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Editorial

Managed Aquifer Recharge: A Key to Sustainability

Enrique Fernández Escalante [1,*], Catalin Stefan [2], Christopher J. Brown [3] and Adam Hutchinson [4]

1 Tragsa, Department of Integrated Water Resources Management, Maldonado 58, 28006 Madrid, Spain
2 Research Group INOWAS, Department of Hydrosciences, Technische Universität Dresden, 01069 Dresden, Germany; catalin.stefan@tu-dresden.de
3 School of Engineering, University of North Florida, Jacksonville, FL 32224, USA; cbrown@alliedengineering.com
4 Orange County Water District, 18700 Ward Street, Fountain Valley, CA 92708, USA; ahutchinson@ocwd.com
* Correspondence: efernan6@tragsa.es

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Citation: Escalante, E.F.; Stefan, C.; Brown, C.J.; Hutchinson, A. Managed Aquifer Recharge: A Key to Sustainability. *Water* **2023**, *15*, 4183. https://doi.org/10.3390/w15234183

Received: 23 October 2023
Accepted: 20 November 2023
Published: 4 December 2023

1. Introduction

"Managed Aquifer Recharge: A Key to Sustainability" is the title of the fourth Special Issue presented by the journal *Water* (MDPI), dedicated to the 11th International Symposium on Managed Aquifer Recharge (ISMAR 11) that was held between 11 and 15 April 2022 in Long Beach, California, USA [1]. It follows previous Special Issues pertaining to ISMAR 8 on "Policy and Economics of MAR and Water Banking", in 2013 [2]; ISMAR 9 on "Water Quality Considerations for Managed Aquifer Recharge Systems", in 2016 [3]; and ISMAR 10 "Managed Aquifer Recharge for Water Resilience", in 2019, comprising 10 contributions [4] (Table 1).

Table 1. The Special Issues by the Journal *Water* (MDPI) for ISMAR 8, 9, 10, and 11, with the number of papers (including the editorial articles), and link to each collection.

ISMAR	Number of Papers	Special Issue Access	Date of Access
8	14	https://www.mdpi.com/journal/water/special_issues/MAR	accessed on 28 August 2023
9	19	https://www.mdpi.com/journal/water/special_issues/ARS	accessed on 28 August 2023
10	23	https://www.mdpi.com/journal/water/special_issues/ISMAR10_2019	accessed on 28 August 2023
11	10	https://www.mdpi.com/journal/water/special_issues/Aquifer_Recharge	accessed on 28 August 2023

The papers collected in this Special Issue explain in detail how MAR is key to sustainability around the globe, as the environment is undoubtedly affected by extreme water-related events, alternating floods, and drought periods, which jeopardise water availability, water quality, and water supply for different uses.

In this case, the term "sustainable" relates to most of the keywords of this Special Issue, such as groundwater replenishment; risk security; policy, economics, and societal challenges; water-quality improvement; groundwater biogeochemical processes, and, in summary, water security.

This editorial article provides an analysis of all contributions to ISMAR 11 (either oral presentations or posters), including the collection of papers published in this issue. According to the book of abstracts [5], 129 contributions were received at the conference, and papers were presented in 25 sessions, covering 14 topics (Table 2). The posters' "minibook" [6] expands the themes covered, most of them categorised under the 14th topic (others).

Table 2. ISMAR 11 topics and the number of accepted abstracts for each topic (according to the book of abstracts [5]).

Number	Topic	Number of Accepted Abstracts
1	Aquifer storage and recovery (ASR) I and II	10
2	Managed aquifer recharge and integrated water management I and II	10
3	Multi-benefits of integrated flood managed aquifer recharge in California	5
4	Managed aquifer recharge engineering and design I, II, III and IV	20
5	Managed aquifer recharge geophysics I and II	11
6	Managed aquifer recharge operations and maintenance	5
7	Managed aquifer recharge and the environment I and II	10
8	Managed aquifer recharge and emerging contaminants I, II and III	14
9	Managed aquifer recharge and water markets	5
10	Managed aquifer recharge modeling I and II	10
11	Managed aquifer recharge and sustainable groundwater management	5
12	International recharge opportunities and innovation	5
13	Managed aquifer recharge of stormwater: rural and agricultural applications	5
14	Others (unclassified posters [6], ISMAR-X, missed abstracts)	14
Total		129

From the total number of submissions, nine papers were selected for publication in this Special Issue that go beyond outlining the benefits of MAR in various climatic, hydrogeological, and social settings. Additionally, these contributions focus on how MAR can be used to increase the "sustainability" of water resources, and how further benefits can be gained from its implementation.

