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Review

Dealing with Water Conflicts: A Comprehensive Review of MCDM Approaches to Manage Freshwater Ecosystem Services

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Abstract: This paper presents a comprehensive review of the application of Multiple-Criteria Decision-Making (MCDM) approaches exclusively to water-related freshwater ecosystem services. MCDM analysis has been useful in solving conflicts and it works well in this framework, given the serious conflicts historically associated with water use and the protection of freshwater ecosystems around the world. In this study, we present a review of 150 papers that proposed the use of MCDM-based methods for the social, economic, or ecological planning and management of water ecosystem services over the period 2000–2020. The analysis accounts for six elements: ecosystem service type, method, participation, biogeographical realm, waterbody type, and problem to solve. A Chi-square test was used to identify dependence between these elements. Studies involving the participation of stakeholder groups adopted an integrated approach to analysing sustainable water management, considering provisioning, regulating, and cultural services. However, such studies have been in decline since 2015, in favour of non-participatory studies that were strictly focused on ecological and provisioning issues. Although this reflects greater concern for the health of freshwater ecosystems, it is a long way removed from the essence of ecosystem services, which entails an integrated approach to the interrelationships between hydrology, landscapes, ecology, and humans.

Keywords: Multiple-Criteria Decision-Making; water; ecosystem services; conflicts; freshwater ecosystems; stakeholders; protected areas

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1. Introduction

Freshwater is vital for the functioning of all terrestrial ecosystems, for the flora and fauna that make up those ecosystems, and, of course, for humans. Humanity depends on water not only for drinking, but mostly for food production, industry, waste treatment, energy, and transport, to give just a few examples [1]. Hoekstra and Wiedmann [2] estimated that humans annually consume between 1000 and 1700 billion m^3 of the world's surface or groundwater resources per year; that is, through direct or indirect water use, between 22% and 150% of the annual global freshwater supply is consumed.

From an ecological perspective, water is an integral component of all ecosystems and their functioning and, thus, is key to ensuring ecosystem health and biodiversity. However, the sensitivity of freshwater ecosystems to a range of threat factors, including climate change, makes water ecosystem services especially vulnerable [3]. Freshwater ecosystems make a disproportionate contribution to global biological richness; however, freshwater species are among those at the greatest risk of extinction [4].

Water resources are an issue of major interest and concern for governments and international institutions. Faced with the prospect of billions of people experiencing serious water shortages and subsequent food shortages, there is a need for urgent strategic action on water resources management. Two billion people currently live in countries with high water stress, and it is estimated that, by 2030, as many as 700 million people could be displaced by intense water scarcity [5]. One of the most powerful international attempts to address this serious humanitarian problem is the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDG) [6]. Specifically, SDG-6 focus is to “Ensure availability and sustainable management of water and sanitation for all”. This target broadly encompasses all aspects of both the water cycle and sanitation systems, and it is designed to be cross-cutting, such that it can contribute to the achievement of other SDGs, particularly in the areas of the environment, health, economy and education.

The current global freshwater crisis threatens the present and future supply of water as a resource for human beings. Although about 70% of the earth’s surface is covered with water, only 2.5% of it is freshwater that is suitable for human consumption. Most of that freshwater is trapped in glaciers or icefields; as such, less than 1% of the world's water is freshwater accessible in liquid form. In turn, of this small percentage, most of the water is found flowing underground, in groundwater reserves, while easily-accessible surface water sources, such as rivers or lakes, account for only a fraction of it. This small proportion of freshwater is the driving force of human health, the global economy, and the wellbeing of societies in the broadest sense. Unfortunately, the world has not succeeded in ensuring the sustainable management of its water resources. Over the past century, freshwater came under increasing pressure as withdrawal rates increased almost sixfold. By 2014, the average global availability of renewable freshwater resources had dropped to less than 6000 m^3 per person per year, a sharp fall of about 40% since the 1970s. Moreover, freshwater resources are unevenly distributed throughout the world and they are affected by strong seasonality; as global demand for water continues to grow (by approximately 1% annually), available resources are further depleted [7]. This crisis has promoted the need for the development of a water-oriented circular economy and the optimization of water resources use [8,9] with the end goal of preservation of water resources.

The importance and vulnerability of freshwater has prompted growing concern and an interest in its analysis from the scientific community, as well as impelling international institutions to protect freshwater ecological systems. The Ramsar Convention, for example, is one of the most notable initiatives aimed at protecting wetlands. Adopted in 1971, it is the longest-standing treaty that seeks to preserve wetlands and aquatic bird species, and it has been responsible for the establishment of the world's largest network of protected areas [10]. The European Union Water Framework Directive (2000/60/EC; 22 December 2000, OJ L 327) provides a guide for the New European water policy. The novelty of the new framework is the integrated approach that it follows in opposition to fragmented water policy initiatives in the past, based on key aims, such as “expanding the scope of water protection to all waters, surface waters and groundwater”, “achieving “good status” for all waters by a set deadline”, “water management based on river basins”, “combined approach” of emission limit values and quality standards”, “getting the prices right”, “getting the citizen involved more closely”, and “streamlining legislation”.

Large watercourses cover different territories, and they are often transboundary, involving different conservation and use objectives, different regulations, and different stakeholders with conflicting interests. As such, their integrated management is extremely complex. Many protected areas around the world (more than 100,000) include aquatic ecosystems, some of which are specifically protected as freshwater ecosystems, but they are often supplied by rivers outside the limits of the protected areas [11].

Planning for such areas is extremely difficult at the operational level, even within the same country. Implementing an environmental conservation programme for freshwater requires the cooperation of multiple stakeholder groups, which often span multiple ecosystems. The complexity increases substantially when the management involves multiple jurisdictions or countries. Although there is international regulation governing the protection and use of transboundary watercourses and international lakes (e.g, "The 1992 UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes and the EU Water Framework), as well as specific bilateral cooperation agreements, at the operational level, stakeholder groups must also decide on upkeep, enforcement, and assessment programmes [12], meaning that the decisions made are not isolated events but rather part of an ongoing decision-making process over time.

The scarcity of water resources, the protection of many aquatic ecosystems, and the complexity associated with the management of large watercourses have traditionally provoked fierce conflicts that are linked to their management. These disputes can block decision-making processes and even trigger armed clashes between countries [13]. That said, some studies have shown that actively involving stakeholders in decision-making processes can mitigate these problems and make it possible to work towards acceptable solutions [14]. Against this background, Multiple-Criteria Decision-Making (MCDM) methods have proven to be extremely useful for conflict management; in particular, they have been widely used for natural resource management [15]. Research on the development and use of MCDM methods to improve decision-making processes that are related to forestry has been very prolific. Kaya et al. [16], Diaz-Balteiro et al. [17], and Nordstrom et al. [18] are only some examples of this trend. Although these studies addressed the full range of ecosystem services provided, including freshwater ecosystem services, to date only a few reviews focused exclusively on the use of MCDM in water resources management have been conducted. Hajkowicz and Collins [19] reviewed 113 articles published between 1973 and 2005 and Herath [20] conducted a review of 89 articles relating to this topic published between 1975 and 2009.

In regard to water, MCDM approaches are used when the analysis incorporates multiple perspectives in order to reach a single decision relating to water management [21]. The capacity of MCDM analysis to assist in conflict resolution between stakeholder's groups is primarily due to its transparency. All parties must specifically express their preferences through a structured process, which makes it possible to identify areas of agreement and disagreement and ultimately manage conflicts [22]. This analysis of alternatives can be carried out by involving the different stakeholders, experts, or institutional/governmental agents (water negotiators), or by simulating different alternatives through stochastic processes. In any case, the opposition and interrelation of different criteria and alternatives give rise to a wide-ranging, complex workspace, where multiple conflicting positions are involved in a single decision-making process.

This framework is well suited to the planning and management of Freshwater Ecosystem Services (FES). Understanding FES requires an integrated view of the interrelationships between hydrology and ecology as well as the landscape. It also calls for a contextualization of how water influences human livelihoods and wellbeing, as well as how the ecosystems themselves are affected by human activities. In order to develop efficient, sustainable decision-making processes, a comprehension of these complex relationships is needed [1].

This article presents a review of 150 current articles covering the application of MCDM with three novel aspects: a focus on water as source of ecosystem services; a focus on natural freshwater ecosystems, the majority of them protected; and, an orientation of the discussion towards conflict resolution and stakeholder participation in decision-making processes. The objective of this review is to describe the use of MCDM techniques in FES planning and management, with a particular focus on conflict management. The aim of carrying out a systematic review is to collect all of the the empirical evidence that meets the pre-specified criteria above, in order to answer several research questions.

2. Methods

Bias is minimised by using explicit and systematic methods when reviewing articles [23]. The main advantage of systematic reviews is that they allow the researcher to determine whether an effect remains constant across various different studies, or to find out whether the type of study or sample level have an effect on the phenomenon under study [23].

