts on the ecosystem services provided by the river and riparian zones	-0.2: weak negative relationship
F9	F11	The expansion of livestock negatively impacts on the qualitative and quantitative status of groundwater.	-0.2: weak negative relationship
F10	F5	An increase of rural households' water demand reduces the quantities of the surface water.	-0.2: weak negative relationship
F10	F11	An increase of rural households' water demand strongly reduces the quantities of the groundwater.	-0.5: medium negative relationship
F11	F8	The improvement of the quantitative and qualitative status of groundwater releases more water for irrigation purposes creating thus very strong positive effects on irrigated agriculture	1: very strong positive relationship
F11	F9	The improvement of the quantitative and qualitative status of groundwater positively impacts on the livestock	0.2: weak positive relationship
F12	F6	Urban runoff negatively impacts on the ecosystem services provided by the river and riparian zones	-0.2: weak negative relationship
F12	F13	Urban runoff strongly increase the flooding from the Pedieos river	1: very strong positive relationship
F13	F6	Flooding from the Pedieos river negatively impacts on the ecosystem services of the river and riparian zones	-0.2: weak negative relationship
F13	F12	Flooding from the Pedieos river strongly increase the urban runoff	1: very strong positive relationship

Documentation of the Fuzzy Cognitive Map for the Rmel river basin

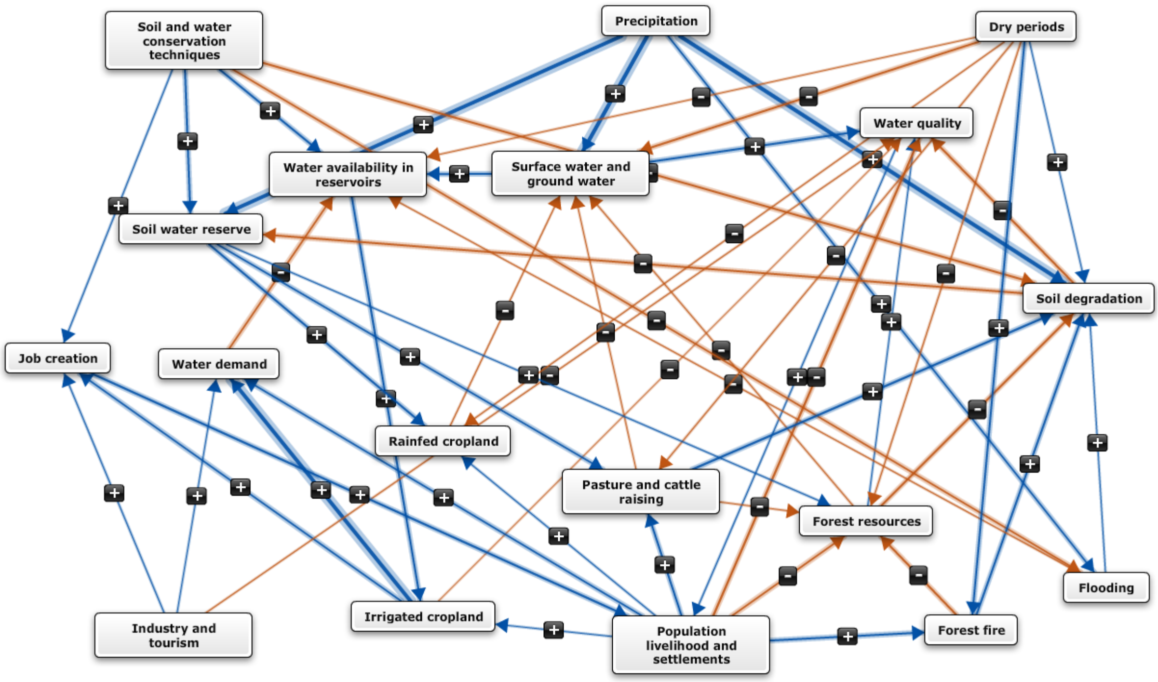


Figure S2: Fuzzy Cognitive Map developed for the Rmel river basin.

Table S4: Definition of the factors for the Rmel river basin

Number	Name of factor	Definition
F1	Precipitation	Irregular and high intensity regime of precipitation
F2	Surface water and ground water	Volumes of water in rivers and the level of aquifers.
F3	Soil water reserve	Volume of water that is stored in the soil
F4	Flooding	Natural extreme event.
F5	Soil degradation	Caused by heavy precipitation on bare soils and steep areas.
F6	Water availability in reservoirs	Volume of water available in dams, hill, lakes, etc.
F7	Irrigated cropland	Irrigated fields that are created downstream after the construction of the dam.
F8	Water quality	Refers to pollution of rivers and aquifers by industrial zone that is recently created.
F9	Forest resources	Various tree species (productive and protected species).
F10	Water demand	Water demand of different sectors (Agriculture, population, industry and tourism).
F11	Soil and water conservation techniques	Limited within the catchment, they are located on steep up stream farmlands to collect runoff water.
F12	Job creation	Creation of jobs in agricultural and environmental sectors to promote development in the region.
F13	Forest fire	Disaster that can be natural or anthropogenic.

F14	Industry and tourism	Includes different enterprises, factories ,olive presses and thermal stations, etc.
F15	Population livelihood and settlements	Includes all population categories and settlements in different sectors based on promoting new agricultural and environmental projects
F16	Pasture and cattle raising	Developed mainly in Rural communities.
F17	Rainfed cropland	Land contains crops that rely on rainfall.
F18	Dry periods	Succession of dry years.

Table S.5: Documentation of the relationships for the Rmel river basin

From	To	Justification
F1 Precipitation	F2 Surface and groundwater	Strong positive relation because a fraction of precipitation reaches rivers directly as runoff or, indirectly, through deep drainage to groundwater and stream base flow.
F1 Precipitation	F3 Soil water reserve	Strong positive relation because a fraction of rainfall infiltrates into the soil and is available for plants.
F1 Precipitation	F4 Flooding	Medium positive relation as flooding occurs occasionally
F1 Precipitation	F5Soil degradation	Strong positive relation because precipitation is the main reason of the soil degradation in the Rmel watershed
F2 Surface water and ground water	F5 water availability in reservoirs	Medium positive relation because the water in reservoirs does not come only from surface water and groundwater ,it comes from precipitations also
F2 Surface water and ground water	F8 water quality	Medium positive relation displays that surface water can affect the quality of water
F3Soil water reserve	F9 Forest resources	Low positive relation because the soil water reserve could maintain the growth of forests
F3Soil water reserve	F16 Pasture and cattle raising	Medium positive relation because the more we have water the more grass we have for the cattle
F3Soil water reserve	F17 Rainfed cropland	Medium positive relation because rainfed croplands depend on water
F4 Flooding	F6 Water availability in reservoirs	Low negative relation due to the damage that could be done by flooding
F4 Flooding	F5 Soil degradation	Low positive relation because flooding may cause runoff that leads to the soil degradation
F5 Soil degradation	F3Soil water reserve	Medium negative relation because when soil is degraded its retention capacity decreases
F5 Soil degradation	F8 water quality	Medium negative relation because when soil is degraded the salinity increases and affects water quality
F6 Water availability in reservoirs	F7 Irrigated cropland	Medium positive relation because when we have water in reservoirs the irrigated cropland will not depend only on rainy seasons
F7 Irrigated cropland	F8 water quality	Low negative relation because of the use of fertilizers and pesticides
F7 Irrigated cropland	F1 Water demand	Strong positive relation because of the water-consuming crops (watermelon, tomatoes…)

F7 Irrigated cropland	F12 Job creation	Medium positive relation because developed agriculture attracting somehow employers
F8 Water quality	F15 population livelihood and settlements	Low positive relation because in somehow when the water quality is good it might improve the population livelihood and hence it would have a positive impact on population-related sectors
F9 Forest resources	F2 surface water and ground water	Low negative relation because in some way with more forest we have more trees consuming water from aquifers
F9 Forest resources	F5 Soil degradation	Medium negative relation because forest resources contribute in protecting the soil
F9 Forest resources	F8 water quality	Low positive relation because forest protect soil from degradation and eventually the water quality, moreover the growth of forest does not require fertilizers so the water quality is intact
F10 Water demand	F5 water availability in reservoirs	Medium negative relation because when the water demand goes up the water availability decreases especially in summer
F11 soil and water conservation techniques	F3 soil water reserve	Medium positive relation because these techniques would decrease the runoff so the soil water reserve is preserved
F11 soil and water conservation techniques	F4 Flooding	Medium negative relation because these techniques can lessen the impact of flooding
F11 soil and water conservation techniques	F5 Soil degradation	Medium negative relation because these techniques can lessen the impact of the rainfall and runoff that cause the soil degradation
F11 soil and water conservation techniques	F5 water availability in reservoirs	Medium positive relation because these techniques provide the protections of reservoirs and do not allow sediment storage in reservoirs. They keep the storage capacity of the reservoirs
F11 soil and water conservation techniques	F12 Job creation	Low positive relation because these techniques require workers and funding, which is lacking currently
F12 Job creation	F15 population livelihood and settlements	Medium positive relation because more jobs may attract more people
F13 Forest fire	F5 Soil degradation	Medium positive relation because fire will damage plants and trees so it will accelerate the soil degradation
F13 Forest fire	F9 Forest resources	Medium negative relation for the fact that more fires destroy forest resources
F14 Industry and tourism	F8 water quality	Low negative relation because of the waste water of factories, olive presses…
F14 Industry and tourism	F10 Water demand	Low positive relation because growing industry and tourism need more water
F14 Industry and tourism	F12 Job creation	Low positive relation because when the industrial and touristic sectors grow, they create jobs

F15 population livelihood and settlements	F7 Irrigated cropland	Low positive relation. higher population would require more food production
F15 population livelihood and settlements	F8 water quality	Medium negative relation because the growth of population livelihood affect the water quality
F15 population livelihood and settlements	F9 Forest resources	Medium negative relation because of the growth of urbanization.
F15 population livelihood and settlements	F10 Water demand	Medium positive relation because when population grows, it needs more water
F15 population livelihood and settlements	F13 Forest fire	Medium positive relation and this is due to the lack of awareness to the importance of forest resources
F15 population livelihood and settlements	F16 Pasture and cattle raising	Low positive relation. This relation is due to the fact that when jobs are created they will target the population livelihood so pasture and cattle raising increases
F15 population livelihood and settlements	F17 Rainfed cropland	Low positive relation. Higher population would require more food production
F16 Pasture and cattle raising	F2 surface water and ground water	Low negative relation because more cattle means more needs in water
F16 Pasture and cattle raising	F5 Soil degradation	Medium positive relation because of the overgrazing and overexploitation of the land
F16 Pasture and cattle raising	F9 Forest resources	Low negative relation because of the overgrazing
F17 Rainfed cropland	F2 surface water and ground water	Low negative relation because rainfed croplands depend on surface and ground water coming from precipitations
F18 Dry periods	F2 surface waterand ground water	Medium negative relation because in dry periods surface water and groundwater are the most important water supply
F18 Dry periods	F5 Soil degradation	Low positive relation because in dry periods vegetation cover will decrease and during autumn period precipitations on bare soils will probably lead to soil loss. The evaporation processes active during dry periods and leads generally to the salinization of the soil surface (bring the salt on surface)
F18 Dry periods	F5 water availability in reservoirs	Low negative relation because in dry periods there is a frequent use of water from the reservoirs
F18 Dry periods	F9 Forest resources	Low negative relation because in dry periods forest resources became more fragile
F18 Dry periods	F13 Forest fire	Medium positive relation because high temperature can ignite fire
F18 Dry periods	F16 Pasture and cattle raising	Low negative relation because in dry periods pasture and cattle raising are affected due to the vegetation shortage

F18 Dry periods	F17 Rainfed cropland	Low negative relation because in dry periods rainfed croplands are affected because of lack of precipitation

Documentation of the Fuzzy Cognitive Map for the Tordera river basin

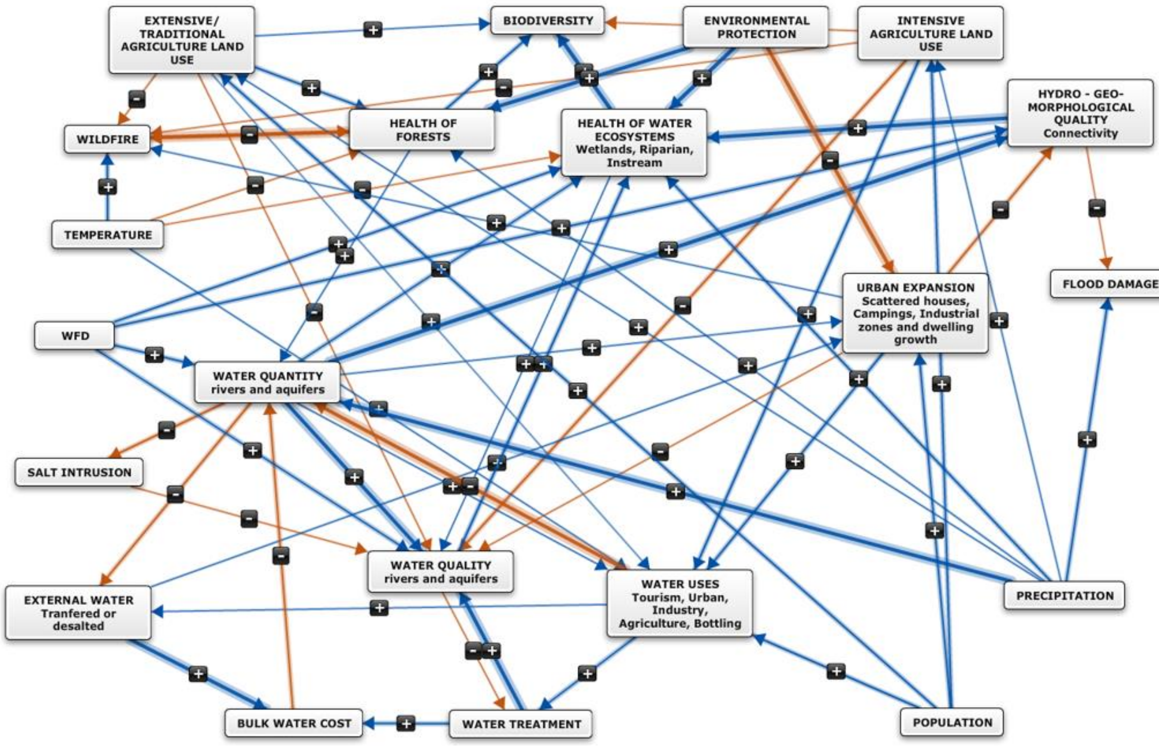


Figure S3: Fuzzy Cognitive Map developed for the Tordera river basin.

