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TESIS

Economy and sustainability of water

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Universidad Pablo de Olavide

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A mi tío Pepe,

ÍNDICE

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2. ABSTRACT OF THE THESIS IN SPANISH (RESUMEN DE LA TESIS EN CASTELLANO).

El sistema de gestión de agua del siglo XXI no sólo debe ser eficaz para garantizar la seguridad de suministro y por lo tanto poner en práctica lo que subyace bajo el término conocido como *"seguridad hídrica"*. Además, debe ser sostenible, de manera que permita a los gobiernos y a sus sociedades atender, de forma eficiente y equilibrada, los objetivos económicos, sociales y ambientales asociados con todos los modelos de crecimiento. El agua, por su naturaleza transversal, juega un papel clave en cualquier modelo de desarrollo sostenible, ya que la garantía de este recurso es una condición indispensable para el progreso económico, el desarrollo social y la conservación de los hábitats y ecosistemas.

La Directiva Marco del Agua (DMA) -Directiva 2000/60/CE- ha establecido un marco legislativo comunitario de actuación en el ámbito de la política del agua en la Unión Europea (UE). Los objetivos ambientales se definen en el Artículo 4 de la DMA. El objetivo de dicho artículo es la gestión del agua sostenible a largo plazo, basada en un alto nivel de protección del medio ambiente acuático. Además, uno de los aspectos más innovadores de la DMA es el hecho de que los objetivos medioambientales deben implementarse en el uso de la economía como una disciplina clave para cumplir con dichos objetivos.

Los aspectos económicos de la DMA se incluyen en:

• Artículo 4: uso de análisis coste-beneficio (ACB) y la decisión de exención de costes desproporcionados.

• Artículo 5: análisis económico del uso del agua y desarrollo de escenarios.

• Artículo 9: aplicación del principio de recuperación de costes, incluidos los costes ambientales y los costes del recurso, a través de la tarificación del agua (probablemente el aspecto económico más mencionado).

• Artículo 11: Análisis coste-eficacia (ACE) para la selección de las medidas.

El Artículo 5 está vinculado a la aplicación del principio de recuperación de costes que se define en el Artículo 9 como *"una contribución adecuada de los diversos usos del agua, desglosados, al menos, en industria, hogares y agricultura, a la recuperación de los costes de los servicios de agua, basado en el análisis económico llevado a cabo"*. Por lo tanto, el análisis económico de los usos del agua y las estimaciones de recuperación de costes requieren procedimientos de armonización. Una de la propuestas de mi tesis es conseguir esta armonización basada en el uso de la metodología SCAE-Agua (Sistema de Contabilidad Ambiental y Económica del Agua), también conocido por sus siglas en inglés, SEEA-Water.

Por su parte, la sostenibilidad en la gestión de los recursos hídricos es fundamental para dar cumplimiento a los objetivos medioambientales establecidos en la DMA. En este sentido, la contribución de mi tesis radica en un análisis de la sostenibilidad de los planes hidrológicos de cuenca en las Demarcaciones Hidrográficas intercomunitarias españolas. Para ello, se han utilizado dos técnicas de Análisis de Decisiones Multicriterio (MCDA) y se ha contado con la participación de 25 expertos en la gestión del recurso.

En definitiva, los principales objetivos de mi tesis se pueden resumir en dos partes.

Por un lado, se trata de integrar el análisis económico establecido por la DMA en la contabilidad ambiental desarrollada por el SCAE-Agua (UNSD 2012). SCAE-Agua ha sido desarrollado por el Departamento de Asuntos Económicos y Sociales de la Secretaría de las Naciones Unidas con el apoyo de otras instituciones (EUROSTAT entre ellos). Proporciona un marco conceptual para organizar la información hidrológica y económica de una manera coherente y consistente. El Sistema tiene su origen en la economía, pero también incluye información física sobre el recurso. La naturaleza híbrida de las cuentas da al analista la oportunidad de estudiar ambas dimensiones. Esto permitiría la armonización del análisis económico del agua para los miembros de la UE creando una herramienta estándar que, si se adopta ampliamente, permitiría la comparación internacional de la situación de los recursos hídricos y, específicamente, para la política europea, que facilitaría a los Estados miembros la elaboración de los informes a cerca del cumplimiento de la DMA que tienen que reportar a la Comisión Europea.

Una mayor normalización en todos los Estados miembros de la UE por lo tanto, sería deseable y la Comisión Europea (2015) ha publicado un documento orientativo sobre la contabilidad del agua con este objetivo y con el de facilitar la comunicación a cerca del cumplimiento de la DMA antes mencionada. Este documento sugiere específicamente la conveniencia de integrar la información económica dentro del SCAE-Agua. Debido a ello, una de las propuestas de mi tesis es conseguir esta armonización al reportar el Artículo 5 (análisis económico del uso del agua y escenarios de desarrollo) y el Artículo 9 (aplicación del principio de recuperación de costes) de la DMA basado en el uso de SCAE-Agua.

La contribución de mi tesis en esta propuesta puede consultarse en los siguientes artículos:

1- Borrego-Marín, M.M.; Gutiérrez-Martín, C.; Berbel, J. "*Estimation of cost recovery ratio for water services based on the System of Environmental-Economic Accounting for water*". Water Resource Management, 2016, 30, 767–783. DOI: 10.1007/s11269-015-1189-2.

2- Borrego-Marín, M.M.; Gutiérrez-Martín, C.; Berbel, J. "*Water productivity under drought conditions estimated using SEEA-Water*". Water 2016, 8(4), 138. DOI:10.3390/w8040138.

Por otro lado, el objetivo de esta tesis es analizar y comparar la sostenibilidad de los planes hidrológicos en las Demarcaciones Hidrográficas intercomunitarias españolas, con el fin de determinar los aspectos que pueden ser mejorados para dar cumplimiento a los requisitos establecidos en la DMA. A pesar de que el concepto de sostenibilidad se ha asociado tradicionalmente con el marco del triple resultado (Triple Bottom Line,TBL), compuesto por las dimensiones económicas, ambientales y sociales, el análisis de sostenibilidad que se presenta se amplía mediante la inclusión de una cuarta dimensión que integra temas de gobernabilidad y participación. Se propone un enfoque de Análisis de Decisión Multicriterio para agregar todas las dimensiones de la sostenibilidad en el que ha participado un panel de expertos en gestión hídrica. Los datos de cada Demarcación Hidrográfica se han obtenido a partir de los Planes Hidrológicos para el Segundo Ciclo de Planificación (2015-2021).

La contribución de mi tesis en este sentido puede consultarse en el siguiente artículo:

3- Borrego-Marín, M.M.; Riesgo, Laura. *"Measuring the Sustainability of Water Plans in Inter-Regional Spanish River Basins".* Water 2016, 8(8), 342. DOI: 10.3390/w8080342.

En cuanto a los resultados obtenidos, por un lado, muestran que SCAE-Agua puede ser útil para la DMA en varios aspectos:

i) Se puede utilizar para llevar a cabo un análisis del uso del agua directamente de las tablas híbridas;

ii) Permite estimar los valores de la productividad del agua de las cuencas hidrográficas con los datos económicos incluidos en la contabilidad del agua;

iii) La naturaleza híbrida de las cuentas da al analista la oportunidad de evaluar el análisis de recuperación de costes de los servicios de agua.

Por tanto, se puede concluir que el uso de SCAE-Agua para la caracterización económica del agua tiene muchas ventajas para la normalización de los procedimientos de información en la aplicación de la DMA.

Por otro lado, los resultados del análisis de sostenibilidad muestran las dimensiones que pueden ser mejoradas para incrementar la sostenibilidad de las Demarcaciones Hidrográficas con el fin de cumplir con los objetivos y requisitos establecidos por la DMA en la gestión de las cuencas. También ilustra la importancia de cada indicador en la contribución a la sostenibilidad. Por tanto, se concluye que podría ser un punto de partida para una gestión del agua más sostenible en las Demarcaciones Hidrográficas españolas en los futuros ciclos de planificación.

3. INTRODUCTION

The water management system of the XXI century must not only be effective to provide supply security and thus give effect which has come to be known “water security”. It must be sustainable, so that allow governments and their societies to attend, in an effectively and balance way, the economic, social and environmental objectives associated with all growth model. Water, by its transverse nature, plays a key role in any model of sustainable development since the guarantee of this resource is a condition for economic progress, social development and conservation of habitats and ecosystems.

The Water Framework Directive (WFD) – Directive 2000/60/CE - has established a legislative framework for Community action in the field of water policy in the European Union. The environmental objectives are defined in Article 4 - the core article - of the WFD. The aim of this Article is long-term sustainable water management based on a high level of protection of the aquatic environment. Although, one of the most innovative aspects of the WFD is the fact that the environmental objectives relays up on the implementation in the use of economics as a key discipline to fulfil its objectives. In the process of implementing the WFD, there have been many ‘ad hoc’ solutions due to the obligation to meet the deadlines and because the lack of information and procedures.

The economic aspects in the WFD are included in:

- Article 4: use of cost-benefit analysis (CBA) for exemptions and disproportionate cost decision.
- Article 5: economic analysis of water use and scenarios development.
- Article 9: application of the cost-recovery principle, including environmental and resource cost, through water pricing (probably the most mentioned economic aspect).
- Article 11: Cost-effectiveness analysis (CEA) for selecting the measures.

Article 5 is linked to the cost recovery principle implementation defined in Article 9 as *"an adequate contribution of the different water uses, disaggregated into at least industry, households and agriculture, to the recovery of the costs of water* services, *based on the economic analysis conducted"*. Therefore, economic analysis and cost recovery estimations require harmonization procedures. One of the proposal of my thesis is to get this harmonization based on the use of SEEA-Water methodology.

Water accounting has been seen as a way of measure of physical unit of water diverted, used or consume, but the advantage of the environmental-economics accounting over other types of water statistics is the ability to integrate water accounts with economic information, which facilitates economic analysis. There are a growing number of countries producing water accounts and SEEA-Water has been developed and implemented in countries in a relatively short space of time (Vardon et al., 2012).

Lange et al. (2007) develop water accounting following SEEA-Water for the Orange River Basin from an economic perspective on managing a transboundary resource building National water accounts for Botswana, Namibia and South Africa level. The accounts include supply and use tables, which are used to compare the contribution to water supply from each riparian state to the amount used. The water accounts are then linked to economic data for each country to calculate water use and productivity by industry and country.

Vardon et al. (2007) make an adaptation of the national level water account practices by the Australia Bureau of Statistics (ABS) to the SEEA-Water framework eased by the similarity between both accounting frameworks. In China, the objectives of National Water Accounting Framework (CWAF) are consistent with those of SEEA (Gan et al., 2012) and the evaluation of measures for a better water management in arid regions has been developed (Ma et al., 2012). Edens and Graveland (2014) present an experimental evaluation of Dutch water resources according to SEEA discussing approaches for the valuation of the water resources provisioning services to the Dutch economy.

In Spain, the SEEA-Water accounting framework was successfully applied to the Segura River Basin (SRB) (Contreras and Hunink, 2015). After an intensive process of data collection and processing, the authors annually derive and analyze a set of use-to-availability water indicators, under two contrasting climate conditions: a normal-precipitation period (2001-2004) and an extreme-moderately dry period characterized by low interbasin inflows. Finally, the adoption of different water management practices and measures under a scenario of population growth and reduction of conventional water resources was evaluated in terms of their impact on the basin's water indicators.

SEEA-Water has been also integrated with others systems as AQUATOOL or WEAP. Pedro-Monzonís et al. (2016) integrate SEEA-Water and AQUATOOL Decision Support System (DSS), using the latter to fill in the physical water supply and use tables and the asset accounts presented in the former. In a similar way, Dimova et al. (2014) use WEAP (Water Evaluation and Planning System) to underpin the development of asset water accounts within the SEEAW platform in Bulgaria.

The topic of sustainability in water resource management has been used quite often in the literature, Hajkowicz and Collins (2007). In order to assess such sustainability, Multicriteria Decision Analysis (MCDA) has been commonly used to analyse it since the decade of 1970'.

Srinivasa Raju et al. (2000) demonstrate the implementation of MCDA for a case study of an irrigation area in a province of Spain. Five MCDA techniques have been used and results indicate that all techniques choose the same alternative strategy as the preferred one. Srdjevic et al. (2002) developed a three-step process to evaluate strategies water management in river basins, taking as an example the river Paraguacu in Brazil. By AHP, the most suitable management plans has been selected taking into account the short, medium and long term. Jaber and Mohsen (2002) proposed a support system for decision evaluation and selection of non-conventional water resources in the river Jordan.

Hajkowicz and Collins (2007) show MCDA in water resource management are widespread and growing. They review 113 studies published since 1973. It was found that the annual publication rate has been steadily growing since the late 1980s. The majority of applications are related to the fields of water policy, supply planning and the evaluation of major infrastructure. In the same year, Kugle, T. (2007) highlighted the importance of an integrated water resource management as a key for a sustainable development.

Martín-Ortega et al. (2008) performed a multicriteria analysis of water management under the WFD. They get a social assessment of the criteria for water management in Guadalquivir river basin and demonstrate the feasibility of applying multicriteria techniques for decision problems in water resources planning.

Freitas and Magrini (2013) presented a case study of a selection of sustainable water management strategies for a mining complex located in the Southeast region of Brazil, which concentrates most part of the country's population as well as most part of the mining facilities, but a small portion of the water available in the territory. Also in this year da Cruz et al. (2013) presents a multicriteria model to determine sustainability level of urban water cycle services (UWCS).

Recently, Rui Cunha et al. (2015) discussed the concept of "sustainable water services" and suggest a multicriteria method to assess it. They illustrate the real-world application of the method in urban water services in Portugal.

4. OBJECTIVES

The main aims of my thesis can be summarized in two parts.

On one hand, it is to integrate the Water Framework Directive (WFD) economic analysis with the environmental accounting developed by Sytem of Environmental Economic Analysis Central Framework (SEEA-CF), and specifically in SEEA-Water (UNSD 2012). SEEA-Water has been developed by the Department of Economic and Social Affairs of the United Nations Secretariat with the support of other institutions (EUROSTATamong them). It provides a conceptual framework for organizing hydrological and economic information in a coherent and consistent manner. The system has its origin in economics, but also includes physical information. The hybrid nature of the accounts gives the analyst the opportunity to study both dimensions.This will allow the harmonization of EU member states water economic analysis create an standard tool that, if adopted widely, would allow international comparison of the state of water resources and specifically for European policy, it would facilitate Member States' WFD reporting to the European Commission.

Further standardization across EU Member States would therefore be desirable and the European Commission (2015) has published a guidance document on water accounting with this aim and to facilitate the above-mentioned WFD reporting. This document specifically mentions the convenience of integrating economic information from within SEEA-Water. Because of that, one of the proposal of my thesis is to get this harmonization to report Article 5 (economic analysis of water use and scenarios development) and Article 9 (application of the cost-recovery principle) of WFD based on the use of SEEA-Water methodology.

The contribution of my thesis in this proposal can be consulted in the following articles:

1- Borrego-Marín, M.M.; Gutiérrez-Martín, C.; Berbel, J. "*Estimation of cost recovery ratio for water services based on the System of Environmental-Economic Accounting for water"*. Water Resource Management, 2016, 30, 767–783. DOI: 10.1007/s11269-015-1189-2.

2- Borrego-Marín, M.M.; Gutiérrez-Martín, C.; Berbel, J. "*Water productivity under drought conditions estimated using SEEA-Water"*. Water 2016, 8(4), 138. DOI:10.3390/w8040138.