The present review was conducted following the six steps proposed by Templier and Paré [24]: (i) formulating the research question and objective(s), (ii) searching the extant literature, screening for inclusion, assessing the quality of primary studies, (iii) extracting data, and (iv) analysing data.

2.1. Formulating the Research Questions and Objectives

The objective of this review is to characterise the use of MCDM techniques in FES planning and management, with a particular focus on conflict management. We addressed specifically the following research questions: (i) how have studies on MCDM applied to FES change over time?; (ii) how collaborative MCDM has been used to solve decisional problems?; (iii) how has stakeholders involvement in water decision-making processes changed over time?; (iv) what MCDM methods have been applied the most to deal with FES?; and, (v) how have these methods been used to solve different types of problems?

2.2. Searching the Extant Literature, Screening for Inclusion and Assessing the Quality of Primary Studies

The search of the literature was performed on the Web of Science (WoS) platform. As such, the only publications included in the search are those from journals indexed in the Journal Citation Report (JCR), thus ensuring the quality of the articles. Book chapters were not included in the queries. The articles were then screened to only select those in where water was analysed from an ecosystem perspective, discarding any articles oriented towards industrial uses of water or the improvement of artificial processes. The keywords used in the selections process included "water" and "ecosystem services" and "MCDM" or "multiple-criteria decision making" and "freshwater" or "water management" and "protected areas". Only articles that were published between 2000 and 2020 were selected. The analysis has been structured by grouping the publication years into four intervals: 2000–2004, 2005–2009, 2010–2014, and 2015–2020.

2.3. Extracting Data

Selected papers were classified according to the following categories in each of the six criteria (Ecosystem services, MCDM method, Participation, Biogeography, Waterbody type, and Problem):

- Ecosystem services class:

FES were categorised according to the Millennium Assessment (MA) [25] classification in provisioning, regulating, cultural, and supporting classes.

Provisioning (PROV): refers to water as a resource for human consumption;

Regulating (REG): refers to the ability of freshwater ecosystems to regulate nutrient cycles, atmospheric regulation and control of natural disasters, such as floods;

Cultural (CULT): refers to the recreational capacity of these ecosystems;

Supporting (SUPPORT): refers to the capacity of ecosystems to maintain their structure and functioning, including biodiversity.

- MCDM method:

Methods comprise eight classes:

Distances (DIS): distance-based methods, such as GP or TOPSIS methods, are based on the minimization of the distance between an alternative and one or several reference points that represent good preferential properties [17];

Fuzzy (FUZ): covers the articles that have used fuzzy sets, fuzzy functions, or fuzzy numbers rather than crisp numbers, approaches with a concrete mathematical structure dealing with the imprecision of the information [26];

Hierarchical (HIER): this group includes methods based on AHP or ANP, working with pairwise comparisons to quantify subjective information, such as preferences of decision-makers, and calculate relative importance (weights) of criteria and alternatives [27];

Mixed (MIX): hybrid models where no one type of method has particular prominence, but rather all are similarly important in the decision-making process. Ortiz-Urbina et al. [28] emphasised the proliferation of these methods in the last few decades;

Outranking (OUT): outranking methods such as the different versions of PROMETHEE or ELECTRE, based on the idea that alternative X outranks alternative Y if alternative X is at least as good as alternative Y, according to concordance and discordant concepts [29,30];

Soft (SOFT): non-structured MCDM methods, such as discussion groups, workshops, or various kinds of collaborative processes based on qualitative analyses [31];

Utility (UT): methods based on utility and value functions, assigning a cardinal value to each alternative considering simultaneously several criteria within a risk (utility) or no risk (value) context [32];

Other methods (Other): those not included in the previous groups.

- Participation:

The participatory approach employed has been assessed according to the extent to which all stakeholders are involved, only experts or institutional/governmental actors, or none of the above. Three groups have thus been identified: non-participatory (NO), experts (EXP), and stakeholders (YES).

- Biogeography:

This element has been analysed at the level of country and biogeographic realm, referring to the seven biogeographic divisions of the planet: Afrotropical (AFRO), Antarctic (AN), Australasia (AUS), Indomalaya (INDO), Nearctic (NEAR), Neotropical (NE), and Paleartic (PA) [33]. In cases the origin of the study was not indicated the publication was classified as Not identified (NI).

- Waterbody type:

The type of waterbody studied has been classified into five categories: estuary, groundwater, lake, river, and wetland. Although estuaries are not freshwater ecosystems, as their waters have some degree of salinity depending on the site, they are included in this study because they represent the transition between freshwater and marine ecosystems, and their management is still subject to conflict. Many studies do not analyse a single type of aquatic ecosystem, since it is very difficult to completely separate the interlacing subsystems that make up river networks. Rivers and lakes are often interconnected, and some studies have taken a comprehensive approach to analysing them. Similarly, in some river courses, it can be difficult to distinguish between estuaries and wetlands. For this reason, in the present review, the classification is based on the predominant type under analysis, unless it is specified that the analysis focuses on a river system.

- Problem:

The problem to be solved refers to the objective of the analysis conducted in the publications. Seven problem types have been identified:

Allocation (ALLOC): allocation and distribution of water as a resource; papers included in this group involve studies analysing best water sources and optimization of water resources distribution to population;

Conservation (CON): solutions to problems related to the conservation of sites and habitats and the survival of species. All of the studies are oriented to the improvement or maintenance of the actual condition of ecosystems;

Flood water analysis (FLOOD): analysis of water flows from river systems and freshwater ecosystems and the associated risks;

Impact/vulnerability assessment (IMPACT-VUL): the articles included in this group focus on measuring and evaluating the impact of human actions on the waterbody under study and assessing its vulnerability. Some also undertake an assessment of water quality;

Management (MAN): water resources planning and management from a broad perspective, excluding articles dealing specifically with the topics covered in the other classes;

Restoration (RESTOR): restoration of river systems and freshwater ecosystems;

Tourism (TOUR): issues related to tourism management in freshwater ecosystems and analysis of suitability of these sites for recreation.

2.4. Analysing and Synthesizing Data

The statistical dependence between the elements described in Section 2.3 was determined using the Pearson Chi-square test. The Chi-square statistic is a non-parametric tool designed to analyse group differences when the dependent variable is measured at a nominal level [34], i.e., this test allows for identifying the association between two categorical variables [35]. The analysis was undertaken using a pairwise comparison between the categories described in Section 2.3. In SPSS v15.0 (SPSS Inc., Chicago, IL, USA) software.

3. Results and Discussion

3.1. Overview

A total of 183 papers were initially found, of which 150 papers were finally selected and reviewed: 27 in the period 2000–2004, 30 in the period 2005–2009, 22 in the period 2010–2014, and 71 in the period 2015–2020. Thirty three papers were discarded because they did not address exclusively freshwater ecosystems. Figure 1 shows the percentage of papers reviewed by category (Section 2.3).

Globally, the studies that dealt with Regulating FES represented the highest frequency (40%) among selected publications, followed by the works that analysed FES in an integrated manner (27.3%). The most usual class of MCDM methods found was mixed (26.7%) and hierarchical (22.0%), and the majority of the studies did not involve the preferences of stakeholder groups, 57.8% did not involve any type of participation, and 28.27% only included expert preferences. Near sixty-one percent of the publications came from the Paleartic biogeographic realm, particularly Europe, the Middle East, and China. Rivers (46.7%) and wetlands (24.0%) were the most studied waterbody types and problems related with management (30.67%) and impact-vulnerability (26.67%) assessment were the most frequently analysed.

3.1.1. Ecosystem Services Class

The majority of publications in the 2000–2020 period were in the class of regulating ES (Figure 1). Since 2015, there has been a significant decline in studies jointly addressing all ecosystem service types, giving way to studies that analyse them separately, with a particularly notable focus on the regulating services: in the latest period, these studies accounted for 47.89% of all the articles reviewed (Figure 2). Articles dealing with supporting functions have shown a marked increase in the last period, as have articles analysing the recreational functions of ecosystem services, albeit to a lesser extent. Interest in provisioning functions declined from 2010 onwards, but has levelled off since coming second behind regulating ecosystem services in the last period, with 14.08% per cent of the articles reviewed in that period. These results reflect a growing concern regarding aquatic ecosystem health, probably prompted by the deterioration of aquatic ecosystems around the world, mainly wetlands.

Figure 1. Percentage of papers by categories described in Section 2.3.