The thematic categories include cost–benefit analysis and benchmarking for check dams, a new concept called monitored and intentional recharge (MIR), environmental assets regarding climate change, stakeholder participation in decision-making processes related to water management (bottom-up approach), science-based policy improvement, the fate of trace organic compounds in soil–aquifer treatment (SAT) schemes, nature-based solutions (NBSs) and associated groundwater-dependent ecosystems, water supply for drought-affected areas, and the use of geospatial mapping and modeling for assessing the MAR potential.

Table 3 provides an overview of the papers included in this Special Issue in the order of their publication, including the geographic coverage, and the main topics addressed.

Table 3. The list of papers included in this Special Issue with their geographic coverage and main topics addressed.

First Author	Number of Authors	Area	Contribution	Main Topic	Secundary Topic
Dashora et al. (2022)	7	India	(1)	Cost–benefit Analysis	Check Dams
Ross (2022)	1	International (Australia)	(2)	Cost–benefit Analysis	Benchmarking
Fernández Escalante et al. (2022)	4	International (Spain)	(3)	Guidelines	Monitored and intentional recharge (MIR)
Henao et al. (2022)	4	Spain	(4)	Climate Change (CC)	Environmental assets
Cruz Ayala et al. (2022)	3	Mexico	(5)	Stakeholders	Science-policy
Guillemoto et al. (2023)	10	France	(6)	Soil-aquifer treatment (SAT)	Fate of trace organic compounds
Szabó et al. (2023)	4	International (Hungary)	(7)	Nature-based solutions (NBS)	Groundwater-dependent ecosystems
Standen et al. (2023)	4	Portugal	(8)	Water supply	Resilience to drought
Mouhoumed et al. (2023)	4	Djibouti	(9)	MAR potential	Modeling

The papers cover case studies located in countries spread over different geographic zones worldwide. Five articles include examples from Europe and one from each remaining continent (Figure 1).

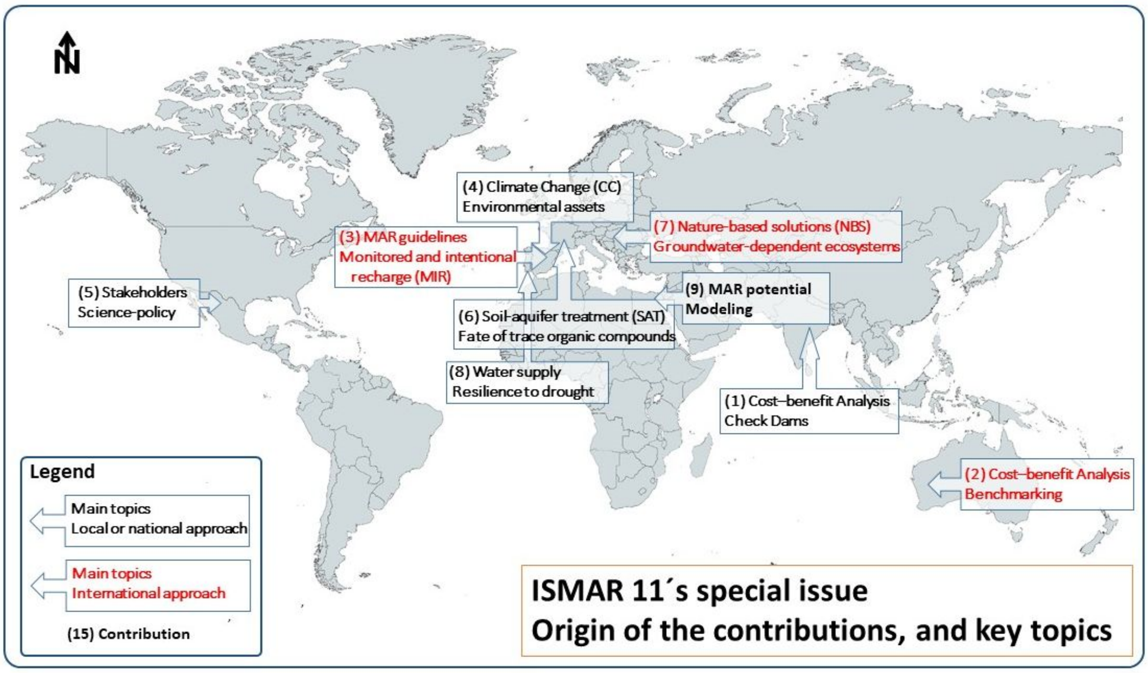

Figure 1. Geographic distribution of case studies addressed in the papers included in the Special Issue resulting from the ISMAR 11 conference. Contributions are listed in Table 4.

