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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.

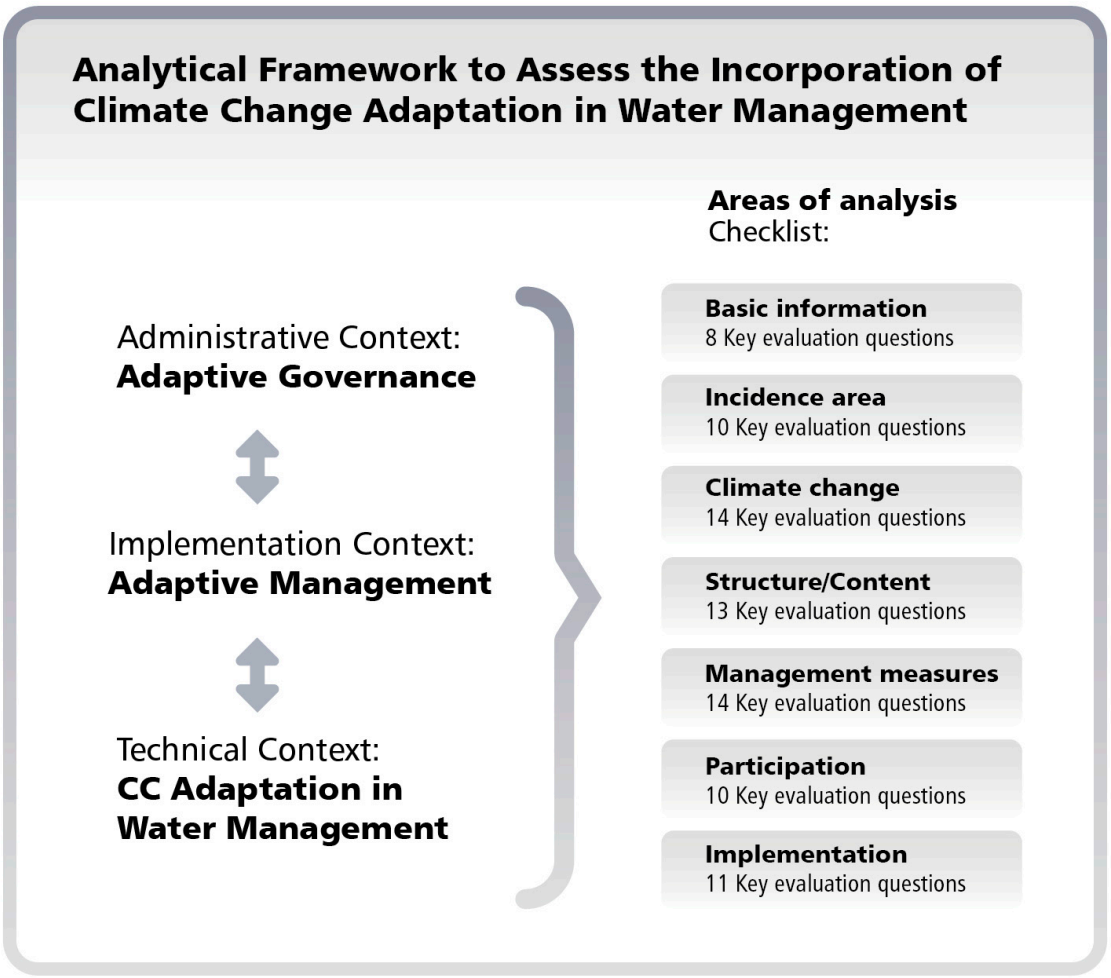

Figure 1. Analytical framework built within this study to assess the degree in which climate change adaptation is taken into account in water management. On the left, criteria and references regarding administrative, implementation and technical context retrieved from the theoretical and methodological 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].