On the other hand, the objetive of my thesis is to analyse and compare the sustainability of the water plans in the Spanish River basins and to determine the dimensions that may be enhanced to improve Basin's sustainability in order to fulfil the objectives and requirements set by the WFD on basin management. Even though the concept of sustainability has been traditionally associated with the triple bottom line (TBL) framework, composed by economic, environmental and social dimensions, the analysis enlarges sustainability by including governance and participation issues. A multicriteria decision analysis approach is proposed to aggregate all sustainability dimensions. Data for each BWA has been obtained from the hydrological plans for the second planning cycle (2015-2021). Experienced stakeholders participated in the evaluation process. Results show a classification of the Spanish basins according to their sustainability and the performance of each basin in every particular dimension. It also illustrates the importance of each indicator in contributing to sustainability, being a starting point to improve water management in Spanish basins for future planning cycles.

The contribution of my thesis in this proposal can be consulted in the following article:

3- Borrego-Marín, M.M.; Riesgo, Laura. *"Measuring the Sustainability of Water Plans in Inter-Regional Spanish River Basins".* Water 2016, 8(8), 342. DOI: 10.3390/w8080342.

5. ARTICLES

1- Borrego-Marín, M.M.; Gutiérrez-Martín, C.; Berbel, J. "*Estimation of cost recovery ratio for water services based on the System of Environmental-Economic Accounting for water*". Water Resource Management, 2016, 30, 767–783. DOI: 10.1007/s11269-015-1189-2.

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Estimation of Cost Recovery Ratio for Water Services Based on the System of Environmental-Economic Accounting for Water

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Abstract This paper proposes a methodology to compute a cost recovery ratio directly from the System of Environmental-Economic Accounting for Water (SEEA-Water) standard tables. The methodology is applied to the Guadalquivir River Basin in southern Spain. Results illustrate that it allows cost recovery analysis in line with Water Framework Directive Article 9. Wider adoption of the methodology would enhance comparability and knowledge sharing between regions, countries and sectors both in the European Union and worldwide.

Keywords Water framework directive · Cost recovery · System of environmental-economic accounting · Water policy

1 Introduction

Water is closely linked with socio-economic development, and the management of water resources therefore has to take an integrated overall approach. Integrating information on the economy, hydrology, other natural resources and social aspects can help to design policies in an informed and integrated manner. The European Water Framework Directive (WFD) (European Commission 2000) adopts such an integrated approach to water management and gives a critical role to economic instruments. The use of 'Water Pricing' and 'full cost recovery' (Art. 9) are probably the most widely known provisions of the WFD.

Environmental accounting is an emerging field which deals with the integration of complex biophysical data, tracking changes in ecosystems and linking those changes to economic and other human activities. The System of Environmental and Economic Accounting (SEEA) of the United Nations Statistics Division (UNSD) was created in 1993 and modified in 2003 and

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2012. Its main aim has been to integrate environmental and economic information in a common, comprehensive and coherent way to measure the contribution of the environment to the economy and the impact that economic activities have on the environment. The Central Framework (SEEA-CF) serves as an international statistical standard and guideline for environmental economic accounting (UNSD 2014). SEEA-CF adopts a compartmental approach where natural resources (forest, water, etc.) are addressed individually. Accounting for ecosystems in physical (i.e., non-monetary) terms is a key feature of SEEA-CF.

This study tries to integrate the WFD economic instruments with the developments in environmental accounting as developed in SEEA-CF, and specifically in SEEA-Water (UNSD 2012). This creates a standard tool that, if adopted widely, would allow international comparison of the state and quantitative management of water resources. For European policy, it would facilitate Member States' WFD reporting to the European Commission on the quantitative status of groundwater resources and on the abstraction pressures on surface and groundwater bodies.

Consequently, the objective of this paper is to produce a method capable of estimating a cost recovery ratio for water services based exclusively on the standard accounting information contained in SEEA-Water. This method will be applied to the Guadalquivir River Basin in southern Spain. There is no precedent of an application of the SEAA-Water tables to estimate cost recovery ratios and this paper may be considered a novelty and useful for a standard and replicable estimation of this ratio. The future adoption of the methodology in the European Union could suppose a significant tool for a better application of "cost recovery principle" established in the WFD.

The next section reviews the concept of cost recovery in the WFD, followed by a short introduction to SEEA-Water and an overview of other examples where it has been applied to river basins. This is followed by a presentation of the case study and our proposed methodology, before discussing our data sources and presenting our results.

2 Cost Recovery in the Water Framework Directive

The Water Framework Directive (WFD) has established a legislative framework for Community action in the field of water policy which is aimed at improving and protecting the status of water bodies in the European Union. The WFD promotes the use of economic instruments to reach these goals, one of which is the cost recovery of water services (Article 9).

In more detail, Article 9 establishes that: i) water prices must allow for the adequate cost recovery of water services, including environmental and resource costs; ii) the main water uses (disaggregated for households, industry and agriculture) must adequately contribute to the recovery of costs of water services, proportionally to their contributions to the pressures imposed on aquatic ecosystems (i.e., be in line with the 'polluter pays principle'); and iii) water pricing policies must 'provide adequate incentives for users to use water resources efficiently and thereby contribute to the environmental objectives' of the WFD (European Environmental Agency, EEA 2013).

Economic information systems are based on prices, but water itself has no price in the European Union, as markets are almost absent (see Giannoccaro et al. 2013). In the literature, water pricing generally refers to the process of assigning a price to water services, using instruments such as utility taxes, charges and tariffs. The definition of water services varies strongly among countries. The widest definitions include all man-made changes to the hydrological system, both those that benefit society as a whole and those that serve specific economic uses. Spain uses a wide definition of water services due to the characteristics of its climate and territory.

Full cost recovery is not compulsory in the European Union, and Member States can deviate from full recovery if found necessary considering its social, environmental or economic effects. Geographic and climatic conditions of the affected basin/region are also allowed to be taken into account when deciding about cost recovery. However, if full cost recovery is not pursued or achieved, the WFD requires the exceptions to be justified in the River Basin Management Plans, and accomplishment of the environmental objectives of the Directive has to be guaranteed (Court of Justice of the European Union 2014).

The WFD does not define the methodology to calculate the costs of water service provision and this method has not yet been defined by any institution. In a large review of the concept in the European Union, the European Environment Agency (2013) concludes that there is a lack of harmonised and operational concepts relating to cost recovery. Similarly, in an examination of how to improve WFD-related economic analysis, Strosser and de Paoli (2013) highlight the need for additional guidance on the topic of cost recovery, arguing that EU Member States have applied a diversity of methods to estimate cost recovery rates, but these methods are rarely well-specified, which limits their usefulness as a source of inspiration for other Member States or for EU-wide assessments.

Fourteen years after approving the WFD, the European Union still lacks a uniform system to report administration and utility revenues and cost recovery rates. The European Commission is using a new standard reporting procedure for 2015 (second cycle of WFD implementation) in order to correct this shortcoming. However, we believe that, even if all 27 Member States present their data in a common standard, the differences in the methodologies used to compute these values would still not allow a useful comparison.

Further standardization across EU Member States would therefore be desirable and the European Commission (2015) has published a guidance document on water accounting with this aim and to facilitate the above-mentioned WFD reporting. This document specifically mentions the convenience of integrating economic information from within SEEA-Water.

We should mention that the WFD states (Article 5) that only services to urban users, industry and irrigation are subject to a cost recovery analysis. There is no such requirement in the WFD neither for the navigation nor for the energy sectors (European Commission 2012). We expect that the revision of WFD due for 2019 will eliminate these exemptions.

The WFD prescribes that 'Member States shall take account of the principle of recovery of the costs of water services including environmental and resource cost' but SEEA-Water tables only capture market prices or payable expenses and do not include environmental and resource costs. Our methodology therefore only provides an estimate of financial cost recovery, this and other shortcomings will be considered in the Discussion Section.

3 SEEA-Water Accounting Framework

The use of an accounting framework enables the stock of ecosystems (*ecosystem assets*) and flows from ecosystems (*ecosystem services*) to be defined in relation to each other, and also in relation to a range of other environmental, economic and social information. SEEA-CF focuses on the flows of materials and energy that either enter the economy as natural inputs or return to the environment from the economy as residuals. It is based on individual environmental assets, such as timber, water and soil resources. SEEA-Water is the specific adaptation of the Central Framework and has been developed by the Department of Economic and Social Affairs of the United Nations Secretariat with the support of other institutions (EUROSTAT among them). It provides a conceptual framework for organizing hydrological and economic information in a coherent and consistent manner. The system has its origin in economics, but also includes physical information. The hybrid nature of the accounts gives the analyst the opportunity to study both dimensions.

The standard approach to measuring the economy is based on human activities that are reflected in markets prices and transactions. SEEA supplements the monetary description of economic activities with the accounting of natural resources in physical terms, such as water stocks measured as cubic meters or water flow measured as cubic meters per second. The idea behind the framework is to capture the dependency of the economy on flows from the environment and vice versa. SEEA-Water has been applied in several countries.

- Lange et al. (2007) use the SEEA-Water tables for the transboundary Orange River Basin, building on national water accounts from Botswana, Namibia and South Africa, and compare each country's contribution to the water supply to the amount it used.
- Vardon et al. (2012) adapt the national water accounts from the Australia Bureau of Statistics to the SEEA-Water framework, which is eased by the similarity between both frameworks.
- Gan et al. (2012) analyse the Chinese National Water Accounting Framework (CWAF) in relation to those of SEEA.
- Statistics Canada (2013) presents an accounting framework based on SEEA designed to support the valuation of ecosystem goods and services and creates pilot ecosystem accounts, which it then applies to wetlands valuation.
- Edens and Graveland (2014) present an experimental evaluation of Dutch water resources according to SEEA discussing approaches for the valuation of the water resources provisioning services to the Dutch economy.

Most of the above-mentioned applications use the hybrid nature of the tables to produce ratios of apparent water productivity by sector/region. Unfortunately, apart from these examples, implementation of SEEA-Water remains scarce, and full exploitation of the economic tables of the framework is negligible.

The SEEA-Water tables organize information by water source and by economic activity according to the United Nations International Standard Industrial Classification of All Economic Activities (ISIC) groups. The industries are grouped into: ISIC divisions 1–3, which include agriculture, forestry and fishing; ISIC divisions 5–33 and 41–43, which include mining and quarrying, manufacturing, and construction; ISIC division 35: electricity, gas, steam and air-conditioning supply; ISIC division 36: water collection, treatment and supply; ISIC division 37: sewerage; ISIC divisions 38, 39 and 45–99, which correspond to the service industries.

We should note that ISIC divisions 36 and 37 may include private firms but also government agencies (river basin authorities and municipalities), water user associations (WUAs) and utilities that can be municipally owned, private companies or mixed. The SEEA-WATER handbook states: "*Note that activities are classified into the relevant ISIC category regardless of the kind of ownership, type of legal organization or mode of operation. Therefore, even when activities for water collection, treatment and supply (ISIC division 36) and sewerage*

(ISIC division 37) are carried out by the Government (...), they should be classified to the extent possible in the specific divisions (ISIC 36 and 37) and not in ISIC division 84, public administration" (UNSD 2012, pg. 71).

Services provided by government agencies (such as RBA) are also classified according to the Classification of the Functions of Government (COFOG). COFOG is a classification of Government expenditures according to the function that the transaction serves. It should be noted that COFOG categories refer to Government collective services although categories COFOG 05.2 (wastewater management) and 06.3 (water supply) should not be confused with activities of "sewerage" and "water collection, treatment and supply", classified under ISIC divisions 37 and 36, respectively, which are considered individual services in SEEA Water. Expenditures incurred by Governments at the national level in connection with individual services, such as water supply and sanitation, are to be treated as collective when they are concerned with the formulation and administration of government policy, the setting and enforcement of public standards, the regulation, licensing or supervision of producers, etc., as in the case of education and health.

4 Case Study: Guadalquivir River Basin 2004–2012

Guadalquivir River (Fig. 1) is the longest river in southern Spain with a length of around 650 km. Its basin covers an area of 57,527 km^2, and population of 4,107,598 inhabitants. The basin has a Mediterranean climate with a heterogeneous precipitation distribution, annual average temperature is 16.8 °C, and the annual precipitation averages at 573 mm, with a range between 260 mm and 983 mm (standard deviation of 161 mm). The average renewable resources in the basin amount to 7043 (arithmetic mean) or 5078 hm^3/year (median), ranging from a minimum of 372 hm^3/year to a maximum of 15,180 hm^3/year. In a normal year a potential volume of around 8500 hm^3 can be stored in a complex and interconnected system of 65 dams. The main land uses in the basin are forestry (49.1 %), agriculture (47.2 %), urban areas (1.9 %) and wetlands (1.8 %). Berbel et al. (2012) describe the River Basin Management Plan, and Berbel et al. (2013) discuss the evolution of the basin's water supply and extraction. Table 1 summarizes the main water uses following SEEA-Water definitions.

SEEA-Water defines water abstraction as the amount of water that is removed from any source, either permanently or temporarily. This definition includes soil water which according to SEEA is the "*water suspended in the uppermost belt of soil that can be discharged into the atmosphere by evapotranspiration*". This is equivalent to the concept of 'green water' as used in the hydrological literature, where 'blue water' refers to surface and groundwater that is abstracted, stored, transported and applied.

An analysis of Table 1 shows that soil water makes up 57 % of total abstraction followed by hydropower generation (31 %). It should be noted that almost all water abstracted for hydropower is returned to the ecosystem, while abstracted soil water is evapotranspired and lost for the basin ('consumed' in hydrological terms). There is therefore a crucial difference between abstracted (used) water and consumed water. In Guadalquivir, soil water constitutes 86 % of the water consumed by the primary sector, with the remaining 14 % supplied by irrigation.

Agriculture is the basin's main water consumer of 'blue water' and it has invested considerably in water saving measures in a process known as 'modernization', which has led to the widespread use of deficit irrigation and drip systems. Berbel et al. (2011a) analyse

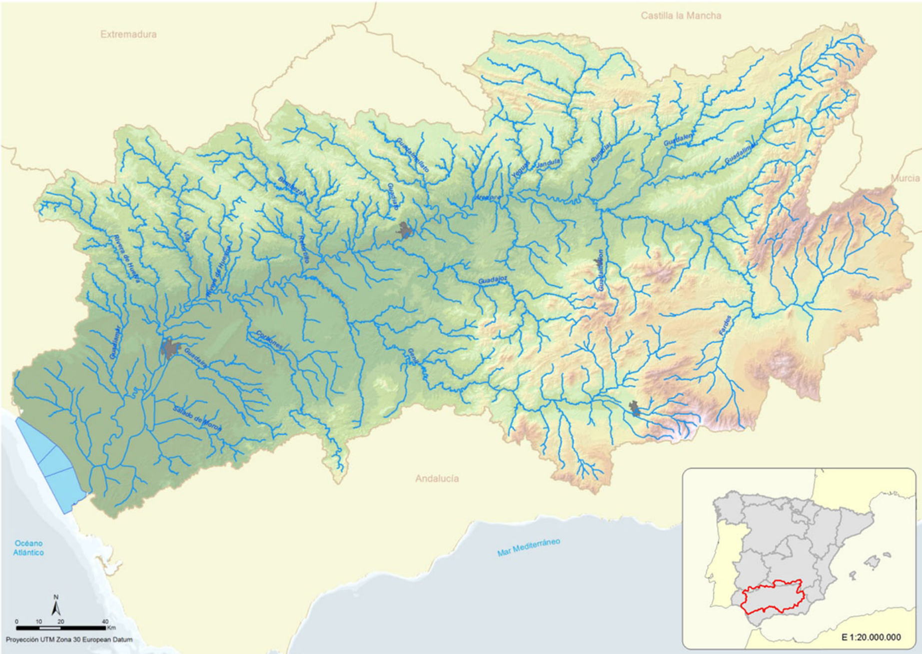

Fig. 1 Guadalquivir basin. Source: Adapted from Confederación Hidrográfica del Guadalquivir, www.chguadalquivir.es

the 'ex-ante' impact of water saving systems in the basin and Berbel et al. (2015) made an 'ex-post' analysis of these measures.