Table 4. The main topics covered in ISMAR 11's Special Issue presented in the Journal *Water*, in relation to the themes and topics of ISMAR 11, and. degree of focus on each topic exposed in Table 2, denoted as low (L), medium (M), and high (H).

First Author	Contribution	Relation with ISMAR 11 Session												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Dashora et al. (2022)	1		M				L			H		M		H
Ross (2022)	2	L		L			L		L	H		L	M	
Fernández Escalante et al. (2022)	3						H					M	L	
Henao et al. (2022)	4							H			M	L		H
Cruz Ayala et al. (2022)	5						H			L		L		
Guillemoto et al. (2023)	6	M	M				M		H		L	M		H
Szabó et al. (2023)	7			L				H				L		
Standen et al. (2023)	8	L	H		L						M	M	M	L
Mouhoumed et al. (2023)	9		H				L		M		H	H	H	

2. Summary of Contributions to this Special Issue

This section summarises the contributions presenting the themes key to sustainability and discusses the previous introduction. The contributions of the authors for this Special Issue were categorised into 13 thematic groups (Table 4), along with an extra category for "others". A concise summary of the contributions, including comments from the authors, is presented below in the order in which the papers were submitted.

Some of the articles relate to MAR applications included in the web-based global inventory [7].

2.1. Cost–Benefit Analysis: Check Dams

Dashora et al. (2022) (contribution 1) investigate the importance of small-scale MAR systems, specifically check dams, which, together with infiltration ponds, are the most frequently used recharge systems in the world [7]. The authors discuss the concept of investment in the small-scale enhancement of groundwater recharge through check dams and other recharge structures in rural India, which is on the order of USD 1 billion/year.

The arguments are demonstrated on a specific MAR site in Udaipur district, Rajasthan, India, and validated using a basic hydrologic model (WaterCress) with the participation of the local population in monitoring the groundwater levels. Recharge datasets were obtained to assess the efficiency and effectiveness of these infrastructures and determine their optimal capacity and the related environmental impacts, including economic aspects, such as the evolution of the benefit–cost ratio (BCR) over time.

The authors utilised water balance calculations, based on data from local farmers, to assess the total recharge contributed by all check dams in the subcatchment area while also considering both wetter and drier meteorological conditions. They concluded that the monitoring of the check dams, at least in terms of rainfall and groundwater levels, is key to deciding whether the construction of additional check dams is economically beneficial. The authors also stated that the costs of upstream check dams averaged more than four times the estimated costs resulting from the interpolation of the costs of downstream check dams (independently of the year chosen). In addition, the effectiveness of downstream check dams was reduced due to the construction of upstream check dams.

This work represents a first step towards developing policy and planning guidance to maximise the benefits of investment in check dams and other recharge structures in watershed development programs. The findings of this study also aim to empower other communities (through citizen science) and provide a low-cost starting point to inform future investors in check dams through government programs.

2.2. Cost–Benefit Analysis: Benchmarking

Ross (2022) (contribution 2) focusses on the economic aspects of MAR, stating, e.g., that cost–benefit analysis provides a systematic method for comparing alternative water infrastructure options. According to the author, the benefits of MAR can be estimated by the cost of the cheapest alternative source of supply or the value of water production using MAR.

Cost–benefit analysis provides a systematic approach for evaluating the effects of the different options available for alternative water infrastructure on society as a whole. In contrast, most of the existing studies focus on small regions or individual cases and do not provide a synthesis at a cross-continental scale.