Table S6: Definition of the factors for the Tordera river basin

Number	Factors	Definition
F1	Wildfire	Forest fire
F2	Health of forests	Composition of species, forest structure and functionality.
F3	Extensive/ traditional agriculture land use	Refers to enterprises with a low input exploitation model. Factor refers to land use, water use these activities enhance is considered part of the F6
F4	Biodiversity	Indicates level of biodiversity in all ecosystems
F5	Water quality	Refers to chemical and biological quality of rivers; chemical quality of aquifers.
F6	Water uses	Urban, Tourism, Industry, Agriculture, Bottling are main uses considered.
F7	Intensive agriculture land use	Refers to enterprises with a high input exploitation model. Factor refers to land use, water use these activities enhance is considered part of the F6
F8	Temperature	Temperature of the air
F9	Health of water ecosystems	Quality of wetlands, riparian, in-stream ecosystems

F10	Salt intrusion	Lowering level of freshwater in aquifers entails intrusion of seawater.
F11	Water quantity	Refers to the volumes of water flowing in rivers, the level of aquifers and feed in ratio of all related water bodies.
F12	Hydro - geo-morphological quality	Broad concept, Includes: river space, all forms of connectivity and delta/coastline morphology. This factor includes Sediment flows (mobilization of sand, gravel and all solid components)
F13	Urban expansion	Scattered houses, Camping, Industrial zones and dwelling growth
F14	External water	Refers to all input from no natural sources of the basin: Transferred from other basins or produced through desalinization or reclaiming plants.
F15	Bulk water cost	Refers to the real costs to obtain bulk water
F16	Water treatment	The presence of wastewater treatment facilities, as well as purification plants.
F17	Flood damage	Refers to the impact on people and infrastructure of floods.
F18	Precipitation	Precipitation regime
F19	Population	Refers to both resident and tourist population
F20	WFD	Refers to those management and policy measures implemented to meet WFD objectives
F21	Environmental protection	Refers to all legislation aiming at environmental protection: N2K, PEIN, Parks, etc.

Table S7: Documentation of the relationships for the Tordera river basin

Relationship	Explanation
F1 Wildfire to F2 Health of Forests	Strong negative relation because where forest fires occur, it destroys the whole ecosystem.
F2 Health of Forests ***to*** **F1 Wildfire**	Medium negative relation because the structure of forests determinate the conditions for wildfires to occur.
F2 Health of Forests ***to*** **F4 Biodiversity**	Medium positive relation because forest ecological quality and functionality are crucial for biodiversity to develop.
F2 Health of Forests ***to*** **F11 Water Quantity**	Light negative relation because the level of water consumption of the forest evapotranspiration is influenced by its structure and composition.
F3 Ext. Agric. ***To*** **F1 Wildfire**	Light negative relation because extensive agriculture increases quality of land use mosaic and reduces fuel load in forests through livestock grazing.
F3 Ext. Agric. ***to*** **F2 Health of Forests**	Medium positive relation because extensive agriculture helps reducing understory vegetation through livestock grazing.
F3 Ext. Agric. ***to*** **F4 Biodiversity**	Light positive relation because traditional agricultural practices generate specific ecosystems and may function as ecological niche and corridor.
F3 Ext. Agric. ***to*** **F5 Water Quality**	Light negative relation because extensive agriculture uses little pesticides and fertilizers (niche products), uses more adapted crops, has better soil quality and may allow riparian / wetlands to co-exist in plots (bio-depuration).
F2 Health of Ecosystems ***to*** **F1 Wildfire**	Medium negative relation because healthy ecosystems the probability of wildfires occurrence, although this is not the only factor involved in prevention conditions.

F2 Health Of Ecosystems *to* F4 Biodiversity	Strong positive relation, as this factor is the main condition for biodiversity to develop.
F2 Health Of Ecosystems *to* F5 Water Quality	Medium positive relation because healthy ecosystems related to water bodies have a strong depurative function until a certain degree of pollution.
F3 Ext. Agric. *to* F6 Water Uses	Light negative relation because extensive agriculture land use is rainfed or supplied by gravity irrigation. The latter consumes much water, but also has very big return rates. In Tordera hydrogeology return rates go directly back to water bodies.
F5 Water Quality *to* F9 Health of Water Ecosystems	Light positive relation because clean water enhances ecosystem health, while pollution may be only partially absorbed by ecosystems.
F5 Water Quality *to* F16 Water Treatment	Light negative relation because purification treatment is less intensive when water quality is higher, but still needed in most cases.
F6 Water Uses *to* F11 Water Quantity	Strong negative relation because Tordera basin suffers strong overexploitation.
F6 Water Uses *to* F14 External Water	Light positive relation because demand is the main impulse for unconventional water production.
F6 Water Uses *to* F16 Water Treatment	Medium positive relation because all uses affect water quality and most wastewater should be treated.
F7 Intensive Agr. *to* F1 Wildfire	Light negative relation because intensive agriculture farming clears the land and contributes to land use mosaic, reducing wildfire fuel.
F7 Intensive Agr. *to* F4 Biodiversity	Light negative relation because intensive agriculture farm practices strongly degrade biodiversity
F7 Intensive Agr. *to* F5 Water Quality	Medium negative relation because intensive farming practices are highly polluting and occupy riparian areas (no buffer strips) increasing direct runoff into rivers
F7 Intensive Agr. *to* F6 Water Uses	Medium positive relation because intensive agriculture has a strong and consolidated demand, in the lower part of the river.
F5 Water Quality *to* F6 Water Uses	Light positive relation because water quality is a limiting factor to water uses, due to high treatment costs. Especially relevant aspect in Tordera.
F5 Water Quality *to* F15 Bulk Water Cost	Light negative relation (actually could be stronger) because salt intrusion and nitrate pollution in groundwater are very costly processes to be developed for drinkwater production.
F8 Temperature *to* F1 Wildfire	Medium positive relation because especially in summer, high temperatures generate the conditions for wildfires to occur.
F8 Temperature *to* F2 Health of Forests	Light negative relation because forest ecosystems suffer from high temperature, even though some species are adapted.
F8 Temperature *to* F6 Water Uses	Light positive relation because agriculture and urban (tourism) water demands increase with high temperature, but this is not valid for bottling plants and industry.
F8 Temperature *to* F9 health of water Ecosystems	Light negative relation because temperature increases evaporation and temperature of the water, but the effect on water ecosystems depends on many factors.
F9 Health of Water Ecosystems *to* F4 Biodiversity	Strong positive relation because water ecosystems highly contribute to quality of biodiversity.

F9 Health of Water Ecosystems *to* F5 Water Quality	Light positive relation because the capacity of water depuration by water ecosystems is constraint to many environmental conditions.
F10 Salt intrusion *to* F5 Water Quality	Light negative relation because the phenomenon is limited to the lower part of the basin. In those areas this is a crucial factor and relationship is strong.
F11 Water Quantity *to* F5 Water Quality	Strong positive relation because quantity determinates water quality at all levels.
F11 Water Quantity *to* F6 Water Uses	Light positive relation because water quantity is a limiting factor to all uses, but the availability of external water may reduce this weight.
F11 Water Quantity *to* F9 Health of Water Ecosystems	Medium positive relation because adequate flow regime is a precondition to ecosystems to exist.
F11 Water Quantity *to* F10 Salt intrusion	Medium negative relation because the phenomenon is limited to the lower part of the basin. In those areas this is a crucial factor and relationship is strong.
F11 Water Quantity *to* F14 External Water	Medium negative relation because Tordera is an overexploited Basin and external water is partially compensating the lack available flows for some uses.
F12 Hydro-Geo-m. *to* F9 Health of Water Ecosystems	Strong positive relation because river morphology is crucial to enhance habitats for the ecosystem to develop
F12 Hydro-Geo-m. *to* F17 Flood Damage	Light negative relation as flood damage to dwellings and people is directly proportional to the quality of river morphology.
F13 Urban Expansion *to* F1 Wildfire	Light positive relation because the more people living in scattered houses or touristic dwellings, the more the risk of wildfire increases
F13 Urban Expansion *to* F5 Water Quality	Light negative relation because the expansion of dwellings also implies more wastewater pollution and most small settlements do not have any treatment facilities.
F13 Urban Expansion *to* F6 Water Uses	Medium positive relation because increased settlements entail increased urban water use.
F13 Urban Expansion *to* F12 Hydro-Geo-m.	Medium negative relation because much urban expansion - especially industrial areas in the middle part of the basin - are positioned in the river space.
F14 External Water *to* F13 Urban expansion	Light positive relation because when there is no water availability for new demands, unconventional water resources are produced.
F14 External Water *to* F 15 Bulk Water Cost	Strong positive relationship, because water desalting and reclaiming plants are costly investments and entail energy consumption.
F 15 Bulk Water Cost *to* F11 Water Quantity	Strong negative relation, as direct catchments from water bodies are cheaper than external water, when bulk water price is high, water service entities will increase direct catchments, reducing the water quantity in water bodies.
F16 Water Treatment *to* F5 Water Quality	Strong positive relation as the presence of water treatment facilities are the main precondition for enhancing water quality.

F16 Water Treatment *to* F 15 Bulk Water Cost	Medium positive relation because water treatment facilities are costly investments and entail energy consumption.
F 18 Precipitation *to* F2 Heath of Forests	Light positive relation because Mediterranean forests ecosystems are sensible to variations in precipitation
F 18 Precipitation *to* F3 Ext. Agric.	Light positive relation because extensive agriculture depends a lot on precipitation but also has more resilience due to the use of native species.
F 18 Precipitation *to* F7 Intensive Agr.	Light positive relation because intensive agricultural practices depend on precipitation, but integrate natural resources with irrigation from regulated water bodies.
F 18 Precipitation *to* F9 Health of Water Ecosystems	Medium positive relation because water related ecosystems are highly dependent on precipitation, especially those in wetlands and smaller streams.
F 18 Precipitation *to* F11 Water Quantity	Strong positive relation because water flows in all water bodies depends on precipitation.
F 18 Precipitation *to* F17 Flood Damage	Medium positive relation because flood intensity is highly related to the intensity of precipitation, although the damage largely depends on the presence of infrastructure and people in the flooding zone.
F19 Population *to* F3 Ext. Agric.	Medium positive relation because extensive agriculture engages a high number of people and food produced is mostly consumed locally.
F19 Population *to* F6 Water Uses	Medium positive relation because this is the direct pressure on urban demand, the most relevant demand in the Basin.
F19 Population *to* F7 Intensive Agr.	Medium positive relation because in the lower part of the basin intensive horticulture is the main agriculture activity and engages many people.
F19 Population *to* F13 Urban Expansion	Medium positive relations because touristic facilities are growing in the basin and so do interregional transport facilities.
F20 WFD *to* F5 Water Quality	Medium positive relation because this legal framework has many actions orientated to directly increase water quality, but it is only partially implemented.
F20 WFD *to* F9 Health of Water Ecosystems	Medium positive relation because this legal framework has many actions orientated to directly increase water related ecosystems, but it is only partially implemented.
F20 WFD *to* F11 Water Quantity	Medium positive relation because this legal framework has many actions orientated to directly increase water flows in rivers and aquifers, but it is only partially implemented.
F20 WFD *to* F12 Hydro-Geo-m.	Medium positive relation because this legal framework has many actions orientated to directly increase Hydro-geo-morphological quality, but it is only partially implemented.
F21 Environmental protection *to* F2 Heath of Forests	Strong positive weight because in Tordera most healthy forests are those with more protection strategies.
F21 Environmental protection *to* F9 Health of Water Ecosystems	Strong positive weight because environmental protection strategies are crucial to avoid complete destruction of Tordera water bodies.
F21 Environmental protection *to* F13 Urban Expansion	Strong negative weight because constructions are prohibited or limited in environmentally protected areas.