For the application of our methodology to the Guadalquivir Basin, we use the SEEA-Water framework as developed by Borrego-Marín et al. (2015) for period 2004–2012 which was characterized by the following occurrences: a) drought 2005–2008; b) water saving investments (modernization); c) increase in energy consumption and water cost for irrigators, and d) the approval of the Program of Measures and the Hydrological Basin Plan (2009–2015).

Table 1 A breakdown of water abstraction in the Guadalquivir River Basin, 2012

Water resource/ use (hm^3)	Total ISIC 1–3[a]	Total industry	Water utilities	Remaining sectors	Total	Abstraction %
Surface water	2324	24	493	17	2858	9 %
Groundwater	805	12	63	0	879	3 %
Energy (hydro)	0	10,270	0	0	10,270	31 %
Abstracted 'blue water'	3129	10,306	556	17	14,008	43 %
Soil (green) water	18,601				18,601	57 %
Total water abstracted from the environment	21,730	10,306	556	17	32,609	100 %
Returns (net)	134	10,149	455	0	10,738	33 %
Total consumption	21,596	157	100	17	21,870	67 %

[a] ISIC 1–3 includes Agriculture, Livestock and Forestry (ISIC 01, 02, 03)

Source: Own elaboration

5 Data Sources

The philosophy behind SEEA-Water is to save time and resources by gathering data in an efficient way and where possible link up to regularly published official sources avoiding 'ad hoc' estimations. Accordingly, we have mainly used existing data bases and official sources to complete the SEEA-Water tables. These sources are summarized in Table 2.

5.1 Hydrological Data

As apparent from Table 2, the hydrological data are measured in physical terms (hm^3/year). The data have been based on the official Ministry for Environment framework SIMPA (Integrated System Modeling Process Precipitation Contribution), which gives rain precipitation and evapotranspiration for the basin at 1 km^2 cells, complemented with further estimates based on the Guadalquivir River Basin Authority (RBA) surveys for irrigated area and measurements of water served to large irrigation schemes and municipal users. The RBA publishes accurate measures of water consumption and river flow in strategic locations that gives us a good estimate of annual water resources use that have been integrated in the analysis of water volumes in the SEEA Tables.

5.2 General Economic Data

The SEEA-Water tables require information on the following economic variables, for both public and private sectors of the economy:

- Output by economic sector (measured at basic prices),
- Intermediate consumption (cost of inputs),
- Personnel costs (salaries and pensions),
- Depreciation of fixed capital,
- Other relevant costs,
- Investment by year and accumulated stock of capital.

For all private sectors, this information, including the value of gross capital formation, was available from the Regional Input/Output Tables, but the tables do not include the public sector. For all the private agents, we can derive the production value and the costs of water services by sector, these are either the costs of self-provision (e.g., groundwater for farmers) or payments to third party water service providers (utilities, basin authorities or WUAs), with the latter split into payments to parties acting as water utilities (ISIC 36) and those providing water sanitation (ISIC 37). Dietzenbacher and Velázquez (2007) used an input–output framework to analyse the consumption of water in the Andalusian production process and an input–output decomposition analysis is also used to find the main drivers of water usage by Di Cosmo et al. (2014).

As mentioned above, annual public expenditure for water services and annual public investments in water related infrastructure is not included in the Regional I/O Tables. For the 2004–2008 period, we used a report from the Ministry of Environment (2009). Data for the remaining years (2009 to 2012) were estimated based on the World Bank series of 'Public Investment Expenditures' (see Table 2 for details).

Table 2 Economic and hydrological variables used in the cost recovery analysis

Variable	Unit	SEEA Standard Table[a]	Data source	Institution	Scale[b]	Comments
Abstraction	hm^3/year	A.1.1	SIMPA, Own calculations	CHG, Ministry for Environment	Basin	
Use	hm^3/year	A.1.1	PHC, Survey water services, Own calculations	CHG, Ministry for Environment, INE	Basin	
Returns	hm^3/year	A.1.1	Own calculations based on IPH	CHG, Ministry for Environment	Basin	
Consumption	hm^3/year	A.1.1	Own calculations based on CHG	CHG, Ministry for Environment, INE	Basin	
Intermediate consumption	€/year	A.1.3	Regional I/O Tables	IECA	Regional	
Gross Value Added	€/year	A.1.4	Regional Accounts	INE	Regional	
Gross fixed capital formation	€/year	A.1.4	Regional Accounts, WB investment series	INE, WB	Regional, National	Investment since 2009 estimated with WB annual investment series
Closing stocks of fixed assets	€/year	A.1.4	Water tariff, Government budget (2004–2008)	Ministry for Environment	Basin	Investment since 2009 estimated with WB annual investment series
Self-supply costs: Groundwater	€/m^3	A.1.5	Ministry for Environment report	Ministry for Environment	Basin	Water cost published by the Ministry for Environment
Self-supply costs: Surface water	€/m^3	A.1.5	Water tariff	Ministry for Environment	Basin	Water tariff (yearly)
Self-sanitation costs	€/m^3	A.1.5	Survey water services	INE	Regional	Yearly average all sectors
Government account table	€/year	A.1.6	Government budget (2004–2008), WB investment series	Ministry for Environment, WB	Regional, National	Expenditure since 2009 estimated with WB annual investment series
Specific transfers	€/year	A.1.7	Government budget (2004–2008), WB investment series	Ministry for Environment, WB	Regional, National	

SIMPA Integrated System Modeling Process Precipitation Contribution, *CHG* Guadalquivir River Basin Authority, *PHC* Guadalquivir Hydrological Plan, *IPH* Water Planning Instruction, *INE* National Statistics Institute, *IECA* Andalusian Statistics Institute, *WB* World Bank

[a] If appearing in several tables, we quote the first appearance

[b] Adjusted to basin limits

Whenever a variable was available at basin scale from an official source, this was used. For data unavailable at basin scale, we adjusted to basin scale he available regional or national level through an algorithm weighting by population or area.

5.3 Collective Services Exempt from the WFD Cost Recovery Provision

Some public services, such as flood control, are defined as collective and not subject to water pricing and cost recovery, because the benefits accrue to society as a whole, rather than to individual agents. This information should be included in 'Table A1.6 Government account table for water-related collective consumption services'. These data were obtained by analysing the Government budget when available and using World Bank series for the missing data estimation.

5.4 Data Related to Cost Recovery Instruments

Tables A1.7 and A1.8 in SEEA-Water present national expenditure and financing accounts for water-related activities classified by purpose, and both tables are synthetized in Table 3 below. The national expenditure accounts give an indication of the expenditure by resident units on specific activities related to water, such as wastewater and water management. The financing accounts are particularly important because users of water and water-related products do not always pay for the entire costs associated with their use. They benefit from transfers from other economic units (generally governmental) which bear part of the costs. Similarly, investments in infrastructure are also often partly financed by units other than the one that benefits from its use. Analysis of the financing of the use of water and water related products, as well as investments in water-related infrastructure, produces information on how the expenditures are financed: by which agent and by means of what instrument, such as the sale of services or environmental taxes. Such information is relevant, for example, for assessing the implementation of the polluter/user-pays principle, as the accounts for financing show the portion of the total cost paid by the polluter or user.

As mentioned in the previous paragraph, expenditure on collective water services that benefits society as a whole is not subject to cost recovery, and can be financed through general taxation. Only water services related to the satisfaction of specific agent needs (irrigation, water as an economic input, water supply and sanitation) are subject to cost recovery. Spanish legislation provides several fiscal and market instruments to recover the cost of water service provision.

Financial cost recovery instruments can be managed by public or private agents at different stages in the provision and management of water services. To calculate cost recovery rates, we need to estimate what public and private agents receive for the water services they provide. We can assume that private agents recover 100 % of their costs (e.g., private groundwater abstraction should pay all cost), while public agents may recover their costs in full or partially as the public agent may support a deficit in a service financed by public sources. We shall first discuss the instruments related to water provision, classified as ISIC 36, for which there are three responsible agents: the RBA, utilities and WUAs.

- Surface water storage and distribution at basin level is financed through a water tariff administered by the RBA. It is intended to cover the cost of reservoirs, distribution, policy

Table 3 EU standard cost recovery table completed for the Guadalquivir River Basin, 2012

Water service		SEEA-water table	Water use	Volume served (hm^3)		Financial costs (EUR·10^6)			Collected income (EUR·10^6)	Cost recovery index (%)
				Water served	Water consumed	O & M expenses	Capital AEC	Financial AEC total	Tariffs, prices and self supply costs	
				A1.1	A1.1	A1.4	A1.4 / A1.6		A1.7/A1.8	
				A	B	C	D	E = C + D	I	K = I/E*100
Abstraction, storage, distribution of water	Upper services: surface water abstraction, supply & distribution	A1.4 / A1.6	1 Urban	447.5		56.8	38.1	95.0	70.0	74 %
			2 Agriculture/ livestock	2088.2		24.0	22.1	46.1	29.5	64 %
			3 Industry/ energy	30.9	30.9	3.9	2.4	6.3	4.8	76 %
	Upper services: groundwater abstraction	A1.4 / A1.6	1 Urban	62.7		12.3	2.7	15.0	15.0	100 %
			2 Agriculture/ livestock	–	–	–	–	–	–	–
			3 Industry/ energy	–	–	–	–	–	–	–
	Lower services: irrigation distribution	A1.4/ A1.6	2 Agriculture	2011.6	,861.4	97.1	69.2	166.3	121.3	73 %
	Urban distribution	A1.4	1 Domestic	323.6	64.7	282.5	39.6	322.1	313.9	97 %
			2 Agriculture/ livestock	–	–	–	–	–	–	–
			1 Industry (connected)	31.8	6.4	27.7	4.0	31.75	30.8	97 %
	Self supply	A1.5	1 Domestic[a]	–	–	–	–	–	–	–
			2 Agriculture/ livestock	1117.1	1117.1	138.9	92.6	231.6	231.6	100 %
			3 Industry/ energy	36.3	36.3	3.0	0.7	3.8	3.8	100 %

Table 3 (continued)

Water service		SEEA-water table	Water use	Volume served (hm^3)		Financial costs ($EUR \cdot 10^6$)			Collected income ($EUR \cdot 10^6$)	Cost recovery index (%)
				Water served	Water consumed	O & M expenses	Capital AEC	Financial AEC total	Tariffs, prices and self supply costs	
				A1.1	A1.1	A1.4	A1.4 / A1.6		A1.7/A1.8	
				A	B	C	D	E = C + D	I	K = I/E*100
	Reuse	A1.4	1 Urban reuse	–	–	–	–	–	–	–
			2 Agriculture/livestock	16.7	16.7	3.8	0.2	4.0	4.0	100 %
			3 Industry/energy	–	–	–	–	–	–	–
	Desalination		1 Urban supply	–	–	–	–	–	–	–
			2 Agriculture/livestock	–	–	–	–	–	–	–
			3 Industry/energy	–	–	–	–	–	–	–
Collection and treatment of used water	Collection outside public networks	A1.5	1 Domestic	–	–	–	–	–	–	–
			2 Agriculture/livestock	–	–	–	–	–	–	–
			3 Industry/energy	16		6.3	0.7	7.0	7.0	100 %
	Public networks	A1.4 / A1.6	1 Domestic	258.9		102.5	19.6	122.1	113.9	93 %
			1 Industry (connected)	25.4		10.0	2.0	12.1	11.1	93 %

[a] Domestic self-supply is neligible (only some gardens and isolated houses). it has not been considered by the Basin Water Authority to be relevant

and management of basin surface resources. The tariff is charged to irrigators, municipalities, industries and energy users in the basin.

- Utilities become responsible once the water enters municipal networks. They recover the cost of treatment and, distribution (ISIC 36) or collection and sewerage (ISIC 37) through the 'urban water charge'.
- WUAs can manage water supplied by the RBA (regulated surface water) or they may abstract and distribute groundwater, in both cases, they should fully recover the internal cost of distribution. WUAs are self-financed by irrigators in a cooperative way and consequently cannot generate deficits in the service of distribution. The instrument to recover the cost of this service is called '*derrama*'.
- Additionally, the cost of self-provision by either farmers or industries is recovered in full.

Regarding water sanitation, besides certain large industries that 'self-provide' sanitation, most frequently, these services are provided by ISIC 37 industries and government, which use the following instruments for cost recovery:

- Regional Government's 'water infrastructure levy', in use since 2011, is an environmental tax designed to protect water resources, with the objective to guarantee supply and quality. The charge is calculated as a function of the water used by domestic and industrial users and is designed as an increasing block tariff. The income from the tax mainly finances sewerage and sanitation plants.
- Industry ISIC 37 (Water sanitation) companies use the 'waste water levy' to cover operation and maintenance costs of waste water treatment plants and – in full or in part – the depreciation of infrastructure as we will see in the Results Section. Private agents and industries are charged according quantity and quality of discharges.
- Internalised in the waste water levy is the 'waste water control levy', which the RBA uses to cover the costs made for pollution monitoring in water bodies.

6 Method of Cost Recovery Estimation

Based on the standard SEEA-Water tables, cost recovery ratios are computed by dividing the income generated from water services (as taxes, prices or any other financial instruments) by the cost of their provision. Figure 2 tries to illustrate the method where each critical value is obtained directly from the different SEEA Tables. Our objective is the reliability, repeatability and reproducibility of cost recovery estimations and we believe that this has been achieved, this section describe the process.

The cost of water service provision is defined as the Annual Equivalent Cost (AEC), consisting of two elements: a) the annual operation and maintenance expenses and b) the annual depreciation and interest related to the infrastructure capital stocks. The definition of AEC can be found in (Berbel et al. 2011a); we use a 4 % interest rate to discount capital stocks.

For the public sector the accumulated water service capital infrastructure is equal to the sum of annual (public) investment. We have defined a time frame of 50 years for civil works (dams and auxiliary infrastructure) and 25 years for waste water treatment facilities.

We have adapted the results of the SEEA cost recovery estimation to the new standard EU reporting procedures mentioned in Section 2. This procedure includes a standard table, which we completed for the Guadalquivir Basin (Table 3). All Member States are obliged to use this

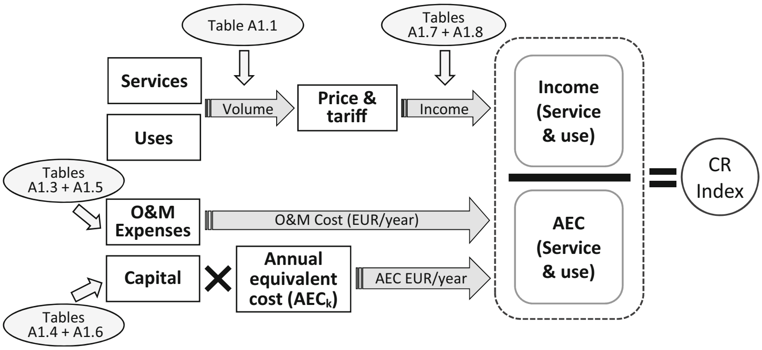

Fig. 2 Methodology for estimation of Cost Recovery Index. Source: Own elaboration

table to report cost recovery results. It requires a detailed estimate of the costs and income for all agents that play a role in water supply and treatment, whether they are public, collective or private. As can be seen, cost recovery estimation is divided between 'Abstraction, storage, and distribution of water' and 'Collection and treatment of used water', and each of these is further subdivided into the sectors Urban, Agriculture/livestock and Industry/energy. We define 'upper' as the services given by the RBA and 'lower' the services given by rest of agents.