This article has a global perspective: It presents a quantitative analysis of two economic approaches, namely levelised costs and the benefit–cost ratios (BCRs), of 21 MAR schemes from 15 countries, together with a qualitative assessment of additional social and environmental benefits. A standardised estimate of the levelised cost of each scheme was calculated, assuming an operating life of 30 years and a discount rate of 5.0%, and hence a capital recovery factor of 0.0650. This standardised approach has the crucial advantage of enabling a comparison between heterogeneous MAR schemes across different regions and scales, although discount rates vary in different countries. Some of the factors that influence levelised costs were identified, including the source and end use of water, MAR objectives, MAR technologies, project size, and country incomes. The profits of MAR schemes also take into account the qualitative estimates of non-extractive environmental and social benefits. The energy costs of these MAR projects are competitive when compared to alternatives.

This contribution provides valuable data for future benchmarking comparisons in terms of factors such as the technical and economic parameters for the 25 full-scale MAR schemes, in particular, the annual volumes of water recharged and recovered, and the levelised costs of water (costs are in USD at year 2016 values). The MAR schemes analysed have positive impacts on aquifer storage and condition, positive or neutral effects on water quality, and significant environmental benefits. Nonetheless, the author highlights that MAR creates a wide range of social and environmental benefits that are difficult to quantify.

This article reveals additional evidence about the economic feasibility of MAR, encouraging and providing incentives for investment in aquifer recharge and water banking, and supporting the development of new policies on how to use MAR to compensate for water shortages. This analysis also highlights the elements common to successful

MAR schemes as well as the reasons for failure incurred as a result of ineffective systems. Lastly, the lessons learned from this comparison can be very useful for the development of future projects.

2.3. Monitored and Intentional Recharge (MIR) for Drafting Guidelines Documents

Fernández Escalante et al. (2022) (contribution 3) present a pragmatic paper of international scope that aims to provide a conceptual model with the minimum number of documents (including regulations, guidelines, and MAR site operation rules), using a scoring system that facilitates the assessment of the significance of their components, establishing a cross-pollination process, to construct a monitored and intentional recharge (MIR) conceptual model. This model considers the most common elements and those with the highest impact. In total, 19 aspects were extracted from the reviewed documents, and they were clustered into several categories (their corresponding scores are presented in Table 3 of the original document): general context (three use cases), risk and impact assessment, operative aspects, receiving medium, risk and impact assessment (4), MAR planning (3), social aspects, financial issues, receiving medium, and operative aspects.

The MIR conceptual model comprises nine blocks that summarise the most important aspects to consider such as (1) water source; (2) hydrogeological and environmental conditions; (3) MAR technology or recharge technique; (4) sensors for data gathering; (5) monitoring guidelines; (6) the final use of the recharged water; (7) analytical aspects related to water, gathered either in the field or in the laboratory; (8) risk or impact assessment; and (9) others. The paper discusses each block and introduces the concept of "hydrodynamic monitoring", developing novel concepts such as standardisation, interoperability, co-managed aquifer recharge, and end-user participation, which also paves the path towards citizen science and a more rigorous control and surveillance of water resources and their related infrastructure.

The term MIR was proposed, despite the risk of creating some confusion with the acronym MAR, to create a synergy between both concepts.

Even though the MIR conceptual model (according to the authors' terminology) provides a complete list of elements to study when drafting guidelines and regulations on MAR, it also encourages a tailored approach based on the specific context of the country or region. Therefore, MIR may also be used as a checklist for developing guidelines. Presently, Peru and Niger are preparing MAR normative bodies guided by the MIR conceptual model (contribution 3). The model has also been suggested to European decision makers to be applied in Europe when drafting the imminent European MAR and water reuse directive for agricultural uses.

2.4. Climate Change

Henao Casas et al. (2022) (contribution 4) analysed a managed aquifer recharge approach as a low-regret measure (i.e., maximising the positive aspects and minimising the negative aspects of nature-based adaptation strategies and options for climate change adaptation), and validated the hypothesis using large datasets collected from the Los Arenales aquifer in Castile and Leon, Spain.

The authors evaluated a series of social and environmental challenges addressed by MAR systems, as well as their attributes (e.g., groundwater level, soil humidity, etc.), that diminish the expected impacts of climate change (CC) in the study area. To this end, several thematic categories were assessed and integrated such as groundwater levels, energy cost for pumping, the density of rural population, the volume of surface water bodies, the occurrence/intensity of floods/droughts, etc.

As regards environmental assets, MAR in the Los Arenales groundwater body has contributed to an overall increase in groundwater levels, a reduction in energy consumption needed for groundwater pumping (and implicitly the costs associated with it), a reduction in CO_2 emissions, the restoration of a surface water body, improvement in rural population indexes (e.g., migration, population growth, wages and salaries) enhanced groundwater demand control, and CC adaptive capacity through irrigation communities.