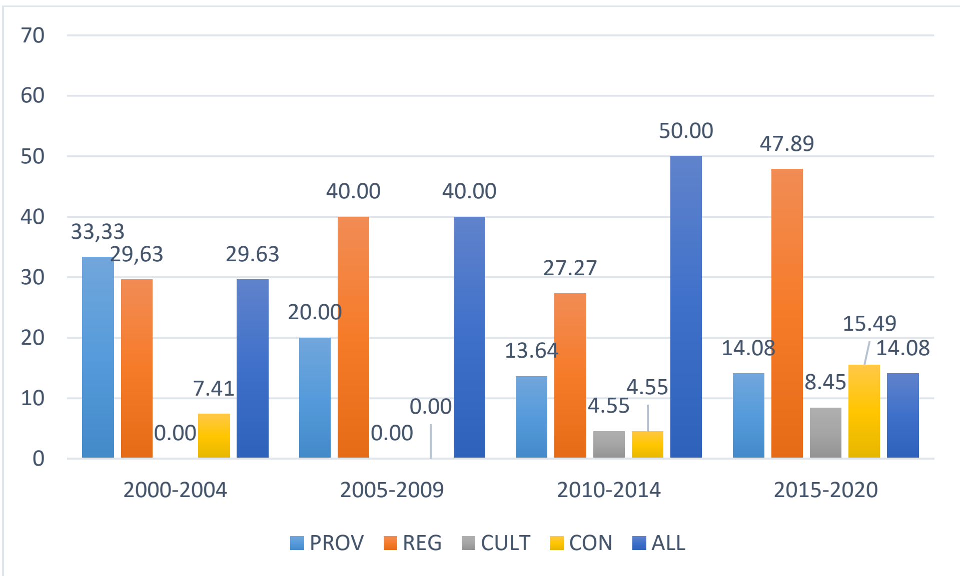

Figure 2. Percentage of papers by ecosystem service and period. For explanation of categories see Section 2.3.

3.1.2. MCDM Method

The most usual methods to the analysis of FES are mixed and hierarchical methods (Figure 1). Particularly interesting is the evolution of mixed methods, which have increased along the time, achieving 36.6% of the reviewed papers in the last (2015–2020) period (Figure 3). Hierarchical methods have been more or less stable, after they increased from 2005–2009 period (16.7%) to figures around 25–27%. Fuzzy, outranking, and utility methods have decreased over time. Utility methods, in fact, disappeared after 2010 (Figure 3). This could be because of the complexity of the collection of data to apply this type of methods, such as MAUT or MAVT. On the other hand, "Other methods" increased (Figure 3). This group includes new models and methods not included in the remaining classes. Particularly interesting are methods that are based on neural networks or random forest, which were applied in diverse manners to solve FES problems.

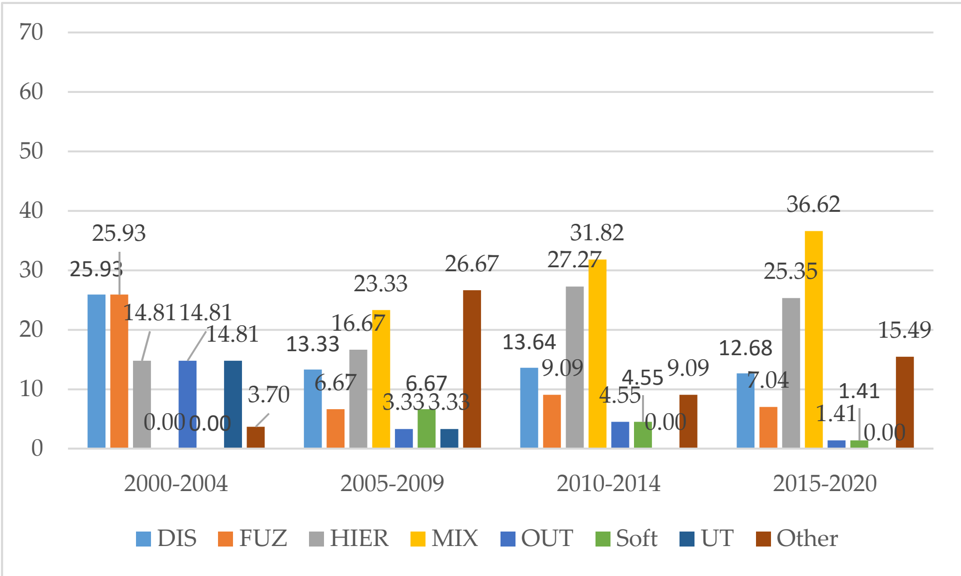

Figure 3. Percentage of papers by MCDM method and period. For explanation of categories see Section 2.3.

3.1.3. Participation

With regard to the evolution over time of participatory studies, the decrease in analyses involving stakeholder participation from the period 2005–2009 is particularly striking (Figure 4). It stands in contrast to the increase in studies that do not involve the participation of any type of stakeholder, or that relied on the participation of experts or water negotiators (Figure 4). This trend seems to be related to the decrease of studies that dealt with FES in an integrated manner since 2010. Taking into account that MCDM methods are particularly useful to the aggregation of different groups providing transparency and rigor to complex decision-making processes and the difficult to make strategic decisions by nations, regions, and local communities regarding water conflicts, this fact is unexpected. Section 3.2.5 discussed this more-in-depth.

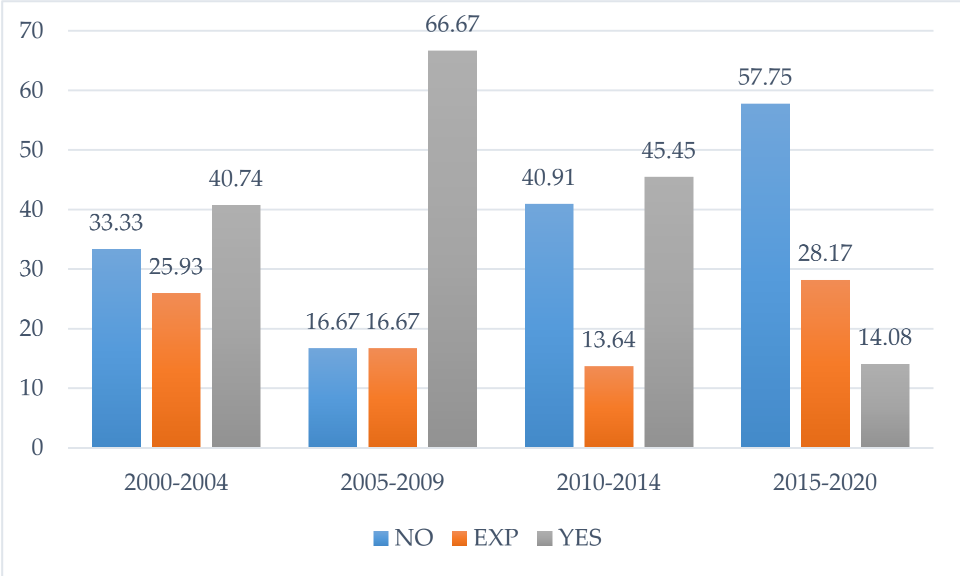

Figure 4. Percentage of papers by participatory approach and period. For explanation of categories see Section 2.3.

3.1.4. Biogeographic Realms

The Paleartic (PA) biogeographic realm was the one where the majority of FES studies were conducted, representing 53 to 64% of the reviewed papers (Figure 5). Indomalaya (INDO) was the second most important biogeographic realm, showing increasing importance over the period covered: 3.7% of the overall papers in 2000–2004 to near 27% in 2015–2020 (Figure 5). No papers were found for the Neartic biogeographic realm. As it would be expected, countries with more scarcity of water are the ones that are most concerned about studying FES, as is the case of Iran, Iraq, and Afghanistan in the Paleartic region or India in the Indomalaya region.

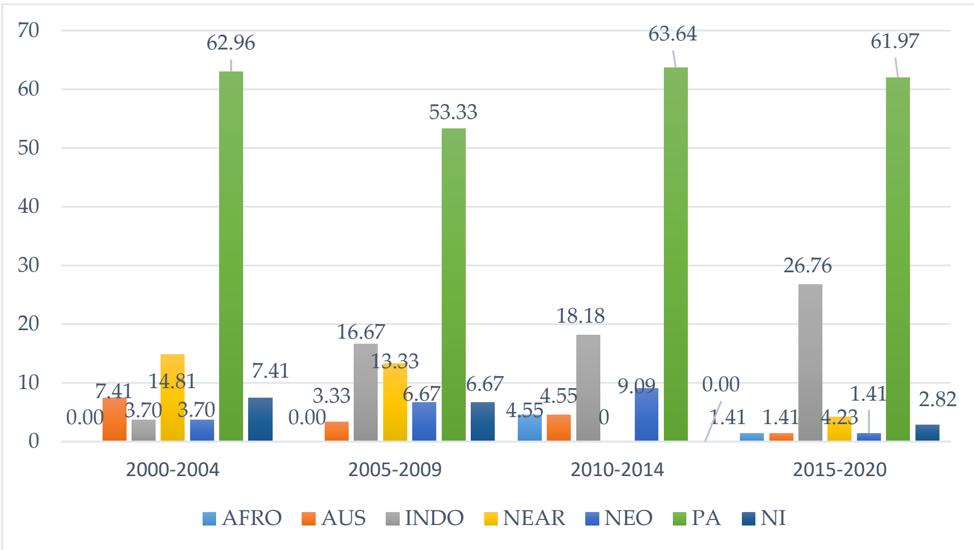

Figure 5. Percentage of papers by Biogeographic realm and period. For explanation of categories see Section 2.3.