Table 3 includes an estimate of the total water volume provided and consumed, (SEEA-Table A1.1) that is consistent with standard WFD reporting. However, unlike other cost recovery estimation applications,[1] we do not use these volumes for the estimation of costs or income.

Income generated by the water services is collected in the column 'Tariffs, prices and self supply costs', which we completed using information from 'Table A1.8 Financing account tables' in the SEEA-Water framework.

7 Results: Cost Recovery Ratios in the Guadalquivir River Basin

The ratios from Table 3 have been brought together in Table 4, to which we added combined ratios for the different sectors and services and a ratio for overall water services. It can be seen that some services reach full (100 %) financial cost recovery: urban groundwater abstraction; self-supply by agriculture and industry; reuse of treated waste water in agriculture/livestock; and the self-managed waste water treatment by industries not connected to public networks. The remaining services or sectors do not reach full cost recovery, which we explain below.

- Overall, upper level surface water services have a cost recovery of around 66 % (2012 data), that implies an implicit subsidy from the RBA for the abstraction, regulation and distribution. This subsidy exists because not all capital (infrastructure) costs are recovered in the water tariff that all RBA, including Guadalquivir apply as only 56 % of the AEC (annual depreciation and financing of the infrastructure) is recovered (Ministry of Environment 2000). Although draft legislation has been drawn up to change this regulation, which dates back 60 years, it has proved difficult to reach political consensus.

[1] Most of the estimation of cost recovery the receipts are computed based on unit prices (EUR/m^3) multiplied by total volumes.

Table 4 Cost recovery ratios for the Guadalquivir River Basin. 2012

		Financial cost recovery index			
Service		Urban	Agriculture	Industry	Total[a]
Water supply: abstraction. storage and distribution. surface and groundwater	Upper level surface water services	74 %	64%[a]	76 %	66 %
	Upper level groundwater abstraction	100 %			100 %
	Irrigation water distribution		73 %[b]		73 %
	Urban cycle (distribution of drinking water)	97 %		97 %	97 %
	Self supply (surface & groundwater)		100 %	100 %	100 %
	Reuse		100 %		100 %
	Desalination	–	–	–	n/a
Collection and treatment of sewage water	Non connected collection	–	–	100 %	100 %
	Public network collection	93 %		93 %	93 %
		87 %	75 %	91 %	78 %

Source: Own elaboration from SEEA tables

Overall ratio based on the total economic income

[a] Non agricultural sectors receive a premium service of having a higher provision guarantee during droughts

[b] Non recovered costs for water irrigation distribution are justified by the reduction in farmers' water rights (25 % on average)

- The RBA provides a multipurpose service in regulating the water supply, and the cost of this service (with the implicit subsidy explained above) is distributed between the three economic sectors: urban users, agriculture and industry. Agriculture has the lowest recovery ratio, and apparently pays less for this service. However, the SEEA Water tables does not reflect the quality of the service when we consider the guarantee and of the water supply. Water rights entitlement that user are acknowledged are probabilistic, the RBA does not guarantee an assured provision of water and gives a probability of failure (0.2 % for non agricultural users and 20 % for agricultural users). Because drought conditions are quite common in the basin, this is a real premium. The premium results in an apparently higher water recovery ratio for non-agricultural users. To correct for this, the value of the guarantee would have to be estimated, but this is beyond the scope of this paper (see Mesa-Jurado et al. 2012) for an analysis of the economic value of water supply guarantees for irrigation under scarcity conditions).
- Cost recovery ratio of 73 % for the distribution of irrigation water is due to subsidies for 'modernization of water networks' (water saving investments). Farmers receive subsidy of 50 % of the total investment (see Berbel et al. 2015) although they pay totally the operation and maintenance costs. In return, the RBA retains 25 % of the water rights held prior to the modernization for 'environmental goals'. In practice this means that farmers renounce to a quarter of their previous water rights, and the subsidies can be interpreted as 'water rights buyouts'. Because the mechanism to retain the water rights is complex, it is not captured by our estimation of the cost recovery ratio, which therefore appears lower than it in fact is.

- Cost recovery rates for urban water distribution (97 %) and waste water collection and treatment (93 %) show that the subsidies to infrastructure are not transmitted to final users. We assume that operation and maintenance cost are fully recovered and the deficit appears because part of the investment is subsidized to the utility manager.

8 Discussion and Concluding Comments

Previously published cost recovery rates for water services in Spain show a heterogeneous picture:

- The Ministry of Environment (2007, page 201 and page 189) provides estimates of 99.83 % for the urban sector and 97.70 % for irrigation services.
- The Guadalquivir Hydrological Plan (CHG 2013) reports a global ratio of 86 % for the basin.
- Krinner (2014) finds an overall rate for Spain of 72 %.
- The European Environment Agency (2013) reports a misleading figure for the Guadalquivir Basin of 49.78 %, but the RBA has never published this figure and it is not clear where the EEA obtained it.

Values for other Mediterranean countries in the mentioned EEA report vary from a low of 20 % in southern Italy to 80 % in northern Italy, with an average of 50 %. The wide range of the estimations is caused in part by the differences in the applied methodologies. For example water self-supply and agricultural drainage services are not included in the different country estimations, and asset life and the interest rate are treated differently in different countries, as well. Our proposal to use the SEEA-Water tables to standardize the estimation is a step towards obtaining comparable figures and would be an improvement on the present disordered situation.

Our methodology does not resolve all existing issues, such as the treatment of government expenses for public collective services (e.g., the protection of the environment, goods and human lives). Another example is how to include environmental and resource costs. Diffuse pollution coming from agricultural or other industries is not addressed by the existing cost recovery instruments and is out of the scope of our analysis. These issues cannot be included in the SEEA-Water tables in their present form. Also, a general consensus on how to measure environmental and resource costs does not yet exist, but would be necessary for them to be included in a uniform way. Some methods to include environmental and resources cost of water in order to achieve the full cost recovery have been developed for the case study area. Berbel et al. (2011b) estimate the value of irrigation water while Martin-Ortega et al. (2011) use the choice experiment method to determine environmental and resource cost of water. Others methods have been used to calculate total cost as in Martínez et al. (2011) or Sechi et al. (2013) among others.

To conclude, we believe that our proposal to use SEEA-Water as the basis for cost recovery estimates should be explored by policy makers within and outside the EU. The advantages of the methodology are that: a) it is based on an international standard methodology, b) it uses definitions that have been agreed by consensus, c) it uses official information that is public and updated periodically, d) it is transparent, and e) cost-efficient. Finally, we believe that our proposal allows territorial comparisons and temporal series analysis with the properties of reliability, repeatability and reproducibility.

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Water Productivity under Drought Conditions Estimated Using SEEA-Water

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Abstract: This paper analyzes the impact of droughts on agricultural water productivity in the period 2004–2012 in the Guadalquivir River Basin using the System of Environmental-Economic Accounting for Water (SEEA-Water). Relevant events in this period include two meteorological droughts (2005 and 2012), the implementation of the Drought Management Plan by the basin's water authority (2006, 2007 and 2008), and the effects of irrigated area modernization (water-saving investment). Results show that SEEA-Water can be used to study the productivity of water and the economic impact of the different droughts. Furthermore, the results reflect the fact that irrigated agriculture (which makes up 65% of the gross value added, or GVA, of the total primary sector) has considerably higher water productivity than rain-fed agriculture. Additionally, this paper separately examines blue water productivity and total water productivity within irrigated agriculture, finding an average productivity of 1.33 EUR/m^3 and 0.48 EUR/m^3, respectively.

Keywords: drought; system of environmental-economic accounting for water; water productivity; agricultural sector

1. Introduction

Water scarcity is a structural condition in arid regions of the world, which can be further exacerbated by drought events. Droughts create periods of water shortage, affecting all economic uses and environmental services of water resources. The efforts of hydrologists have helped to characterize and forecast droughts, with several standard indicators available in the literature.

According to Wilhite and Glantz [1], there is no single definition of a drought, with different definitions relating to the different aspects or effects that droughts have. Meteorological droughts usually relate to the degree of dryness (in comparison to some average quantity) and the duration of the dry period. Hydrological droughts relate to water flows through the hydrological system and usually lag the occurrence of meteorological and agricultural droughts. They can be defined as "periods during which streamflow is inadequate to supply established uses under a given water management system" [2]. The concept of agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts. With agricultural droughts, the focus lies on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and so forth. Finally, socioeconomic drought is associated with the supply and demand of certain economic goods, and includes elements of meteorological, hydrological, and agricultural droughts. There are indices for all types of drought, but there is no one-size-fits-all drought index or indicator.

In a recent review on the costs of natural hazards, Meyer, *et al.* [3] report a lack of studies that document drought-related economic losses. The studies that do exist differ in their scope and methodology; a review of methods and a complete assessment of drought-related costs can be found in Martin-Ortega and Markandya [4].

Droughts have a large impact on biomass production and usually affect biodiversity and the environmental health of ecosystems in a negative way. They also have a significant economic impact, which is the topic of the current study. Specifically, we use the System of Environmental-Economic Accounting for Water (SEEA-Water) [5] to assess the impact of drought on agricultural water productivity and, if possible, its indirect impact on the economy as a whole. SEEA-Water provides a conceptual framework for organizing hydrological and economic information in a coherent and consistent manner.

The European Commission recently published a guidance document to standardize economic information about water use in Europe [6], proposing a wider use of the SEEA, but to date there have been few practical applications in European basins and regions. Some applications that use SEEA-W can be found in the literature: a valuation of water resources in the Netherlands using the System of National Accounts and SEEA-Water [7]; an application to the Vélez River Basin in Southeastern Spain [8]; the evaluation of measures for better water management in arid areas in China [9]; and lastly, a methodological proposal for estimating cost recovery ratios based on SEEA-Water accounts as applied to the Guadalquivir River Basin (Southern Spain) [10].

SEEA-Water provides the basis for the analysis of the water productivity and the drought impact in Guadalquivir between 2004 and 2012. Lange *et al.* [11] use the SEEA framework for water accounting applied to the Orange River Basin, which is shared by four nations, and calculate water use and productivity by industry and country.

The agricultural productivity literature focuses on Total Factor Productivity (TFP) indices and DEA models, while in irrigation water economics literature, single-factor productivity has been widely used. Agricultural economists have estimated water productivity by means of crop yield measurements and water use at experimental stations and farmer fields, as either a ratio of kilograms of yield relative to evapotranspiration or kilograms to applied irrigation water. When the analysis is conducted at a regional or basin level, Molden *et al.* [12] propose using the ratio of a dollar value relative to the consumed for the whole basin.

The objective of this study is to investigate whether the SEEA-Water tables can be used to estimate the economic impact of drought on agricultural water productivity. We apply the methodology to a Euro-Mediterranean river basin (Guadalquivir). By covering periods when meteorological, hydrological and agricultural droughts occur and when Drought Management Plans (DMPs) were implemented, we can track and characterize the economic impact of drought events. DMPs are regulatory instruments that establish priorities among the different water uses during droughts; in recent years, they have been widely adopted across southern EU basins. Estrela and Vargas [13] present a general overview of drought governance and DMPs in the EU, reviewing scientific and technical advances, as well as the implementation of policy tools.

Section 2 shows general information about the case study and the data sources. Section 3 focuses on the results of meteorological and hydrological data in the period under study and presents the economic analysis. Discussions are developed in Section 4 and some concluding remarks can be found in Section 5.

2. Materials and Methods

2.1. Case Study: Guadalquivir River Basin 2004–2012

The Guadalquivir River is the longest river in southern Spain with a length of around 650 km. Its basin covers an area of 57,527 km^2 and has a population of 4,107,598 inhabitants (see Figure 1 for a map of the basin). The basin has a Mediterranean climate with a heterogeneous precipitation distribution. For the period 1940–2012, the annual average temperature was 16.8 °C, and the annual precipitation averaged 573 mm (similar to the average precipitation between 1987–2013 shown in Figure 2), with a range between 260 mm and 1033 mm (standard deviation of 161 mm). The average renewable resources in the basin amount to 7043 (arithmetic mean) and 5078 hm^3/year (median), ranging from a minimum of 372 hm^3/year to a maximum of 15,180 hm^3/year [14]. In a normal year, a potential volume of around 8500 hm^3 can be stored through a complex and interconnected system of 65 dams. The main land uses in the basin are forestry (49.1%), agriculture (47.2%), urban areas (1.9%) and wetlands (1.8%).

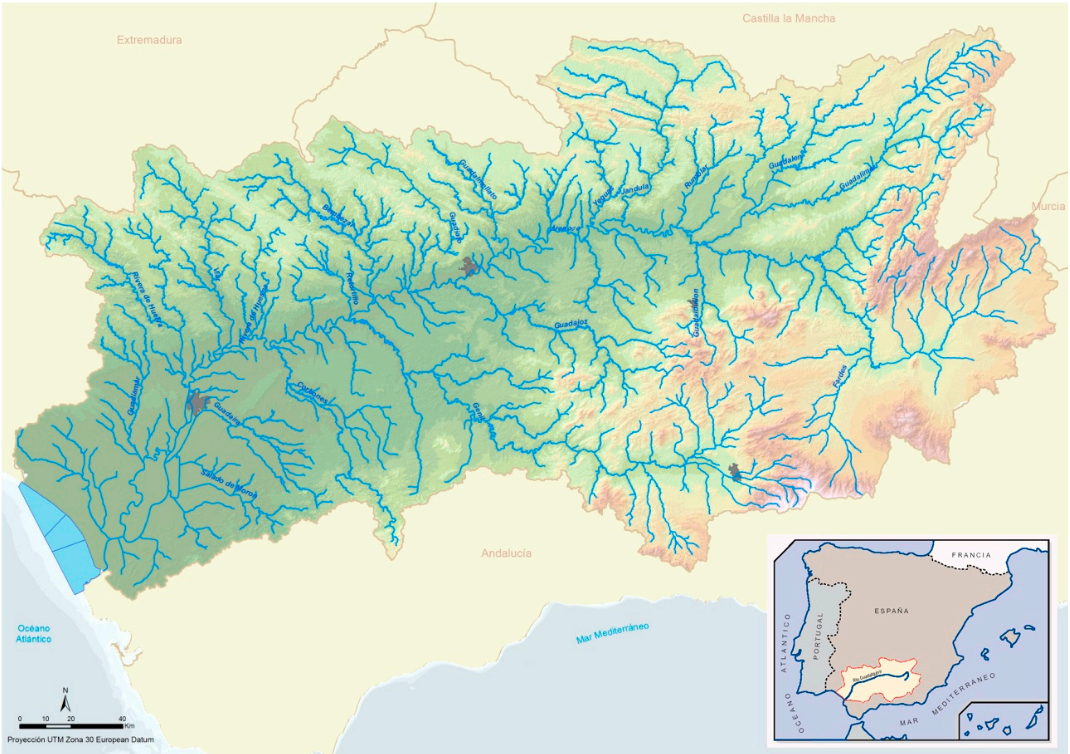

Figure 1. Guadalquivir River Basin map. (Source: Adapted from the Guadalquivir River Basin Authority, www.chguadalquivir.es).