In terms of the attributes related to CC adaptation, the Los Arenales MAR systems can further help to buffer the impact of water scarcity and dry spells on water resources through wastewater recycling under the threat of declining source river flow. To date, the volume of wastewater (not specifying the type of treatment) in the region is 2.7–4.8 times higher than the average volume of water withdrawal from river sources for MAR.

Low-regret solutions, such as MAR, are a good compromise between bottom-up and top-down CC adaptation approaches, resulting in win–win scenarios regardless of CC evolution. These adaption solutions are particularly suitable in developing countries and rural areas, which are more vulnerable to extreme water-related events and are often afflicted by underinvestment in adapting to long-term climate variability. All these aspects were integrated and analysed using statistical tools, and qualitative analyses were performed, followed by a comparative study.

To summarise, this research shows that low-regret measures can bridge the gap between adaptation approaches. However, considering the current challenges and future climate change scenarios, they could result in more robust and holistic solutions.

However, the authors did not consider some long-term CC modeling forecasts, leaving the field open for future lines of investigation.

This article is part of the doctoral dissertation of the first author, entitled "Managed aquifer recharge as a low-regret measure for climate change adaptation" and defended at the Technical University of Madrid on 16 April 2023.

2.5. Stakeholder Engagement

Cruz Ayala et al. (2022) (contribution 5) reported that in Mexico, the Law of the Nation's Waters (LAN) allows for the establishment of basin councils to increase citizen participation. However, the involvement of stakeholders, including researchers, in basin councils has not been very effective. Within this context, the authors presented a methodology based on a collection of Mexican MAR sites, duly monitored, to describe the significant advances in science–policy collaboration and stakeholder participation that are especially applicable in the North American context.

Based on the results of seventy surveys conducted in eight Mexican states, the authors identified science–policy interactions between researchers, policymakers, and non-governmental organisations that are critical for the effective development and implementation of water recharge projects, concluding that trust and stakeholder participation are the most critical elements for building collaborative relationships.

The authors describe the working interactions between stakeholders and their characteristics, distinguishing six stages or categories of interactions: no interaction at all, networking cooperation, coordination, coalition, and collaboration. The most effective types of interaction were assessed and ranked from a total of 31 interviews primarily held with members of state universities and municipal governments because these target groups are the most related to the development of water projects.

Another novel contribution of this article is the identification of drivers and barriers to building collaborative interactions. The responses from 27 interviews led to the identification of seven barriers, the most remarkable of which involve the financial budget of the project, regulations, barriers to the integration of stakeholder participation (due to the centralisation of power and authority in the federal water agency), and the absence of a long-term perspective.

The authors concluded that inter-sectoral and inter-agency collaboration among sectors will help achieve water recharge policy goals. Their results align with the findings in the scholarly literature suggesting that the involvement of water users and the inclusion of scientific sound information are fundamental requirements to sustain collaboration. By contrast, their study found that a lack of formal and supported communication channels is a barrier to enhancing collaboration around MAR.

In conclusion, regarding science–policy collaboration and water security, the authors claim that finding ways to supersede structural challenges and promote science–policy collaboration among sectors and interagency with water management responsibilities will help achieve environmental and policy goals and increase water recharge development across Mexico.

2.6. Soil Aquifer Treatment (SAT)

Guillemoto et al. (2023) (contribution 6) focus on the fate of trace organic compounds (TrOCs) at a full-scale soil–aquifer treatment (SAT) site in France. The methodology included the simulation of groundwater flow and the transport of contaminants using the modelling framework MARTHE.

The unique feature of the Agon-Coutainville site is that it is part of a coastal system with strong potentiometric variations, mainly caused by tides, natural recharge, and the infiltration of secondary treated wastewater (STWW). Due to the uncertainties regarding the reactivity of TrOCs and the possible variations in hydrodynamic conditions, understanding the fate of TrOCs in the SAT context at an annual time scale is very complex. The main objectives of this research include the identification of reactive processes and the analysis of their variations over time, using a numerical flow and transport model developed for simulating changes in the flow and mixing the velocities of infiltrated water (STWW) in the SAT at the hydro system or watershed scale.

Once the boundary conditions and the water balance for the area were defined, the computational code generated with the MARTHE finite-volume method was used to solve flow and solute transport equations considering transient mass transport, which allowed for controlling the convergence of iterative calculations.