Documentation of the Fuzzy Cognitive Map for the Vipava river basin

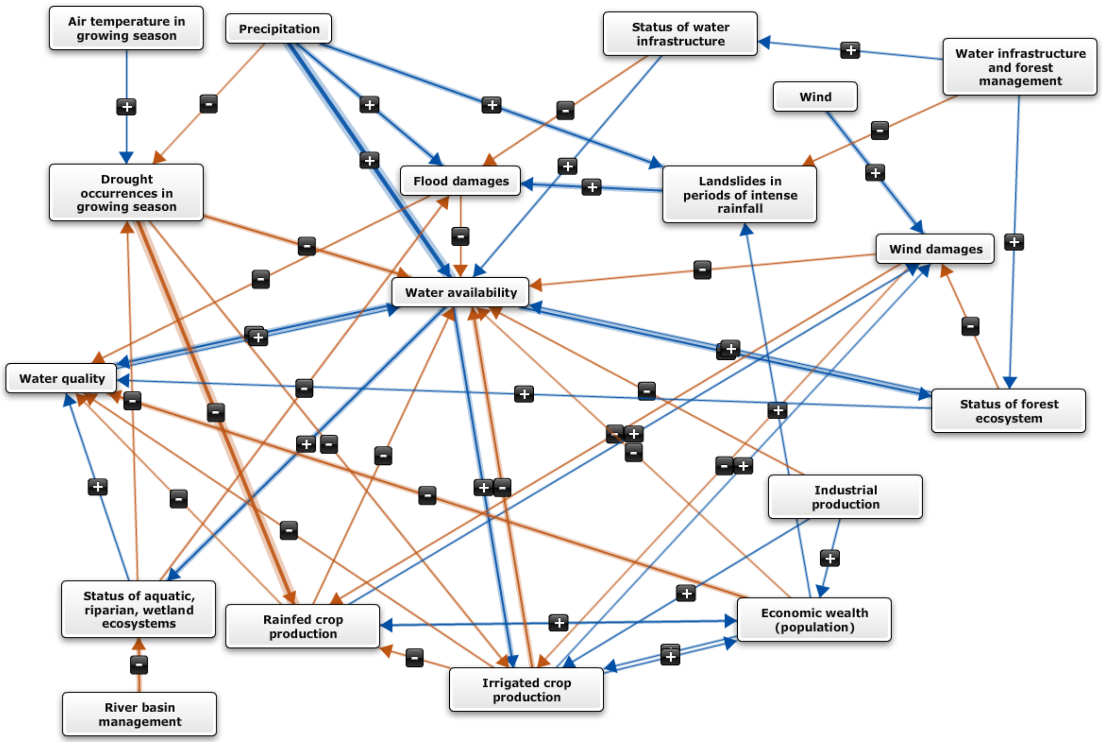


Figure S4: Fuzzy Cognitive Map developed for the Vipava river basin.

Table S8: Definition of the factors for the Vipava river basin

Number	Name of factor	Definition
F1	Precipitation	Annual average precipitation.
F2	Air temperature in growing season	Growing season - the period of time in a given year when the climate is prime for both indigenous and cultivated plants experience the most growth.
F3	Wind	Strong bora wind, cold and gusty north-eastern wind, especially in the cold half of the year (October to March).
F4	Water infrastructure and forest management	Management of water infrastructure of aquatic and riparian area, forests.
F5	Drought occurrences in growing season	Droughts that occur in growing season. Meaning meteorological and hydrological droughts.
F6	Flood damages	Damages caused by floods along the Vipava river and its tributaries.
F7	Landslides in periods of intense rainfall	Landslides on the slope of the Vipava valley – mostly associated with geological and morphological conditions.
F8	Wind damages	Damages caused by strong bora wind.
F9	Status of water infrastructure	Physical condition of existing water infrastructure – e.g. accumulation with dam (Vogrščček), river embankments, check dams (storage of sediments)

F10	Status of forest ecosystems	Ecological condition of forest ecosystems.
F11	Status of aquatic, riparian, wetland ecosystems	Ecological, Hydrological, Morphological, Biological status of aquatic, riparian and wetland ecosystems
F12	Water availability	The availability of the water at its source (river, spring, accumulation) for all users – ecosystems and needs arising from human activities.
F13	Water quality	Physical-chemical parameters of water.
F14	River basin management	Management of surface waters and groundwater; e.g. the status, program of measures, maintenance and investment work planned and carried by concessionaire with confirmation of ministry responsible for the environment.
F15	Rainfed crop production	Crops that are not irrigated and they are dependent only from rain.
F16	Irrigated crop production	Crops that are irrigated (also in closed spaces – glasshouses).
F17	Economic wealth (population)	Including population and settlements development in the RB.
F18	Industrial production	Mostly food processing and textile industry.

Table S9: Documentation of the relationships for the Vipava river basin

From	To	Justification	Strength of the relationship
F1	F5	more precipitation mean less drought occurrences	1-: weak negative relationship
F1	F6	longer periods of rainfall or even shorter periods of heavy rainfal cause flood events that cause damages mostly to infrastructure	2+: medium positive relationship
F1	F7	longer periods of rainfall or even shorter periods of heavy rainfal can trigger landslides; in Vipava RB it has been observed that most landslides are triggered in periods of heavy rainfall, due to impacts of water on the geological structure and formation of the terrain	2+: medium positive relationship
F1	F12	more precipitation mean more water available in streams, soil and groundwater; for ecosystems (aquatic, riparian, wetland and forest) and water users (agriculture, households, industry)	3+: strong positive relationship
F2	F5	if air temperature (average annual or monthly) in growing season is getting higher, more droughts occur (weak relationship as droughts are not affected just by the air temperature, there are other factors like changes in precipitation patterns – temporal, spatial)	1+: weak positive relationship
F3	F8	strong Bora wind (mostly from October to March) cause wind damages, mostly to infrastructure and vegetation, it does not affect the whole basin	2+: medium positive relationship

F4	F7	current management of water infrastructure is present in the basin, but is not efficient enough, not optimal drainage and maintenance of existing water infrastructure. Still management of water infrastructure is present (weak negative relationship) with the objective to decrease landslides	1-: weak negative relationship
F4	F9	current management of water infrastructure is present in the basin, but is not efficient enough, so weak positive relationship is defined as status of water infrastructure is not optimal; only important (most needed) intervention works are done and less maintenance works are carried out	1+: weak positive relationship; example for water reservoir Vogršček – leakage on the dam - intervention works were carried out but due to lack of funding only 1st phase was carried out; water infrastructure on torrents are in poor state not serving its purpose, etc.
F4	F10	forest management is present in the basin and is positively affecting status of forest ecosystem, as most of the forest is in the hinterlands of the basin (sparsely populated) and only present in small parts of the valley where established protected areas of forest along Vipava river; weak positive relationship was determined	1+: weak positive relationship; (Forest management service - units Tolmin and Ajdovščina)
F5	F12	when droughts occur in growing season there is less water available for ecosystems and their services and for water users (agriculture sector, urban users)	2-: medium negative relationship
F5	F15	increased frequency and intensity of droughts in growing season (mostly crop-growing periods) reduces the rainfed crop production (smaller or loss of income) - droughts can harm crops and reduce yields, water demand of crops is difficult to meet as water supplies are reduced	3-: strong negative relationship; SH in 1st WS indicated, that droughts pose a bigger problem for agriculture in the upper part of the RB. In the period from April to September major part of the Vipava valley is endangered or much endangered by drought. (http://geo.ff.uni-lj.si/pisnadela/pdfs/zaksem_201407_jus_znidarsic.pdf).
F5	F16	increased frequency and intensity of droughts in growing season (mostly crop-growing periods) reduces the irrigated crop production (smaller or loss of income) - droughts can harm crops and reduce yields, water demand of crops is difficult to meet as water supplies are reduced	1-: weak negative relationship; only a small part of the agricultural land is being irrigated from water reservoir Vogršček (lower part of the basin) and Vipava

			river (upper part of the basin) (irrigation needs in the Vipava Valley are greater than the available water quantities and other water sources beside water reservoir Vogršček would be needed)
F6	F12	floods cause damages to water supply systems (power failure – problems in water purifying plants, after heavy rainfall water in karst spring becomes turbid and it needs to be cleaned for further use) and so less water is available for its users	1-: weak negative relationship
F6	F13	floods cause damages to water supply systems (power failure – problems in water purifying plants, after heavy rainfall water in karst spring becomes turbid and it need to be cleaned for further use) and so quality of drinking water deteriorates, also surface water becomes turbid, carrying potential pollutants downstream – surface water quality also deteriorates	1-: weak negative relationship
F7	F6	more landslides trigger in periods of intense rainfall, more damages caused by floods occur; when landslides trigger they move large amounts of sediments, which not only stay on slopes, but also reach the fluvial network. Under catastrophic conditions, land sliding may lead to torrential outbursts, debris flows or dam-break waves after a dam-breach of natural dams. As a result, floods of larger scope occur.	2+: medium positive relationship; landslides occur on specific places of the basin, where the terrain is becoming more steep (hillslopes)
F8	F12	strong bora wind damages infrastructure and causes power failure - drinking water cannot be transported to some settlements, also purifying plant for drinking water cannot not work	1-: weak negative relationship, temporally and spatially limited impact
F8	F15	strong bora wind causes damages in agriculture mostly through wind erosion - removal of top soil, additionally drying soil and causing damages to the crops (damages to leaves); the result is lower crop production	1-: weak negative relationship, spatially limited impact meaning where planted wind barriers, this effects are not so strong, and where strong bora wind prevails, permanent grassland are present
F8	F16	strong bora wind causes damages in agriculture mostly through wind erosion - removal of top soil, additionally drying soil and causing damages to the crops (damages to leaves); the result is lower crop production	1-: weak negative relationship, spatially limited impact, where irrigation prevails, wind is not so strong and causes less damages; the expansion of irrigation

			crop production in greenhouses is also limited
F9	F6	if status of infrastructure is good, floods cause less damage	1-: weak negative relationship; spatially limited impact, e.g. water reservoir Vogršček also provides flood safety downstream, but due to leakage of the dam and not finished intervention works, lower water level is maintained by higher discharge of water into Vogršček
F9	F12	if status of water infrastructure, where present and intended for water use (e.g. irrigation system) is in good condition, working properly, more water is available for ecosystems and sectors (agriculture)	1+: weak positive relationship; spatially limited impact, some water infrastructure is present but not in good condition to fully provide water available in the basin
F10	F8	when forest is in good condition, there are less damages caused by strong bora wind	1-: weak negative relationship; weak relationship is due to low percent of forest in the form of wind barriers (wind breaks) in the valley
F10	F12	the main catchment area of the Vipava river and its tributaries are plateaus in the north, north-east side covered with forest, the status of forest ecosystem positively affects water availability in the flat part of the basin	1+: weak positive relationship
F10	F13	if the forest ecosystems is in better status, water is better quality - forests impact positively on quality of surface and ground water through minimizing soil erosion on site, thus reducing sediment in water bodies (wetlands, ponds and lakes, streams and rivers), and through trapping or filtering other water pollutants	1+: weak positive relationship; in the hinterland of the basin forests prevail, this area is also sparsely populated; good chemical status of groundwater and moderate status of surface waters
F11	F5	with better status of aquatic, riparian, wetland ecosystems more water is retained and not drained away (better retention function, infiltration of water in the ground) and so less hydrological drought occur	2-: medium negative relationship
F11	F6	with better status of aquatic, riparian, wetland ecosystems flood cause less damages, ecosystems services slow down the flow velocity – like for	1-: weak negative relationship; some floodplains and meanders

		example menders and floodplains connected to the river	are present in the lower part of the basin, and are in a function of slowing down the flow velocity, but due to cannot alone reduce the extend of floods due to regulations of the watercourses in the upper part on the basin (more rapid water runoff from the basin, increased flow velocity, decreased retention function of the riverbed and soil)
F11	F13	with better status of aquatic, riparian, wetland ecosystems better self-cleansing capability of the aquatic environment (improvement in water quality through reduced nutrients)	1+: weak positive relationship; weak relationship due to moderate ecological status of surface water
F12	F10	water available in streams, soil and groundwater, satisfies basic environmental needs and if more water is available, forest ecosystem is in better state	2+: medium positive relationship
F12	F11	water available in streams, soil and groundwater, satisfies basic environmental needs and if more water is available, aquatic, riparian, wetland ecosystems are in better state	2+: medium positive relationship
F12	F13	when there is more water in watercourses and groundwater, water quality is of better quality mostly due to dilution of (potential) pollutants	2+: medium positive relationship; in the case of where net water quantities increase by moderate amounts, and surface water quality will generally improve as streams fill and dilute their pollutants
F12	F16	when more water is available for irrigation, agriculture production is higher	2+: medium positive relationship; spatially limited impact
F13	F12	if water is of better quality, more water is available for users (drinking water, water for irrigation and industry)	1+: weak positive relationship; one of the factor, but not the most important one - for domestic use raw water is being purified (due to nature of Hubelj (and Mrzlek) karst spring, used for drinking water, water is being purified with the help of water purification plant)