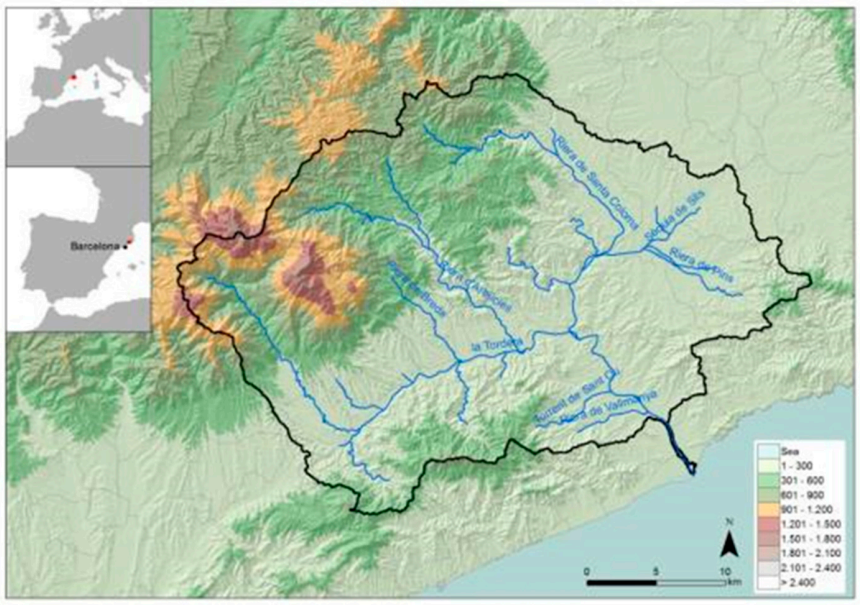

Figure 2. Location of the Tordera river basin.

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).

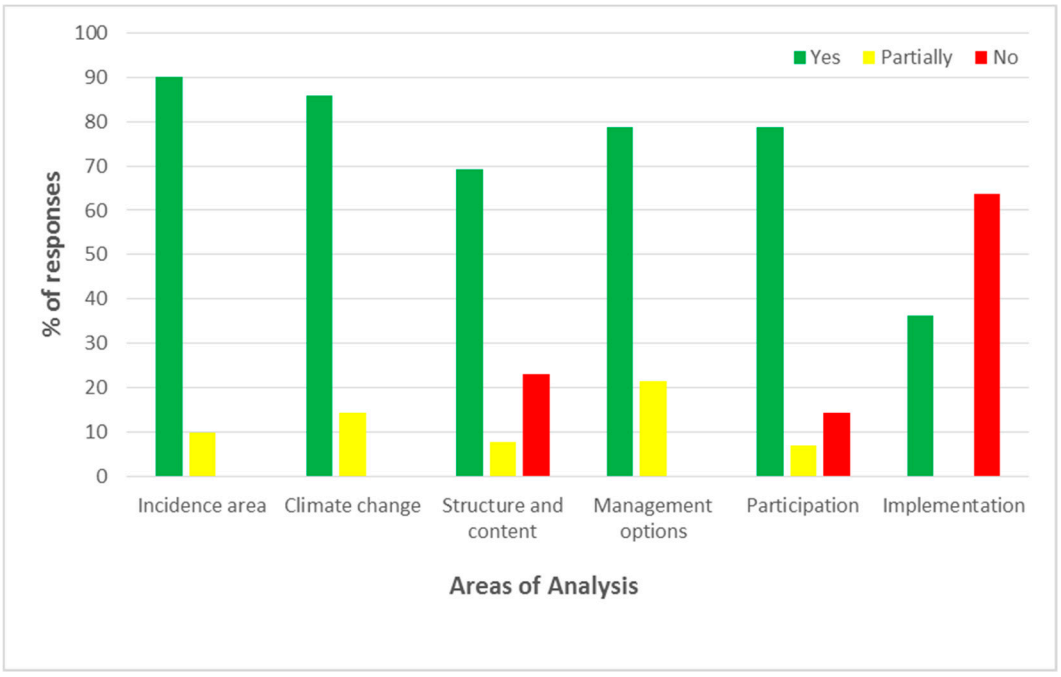

Figure 3. Percentage of responses to key questions of each area of analysis after applying the analytical framework to the Tordera River Basin Adaptation Plan. Categories: *Yes*- The question is properly considered in the plan; *Partially*- The question is partially considered in the plan; and, *No*- 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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