The results of the simulations indicate strong dynamics in SAT functioning, with high variations in the operational parameters, including large variations (from 70 to 500 days) in the mean STWW residence time calculated between the infiltration pond and the outfall (groundwater discharge to surface water bodies), which are mainly related to STWW discharge conditions, and meteorological factors. The dilution rates of STWWs vary (the underlying mechanisms through which STWW is diluted are not explicitly specified), depending on operational conditions, whereas the seasonal variation in STWW concentration, the mean residence times, and the temperature differences influence the SAT reactivity over time.

Additional measurements of TrOCs, as well as redox conditions, organic matter availability, temperature, etc., with further modelling support, will help to interpret effective SAT reactivity (including both thermodynamic factors and kinetic factors), depending on varying flow conditions and influencing dynamic factors. This will help to enhance the further understanding of the key conditions that influence TrOC degradation at the scale of an operational SAT site.

This article provides a detailed model-based assessment of the fate of TrOCs and their behaviour in an SAT site in France under site-specific conditions. Nevertheless, its applicability in other scenarios remains unclear, as it has been applied in a unique SAT-MAR site.

2.7. Nature-Based Replenishment

Szabó et al. (2023) (contribution 7) focus on the use of nature-based solutions (NBSs) in a large-scale real situation of Lake Kondor, a groundwater-dependent ecosystem (GDE) of the Danube–Tisza Interfluve in Hungary. The system is currently under rehabilitation.

The authors elaborate on the advantages and limitations of the MAR scheme, underlining its potential to alleviate the impacts of extreme hydroclimatic events by managing infiltration and providing ecological benefits.

The assessment is based on theoretical flow simulations using the finite element software GeoStudio SEEP/W V.2019 to identify the most critical parameters influencing the increase in groundwater levels at the discharge area. The description of the boundary conditions includes the perimeter, topography, hydraulic head difference, water levels, anisotropy coefficient, saturated water content, and water depth in the infiltration basin. According to the sensitivity analysis, the authors identified the parameters in the study area with the highest impact on MAR efficiency: topography, the distance between the recharge area (the location of the MAR system) and the discharge area, groundwater depth, soil properties and their spatial variation, the heterogeneity of horizontal and vertical hydraulic conductivity, and the physical parameters of the infiltration basin (in particular the basin width and the water depth in the infiltration basin, for different simulation scenarios). The established efficiency index, involving the resulting increase in groundwater levels and the volumes of infiltrated water, can be used to select the most realistic infiltration scenarios and optimise the future design of MAR schemes.

In terms of upscaling, the case study demonstrates that the theoretical approach considered can be applied to real-life scenarios as well, and it is worth considering this method as a potential water replenishment measure in this area and beyond; nevertheless, the limitations of this assessment are not discussed.

2.8. Water Supply

Standen et al. (2023) (contribution 8) analyse the applicability of MAR in the Algarve region of Portugal, which experiences severe water scarcity, with insufficient water supplies to meet demand and limited resilience to drought.

In the conceptualisation of the site (regional scale), the authors discuss the characteristics of 12 different aquifers and demonstrate that MAR can cover 10% of the total water demand of the region (24 Mm^3/year) using water that is not otherwise captured, with quality that meets the requirements of the European Groundwater Directive. Thus, MAR can replace 15 Mm^3/year of surface water used in the public irrigation perimeters, and 9 Mm^3/year can be used to develop and maintain a strategic groundwater resource in the aquifers of the Central Algarve.

Although climate change is predicted to result in an 8–13% decrease in MAR recharge, this can be addressed by incrementally increasing MAR design capacity.

The authors used different practical tools to assess the suitability of MAR application in the area, e.g., multicriteria decision analysis (MCDA) methods for MAR mapping, hydrological studies to estimate the water available for MAR, the consideration of flood-MAR options, climate change scenarios (EURO-CORDEX regional climate models), water quality issues, modelling, and their effect on integrated water resource management (IWRM).

The authors also discuss alternative solutions, deriving regional MAR estimations, in general for agricultural purposes. In this respect, the authors claim that MAR can support public irrigation perimeters, and in conjunction with the direct reuse of treated wastewater and reduced groundwater abstraction, it can provide a strategic groundwater resource for use during drought periods.