F14	F11	due to past regulations of watercourses and also due to improper intervention works on watercourses, aquatic, riparian and wetland ecosystems are not achieving e.g. good status according to Water framework Directive and natural habitats and habitats of species according to Habitats Directive	2-: medium negative relationship
F15	F8	if rainfed crop production is expanded or intensified, more wind damages occur due to expansion of arable land – in the past farmers alone have removed wind barriers that were introduced with Republic Green plan to expand the arable land – consequently more wind damages occur	1+: weak positive relationship
F15	F12	if rainfed crop production is expanded or intensified, the higher water uptake by plants and less water available for water-dependent ecosystems and sectors	2-: medium negative relationship
F15	F13	if rainfed crop production is expanded or intensified, water quality deteriorates due to the use of plant protection products and nutrients	1-: weak negative relationship; less pollution than from settlements (nutrients), but still present in Vipava RB, fungicides in fruit growing, Viticulture
F15	F17	if rainfed crop production is expanded or intensified, economic wealth gets higher – jobs guaranteed with higher income	1+: weak positive relationship
F16	F8	if irrigated crop production is expanded or intensified, more wind damages occur due to expansion of arable land – in the past farmers alone have removed wind barriers that were introduced with Republic Green plan to expand the arable land – consequently more wind damages occur	1+: weak positive relationship; limitations for vegetable crop production in closed areas (greenhouses) as wind tends to damage infrastructure
F16	F12	if irrigated crop production is expanded or intensified, less water is available for water-dependent ecosystems and sectors	2-: medium negative relationship; Water is used for irrigation that means irreversible water use. Irrigation crop production is present mostly in the lower part of the basin, near water reservoir Vogrščnovel and where irrigation systems are present and functioning. In the upper part of the basin, irrigation of agricultural land is also present and the Vipava River is the only water source for irrigation

F16	F13	if irrigated crop production is expanded or intensified, water quality deteriorates due to the increased use of plant protection products and fertilizers	1-: weak negative relationship; less pollution than from settlements (nutrients), but still present in Vipava RB, fungicides in fruit growing, vegetable crop production
F16	F15	if irrigated crop production is expanded or intensified, area intended for rainfed crop production decreases – only if no expansion of arable land is planned	1-: weak negative relationship
F16	F17	if irrigated crop production is expanded or intensified, economic wealth increases – jobs guaranteed, self-sufficiency increases	1+: weak positive relationship; due to low purchase prices, agriculture crop productions is not so strong(e.g. peaches)
F17	F7	with increased economic wealth the expansion of settlement (individual houses) also occur and if the buildings extend into "problematic »terrain more landslides in periods of intense rainfall can occur due to inadequate regulation of storm water and hinterland water drainage	1+: weak positive relationship; spatially limited impact – on the slopes
F17	F12	if economic wealth gets higher and the population increases, domestic water use decreases water availability	1-: weak negative relationship; less water is used compared to the past, some SH say that due to the economic crisis people care more about the consumption
F17	F13	if economic wealth and the population increases, water quality deteriorates (more waste, waste waters) – in basin small and dispersed settlements have insufficient drainage and municipal wastewater treatment that are causing organic pollution of the surface water	2-: medium negative relationship
F17	F15	if economic wealth and population growth increases, rainfed crop production can be expanded or intensified due to increase in demand for food	1+: weak positive relationship
F17	F16	if economic wealth and population growth increases, irrigated crop production can be expanded or intensified due to increase in demand for food	1+: weak positive relationship
F18	F12	if the industrial production increases (heavy industry), water availability decreases – industry using a great amount of water (Fructal, Mlinotest, Tekstina) impacts water availability (where the same water source is being used - Vipava river, Hubelj spring)	1-: weak negative relationship; only if industry increases the consumption of water

F18	F16	if the industrial production increases (food processing industry, beverage production), irrigated crop production is expanded or intensified due to the increase in demand for crops	1+: weak positive relationship; industrial activities, food processing, beverage production purchase crops – right now as food processing industry is not so strong, low purchase prices for peaches allow only a small portion of irrigated crop production
F18	F17	if the industrial production increases, economic wealth together with population growth increases	1+: weak positive relationship; industrial activities (SME) are not so strong but still people work there and so the industry enables population development and economic wealth

A1.2. Material suplementario: Participatory Evaluation of Water Management Options for Climate Change Adaptation in River Basins

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 €

	100,000 - 1,000,000 €
	> 1,000,000 €
Operational costs	< 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	✓		✓	✓
Feasability	✓		✓	✓
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 reservoris				✓
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 infraestructure		✓		
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	€€

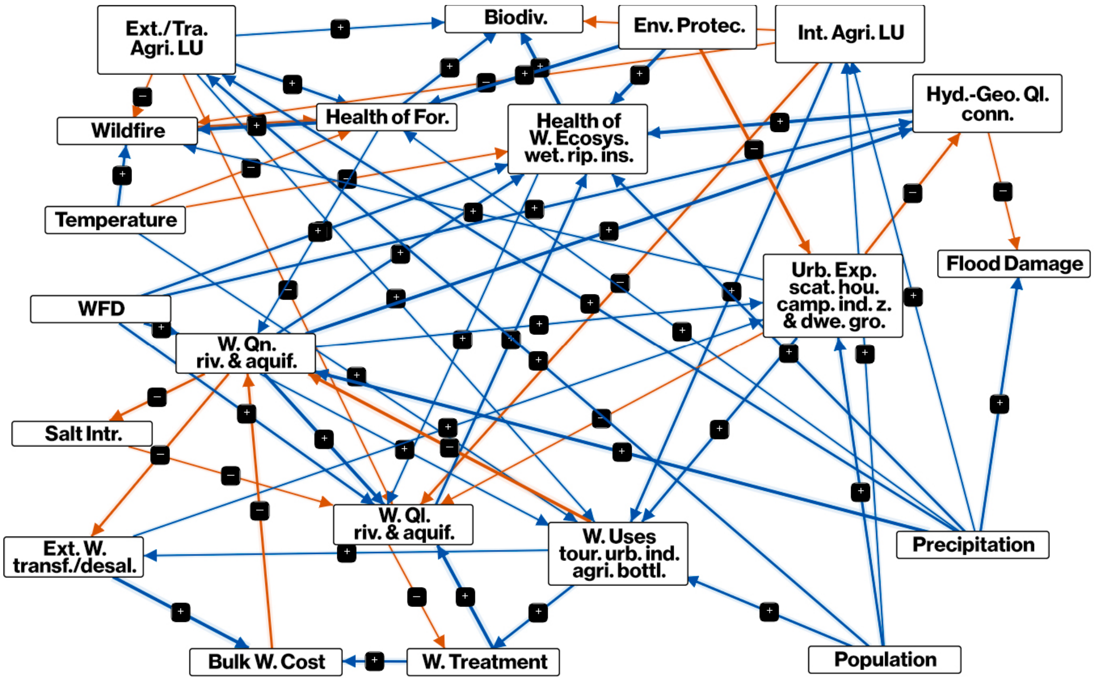


Figure S1. Fuzzy Cognitive Map developed for the Tordera river basin. Line thickness indicates the strength of the relationship (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships. Factors abbreviations (from left-up to right and downwards): Extensive/Traditional 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.

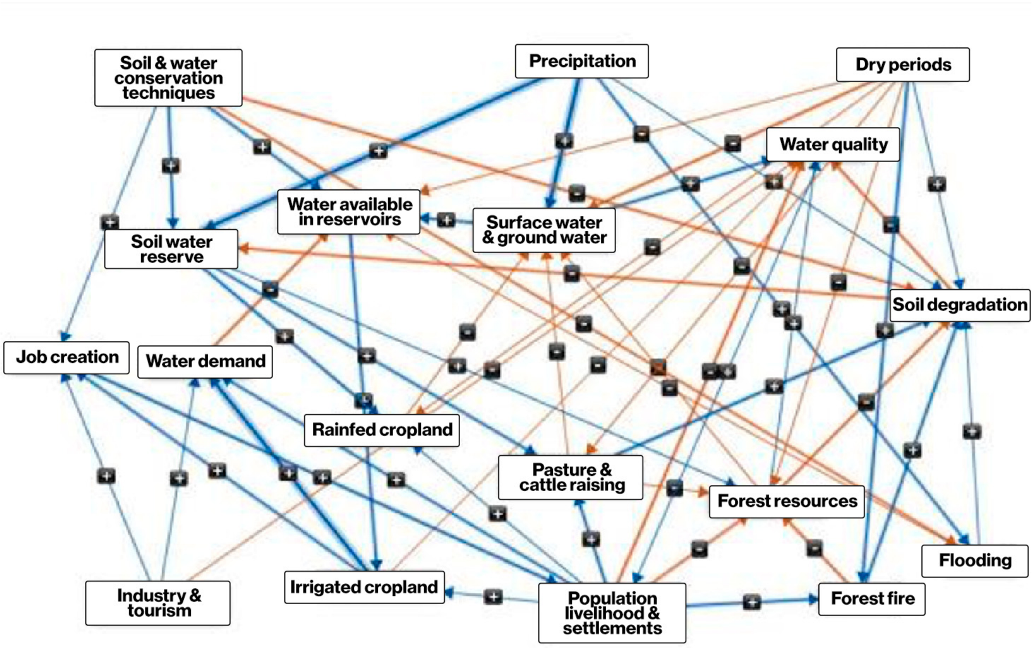


Figure S2. Fuzzy Cognitive Map developed for the Rmel river basin. Line thickness indicates the strength of the relationship between factors (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships.

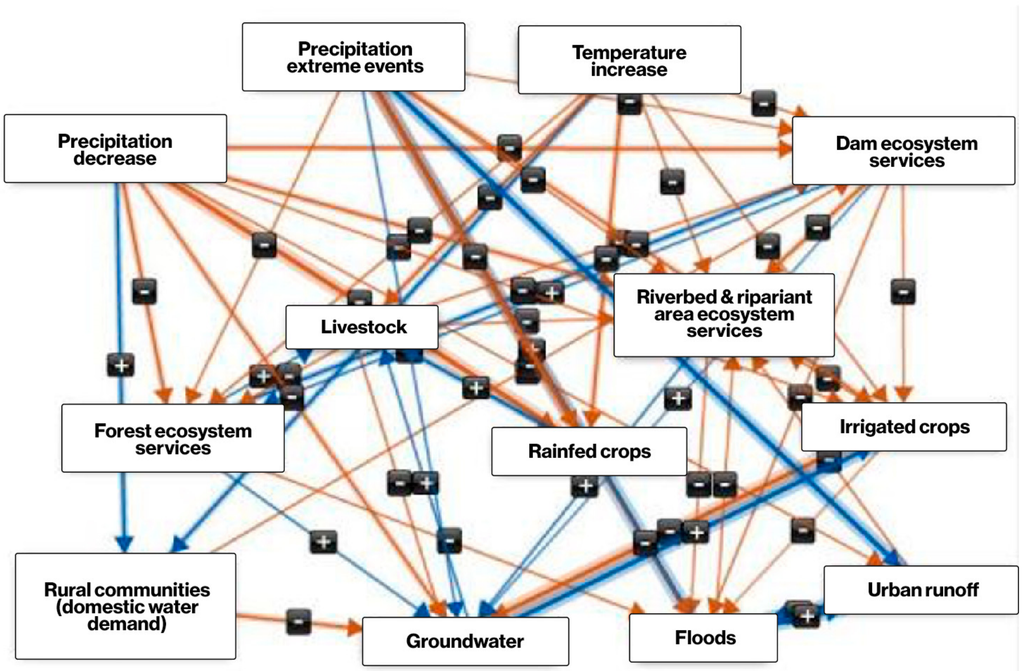


Figure S3. Fuzzy Cognitive Map developed for the Pedieos river basin. Line thickness indicates the strength of the relationship between factors (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships.