Some works could not be included in a specific biogeographic realm because they were theoretical or modelling and simulation works, and were categorized as "Not identified" (NI).

3.1.5. Waterbody Type

Globally, rivers have been the most analysed freshwater ecosystem (46.7%) (Figure 1). However, since 2010, this waterbody type has decreased in frequency in favour of wetlands that have progressively increased ovel time representing 33.8% of the reviewed studies in 2015–2020 (Figure 6).

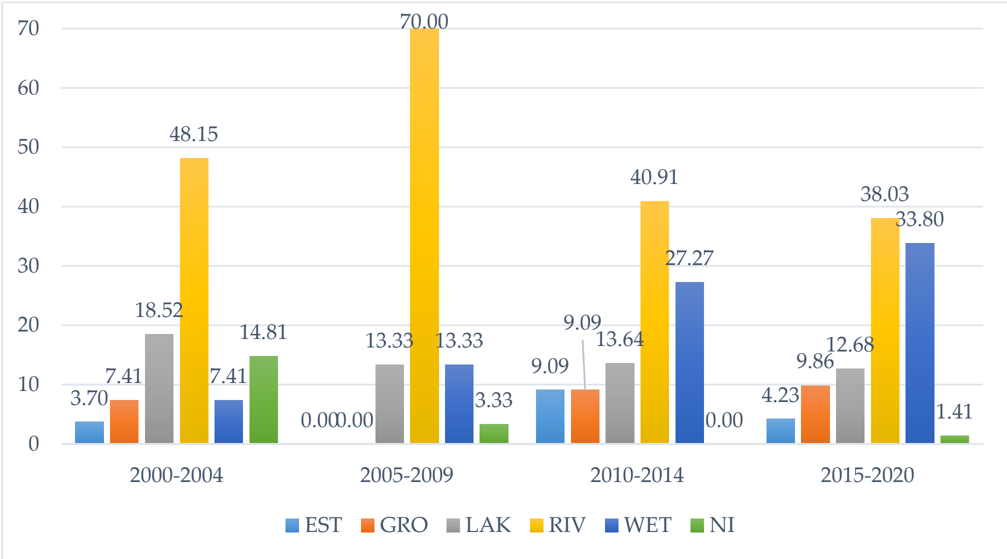

Figure 6. Percentage of papers by waterbody type and period. For explanation of categories see Section 2.3.

Groundwater studies increased in the last two periods, involving 9.9% of the papers that were reviewed between 2015 and 2020. Lakes have been slightly less studied, decreasing in frequency inform the first (18.5%) to the last period (12.7%). Estuaries have not followed a regular trend over the 20-year period considered (Figure 6).

Ninety-two percent of studies on wetlands sought to solve problems by analysing impact or vulnerability and conservation management and they were aimed at protecting the supporting and regulating FES.

According to the latest data, wetlands cover 12.1 million km2 globally. Between 1970 and 2015, 35% of natural wetlands were lost (three times the rate of forest loss), while 81% of inland wetland species populations and 36% of coastal species declined [36]. Increasing wetland pollution, invasive species, and rapid urban development currently present a grave threat to wetlands. These data certainly justify the studies aimed at preserving the ecological functions of wetlands.

3.1.6. Problems

Up to the period 2015–2020, the most commonly studied problem was water management (MAN), with 44.4 to 46.7% of the publications in each of the three initial periods, as shown in Figure 7. However, in the last period, the proportion of publications focused on water management dropped to 14.1%, accompanied by a growing interest in the assessment of the impact and vulnerability (IMPACT-VUL) of aquatic ecosystems (39.4%) and in conservation aspects (CON), 16.9% of the publications in this period.

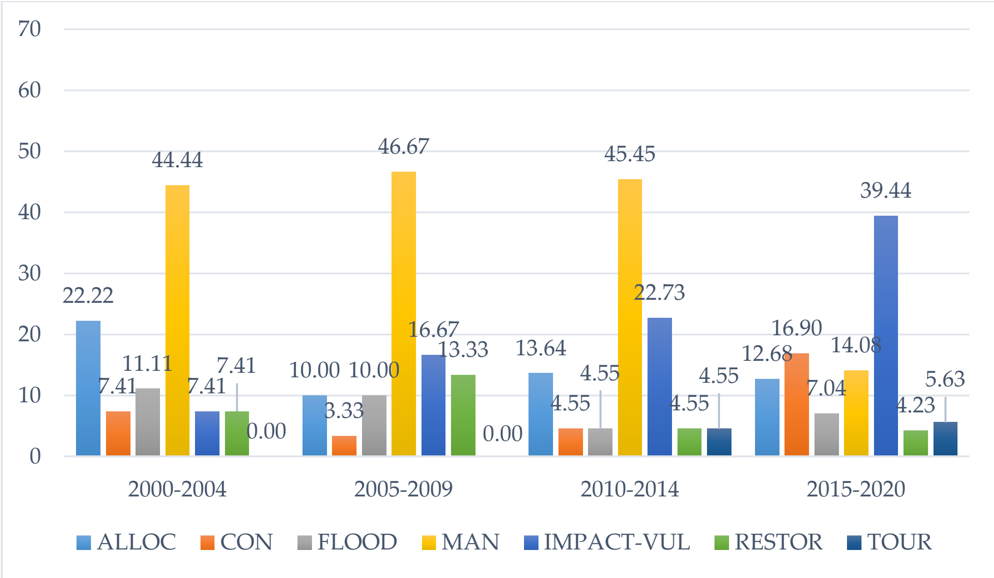

Figure 7. Percentage of papers by problem and period. For explanation of categories see Section 2.3.

Near 70% of all the participative studies dealt with management problems. This result could be expected since management problems are usually related with social an economic issues. Near 75% of the studies whose objective was related to conservation, 50% to restoration, and nearly 86% related to tourism, did not considered preferences of stakeholders. Although this could also be expected, this detachment of stakeholders in decision making is one of the most important problems in nature conservation, and it is a source of strong conflicts in rural areas, especially in protected areas. As an example, the restoration of a watershed involves many actions causing changes in the landscape and in different resources, often affecting a relevant number of stakeholders. Decisions regarding tourism planning also affect residents and other people with interests in specific sites. Failing to involve owners, managers, and residents in decision making in cases like these can create feelings of frustration within some stakeholders' groups, generating conflicts that sometimes result in environmental crimes, such as illegal fire-setting or wildlife poisoning [37].

3.2. Relationships among Attributes

The review identified a total of 28 (18. 7%) articles on provisioning, 60 (40.0%) on regulating, 7 (4.7%) on cultural, 14 (9.3%) on supporting, and 41 (27.33%) on simultaneously provisioning, regulating or cultural ecosystem services. Within each class of FES, we reviewed, in detail, the publications selected in this study adopting the classification described in Section 2.3. The Chi-square test indicated significant relationships between type of FES, biogeographic realm, method, problem, and participation ($p = 0.00$). These relationships are described and discussed in detail in Sections 3.2.1–3.2.5.

3.2.1. Provisioning FES

Although there has been a reduction in the number of articles analysing water as a provisioning ecosystem service since 2010, over the total period, 75% of the articles have, to a greater or lesser extent, analysed water from this perspective (Table 1). Most of these articles have focused on the Palearctic realm, especially arid and semi-arid regions, such as Iran, Afghanistan, or India, and they have addressed problems of resource allocation and the identification of potential sources of provisioning services. In this regard, a degree of dependence between countries and methods has been identified ($p = 0.051$), with the analysis showing a tendency to use hierarchical methods in India.

Water resources management has mainly been studied using mixed and hierarchical methods (46.43%) with the involvement of experts. AHP has been the most widely-used method to analyse water as a resource. To address related issues, Jaber and Mohsen [38], Chowdhuri et al. [39], Machiwal et al. [40], Machiwal et al. [41], Çelik [42], and Rana and Suruanarayana [43] used AHP; all but [38] combined it with GIS to do so. Swetha et al. [44] also used GIS with a hierarchical method, but in that case with ANP.

Two articles have been found that use outranking methods—Prato [45] and Hyde et al. [46]—and two others that have use utility functions—Arriaza et al. [47] and Lopez-Baldovi et al. [48], with the latter two both focusing on Spain.

The mixed methods that are applied in this type of analysis generally combine stochastic methods, such as Bayesian networks with utility functions, outranking, or fuzzy methods, usually with GIS.

Of the 28 articles that were reviewed in this group, only four have involved stakeholder participation in some way, while eight have involved expert participation, and 16 articles have proposed models that do not incorporate any type of participation. In the latter case, they have performed simulations or worked with analyses of non-participatory scenarios.

Arriaza et al. [47] are the only authors who adopted a semi-participatory approach to address the allocation of water resources, when considering the interests of the different groups of stakeholders. They proposed a model based on utility functions to improve efficiency in the allocation of water resources and examined a case study in the Guadalquivir River Basin (Spain) involving water allocation to three groups of farmers. Although the model did not incorporate the interaction of these groups, they were asked about their degree of agreement with the results.