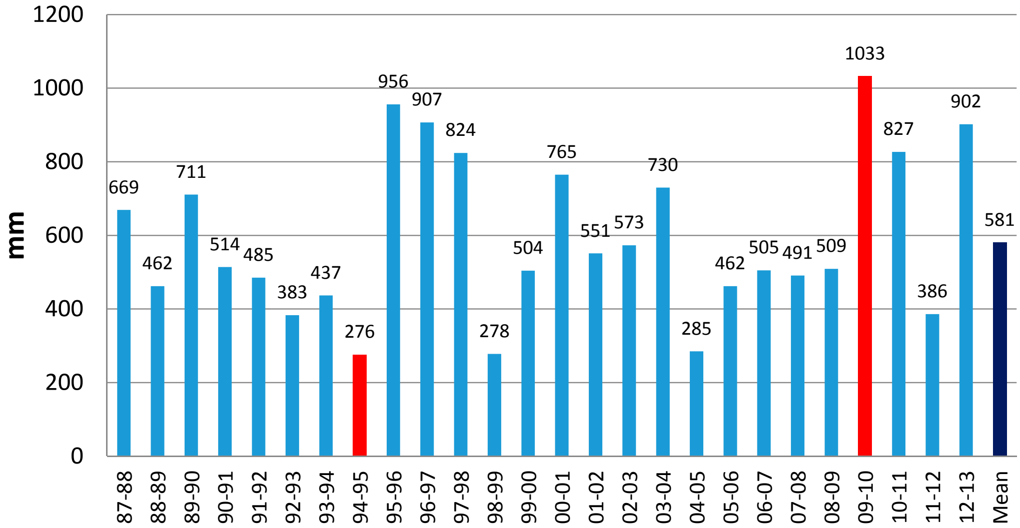

Figure 2. Precipitation in the Guadalquivir River Basin (1987/1988–2012/2013). Red bars show years with maximum and minimum precipitation. (Source: Guadalquivir River Basin Authority).

An analysis of the Guadalquivir Hydrological Basin Plan can be found in Berbel *et al.* [15]. Agriculture is the main water user in the basin and has made large investments in water-saving measures, referred to as "modernization" [16]. Berbel *et al.* [17] analyze the impact of modernization on water use and cost for a sample of irrigation water user associations during the period 2004–2012.

The Guadalquivir River Basin Authority [18] approved a DMP that was first implemented in the most recent period of drought in 2005–2008. The resulting effects of the reduction in irrigation quotas will be shown later as part of the discussion on SEEA accounts. The full period of analysis (2004–2012) starts before the implementation of water-saving measures, includes the last drought (2012), and is long enough to study the implementation of water-saving measures and their impact.

2.2. Data Sources

Implementation of the SEEA-Water tables requires good quality hydrological and economic data. Several sources have been consulted to estimate the hydrological variables required. As can be seen in Table 1, the data are based on the official Ministry for Environment framework, SIMPA (Integrated System Modeling Process Precipitation Contribution), which gives rain precipitation and evapotranspiration for the basin in 1 km^2 cells, along with further estimates based on the Guadalquivir River Basin Authority (RBA) surveys for irrigated areas and measurements of water served to large irrigation schemes and municipal users. The RBA publishes accurate measures of water consumption and river flow in strategic locations that provide a good estimate of annual water resources use and that have been integrated in the analysis of water volumes in the SEEA Tables.

Table 1. Data source for hydrological variables.

Variable	Data Source	Producer	Comment
Agricultural production by branch	MAGRAMA	MAGRAMA	–
Evaporation rate from reservoirs	MAGRAMA/CEDEX	MAGRAMA/ CEDEX	Evaporation stations available in the Guadalquivir River Basin
Agricultural surface evolution	RBA	RBA	–
Volume in reservoirs	RBA	RBA	–
Rainfall	SIMPA	RBA	–
Rainfall	REDIAM	AEMET	Principal network of meteorological stations
Infiltration	SIMPA	RBA	–
Potential evaporation ETP	SIMPA	RBA	–
ETR	SIMPA	RBA	–
Groundwater runoff	SIMPA	RBA	–
Irrigation efficiency by units	RBA	RBA	Efficiencies by irrigation unit
Irrigation use (water doses)	RBA	RBA	–
Surface runoff	SIMPA	RBA	–
Temperature	SIMPA	RBA	–
Gauging stations	SAIH/Gauge monitoring network	RBA/CEDEX	–
Groundwater resources, aquifer characterization	RBA /IGME	RBA/IGME	Management plan for sustainability of GW resources
Volume of dam/ regulation capacity	RBA	RBA	Annual report
Water demand	RBA	RBA	Own elaboration based on RBA reports, INE
River flow	SAIH	RBA	Water levels for river volume estimation
Returns	RBA	RBA	–
Aquifer level (piezometric)	Piezometric monitoring network	MAGRAMA/IGME	Reference for the assessment of flows between groundwater and superficial resources

MAGRAMA: Ministry of Agriculture, Food and Environment; CEDEX: Centre for Hydrographic Studies; RBA: Guadalquivir River Basin Authority; SIMPA: Integrated System Modeling Process Precipitation Contribution; REDIAM: Environmental Information Network of Andalusia; AEMET: Spanish Meteorological Agency; SAIH: Automatic Hydrological Information System; INE: National Statistics Institute.

2.3. Hydrological/Agricultural Drought in the Guadalquivir River Basin 2004–2012

The nine consecutive years under study include dry and wet years (see Table 2). For the purpose of this paper, we treat hydrological and agricultural droughts as equivalent, meaning that a lack of water flow through the hydrological system results in restrictions to irrigation, while a good reservoir water storage situation allows full irrigation despite the meteorological situation. These years can be grouped, hydrological and meteorologically, into four classes:

1. Two very dry years with normal irrigation: 2004/5 and 2011/12, when rainfall was 51% and 33% below average, respectively. These years can be defined as meteorological droughts with no effect on agriculture.
2. Three years with normal-to-low precipitation (80%–87% of the average). In these years, rain-fed crops suffered a minor reduction in productivity, but they are not considered proper drought periods by meteorological standards. However, water storage fell below its critical point and irrigation cuts were applied according to the DMP. We consider these years as hydrological/agricultural droughts.
3. One year with normal precipitation (88% of the average) and with no irrigation constraints: 2008/09.
4. Three wet years (126%–178% of average) with full irrigation: 2003/4; 2009/10 and 2010/11.

Table 2. Precipitation and irrigation in the Guadalquivir River Basin (2004–2012).

Year	Rain (mm)	Irrigation (mm)	Rain % of Average	Irrigation% of Average	Comments
2003–2004	730	343	126%	123%	Wet year, full irrigation
2004–2005	285	389	49%	140%	Very dry year, full irrigation
2005–2006	462	198	80%	71%	Dry year, restricted irrigation
2006–2007	505	190	87%	68%	Normal year, restricted irrigation
2007–2008	491	194	85%	70%	Normal year, restricted irrigation
2008–2009	509	276	88%	100%	Normal year, full irrigation
2009–2010	1,033	284	178%	102%	Wet year, full irrigation
2010–2011	827	279	142%	100%	Wet year, full irrigation
2011–2012	386	345	66%	124%	Very dry year, full irrigation
Mean	581	278	100%	100%	–

A normal year is defined as precipitation being within 15% of the average; the 2004–2012 average rainfall is taken as the average of the previous 25 years (1987–2013). (Source: Guadalquivir River Basin Authority).

Figure 3 shows the reservoir water storage situation on October 1st, at the end of the irrigation season and the start of the new hydrological year, and on May 1st, which is a critical value as the new irrigation season begins and no significant additional resources are expected. It can be seen that in the 2004–2012 period, water volumes stored on May 1st in 2006, 2007 and 2008 were low compared to the rest of the series under study. In those years, implementation of the DMP meant that irrigation quotas were reduced to 50% of normal water rights, whereas the supply to urban and industry was not affected. For further information about water storage in the Guadalquivir Basin, we refer to Argüelles, Berbel and Gutiérrez-Martín [14], who analyze the evolution of water supply and reservoir volume in the basin, and Berbel *et al.* [19], who discuss the trajectory towards basin closure as a result of the inability to meet growing demand by increasing supply.

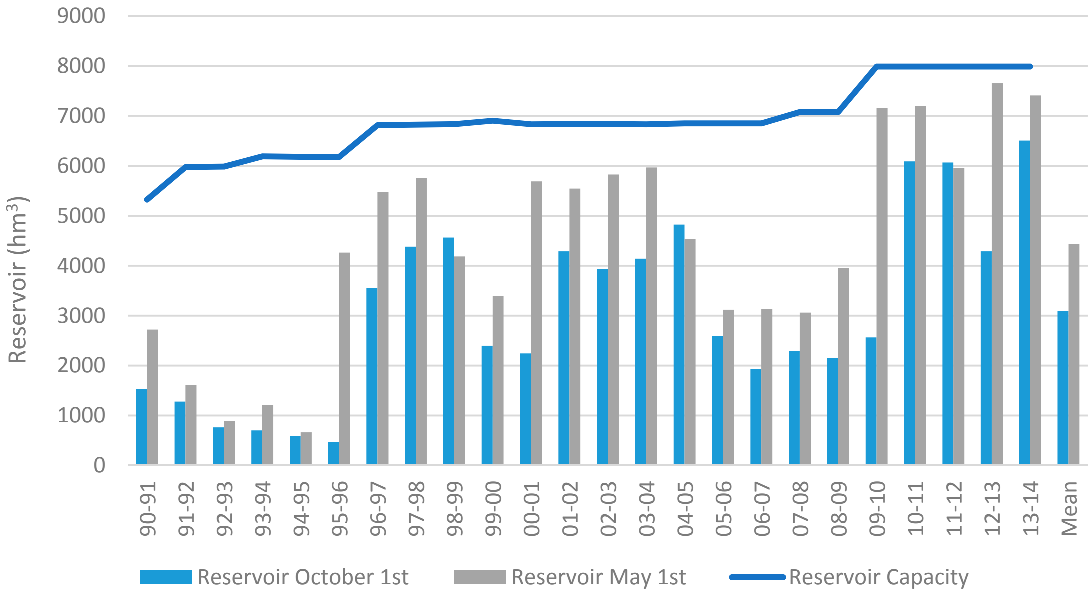

Figure 3. Water storage in the Guadalquivir River Basin (1990–2014) (Source: Guadalquivir River Basin Authority).

2.4. Method

The SEEA-Water system links physical water balances to socio-economic information, such as gross income, value added and employment of the main water abstractors. The economic data for this study were obtained from official sources in order to maximize reproducibility and transparency, and to minimize the cost of compiling the water account tables. The full set of tables can be found in Berbel *et al.* [20].

As mentioned above, SEEA-Water is used to analyze water productivity and drought impact in Guadalquivir between 2004 and 2012, and to compute water use and productivity during the period. The added value of using SEEA for this is the standardization for all temporal and spatial contexts.

The meteorological conditions and water storage management affect other basin water variables that are significant for agriculture. According to the SEEA-Water methodology, the key variables in this respect are: soil water, supply of irrigation, and reused water and return flows. Values for these variables are given in Table 3. Soil water was estimated with SIMPA software [21] that uses 1 km^2 simulation cells, and was estimated for irrigated area, rain-fed crop area and forests including pastures. Soil water estimates are based on the estimated rain in a location and the type of vegetation. Three groups of vegetation are distinguished within agrarian soil: permanent trees, herbaceous and heterogeneous systems. SIMPA is the official model in Spain for estimating water resources and we adopt this standard tool to create the water tables for hydrological variables.

The SEEA-Water handbook [5] states that "Abstraction from soil water includes water use in rain-fed agriculture, which is computed as the amount of precipitation that falls onto agricultural fields". This definition may lead some researchers to measure soil water only for rain-fed land, thus failing to take into account the rain that falls on irrigated land. We believe this is not a practical approach for Mediterranean basins where a significant proportion of the agricultural area is irrigated. In addition, it does not account for forestry or rangelands. Therefore, we use the following definition: soil water abstraction is the rain water evapotranspired by crops in both rain-fed and irrigated agriculture and by pastures and trees in forested areas. For irrigated areas in the Guadalquivir Basin, 62% of soil water comes from rain water (also called "green water"), with the remaining 38% coming from irrigation water (or "blue water").

3. Results

Table 3 shows the figures for green and blue water for the period under study ("Soil water irrigated land" and “Irrigation supply”, respectively), with an average of 453 mm of green water compared to 278 mm of blue water. The low proportion of irrigation supply is a consequence of the widespread use of deficit irrigation, which is applied to 70% of the irrigated area [22]. Finally, the supply of reused water is very small (16 hm^3, *i.e.*, less than 1% of irrigation supply).

Table 3 shows the water volume in absolute terms (hm^3) since it is the measure that needs to be included in SEEA Tables. We have also included the relevant value for agronomic information in ‘mm’. The first value is the result of multiplying the unit of water resource (mm) by the area (km^2). We can see that rainfall on irrigated land is slightly higher than the estimated value for rain-fed and forested land, and this is estimated by the SIMPA tool using the available hydrological information.

Table 3. SEEA hydrological variables related to agriculture (2004–2012).

Water (hm^3)	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mean
Soil water irrigated land	3833	2091	3923	4152	3990	4052	4593	4626	2631	3765
Irrigation supply	2448	3227	1655	1589	1645	2354	2431	2400	2989	2304
Total irrigation	6281	5318	5577	5742	5635	6406	7024	7026	5621	6070
Soil water rain-fed land	14,589	7396	12,835	13,378	12,627	12,607	13,824	13,735	8800	12,199
Soil water forested land	10,560	5901	9796	10,410	9759	9542	10,741	10,464	7153	9369
Total	31,430	18,615	28,208	29,529	28,021	28,555	31,589	31,224	21,574	27,638
Water (mm)	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Mean**
Soil water irrigated land	537	252	470	496	471	476	537	537	304	453
Irrigation supply	343	389	198	190	194	276	284	279	345	278
Total irrigation	879	641	669	685	666	752	821	816	650	731
Soil water rain-fed land	511	270	469	490	464	464	509	507	325	446
Soil water forested land	495	277	460	488	458	448	504	491	336	440

By definition, SEEA-Water is a hybrid accounting system that includes both economic and hydrological data. This allows several combined indicators to be calculated; we have selected the ratio of GVA to water consumption, although we distinguish between rain and irrigation water productivity. Apparent water productivity does not capture the productivity of the resource alone, since other factors-mainly land, labor, capital and management are also included [23]. In the remainder of this paper, we refer to this ratio using the abbreviated term 'water productivity', because this ratio gives not the value of marginal productivity and additionally, the numerator is the GVA which also includes items such as salary and interest. However, according to Young and Loomis [23] the ratio is a useful indicator for economic analysis and water management.

Table 4 shows the evolution of agricultural GVA in real terms. We can see the impact of the years with meteorological droughts (2005 and 2012) compared to years prior to those droughts (2004 and 2011, respectively). Years when water supply was restricted due to the DMP being in force (2006, 2007 and 2008) also had lower GVA than previous years with normal rainfall and no restrictions (2004). The SEEA uses aggregated regional data and we cannot clearly determine whether other sectors are affected by the droughts; obviously there should be some impact in sectors such as the food industry (29% of industrial output in the region) but we have not been able to detect this impact based on the regional statistics.

Common Agricultural Policy (CAP) subsidies in agricultural GVA for the years 2004 and 2005 have been corrected. The reformed CAP does not include price support from 2006 onwards, and so to enable comparison of all economic data in the period, we have subtracted price support from the official GVA data for the first two years of the series. In a preliminary version of this paper, the agricultural production value was taken directly from the Ministry's official estimation and that includes the CAP subsidies for 2004, and 2005 [24].