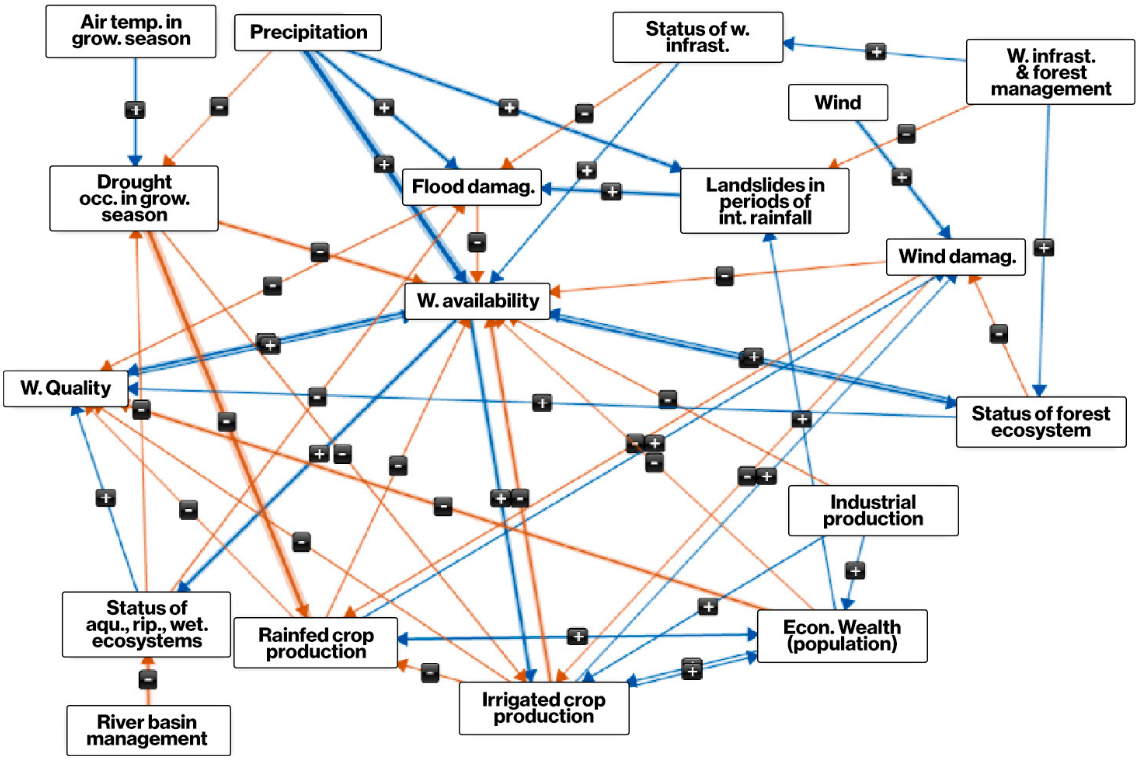
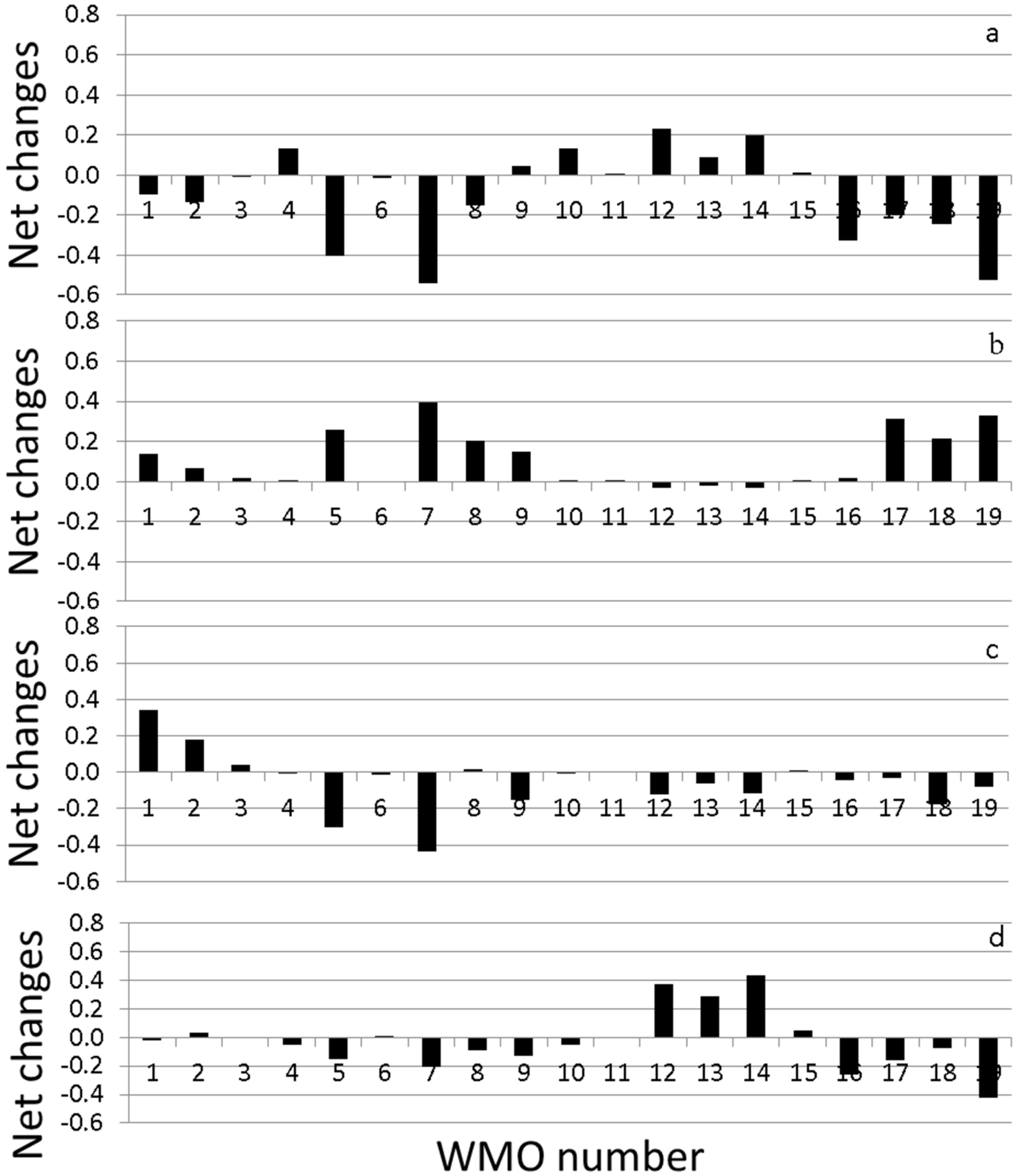


Figure S4. Fuzzy Cognitive Map developed for the Vipava river basin. Line thickness indicates the strength of the relationship (the thicker the stronger) and line color indicates positive (blue) or negative (red) relationships. Factors abbreviations (from left-up to right and downwards): Air temperature 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.



a
b
c
d
Net changes
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
WMO number

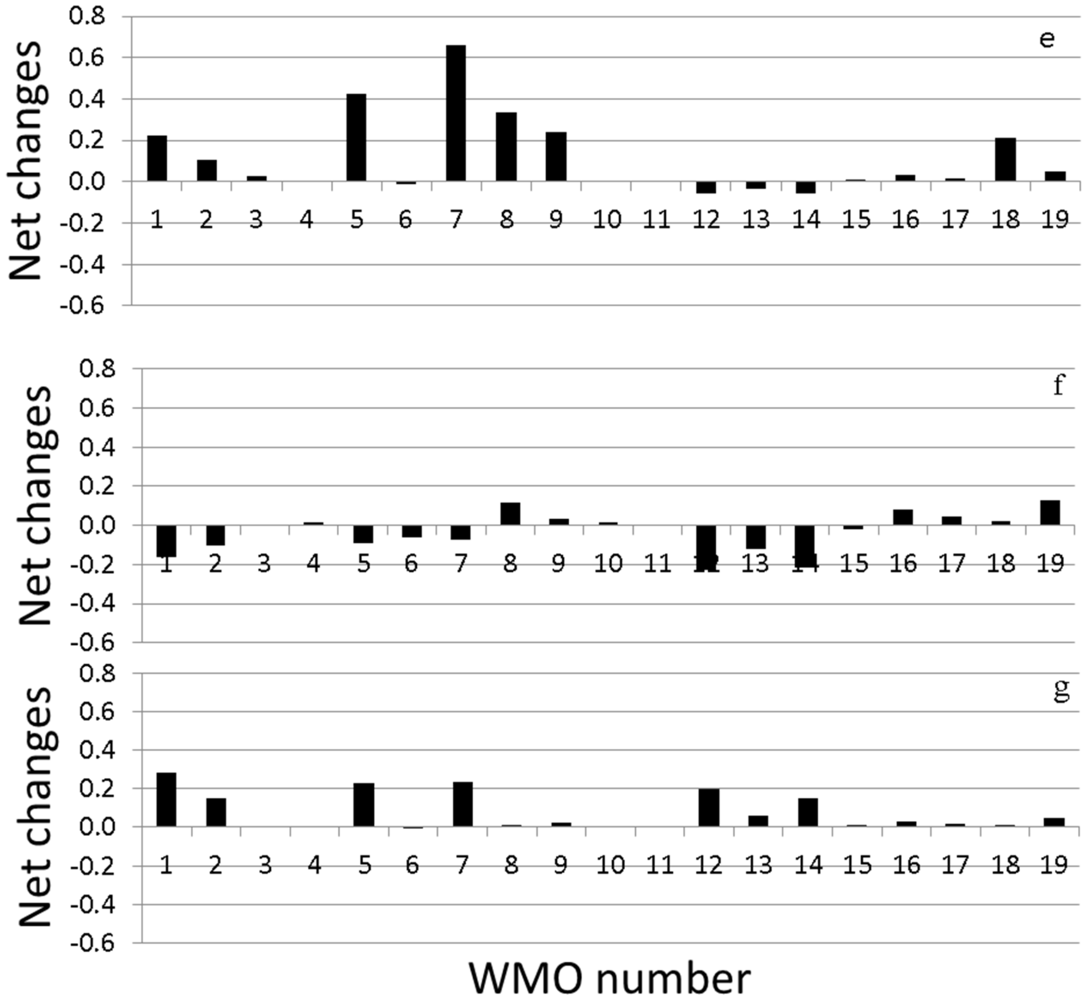


Figure S5. Graph showing how Rmel river basin challenges are impacted by all WMOs as net changes from baseline situation estimated with the FCM. Impacts on challenges: a) Water quality, b) Job creation, c) Water availability in reservoirs, d) Forest resources, e) Irrigated cropland, f) Surface water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

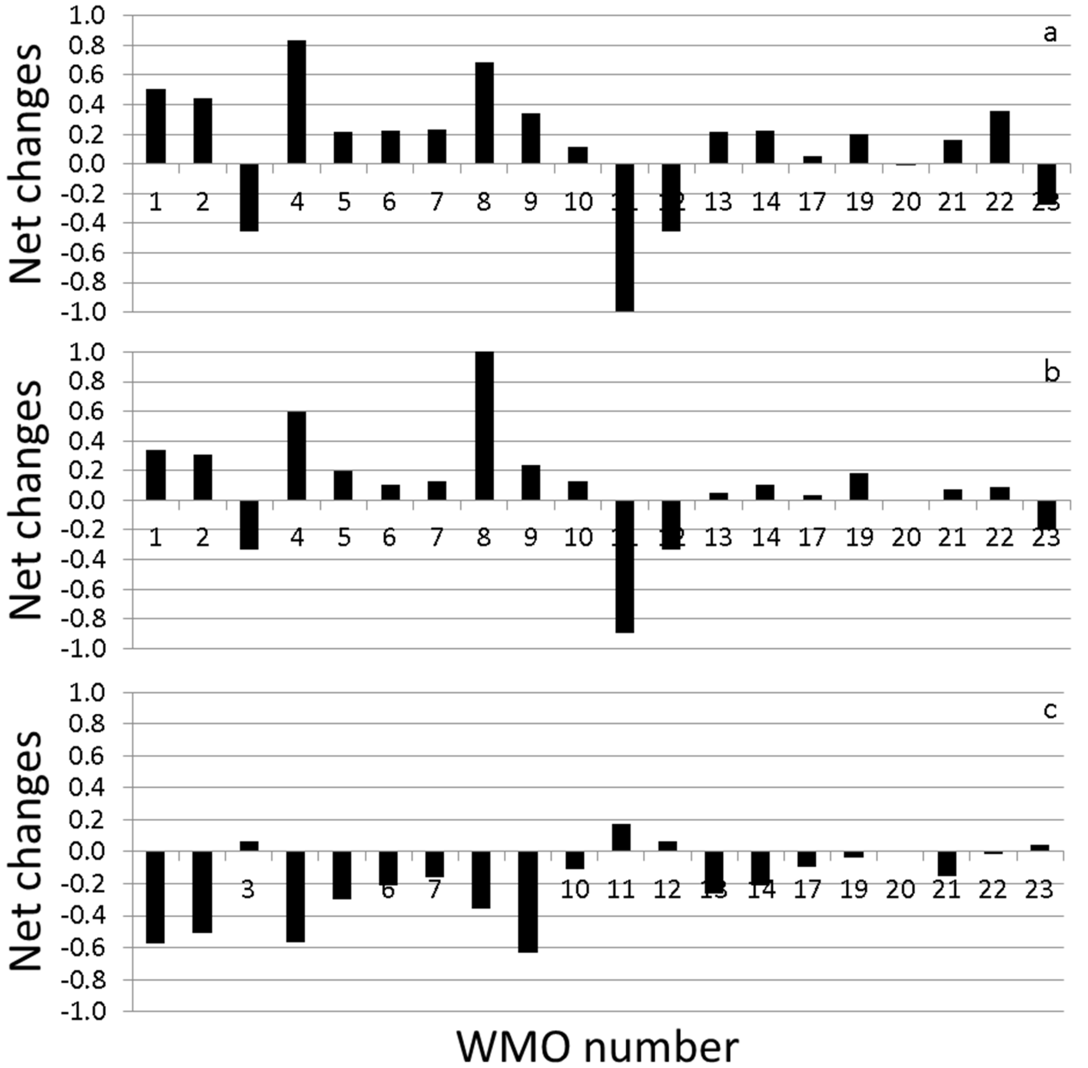


Figure S6. Graph showing how Vipava river basin challenges are impacted by all WMOs as net changes from baseline situation estimated with the FCM. Impacts on challenges: a) Water quality, b) Water availability and c) Flood damages.