Mysiak et al. [49] and Rouzbahani et al. [50] also involved stakeholders to resolve management problems. A tool was proposed by Mysiak et al. [49] for the integration of hydrological models in a decision support system for water management, while considering the preferences of different stakeholders and applying it in five European countries. Rouzbahani et al. [50] analysed a number of different scenarios for aquifer restoration in Iran, using Bayesian networks, TOPSIS, SAW, and PROMETHEE II methods, accounting for the socio-cultural acceptance of stakeholders. Although the focus was on the restoration of these aquifers, the purpose was to ensure water supply to the affected regions.

Zarghami [51] and Estalaki et al. [52] also considered stakeholders in their studies of the impact of different management policies. Different water management alternatives were analysed by Zarghami [51] by means of a stochastic approach, using fuzzy quantifiers to incorporate the assessment of various stakeholders. Fuzzy social choice was used by Estalaki et al. [52] to incorporate stakeholder participation in the assessment of the impact of management policies on water quality in Iran.

Finally, a relationship was found between problem and participation ($p = 0.015$); studies that solve problems aimed at addressing resource allocation issues are the least likely to consider stakeholder preferences, as opposed to impact/vulnerability studies.

Table 1. Reviewed papers that analyse water from a provisioning ecosystem service perspective classified by region, method, problem, participation, study area, and waterbody type.

Reference	Region	Method	Problem	Participation	Study area	Water Course Type
Jaber and Mohsen, 2001 [38]	Jordania	HIER	ALLOC	NO	Ceyhanand Seyhan River	River
Nayak and Panda, 2001 [53]	India	FUZ	ALLOC	EXP	Mahanadi Delta	River
Arriaza et al., 2002 [47]	Spain	UT	ALLOC	YES	Guadalquivir Valley	River
Mimi and Sawalhi, 2003 [22]	Jordania, Israel, Palestina	DIS	ALLOC	EXP	Jordan River	River
Prato, 2003 [45]	USA	OUT	MAN	NO	Missouri River	River
Hyde et al., 2004 [46]	Spain-Adelaide	OUT	ALLOC	EXP	Flumen Monegros-Northern Adelaide Plains	River
Karnib, 2004 [54]	Theoretical	FUZ	MAN	NO	-	-
McPhee and Yeh, 2004 [55]	USA	FUZ	MAN	NO	Upper San Pedro River Basin	River
Srdjevic et al., 2004 [56]	Brazil	DIS	ALLOC	NO	Paraguaçu River basin	River
Mysiak et al., 2005 [49]	Various	Other	MAN	YES	-	River
López-Baldoví et al., 2006 [48]	Spain	UT	ALLOC	NO	Guadalquivir Valley	River
Zarghaami, 2006 [57]	Irán	DIS	ALLOC	EXP	Polrud River basin	River
Raju and Vasan, 2007 [58]	India	MIX	ALLOC	NO	Various	River
Zarghami and Szidarovszky, 2009 [51]	Hungary	MIX	IMPACT-VUL	YES	Central Tisza River	River
Gómez-Limón and Riesgo, 2009 [59]	Spain	MIX	MAN	EXP	Duero basin	River

Table 1. *Cont.*

Reference	Region	Method	Problem	Participation	Study area	Water Course Type
Chowdhury et al., 2010 [39]	India	HIER	ALLOC	EXP	Subarnarekha and Kasai Rivers	Groundwater
Machiwal et al., 2011 [40]	Theoretical	HIER	ALLOC	NO	-	Lake
Opricovic, 2011 [60]	Serby	MIX	MAN	NO	Mlava River	River
Machiwal et al., 2015 [41]	India	HIER	ALLOC	NO	Ahar catchment	Groundwater
Estalaki et al., 2016 [52]	Iran	FUZ	IMPACT-VUL	YES	Chitgar Lake	Lake
Swetha et al., 2017 [44]	India	HIER	ALLOC	NO	Kuttiyadi River basin	Groundwater
Zeng et al., 2017 [61]	China	Other	ALLOC	NO	Guanting reservoir basin	River
Roozbahani et al., 2018 [50]	Iran	MIX	MAN	YES	Lake Urmia	Lake
Arabameri et al., 2019 [62]	Iran	DIS	ALLOC	NO	Shahroud plane	Groundwater
Bera and Bnik, 2019 [63]	India	Oher	ALLOC	NO	Kansachara watershed	River
Çelik, 2019 [42]	Turkey	HIER	ALLOC	EXP	Tigris River	Groundwater
Arabameri et al., 2020 [64]	Iran	MIX	ALLOC	NO	Bastam watershed	Groundwater
Rana and Suruanarayana, 2020 [43]	India	HIER	ALLOC	EXP	Vishwamitri watershed	River

3.2.2. Regulating FES

The 60 articles dealing with water from a regulating ecosystem service perspective (Table 2) have primarily studied problems relating to flood control and the vulnerability, impact and restoration of lakes and wetlands, and on the capacity of wetlands to regulate biological cycles.

The most commonly used methods in this group are hierarchical (28.3%) and mixed (25%), but the review yields a substantial number of studies using other methods (16.7%), distance-based methods (11.7%), and fuzzy sets (10%).

A total of 51.7% of the reviewed studies have addressed problems that are associated with impact or vulnerability, of which 41.9% involved expert participation and 54.8% did not include any type of participation. Only one article in this group took stakeholder preferences into account [65].

The only relationship of dependence found was between the problem to be solved and participation ($p = 0.019$). A mere 20% of the articles that were reviewed in this group incorporated stakeholder participation. For example, Janssen et al. [66] attempted to resolve management problems using the software package DEFINITE with GIS to assess wetland functions and the impact of three management alternatives: modern peat pasture, historical peat pasture, and dynamic mire.

Brouwer and Ek [67], Levy [68], Kenyon [69], Levy et al. [70], and Perrone et al. [71] focused on the study of flood control problems.

An integrated model of flood control policies was proposed by Ek [67] in the Netherlands, considering effects, such as land use change and floodplain restoration, using cost-benefit analysis and a multicriteria analysis in order to incorporate the participants' judgement in the model. Flood risk management was evaluated by Kenyon [69] in Scotland, using a participative approach. She used citizens' juries, deliberative monetary evaluation, and multi-criteria visual methods, considering criteria, such as looks, nature, cost, maintenance, safety, and flooding. Levy et al. [70] proposed a multi-criteria decision support tool to enhance communication among stakeholders and improve emergency management resource allocation in Tokai (Japan). A collaborative approach based on fuzzy methods was proposed by Perrone et al. [71] to manage flood risk in a river in Italy.

Rohde et al. [72], Randhir and Shriver [73], and Gross and Hagy [74] studied restoration issues. In an application to the Rhône-Thur river project, Rohde et al. [72] used GIS and MCDM for an integrated assessment of different river restoration strategies, jointly evaluating environmental criteria, such as natural flow and sufficient bed load material and socio-economic criteria associated with public attitude.

A deliberative attribute prioritization procedure using AHP was applied by Randhir and Shriver [73] to the case of subwatersheds for restoration in the Chicopee river in western Massachusetts, USA.

Restoration issues were also addressed by Gross and Hagy [74] using a participatory approach, in this case focusing on lakes and estuaries degraded by nutrient pollution. They analysed 16 case studies in different lakes and estuaries around the world to identify common attributes for nutrient management and variations thereof and explored the relationships between them using multicriteria analysis.

Daneshvar et al. [65] evaluated the impact of natural wetland implementation on total phosphorus reduction in the Saginaw River Watershed (Michigan) using the VIKOR method and SWAT model in order to provide a guide for policymakers.

Table 2. Reviewed papers that analyse water from a regulating ecosystem service perspective classified by region, method, problem, participation, study area, and waterbody type.