Table 4. Gross Value Added for water abstracting sectors in the Guadalquivir River Basin 2004–2012 (in million 2012 EUR).

Gross Value Added (GVA)	2004	2005 [1]	2006 [2]	2007 [2]	2008 [2]	2009	2010	2011	2012 [1]	Mean
Agriculture	4773	3751	3561	4442	4639	4650	5038	5334	4886	4564
Industry	9324	10,089	10,211	10,392	8039	7085	7511	7699	6901	9324
Building	8644	9859	10,859	11,498	11,379	10,260	7756	7079	6060	8644
Services	43,266	44,078	46,208	48,905	50,184	51,002	49,402	48,856	48,581	43,266
Total GVA	64,962	67,342	70,511	74,507	73,128	71,711	68,333	67,075	64,503	64,962

[1] Meteorological drought; [2] hydrological drought. Source: Own elaboration using data from the National Statistics Institute.

Table 5 shows the water productivity of the primary sectors (ISIC Sectors 01–03) for the period under study. Both livestock and forestry (together making up around 15% of total agricultural GVA in the basin) and rain-fed agriculture (around 20% of total GVA) have mean values below the overall average ratio (0.06 and 0.09 compared to 0.17 EUR/m^3, respectively), whereas irrigated agriculture (65% of total primary sector GVA) has a considerably higher water productivity.

Table 5. Apparent productivity of water in the Guadalquivir River Basin (2004–2012).

Water Consumption	Total Water Consumed	Livestock + Forest (Green Water)	Rain-fed (Green Water)	Irrigation (Blue Water)	Irrigation (Green + Blue Water)
GVA	Total	Livestock + Forest	Rain-fed	Irrigation	Irrigation
Productivity EUR/m^3	Total	Livestock + Forest soil water	Rain-fed soil water	Irrigation (blue water)	Total irrigation (green + blue water)
2003–2004	0.15	0.06	0.08	1.24	0.48
2004–2005	0.20	0.08	0.12	0.74	0.45
2005–2006	0.13	0.05	0.06	1.37	0.41
2006–2007	0.15	0.06	0.08	1.78	0.49
2007–2008	0.17	0.06	0.09	1.80	0.53
2008–2009	0.16	0.06	0.09	1.26	0.46
2009–2010	0.16	0.06	0.08	1.32	0.46
2010–2011	0.17	0.07	0.09	1.42	0.48
2011–2012	0.23	0.09	0.13	1.04	0.55
Mean	0.17	0.06	0.09	1.33	0.48

Within irrigated agriculture, we separately examined blue water productivity (Table 5, Irrigation (blue Water)) and total water productivity Irrigation (green + blue Water), finding average productivity values of 1.33 EUR/m^3 and 0.48 EUR/m^3, respectively. Of course, these results cannot be compared directly as the same GVA values were used in both ratios, but the interest lies in how both relate to precipitation and irrigation water, as shown in Figure 4.

In our opinion, we can separate observations into three groups of years: (a) Normal precipitation with restricted irrigation; (b) Dry years with full irrigation and (c) Normal precipitation with full irrigation. Only 2009 (normal year, normal irrigation) is an "independent year". In comparison with "blue water" productivity, the productivity of 'blue + green water' is more diverse, ranging widely in the first and second groups. Figure 4 is a curve that relates the use of the factor (either blue water or blue + green water) with the average apparent productivity, that is, GVA per m^3; although water is on both axes, the productivity decreases when the use of the factor increases according the law of marginal decreasing returns.

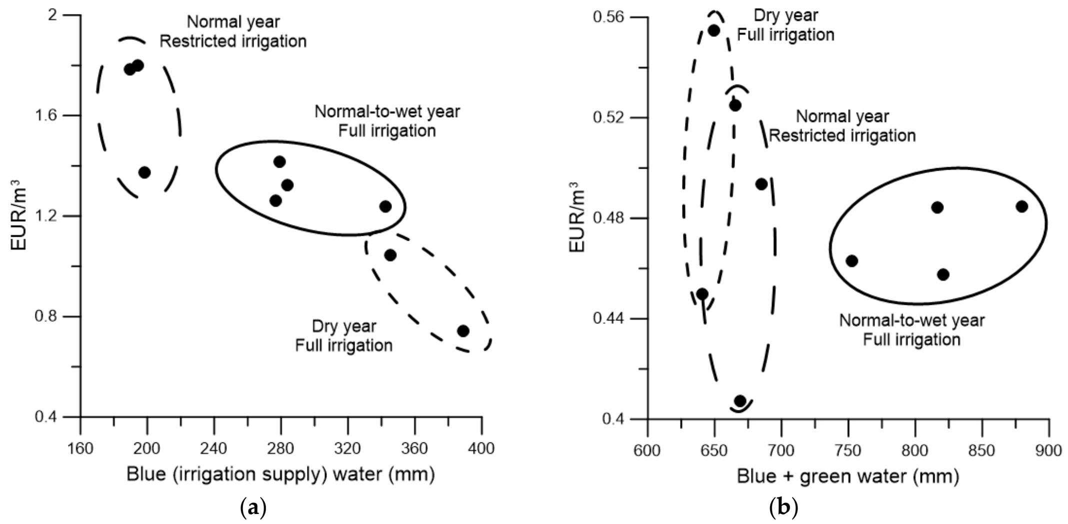

Figure 4. Water productivity in irrigated agriculture (EUR/m^3 base 2012) and water consumed (mm). (**a**) Water productivity blue water; (**b**) Water productivity blue + green water.

4. Discussion

We have estimated the impact of droughts on the evolution of agricultural GVA in years with meteorological droughts and hydrological droughts. Numerous papers have studied the economic impacts of droughts, including the report on the ongoing Californian drought [25], which was based on data from the USDA National Agricultural Statistics Survey. The conclusion from that paper is that the impact of the drought on California's agricultural sector was less severe than expected in 2014. This fact can be explained by various factors: (a) increased, but unsustainable, groundwater pumping; (b) the role played by water transfers; and (c) short and long-term shifts in the types of crops grown and improvements in irrigation technologies and practices.

In Australia, The Murray-Darling Basin Authority commissioned, as one of a number of consultancy reports, a report [26] on a range of different aspects of the socio-economic implications of reducing current diversion limits, a situation similar to a hydrological drought. It suggests that the reduced water availability could result in a 16%–20% decline in regional farm profits compared to those under the current diversion limits. However, the impacts could vary substantially across catchments, reflecting the mix of agricultural activities, the proposed adjustment to the water withdrawal cap compared to current water use, and the availability of water trading. All the above factors influence the opportunity costs faced by irrigators and the feasible options for adjustment.

In our application, results have shown that the range of water productivity is lower (0.41–0.55 EUR/m^3) for total (green + blue) water than for blue water alone (0.74–1.80 EUR/m^3). In addition, with respect to blue water only, there does seem to be a pattern whereby increased volumes of irrigation water leads to lower water productivity according to the law of marginal decreasing returns. It can be observed that, in general, normal and wet meteorological years with full irrigation produced medium productivity values, while dry years with full irrigation and normal years with restrictions tended to the extremes.

The relationship between water productivity and blue water use is almost linear (coefficient of determination = r^2 = 0.8). On the contrary, there is no good fit when green water is included. The explanation for this may be that while blue water is a well-controlled input that is applied by farmers under optimal conditions, the distribution of rain is not controlled and the "productivity" of green water is therefore more uncertain, or even counterproductive if rain falls before seeding or after crops have completed their growth cycle and some of the water is lost by evapotranspiration.

The water productivity values determined in this study are in line with those in a number of previous studies. Carrasco *et al.* [27] studied the evolution of irrigated crop water productivity for the

Guadalquivir Basin between 1989 and 2005 using statistical data at regional and crop level. The results indicated that the irrigated crop water productivity was 0.12 EUR per m^3 (in 2005 prices) in 1989, increasing to 0.50 EUR per m^3 in 2005 (9% annual growth). Berbel, Mesa-Jurado and Piston [22] also study water productivity ratios, finding a similar figure for 2005 as well as providing results for the residual value of water, signaling the differences between apparent productivity and water value.

García-Vila *et al.* [28] conducted a study aimed at characterizing the behavior of an irrigated area from 1991 to 2010 encompassing over 7000 ha in Southern Spain. Water productivity (value of production divided by the volume of irrigation water delivered) in the district was moderate and highly variable (around 2.0 EUR/m^3) and did not increase with time; that value is higher than the values calculated in this study because the focus is on the value of production rather than GVA. Irrigation water productivity (increase in production value due to irrigation divided by irrigation water delivered) was much lower (0.65 EUR/m^3) and similarly, it did not increase with time. The low irrigation water productivity shows the important role of green water in total productivity.

The Regional Government of Andalusia [29] estimates for determining the productivity of Andalusian irrigated agriculture are valued as 1.37 EUR/m^3 (Guadalquivir basin represents 90% of total irrigated land in Andalusia); this value for the Andalusian region is within the range obtained in this analysis and also in the range of the values reported by the Hydrological Plan [30] for irrigation water of 0.77 EUR/m^3.

Nevertheless, it would be advisable to look at total factor productivity, which represents the ratio of the total quantity of outputs to the total quantity of inputs, in order to account for total effect [31]. Along these lines, Mallawaarachchi *et al.* [32] performed an economic analysis of the impact of the Australian National Water Initiative on the efficiency and productivity of water use. They conclude that the average annual growth rate of total factor productivity for all irrigated farms is 1.1% a year, which is mainly driven by a decrease in input usage, including irrigation water. While this decrease in input usage may be attributable to efficiency gains in water use, the principal reason for reducing water use is the drought rather than any policy changes. Policy changes did, however, enable the irrigators to better manage the water scarcity.

5. Concluding Remarks

The Department of Economic and Social Affairs of the United Nations Secretariat, with the support of other institutions, has made an ambitious effort to build the SEEA-Water accounts and define a standard methodology that can facilitate international inter-basin comparisons and knowledge creation on the status and quantitative management of water resources.

This study has made a contribution by providing a practical application of these accounts in the Guadalquivir River for a period with different hydrological and meteorological conditions (2004–2012). We found three types of years: (a) meteorological drought years with rainfall below 33% of average but no constraints on irrigation water; (b) normal years (rainfall $\pm$15%) and irrigation supply reductions; and (c) normal-to-wet years with no constraints on irrigation.

When economic and hydrological data are linked, water productivity values (the ratio of GVA to consumed water) can be estimated by sector and year. The analysis of this ratio over the study period helps to understand the effect of meteorological and hydrological conditions on productivity, and the role of blue (abstracted) water and green (rain) water in irrigated agriculture.

The innovative contribution of the present study is to separate the productivity of blue and green water; we have thus been able to illustrate the impact of the different type of droughts on water productivity. This analysis provides additional information that may help improve the decision making of policy makers, administrators and farmers and can also be used for scenario exercises that simulate the impact of institutional or natural events.

The results of the current case study in the Guadalquivir Basin are as follows:

- The impact of meteorological droughts is observed in economic aggregated data for agriculture but not for other economic sectors. Agriculture is more directly dependent on weather conditions than most other sectors. Moreover, other sectors did not face reductions in allocated water, and "contagion" from agriculture to other sectors is limited due to the relatively low economic contribution of agriculture to the overall economy (7% of total GVA including livestock and forest).

- Hydrological/agricultural droughts, when they lead to reductions in irrigation volumes (due to low stocks and implementation of DMPs), result in higher 'blue water' productivity.
- Our estimation of blue/green water use in the basin reveals that only 38% of total water consumed by irrigated agriculture is 'blue water' with the remaining 62% being green (soil) water. This result adds to previous reports by Berbel, Mesa-Jurado and Piston [22] and Berbel, Pedraza and Giannoccaro [19], who stated that 70% of the area in the basin irrigates crops under a deficit irrigation regime.

These results show that hybrid tables can be used to estimate river basin water productivity values. Studying the ratio over the 2004–2012 period has provided useful knowledge about water productivity in these years and its relationship to rainfall and irrigation volumes. Furthermore, using the standard SEEA methodology allows this knowledge to be more easily shared and compared to other basins.

The application of SEEA accounts enables the determination of the direct impacts of meteorological and hydrological droughts, but it fails to detect the indirect effects (on the basin economy) based on aggregated basin data. The lack of non-farm impact may be explained by four factors: a) the fact that agriculture only represents 4% of basin GDP; (b) the role of irrigation in the basin, which mitigates the effects meteorological droughts by compensating for the lack of rain (this is relevant as irrigation provides 65% of the sector's overall value); (c) the effect the Common Agricultural Policy; and (d) fluctuating prices, which compensate for lower production. Further research is therefore required to fully assess the economic impact of droughts using aggregated data.

Finally, our research demonstrated the importance of "green water" in irrigated areas, illustrating the fact that SEEA-Water's definition of "soil water" is incomplete since it focuses exclusively on rain-fed agriculture. The volume of consumed soil water (green water) by irrigated crops makes up around 62% of their total water consumption in this basin, with blue water supplying only 38% of crop requirements (at global basin level).

To conclude, we confirm that the SEEA-Water accounts are a useful tool for the economic analysis of water use and the impact of climatic conditions, but this exercise has also demonstrated the limitations of using aggregated economic data and has shown there are still conceptual problems with the SEEA-Water definitions that need to be addressed.

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Abbreviations

The following abbreviations are used in this manuscript:

SEEA	System of Environmental-Economic Accounting
DMP	Drought Management Plan
PETmax	Potencial Evapotranspiration
CAP	Common Agricultural Policy
GVA	Gross Value Added
GDP	Gross Domestic Product

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Measuring the Sustainability of Water Plans in Inter-Regional Spanish River Basins

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Abstract: This paper analyses and compares the sustainability of the water plans in the Spanish River basins according to the objectives of the Water Framework Directive. Even though the concept of sustainability has been traditionally associated with the triple bottom line framework, composed of economic, environmental, and social dimensions, in this paper sustainability has been enlarged by including governance aspects. Two multicriteria decision analysis approaches are proposed to aggregate the sustainability dimensions. Results show that the environmental dimension plays the most important role in the whole sustainability (40%) of water basins, followed by both economic and social criteria (25%). By contrast, the dimension of governance is the least important for sustainability (11%). A classification of the Spanish basins according to their sustainability indicates that the water agency with the highest sustainability is Western Cantabrian, followed by Eastern Cantabrian and Tagus. By contrast, Minho-Sil, Jucar, and Douro are the least sustainable.

Keywords: sustainability; Water Framework Directive; integral water management; multicriteria decision analysis; water policy design

1. Introduction

A modern water management system must be not only effectively provide water security, but also be sustainable, combining economic progress with social development and the conservation of habitats and ecosystems. The Water Framework Directive (WFD)—Directive 2000/60/EC [1]—and the introduction of river basin districts may help to fulfil such objectives. The environmental objectives are defined in Article 4—the core article—of the WFD, aiming to achieve a sustainable water management system on the basis of a high level of protection of the aquatic environment. Achieving such sustainability requires some boundaries, as through the definition of river basin districts. These districts are hydrological units selected on the basis of the spatial catchment area of the river, and not depending on any administrative or political boundary.

Spain has a wide tradition in water management through agencies called basin water agencies (BWAs), which have been operative since 1920. BWAs play an important role in water planning, resource management and land use, protection of the public water domain, management of water use rights, water quality control, planning and execution of new water infrastructure, dam safety programs, etc.