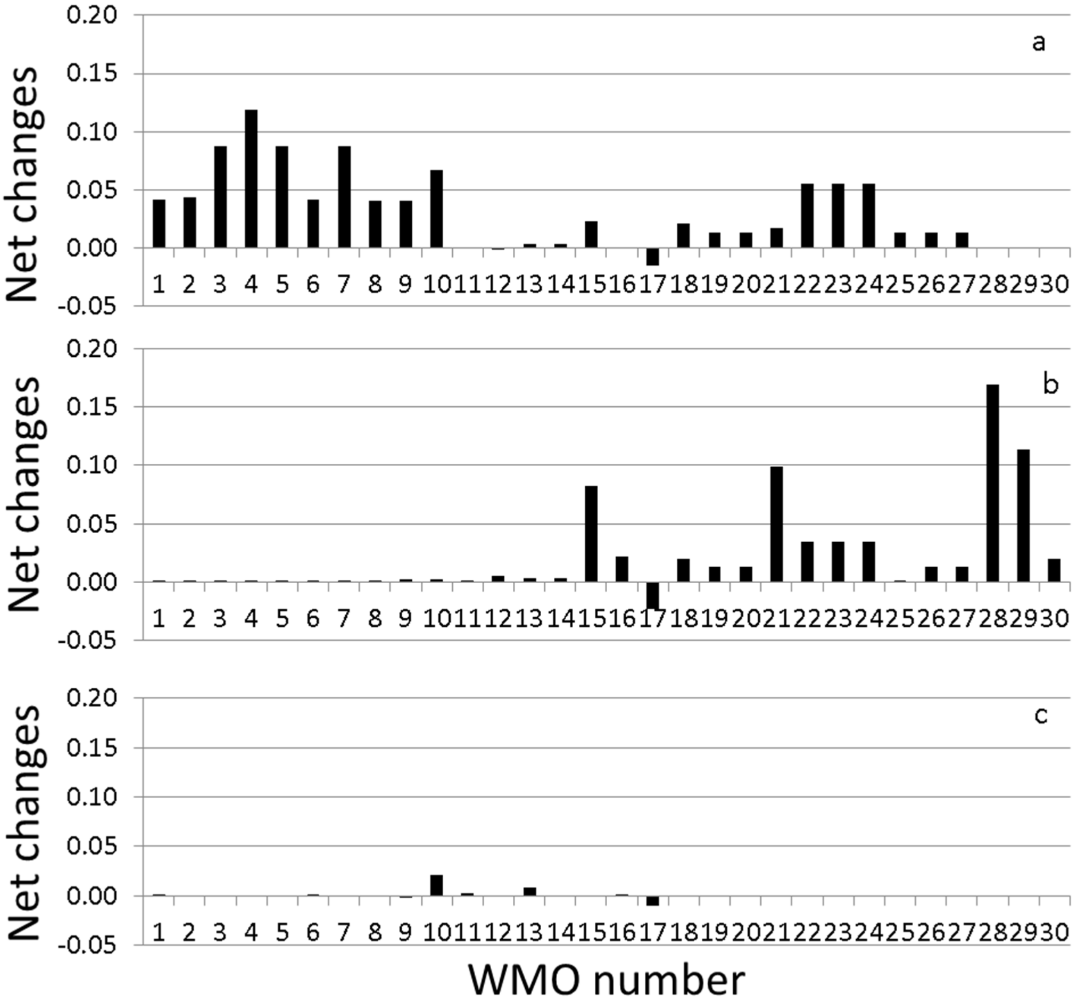


Figure S7. Graph showing how Pedieos river basin challenges are impacted by all WMOs as net changes from baseline situation estimated with the FCM. Impacts on challenges: a) Groundwater, b) Flood, and c) Dam ecosystem services (proxy of surface water status).

A1.3. Material suplementario: Analytical Framework to Assess the Incorporation of Climate Change Adaptation in Water Management: Application to the Tordera River Basin Adaptation Plan.

Supplementary materials

Contents

Documentation of the list of literature sources analysed for the construction of the analytical framework.

Table S1. List of literature sources analysed.

1. Coral, C. and Bokelmann, W. The Role of Analytical Frameworks for Systemic Research Design, Explained in the Analysis of Drivers and Dynamics of Historic Land-Use Changes. Systems. 2017, 5 (20).
2. Djalante, R. Adaptive governance and resilience: the role of multi-stakeholder platforms in disaster risk reduction. Nat. Hazards Earth Syst. Sci. 2012, 12: 2923–2942.
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Documentation of the complete Analytical Framework to assess the incorporation of climate change adaptation in water management.

Table S2. Complete Analytical Framework containing all areas of analysis and all key evaluation questions. For answers use '+' if the question is properly considered in the plan, '±' if it is partially covered and '–' if the question is not considered in the plan.

Analytical framework and key evaluation questions		
1. Basic information		
1.1 Title		
1.2 Promoter		
1.3 Authors and type of entity they belong to		
1.4 Year of publication		
1.5 Temporal horizon		
1.6 Geographical scale		
1.7 General objective		
1.8 Annexed or complementary documents to the plan included in the analysis.		
2. Incidence area characterisation		
Key evaluation questions	**+ / ± / -**	**Comments**
2.1 Is a diagnosis made of the **current status** of the plan's incidence area?		
2.2 Does the diagnosis include a **pressure** and **impact** analysis?		
2.3 Does the diagnosis integrate **biophysical studies**?		
2.4 Does the diagnosis integrate **socio-economic studies**?		
2.5 Does the diagnosis describe the **political context**?		
2.6 Does the diagnosis describe the **legal context**?		
2.7 Does the plan describe the **methodologies** used to carry out the diagnosis?		

2.8 Are **uncertainties** related to the ecosystems and their functioning considered?		
2.9 Are the **information sources** clearly indicated and are they accessible?		
2.10 Does the diagnosis use information contained in **other studies** (scientific)?		
3. Incorporation of Climate change		
Key evaluation questions	**+ / ± / -**	**Comments**
3.1 Does the plan include **climate change projections**?		
3.2 Is the **time horizon** of the projections used indicated?		
3.3 Do climate projections come from **recognised organisms**, as for example the IPCC?		
3.4 Is the **scale** of the climate projections adequate for the scale of study? (**Climate downscaling**).		
3.5 Does the plan evaluate the **vulnerability** of the **ecosystems** found in its incidence area?		
3.6 Does the plan evaluate the **social vulnerability** of its incidence area?		
3.7 Does the plan explain how ecosystems and social vulnerabilities have been evaluated?		
3.8 Does the plan include a climate change **impacts** on the ecosystems present?		
3.9 Does the plan include a climate change **impacts** on the socio-economic sectors present?		
3.10 Does the plan indicate the **methodologies** used to evaluate climate change impacts?		
3.11 Does the plan indicate which type of **impact and vulnerability information** has been used? a. Is it quantitative information coming from modelling? b. Is it qualitative information? c. Is it semi-quantitative information? d. Is it information based on expert judgement?		
3.12 Are **scientific uncertainties** related to climate change projections and impacts on ecosystems considered?		

3.13 Does the plan clearly indicate its sources of **information** and are they **accessible**?		
3.14 Does the climate change section of the plan use information contained in **other studies** (scientific)?		
4. Structure and general content		
Key evaluation questions	**+ / ± / -**	**Comments**
4.1 Does the plan contain **specific objectives**?		
4.2 Does the plan contain **the challenges** it aims at tackling?		
4.3 Does the plan include a clear **abstract**?		
4.4 Does the plan include a **glossary** of concepts and terminology used?		
4.5 Does the plan indicate its **target audiences**?		
4.6 Is information included about the **limitations** of the plan?		
4.7 Does the plan mention the **complexity** associated with the issues included in it?		
4.8 Does the plan address in one way or another this **complexity**?		
4.9 Is there a **plan of measures**?		
4.10 Does the plan include an **implementation** strategy?		
4.11 Does the plan include a specific section on the measures' **follow up**?		
4.12 Does the follow-up section consider **indicators**?		
4.13 Does the follow-up section consider an associated **budget**?		
5. Management measures		
Key evaluation questions	**+ / ± / -**	**Comments**
5.1 Does the plan contain an in depth **description** of the measures?		
5.2 Does the plan relate specific **challenges** to the measures that intend to tackle them?		
5.3 Does the plan analyse the **adaptive** character of the measures included?		
5.4 Are management measures categorised using **adaptive criteria**? Flexibility, robustness, no-regret, win-win…		
5.5 Does the plan consider **characteristics** for the measures such as:		

a. feasibility b. acceptability c. preconditions		
5.6 Does the plan include an **economic valuation** of the measures?		
5.7 Does the plan include an **impact assessment** for the measures?		
5.8 Does the plan consider an evaluation of the **synergies, co-benefits and conflicts** between measures?		
5.9 Does the plan specify the measures' **identification and selection** mechanisms?		
5.10 Does the plan consider **uncertainties** related to the process of identification and selection of measures?		
5.11 Are **roles and responsibilities** for measure implementation defined?		
5.12 Does the plan define the **implementation time** for the measures?		
5.13 Does the plan consider **prioritisation** of measures for its implementation?		
5.14 Are **funding opportunities** for measure implementation considered?		
6. Participation		
Key evaluation questions	**+ / ± / -**	**Comments**
6.1 Has **participation** been included in the preparation of the plan? How? a. In the form of information b. In the form of consultation c. In the form of active participation d. In the form of active participation at all stages of its development		
6.2 Are the **reasons and objectives** for including participation in the plan explicit?		
6.3 Is **social learning** considered?		
6.4 Does the development of the plan consider **stakeholder mapping**?		
6.5 Have all the identified stakeholders been involved?		
6.6 Has the diversity of sectors and interests involved been sufficiently represented to		

ensure the **intersectoriality** necessary for adaptation?		
6.7 Has **specific material** been developed to facilitate interaction with participants?		
6.8 Does the plan clearly indicates which information has been collected and how has the **knowledge of participants** been **integrated** in the plan?		
6.9 Have participants been given the opportunity to make an **evaluation** on the plan development process?		
6.10 Does the plan consider the revision of current **governance structures and practices**?		
7. Implementation		
Key evaluation questions	**+ / ± / -**	**Comments**
7.1 Are **barriers and opportunities** for plan implementation indicated?		
7.2 Is there a **commitment** to implement the plan by the competent authorities?		
7.3 Is there an assessment of the level of **synergy** existing between the plan and the administrative and management context?		
7.4 Does the plan consider **uncertainties** related to possible inconsistencies between the definition of measures and their actual implementation?		
7.5 Has an **impact assessment of the plan** been considered?		
7.6 Does the plan foresee future **revisions**?		
7.7 Does the plan foresee the inclusion of **lessons learned** from its implementation in future management cycles?		
7.8 Does the plan clearly indicate the organisms **responsible** for the plan's evaluation?		
7.9 Does the plan include a complete **budget** and entities that could contribute co-finance its implementation?		
7.10 Has the plan and supporting documents been structured with an approach that promotes **transferability**?		
7.11 Does the plan consider developing public **dissemination and awareness** activities associated with its implementation?		

Documentation of the results of the Analytical Framework application to the TRBAP.

Table S3. Results of the Analytical Framework application to the Tordera River Basin Adaptation Plan. Categorisation of answers '+' if the question is properly considered in the plan, '±' if it is partially covered and '–' if the question is not considered in the plan.

Analytical framework and key evaluation questions		
1. Basic information		
1.1 Title	Tordera River Basin Adaptation Plan[i]	
1.2 Promoter	European Commission	
1.3 Authors and type of entity they belong to	CREAF- public research center	
1.4 Year of publication	September 2016	
1.5 Temporal horizon	2018-2030	
1.6 Geographical scale	Tordera River Basin, Catalonia, Spain.	
1.7 General objective	Develop an Adaptation to Global Change Plan for the Tordera River Basin.	
1.8 Annexed or complementary documents to the plan included in the analysis.	Methodological documentation Results documentation Guidance Document	
2. Incidence area characterisation		
Key evaluation questions	**+ / ± / -**	**Comments**
2.1 Is a diagnosis made of the **current status** of the plan's incidence area?	+	All available information has been collected and complemented with local knowledge.
2.2 Does the diagnosis include a **pressure** and **impact** analysis?	+	All available information has been collected and complemented with local knowledge.
2.3 Does the diagnosis integrate **biophysical studies**?	+	Data from the Adaptations to Climate Change in Water Use project (ACCUA[ii]) complemented with local knowledge.
2.4 Does the diagnosis integrate **socio-economic studies**?	+	Data from the ACCUA project complemented with local knowledge.
2.5 Does the diagnosis describe the **political context**?	+	Basic research conducted together with specific interviews. Participants validated results.