Reference	Region	Method	Problem	Participation	Study Area	Water Course Type
Arondel and Girardin, 2000 [75]	France	FUZ	IMPACT-VUL	EXP	Rhine Plain	Groundwater
Chuntian and Chau, 2002 [76]	China	FUZ	FLOOD	NO	Fengman Reservoir	River
Wang et al., 2003 [77]	China	HIER	IMPACT-VUL	NO	Jianghan Plain	Wetland
Bana e Costa et al., 2004 [78]	Portugal	UT	FLOOD	EXP	Livramento creek in the peninsula of Setúbal	River
Brouwer and Ek, 2004 [67]	Netherlands	Other	FLOOD	YES	River Rhine and Meuse Delta	River-Wetland
Herath, 2004 [79]	Victoria	HIER	MAN	YES	Wonga Wetlands	Wetland
Olenick et al., 2004 [80]	USA	DIS	MAN	NO	Edwards Aquifer and Twin Buttes watersheds	Other
Tzionas et al., 2004 [81]	Greece	FUZ	RESTOR	EXP	Lake Koronia	Lake
Almasri and Kaluarachchi, 2005 [82]	Whashington	NEU	IMPACT-VUL	NO	Sumas–Blaine aquifer	River
Janssen et al., 2005 [66]	Germany	Other	MAN	YES	Noord-Hollands Midden	Wetland
Lee and Chang, 2005 [83]	Taiwan	FUZ	IMPACT-VUL	NO	Tou-Chen River basin	River
Levy, 2005 [68]	China	HIER	FLOOD	YES	Tokai flood	River
Elshorbagy, 2006 [84]	Canadá	OUT	RESTOR	NO	Fort McMurray (reconstructed watershed)	River
Liu et al., 2006 [85]	New South Wales	DIS	RESTOR	EXP	Clarence River	Wetland
Rohde et al., 2006 [72]	Switzerland	Other	RESTOR	YES	Rhône-Thur Rivers	River
Kenyon, 2007 [69]	Scotland	SOFT	FLOOD	YES	Scotland (general)	River
Levy et al., 2007 [70]	Japan	HIER	FLOOD	YES	Shinkawa and the Shonai rivers (Tokai floods)	River

Table 2. *Cont.*

Reference	Region	Method	Problem	Participation	Study Area	Water Course Type
Li, 2007 [86]	China	HIER	CON	EXP	Chaohu Lake	Lake
Qin et al., 2008 [87]	Canadá	MIX	IMPACT-VUL	EXP	Georgia basin	River
Randhir and Shriver, 2009 [73]	USA	HIER	RESTOR	YES	Chicopee River	River
Olu-Owolabi et al., 2012 [88]	Nigeria	FUZ	IMPACT-VUL	NO	Ondo coast	Estuary
Sun et al., 2012 [89]	China	MIX	IMPACT-VUL	NO	Dayang Estuary	Wetland-Estuary
Wu et al., 2012 [90]	China	MIX	ALLOC	YES	Qixinghe	Wetland
Sener and Davraz, 2013 [91]	Turkey	HIER	IMPACT-VUL	NO	Egirdir Lake basin	Groundwater
Lee et al., 2014 [92]	Korea	MIX	FLOOD	NO	Han River	River
Malekmohammadi and Blouchi, 2014 [93]	Iran	HIER	IMPACT-VUL	EXP	Shadegan Wetland	Wetland
Chatterjee et al., 2015 [94]	India	MIX	IMPACT-VUL	NO	Keoladeo National Park	Wetland
McVittie et al., 2015 [95]	Theoretical	Other	IMPACT-VUL	NO	Theoretical	River
Meraj et al., 2015 [96]	India	Other	FLOOD	NO	Lidder and Rembiara watersheds of the Jhelum basin	River
Shafiee et al., 2015 [97]	Iran	MIX	IMPACT-VUL	NO	Heleh protected area	Wetland
Walker et al., 2015 [98]	Serbia	Other	IMPACT-VUL	NO	Danube River	River
Abd-El Monsef et al., 2017 [99]	Egypt	HIER	CON	NO	Sharm El-Bahari	Wetland
Daneshvar et al., 2017 [65]	USA	DIS	IMPACT-VUL	YES	Saginaw River watershed	Wetland
Duodu et al., 2017 [100]	Queensland	OUT	IMPACT-VUL	NO	Brisbane River	River
Gross and Hagy, 2017 [74]	Various	SOFT	RESTOR	YES	Various	Lake-Estuary
Man et al., 2017 [101]	China	HIER	CON	NO	Sanjiang plain	Wetland
Malekmohammadi and Jahanishakib, 2017 [102]	Iran	HIER	IMPACT-VUL	EXP	Choghakhor Wetland	Wetland
Rather et al., 2017 [103]	India	Other	IMPACT-VUL	NO	Jhelum Basin	River
Golbarg et al., 2018 [104]	Iran	HIER	IMPACT-VUL	EXP	Shadegan International Wetland	Wetland
Maleki et al., 2018 [105]	Afghanistan-Iran	HIER	RESTOR	NO	Hamun Wetlands	Wetland

Table 2. *Cont.*

Reference	Region	Method	Problem	Participation	Study Area	Water Course Type
Rahdari et al., 2018 [106]	Iran	MIX	CON	EXP	Gavkhooni Wetland-Plasjan sub-bsin	River-Wetland
Arabameri et al., 2019 [107]	Iran	DIS	IMPACT-VUL	EXP	Semnan watershed	River
Bid and Siddique, 2019 [108]	India	DIS	FLOOD	EXP	Damodar River-Panchet dam	River
de Souza et al., 2019 [109]	Brazil	MIX	IMPACT-VUL	EXP	Doce River basin	River
Ghosh and Das, 2019 [110]	India	MIX	IMPACT-VUL	NO	East Kolkata Wetland (Ramsar)	Wetland
Li et al., 2019 [111]	China	MIX	IMPACT-VUL	NO	Eastern Pearl River Delta	Estuary
Roy and Majumder, 2019 [112]	India	Other	IMPACT-VUL	NO	Loktak Lake	Lake
Xu et al., 2019 [113]	China	HIER	IMPACT-VUL	NO	Xiangjian River basin	River
Akay and Koçyigit, 2020 [114]	Turkey	MIX	FLOOD	NO	Akçay basin	River
Alamanos and Papaioannou, 2020 [115]	Canadá	HIER	IMPACT-VUL	EXP	Lake Erie watershed	Wetland
Arabameri et al., 2020 [116]	Iran	HIER	IMPACT-VUL	EXP	Kalvari basin	River
Bhattacharya et al., 2020 [117]	India	DIS	IMPACT-VUL	NO	Kangsabati basin	River
Ghaleno et al., 2020 [118]	Iran	MIX	IMPACT-VUL	EXP	Gorganrud basin	River
Ghosh and Das, 2020 [119]	India	NEU	IMPACT-VUL	EXP	East Kolkata Wetland (Ramsar)	Wetland
Perrone et al., 2020 [71]	Italy	FUZ	FLOOD	YES	Bradano River	River
Popovic et al., 2020 [120]	Serbia	MIX	RESTOR	NO	Lake Vrutci	Lake
Sarkar and Majumder, 2020 [121]	India	MIX	IMPACT-VUL	EXP	Tripura River	River
Souissi et al., 2020 [122]	Tunisia	HIER	FLOOD	EXP	Gabes region	River
Sun et al., 2020 [123]	China	MIX	FLOOD	NO	Yangtze River delta	River
Yang and Wang, 2020 [124]	China	DIS	IMPACT-VUL	EXP	Taihu basin	Lake-River

3.2.3. Cultural FES

A total of seven articles have been identified that deal with recreational services of freshwater ecosystems, six of them in the last period analysed (Table 3). Zhang et al. [125] used TOPSIS to evaluate competitive tourist destinations in the Yangtze River Delta (China) and Tang et al. [126] used fuzzy techniques to evaluate the coordinative green development of tourist experience and commercialization of tourism when considering the perspectives of tourists in the Ancient City of Pingyao and West Lake Cultural Landscape of Hangzhou (China). Aiping et al. [127] used AHP and GIS to identify and map ecotourism areas in one area of the Yellow River (China). Biglarfadafan et al. [128] and Tang et al. [126] both assessed impact/vulnerability, while the rest identified suitable places for tourism. The suitability of areas for birdwatching was identified by Biglarfadafan et al. [128] in wetlands, as well as the impact of ecotourism, and Tang et al. [126] studied the green development of tourism in a protected area. The studies were carried out in Iran and China, and none of them accounted for stakeholder preferences.

Table 3. Reviewed papers that analyse water as a cultural ecosystem service classified by region, method, problem, participation, study area, and waterbody type.

Reference	Region	Method	Problem	Participation	Study Area	Water Course Type
Zhang et al., 2011 [125]	China	DIS	TOUR	NO	Yangtze River Delta	River
Aiping et al., 2015 [127]	China	HIER	TOUR	NO	Yellow River	Wetland
Erfani et al., 2015 [129]	Iran	MIX	TOUR	NO	Hamoon Lake	Lake
Biglarfadafan et al., 2016 [128]	Irán	MIX	IMPACT-VUL	NO	Bazangan Lake	Wetland
Balist et al., 2019 [130]	Iran	MIX	TOUR	NO	Zarivar Lake	Lake
Maghsoudi et al., 2019 [131]	Iran	MIX	TOUR	NO	Shur River (Lut desert)	River
Tang et al., 2019 [126]	China	FUZ	IMPACT-VUL	NO	West Lake of Hangzhou	Wetland

3.2.4. Supporting FES

The 14 studies included in this group have a strict focus on site conservation, especially biodiversity conservation (Table 4). Only Qureshi and Harrison [132], Eliasson et al. [133], and Choulak et al. [134] incorporated stakeholder participation in resolving issues associated with supporting ES. The first of these studies evaluated different alternatives for riparian revegetation in a small sub-catchment in the Johnstone River catchment (North Queensland) while using hierarchical methods and a collaborative approach.