In summary, the authors claim that the application of MAR in the area will reduce environmental impacts. Based on a cost–benefit assessment, investment in this approach will be lower than almost all feasible alternatives. The authors also conclude that MAR is an important measure to increase water supply security and drought resilience in the Algarve region.

This article is part of the doctoral dissertation of the first author, entitled "Managed Aquifer Recharge: An integrated water resource management solution for the Algarve, Portugal", which was defended on 21 July 2023 at the University of Algarve.

2.9. Managed Aquifer Recharge (MAR) Potential Assessment

Mouhoumed et al. (2023) (contribution 9) developed a model to identify suitable regions for MAR projects in Djibouti at the country level under severe dry climate and water-stressed conditions.

The proposed approach combines the fuzzy analytical hierarchy process (AHP) algorithm with the technique for the order of preference by similarity to an ideal solution (TOPSIS) to delineate the suitable sites for MAR structures (GIS-MCDA schemes).

The selected model led to the identification of nine decision criteria and the determination of their relative importance. The criteria were grouped into two clusters: (a) environment (rainfall, the normalised difference vegetation index (NDVI), and drainage density); and (b) subsurface (depth to groundwater, geology, and groundwater quality). Additionally, the TOPSIS method was employed to integrate the decision layers and prioritise the study area.

A sensitivity analysis was performed, which highlighted the significance of the rainfall, slope, and NDVI as the most influential decision parameters, while the drainage density had the least impact. The results of this analysis revealed that 16%, 18%, and 30% of the country have a very high, high, and moderate potential for MAR activities, respectively. The sensitivity analysis also demonstrated the stability of the proposed model, affirming the usefulness of the generated suitability map.

According to the Conclusions section, the overall comprehensive approach proposed in this study empowers policymakers and stakeholders to identify and prioritise areas with promising MAR potential, facilitating informed decision making and the efficient allocation of resources for sustainable water management practices.

2.10. MAR for Sustainability

Based on the nine articles gathered in the Special Issue related to ISMAR 11, presented in the Journal *Water*, the detailed analysis of their content and their discussions pertaining to sustainability leads us to the conclusion that the title of the Special Issue is fitting given the current circumstances of MAR and the contributions justify why indeed managed aquifer recharge is key to sustainability.

All the topics covered by the nine articles published in this Special Issue provide an important contribution to the sustainable and reasonable use of water resources, as well as adaptation to the new societal challenges posed by climate change, water scarcity, deterioration in water quality accelerated by emerging compounds, and alternating extreme weather events causing floods and droughts. The successful response to these challenges, along with many others, presents MAR as a powerful and reliable approach to mitigate the resulting impacts. The different topics covered converge on this key point, claiming that MAR is a sound, safe, and sustainable technique, which justifies its growing potential and application by adopting local solutions to solve the global water crisis.

3. Discussion

This section is divided into subheadings involving the collection of previous Special Issues published by MDPI after the last four ISMAR events. The association between these issues and the themes and topics of ISMAR 11, as well as their integration with the content of the present Special Issue, are discussed.

3.1. MDPI Special Issues on ISMARs

A total of 66 papers selected from four ISMAR conferences were published in the MDPI journal *Water* in four consecutive Special Issues, with an average of 16.5 papers for each issue.

It is worth noting that most of the ISMARs resulted in more than one Special Issue. For example, the papers presented in ISMAR 8 were included in two parallel Special Issues; ISMAR 9 had three; ISMAR 10 was held exclusively by MDPI, and the organisers published a proceedings book [8], while the contributions from ISMAR 11 were also bundled in two parallel issues. More details about these publications and the links for downloading them are available at the IAH-MAR commission website: https://recharge.iah.org/ismar, accessed on 28 August 2023.

3.2. ISMAR 11 Themes and Topics

According to the ISMAR 11 book of abstracts [5], the sessions with the most contributions were Managed Aquifer Recharge Engineering and Design (Part I to IV), including 20 papers; Managed Aquifer Recharge and Emerging Contaminants (Part I–III), with 14 papers; and, Managed Aquifer Recharge Geophysics (Part I–II), with 11 papers. Four other sessions had 10 papers accepted with their corresponding oral presentations grouped into the following themes (each session including two parts):

Aquifer storage and recovery (ASR);

Managed aquifer recharge and integrated water management;

Managed aquifer recharge and the environment;

Managed aquifer recharge modelling.