2.6 Does the diagnosis describe the **legal context**?	+	Basic research conducted together with specific interviews. Participants validated results.
2.7 Does the plan describe the **methodologies** used to carry out the diagnosis?	+	Methodology described in the plan. A specific participatory session with stakeholders dedicated to the diagnosis.
2.8 Are **uncertainties** related to the ecosystems and their functioning considered?	±	The studies carried out in the ACCUA project include uncertainties; these were complemented with local knowledge.
2.9 Are the **information sources** clearly indicated and are they accessible?	+	All documents accompanying the plan include exhaustive bibliographic references.
2.10 Does the diagnosis use information contained in **other studies** (scientific)?	+	Mainly: • ACCUA project, CREAF • Analysis of Pressures and Impacts (IMPRESS[iii]), Catalan Water Agency • Land Cover and Land Use Map, CREAF[iv] • IDESCAT, Generalitat de Catalunya[v]. • Information from the Plan for the Conservation of the Montseny Natural Park and Biosphere Reserve, Diputació de Barcelona[vi].
3. Incorporation of Climate change		
Key evaluation questions	**+ / ± / -**	**Comments**
3.1 Does the plan include **climate change projections**?	±	Downscaling to the study area of ECHAM5 for IPCC A2 and B1 scenarios (ACCUA).
3.2 Is the **time horizon** of the projections used indicated?	+	2030
3.3 Do climate projections come from **recognised organisms**, as for example the IPCC?	+	Yes
3.4 Is the **scale** of the climate projections adequate for the scale of study? (**Climate downscaling**).	+	Yes

3.5 Does the plan evaluate the **vulnerability** of the **ecosystems** found in its incidence area?	+	Information from ACCUA project, and cognitive map[vii].
3.6 Does the plan evaluate the **social vulnerability** of its incidence area?	+	Information from ACCUA project, and cognitive map.
3.7 Does the plan explain how ecosystems and social vulnerabilities have been evaluated?	+	Yes
3.8 Does the plan include a climate change **impacts** on the ecosystems present?	+	Information from ACCUA project, and cognitive map.
3.9 Does the plan include a climate change **impacts** on the socio-economic sectors present?	+	Information from ACCUA project, and cognitive map.
3.10 Does the plan indicate the **methodologies** used to evaluate climate change impacts?	+	Yes
3.11 Does the plan indicate which type of **impact and vulnerability information** has been used?	+	Yes
a. Is it quantitative information coming from modelling?	+	Information from ACCUA project.
b. Is it qualitative information?	+	Workshops and interviews with local stakeholders.
c. Is it semi-quantitative information?	+	Using the cognitive map
d. Is it information based on expert judgement?	+	Workshops and interviews with local stakeholders.
3.12 Are **scientific uncertainties** related to climate change projections and impacts on ecosystems considered?	±	Information from ACCUA project.
3.13 Does the plan clearly indicate its sources of **information** and are they **accessible**?	+	All documents accompanying the plan include exhaustive bibliographic references.
3.14 Does the climate change section of the plan use information contained in **other studies** (scientific)?	+	Information from ACCUA project.
4. Structure and general content		
Key evaluation questions	**+ / ± / -**	**Comments**
4.1 Does the plan contain **specific objectives**?	+	Yes
4.2 Does the plan contain **the challenges** it aims at tackling?	+	- Quantity and Quality of water. - Health of forest and water ecosystems. - Integrated water management.
4.3 Does the plan include a clear **abstract**?	+	In English and Catalan

4.4 Does the plan include a **glossary** of concepts and terminology used?	+	Yes
4.5 Does the plan indicate its **target audiences**?	+	Managers and responsible for the design and development of policies.
4.6 Is information included about the **limitations** of the plan?	+	The promoter and the authors do not have competencies for plan implementation.
4.7 Does the plan mention the **complexity** associated with the issues included in it?	+	Yes
4.8 Does the plan address in one way or another this **complexity**?	±	Through mutual learning, knowledge transfer and active participation.
4.9 Is there a **plan of measures**?	+	Yes
4.10 Does the plan include an **implementation** strategy?	-	It does not fit into the objectives of the project.
4.11 Does the plan include a specific section on the measures' **follow up**?	+	Yes
4. 12 Does the follow-up section consider **indicators**?	-	No, although the plan indicates the importance of an adequate development of indicators.
4. 13 Does the follow-up section consider an associated **budget**?	-	It does not fit into the objectives of the plan
5. Management measures		
Key evaluation questions	**+ / ± / -**	**Comments**
5.1 Does the plan contain an in depth **description** of the measures?	+	The plan has a dedicated section for in depth measure description.
5.2 Does the plan relate specific **challenges** to the measures that intend to tackle them?	+	Yes
5.3 Does the plan analyse the **adaptive** character of the measures included?	+	The results document, explains all characterization criteria used.
5.4 Are management measures categorised using **adaptive criteria**? Flexibility, robustness, no-regret, win-win…	+	The detailed description of the measures indicates flexibility and robustness among other characteristics.
5.5 Does the plan consider **characteristics** for the measures such as: a. feasibility b. acceptability c. preconditions	+ + + +	Yes

5.6 Does the plan include an **economic valuation** of the measures?	±	Simplified economic valuation.
5.7 Does the plan include an **impact assessment** for the measures?	+	Indicated in the methodological and results documentation. Use of cognitive map and a sensitivity analysis.
5.8 Does the plan consider an evaluation of the **synergies, co-benefits and conflicts** between measures?	+	Indicated in the methodological and results documentation. Specific analysis validated by local stakeholders.
5.9 Does the plan specify the measures' **identification and selection** mechanisms?	+	Methodology explained in the documentation. Dedicated workshop and multi-criteria analysis.
5.10 Does the plan consider **uncertainties** related to the process of identification and selection of measures?	±	Specific workshop session to validate measure identification and selection.
5.11 Are **roles and responsibilities** for measure implementation defined?	+	For each measure, key actors and their possible contribution to the realisation of the measures were identified.
5.12 Does the plan define the **implementation time** for the measures?	+	Implementation time defined for each measure and validated by stakeholders.
5.13 Does the plan consider **prioritisation** of measures for its implementation?	±	Done within a workshop session.
5.14 Are **funding opportunities** for measure implementation considered?	+	Indicated in the detailed description of measures.
6. Participation		
Key evaluation questions	**+ / ± / -**	**Comments**
6.1 Has **participation** been included in the preparation of the plan? How?	+	Yes
a. In the form of information	+	Scientific information on climate change impacts and vulnerabilities available for stakeholders.
b. In the form of consultation	+	Specific interviews and surveys.
c. In the form of active participation	+	Local stakeholders involved in identifying and solving the challenges tackled in the plan.

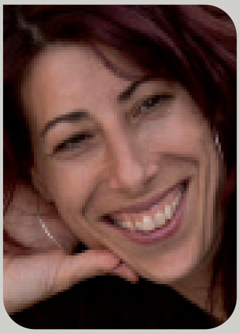
d. In the form of active participation at all stages of its development	+	Iterative process of interaction at all stages of plan development.
6.2 Are the **reasons and objectives** for including participation in the plan explicit?	+	Functional to adaptive water management.
6.3 Is **social learning** considered?	+	Stakeholder workshop have a central role in the plan developement.
6.4 Does the development of the plan consider **stakeholder mapping**?	+	Yes
6.5 Have all the identified stakeholders been involved?	-	Most identified stakeholders were involved but not all of them.
6.6 Has the diversity of sectors and interests involved been sufficiently represented to ensure the **intersectoriality** necessary for adaptation?	±	The most relevant sectors and interest were represented.
6.7 Has **specific material** been developed to facilitate interaction with participants?	+	Specific materials developed for sessions, workshops dissemination and awareness raising activities.
6.8 Does the plan clearly indicates which information has been collected and how has the **knowledge of participants** been **integrated** in the plan?	+	The result document gives clear details.
6.9 Have participants been given the opportunity to make an **evaluation** on the plan development process?	-	Stakeholder evaluation of the process was collected at all participatory events.
6.10 Does the plan consider the revision of current **governance structures and practices**?	+	Through concrete measures and recommendations to policy makers.
7. Implementation		
Key evaluation questions	**+ / ± / -**	**Comments**
7.1 Are **barriers and opportunities** for plan implementation indicated?	+	Through related information research and a session in a participatory workshop.
7.2 Is there a **commitment** to implement the plan by the competent authorities?	-	It is a limitation of the plan, although there is a strong interest of the stakeholders to promote its implementation.
7.3 Is there an assessment of the level of **synergy** existing between the plan and the administrative and management context?	+	Details in the description of measures.
7.4 Does the plan consider **uncertainties** related to possible inconsistencies between the	-	It is a limitation of the plan

definition of measures and their actual implementation?		
7.5 Has an **impact assessment of the plan** been considered?	-	It is a limitation of the plan
7.6 Does the plan foresee future **revisions**?	-	It is a limitation of the plan
7.7 Does the plan foresee the inclusion of **lessons learned** from its implementation in future management cycles?	-	It is a limitation of the plan
7.8 Does the plan clearly indicate the organisms **responsible** for the plan's evaluation?	-	It is a limitation of the plan
7.9 Does the plan include a complete **budget** and entities that could contribute co-finance its implementation?	-	It is a limitation of the plan
7.10 Has the plan and supporting documents been structured with an approach that promotes **transferability**?	+	Through the release and dissemination of the guidance document.
7.11 Does the plan consider developing public **dissemination and awareness** activities associated with its implementation?	+	A specific awareness and dissemination campaign.

[i] Broekman, A; Sanchez, A.; Libbrecht, S.; Robert, N.; Verkerk, H. Results of the identification and evaluation of water management options for the Tordera River. 2016. Available online: http://bewaterproject.eu/images/results/adaptations-plans/Results_Tordera_final.pdf.
[ii] ACCUA. Adaptations to Climate Change in Water Use project. Memoria final. 2011. Available online: http://www.creaf.uab.cat/accua/ACCUA_divulgativa_internet.pdf (in Catalan).
[iii] ACA, 2009. Aigua i canvi climátic. Diagnosi dels impactes previstos a Catalunya. Available online: http://www.gencat.cat/mediamb/publicacions/monografies/aigua_canvi_climatic.pdf (in Catalan)
[iv] CREAF, Land Cover and Land Use Map, LCMC (2005). http://www.creaf.uab.es/mcsc/esp/index.htm (in Spanish)
[v] Idescat, Catalan Statistical Institute, (2012). http://www.idescat.cat/en/
[vi] Conservation plan for the Montseny Natural Park and Biosphere Reserve (2014). http://parcs.diba.cat/documents/155678/21045014/PlaConservacioMontseny.pdf/1f9cb5e7-50d7-4da2-8735-89ad4b52cfc3 (in Catalan)
[vii] Verkerk, P.J.; Sanchez, A.; Libbrecht, S.; Broekman, A.; Bruggeman, A.; Daly-Hassen, H.; Giannakis, E.; Jebari, S.; Kok, K.; Krivograd Klemenčič, A.; Magjar, M.; Martinez de Arano, I.; Robert, N.; Smolar Žvanut, N.a; Varela, E.; Zoumides, C.. A Participatory Approach for Adapting River Basins to Climate Change. Water 2017, 9(12): 958.

Anexo 2: Curriculum Vitae

Curriculum vitae



Anabel Sánchez Plaza

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Biologist dedicated to scientific research since 1996

I have attained a wide experience, around 24 years, of participation in national and EU projects. I've been engaged in over 30 projects and collaborated with over two hundred researchers of very diverse disciplines having the chance to interact with several research consortiums, institutions and Universities from many nationalities. I've also interacted and worked together with over three hundred end-users and stakeholders from all type of sectors and administrations and various nationalities. Besides the actual implementation of research projects, I've had the responsibility to be involved in the definition and elaboration of research project proposals and funding applications. During the last 8 years my responsibilities have also included that I would undertake coordination tasks in innovative European and national participatory and Citizen Science projects.

Professional experience

Biologist (UB, 1997) working at CREAF as research technical staff since 1996, I hold a Master's degree on Sustainable Water management (Universidad de Zaragoza, 2017) and I'm enrolled in the PhD Environment and Society from the Universidad Pablo de Olavide, Seville. Since 1998 I've been involved in national and European projects aiming at quantifying carbon and water balances in Mediterranean and European forests and assessing the impacts (drought, fire) of Climate Change on forest ecosystem services and their vulnerability. I've also been involved in identifying adaptive forest management strategies working closely with the forest sector stakeholders.
From 2013 my work has been more specifically oriented towards the analysis of vulnerability to Global Change in the use of water and the definition of adaptation measures and strategies in water management working together with local stakeholders and public administrations. I have collaborated in the LIFE + MEDACC and ISACC TorDelta (Fundación Biodiversidad), projects and I have been the coordinator of the BeWater project (FP7 Science in Society). I have also coordinated Alerta Forestal, a citizen science platform that involves society in the detection of forest health perturbations. More recently, I have participated in projects involving stakeholders in the co-creation of solutions to environmental challenges related to climate change and the need for societal adaptation to its impacts as for example: CLISWELN (JPI Clima), FASTER (H2020-Widespread), REDAPTA (Fundación Biodiversidad), Observatorio ciudadano de la sequía (FECYT) and BESTMAP (H2020-RUR-04-2018-2019).
I have recently been appointed Societal Impact Officer for the Severo Ochoa program at CREAF and thus, I have the responsibility to lead the institutional research impact strategy of the center and to maximaze and give visibility to the impact of CREAF's research.