Eliasson et al. [133] evaluated the impact of the construction of a new road on an important glaciofluvial esker aquifer in Sweden. Scenario analysis and a multi-criteria decision model were used to examine the preferences of the main stakeholders in the affected municipalities, in order to assess four different alternatives accounting for conflicts with aquatic, agricultural, natural and cultural resources. A meta-decision analysis carried out by [134] in an application to wetland prioritization in the Bourgogne region (France), seeking to encourage and finance wetland conservation plans considering their contribution to biodiversity. Chen et al. [135] relied on expert participation in their study that aimed at improving wetland environmental protection plans, using DEMATEL and VIKOR techniques and a modified ANP. In this case, experts were consulted to identify four dimensions and 11 criteria to determine the best management alternative aimed at achieving the objective of wetland environmental protection.

Saha [136] and Talukdar et al. [137] focused on assessing the vulnerability of two Indian wetlands of the Atreyee River and Tangan River, respectively. The former used fuzzy logic, while the latter used random forest and neural networks to explore the habitat quality and Trophic State Index. Buruso [138] studied the suitability of Lake Tana as habitat for the African hippo, while Wu et al. [139] analysed the ecological value of 60 national parks (wetlands) in China. Jafari [140] also focused on analysing the ecological value of sites in Kavir National Park (Iran).

Table 4. Reviewed papers that analyse water from a supporting ecosystem service perspective classified by region, method, problem, participation, study area, and waterbody type.

Reference	Region	Method	Problem	Participation	Study Area	Water Course Type
Qureshi and Harrison, 2001 [132]	Queensland	HIER	CON	YES	Johnstone River catchment	River
Eliasson et al., 2003 [133]	Sweden	DIS	CON	YES	Aquifer Nybroåsen (Kalmar)	Groundwater
Dong et al., 2013 [141]	China	HIER	CON	NO	West Songnen Plain	Wetland
Kozlov et al., 2016 [142]	Rusia	Other	CON	NO	Volga-Akhtuba Wetlands	Wetland
Qiu et al., 2016 [143]	USA	MIX	CON	NO	Raritan River basin	River
Xue et al., 2016 [144]	China	FUZ	CON	NO	Yangtze River Estuary	Estuary
Buruso, 2018 [138]	Ethiopia	Other	CON	NO	Lake Tana Biosphere Reserve	Lake
Wu et al., 2017 [139]	China	HIER	CON	NO	60 National Wetlands Parks	Wetland
Qi et al., 2018 [145]	China	MIX	CON	NO	Lake Poyang	Lake
Chen et al., 2019 [135]	Taiwan	MIX	MAN	EXP	Guan-Du Wetland	Wetland
Choulak et al., 2019 [134]	France	MIX	CON	YES	Bourgogne comte	Wetland
Saha and Pal, 2019 [136]	India	FUZ	IMPACT-VUL	NO	Atreyee River	Wetland-River
Jafari et al., 2019 [140]	Iran	MIX	CON	NO	Kavir National Park	River
Talukdar et al., 2020 [137]	India	NEU	IMPACT-VUL	NO	Tangan River	Wetland-River

3.2.5. Integrated FES and Participation

The strong decrease in analyses involving stakeholder participation from the period 2005–2009, as shown in the results, can be primarily explained by the growing concern about conservation, in the strict sense, and provisioning issues, which have not traditionally incorporated stakeholder participation in decision-making processes. The review identified another group of studies that approach water as an integrative element, analysing problems that are associated with its provisioning, regulating, cultural, and sometimes supporting functions, and which consider the interests of different stakeholder groups. There was a very substantial increase in the publications of this type of study in the period 2000–2005 and, to a lesser extent, in the second period 2006–2010, before decreasing significantly from 2011 onwards and contributing to the gradual decline in participatory studies of FES from 2011 (Figure 4).

Thirty-one studies (75.6%) that take an integrated approach to analysing FES incorporated stakeholder participation. These studies were mainly conducted in European countries and address issues of sustainable management (Table 5). A high degree of dependence was identified between participation and the problem to be solved (p = 0.00): the articles dealing with solving management problems were the most participatory.

In this group, only two papers dealt with problems of impact/vulnerability and restoration: Gregory and Wellman [146] and Azarnivand et al. [147]. A participative tool was proposed by Gregory and Wellman [146] to restore the functioning of the Tillamook Bay estuary with the values assessed by community residents. Azarnivand et al. [147] evaluated different alternatives for the restoration of Lake Urmia in Iran. To that end, they used an extended fuzzy analytical hierarchy process and a SWOT-TOWS matrix, while considering the preferences of stakeholders, managers, and experts.

Among the studies that jointly examined provisioning and regulating services, those involving stakeholder participation were Derak et al. [148], Weng et al. [149], and Dowlatabadi et al. [150]. Land use alternatives were evaluated by Derak et al. [148] evaluated in Beni Boufrah Valley, a semi-arid area of Morocco, incorporating 67 stakeholders' preferences regarding water supply, soil fertility, protection against erosion, and food provision. To do so, they used an AHP model. Multi-objective programming was used by Weng et al. [149] and proposed a decision support system for water resources management and planning in the Haihe River Basin (China), in which stakeholders could include their preferences in the assessment of different management scenarios. This is the only study carried out in China that incorporates stakeholder preferences into the model. DEMATEL, AHP, and game theory were used by Dowlabati et al. [150] to resolve conflicts surrounding a transboundary wetland, Hawizeh Wetland/Hoor-Al-Azim, involving Iran, Iraq, Turkey, and Syria. By applying the model, the authors were able to identify three strong equilibrium points among 15 feasible alternatives: establishing a regional agreement among Iran, Iraq, and Turkey to reduce the effects of conflicts on the wetland; an Iran-Iraq coalition to motivate Turkey to reduce water withdrawal from the Tigris River; and, exchanging water release for the commodity market in Iran and Iraq for Turkey.

Finally, two papers were identified that jointly analysed regulating and cultural functions. Väntänen and Marttunen [151] proposed several ways to include stakeholder participation in order to assess the impact of different regulation strategies on recreational use and aquatic ecosystems in a Finnish lake. Wang et al. [152] addressed tourism development in a wetland in China, considering its effect on the biochemical conditions of the water. To do so, they used fuzzy neuronal networks, but did not rely on the participation of stakeholders or experts.

Environmental policies are implemented in complex socio-economic contexts, involving a large number of different stakeholder groups with diverse and often conflicting interests. Conflicts are exacerbated in a context of scarce resources, and often protected resources, as is the case with water. Nevertheless, although there are many links between water and conflicts, and many opposing interests have a bearing on its management, most disputes are resolved peacefully through negotiation processes; accordingly, since the early 2000s, different formulas for cooperation in water management have been promoted [153]. Generally speaking, economic cooperation between countries can be used as a negotiating tool for solving water problems [150].

Two key elements should be taken into account when it comes to managing water-related conflicts: the legislative framework and operational framework. Regarding the former, there is a need for a legal and regulatory framework to support the management of large watercourses. Indeed, in international river basins, water management institutions do not tend to manage conflicts if there is no treaty stating the rights and responsibilities of each nation, or any implicit agreement [153]. In terms of the operational framework, MCDM methods can be a very useful tool for identifying conflicts and efficiently managing them [154]. In addition to the scientific soundness of the models, participation plays a relevant role in a number of ways: on the one hand, expert recommendations are needed to improve their operability and support their legitimacy [134] and, on the other hand, incorporating participation in the early stages of the decision-making processes helps to minimise conflicts and facilitates their management in the development of public policies [155]. Alamanos et al. [156] provide an integrated decision support tool for evaluating water resource management strategies in a lake in Greece. They combined four MCDM techniques to assess seven alternative policies and involved experts and stakeholders to weight the analysed criteria and then compared the results. This illustrated the differences in the perception of the problems, and guided an integrated solution expressed by experts in the field of water management and by the responsible authorities. Moreover, this study compared several MCDM techniques, which is very useful for defining a complete framework of alternative possibilities when divergences between participants are strong. Papaioannou et al. Several multiple-criteria analysis methods were compared by [157] for potential flood prone areas mapping in the Xerias River watershed (Greece).

Although this is acknowledged by the scientific community and accepted by the general public, the present review has shown that, in recent years, there has been a trend towards the proliferation of non-participatory studies regarding MCDM methods aimed at solving problems of a strictly ecological nature without accounting for social preferences.

Table 5. Reviewed papers that analyse water as an integrated ecosystem service.