The WFD sets out clear deadlines for each of the requirements as can be consulted in [2]. Within such milestones, water administration agencies from each member state have to report each issue to the European Commission on time, with 2015 being a relevant date in the WFD implementation. Thus, the first management plan (River Basin Management Plan 2009–2015) has been finalised and the second management plan (River Basin Management Plan 2015–2021) and the First Flood Risk Management Plan have just started.

Since the first River Basin Management Plan has finalised quite recently, it is of particular interest analysing the sustainability of Spanish BWAs in water management and their contribution to fulfil the WFD objectives. In this sense [3], it is recommended to strengthen the links between water planners and academics in order to improve future revisions of the River Basin Management Plans. More concretely, it is proposed that the assessment and the selection of methods were done jointly in order to design and implement new water policies in Spain. In addition, the role of BWAs is highlighted as potential coordinators of such evidence-based policy-making.

Considering this framework, the objective of this paper is to analyse and compare the sustainability of water plans in the Spanish river basins according to the objectives of the WFD. In addition, dimensions that may be enhanced to improve the basins' sustainability are analysed, being this analysis a starting point to improve water management sustainability in the following management plans.

After this brief introduction, Section 2 reviews some of the previous works on assessing sustainability by using multicriteria decision-making methods. In the Section 3 the case study is presented. Sections 4 and 5 include the methods used to assess the sustainability of water plans and results. Finally, Section 6 concludes the paper.

2. Literature Review

Sustainability has been used as a criterion to analyse water resource management quite often in the literature. In order to assess such sustainability, multicriteria decision analysis (MCDA) has been commonly used since the 1970s. It is possible to find a considerable number of applications related to water management on different river basins. Thus, Hajkowicz and Collins [4] reviewed 113 studies that used MCDA for analysing water resource management. They found that these methods are of relevance since the annual publication rate has been steadily growing since the late 1980s. The majority of applications are related to the fields of water policy, supply planning and the evaluation of major infrastructure.

Regarding the evaluation of different water management strategies, it is worth highlighting [5], in which a three-step process is developed to evaluate different water management strategies in a river basin in Brazil. The analytical hierarchy process (AHP) was used to help identifying the groups of interest, articulate their preferences and find the dominant preferences of the community within the river basin, as well as to get a consistent evaluation of management strategies. In addition, Martín-Ortega et al. [6] performed a multicriteria analysis of water management under the WFD. They selected some measures for a sustainable and socially accepted water management in the Guadalquivir river basin in order to test the applicability of the AHP in the new WFD context. A survey was carried out in the context of a future enlargement of a reservoir. Results suggest that the AHP is an adequate tool for the WFD purposes and a useful complement for the cost-effectiveness analysis.

There are other works that analyse different water management strategies to address concrete problems in some areas. In this line, Jaber and Mohsen [7] proposed a support system for decision evaluation and selection of nonconventional water resources in the river Jordan. They include desalination of saline and seawater, treated waste water, importation of water across boundaries, and water harvesting. Using AHP, they found that water desalination was ranked the highest, being the most promising resource, followed by water harvesting. Freiras and Magrini [8] presented a selection of sustainable water management strategies for a mining complex located in the southeast region of Brazil, which concentrates most of the country's population and the mining facilities, but a small portion of the water available in the territory. A stepwise process for incorporating environmental risks into the decision-making using a multicriteria approach and AHP was developed and applied in this case study. Da Cruz and Marques [9] used the MACBETH multicriteria model to determine sustainability level of urban water cycle services (UWCS). They show that it is possible to assess both global sustainability and performance of UWCS in each particular dimension of the sustainability, taking into account the values and judgments of the legitimate stakeholders. Recently, Marques et al. [10] discussed the concept of sustainable water services and suggested using MACBETH multicriteria method to assess it. They illustrated a real-world application of the method in urban water services (UWSs) in Portugal and used a simple additive aggregation model to calculate the sustainability score of each UWS. Finally, the work of [11] implemented MCDA in an irrigated area in Spain. They found six factors to define alternative strategies (policies) that could change the planning scenario of the irrigation system: irrigation system, water pricing, water allocation, crop distribution, fertiliser use and subsidies received. Five different MCDA techniques were used and results indicated that all techniques choose the same alternative strategy as the preferred one: sprinkler irrigation system, with no change in the existing water pricing and water allocation schemes, growing wheat and barley as the main crops with organic fertilisers and without any change in the subsidy policy.

3. Case Study

The main Spanish BWAs exceed a single region, being called as inter-regional water agencies (IRWAs). We can distinguish ten different IRWAs in Spain, that is, Western and Eastern Cantabrian (Cantábrico oriental y occidental), Minho-Sil (Miño-Sil), Douro (Duero), Tagus (Tajo), Guadiana, Guadalquivir, Segura, Jucar, and Ebro. In addition, there are minor basins comprised in one single region, and called intra-regional water agencies, such as Galician Coast, Andalusian Mediterranean Basin, Tinto, Odiel and Piedras, Guadalete and Barbate, inland basins of Catalonia, Balearic Islands, and Canary Islands. The location of BWAs is showed in Figure 1.

Figure 1. Location of inter-regional and intra-regional basins in Spain. Source: Adapted from [12].

This paper is focused on the analysis of the sustainability of integral water management in IRWAs, which account for 87% of the Spanish area and 64% of population. Among the IRWAs we can see high differences in the area and population covered. Tagus is the river basin that supplies water to the highest percentage of population, mainly because it includes one of the biggest Spanish cities, Madrid, with a metropolitan area population of around 6.5 million. Regarding the size of the IRWA, Ebro extends for nine regions, being the largest basin in Spain. By contrast, Eastern Cantabrian is the lowest basin and covers the lowest ratio of population.

The main characteristics of the inter-regional water basins under study are summarized in Table 1.

Table 1. Main characteristics of the Spanish inter-regional water basins.

River Basin	Area (km^2)	Area over Spain (%) *	Population (No. of Inhabitants)	Population over Spain (%) **	Number of Regions Involved in Spain
Western Cantabrian	19,002	3.8	1,656,626	3.6	5
Eastern Cantabrian	6405	1.3	1,297,494	2.8	3
Minho-Sil	17,619	3.5	825,851	1.8	3
Douro	78,859	15.6	2,222,532	4.8	8
Ebro	85,569	16.9	3,226,921	6.9	9
Tagus	55,781	11.1	7,273,871	15.6	5
Jucar	42,851	8.5	5,178,000	11.1	4
Guadiana	55,527	11.0	1,443,707	3.1	3
Guadalquivir	57,527	11.4	4,480,321	9.6	4
Segura	20,234	4.0	1,884,220	4.3	4

Notes: * This percentage shows the area that each river basin represents in the total area of Spain; ** This percentage shows the population in each basin over the total population in Spain. Source: River Basin Management Plans 2015–2021 [13–22].

4. Methods

Within the framework of the MCDA, this paper assesses the sustainability of inter-regional water agencies (IRWAs). Sustainability is assessed by considering the traditional economic, environmental, and social dimensions (Triple Bottom Line [23]), but also governance. Each of the sustainability dimensions has been analysed using a number of indicators that will be presented below in detail. In a second step, the relative importance of indicators and dimensions/criteria is assessed through the analytical hierarchy process (AHP). Later, the IRWAs are classified in a ranking in terms of their sustainability according to the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (see Figure 2). In summary, MCDA allows us to aggregate the performance of each attribute in each dimension, and afterwards to get a sustainability measure on the basis of the aggregation of each dimension.

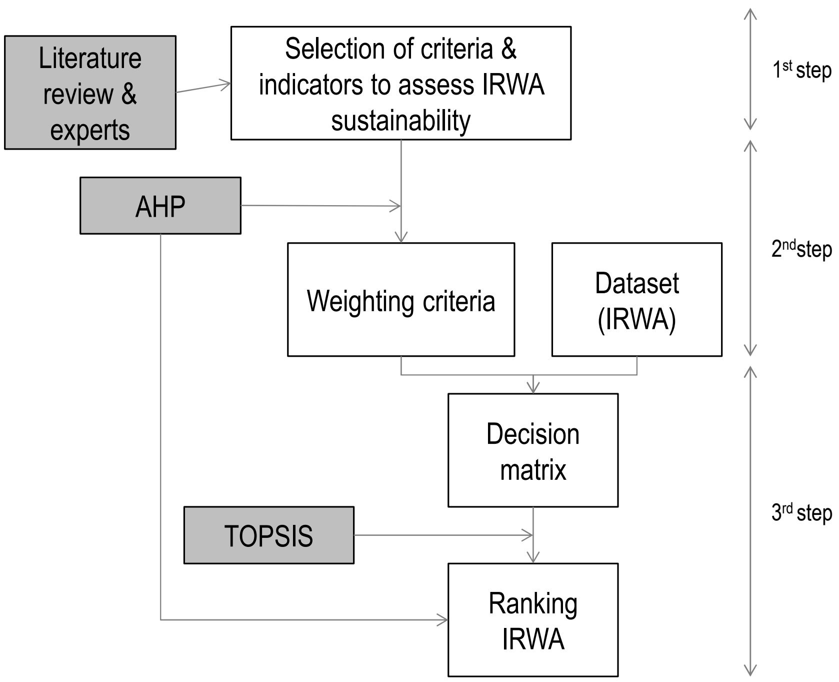

Figure 2. Outline of the methodological approach.

Table 2 shows the dimensions/criteria and indicators selected to assess IRWAs' sustainability.

Table 2. Dimensions and indicators to assess the sustainability of BWA.

Dimension/Criterion	Indicators
Economic	Ratio of cost recovery for water services.
	Water productivity, measured as the ratio between the gross values added of economic sectors (GVA) and the volume of water supplied to each sector.
	Budget limits, measured as the maximum expenditure in investments.
Environmental	Water stress, measured as the ratio of the volume of water consumed and existing water resources in the basin.
	Number of measures aimed at achieving environmental objectives.
	Efficiency: losses in distribution infrastructures.
	Volume of reused water in the total amount of water supplied.
Social	Additional population served over the resident population in the basin.
	Number of measures aimed at satisfying demands.
	Employment relative to the volume of water supplied in the basin.
Governance	Number of measures to improve governance.
	Number of administrations involved in the management, implementation and/or financing measures.
	Number of initiatives to encourage active participation of the public.

The selection of indicators in each dimension has been based on both a literature review [24–26] and the expertise of a panel of experts.

The *economic* dimension is measured through three indicators:

1. Ratio of cost recovery for water services. The concept of cost recovery appears in the WFD (Article 9) in the sense that member states shall take into account such principles, including environmental and resource costs, having regard for the economic analysis, and in accordance to the polluter-pays principle. Member states shall report in the river basin management plans the steps towards implementing the recovery of the costs of water services. Taking into account the WFD, the ratio of cost recovery is calculated as the ratio between revenues and costs for water services, including financial, environmental, and resource costs. An estimation of the cost recovery ratio of financial costs related to water services can be found in [27]. Environmental costs are related to the externalities that occur mainly in water extraction and discharge processes when affecting other users or ecosystems. Resource costs refer to the value of water scarcity. More information about environmental and resource cost in the context of the European WFD can be found in [28]. The higher the ratio of cost recovery, the higher the economic sustainability of the IRWA.
2. Water productivity, measured as the ratio between the gross value added (GVA) of economic sectors and the volume of water supplied to each sector. More information about the estimation of water productivity values can be found in [29]. The higher the water productivity the higher the economic sustainability of the BWA.
3. Budget limits, measured as the maximum expenditure in water investments. Due to the economic crisis in Spain, the IRWAs have limited their budget for investments. This may have an impact on the measures needed to achieve the objectives of the WFD. The lower the budget limits, the higher the economic sustainability of the IRWA.

The *environmental* dimension is assessed on the basis of four indicators:

1. Water stress, measured as the ratio of the volume of water consumed and existing water resources in the basin. Water stress is an increasingly important phenomenon that causes deterioration of

fresh water resources in terms of quantity (overexploited aquifers, dry rivers, and polluted lakes) and quality (eutrophication, organic matter pollution, and saline intrusion). It happens when water demand is greater than the available amount during a certain time or when it is restricted by its low quality for a time period. The lower the water stress, the higher the environmental sustainability of the IRWA.

2. Number of measures aimed at achieving environmental objectives. The main environmental objective established in the WFD is to achieve good status of water bodies. To do this, the IRWAs establish measures to prevent or mitigate the punctual and diffuse pollution and to involve hydrological and environmental restoration of the basin. The higher the number of measures aimed at achieving environmental objectives, the higher the environmental sustainability of the IRWA.
3. Efficiency measured as losses in distribution infrastructures. Once captured, the water must be transported to the point of purification, to then be stored in tanks from which the distribution infrastructures are supplied to the points of domestic, agricultural, or industrial supply, in which once used it is evacuated. The main technical problem of water distribution infrastructures is the volume of losses due to deterioration. The lower the losses in distribution infrastructures, the higher the environmental sustainability of the IRWA.
4. Recycled water volume in the total amount of water supplied. Reusing wastewater is an increasing practice in arid or semiarid countries, where water resources are scarce. The uses that can be given to recycled wastewater are many and varied: watering (crops, gardens, greenbelts, golf camps, etc.), industrial reuse (cooling, boiler feed), non-potable urban uses (greenery, fire extinction, sanitary, air conditioning, washing cars, cleaning streets, etc.), and others (aquaculture, livestock cleaning, snowmelt, construction, dust removal, etc.). The higher the recycled water volume, the higher the environmental sustainability of the IRWA.

The *social* dimension is measured using three indicators:

1. Additional population served over the resident population in the basin. In addition to the local population in the basin, the population may increase during certain seasonal periods for different reasons: work, holidays, etc. This indicator measures the capacity of the basin to satisfy this additional water demand. The higher the additional population served, the higher the social sustainability of the IRWA.
2. Number of measures aimed at satisfying demands. Economic sectors require water (and other resources) to develop their economic activities. The IRWA provides a series of measures to be able to respond to this demand. The objectives of these measures are to increase the availability of resources through regulation and management infrastructures, encourage recycling, and increase water use efficiency. The higher the number of measures aimed at satisfying demands, the higher the social sustainability of the IRWA.
3. Employment relative to the volume of water supplied in the basin. This indicator refers to employment on activities that require water resources for their economic development. The higher the employment ratio, the higher the social sustainability of the IRWA.

Finally, the *governance* dimension is assessed using three indicators:

1. Number of measures to improve governance. Governance allows addressing the problems of resource and territory management through an integrated and systematic way. Clark and Semmahasak [30] examine the introduction of adaptive governance to water management in Thailand. The analysis shows the significant role that the new approach may play in resolving underlying differences between stakeholders. The higher the number of measures to improve governance, the higher the governance sustainability of the IRWA.
2. Number of administrations involved in management, implementation and/or financing of measures. Besides the IRWAs, other administrations and institutions are also involved in the

development, implementation, and financing of programs of measures. The higher the number of administrations, the higher the governance sustainability of the IRWA.

3. Number of initiatives to encourage active participation of the public. These initiatives encourage the transparency and participation of stakeholders in both the decision-making and the planning processes. Hedelin [31] analyses two criteria based on the concepts of participation and integration. She notes that these concepts work as well-established dimensions of both sustainable development and management. The higher the number of initiatives, the higher the governance sustainability of the IRWA.

The values of these indicators for each IRWA have been assessed using the information included in the IRWA management plans [13–22], and can be found in the Supplementary Materials (Table S1).

Considering the indicators mentioned above, two multicriteria decision-making methods were used to assess the sustainability of IRWAs. More concretely, AHP was used to get the importance of each dimension and each indicator in the sustainability of the IRWA, and afterwards TOPSIS allowed us to rank the IRWAs according to their sustainability.