Areas of Expertise and Interest

Adaptation in Forest and Water Management, Citizen Science, Science-Society participatory processes, innovative governance, science into policy, climate change impacts and related social-ecological vulnerabilities, societal impact of research.

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Research projects (last 5 years)

2019-2024 CREAF — **MIDMAC. Adaptación de la montaña media al cambio climático.** Financing organism: European Union LIFE+ Program. Principal investigator: Dr. Javier Retana.

2019-2023 CREAF — **BESTMAP. Behavioural, Ecological and Socio-economic Tools for Modelling Agricultural Policy** Financing organism: European Union H2020 GA no. 817501 RUR-04-2019-2023. Principal investigator: Dr. Joan Masó.

2020-2021 CREAF — **Observatorio Ciudadano de la Sequía.** Financing organism: EFCT-19-14568 FECYT. Ministerio de Ciencia, innovación y Universidades. Principal investigator: Dra. Pilar Paneque (Universidad Pablo de Olavide).

2019-2021 CREAF — **MONTCLIMA. Clima y riesgos naturales en las montañas del SUDOE.** Financing organism: European Union INTERREG EUROPE-SUDOE. Principal investigator: Dr. Javier Retana.

2018-2021 CREAF — **FASTER. Farmers' Adaptation and Sustainability in Tunisia through Excellence in Research.** Financing organism: European Union H2020-WIDESPREAD-05-2017-Twinning 810812. Principal investigator: Anabel Sánchez and Dr. Javier Retana.

2019-2020 CREAF — **REDAPTA. Use of governance spaces for climate change adaptation in sensitive stretches of Mediterranean rivers.** Financing organism: Fundación Biodiversidad. Principal investigator: Dr. Javier Retana.

2018-2020 CREAF — **INMODES. Integrated modelling and planning for forest biodiversity and ecosystem services under global change scenarios.** Financing organism: I+D+I MINECO Retos. Principal investigator: Dr. Javier Retana

2017-2020 CREAF — **CLISWELN. Climate Services for the Water-Energy-Land-Food Nexus.** Nexus elements and their links to SDG's. Financing organism: ERANET ERA4CS del JPI-Climate. Principal investigator: Dr. Jordi Martinez-Vilalta.

2016-2019 CREAF — **Forests and Health. Citizen Science platform ALERTA FORESTAL.** Financing organism: Fundació La Caixa. Principal investigator: Dr. Lluís Brotons and Dr. Jordi Vayreda.

2017-2018 CREAF — **ISACC TorDelta. Involving society in climate change adaptation in the Tordera Delta.** Financing organism: Fundación Biodiversidad. Principal investigator: Dr. Javier Retana.

2014-2018 CREAF — **MEDSOUL. Improvement of water resources management in Mediterranean basins with high demand and scarcity of water, under the perspective of One Health.** Financing organism: I+D+I MINECO Retos Principal investigator: Dr. Santiago Sabaté.

2015-2017 CREAF — **FORESTCAST. Assessment and forecasting of ecosystem services in forests: impacts and adaptation to extreme climate events.** Financing organism: I+D+I MINECO Retos Principal investigator: Dr. Javier Retana.

2013-2017 CREAF — **BEWATER. Making society an active participant in water adaptation to global change.** FP7-SIS.2013.1.2-1/612385. Financing organism: European Union. Principal investigator: Dr. Javier Retana.

2013-2017 CREAF — **MEDACC. Demonstration and validation of innovative methodology for regional climate change adaptation in the Mediterranean area.** LIFE ENV/ES/000536. Financing organism: European Union. Principal investigator: Gabriel Borràs (OCCC) .

Academic degrees

2017
Degree

Master's Degree in Sustainable Water Management. Capacity for dialogue, organization and interdisciplinary management; Use of new technologies and management systems; and integration of citizen participation in water planning and management process. Universidad de Zaragoza.

1997
Degree

Degree in Biology. Speciality in Biology of Organisms and Sistems, which includes Botany, Zoology and Ecology, with elective subjects: Forest Ecology, Applied Ecology, Phytogeography, Soil Science and Animal Physiology. Facultat de Biologia. Universitat de Barcelona (UB).

Scientific articles (last 5 years)

ANABEL SANCHEZ-PLAZA, ANNELIES BROEKMAN, JAVIER RETANA, ADRIANA BRUGGEMAN, ELIAS GIANNAKIS, SIHEM JEBARI, ALEKSANDRA KRIVOGRAD-KLEMENČIČ, STEVEN LIBBRECHT, MANCA MAGJAR, NICOLAS ROBERT, PIETER J. VERKERK. 2021. *Participatory Evaluation of Water Management Options for Climate Change Adaptation in River Basins. Environments*. 8, no. 9: 93.

ROGER CREMADES, **ANABEL SANCHEZ-PLAZA,** RICHARD J HEWITT, HERMINE MITTER, JACOPO A. BAGGIO, MARTA OLAZABAL, ANNELIES BROEKMAN, BERNADETTE KROPF, NICU CONSTANTIN TUDOSE. 2021. *Guiding cities under increased droughts: The limits to sustainable urban futures.* Ecological Economics. Volume 189, 107140.

NICU CONSTANTIN TUDOSE, ROGER CREMADES, ANNELIES BROEKMAN, **ANABEL SANCHEZ-PLAZA**, HERMINE MITTER, MIRABELA MARIN. 2021. *Mainstreaming the nexus approach in climate services will enable coherent local and regional climate policies. Advances in Climate Change Research*. ISSN 1674-9278.

ROGER CREMADES, HERMINE MITTER, NICU CONSTANTIN TUDOSE, **ANABEL SANCHEZ-PLAZA**, ANIL GRAVES, ANNELIES BROEKMAN, STEFFEN BENDER, CARLO GIUPPONI, PHOEBE KOUNDOURI, MUHAMAD BAHRI, SORIN CHEVAL, JÖRG CORTEKAR, YAMIR MORENO, OSCAR MELO, KATRIN KARNER, CEZAR UNGUREAN, SERBAN OCTAVIAN DAVIDESCU, BERNADETTE KROPF, FLOOR BROUWER, MIRABELA MARIN. 2019. *Ten principles to integrate the water-energy-land nexus with climate services for co-producing local and regional integrated assessments.* Science of the Total Environment, STOTEN. Volume 693, 133662.

ANABEL SANCHEZ-PLAZA, ANNELIES BROEKMAN, PILAR PANEQUE. 2019. *Analytical Framework to Assess the Incorporation of Climate Change adaptation in Water Management: Application to the Tordera River basin Adaptation Plan.* Sustainability. MDPI, Open Access Journal. Volume 11(3), pages 1-13.

PIETER J. VERKERK, **ANABEL SANCHEZ**, STEVEN LIBBRECHT, ANNELIES BROEKMAN, ADRIANA BRUGGEMAN, HAMED DALY-HASSEN, ELIAS GIANNAKIS, SIHEM JEBARI, KASPER KOK, ALEKSANDRA KRIVOGRAD KLEMENČIČ, MANCA MAGJAR, INAZIO MARTINEZ DE ARANO, NICOLAS ROBERT, NATAŠA SMOLAR-ŽVANUT, ELSA VARELA, AND CHRISTOS ZOUMIDES. 2017. *A Participatory Approach for Adapting River Basins to Climate Change.* Water. MDPI, Open Access Journal. Volume 9, no. 12: 958.

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Other publications (last 5 years)

ANNELIES BROEKMAN, **ANABEL SÁNCHEZ,** VIRGINIA GARÓFANO-GÓMEZ, FRANCISCO MARTÍNEZ-CAPEL. 2020. *Guía metodológica para el codiseño de medidas de adaptación al cambio global. REDAPTA technical report (23 p).* http://isacc.creaf.cat/wp-content/uploads/2020/10/GuiaMetodologica_ES.pdf

ANNELIES BROEKMAN, **ANABEL SÁNCHEZ,** VIRGINIA GARÓFANO-GÓMEZ, FRANCISCO MARTÍNEZ-CAPEL. 2020. *Estratègia integrada per a la reducció de la vulnerabilitat als impactes del canvi global a la conca de la Tordera. REDAPTA technical report (42 p).* http://isacc.creaf.cat/wp-content/uploads/2020/10/Estrategia-Tordera_CA1.pdf

VIRGINIA GARÓFANO-GÓMEZ, ANNELIES BROEKMAN, FRANCISCO MARTÍNEZ-CAPEL, **ANABEL SÁNCHEZ**. 2020. *Estratègia integrada per a la reducció de la vulnerabilitat als impactes del canvi global a la conca del Serpis. REDAPTA technical report (48 p).* http://isacc.creaf.cat/wp-content/uploads/2020/10/Estrategia-Serpis-1.pdf

STEIN, U.; DAVIS, M.; TRÖLTZSCH, J.; **SÁNCHEZ, A.**; ET AL. 2016. *Developing participatory adaptation plans for river basins - a handbook. BeWater project deliverable 4.4 (p. 67).* Zenodo. ISBN 978-3-937085-30-2 https://doi.org/10.5281/zenodo.439522

ANNELIES BROEKMAN, **ANABEL SÁNCHEZ**. 2016. *Tordera River Basin Adaptation Plan. BeWater project deliverable 4.3 (p. 161).* Zenodo. https://doi.org/10.5281/zenodo.439491

Conferences and Dissemination events: selected contributions

BROEKMAN, A., GAROFANO, V. **SÁNCHEZ, A.** *XI Congreso Ibérico de Gestión y Planificación del agua. REDAPTA: Espacios De Gobernanza para la Adaptación al Cambio Climático en Rios Mediterráneo. Madrid/virtual, 3-9 September 2020. Presentation.*

SÁNCHEZ, A. BROEKMAN, A. *XI Congreso Ibérico de Gestión y Planificación del agua. FASTER LIVING-LAB: a multi-stakeholder platform of communication, knowledge sharing and co-design to promote adaptation to climate change. Madrid/virtual, 3-9 September 2020. Presentation.*

SÁNCHEZ, A. *COP25 Side Event. Invited participant in the event "Missions in Horizon Europe: Design and Impact by and for Spanish society" session Adaptation to climate change, including social transformation. IFEMA Green Area. Madrid, 12 December 2019. Round table.*

SÁNCHEZ, A. *Citizen Science and Climate Change. Experiences from academia. Organised by TeRRIFICA (Territorial RRI fostering Innovative Climate Change Action) SWAFS-H2020. Engaging citizens in natural resources management and governance for climate change adaptation. ICTA-UAB, Bellaterra, 5 December 2019. Presentations.*

SÁNCHEZ, A. *Invited speaker at CitieS-Health Horizon 2020-SwafS event. Engaging and keeping a citizen science community. Barcelona. 5 February 2019. Presentation.*

SÁNCHEZ, A. *XV CREAF SCB ICHN seminar, Retos, ideas y soluciones para hacer una ciencia ciudadana útil y con impacto. People at the center of each citizen science initiative. Barcelona. 21 November 2018. Presentation.*

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Conferences and Dissemination events: selected contributions (continued)

SÁNCHEZ, A. *X Congreso Ibérico de Gestión y Planificación del agua. Assessment of the inclusion of adaptation to climate change in hydrological management: application to the case of the Tordera Basin. Coimbra, Portugal 6-8 September 2018. Presentation.*

SÁNCHEZ, A. *COP22 Side Event. Accompagner des collectifs d'acteurs locaux dans l'adaptation au changement climatique sur un territoire : retours d'expériences. Marrakech, Morocco 17 Nov. 2016. Workshop.*

SÁNCHEZ, A.
BeWater: Making Society an Active Participant in Water Adaptation to Global Change. NEPAD Networks of Centres of Excellence in Water Sciences PHASE II Thematic session on Water Governance and Diplomacy. Accra, Ghana 31 Oct - 4 Nov 2016. Presentation.

Stakeholder Workshop organization

From 2019 REDAPTA, 3 workshops and 2 seminars. Over 140 stakeholders participating.

From 2018 FASTER, 3 workshops. Over 80 stakeholders participating.

2017-2019 ALERTA FORESTAL, 10 meetings with local and Catalan administrations and 6 stakeholder events. Over 70 stakeholders involved.

2017-2018 ISACC TorDelta, 70 interviews, 3 workshops and 3 seminars. Over 150 stakeholders participating.

2014-2017 BeWater, 8 workshops and stakeholder events. 125 stakeholders participating.

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Anexo 3: Otras publicaciones

A3.1. Publicación: Tordera River Basin Adaptation Plan

- Tordera River Basin Adaptation Plan – English: https://doi.org/10.5281/zenodo.439491

- Pla d'Adaptació per la Conca de la Tordera – Català: https://doi.org/10.5281/zenodo.439508

A3.2. Guía metodológica. Developing Participatory Adaptation Plans for River Basins – a Handbook.

- Developing Participatory Adaptation Plans for River Basins – a Handbook – English: https://doi.org/10.5281/zenodo.439522

- Guia per al desenvolupament de plans d'adaptació participatius a escala de conca – Català: https://doi.org/10.5281/zenodo.439524

- Guía para el desarrollo de planes de adaptación participativos a escala de cuenca – Castellano: https://doi.org/10.5281/zenodo.495584