In total, the 25 sessions of the ISMAR 11 conference covered 13 + 1 themes and topics (aggregated in Table 2).

3.3. Topics Covered by Each Contribution

In total, 41 authors participated in this Special Issue (excluding the current editorial, which provides a synopsis of the whole collection and has been written by 5 authors). Three authors were involved in both contributions (3) and (4). Therefore, the real number is 38, with authors from the five continents, especially from Europe. The number of contributing writers varies between 1 (2), and 10 authors (6). Five papers were written by four authors (3, 4, and 7–9). That means the mean of contributors is 4.55 authors/paper.

Table 4 shows the main topics covered in the ISMAR 11 sessions, grouped into 13 categories, and it also shows the extent they were covered by each paper in this Special Issue. The structure of the table includes the reference number, first author, and relation to ISMAR 11's topics (after classification into 13 categories). The degree of emphasis on each topic was evaluated in each paper, which was ranked as low (L), medium (M), and high (H).

According to these figures, the topic with the highest focus in this Special Issue was "MAR and Sustainable Groundwater Management" (theme 11), with all the papers of the Special Issue (nine + one) involving this theme to some extent. The second most considered topic falling under the high category was "Managed Aquifer Recharge Operations and Maintenance" (theme 6), with six papers. On the other extreme, scant attention was paid to the topic "MAR and Geophysics" (theme 5), with none of the papers presented in this Special Issue involving this theme in whole or in part.

Only one paper focused on managed aquifer recharge engineering and design (theme 4), even though it had four different sessions in ISMAR 11 (I, II, III, and IV, with 20 different oral slots). A possible explanation is the consigned occupation or affiliations of the contributing authors. Most of them work for universities, research centres, or colleges, and very few work for companies (two practitioners were authors for contribution (1); four were involved in contribution (3) (two of whom work in both a company and a university); three in contribution (4) (who were also involved in contribution (3)); one in contribution (6); and another in contribution (8)). This means that from the 38 authors involved in this Special Issue, 8 work for the industry (21%), with 2 of them presenting as first authors (precisely those sharing their occupation between industry and academia). The rest (30/38) are involved in research activities, according to the affiliations provided by the authors in their corresponding papers.

4. Conclusions

Despite the low number of contributions (the least compared with the four previous ISMAR Special Issues), all five continents have been represented, with five papers from Europe and one for each additional continent (including this editorial). Three papers have a clear international scope (see Table 4 and Figure 1).

In terms of outlook, the authors of this editorial expect that ISMAR 12 will include more contributions about information technologies such as artificial intelligence, and especially tools and techniques that combine artificial intelligence and MAR. Some of these topics were already considered in the program of the previous ISMAR 10 conference, which included water management and MAR innovative systems, IT applications, normalisation, standardisation, and interoperability advances in the session entitled "MAR and Monitoring", and, e.g., building information modeling (BIM) applied to MAR in the session involving sustainably managed aquifer recharge technical solutions (SMARTS) [8].

The main topics covered in ISMAR presentations are not fully included in this Special Issue, covering a vast array of themes if they are integrated. A possible interpretation might be the different interests of the authors according to their preferences (e.g., most of the ISMAR 11 attendees from the USA, who published their research in a journal, preferred an American-based journal).

Last, but not least, it is worth mentioning the importance of web sites [9–15], and social networks when sharing the results of different research approaches, in addition to the more conventional publications in academic journals. In that sense, the IAH-MAR commission is publishing a comprehensive bulletin of news on an (almost) monthly basis (https://recharge.iah.org/newsletters, accessed on 29 August 2023), disseminating the primary news and messages of interest for the community of scientists, practitioners, and students who consider MAR as a sound, safe and sustainable technique, and continue to make efforts towards spreading this message.

Author Contributions: The first three guest editors of this Special Issue (introduced in the link of the previous section, as E.F.E., C.S. and C.J.B.), and the chairman of ISMAR 11 (A.H.) contributed as an author to formulating the concept and structure of this editorial, writing specific sections (E.F.E. and C.S.), and revising the text and tables (all). All authors have read and agreed to the published version of the manuscript (E.F.E., C.S., C.J.B. and A.H.).

Funding: This research received no external funding.

Data Availability Statement: Data supporting reported results can be found at https://www.mdpi.com/journal/water/special_issues/Aquifer_Recharge, accessed on 29 August 2023. Some papers include additional supporting information.

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

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