The AHP method was created by [32] as a structured but flexible technique for making decisions in a multicriteria context. This method is based on dealing with complex decision problems using a hierarchical structure. Figure 3 shows the three-level structure considered for our case study.

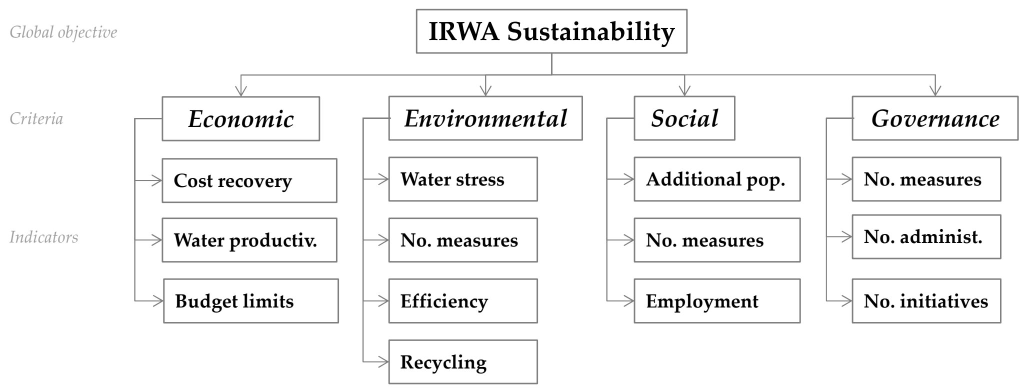

Figure 3. AHP structure.

In this hierarchical structure, the relative importance or weights (w_k) of each criterion or subcriterion hanging on each node are obtained from pairwise comparisons between them. In order to perform these pairwise comparisons, a 1–9 scale is used, as proposed by [33]. Table 3 shows the relative scores and their interpretation.

Table 3. Table of relative scores.

Value of a_{jk}	Scale Meaning
1	j and k are equally important
3	j is slightly more important than k
5	j is more important than k
7	j is strongly more important than k
9	j is absolutely more important than k
2, 4, 6, 8	Middle values of the above
reciprocal	$a_{jk} = 1/a_{kj}$

Scores of these comparisons are used to build the Saaty matrices ($A = a_{jk}$), which are employed to determine the vector of priorities or weights (w_1, ...w_k, ...w_n). Although different procedures to estimate these weights have been proposed, for this case we selected the simplest one: the geometric mean method [34].

The AHP decision technique was originally designed for individual decision-makers, but was promptly extended for group decisions [34], such as our case study. Thus, in order to determine the weights attached to each criterion we have to consider the judgments of a group of people (p), each with his/her own pairwise comparison matrix ($A_p = a_{jkp}$) and its related weights (w_{kp}). This individual information is suitably treated in order to obtain a synthesis of aggregated weights (w_k).

For this purpose, Saaty et al. [35,36] suggest that group decision-making should be done by aggregating individual priorities using the geometric mean:

$$w_k = \sqrt[m]{\prod_{p=1}^{p=m} w_{kp}} \quad (1)$$

For indicators weights, a panel of 25 experts in water management sustainability was consulted. The members of this panel have been selected on the basis of their experience in water management, their scientific and technical contribution to the analysis of water sustainability and their involvement in the development and implementation of river basin plans. In addition, experts have been also selected in order to cover different technical profiles, such as university lecturers, researchers in agricultural research centres, civil servants in charge of water policy implementation, environmental journalists, hydrogeologists, agronomists, economists, environmental organisations, and farmers.

Before aggregating priority scores, the consistency of respondents' pairwise choices was tested by means of the consistency ratio (CR) based on the eigenvalue method [37]. In this paper we consider only CR lower than 0.1 [38]. Taking into account this CR, the percentage of consistent experts was 72%.

Once the weights of each dimension had been calculated, by considering the experts' evaluations, another MCDA technique was applied in order to rank IRWAs according to their sustainability. To do that, TOPSIS was used. The principle behind the method is that the optimal alternative should have the shortest distance from the positive ideal solution and the furthest distance from the negative ideal solution. The positive and negative ideal solutions are artificial alternatives which are hypothesised by the decision-maker, based on the ideal solution for all criteria and the worst solution which possesses the most inferior decision variables. Assuming that every indicator has an increasing or decreasing scale, TOPSIS calculates the results by comparing Euclidean distances between the actual and the hypothesised alternatives.

Generally, the TOPSIS approach consists of seven steps, as it is summarized below [39,40].

Step 1. Constructing the decision matrix D on the basis of the value of each indicator (F_i) by IRWA (A_i), where f_{ij} is the performance of the IRWA A_i with respect to the indicator F_j.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} F_1 & F_2 & \cdots & F_j & \cdots & F_n \end{array} \\ \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1j} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2j} & \cdots & f_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{i1} & f_{i2} & \cdots & f_{ij} & \cdots & f_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mj} & \cdots & f_{mn} \end{bmatrix} \end{array} \quad (2)$$

Step 2. Normalizing the initial decision matrix to eliminate the effects of complex relations. The normalized value v_{ij} is calculated as:

$$v_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \quad (3)$$

Step 3. Calculating the weighted normalized decision matrix R by using the weights w_j obtained through the APH for each indicator. The weighted normalized value f_{ij} is calculated as:

$$r_{ij} = v_{ij} \cdot w_j \tag{4}$$

Step 4. Determining the positive and negative ideal reference points:

$$T^+ = \{r_1^+, r_2^+, \ldots, r_n^+\} = \{(\max_i r_{ij} \,|j \in J'), (\min_i r_{ij} \,|j \in J'')\} \tag{5}$$

$$T^- = \{r_1^-, r_2^-, \ldots, r_n^-\} = \{(\min_i r_{ij} \,|j \in J'), (\max_i r_{ij} \,|j \in J'')\} \tag{6}$$

where J' and J'' are linked to the indicators with positive polarity (more is better) and the indicators with negative polarity (less is better), respectively.

Step 5. Calculating the distances to the positive and negative ideal reference points using the Euclidean distance. The separation of each IRWA from the positive-ideal solution (S_i^+) and the separation of each IRWA from the negative-ideal solution (S_i^-) is given by the expressions:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (r_{ij} - r_j^+)^2} \tag{7}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (r_{ij} - r_j^-)^2} \tag{8}$$

Step 6. Calculating the relative closeness to the ideal solution for each IRWA (C_i):

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}, \; i = 1, \ldots, m \tag{9}$$

where C_i is an index with values ranging between 0 and 1, where 0 corresponds to the worst possible performance of the IRWA and 1 to the best.

Step 7. ranking the IRWA, according to the C_i values.

5. Results

Table 4 shows the results of the application of the AHP method. First, we can see the weights for the sustainability dimensions according to the preferences of the group of experts. The environmental dimension is playing the most important role in the whole sustainability (40%), followed by both the economic and social criteria (25%). The governance dimension is the least important for sustainability (11%) according to the panel of experts.

Table 4. Normalised weights for dimensions/criteria and indicators.

Dimensions		Indicators	
Economic	0.246	Ratio of cost recovery	0.471
		Water productivity	0.313
		Budget limits	0.216
Environmental	0.402	Water stress	0.380
		Number of measures of environmental objectives	0.358
		Efficiency: losses in distribution infrastructures	0.133
		Reused water	0.128
Social	0.246	Additional population served	0.236
		Number of measures aimed at satisfying demands	0.394
		Employment	0.370
Governance	0.106	Number of measures to improve governance	0.434
		Number of administrations	0.247
		Number of initiatives	0.319

Considering these weights, the overall sustainability level of each IRWA can be assessed through TOPSIS. Table 5 shows the ranking of the Spanish IRWAs according to their sustainability in the water plans. The river basin with the highest sustainability is Western Cantabrian, followed by Eastern Cantabrian and Tagus. By contrast, Minho-Sil, Jucar, and Douro are the least sustainable basins. Regarding the Segura Basin, our results coincides with [41], classifying this basin as intermediate sustainable. Senent-Aparicio et al. [41] applied a watershed sustainability index (WSI), assuming that the sustainability of the basin depends on its hydrology environment, life, and policies in water resources. The greatest strengths of the basin were related to political indicators, while the biggest weaknesses were the hydrological indicators on quantity mainly due to the situation of water scarcity. Although not all the dimensions are comparable between studies, water scarcity or water stress appears to be one of the main weaknesses of Segura sustainability in both analyses.

Table 5. Global sustainability of inter-regional water agencies (IRWAs).

IRWA	Sustainability (C_i)	Ranking
Western Cantabrian	0.602	1
Eastern Cantabrian	0.530	2
Tagus	0.513	3
Ebro	0.482	4
Guadalquivir	0.410	5
Segura	0.397	6
Guadiana	0.383	7
Minho-Sil	0.376	8
Jucar	0.353	9
Douro	0.277	10

When analysing separately the dimensions of the sustainability (i.e., economic, environmental, social, and governance dimensions) for each IRWA, we obtained the results in Tables 6–9.

Table 6. Economic sustainability of IWBA.

IRWA	Economic Sustainability	Ranking
Eastern Cantabrian	0.677	1
Western Cantabrian	0.460	2
Tagus	0.441	3
Jucar	0.376	4
Ebro	0.360	5
Guadiana	0.319	6
Guadalquivir	0.311	7
Minho-Sil	0.311	8
Douro	0.308	9
Segura	0.148	10

Table 7. Environmental sustainability of IWBA.

IRWA	Environmental Sustainability	Ranking
Minho-Sil	0.610	1
Tagus	0.604	2
Western Cantabrian	0.593	3
Douro	0.585	4
Guadalquivir	0.575	5
Eastern Cantabrian	0.562	6
Guadiana	0.525	7
Ebro	0.431	8
Segura	0.385	9
Jucar	0.271	10

Table 8. Social sustainability of IRWA.

IRWA	Social Sustainability	Ranking
Eastern Cantabrian	0.713	1
Western Cantabrian	0.521	2
Tagus	0.452	3
Segura	0.439	4
Minho-Sil	0.343	5
Ebro	0.265	6
Guadalquivir	0.234	7
Douro	0.197	8
Jucar	0.138	9
Guadiana	0.016	10

Table 9. Governance sustainability of IRWA.

IRWA	Sustainability in Governance	Ranking
Ebro	0.561	1
Segura	0.511	2
Minho-Sil	0.399	3
Tagus	0.335	4
Jucar	0.315	5
Guadiana	0.237	6
Eastern Cantabrian	0.224	7
Douro	0.137	8
Guadalquivir	0.116	9
Western Cantabrian	0.068	10

The basin with the greatest economic sustainability is the Eastern Cantabrian river basin, followed by the Western Cantabrian basins. In this case, Douro and Minho-Sil are still in the last places of the ranking, and Segura shows the least economic sustainability.

Regarding the environmental sustainability, the dimension with the largest importance in river basin sustainability (Table 7), we can see that Minho-Sil is the basin with the greatest environmental sustainability, followed by Tagus.

Table 8 shows the classification of basins derived from the social dimension of sustainability. In this case, Eastern Cantabrian is in the first position, followed by Western Cantabrian and Tagus. The lasts are Jucar and Guadiana, showing the last one a significant distance with the others.

Finally, analysing the dimension of governance, which has the lower weight in sustainability, we can see that Ebro is the most sustainable basin, followed by Segura and Minho-Sil. By contrast, Guadalquivir and Western Cantabrian show the lowest sustainability in governance.

Different sustainability scores can be explained mainly by lower water stress (environmental dimension) and higher water productivity (economic dimension) of northern water basins. Due to the location of these basins, rainfall is more constant and consequently water stress is lower than in other basins of the country. In addition, we can see that water productivity is also higher in northern basins due to the weight of industrial activities. By contrast, IRWAs such as Jucar or Douro show the lowest sustainability due to the lower scores on economic, social, and governance dimensions for Douro, and environmental and social dimensions for Jucar. In Douro, low water productivity and water efficiency on distribution results in lower global sustainability. For Jucar, water stress due to the location of the basin and a low number of environmental and social measures make the basin the least sustainable.

Global and partial sustainability results have been showed to the panel of experts for their feedback. The experts agreed that the methodology is appropriate to measure the sustainability of IRWAs, and that the identification of the weaknesses of each IRWA may contribute to improve its sustainability in the future.

6. Concluding Remarks

This paper contributes to analysis of the dimensions that may be enhanced to improve basins' sustainability in order to fulfil the objectives and requirements set by the WFD on basin management, and consequently may be a starting point to improve water management sustainability in the following planning cycles.

The river basins of Minho-Sil, Jucar, and Douro are the least sustainable in the integral water plans. Such results on sustainability can be improved following different strategies depending on the river basin analysed. Douro, the river with the lowest sustainability, may improve in most of the dimensions (i.e., economic, social, and governance), whereas it is well positioned on the environmental criterion. In the case of the Jucar basin, it may focus on environmental and social aspects in order to improve its sustainability. Since environment is the dimension with the highest importance in global sustainability, Jucar may decrease the water stress or raise the number of measures aimed at achieving environmental objectives, since these two indicators show the highest contribution to environmental sustainability. Finally, Minho-Sil may raise mainly its economic and social dimensions. It has a good position on environmental and governance aspects, but it needs to improve mainly on the economic dimension.

Not only basins positioned in the last places may improve their sustainability, but the rest as well, since the maximum score is 0.677. The Western Cantabrian river basin is in the first position on sustainability of river basins but with the lowest score in governance. It may make progress in at least this dimension in order to improve. The same strategy should be followed by Eastern Cantabrian. Tagus is the most stable river basin in all the dimensions of the sustainability, but there is still room for improvement, especially on governance of stakeholders in decision-making.

Future research on this topic might analyse what would happen with sustainability in each water use provided in the Article 9.1 of WFD: agricultural, domestic, and industrial. In this case it would be very interesting to analyse how results may change when industrial and agricultural uses are differentiated to measure water productivity. Potential follow-up studies might also evaluate the sustainability of the different water services as provided in Article 2.38 of WFD, such as abstraction, storage and distribution of water, and collection and treatment of used water. River basin planning may include more information on these issues in order to allow us to refine the analysis of the sustainability.

Supplementary Materials: The following are available online at www.mdpi.com/2073-4441/8/8/342/s1, Table S1: Indicators value per inter-regional water agency.

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6. CONCLUSIONS AND OTHER SCIENTIFIC CONTRIBUTIONS

On one hand, the results show that SEEA-Water can be useful to the WFD in several ways: i) it can be used to perform an analysis of the use of water almost directly from hybrid tables; ii) it allows to estimate river basin water productivity values with the economic data included in the water accounting. iii) the hybrid nature of the accounts gives the analyst the opportunity to assess the cost recovery analysis of water services.

The use of the SEEA-Water for characterization has many advantages for the standardization of reporting procedures in the WFD implementation:

- Common requirement of information.
- Common presentation (standard tables).
- Common definitions (SEEA handbook).
- Hybrid tables: economic and physical tables.
- Use of officials published sources.
- Easy revision in following cycles

On the other hand, the results show the dimensions that may be enhanced to improve Basin's sustainability in order to fulfil the objectives and requirements set by the WFD on basin management. It also illustrates the importance of each indicator in contributing to sustainability. So that, it could be a starting point for a most sustainable water management in Spanish basins in the future planning cycles.

Finally, in reference to other scientific contributions, a fourth article from the thesis is currently under revision. It is called:

4- Gutiérrez-Martín, C.; Borrego-Marín, M.M.; Berbel, J. "*The economic analysis of water use in the Water Framework Directive based on the System of Environmental-Economic Accounting for Water*".