Reference	Region	Method	Problem	Ecosystem Service	Participation	Study Area	Water Course Type
De Marchi et al., 2000 [158]	Sicilia	FUZ	MAN	PROV-REG-CULT	YES	Dam and lake in Ancipa	Lake
Srinivasa et al., 2000 [159]	Spain	OUT	MAN	PROV-REG-CULT	NO	Flumen Monegros irrigation area (Hoya de Huesca and Monegros)	River
Gregory and Wellman, 2001 [146]	USA	UT	RESTOR	PROV-REG-CULT	YES	Tillamook Bay	Estuary
Hamalainen et al., 2001 [160]	Finland	DIS	MAN	PROV-REG-CULT	YES	Lake Päijänne-River Kymikoki	Lake
Pavlikakis and Tsihrintzis, 2003 [161]	Greece	DIS	MAN	PROV-REG-CULT	YES	National Park of river Nestos delta and Lakes Vistonida and Ismarida	Lake
Cai et al., 2004 [21]	China	DIS	MAN	PROV-REG-CULT	YES	Theoretical	NI
Mustajoki et al., 2004 [162]	Finland	UT	MAN	PROV-REG-CULT	YES	Lake Päijänne	Lake
Raju and Duckstein, 2004 [163]	Spain	OUT	MAN	PROV-REG-CULT	EXP	Flumen Monegros irrigation area	River
Vantanen and Marttunen, 2005 [151]	Finland	SOFT	IMPACT-VUL	REG-CULT	YES	Lake Kemijärvi	Lake
Wattage and Mardle, 2005 [164]	India	HIER	MAN	PROV-REG-CULT	YES	Muthurajawela Marsh and Negombo Lagoon	Wetland
Messner et al., 2006 [165]	Germany	Other	MAN	PROV-REG-CULT	YES	Spree river basin	River
Wang et al., 2006 [166]	China	FUZ	MAN	PROV-REG-CULT	YES	Lake Quionghai	Lake
Goosen et al., 2007 [167]	Holland	Other	MAN	PROV-REG-CULT	YES	Wormer and Jisperveld	Wetland
Marchamalo and Romero, 2007 [168]	Costa Rica	DIS	MAN	PROV-REG-CULT	YES	Birrís River	River
Srdjevic, 2007 [169]	Brazil	MIX	MAN	PROV-REG-CULT	YES	San Francisco river basin	River
Hajkowicz and Higgins, 2008 [170]	NI	Other	MAN	PROV-REG-CULT	YES	Various	NI
Marttunen and Hamalainen, 2008 [14]	Finland	Other	MAN	PROV-REG-CULT	YES	Lake Päijänne-RIV Kymikoki	Lake
Van Cauwenbergh et al., 2008 [171]	Spain	MIX	MAN	PROV-REG-CULT	YES	Andarax catchment	River
Chung and Lee, 2009 [172]	Korea	MIX	MAN	PROV-REG-CULT	YES	Anyangcheon watershed (Han river)	River
Ryu et al., 2009 [173]	Korea	DIS	MAN	PROV-REG-CULT	YES	Geum river basin	River
Calizaya et al., 2010 [174]	Bolivia	HIER	MAN	PROV-REG-CULT	YES	Lake Poopo Basin (Ramsar)	Lake

Table 5. *Cont.*

Reference	Region	Method	Problem	Ecosystem Service	Participation	Study Area	Water Course Type
Chen et al., 2010 [175]	Taiwan	MIX	MAN	PROV-REG-CULT	YES	Pei-Keng watershed	River
Silva et al., 2010 [176]	Brazil	OUT	MAN	PROV-REG-CULT	YES	Jabuatao River watershed	River
Yilmaz and Harmancioglu, 2010 [177]	Turkey	DIS	MAN	PROV-REG-CULT	YES	Gediz River basin	River
Weng et al., 2010 [149]	China	Other	MAN	PROV-REG	YES	Haihe river basin	River
Chen et al., 2011 [178]	China	FUZ	MAN	PROV-REG-CULT	EXP	Pei-Keng brook of catchments area	River
Lennox et al., 2011 [179]	New Zealand	SOFT	MAN	PROV-REG-CULT	YES	Canterbury region	River
Wang et al., 2012 [152]	China	NEU	IMPACT-VUL	REG-CULT	NO	Others-Theoretical	Wetland
Azarnivand et al., 2014 [147]	Iran	MIX	RESTOR	PROV-REG-CULT	YES	Lake Urmia	Lake
Aznar et al., 2014 [180]	Spain	MIX	MAN	PROV-REG-CULT	YES	Pego-Oliva Wetland	Wetland
Pinto et al., 2014 [181]	Portugal	DIS	MAN	PROV-REG-CULT	YES	Mondego Estuary	Estuary
Aher et al., 2017 [182]	India	HIER	ALLOC	PROV-REG	NO	Dhalai River	River
Derak et al., 2017 [148]	Morocco	HIER	MAN	PROV-REG	YES	Beni Boufrah Valley	River
Sheikhipour et al., 2018 [183]	Iran	MIX	MAN	PROV-REG-CULT	NO	Shahrekord aquifer	Groundwater
DasGupta et al., 2019 [184]	India	DIS	MAN	PROV-REG-CULT	YES	Indian Sundarban Delta	Estuary
Everard et al., 2019 [185]	India	other	MAN	PROV-REG-CULT	YES	SudhanyakhaliIsland-Gosaba Island-East Kolkata Wetland	Wetland
Hosseini et al., 2019 [186]	Iran	MIX	MAN	PROV-REG	EXP	Various	Groundwater
Kacem et al., 2019 [187]	Morocco	MIX	IMPACT-VUL	PROV-REG	EXP	Draden basin	River
Karabulut et al., 2019 [188]	Mediterranean region	DIS	MAN	PROV-REG	EXP	Theoretical-Mediterranean region	Theoretical
Yun et al., 2019 [189]	Korea	HIER	MAN	PROV-REG-CULT	EXP	Various	Wetland
Dowlatabadi et al., 2020 [150]	Iran-Irak-Turkey	MIX	CON	PROV-REG	YES	Tigris and Karkheh rivers and the Hawizeh/Hoor-Al-Azim wetland	Wetland

4. Conclusions

FES represent a source of conflict around the world, especially in countries where this resource is scarce. Moreover, their management becomes extremely complicated once waterbodies cross different regions and countries, involving different governments, cultures, and administrations—often already in conflict over other issues.

Multi-criteria models are very useful in helping to identify these conflicts and tackle them effectively. In addition, they provide a key tool for managing water-related decision-making processes by incorporating the preferences of different agents and dealing with conflicts from the outset.

Between 2000 and 2005, there was a marked increase in the number of studies addressing sustainable water management from an integrated perspective, jointly considering all of the ecosystem services and incorporating the preferences of all the relevant stakeholders. However, such articles are becoming less common, giving way to studies that separately explore strictly ecological functions of water and, to a lesser extent, provisioning services. This trend is reflected in the 78.88% reduction in studies involving participation since 2006.

In contrast, the substantial and serious loss of wetlands over the past decade has prompted an increase in studies focusing on these sites, which aimed at preserving their supporting and regulating functions. They are mainly concerned with solving problems of conservation management and analysing impact or vulnerability.

Articles dealing with provisioning, cultural, and supporting services individually do not involve stakeholder participation. Specifically, provisioning services are generally addressed by calling on the participation of experts or water negotiators. While analyses of the regulating ecosystem services of freshwater ecosystems have involved participation to a greater extent than other groups of studies, there is still a higher proportion of studies not involving stakeholders in decision-making processes.

International diplomacy should incorporate conflict management from the outset, while taking into account the interests of different stakeholder groups from the early stages of public policy planning, mainly in transboundary sites where conflicts are particularly challenging.

Studies on water management and conservation that reflect its essence from an ecosystem service point of view should be promoted; there is a need for studies that take an integrated approach to exploring the interrelationships between hydrology, landscapes, ecology, and humans. This scientific approach should be complemented with an integrated framework that is supported by legal and normative strategies of land and landscape management, to ensure the viability and sustainability of these initiatives.

Such an integrated approach should be broadly encouraged, seeking to involve all relevant stakeholders that are affected by national and international regulations and policies on water management. It is recommended that experts, governments, and water negotiators should continue to participate, but efforts should also be made to ensure that the preferences of the main stakeholder groups are represented in decision-making processes, in order to underscore their legitimacy. A particular emphasis should be placed on the concept of sustainability welfare, prudence, and justice. Given the expansive scope of this approach, it becomes possible to simultaneously achieve goals relating to the conservation of nature and peace, thereby helping to improve the wellbeing of humanity.

It is relevant to highlight that the decrease of participation found in this analysis is exclusively related to MCDM techniques. This does not correspond to efforts to apply participatory approaches in the implementation of water policy. In Europe, for example, the Water Framework Directive sets requirements to stakeholder participation in its implementation which has been followed by all Member States. In this sense, MCDM can contribute to the improvement of the implementation of European water policy. Moreover, it would be interesting to simultaneously combine experts and stakeholders in participatory initiatives, making these processes advance towards higher quality and integrated solutions.

From a methodological perspective, future research lines should be oriented to specific reviews separately analysing the function and usefulness of MCDM exclusively providing information and MCDM providing tools to the implementation of decision-making processes, as well as MCDM providing solutions to conflicts or guiding negotiation processes (decision support systems).

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